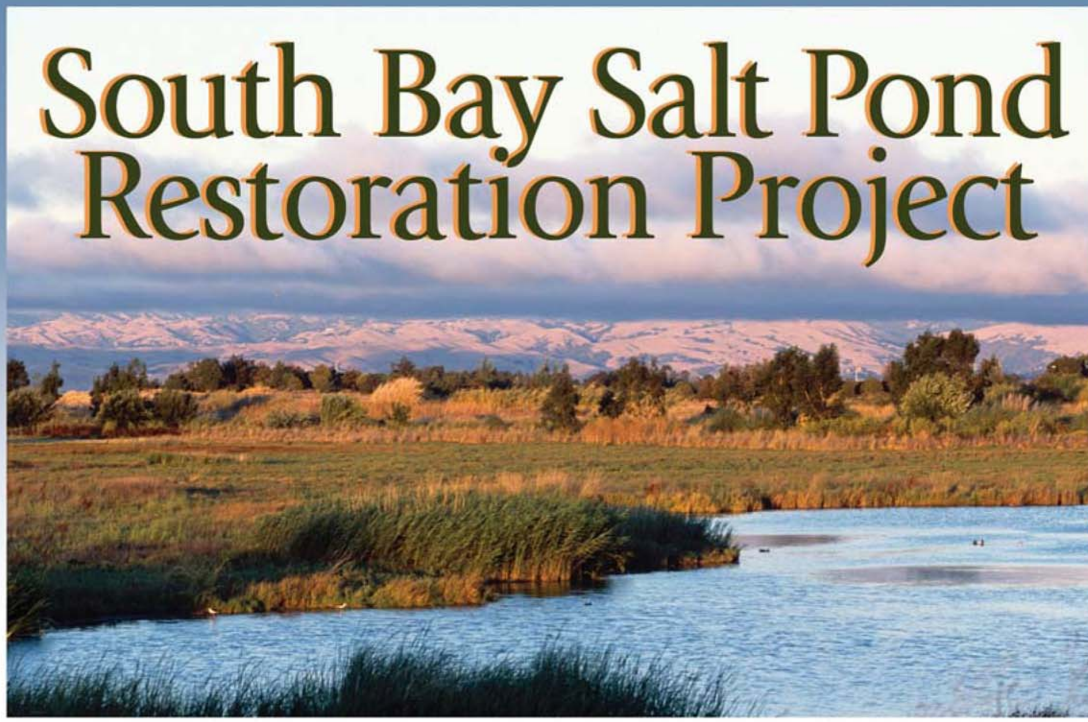


# Data Summary Report

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

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**APPENDICES:**

## LIST OF ACRONYMS AND ABBREVIATIONS

| Abbreviation | Organization |
|---|---|
| ABAG | Association of Bay Area Governments |
| ACFCC | Alameda Creek Flood Control Channel |
| ACPWA | Alameda County Public Works Agency |
| ACWD | Alameda County Water District |
| ALERT | Automated Local Evaluation in Real Time |
| BACWA | Bay Area Clean Water Agencies |
| BAOSC | Bay Area Open Space Council |
| BASMAA | Bay Area Stormwater Management Agencies Association |
| BCDC | Bay Conservation and Development Commission |
| BPC | Bay Planning Coalition |
| CALFED | CALFED Bay-Delta Program |
| CBDA | California Bay-Delta Authority |
| CCC | California State Coastal Conservancy |
| CDFG | California Department of Fish and Game |
| CEP | Clean Estuary Partnership |
| CPC | Center for Plant Conservation |
| DELFT2D | Model System of the WL / Delft hydraulics |
| DELFT3D | Model System of the WL / Delft hydraulics |
| DWR | California Department of Water Resources |
| EDAW | EDAW, Inc. |
| EIP | EIP Associates |
| EIS/EIR | Environmental Impact Statement/Environmental Impact Report |
| FEMA | Federal Emergency Management Agency |
| FIRM | Flood Insurance Rate Map |
| FIS | Flood Insurance Study |
| GIS | Geographic Information Systems |
| HEC-FDA | Hydrologic Engineering Center's Flood Damage Analysis |
| HET | highest estimated tide |
| HOWL | highest observed water level |
| IKONOS | Space Imaging’s satellite |
| ISP | Initial Stewardship Plan |
| LIDAR | Light Detection And Ranging |
| LOWL | lowest observed water level |
| LSA | LSA Associates |
| LTMS | Long-Term Management Strategy |
| MHHW | mean higher high water |
| MHW | mean high water |

| Abbreviation | Organization |
|---|---|
| MIKE-21 | Modeling System for Estuaries, Coastal Waters and Seas |
| MLLW | mean lower low water |
| MLW | mean low water |
| MTL | mean tide level |
| NASA | National Aeronautics and Space Administration |
| NAVD88 | North American Vertical Datum 1988 |
| NCDC | National Climate Data Center |
| NFIP | National Flood Insurance Program |
| NGVD | National Geodetic Vertical Datum |
| NOAA | National Oceanic and Atmospheric Administration |
| NOS | National Ocean Service |
| NWS | National Weather Service |
| PAHs | polycyclic aromatic hydrocarbons |
| PCBs | polychlorinated biphenyls |
| PG&E | Pacific Gas & Electric |
| PORTS | Physical Oceanographic Real-Time System |
| PRBO | Point Reyes Bird Observatory |
| PWA | Philip Williams and Associates |
| RMA Model | Rate Monotonic Analysis |
| RMP | Regional Monitoring Program |
| ROWD | Report of Waste Discharge |
| RWQCB | Regional Water Quality Control Board |
| SBSP | South Bay Salt Pond |
| SCVWD | Santa Clara Valley Water District |
| SED-2D | 2-Dimensional Sediment Transport Numerical Model |
| SETAC | Society of Environmental Toxicology and Chemistry |
| SFBBO | San Francisco Bay Bird Observatory |
| SFBNWR | San Francisco Bay National Wildlife Refuge |
| SFEI | San Francisco Estuary Institute |
| SJSU | San Jose State University |
| SSC | suspended sediment concentrations |
| SWAN | Simulating WAves Nearshore |
| SWRCB | State Water Resources Control Board |
| TMDL | total maximum daily load |
| TRIM2D | 2 dimensional hydro model Tidal, Residual, Intertidal Mudflat 2D |
| TRIM3D | 3 dimensional hydro model Tidal, Residual, Intertidal Mudflat 3D |
| TSS | total suspended solids |
| USACOE | U.S. Army Corp of Engineers |
| USDA | U.S. Department of Agriculture |

| Abbreviation | Organization |
|---|---|
| USDA NRCS | U.S. Department of Agriculture Natural Resources Conservation Service |
| USEPA | United States Environmental Protection Agency |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| USGS-BRD | US Geological Survey, Biological Resources Division |

# 1. INTRODUCTION

## 1.1 Overview

This document, the Final Data Summary Report for the South Bay Salt Pond Restoration Project (SBSP Restoration Project), was prepared in accordance with the Final Data Acquisition Plan (H. T. Harvey & Associates and others 2004). This report distills the pertinent information gathered by topic and identifies the most important data-gaps that need to be addressed for effective restoration planning. The report is organized to first provide a list of the priority data-gaps essential to fill now to inform the restoration planning process. This summary of the critical data-gaps is then followed by a data summary by topic, complete list of data-gaps by topic, and list of references.

The references provided by topic herein are a subset of those compiled in an EndNote library (bibliography) in accordance with the format and content outlined in the Data Acquisition Plan. A digital copy of the EndNote Library will be submitted to the Project Management Team and to San Francisco Estuary Institute (SFEI; Michael May) for inclusion in the bibliography posted on the project website.

Information was collected, reviewed and compiled on the general topics outlined in Table 1. These topics were identified during the SBSP Restoration Project's Data-gaps Workshop as topics for which review of existing available information was needed to determine if actual data-gaps pertinent to restoration planning exist. The Data-gaps Workshop was a one-day event (held on March 25, 2003) hosted by the California Coastal Conservancy, the U.S. Fish and Wildlife Service, and the California Department of Fish and Game. Approximately 75 scientists attended the workshop from public agencies, universities, and private firms.

Information gathering was focused on that which is most relevant to restoration planning as outlined in Appendix A of the Data Acquisition Plan. Data collection efforts were also guided by the questions developed by the Science Team in the Science Strategy Report (Table 3.2) and by the draft detailed project objectives being developed by the Philip Williams & Associates (PWA) Team.

**Table 1. Information Gathering Topics.**

| Topic No. | Topic |
|---|---|
| 1 | Wildlife Use of Ponds, Marshes, Sloughs, Mudflats, and Bay |
| 2 | Vegetation/Plankton in Ponds, Marshes, Sloughs, Mudflats, and Bay |
| 3 | Design of Habitat and Landscape |
| 4 | Lessons Learned from Prior Restoration Projects |
| 5 | Hydrodynamics and Related Data |
| 6 | Invasive Species |
| 7a | Wildlife/Human Interaction Effects |
| 7b | Species Resilience/ Response of Species During Restoration |
| 7c | Predation |
| 7d | Contaminants in Wildlife |
| 7e | Food Resources |
| 8a | Physical distribution of Mercury and Other Contaminants in Project and Adjacent and Upstream Areas |
| 8b | Mercury Methylation |
| 9 | Effects of Cargill Operations |
| 10 | Seasonal Pond/Groundwater Interactions |
| 11 | Infrastructure Assessment |
| 12a | Imported sediment supply and quality |
| 12b | Literature survey on in-place sediment quality (ponds, sloughs, bay) |
| 12c | Sediment characteristics for imported sediment |
| 13 | Vector Control |
| 14a | Flooding Issues Protection |
| 14b | Levee Conditions |
| 15 | Recreation and Public Access |

## 1.2 Habitat Definitions

The habitats referred to in this report are defined below.

Salt Pond: A constructed pond utilized for the commercial production of salt via solar evaporation. For the purpose of this report, this term includes salt ponds within the SBSP Restoration Project area currently operated and maintained by the California Department of Fish and Game and the U. S. Fish and Wildlife Service under the South Bay Salt Ponds Initial Stewardship Plan (ISP).

Managed Pond: A constructed pond managed to provide suitable habitat for specific animal populations.

Tidal Salt Marsh: Vegetated intertidal (i.e. regularly flooded and drained by the tides) habitat dominated by emergent, vascular plant species adapted to high interstitial soil salinities. Average interstitial salinities of tidal salt marsh habitat in the South Bay are greater than approximately 27 ppt (H. T. Harvey & Associates 2002b). These species include Pacific cordgrass (*Spartina foliosa*), pickleweed (*Salicornia virginica*), marsh gumplant (*Grindelia stricta*), saltgrass (*Distichlis spicata*), alkali heath (*Frankenia salina*), and jaumea (*Jaumea carnosa*). Tidal salt marsh includes higher order slough channels within the marshplain and high marsh/upland ecotone habitat along the upper elevation periphery.

Tidal Brackish Marsh: Vegetated intertidal habitat dominated by emergent, vascular plant species adapted to intermediate (brackish) interstitial soil salinities. Average interstitial salinities of tidal brackish marsh range from 15 ppt to 20 ppt in the South Bay (H. T. Harvey & Associates 2002b). These species include alkali bulrush (*Scirpus maritimus* and *S. robustus*) and perennial pepperweed (*Lepidium latifolium*), an introduced species. Higher order slough channels within the marsh and high marsh/upland ecotone habitat are included.

Tidal Marsh: This term includes both tidal salt marsh and tidal brackish marsh.

Tidal Mudflat: Intertidal habitat that is not vegetated with emergent, vascular plants. This habitat type occurs along the perimeter of large, lower-order channels and along the interface between tidal salt marsh and the Bay.

Tidal Habitats: This is a "catch-all" term that includes all intertidal habitats of the South Bay: tidal salt marsh, tidal brackish marsh and tidal mudflats. Tidal freshwater marsh does occur in the tidal reaches of the tributaries draining to the South Bay, however this habitat type is not included in this term, for the purpose of this report.

## 1.3 Data-gaps Approach

Data-gaps are listed after the data summary for each topic below. Data-gaps were put into two categories for each topic:

- Data-gaps essential to fill for restoration planning
- Data-gaps to fill during adaptive management and monitoring

In addition to the data-gaps outlined in this report, there are currently data being collected that will need to be analyzed and synthesized. Although not technically a data-gap, critical items have been identified where analysis of existing data is needed for restoration planning. This report therefore aims to identify data that need to be collected, as well as data that need to be synthesized, analyzed and/or included in the models.

## 1.4 Priority Data-gaps for Restoration Planning

We have identified the most important data-gaps to fill to inform restoration planning. Based on the project's current schedule, these gaps need to be filled in the next 1-2 years. These high-priority data-gaps were chosen based on the project goal and on the principal constraints to meeting this goal. The project's overarching goal is the restoration and enhancement of wetlands in the South San Francisco Bay while providing for flood management and wildlife-oriented public access and recreation. The principal constraints identified to date include sediment supply, shorebird and waterfowl response to salt pond conversion, invasive cordgrass (*Spartina alterniflora* and hybrid *S. alterniflora* x *foliosa*), and mercury. The number of priority data-gaps identified below was also derived, in part, with the understanding that funding for collection and synthesis of data is limited.

Table 2 provides our recommended list of priority data-gaps for restoration planning. *This is a subset of priority data-gaps from the entire list of data-gaps developed for each topic below and do not include data-gaps for work already funded and underway.*

**Table 2. Priority Data-gaps for Restoration Planning.**

| Topic | Priority Data-gaps* |
|---|---|
| Wildlife Use (Topic 1) | How do birds use tidal marsh, tidal mudflat and Bay habitats concurrently with use of salt pond, managed pond and open Bay habitat? |
| | What is the response of birds to existing, implemented tidal marsh restoration projects in the South Bay? |
| Vegetation (Topic 2) | What are the elevation ranges for the dominant plant communities targeted for restoration in existing South San Francisco Bay tidal marshes? |
| Design of Habitat and Landscape (Topic 3) | How will different restoration strategies affect bird populations in the South Bay? |
| | How do the number, distribution, and size of potential nesting islands affect the abundance of nesting California Gulls? |
| Lessons Learned From Prior Restoration Project (Topic 4) | What are sedimentation rates at breached sites and marinas in the San Francisco Bay? |
| Hydrodynamics and Related Data (Topic 5) | What are the existing and expected future subsidence rates in the South Bay? |
| | What are the relationships between tidal (e.g., MLLW) and geodetic (e.g., NAVD88) datums around the South Bay? |
| | How do the sediment bed characteristics (i.e. critical shear stresses for erosion, age, etc.) vary over the shoals and pond areas of the South Bay? |
| Invasive Species (Topic 6) | Are there salinity regimes and water depths within the SBSP Restoration Project area where *S. alterniflora* [hybrids] will not establish? |
| | How can it be determined that there is not a significant risk for *S. alterniflora* [hybrids] invasion into tidal salt marshes scheduled for restoration? |
| | What are the projected distributions of *S. alterniflora* [hybrids] in 2009-10, at the start of SBSP Restoration Project? What will be the effectiveness of the Invasive Spartina Project control efforts? |
| Wildlife/Human Interactions (Topic 7a) | What level of human disturbance causes a response in California Clapper Rails? |
| Predation (Topic 7c) | How do characteristics of tidal salt marsh, salt pond, and managed pond habitats affect levels of predation by terrestrial mammals (e.g., fox, raccoon) and birds (e.g., raven)? How can tidal salt marshes and managed ponds be designed or managed to minimize predation? |
| Water and Sediment Quality/Mercury (Topics 8a, and 8b) | What are the spatial gradients for contaminants, especially mercury, within the South Bay Salt Ponds? |
| | How will spatial gradients of contaminants within the greater San Francisco Bay, outside of the SBSP Restoration Project area, affect sediment quality of restored tidal habitats? |
| | Are there existing spatial gradients for methylmercury and net methylation rates within the salt ponds and within adjacent sloughs and tidal mudflats? |
| | How does mercury methylation differ throughout the continuum of habitat types, pertinent to SBSP Restoration Project? |

| Topic | Priority Data-gaps* |
|---|---|
| Effects of Likely Long-term Operations by Cargill (Topic 9) | How will management of retained Cargill ponds affect population numbers and distribution of birds in the South Bay? |
| Vector Control (Topic 13) | Can the Winter Salt Marsh Mosquito and Washino's Mosquito harbor and transmit West Nile Virus in the South Bay? |
| Flood Control (Topic 14A) | What is the upstream boundary of tidal influence in the tributaries and sloughs under existing conditions? |
| | Which project areas (and vicinity) with identified flood risk are flood sensitive and must not experience any increase in water level / flood frequency? |
| | What should be the basis for the delineation of flood hazard areas? |
| Construction Methods of Levees; Levee Materials, and Subsurface Conditions Beneath Levees (Topic 14b) | What are the subsurface soil conditions underneath the levees? |
| | What will be the future levee maintenance needs? |

* Data-gaps are defined in detail in data-gap summary for each topic in the report. Data-gaps are either gaps in raw data or gaps in data synthesis.

## 2. GIS DATA SUMMARY

The Consultant Team is in the process of acquiring and compiling the following data for inclusion in a GIS summary: habitat/vegetation maps for existing South Bay marshes, soil and water salinity, infrastructure (buildings, utilities, railroads, landfills etc.), hydrology, transportation, political and district boundaries, elevation and bathymetry, channel classification, tide gauge readings, recreation and open space location, wetland boundaries, vegetation composition, pollutant concentrations, and some historic coverages. Pond-specific data will include boundaries, pump locations, levees and ditches, and riprap. Imagery will include multiple years of IKONOS and LIDAR imagery, as well as color infrared aerial photography. A complete list is provided in Appendix A.

# 3. TOPIC 1: WILDLIFE USE OF PONDS, MARSHES, SLOUGHS, MUDFLATS, AND BAY

## 3.1 Data Summary

### 3.1.1 Bird Use of Salt Ponds and Other Bay Habitats

**Salt Ponds.** Bird use of South San Francisco Bay (South Bay) salt ponds is currently being studied in detail by U.S. Geological Survey (USGS) and PRBO Conservation Science (PRBO). USGS is conducting monthly surveys at 53 ponds in the South Bay, recording data on bird use, water quality (including salinity), and fine-scale habitat use relative to pond depth (U.S. Geological Survey 2003b). These surveys have been conducted since 2003. PRBO and USGS have historically conducted similar bird counts in salt ponds and other South Bay habitats. While some of these data are not yet available, much of the data are summarized in reports and publications (Stenzel and others 2002; Takekawa and others 2001; Warnock and others 2002). Takekawa and others (2001) and Warnock and others (2002) provide recommendations regarding restoration of South Bay salt ponds. In addition, PRBO has suggested the potential for certain changes in bird populations based on statistical comparison of salt ponds vs. salt marshes (Stralberg and others 2003). This "phase one" analysis is due to be updated by a "phase two" model in 2004. Findings of Warnock and others (2002) include:

- Shorebirds use salt ponds primarily at high tides—at low tides they are presumably foraging on mudflats, which are unavailable at high tide (except Black-necked Stilt and American Avocet which occur in ponds at all times).
- Whereas shorebird abundance is less at low tide, a greater proportion of shorebirds in the ponds forage at low tide (most roost at high tide).
- Dabbling ducks use ponds mostly at low tide (presumably because shallow bay habitat is less available).
- Highest diversity and abundance of birds in salt ponds occurs at 120-150 ppt salinity. Certain birds feed on brine shrimp, water boatmen, and brine flies that thrive in this salinity range.
- Plant-eating ducks (some dabbling ducks) occur in lower salinity, intake ponds, as do piscivorous birds (fish do best at <40 ppt).
- Very high salinity (>200 ppt) are not attractive to birds. No prey can survive, and high salinity can affect waterproofing of feathers.
- Waterfowl may use ponds farther from human use because of disturbance.

There are dozens of reports and publications providing historic data on bird use of the South Bay, as well as information on bird use at specific locations within the South Bay (Casady 1998; Gill 1977; Holway 1991; Rigney and Rigney 1981; Stenzel and Page 1989; Swarth and others 1982). These information sources provide good data on bird use of South Bay salt ponds. The South Bay is used by a significant portion of many shorebird species' western nearctic populations during migration (Page and others 1999). Population estimates of North American shorebirds are provided by Morrison and others (2001); these can be used to assess the importance of San Francisco Bay habitats to shorebird populations.

**Tidal Marshes and Tidal Mudflats.** Fewer data are available on bird use of tidal mudflats and tidal marshes of the South Bay. There are a number of small-scale studies of waterbird use of tidal marshes around the Bay, but few systematic studies on the scale of those currently being conducted in the salt ponds. PRBO data (Stenzel and others 2002; Stenzel and others 1989) provides information on use of mudflat habitats, and the phase one analysis (Stralberg and others 2003) also uses some limited data from tidal salt marshes. In addition, PRBO used historic data on shorebird use of tidal mudflats in their projections on the effects of *Spartina* on shorebirds (Stralberg and others 2004). Waterfowl use of both salt ponds and adjacent tidal habitats has been quantified using annual mid-winter aerial surveys conducted by U.S. Fish & Wildlife Service (USFWS) and USGS. These data have been summarized in a number of sources (Accurso 1992; Goals Project 1999; Goals Project 2000; Harvey and others 1992a; Takekawa and others 1988). Some information sources that provide data on densities, abundance, or relative use of different habitats in the South Bay, or in similar habitats elsewhere, are provided in Table 3.

**Table 3. Some Studies of Water Bird Use of Salt Pond (SP), Tidal Marsh (TM), Tidal Mudflat (MF), and Open Water (OW) Habitats in the South Bay and Elsewere.**

| | South Bay | | | | Other San Francisco Bay | | | | Elsewhere | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Source** | **SP** | **TM** | **MF** | **OW** | **SP** | **TM** | **MF** | **OW** | **SP** | **TM** | **MF** |
| Accurso 1992 | WO | | | WO | WO | | | WO | | | |
| Bollman and Thelin 1970 | SWO | SWO | SWO | SWO | SWO | SWO | SWO | SWO | | | |
| Casady 1999 (no date) | SW | | | | | | | | | | |
| Connors 2003 | | | | | | | | | | S | S |
| Ford and others 2002 | | | | WO | | | | WO | | | |
| Gresternberg 1979 | | | | | | | | | | S | S |
| H.T. Harvey unpubl. | | | | | | | | | SWO | | |
| Holway 1990 | | | | | | S | S | | | | |
| Masero and others 2000 | | | | | | | | | S | | |
| Neuman 2003 | | | | | | SWO | SWO | | | | |
| Page and others 1979 | | | | | | | | | | S | S |
| Ramer and others 1991 | | | | | | | | | | S | S |
| Rigney and Rigney 1981 | SWO | | | | | | | | | | |
| Rintoul and others 2003 | S | S | S | | | | | | | | |
| Shuford and others 1989 | | | | | | | | | | SWO | SWO |
| Stenzel and others 2002 | S | S | S | | S | S | S | | | | |
| Stralberg and others 2003 | SWO | SWO | | | | | | | | | |
| Strong and Dakin 2004 | S | | | | | | | | | | |
| Swarth and others 1982 | SWO | | | | | | | | | | |
| Takekawa and others 2001 | | | | | SWO | SWO | | | | | |
| Warnock and others 2002 | SWO | | | | | | | | | | |

**Note: Bird groups are: shorebirds (S), waterfowl (W), and other birds (O). These sources are multispecies studies, and do not include species-specific surveys, e.g., for Snowy Plovers or Clapper Rails.**

The Goals Project publications (Goals Project 2000; San Francisco Bay Area Wetlands Ecosystems Goals Project 2000) provide extensive summaries of wildlife use of Baylands, recommendations on restoration goals, and information on key wildlife species. Other summary reports on wildlife use of South Bay habitats include Harvey and others (1992a) and Herbold and others (1992). Pertinent data are also available on bird use of salt ponds and other saline evaporation ponds outside of the project area (e.g., Masero and others 2000, H. T. Harvey & Associates, unpubl. data).

### 3.1.2 Fish and Aquatic Invertebrates

Species accounts of key fish and aquatic invertebrate species can be found in the Goals Project's Species and Community Profiles (Goals Project 2000). A substantial amount of additional information on aquatic resources in the Bay is provided in Herbold and others (1992) and Baxter and others (1999). Several sources provide information on invertebrate use of mudflats and salt marshes of California (Levin and others 1998; Nichols and Pamatmat 1988; Nichols and Thompson 1985; Niesen and Lyke 1981), and fish use of mud flats and salt marshes (Beck and others 2003; Boesch and Turner 1984; Wooster 1971).

Pittman (1996), Thompson (2002), and Shouse (2003) also sampled salt marsh invertebrates in the South Bay. Fish and invertebrates in some South Bay marshes near Coyote Creek were sampled in the mid 1980's (Kinnetic Laboratories 1987), and some of these data are reviewed by (Hansen 2003). Potential responses of fishes to South Bay salt marsh restoration are reviewed by Brown (2003) and Hansen (2003). Relatively few data are available regarding use of South Bay marshes by salmonids, due to the difficulty of sampling small fish in this habitat (J. Smith, pers. comm.). Salmonid use of the South Bay is limited, with spawning runs only in Coyote Creek, the Guadalupe River, Stevens Creek, and San Francisquito Creek (J. Smith, pers. comm.). While data are limited on fish use of tidal marshes in the South Bay, extensive data on this topic are available from Suisun Bay (e.g., Feyrer and others 2004; Matern and others 2002). Data on fish use of freshwater streams flowing into the South Bay, sampled by R. Leidy from 1992 to 1998, are available in an online database (San Francisco Estuary Institute 1999).

Information on aquatic invertebrates and fishes of the South Bay salt ponds has been studied and reviewed in a number of studies (e.g., (Anderson 1970; Carpelan 1957; Lonzarich 1989). Information on key species is available in the Goals Project's Species and Community Profiles (Goals Project 2000), and W. Maffei has unpublished data on invertebrate distribution in South Bay ponds that are available. USGS is currently studying invertebrates and fishes in South Bay salt ponds, but these data are not yet available.

### 3.1.3 Mammals

Small mammal trapping efforts are discussed below under Salt Marsh Harvest Mouse. Use of South Bay habitats by harbor seals (*Phoca vitulina*) are summarized in a number of sources (Fancher and Alcorn 1982; Grigg and others 2004; Kopec and Harvey 1995; Lidicker and Ainley 2000).

### 3.1.4 Key Wildlife Species

There are three federally listed species of primary concern to the SBSP Restoration Project: the salt marsh harvest mouse (*Reithrodontomys raviventris*), California Clapper Rail (*Rallus longirostris obsoletus*), and Western Snowy Plover (*Charadrius alexandrinus nivosus*). Information on these key wildlife species was summarized in the Goals Project's Species and Community Profiles (Goals Project 2000). These species, along with other key mammals, are briefly addressed below.

**Salt Marsh Harvest Mouse (*Reithrodontomys raviventris*)**. Howard Shellhammer, his students and his colleagues at H. T. Harvey Associates have authored most of the literature and trapping reports on the salt marsh harvest mouse (Shellhammer 1982; Shellhammer 2000a; Shellhammer 2000b; Shellhammer and Duke 2004). Additional information can be found in the *Salt Marsh Harvest Mouse and California Clapper Rail Recovery Plan* (U.S. Fish and Wildlife Service 1984) and G. F Fisler's 1965 monograph on the salt marsh harvest mouse (Fisler 1965). Lidicker (2000) provides an excellent review of studies on the California Vole (*Microtus californicus*). The salt marsh wandering shrew (*Sorex vagrans halicoetes*) has not received much attention in the last 30 years; the most pertinent papers are listed in Shellhammer (2000b). H. Shellhammer has developed a database and location maps of nearly all trapping studies for the salt marsh harvest mouse throughout its range. As of January 2004 this includes 507 entries, of which 234 are from the South Bay. The database and associated maps will be available electronically from H. T. Harvey and Associates in 2004.

Most of the literature and trapping studies in the South Bay, indicate that these species, especially the mouse and the shrew, suffer from a lack of escape cover and upland vegetation at the upper edge of the tidal marshes (Shellhammer 1982; Shellhammer 1989; Shellhammer 2000a; Shellhammer 2000b; Shellhammer and Duke 2004; U.S. Fish and Wildlife Service 1984). Shellhammer and Duke (2004) note that most of the South Bay tidal salt marshes lack a tidal salt marsh-upland transition zone habitat that would function as sufficient escape cover during high tides. Escape cover in most of the South Bay today comprises pickleweed mixed with peripheral halophytes located on narrow, steep slopes between the upper elevation of the marsh plain and a dike top road. Escape cover also exists as emergent vegetation along the raised berms that border internal channels of marshes.

Salt marsh harvest mice will move through corridors covered with appropriate halophytic vegetation but the maximum distance they will move through such areas is not known. Salt marsh harvest mice are known to move across 5 m on land, 4 m in water and 250 m through brackish or fresh water vegetation; distances greater than those are considered barriers to movement and hence gene flow (Shellhammer and Duke 2004) .

**California Clapper Rail (*Rallus longirostris obsoletus*).** There are more than 50 references relating to the California Clapper Rail entered in the EndNote database. This subspecies is endemic to salt marshes of San Francisco Bay, and will benefit from planned restoration. Recent information on the subspecies, including the distribution in the South Bay, has been compiled by Albertson (Albertson 1995) and in the Goals Project's Species and Community Profiles (Goals Project 2000). These sources provide information on habitat preferences of Clapper Rails, which include extensive dendritic channels. The San Francisco Bay National Wildlife Refuge (SFBNWR) conducts annual (or semi-annual) winter high-tide surveys for rails in all accessible tidal marshes in the South Bay. These airboat surveys <u>do</u> <u>not</u> provide data on rail distribution in brackish marshes, which include considerable potential rail habitat south of Coyote Creek (Albertson, pers. comm.). Various other studies provide some data on rail abundance distribution and abundance in South Bay habitats (e.g., (H. T. Harvey & Associates 1989b; H. T. Harvey & Associates 1990a). Future collaborative efforts of the California Department of Fish & Game (CDFG), USFWS, USGS, and PRBO may help to fill this data-gap with annual Bay-wide surveys. This effort is planned to happen in winter 2004/2005 (Albertson, pers. comm.).

**Western Snowy Plover (*Charadrius alexandrinus nivosus*).** Western Snowy Plovers breed (during spring and early summer) and forage (year-round) in the South Bay. Breeding habitat includes open exposed levees, dry salt pans and dry salt pond habitat. Data on the distribution of this subspecies in the South Bay has been lacking. Historic data include surveys of a few accessible areas (e.g., (Page and Stenzel 1981; Ryan and Parkin 1998c), CDFG surveys of the Baumberg Tract (e.g., Casady 1999) and SFBNWR surveys (e.g., Hannon and Clayton 1995). Recently, the San Francisco Bay Bird Observatory (SFBBO) has begun systematic surveys of breeding Snowy Plovers in the South Bay (Strong and Dakin 2004). These data, coupled with ongoing USGS bird surveys, will be useful in determining which ponds are currently most utilized by this federally-listed subspecies. This subspecies has been well studied on the Pacific Coast, and, thus, much is known about habitat preferences, predation levels and predator management, human disturbance issues, and population status (e.g., (Neuman and others 2001; Page and others 1986; Page and others 2000; Page and others 1985; Page and others 1991; Ruhlen and others 2003).

In addition to the data-gaps, there are several gaps in knowledge that can be filled with existing data. These data synthesis needs include:

*Determining the effect of salt pond conversion on breeding birds.* If current California Gull colonies are displaced, these birds could compete for breeding habitat with Snowy Plovers and other nesting birds through displacement or trampling of nests. Synthesis is needed of the available data on the numbers and distribution of nesting California Gulls and other waterbirds, and how these birds would be affected by various conversion plans. Aspects of this topic have been addressed (Strong and others In Prep), but synthesis with Snowy Plover distribution data is still needed.

*Identifying wildlife species that are most dependent on salt ponds.* Ranking species' dependence on ponds and potential resilience to restoration will aid in determining the number and management of ponds to be retained. In other words, the proportion of each species South Bay population that is contributed by different habitats (Bay, salt pond, mudflat, saltmarsh) is needed. Current data collected by USGS, combined with North American and regional population estimates of each species will help answer this question. Data will be available (currently funded), but there may be a gap in analysis/synthesis.

## 3.2 Data-gaps

### 3.2.1 Data-gaps Essential to Fill for Restoration Planning

*How do birds use tidal marsh, tidal mudflat and Bay habitats concurrently with use of salt pond, managed pond and open Bay habitat?* Detailed data on waterbird use of salt ponds with different habitat characteristics are being collected by USGS and PRBO. Some data are being collected concurrently in tidal marsh habitat, but fewer data exist on habitat characteristics of tidal mudflats and tidal marsh that affect their use by waterbirds. Although historic data exist on bird use of tidal mudflat habitat, for a robust model of bird use of the South Bay, data should be collected on bird use of tidal mudflat and additional tidal marsh habitat sites concurrently with current studies in the Salt Ponds and open Bay. There is a data-gap of shorebird use of tidal mudflat and tidal marsh habitats, and a synthesis gap for the combined analysis of all habitat data sets.

*What is the response of waterbirds to existing, implemented tidal marsh restoration projects in the South Bay?* Although several habitats similar to South Bay salt ponds have been restored to tidal action, few data are available regarding bird use of restored vs. diked habitats before and after restoration. Data were collected on bird use of Outer Bair Island prior to restoration, but there are no comparative data available after restoration. Current surveys of Outer Bair Island, and other restored habitats, such as Cooley Landing, would be useful to fill this data-gap.

### 3.2.2 Data-gaps to Fill During Adaptive Management and Monitoring

*How do food resources available for shorebirds on tidal mudflats and in tidal marshes compare to resources available in salt ponds?* These data will aid in determining the impact of restoration on birds currently using the ponds.

*What is the impact of smooth cordgrass (*Spartina alterniflora *and* S. foliosa *x* alterniflora*) on the distribution and extent of the pickleweed band in tidal salt marshes and hence on the existence of salt marsh harvest mice and shrews in smooth cordgrass-invaded areas?* All indications are that smooth cordgrass will change the relative sizes of the various zones of tidal marshes and hence affect many native animals and plants in different ways than native cordgrass. This is likely to be true of hybrid cordgrass as well.

*How far will salt marsh harvest mice travel through the vegetation lining creeks near their mouths, i.e., entrances to the Bay?* It is important to provide as much connectivity between tidal marshes as possible to maintain adequate populations of various species and prevent the loss of genetic variation that might come about if units are isolated from one another. This information can be acquired through an extensive trapping program.

*At what density and extent of perennial pepperweed (*Lepidium latifolium*) do salt marsh harvest mice stop using an invaded area?* High peppergrass density in the Suisun Bay is correlated with reduced salt marsh harvest mouse populations. Peppergrass is extensive in the South Bay at present and may be hard to control. Various densities of peppergrass should be trapped to ascertain at what density salt marsh harvest mice disappear.

*How much genetic variation exists in the major populations of salt marsh harvest mice?* The original range of the mouse has been divided into small units by bridges and freeways, salt ponds and filling. Further separation may be harmful at the genetic level, i.e. it may reduce population vigor, and hence knowing the nature of genetic variation of the various populations will make planning to avoid such damage more effective.

*How will anadromous fish use restored marshes as migration corridors?* Little information is available regarding movement patterns of salmonids in the South Bay.

# 4. TOPIC 2: VEGETATION/PLANKTON IN PONDS, MARSHES, SLOUGHS, MUDFLATS, AND BAY

## 4.1 Data Summary

### 4.1.1 Vascular Plant Community Ecology of South San Francisco Bay and Similar Estuarine Systems

The Goals Project publications (Goals Project 2000) provide the best review of the distributions and abundances of vegetation in the San Francisco Bay. *The South Bay Salt Ponds Initial Stewardship Plan* (Life Science 2003) and the *South Bay Salt Pond Restoration Feasibility Analysis* (Siegel and Bachand 2002) are subsequent reports that direct readers to the Goals Project. The Goals Project's Species and Community Profiles (Goals Project 2000) covers the shallow subtidal flora (Hanson 2000) with emphasis on eelgrass (*Zostera marina*), tidal marsh plants (Baye and others 2000) and diked Baylands plants and environments (Baye 2000). There is also a section on the ecotonal plant communities surrounding the Baylands (Holstein 2000). The Goals Project's Species and Community Profiles report provides extensive plant lists with comments on historic and current distributions, including rare and extirpated species. In addition, a review of the ecology of San Francisco Bay tidal marsh vegetation is provided in *The Ecology of San Francisco Bay Tidal Marshes: A Community Profile* (Josselyn and San Francisco State Univ. 1983). Descriptions of tidal salt, brackish and freshwater plant community structure and revegetation techniques provided in reports prepared by (H. T. Harvey & Associates 1977; H. T. Harvey & Associates and others 1982; Jones and Stokes Associates Inc. 1979). The spatial distribution of tidal marsh plant communities within the SBSP Restoration Project area will be mapped as part of the current scope for characterizing existing conditions.

Valuable information is available concerning the historic distribution of plant communities in the South Bay. Cooper (1926) reconstructed the "original" vegetation distributions on the alluvial fans (including some observations of the Baylands) in the Palo Alto vicinity from a combination of field observations, literature review and interviews with elder residents. The San Francisco Estuary Institute (SFEI) has developed a map of likely historic distributions of habitats in the South Bay (San Francisco Estuary Institute 1997). In addition, San Francisco Estuary Institute (1998) provides a map of the potential distribution of current tidal marsh vegetation types in the South Bay. This report also provides conceptual models of tidal marsh form and factors controlling root zone salinity in the South Bay. Several tidal salt marshes in the South Bay have not been diked (to preclude tidal flushing) or filled and could serve as reference sites of the plant community structure in pre-European settlement tidal salt marshes. These include: Dumbarton Marsh, Greco Island, Laumeister Tract, Ravenswood, and portions of the Palo Alto Baylands Nature Preserve. Quantitative plant species composition data were collected at Dumbarton Marsh, Laumeister Tract, and Ravenswood in conjunction with the Ecological Risk Assessment done for the Rhone Poulenc (Bay Road) Site (JSA Environmental 1998). No detailed vegetation information or data have been located for Greco Island or the Palo Alto Baylands Nature Preserve. There are no remaining historic tidal salt marsh/upland transition zone (ecotone) plant communities.

Understanding the relationship between soil edaphic parameters (pore water salinity, percent organic matter, bulk density, texture, pH, macro and micro nutrient concentrations) and tidal marsh plant community composition is important for projecting the distribution and surface area of tidal salt, brackish and freshwater marsh habitat in the South Bay. In addition, this information is necessary to select appropriate dredged material to support target vegetation establishment. Adequate information on soil edaphic parameters is available (H. T. Harvey & Associates 2002b).

Concerning California tidal salt marsh vegetation in general, Zedler and others (1999) documents the spatial patterns of California, pre-European settlement tidal salt marsh vegetation by surveying a near-pristine marsh in San Quintin Bay, Mexico. Zonation of salt marsh vegetation in the San Francisco Bay as a function of elevation has also been generally described (H. T. Harvey & Associates and others 1982; Josselyn and others 1993). In addition, Zedler (1977) and Zedler and others (1992) analyze the zonation of tidal salt marsh plant species in southern California as a function of elevation. Studies have addressed the role of biotic (competition, parasitism, plant establishment mechanisms) and abiotic (water logging, salinity, physical disturbance, freshwater inputs; nitrogen availability) factors in the distribution of California tidal salt marsh plant species (Allison 1996; Covin and Zedler 1988; Griswold 1988; Josselyn and San Francisco State Univ. 1983; Pennings and Callaway 1992; Pennings and Callaway 1996; Zedler and Beare 1986; Zedler and others 1992; Zedler and others 1986). Research has been done on factors controlling the productivity, density and height of Pacific cordgrass (*Spartina foliosa*) in southern California and the relationship of Pacific cordgrass height to Light-footed Clapper Rail nesting (Covin and Zedler 1988; Trnka and Zedler 2000; Zedler 1993).

Wyllie-Echeverria and Fonseca (2003) summarized the information available on vascular plants of subtidal habitats in the San Francisco Bay and they also report on a pilot study of eelgrass recovery in San Francisco Bay (Fonseca and others 2003). Hanson (2000) provides a review of eelgrass in the San Francisco Bay. In addition, Merkel & Associates are currently conducting an inventory of eelgrass distribution in San Francisco Bay (Merkel & Associates 2003).

Vegetation data include the City of San Jose's detailed mapping of the tidal marshes surrounding the Alviso Complex ponds. This City of San Jose's coverage includes approximately 2,000 acres between Mowry Slough and Alviso Slough (H. T. Harvey & Associates 2002a). The tidal marshes mapped in the above referenced study developed after the construction of salt pond levees, and range from 1 to 40 years old. Therefore, they could serve as a South Bay model of tidal marsh vegetation establishment on recently accreted sediments along a salinity gradient from tidal freshwater to tidal saltwater. The City of San Jose's data include information on soil edaphic characteristics relative to vegetation composition and distribution (H. T. Harvey & Associates 2002b). The USGS is acquiring LIDAR topographic data that would allow for correlation analysis of the recent vegetation datasets to 1-foot contour elevation data.

There is some vegetation data for the Baumberg Complex. H. T. Harvey & Associates mapped the lower portions of Old Alameda Creek in previous years and in 2003, mapped the entire downstream portion of the Alameda Flood Control Channel (H. T. Harvey & Associates 2003b). PRBO's wildlife models for the area include tidal marsh mapping around their point count stations and slough channel density (Stralberg and others 2003). PRBO's study sites are: Whale's Tail, Hayward Shoreline, Alameda Creek, and Dumbarton Marsh in the East, and Faber Tract, Laumeister, and Ravenswood Slough in the West. No mapping has been performed in support of the Eden Landing Wetland Restoration Project. Whale's Tail and Ideal Marsh are salt ponds that naturally breached in the 1930s. There are mitigation monitoring reports for the 1998 Cargill B1 mitigation site near the Whale's Tail (Wetlands Research Associates 1995). No quantitative vegetation data was located for Ideal Marsh. Specific vegetation data for various shoreline restoration projects (Cogswell, Hayward Shoreline, Hayward Marsh and Oro Loma) were not yet acquired, although there should be data available for areas north of the Baumberg Complex as part of their monitoring programs.

Some vegetation data exist for areas in and around the Redwood City Pond Complex. The PRBO wildlife monitoring project includes visual estimates of plant species cover at point count stations in this complex (Stralberg and others 2003). Jenkins-Sanders (1994) surveyed several tidal salt marshes that existed prior to European settlement around the South Bay, including Ravenswood and Laumeister, in an Ecological Risk Assessment for the Rhone Poulenc Site. These data include soil edaphic characteristics, invertebrate sampling and vegetation sampling. Vegetation monitoring data are available from for the Cooley

Landing tidal salt marsh restoration site where Wetland Research Associates has monitored vegetation colonization (Jenkins Sanders & Associates 1994; Philip Williams & Associates 2004a). Further to the south, vegetation data were collected for the Long-Term Management Strategy at the Faber Tract, which was restored using dredge spoil in 1969 (LTMS 1994). To the north there are habitat mapping data available for Bair Island (H. T. Harvey & Associates and Philip Williams and Associates 2004).

### 4.1.2 Unicellular and Multicellular Algae

Little information is available on the algae and phytoplankton of the South Bay, or of California tidal marshes in general. The available information on the phytoplankton of the South Bay is summarized below in Section 5D. Research has examined the contribution of micro and macroalgae to the primary productivity of tidal salt marshes and tidal mudflats in San Francisco Bay (Josselyn and San Francisco State Univ. 1983; Shellem and Josselyn 1982) and in southern California (Zedler 1980; Zedler 1982).

Hanson (2000) briefly mentions various seaweeds found in San Francisco Bay. Hanson refers to additional references on flora found in the shallow subtidal habitats of San Francisco Bay (Herbold and others 1992; Meorin and others 1991; Nichols and Pamatmat 1988; Silva 1979). Baye (Baye 2000) reviews the flora of the salt ponds.

### 4.1.3 Special-status Plant Species Targeted for Reintroduction

Three special-status plant species are targeted for potential reintroduction during the SBSP Restoration Project: Point Reyes bird's beak (*Cordylanthus maritimus* ssp. *palustris*), California seablite (*Suaeda californica*), and Contra Costa goldfields (*Lasthenia conjugens*). The Baylands Ecosystem Species and Community Profiles (Goals Project 2000) provide an in-depth synopsis of these species including current and historic distributions, microhabitat requirements, and associated species. Many references described above also describe the plant communities supporting these and other rare plant species. Numerous floral references including Hickman (1993), Munz (1968), and Mason (1969) provide brief taxonomic and physiognomic descriptions of these species and their habitats.

Additional information on restoration efforts and associated life histories of each of these species is available. For example, the Center for Plant Conservation (CPC April 15, 2004), contains a plant profile of Point Reyes Bird's Beak that describes the ecology and current restoration efforts of this species and also provides a comparison to the ecology and reproduction of salt marsh bird's beak (*Cordylanthus maritimus* ssp. *maritimus*), a related species from Southern California (Kaye 1991). Other references pertaining to Point Reyes bird's beak, including factors affecting reestablishment of salt marsh birds beak and observations of root-parasitism and genetic variation (Parsons and Zedler 1997) are included in this profile (CPC April 15, 2004).

There is little information on the restoration of California seablite, now entirely restricted to the estuary in Morro Bay, California. Some references offer insight as to the preferred habitat for this species. Of these, Mayer and Laudenslayer (1988) details the salinity and elevation gradients of saline emergent wetlands, and names California seablite as a characteristic species in this habitat type. Ferren and others (1995) specifically name California seablite as a dominant species. This reference describes the specific habitat for California seablite using Cowardin (1979).

### 4.2 Data-gaps

#### 4.2.1 Data-gaps Essential to Fill for Restoration Planning

*What are the elevation ranges for the dominant plant communities targeted for restoration in existing South San Francisco Bay tidal marshes?* These plant communities include low tidal salt marsh (*Spartina foliosa*-dominated), tidal salt marshplain (*Salicornia virginica*-dominated), tidal salt marsh upland transition/ecotone, tidal brackish marsh (dominated by *Scirpus maritimus* and *S. robustus*), and tidal freshwater marsh (dominated by *Scirpus californicus*, *S. acutus*, *Typha latifolia*, and *T. angustifolia*). Precise elevation range data for South Bay tidal habitats will be required to accurately predict the distribution and surface area of tidal marsh vegetation (e.g. freshwater marsh, brackish marsh, salt marsh) and intertidal mudflat for various restoration alternatives. Some older summary information is available but the original data sets are not available for quality review (Atwater and others 1979). The USGS (Judy Drexler) is currently analyzing data that was collected in 1983 by Kent Dedrick of the California State Lands Commission on the distribution of South Bay tidal salt marsh vegetation with respect to precise elevation ranges. This USGS work begins to address this data-gap; however, additional data collection will be necessary for tidal brackish and tidal freshwater habitats.

#### 4.2.2 Data-gaps to Fill During Adaptive Management and Monitoring

*What are the most effective revegetation methods for the special-status plant species (*Cordylanthus maritimus *ssp.* palustris, Suaeda californica, *and* Lasthenia conjugens*) to be reintroduced to the South Bay?* Effective methods can be inferred from recovery work on similar species and subspecies. However, the project should design and incorporate field experiments on various revegetation techniques prior to full-scale implementation.

*What are the life history characteristics of special-status plant species to be reintroduced to the South Bay?* Germination requirements, flood depth and duration tolerances, salinity tolerances, and competition, need to be better understood for reintroducing special-status species (*Cordylanthus maritimus* ssp. *palustris*, *Suaeda californica*, and *Lasthenia conjugens*).

*Which insects are critical pollinators of plant species that are desired after restoration and what are their habitat requirements?* Certain plants, such as Point Reyes bird's beak (*Cordylanthus maritimus* ssp. *palustris*), may not thrive without sufficient populations of key insect pollinators.

# 5. TOPIC 3: DESIGN OF HABITAT AND LANDSCAPE WITH FOCUS ON RESTORATION DESIGN FEATURES

## 5.1 Data Summary

### 5.1.1 Overview

A significant amount of information on the design of tidal marsh habitat restoration and managed pond features in the San Francisco Bay exists in reports and plans. Many of these designs involve projects that are planned, or already implemented. These reports describe design rationale and criteria, but less information is available on the success of constructed features due to the paucity of long-term monitoring programs. Tidal salt marsh restoration design features for past San Francisco Bay projects and for the SBSP Restoration Project, have and will be shaped, in part, by the habitat requirements of the target endemic tidal salt marsh species, primarily the California Clapper Rail and the salt marsh harvest mouse. These habitat requirements include dendritic channel networks, productive, dense and tall Pacific cordgrass-dominated habitat, dense and tall pickleweed-dominated tidal marshplain habitat and broad higher elevation tidal salt marsh-upland transition zones that provide ample escape cover. The following list of design features is based in part on these habitat goals. The list includes a short description of each element, and information regarding its intended function. These elements may be useful for restoration planning of tidal marsh and managed pond habitat within the SBSP Restoration Project site. In addition, there is a section below on design of restored habitat features for key wildlife species.

### 5.1.2 Levee Breach

The purpose of a levee breach is to re-open the salt pond or diked bayland to tidal action. A breach is an excavated section through an earth levee; excavated with either land-based or floating equipment. Levee breaches are often over-sized initially, since compacted levee material may be relatively erosion resistant and damped tides may delay the evolution of desirable wetland functions and associated ecological values. Large levee breaches also provide material that can be re-used as fill to construct training berms and borrow-ditch cutoff berms (also known as ditch blocks). Design criteria for levee breach location and size are included in the following reports:

- Bair Island Restoration (H. T. Harvey & Associates and Philip Williams and Associates 2004)
- Napa River Salt Marsh Restoration (Philip Williams & Associates 2002a)
- Petaluma Marsh Expansion (Philip Williams & Associates 2002d)
- Pacheco Marsh Restoration (Philip Williams & Associates 2003)

The following projects containing levee breaches have been implemented:

- Martin Luther King, Jr. Regional Shoreline Wetlands Project (Levine-Fricke 1999; Wetlands and Water Resources 2001)
- Sonoma Baylands Enhancement (Philip Williams & Associates 1989; Philip Williams & Associates 1991)
- Meadows Drive Habitat Enhancement (Demgen Aquatic Biology 1994; EIP Associates 1988)
- Oro Loma Marsh Enhancement (Levine-Fricke 1996; Wetlands and Water Resources 2002)
- Cooley Landing Tidal Marsh Restoration (Philip Williams & Associates 2002b; Philip Williams & Associates 2002c)

### 5.1.3 Levee Lowering

Levee lowering requires the excavation of material to lower the levee to a specified elevation, such as mean higher high water (MHHW). Design elevations are determined so that these elements will provide suitable elevations for high elevation tidal marsh vegetation, wildlife corridors, and high tide refugial habitat for salt marsh endemic, shorebird and waterfowl species. Levees can provide access and habitat for predators that compromise the ecologic objectives of restoration; levee lowering can reduce these negative effects. In some instances, levee lowering has been proposed to mitigate short-term impacts associated with disturbances to existing habitats associated with construction. Levee lowering has also been shown to lessen potential flood risks by more fully connecting restored wetlands to fluvial systems during flood events (increase the floodplain storage). Design criteria for levee lowering are included in the following reports:

- Bair Island Restoration (H. T. Harvey & Associates and Philip Williams and Associates 2004)
- Napa River Salt Marsh Restoration (Philip Williams & Associates 2002a)
- Petaluma Marsh Expansion (Philip Williams & Associates 2002d)
- Pacheco Marsh Restoration (Philip Williams & Associates 2003)

The following projects containing levee lowering have been implemented:

- Cooley Landing Tidal Marsh Restoration (Philip Williams & Associates 1999b; Philip Williams & Associates 2002b; Philip Williams & Associates 2002c)

### 5.1.4 Levee Creation and Sacrificial Bench

New levees can enhance flood protection for existing infrastructure, as has been proposed for the SBSP Restoration Project. In addition, levee slopes can be designed with appropriate slopes, elevations, surface area and vegetation to provide high-tide refugial habitat for key wildlife species. A vegetated, sacrificial bench can be used for outboard slope protection on levees that are useful as wind-wave breaks during tidal marsh habitat evolution. Wind-wave breaks reduce fetch and enhance sedimentation until bed elevations increase and relatively erosion-resistant vegetation can be established. The outboard bench is designed to erode until the tidal marsh forms, and eliminates the need to armor the outboard side of the levee. The outboard side of the bench may be revegetated by seeding and/or planting, and the vegetation is allowed to establish prior to breaching the site. Design criteria for levee creation and/or sacrificial benches are included in the following reports:

- Petaluma Marsh Expansion (Philip Williams & Associates 2002d)
- Hamilton Army Airfield Wetlands Restoration (Philip Williams & Associates 1998b)

The following projects containing levee creation have been implemented:

- Sonoma Baylands Enhancement (Philip Williams & Associates 1989; Philip Williams & Associates 1991)
- Oro Loma Marsh Enhancement (Levine-Fricke 1996; Wetlands and Water Resources 2002)

### 5.1.5 Pilot Channels

Construction of pilot channels has been considered in cases where existing fringe tidal marsh is expected to mute the tide signal within the restored wetland. These elements are typically considered only across sections of fringe tidal marsh (i.e., not across outboard mudflats) since the vegetation greatly reduces the ability of the restored tidal prism to scour undersized inlet channels. Channel cross-sections are designed using hydraulic geometry relationships, and refined using hydrodynamic computer modeling (Philip

Williams & Associates 1995; Williams and others 2002b). Where pilot channel construction would significantly impact special-status species habitat, natural tidal scour over a longer time frame may be preferable to pilot channel construction. Pilot channel design criteria and rationale have been described in the following reports:

- Napa River Salt Marsh Restoration (Philip Williams & Associates 2002a)
- Pacheco Marsh Restoration (Philip Williams & Associates 2003)

The following projects containing pilot channels have been implemented:

- Cooley Landing Tidal Marsh Restoration (Philip Williams & Associates 1999b; Philip Williams & Associates 2002b; Philip Williams & Associates 2002c)
- Roberts Landing Wetland Mitigation (Resource Management International 1995)

### 5.1.6 Starter Channels

The excavation of starter channels inside the restored site provides immediate new channel habitat and improves drainage, which enhances rates of sedimentation, benthic invertebrate establishment,, vegetation establishment, and hence, wildlife colonization. Inboard channels extend from a breach into the interior, generally located along historic channel paths. Starter channels are usually considered as viable design features in cases where remnant channels are not expect to re-form naturally (due to erosion-resistant substrate), or where no relict channel system has been preserved. Channels should be self-maintaining through natural scour, and not require extensive future dredging to remain operational. Channel design utilizes empirical hydraulic geometry relationships, which are refined using hydrodynamic computer modeling (Philip Williams & Associates 1995; Williams and others 2002b). Inboard channels benefit habitat restoration by providing habitat for benthic invertebrates, fish and waterbirds soon after construction, and by facilitating more rapid channel development. Design criteria and rationale for starter channels have been described in the following reports:

- Bair Island Restoration and Management Plan (H. T. Harvey & Associates and Philip Williams and Associates 2004)
- Napa River Salt Marsh Restoration (Philip Williams & Associates 2002a)
- Petaluma Marsh Expansion Project (Philip Williams & Associates 2002d) ph

The following projects containing starter channels have been implemented:

- Martin Luther King, Jr. Regional Shoreline Wetlands Project (Levine-Fricke 1999; Wetlands and Water Resources 2001)
- Pacheco Marsh Restoration(Philip Williams & Associates 2003)
- Richmond Parkway Wetland Mitigation(LSA Associates and Philip Williams & Associates 1993)
- Meadows Drive Habitat Enhancement (Demgen Aquatic Biology 1994)
- Oro Loma Marsh Enhancement Plan (Levine-Fricke 1996; Wetlands and Water Resources 2002)
- Martinez Regional Shoreline Salt Marsh Enhancement (Philip Williams & Associates 1998a)
- San Leandro Shoreline Restoration(ESA 1988)

### 5.1.7 Training Berms

If a perimeter levee is breached without interior grading, borrow ditches present in diked Baylands or former salt ponds may become the primary tidal channels, potentially reducing the long-term ecological value of the site. Development of dendritic channel networks facilitates the establishment of a productive, diverse vascular plant and benthic invertebrate community as well as potential breeding and foraging habitat for California Clapper Rail. In addition, tidal salt marsh habitat, well drained by a dendritic channel network should create conditions for more productive, taller pickleweed-dominated habitat. Therefore, berms (curvilinear earth fill) are designed to promote the re-occupation of the natural historic tidal channels. Training berms are constructed alongside historical channels and/or starter channels to direct flow along historic paths, promoting scour and the re-establishment of the channels. Berms are also used to create habitat diversity by providing high marsh areas, provide dissipation of wave energy, and reduce agitation by wind-waves by reducing fetch lengths. Design criteria and rationale for training berms have been described in the following reports:

- Petaluma Marsh Expansion Project (Philip Williams & Associates 2002d)

The following project containing training berms has been implemented:

- Cooley Landing Tidal Marsh Restoration (Philip Williams & Associates 1999b; Philip Williams & Associates 2002b; Philip Williams & Associates 2002c)

### 5.1.8 Ditch Block

A ditch block is an earth fill that crosses an existing borrow ditch to inhibit tidal flow. Borrow ditches are human constructed channels adjacent to levees that tend to be straighter and offer less habitat complexity than natural channels. A ditch block prevents the borrow ditches from capturing tidal flows, hence impeding the re-establishment of historic channel systems that are typically found to have greater ecological value. The locations of ditch blocks with respect to levee breaches are specified in order to ensure safe fish passage at low tide. Design criteria and rationale for ditch blocks have been described in the following reports:

- Bair Island Restoration and Management Plan (H. T. Harvey & Associates and Philip Williams and Associates 2004)
- Napa River Salt Marsh Restoration (Philip Williams & Associates 2002a)
- Petaluma Marsh Expansion Project (Philip Williams & Associates 2002d)

The following project containing ditch blocks has been implemented:

- Cooley Landing Tidal Marsh Restoration (Philip Williams & Associates 1999b; Philip Williams & Associates 2002b; Philip Williams & Associates 2002c)

### 5.1.9 Peninsula and Island Creation

Peninsulas and/or narrow-elongated islands can be created to limit fetch length in cases where wind-wave agitation is expected to slow tidal marsh habitat development or, in cases of high wind-wave action, change the morphological endpoint of the restored site to a tidal mudflat. Peninsulas and/or narrow-elongated islands may also increase the life of flood protection levees by reduced wave erosion, direct major slough channel formation away from levee toes, and maximize sediment deposition. In addition, these features could be designed to provide valuable breeding habitat for various bird species (e.g., high enough to prevent inundation with foam, and free of vegetation), particularly in managed ponds (see wildlife section below). Design criteria and rationale for peninsulas and islands have been described in the following report (this project has also been implemented):

- Sonoma Baylands Enhancement (Philip Williams & Associates 1989; Philip Williams & Associates 1991)

### 5.1.10 Water Control Structures

Water control structures (e.g. culverts, flap gates, slide gates, weirs) may be necessary to manage tidal exchange, salinity, water circulation between ponds, and pond drainage. Although these features are less common in tidal habitats, water control structures are essential in managing proper hydrological and salinity regimes in managed ponds. Design criteria and rationale for water control structures have been described in the following reports:

- Petaluma Marsh Expansion Project (Philip Williams & Associates 2002d)
- Bair Island Restoration (H. T. Harvey & Associates and Philip Williams and Associates 2004)
- South Bay Salt Ponds Initial Stewardship Plan (Life Science 2003)

The following projects containing water control structures have also been implemented:

- Stevens Creek Tidal Marsh Restoration (Swent 1992; Swent 2001)
- San Leandro Shoreline Restoration (ESA 1988)
- Roberts Landing Wetland Mitigation (Resource Management International 1995)

### 5.1.11 Excavation and Fill

Excavation or placement of fill has been used in various restoration designs in order to accelerate development of tidal habitats, and to create the various design features listed above (levees, sacrificial bench, ditch blocks, peninsulas and islands). Design criteria for marshplain excavation and placement of fill material, and the associated pros and cons, have been described in the following reports:

- Napa River Salt Marsh Restoration (Philip Williams & Associates 2002a)
- Pacheco Marsh Restoration (Philip Williams & Associates 2003)

The following projects containing excavation and fill have been implemented:

- Martin Luther King, Jr. Regional Shoreline Wetlands Project (Levine-Fricke 1999; Wetlands and Water Resources 2001)
- Sonoma Baylands Enhancement (Philip Williams & Associates 1989; Philip Williams & Associates 1991)
- Richmond Parkway Wetland Mitigation (LSA Associates and Philip Williams & Associates 1993)
- Meadows Drive Habitat Enhancement (Demgen Aquatic Biology 1994; EIP Associates 1988)
- Oro Loma Marsh Enhancement (Levine-Fricke 1996; Wetlands and Water Resources 2002)
- Martinez Regional Shoreline Salt Marsh Enhancement (Philip Williams & Associates 1998a)
- San Leandro Shoreline Restoration (ESA 1988)
- Roberts Landing Wetland Mitigation (Resource Management International 1995)

### 5.1.12 Wildlife

The physical features discussed above should be designed to maximize both interim and long-term habitat for certain wildlife species, including but not limited to the key ones identified above. The design of habitat features and layout at the landscape, pond-complex, and pond scales will be based, in part, on an understanding of the factors that affect distributions of wildlife and plant species in the San Francisco Bay. One of the greatest design challenges will be balancing the creation of new habitat for salt marsh endemics, such as the California Clapper Rail, while retaining and enhancing habitat for shorebirds and other wildlife that have come to use South Bay salt ponds in large numbers. Sources cited under Topics 1 & 2 in this document provide information on biotic and abiotic factors affecting the distribution of target wildlife species and PRBO is currently working on a comparison of bird use in salt ponds and salt marsh that will allow managers to assess positive and negative impacts to birds under varying management strategies (Stralberg and others 2003). Design of restored habitats will involve a balance between the needs of various key wildlife species, such as Snowy Plovers (preferring salt panne), waterfowl (preferring large open water channels and salt or managed ponds, as well as open Bay habitat), and Clapper Rails (preferring dendritic tidal channels). Raised peninsulas and islands within tidal marshes will provide potential nesting sites for birds, and important high-tide roost habitat, and refugia habitat for small mammals.

H. T. Harvey & Associates has been involved in several long-term projects in the Central Valley in which agricultural drainwater evaporation ponds were enhanced for shorebirds (H. T. Harvey & Associates 1993). While habitat conditions are slightly different from those of the South Bay salt ponds, the overall similarities make the evaporation basins and salt ponds quite comparable. The evaporation basins have been rendered relatively unsuitable for bird use (a management goal brought about by high levels of selenium in some of the basins) by making them structurally similar to salt ponds (i.e., relatively deep water, steep side slopes and flat bottoms). Conversely, managed ponds design and constructed specifically for bird use, primarily the same species involved in the South Bay salt ponds, have attracted large numbers and high densities of breeding and migrating shorebirds (Gordus and others 1996) relative to salt ponds configured and managed for salt production. Additional information on management of saline habitats is available in Reed and others (1997).

Characteristics of tidal salt marsh habitat that will support maximum numbers of Clapper Rails and salt marsh harvest mice are fairly well understood. Ideal Clapper Rail habitat includes dendritic channels and native Pacific cordgrass for cover. Habitat segments must be sufficiently large to support rails, and ideally will be interconnected, allowing for dispersal of rails into new habitat with a low probability of predation. These optimum habitat characteristics are discussed by Albertson and Evens (2000). Similarly, habitat characteristics of tidal marsh that support songbirds have been well studied (Nur and others 1997; Spautz and others 2003).

Based on existing information, the South Bay tidal salt marshes will be most beneficial to the salt marsh harvest mouse if they include the creation of complete tidal salt marshes, i.e. marshes with all zones (i.e. cordgrass, pickleweed, peripheral halophytes, and upland vegetation) and hence provide ample escape cover from tidal inundation. For the salt marsh wandering shrew it should include restoration of the upper portions of the pickleweed zone and the lower portions of a broad peripheral halophyte zone and for the vole it should include grasslands above and adjoining the recreated tidal salt marshes. While it has not been documented by extensive trapping, H. Shellhammer and other investigators hypothesize that berms along higher order channels (within marshes big and mature enough to develop the higher order channels) provide important escape cover habitat. Various species of mice, including harvest mice, have been seen clinging to bushes on such berms during high tides by a number of investigators over the years (Shellhammer and Josh Collins, pers. comm. among them).

Data are available on the response of salt marsh harvest mice and Black Rails (*Laterallus jamaicencis*) to the restoration of a tidal salt marshes at the Concord Naval Weapons Station in Suisun Bay (H. T. Harvey & Associates 1997a; H. T. Harvey & Associates 1999). Dense pickleweed-dominated intertidal habitat was restored at this site using dredged material. Escape cover habitat was created with dredged material by creating vegetated mounds above MHHW in the tidal salt marsh and salt marsh harvest mice successfully recolonized this site.

In addition to these sources, there are several sources available regarding the optimum design of tidal marshes for small fishes (Minello and others 1987; Talley 2000; West and Zedler 2000).

## 5.2 Data-gaps

### 5.2.1 Data-gaps Essential to Fill for Restoration Planning

*How will different restoration strategies affect bird populations in the South Bay?* This is perhaps the most important question to be answered before project implementation. Although PRBO is currently working on answering this question, the current model lacks several key components:

- Bird use of tidal mudflats needs to be considered. This is the most important habitat for many shorebird species during the non-breeding season. With models of how tidal mudflat habitat may change under differing management scenarios, it should be possible to estimate the number and diversity of birds using tidal mudflat habitat in the South Bay. Although there are historic data on bird use of South Bay tidal mudflats, data should be collected during the current surveys within salt ponds (USGS/PRBO effort).
- Bird use of open water habitats needs to be considered. Waterfowl that use salt ponds also use shallow-water bay habitats. As with data of the use by birds of tidal mudflat, these data should be collected concurrently with current bird surveys in salt marsh and salt ponds.
- Prey densities and energetic values need to be compared between salt ponds and tidal mudflat habitats. These data have not been collected, but will be useful in modeling the effects of restoration on food webs, and how birds respond to changes in food webs.
- Enhancement of current ponds needs to be considered. Under the Goals Project Habitat Goals (1999) scenario, tidal marsh in the South Bay would be increased from 9,000 acres to 25,000-30,000 acres, and 10,000-15,000 acres of salt pond habitat would be retained and managed. By managing these salt ponds (e.g., maintaining levels of salinity and providing nesting/roosting islands), waterbird use of remaining ponds could be maximized, and densities could potentially exceed those occurring in the salt ponds under current management. Data are available on potential salt pond enhancement techniques and shorebird response to those techniques. However, these data need to be analyzed with respect to the design alternatives to be developed for the SBSP Restoration Project (USGS shorebird use data, and H. T. Harvey & Associates Central Valley evaporation ponds data).

*How do the number, distribution, and size of potential nesting islands affect the abundance of nesting California Gulls?* California Gulls, which are often dominant over other bird species, could negatively impact other bird populations through competition for nesting space, and perhaps predation on eggs and chicks of other waterbird species. The retained salt pond habitats should be designed to maximize use by key waterbird species, including Snowy Plovers, stilts, and avocets, but not California Gulls. To meet this objective it will be useful to know the current availability of suitable nesting habitat for all nesting waterbird species including California Gulls in the South Bay, and the proportion and distribution of this habitat currently being used. Density dependence factors should be kept in mind when determining the distribution of nesting habitat that will remain in the South Bay following salt pond conversions. Information (currently being gathered by SFBBO) on effects of landfills on gull distribution will also be important.

### 5.2.2 Data-gaps to Fill During Adaptive Management and Monitoring

*How will the levee breaches at the Island Ponds (A19, A20, and A21) to be implemented by the Initial Stewardship Plan affect mudflat habitat and bird use?* The ISP provides an opportunity to begin to understand empirically how conversion of salt pond habitat to tidal habitats affects existing mudflat habitat and bird use in the South Bay.

*How successful have constructed elements been?* Much of the information described above comes from restoration projects currently in the planning stages, with much less information available from constructed sites. Monitoring of constructed sites and features built in the initial phase of the SBSP Restoration Project will help determine if these design features have performed as expected.

*Do borrow ditches provide valuable fish habitat after restoration?* Borrow ditches may provide important refugia habitat for small fishes (potentially including Chinook salmon), but may also provide habitat for predatory fish (e.g., striped bass). Monitoring of fish use in borrow ditches during initial restoration efforts will aid in determining the value of this habitat.

# 6. TOPIC 4: LESSONS LEARNED FROM PRIOR RESTORATION PROJECTS

## 6.1 Data Summary

### 6.1.1 Overview

Limited long-term monitoring data exist from restored tidal marshes in the San Francisco Bay, the rest of the U.S., and internationally. Of the studies examining such monitoring data, few have been published in peer-reviewed literature, with the bulk of published reports focusing on natural marsh functions (Orr and others 2003; Williams and Orr 2002c). However, substantial monitoring work has been performed comparing the ecological functions and values of restored southern California tidal salt marshes to natural systems and utilizing manipulative ecological field experiments to guide improvements in tidal salt marsh restoration techniques (Zedler 2001). All of the non-published reports and the publications evaluating current and past restoration efforts recognize the need to develop a conceptual model of restored tidal marsh evolution (Orr and others 2003; Philip Williams & Associates 2002e; Philip Williams & Associates 2004b; Williams and Faber 2001; Williams and Orr 2002c).

A conceptual model is useful for the restoration process because it can define criteria for the success of the restoration design (CALFED 2000). It is equally useful for defining key uncertainties in the development of the restoration design, which lead to areas where research may be needed to aid restoration. From a management perspective, a conceptual model allows environmental practitioners to reach a consensus, despite differing opinions on the opportunities and constraints for the restoration of a particular site.

To refine a general conceptual model of the evolution of restored tidal marshes in the San Francisco Bay area, Williams and Orr (2002c) studied 15 large (>18 ha) breached-levee restoration sites in San Francisco Bay, including 6 sites in the South Bay. The 15 sites selected include most of the larger restoration sites in existence and all those for which long-term physical processes monitoring data were available. Potential study sites were identified by using inventories of completed restoration projects (San Francisco Estuary Project 1996; San Francisco Estuary Project 1999), regional wetlands mapping (Goals Project 1999), aerial photograph review, and field reconnaissance.

The findings of Williams and Orr (2002c) illustrate three important geomorphic lessons learned, all of which pertain to the South Bay. The first is that it is possible to rejuvenate the tidal drainage system upon breaching wherever the former channel network still retains some of its relict morphology. The second lesson is that it is possible to estimate how outboard tidal channels will adjust to the restored tidal prism. The third lesson learned pertains to net sediment delivery, a function of three important geomorphic processes, which can separately, or in combination, prevent the physical evolution of a subsided restored site to a tidal marsh. Specific lessons pertaining to these three geomorphic processes are described below.

### 6.1.2 Restricted Tidal Exchange

For a number of accidental or intentionally restored sites tidal action can be significantly damped by the hydraulic constriction of a narrow levee breach or small inlet channel. Over time, scouring action tends to enlarge these constrictions, eventually restoring full tidal exchange (a full tidal range within the site). Until this occurs, the volume of sediment entering the site on the flood tide will be reduced proportionally to the reduction in tidal prism, extending the time of evolution. In addition, restricted tidal regimes can alter the internal site hydroperiod and raise vegetation colonization elevations relative to the open Bay, increasing the time for vegetation establishment. The solutions to preventing restricted tidal exchange are creation of an appropriate size breach, as well as creating pilot channels to ensure effective tidal exchange.

#### 6.1.3 Limited Sediment Supply

Long-term average suspended sediment concentrations brought in to the site on the flood tide are influenced by the long-term sediment budget of the estuary, as well as the proximity of the site to the estuarine circulation turbidity maxima or proximity to extensive intertidal mudflats where sediment can be locally resuspended by wave action. Sediment concentrations tend to be very high in the South Bay, so lack of available sediment to replenish the tidal marshes is not likely to be a limiting factor of restoration. However, the SBSP Restoration Project presents a large sediment sink, and if restored all at once, increased rates of shoreline and intertidal mudflat erosion may result in the South Bay.

#### 6.1.4 Internally Generated Wind Waves

Propagating waves create turbulence in the water column that prevent deposition and breaking waves create high bed shear stresses that resuspend deposited estuarine muds, allowing sediment to be exported on the ebb tide. Wave induced bed shear stresses are a function of wave power, which in turn is a function of fetch length and wind velocity squared, and are inversely related to water depth (U.S. Army Corps of Engineers 1984) There are two primary concerns with wind waves in the South Bay. First, the East shore could be particularly susceptible to high winds given the long fetch across the entire Bay, and second, internal wind waves can create high shear stress within the site.

### 6.2 Data-gaps

#### 6.2.1 Data-gaps Essential to Fill for Restoration Planning

*What are some sedimentation rates at breached sites and marinas in the San Francisco Bay? At what rate might breached sites in the South Bay accumulate sediment?* Sedimentation rates have been collected at breached sites in the delta as part of the BREACH project, but the San Francisco Bay, particularly the South Bay, may have different rates (Orr and others 2003; Simenstad and others 2000; Simenstad and others 1996). Monitoring data from past restoration projects, or sediment cores from previously breached sites, will be important to establish local sedimentation rates.

*What are the historical changes in tidal mudflats and shallow water environments in the South Bay? How much historical shoreline retreat has occurred in the South Bay?* Robin Grossinger of SFEI recently completed mapping of historic mudflats, shorelines, and channel networks to add to the previously existing work done for the EcoAtlas project (San Francisco Estuary Institute 1998). These mapping efforts, in combination with the historical bathymetric analysis of Foxgrover and others (2004), will greatly aid the South Bay Salt Ponds Project.

#### 6.2.2 Data-gaps to Fill During Adaptive Management and Monitoring

*What are the long-term sedimentation rates in restored marshes that were heavily subsided?* SETs have proven useful for monitoring sedimentation in breached sites for the BREACH project. They should be implemented at each restoration site to evaluate the progress of marshplain development in the salt ponds.

*How quickly do tidal mudflats become vegetated?* It will be important to ensure that mudflats do collect enough sediment, and quickly become vegetated. Morphologic changes can be monitored by bathymetric, shoreline, and mudflat mapping efforts in the field and through the use of satellite photography, respectively.

*How quickly do historic channels rejuvenate upon breaching?* Surveys of channel geometry have proven useful for monitoring sites in the South Bay, and planform metrics developed from aerial photo analysis of tidal drainage networks in restored and natural marshes have proven successful for the BREACH project. These data will be useful for evaluating the progress of complex channel network development in the salt ponds, and subsequently adjusting the design of pilot channels and control structures for future breached sites.

*What is the effect of increased tidal prism from salt pond restoration on neighboring mudflats, marsh, and shoreline?* Monitoring of existing mudflats, marsh, and shoreline areas will be important to determine the effects, such as increased erosion, of increased tidal prism and increased sediment demand of the ponds. The effects of breaching the Island Ponds (A19, A20, and A21) on existing mudflats and tidal marsh could be monitored to provide empirical data concerning this question.

# 7. TOPIC 5: HYDRODYNAMICS AND RELATED DATA

## 7.1 Topic 5a. Bathymetry

### 7.1.1 Data Summary

Bathymetric data for the South Bay has been collected periodically since 1857. Hydrographic surveys of the South Bay were conducted by the National Ocean Service (NOS, formerly called the U.S. Coast and Geodetic Survey) in 1857-58, 1897-1899, 1931, 1954-1956 and 1981-1985; details of the surveys are given by Foxgrover and others (2004). The density of bathymetric data has been low in the intertidal zone of the South Bay, particularly in modern surveys. In 1993, the U. S. Geological Survey (USGS) mapped the intertidal zone of the far South Bay at a horizontal resolution of 25 meters and vertical resolution of 0.1 meters from a combination of aerial photographs and depth soundings. Very limited information is available in the tidal reaches of the sloughs and creeks. Sufficient resolution bathymetry in shallow regions of the Bay, in particular the tidal mudflats and the far South Bay, will be critical in determining the hydrodynamics and sediment dynamics of the Bay.

### 7.1.2 Data-gaps

**Data-gaps Essential to Fill for Restoration Planning**

*What is the current bathymetry of the South Bay, in particular the subtidal, intertidal and supratidal regions and the lower reaches of the tributary sloughs and creeks?* The USGS is currently planning a new bathymetric survey of the South Bay for the spring of 2004. The survey will use soundings in the subtidal zones and LIDAR for intertidal and supratidal topographic mapping. This new survey will provide important current bathymetric and topographic data inputs for hydrodynamic and sediment modeling. The USGS is also assessing the hydrology and present morphology of the South Bay sloughs by analyzing existing data.

*How does the pre-salt pond equilibrium form of the South Bay compare to today? How has the distribution of subtidal, intertidal, and tidal marsh changed from pre-salt pond conditions to today?* Foxgrover and others (2004) present the results of historical bathymetric change in the South Bay from 1858 to 1983, similar to previous work in San Pablo and Suisun Bays (Cappiella and others 1999; Jaffe and others 1998). This report characterizes the historical patterns of deposition and erosion and changes in the distributions and morphologies of subtidal channels, tidal mudflats, and tidal marsh. This report was recently issued and contains valuable information in relation to the recent evolution of the South Bay.

**Data-gaps to Fill During Adaptive Management and Monitoring**

None.

## 7.2 Topic 5b. Hydrology/Hydrodynamics

### 7.2.1 Data Summary

The South Bay is a hydrodynamically complex system, with freshwater tributary inflows, tidal currents, and wind stress on the water surface interacting with complex bathymetry. These forcing mechanisms define the residual circulation patterns and residence time, and determine the level of vertical mixing and stratification.

**Tributary Inflows.** Limited data are available on water levels near the mouths of the tributaries to the South Bay. The Santa Clara Valley Water District (SCVWD), the City of Palo Alto, and the USGS collect river stage and flow for the tributaries, however, most of these measurement sites are upstream of the salt pond levees. The USGS maintains stations on Coyote Creek, Guadalupe River, Alameda Creek, Alameda Flood Control Channel, Matadero Creek, and San Francisquito Creek, and most stations contain historical records dating back to the 1950s. The City of Palo Alto maintains flow gauges in San Francisquito Creek, Matadero Creek, and Adobe Creek, although historical archiving did not begin until August 2003. Wastewater flows from the treatment plants are monitored and available. Moffatt & Nichol Engineers (2003a) have compiled a comprehensive inventory of tributary and wastewater inflows for the South Bay. Much of the data will require manipulation to tie benchmarks to a uniform datum.

**Tidal Currents and Water Levels.** The main tidal constituent is semidiurnal, with a strong overlying fortnightly spring-neap variation (Walters and others 1985). The tides propagate through the Golden Gate as shallow water waves, and the amplitudes and phases of the waves are modified by the 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, where the wave is reflected back upon itself (Walters and others 1985). The harmonic addition of the original wave plus the reflected wave leads to tidal amplitude increases, or tidal amplification.

The National Oceanic and Atmospheric Administration (NOAA) and NOS collect water surface elevation data at Oyster Point Marina, San Leandro Marina, San Mateo Bridge, Dumbarton Bridge, and Dumbarton Point. The only real-time operational tide gage in the South Bay is located in Redwood Creek, near the Port of Redwood City. This gage is part of the Physical Oceanographic Real-Time System (PORTS) installed in 1998 by NOAA in San Francisco Bay. PORTS allows access to real time data (24 hours in the past, and 24 hour projections to the future) of Bay-wide wind distribution, tides, tidal currents, and salinity (Cheng and Gartner 1985). Limited archived data is available. Tidal current data was collected by the USGS and NOAA at several stations throughout the Bay during the 1980s, with the largest concentration of current meters located in the channel (Gartner and Walters 1986).

Several modeling studies have been performed in the South Bay using a variety of numerical tools in order to quantify tidal currents, salinity, and residual flow characteristics. Two- and three-dimensional models (TRIM2D and TRIM3D, respectively) have been applied extensively to the South Bay by the USGS and Stanford University (Cheng and others 1993; Gross 1997; Gross and others 1999; Lucas 1997; Lucas and others 1999). Moffat & Nichols Engineers (2003b) developed several models of San Francisco Bay, including two- and three-dimensional models of the entire San Francisco Bay (MIKE-21 and DELFT3D, respectively), and a two-dimensional model of the South Bay (DELFT2D). URS (2002c) also developed two- and three-dimensional models (MIKE-21 and TRIM3D, respectively) for the San Francisco runway reconfiguration study. In addition, a physical model of the Bay (the Bay Model), created by the US ACOE in the 1950s, has been used to study currents, salinity, and the effects of various construction alternatives. Possible applications exist for the SBSP Restoration Project; however, the cost and time involved in rehabilitation and calibration may be prohibitive.

**Wind and Wind-waves.** The National Climate Data Center (NCDC) maintains several meteorological stations with long-term historical records throughout the Bay, including Moffett Field, Fremont, Redwood City, Newark, Hayward Air Terminal, and Oakland, San Jose and San Francisco International Airports. The wind direction over the South Bay is typically from the west and northwest in late spring, summer, and early fall, with more variable conditions in winter (Cheng and Gartner 1985).

Little characterization of the wind-wave climate has been performed for the South Bay, although the importance of wind-waves and wind-generated shear stresses is recognized as a significant mechanism for sediment resuspension. 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). Bricker (2003) completed a small-scale wave study near Coyote Point, which concluded that the wave model Simulating WAves Nearshore (SWAN), which predicts wave spectra based on wind speed, direction, and water column depth, is suitable in the near shore environment. Inagaki (2000) coupled the TRIM3D model with an empirical wind-wave model developed by the US ACOE (U.S. Army Corps of Engineers 1984); however, Bricker (2003) found that the US ACOE model over predicted wave heights in some regions because it did not account for wave breaking, and under predicted wave heights in other regions because it did not account for wave refraction. URS coupled MIKE-21 with the Nearshore Spectral Wave Model (NSW; (URS 2002c). NSW can be used to simulate radiation stresses in the surf zone, which generate wave-induced littoral currents that effect sediment transport, and estimate wind-wave induced bottom shear stresses.

**Residual Circulation and Residence Time.** The most important factor influencing circulation patterns in South Bay is bathymetry (Cheng and Gartner 1985). Bathymetric variations create differences in the flow patterns north of the San Bruno shoal, between the San Bruno shoal and the San Mateo Bridge, between the San Mateo Bridge and Dumbarton Bridge, and south of the Dumbarton Bridge. The dominant flows in South Bay are tidally driven with a semidiurnal period and significant overlying spring-neap variability (Cheng and Gartner 1985). The winds typically cause flow in the direction of the wind over the shoals, and a return flow in the channel. The combination of tidally- and wind-driven flows interacting with the South Bay's complex bathymetry led Powell and others (1986) and Cheng (1985) to observe a series of gyres in the South Bay. The presence of the gyres and their effect on residual currents, salinity, and scalar transport has been verified with numerical modeling studies (Gross 1997; Lucas 1997).

As with the residual currents, the residence time is also determined by the combination of tidally- and wind-driven flows, bathymetry, and fresh water inflow. The residence time of South Bay fluctuates seasonally. As a whole, the residence time is less than a month in the winter and early spring during wet years, and considerably longer (on the order of several months) during summer (Powell and others 1986; Walters and others 1985). Understanding the residual circulation and residence times in the South Bay is important to the SBSP Restoration Project because they help determine the potential movement patterns of suspended sediment and other water quality constituents (i.e. phytoplankton, nutrients). URS (2002c) performed residence time simulations for the South Bay using both MIKE21 and TRIM3D, and Gross (1997) performed residence time simulations using TRIM2D and TRIM3D for the far South Bay (below Dumbarton Bridge).

**Vertical Mixing and Stratification.** The South Bay is generally well mixed vertically (i.e. there is little tidally-averaged vertical salinity variation) with near oceanic salinities (20 – 32 ppt) due to low fresh water inputs in the far South Bay. In summer months and dry years, the wastewater inflows exceed natural stream flows (Cheng and Gartner 1985). Significant lateral variations in salinity exist in the South Bay due to changes in the direction and magnitude of lateral flows (Huzzy and others 1990). Typically, the highest lateral variation in salinity occurs at slack after flood, when salt water from Central Bay is advected farther along the channel than in the shoals, making the channel more saline than the shoals; the smallest lateral variation occurs on slack after ebb, although the channel is still more saline than the shoals (Gross 1997; Gross and others 1999). Lateral variations in salinity are also affected by nontidal mechanisms, such as tributary inflows, persistent lateral density gradients, and cross-estuary winds (Huzzy and others 1990).

High fresh water inflows (typically in the winter and early spring in wet years) from the local tributaries in the far South Bay can set up density stratification in the main South Bay channel, as well as stratification on tidal time scales in the tributaries and sloughs. Salinity stratification is very pronounced in Artesian Slough due to the large freshwater inflow from the San Jose Wastewater Treatment Plant (Life

Science 2003). Density stratification in the main channel is also caused by high fresh water flows from the North Bay intruding into the South Bay (Cheng and Gartner 1985; Powell and others 1986).

Time series of salinity have been measured by the USGS at the Oakland Bay Bridge, the San Mateo Bridge and the Dumbarton Bridge. At both the Oakland Bay Bridge and San Mateo Bridge stations, salinity is measured continuously by two sensors, a top sensor and a bottom sensor (Edmunds and others 1995). At the Dumbarton Bridge, salinity is measured by a single sensor, located 2 meters above the bed (Schemel 1998). In 2004 the Oakland Bay Bridge station was moved to Alcatraz, and a salinity sensor was added to Channel Marker 17 in the far South Bay (Schoellhamer, pers. comm.).

Vertical profiles of salinity in the main channel of South Bay have been collected since 1969 as part of the pilot Regional Monitoring Program (RMP) (Buchanan 2003b; Edmunds and others 1995; Edmunds and others 1997). During these cruises, salinity profiles are measured at a series of stations located between the Oakland Bay Bridge and Coyote Creek. The measured salinity profiles are reported by the USGS at 1- meter vertical resolution. The City of San Jose also has some limited data available from the Coyote Creek region as part of their monitoring activities related to treatment plant operations (City of San Jose 2004). Data was collected at nine stations for short-duration periods during 1997, 1999, and 2000. The data collected includes specific conductance, salinity, temperature, pH, dissolved oxygen, and depth. Not all types of data are available for all records. Salinity data for the tidal creeks will be required to establish the limits of saltwater intrusion.

### 7.2.2 Data-gaps

**Data-gaps Essential to Fill for Restoration Planning**

*What is the level of tidal muting within the tributaries, and its relationship to existing levees and control structures?* The available data are likely insufficient to determine the level of salinity intrusion and tidal influence in the South Bay tributaries and sloughs. A sampling program at the tributaries and sloughs should be initiated to collect water levels, currents and/or waves, suspended sediment concentration (SSC), and salinity in order to support numerical modeling efforts such as model initiation, calibration, and validation, and to provide boundary condition data. The USGS has gathered existing hydrologic and sediment datasets from all available sources in the South Bay, and have proposed an exploration of the quality of each collected dataset within a study and between studies. USGS has also proposed to describe the temporal variability (e.g., temperature minimums and maximums) and spatial gradients of the gathered data. SCC data will be collected by the USGS in the sloughs and South Bay during winter 2004 to support model development.

*What are the relationships between tidal (e.g., MLLW) and geodetic (e.g., NAVD88) datums around the South Bay?* Construction and calibration of hydrodynamic models will require relationships (conversions) between tidal datums and a coherent geotic datum. This is especially true for the South Bay since the local tidal datums change substantially as the amplitude of the tidal wave increases along its longitudinal axis.

**Data-gaps to Fill During Adaptive Management and Monitoring**

None.

## 7.3 Topic 5c. Sediment Dynamics

### 7.3.1 Data Summary

Suspended sediment concentrations (SSC) in South Bay exhibit highly dynamic short-term variability, primarily in response to riverine input from tributaries and sloughs, spring-neap variations in tidally driven resuspension, and wind driven resuspension (Cloern and others 1989; Powell and others 1989; Schoellhamer 1996). The USGS has actively monitored and analyzed SSC data throughout the Bay (Buchanan and Ganju 2002; Buchanan and Ruhl 2000; Buchanan and Ruhl 2001; Buchanan and Schoellhamer 1998; Buchanan and Schoellhamer 1999; McKee 2002; Ruhl and Schoellhamer 2001; Schoellhamer 2002; Schoellhamer and others 2002; Schoellhamer and others 2003; Wright and Schoellhamer 2003). Cloern and others (1989) found that SSC in the South Bay is weakly correlated with the advective flux, highlighting the importance of local resuspension. Tidally induced bed shear stresses cause sediment resuspension, and tidal currents also generate turbulent mixing that helps retain sediment in the water column. In shallow areas, tidal forcing is generally weak and insufficient to resuspend sediment; however, SSC is typically greater on the shoals than the deeper channels due to the stronger influence of wind-wave resuspension.

Wind is probably the most dynamic factor affecting temporal and spatial variability in SSC. Generally, increases in fetch and wind speed will result in larger wind-waves with corresponding larger particle orbits and increased wind wave induced orbital velocities. Because these particle orbits and orbital velocities decay with depth, the effect of wind is most pronounced in shallow regions where wind-waves interact with the bed producing a wind wave induced shear stress. This stress, when combined with the tidally induced shear stress (producing an "effective" bed stress), increases the potential for sediment resuspension.

Schoellhamer (1996) found that SSC is well correlated with wind and wind wave induced shear stress. However, sediment resuspension also depends on sediment properties, such as the critical shear stress for erosion (McDonald and Cheng 1996). This stress will vary with the level of compaction of the sediment bed layer. Areas that are typically net erosional will likely have a higher critical shear stress for erosion than areas that tend to be net depositional, due to the less compacted nature of recently deposited sediments. Krone (1962) performed flume studies using Bay sediments, and identified ranges of sediment properties likely found in South Bay; however, more comprehensive studies of sediment properties and bed characteristics are likely necessary in order to model wind-wave sediment resuspension along the shoals and in the restored and managed ponds.

Lateral exchange (between the channel and shoal) is also an important mechanism for sediment transport (Jassby and others 1996; Schoellhamer 1996). Bathymetric variations in the estuary interact with the tides, freshwater inflow, and wind to modify flow patterns. For example, lateral surface flows (between the channel and the shoal) result from the phase lag of the flow in the channel relative to the shoals, and the interaction of the tidal flow with the channel-shoal bathymetry. These lateral flows can transport a significant amount of sediment to the channel, thereby reducing SSC in the shoal (Jassby and others 1996). The process can also work in reverse, transporting less turbid water from the channel to the shoal, thus reducing SSC and turbidity in the shoal (May and others 2003).

The major external sediment inputs to the South Bay are tributary sediment load and exchange between the Central and South Bays. The USGS collects SSC data in Alameda Creek and Guadalupe River, and in 2004 a SSC station was added in Coyote Creek (Schoellhamer, pers comm.). The level of sediment exchange between Central and South Bay is poorly understood.

Cohesive sediment transport models have been coupled with hydrodynamic models of the South Bay for a variety of purposes. McDonald and Cheng (1996) developed a 1D model for the bay based on the work of Krone (1962). Moffat & Nichols Engineers (2003b) coupled the two-dimensional RMA Model with SED-2D in order to perform hydraulic scour analysis of the proposed replacement span of the Bay Bridge. Bricker (2003) coupled TRIM3D with SWAN in order to compare erosional and depositional patterns in the South Bay with earlier modeling work performed by Inagaki (2000), which coupled TRIM3D and an empirical US ACOE wind-wave formulation. URS (2002c) also studied sediment transport in the South Bay for the airport expansion study by coupling MIKE-21 MT with NWS.

In order to fully understand sediment dynamics in the South Bay, the sources and sinks must be quantified and a sediment budget developed. Since Gilbert's (1917) seminal study, numerous sediment budgets have been developed for San Francisco Bay. Many of the early sediment budgets were developed to assess the impacts of the construction of barriers across the Bay for water supply purposes (Grimm 1931; Smith 1965; U.S. Army Corps of Engineers 1954). The most recent published sediment budgets for San Francisco Bay cover the period of 1955 to 1990 (Krone 1979; Krone 1996; Ogden Beeman & Associates and Ray B. Krone & Associates 1992). These budgets include estimates of fluvial sediment inputs from the Delta and local watersheds, bathymetric changes, upland disposal of dredge material, and loss of sediment through the Golden Gate. In addition, the USGS developed a sediment budget for the South Bay specifically aimed at wetland restoration efforts (Shellenbarger 2004). However, recent research by Foxgrover and others (2004) proposes significant revisions to earlier sediment budgets with important implications for the SBSP Restoration Project.

McKee (2002) found that total fluvial sediment inputs to be about 75% of Krone's (1996; 1992) estimates. McKee (2002) also conclude that local watershed inputs are nearly equal to sediment inputs from the Central Valley (57% Central Valley and 43% local tributaries). This difference is attributed to overall decreased sediment supplies from the Central Valley due to reservoir construction and watershed recovery from 19$^{th}$ century land use changes (McKee and Patrick 1988; Wright and Schoellhamer 2004). Results presented by Foxgrover (2004) indicate that the South Bay has undergone net erosion from 1955 to 1990, rather than deposition as presented in Krone (1996; 1992).

### 7.3.2 Data-gaps

#### Data-gaps Essential to Fill for Restoration Planning

*What are the existing and expected future subsidence rates in the South Bay?* Subsidence in the project area has occurred with development and significantly increased the sediment demand of many of the salt ponds. Understanding the existing and expected future subsidence rates in the salt ponds will be required to assess the feasibility of tidal marsh restoration.

*How do the sediment bed characteristics (i.e. critical shear stresses for erosion, age, etc.) vary over the shoals and pond areas of the South Bay?* The bed characteristics (sediment properties and critical shear stress for erosion) are important for predicting regions of net erosion vs. net deposition in the South Bay, as well as determining the potential for wind-wave resuspension in the ponds. It is likely that bed characteristics vary widely throughout the study area (i.e. higher values on the eastern shoal than in the far South Bay). Field measurements and/or lab experiments should be conducted using sediment cores from various regions in the South Bay to determine bed characteristics. This information will be invaluable for modeling sediment dynamics and predicting potential erosion/deposition patterns.

*Has the South Bay undergone net erosion between 1955 and 1990? Under the 'No Action' scenario, will the South Bay continue to export sediment?* Foxgrover and others (2004) presents the results of historical bathymetric change in the South from 1857 to 1990, similar to previous work in San Pablo and Suisun

Bays (Cappiella and others 1999). This report characterizes the historical patterns of erosion and deposition, including the period between the most recent bathymetric surveys, 1958 and 1983. Foxgrover and others (2004) determined that the South Bay has undergone net erosion from 1955 to 1983 rather than deposition, although the far South Bay remains depositional.

*What is the level of sediment exchange between the Central and South Bay?*

**Data-gaps to Fill During Adaptive Management and Monitoring**

None.

## 7.4 Topic 5d. Phytoplankton Blooms

Spring phytoplankton blooms in the South Bay vary in magnitude and duration in response to variable river inflow, vertical and horizontal stratification, turbulent mixing, benthic and pelagic grazing, and nutrient and light availability (Cloern 1996; Cloern and others 1989; Powell and others 1986; Powell and others 1989). The primary requirements for phytoplankton growth to occur are light and nutrient availability (Cloern and others 1995). The South Bay is typically a turbid system with high SSC, and high nutrients levels, with phytoplankton growth occurring during periods of low SSC (Cloern 1999). For example, years of high river inflow lead to strong density stratification in the channel. When the channel stratifies, SSC cannot be maintained in the surface layer, creating a clear upper layer that is ideal for photosynthesis. In addition, the upper stratified layer is isolated from benthic grazers, further enhancing the potential for phytoplankton bloom formation (Koseff and others 1993; Lucas and others 1999; Thompson and others 1999). Therefore, wet years with corresponding high river inflows are typically years of large phytoplankton blooms (Cloern 1991; Cloern 1996; Cloern 2001; Koseff and others 1993). In drier years, wind-wave resuspension of sediments in the shallow regions has the potential to deter a bloom by increasing the turbidity in both the channel and shoals (May and others 2003). Early estimates by Shellenbarger (2004) indicate that the inter-annual variability of benthic grazing rates on the shoals may have a greater influence on controlling phytoplankton populations than the potential decrease in SSC that may result from pond restoration.

The USGS collects salinity, temperature, suspended particulate matter, dissolved oxygen, light penetration, and chlorophyll concentration (a measure of phytoplankton abundance) as part of their long-term water quality monitoring system, primarily along the channel (U.S. Geological Survey 2004a). The available data are sparse (collected on one or two cruises per month in the South Bay), and limited data are available for the shoals (Arnsberg and others 1998; Baylosis and others 1997; Baylosis and others 1998; Edmunds and others 1995; Edmunds and others 1997). The USGS collects continuous data on salinity, temperature, and SSC at San Mateo Bridge, Dumbarton Bridge, and SSC at Channel Marker 17 south of Dumbarton Bridge; during winter 2004 salinity and temperature data were also collected at Channel Marker 17 (Buchanan 2003b; Buchanan and Ganju 2002).

**Data-gaps to Fill During Adaptive Management and Monitoring**

*How will SBSPR Project impact phytoplankton levels in South Bay? Will the ponds as act net sources or sinks of phytoplankton and nutrients?* Early estimates by Shellenbarger (2004) indicate that full tidal restoration may have a small effect on phytoplankton bloom dynamics, owing to the already high variable nature of the spring phytoplankton bloom, and the inter-annual variability in the benthic grazing populations which act as a first order control on bloom magnitude (Koseff and others 1993; Lucas and others 1999). This analysis should be refined, and the impact of the ponds as a potential source or sink of phytoplankton and nutrients should be considered.

# 8. TOPIC 6: INVASIVE SPECIES

## 8.1 Data Summary

### 8.1.1 Priority Invasive Plant Species of South San Francisco Bay

The SBSP Restoration Project EndNote bibliography includes references for the twelve invasive plant species, while this summary covers two “key species of concern” (*Spartina alterniflora* [hybrids] and *Lepidium latifolium*) listed in Grossinger (1998).

**Invasive Cordgrass Species (*Spartina* spp.)** *S. alterniflora*, and its hybrids with *S. foliosa* (*S. alterniflora* [hybrids]), present the greatest invasive plant threat to tidal salt marshes and mudflats of the South Bay (California State Coastal Conservancy and U.S. Fish and Wildlife Service 2003). The Invasive Spartina Project is the primary source for information on *S. alterniflora* [hybrids] in the San Francisco Bay.

*Historical, Current and Future Distribution.* The mechanisms, geography and history of *S. alterniflora* [hybrids] invasion in the San Francisco Bay, has been documented (Ayres and others 1999; Callaway 1990; Callaway and Josselyn 1992; Cohen and Carlton 1995; Collins 2001a; Collins and May 2001b; Daehler and others 1999; Daehler and Strong 1994a; Faber 2000b; Larsson 1996; McKee and Patrick 1988; Spicher and Josselyn 1985). The regional distribution of *S. alterniflora* [hybrids] was mapped in 1998 (Grossinger and others 1998), and in 2000 – 2001 (Collins and May 2001b). Environmental requirements of *S. alterniflora* [hybrids] have been studied (Callaway and Josselyn 1992; Collins 2002; Daehler and Strong 1996c; Donnelly and Bertness 2001). Models predict distribution and spread of colonies (Collins 2002; Daehler and Strong 1996c; Feist and Simenstad 2000; Gray 1992).

Literature on *S. alterniflora* in its native range (North American Atlantic coast) is cited to predict impacts in the San Francisco Bay (Bertness and Ellison 1987; Bradley and Morris 1990; Callaway 1990; Clark and Patterson 1985; Cooper 1974; Josselyn and others 1993). Additional data on *S. alterniflora* in its native range could be reviewed to predict effects in the South Bay (Bertness and Ellison 1987; Bradley and Morris 1990; Clark and Patterson 1985; Craft and others 2003; Linthurst 1980; Morris and others 2002; Proffitt and others 2003; Ranwell 1964; Vivian-Smith and Stiles 1994; Woodhouse and Seneca 1976).

*Life History.* Researchers have described reproductive and growth characteristics of *S. alterniflora* [hybrids] (Anttila and others 1998; Ayres and others 1999; Callaway and Josselyn 1992; Daehler 1996a; Daehler 1996b; Daehler 1996c; Daehler and others 1999; Daehler and Strong 1994b; Daehler and Strong 1996c; Daehler and Strong 1996d). The understanding of *S. alterniflora* invasion was altered by verification of hybridization between native *S. foliosa* and non-native *S. alterniflora* (Anttila and Daehler 1997; Anttila and others 1998; Anttila and others 2000; Ayres and others 1999; Daehler and others 1999; Daehler and Strong 1997a). Important topics include reproductive vigor, DNA identification (Sloop 2002), and phenotypic and environmental tolerances (Proffitt and others 2003) of hybrids.

*Effects.* Callaway (1990; 1992) predicted the impacts of non-native *Spartina* species in the San Francisco Bay. Roles of native and non-native *Spartina* species have been compared (Josselyn and others 1993; Sayce 1988). *S. alterniflora* [hybrids] affect feeding areas for shorebirds (Buchanan 2003a; Evans 1986; Stralberg and others 2004; White 1995), and potentially degrade California Clapper Rail foraging habitat (California State Coastal Conservancy and U.S. Fish and Wildlife Service 2003; Grossinger and others 1998). *S. alterniflora* [hybrids] severely affects the native *S. foliosa* through both competition and hybridization (Anttila and others 1998; Ayres and others 1999; Ayres and others 2003b; Baye 2004; Daehler and Strong 1997b).

*Management/Control.* No secure way, except for eradication, exists to prevent introductions of *S. alterniflora* [hybrids] once salt ponds are open to the Bay. Keys to preventing new invasion include 1) developing BMPs to minimize propagule introduction; 2) identifying pathways of invasive species entry for each pond, and; 3) developing detection and response plans. This information will be provided during preparation of the SBSP Restoration Project Monitoring and Adaptive Management Plan.

Methods have been used to control S. alterniflora [hybrids] in the northwest (Aberle 1993; Grossinger and others 1998; Mumford and others 1990). The California Coastal Conservancy will begin implementing a S. alterniflora [hybrids] eradication program in the San Francisco Bay (California State Coastal Conservancy and U.S. Fish and Wildlife Service 2003). Two critical factors that may limit the success S. alterniflora [hybrids] control are: a NOAA restriction on the use of R-11, a surfactant that when used with glyphosate is effective in controlling S. alterniflora [hybrids], and; lack of approval by the State of California for use of Imazapyr, an herbicide that is more effective than glyphosphate to control S. alterniflora [hybrids] (Olofson 2004). The Invasive Spartina Project is currently working to resolve these issues.

**Perennial Pepperweed (*Lepidium latifolium*).** The Nature Conservancy Element Stewardship Abstract (Renz 2004b), Grossinger (1998) and Renz (2004b) are primary sources of information for *L. latifolium*. PRBO Conservation Science is currently preparing a report on the impact of *L. latifolium* on tidal marsh birds.

*Historical, Current and Future Distribution. L. latifolium* has been reported and mapped throughout the San Francisco Bay and Delta area (Atwater and others 1979; Grossinger and others 1998; Herbold and Moyle 1989; Madrone Associates 1977; May 1995; Mooney and others 1986; Robbins and others 1951). The distribution of *L. latifolium* in the Alviso Pond Complex has been mapped and soil characteristics related to *L. latifolium* distribution collected (H. T. Harvey & Associates 2002a; H. T. Harvey & Associates 2002b). It is recognized that the restoration of tidal action to dikes areas, may increase *L. latifolium* distribution (Grossinger and others 1998).

*Life History.* Details of the life history of *L. latifolium* are provided (Grossinger and others 1998; May 1995; Miller and others 1986; Renz 2000; Renz and others 2002; Renz 1994; Renz 2004b; Renz and DiTomaso 1998a; Renz and DiTomaso 1998b; Renz and DiTomaso 1999a; Renz and DiTomaso 1999b; Renz and DiTomaso 2001a; Renz and DiTomaso 2002; Renz and DiTomaso 2004c; Renz and DiTomaso In Press.; Renz and others 2001b; Renz and others 1997).

*Effects.* Once established, *L. latifolium* can create dense monospecific stands that displace native plants and animals, and that can increase soil erosion by destabilizing banks and increase soil salinity by acting as a 'salt pump' (Blank 2002a; Blank and others 2002b; Blank and Young 1997; Blank and Young 2002c; Blank and Young 1999; Renz and DiTomaso 1998a; Trumbo 1994; Young and others 2002; Young and Longland 1996; Young and others 1997a; Young and others 1998b; Young and others 1995a; Young and others 1997b; Young and Turner 1995b; Young and others 1995c). *L. latifolium* invasion may threaten the conservation and recovery of rare or endangered plant species, most of which occur in the higher elevation tidal marsh zone (Goals Project 2000).

*Management/Control.* Researchers have successfully controlled *L. latifolium* by flooding (Fredickson and Murray 1999). Herbicide treatments, and control recommendations have been described (Renz 1994; Trumbo 1994; Young 2004; Young and others 2002; Young and others 1998b), but have not been fully developed. With the exception of flooding, non-chemical treatments alone have not been highly effective

(Grossinger and others 1998; Renz 2004b), but herbicide alternatives have been explored (Fredickson and Murray 1999; Kilbride and others 1997). Early and careful monitoring is required for successful control (Renz 2000).

### 8.1.2 Invasive Aquatic Animal Species in the San Francisco Estuary

"The San Francisco Estuary can now be recognized as the most invaded aquatic ecosystem in North America" (Cohen and Carlton 2003). This study is the most recent and most inclusive compilation of information on aquatic invasive species in the San Francisco Estuary. Previous lists and/or descriptions of introduced aquatic species include works on fish fauna by Moyle (1976) and McGinnis (1984), freshwater mollusks by Hanna (1966) and Taylor (1981), marine mollusks by Nichols and others (1986), and introduced marine and estuarine invertebrates by Carlton (Carlton 1975; Carlton 1979a; Carlton 1979b; Carlton and others 1990).

Cohen and Carlton (2003) note that at least 212 species have been introduced to the Bay and Delta since 1850 as well as 123 other species that are classified as "cryptogenic taxa, *i.e.* not clearly native or introduced. The most important of these species include a number of clams such as the introduced Asian species of *Venerupis* and *Musculista*, and the Atlantic clam *Gemma.* Collectively, these introduced clam species are capable of filtering the entire volume of the South Bay daily, in addition to having dramatic impacts on the Bay's phytoplankton populations. Cohen and Carlton (Cohen and Carlton 2003) postulate that the phytoplankton populations of the northern reaches of the San Francisco Bay may be "continuously and permanently controlled by introduced clams". Cohen and Carlton (Cohen and Carlton 2003) discuss the potential impacts of the Asian Clam (*Potamocorbula* sp.), which feeds at many levels of the food chain, along with the multiple impacts of the Atlantic green crab (*Carcinus maenas*), which eats a great variety of plants and animals. They also cover potential impacts of introduced marine, brackish and freshwater fish on native fish species, as well as potential impacts of introduced crayfish of the genera *Procambarus* and *Pacifastacus* on various levels of the food chain. Their paper also addresses the impacts of the Australian-New Zealand boring isopod (*Sphaeroma quoyanum*) which riddle mud banks and levees with holes, weakening them and leaving them prone to destruction by wave action.

Another species that may cause the same type of problems as the Australian-New Zealand boring isopod is the Mitten Crab (*Eriocheir sinensis*), which has been known to accelerate bank erosions in Germany. Halat (1996) has reported that the burrows of this crab reach densities of 30 burrows/$m^2$ along San Francisquito Creek. Halat did not report any bank erosion even at this density of mitten crab borrows but suggested that if bank erosion does occur it is likely to occur along steep clay banks in tidally influenced alluvial controlled reaches of the Bay.

It is not known at this time what impact these invertebrates may have on the restoration process. We suggest that specific research be carried out if problems occur in the future.

## 8.2 Data-gaps

### 8.2.1 Data-gaps Essential to Fill for Restoration Planning

*Are there salinity regimes and water depths within the SBSP Restoration Project area where S. alterniflora [hybrids] will not establish?* This question is important if *S. alterniflora* [hybrids] are not controlled before restoration begins. This data-gap can be filled by: 1) interstitial soil salinity measurements where *S. alterniflora* [hybrids] are currently established; 2) correlating the current distribution of *S. alterniflora* [hybrids] with the USGS bathymetry/LIDAR topography data currently being collected; 3) assessing LIDAR-derived Willapa Bay mudflat topography, its relationship to

*Spartina* spread, and relevance to San Francisco Bay; 4) research on *S. alterniflora* [hybrids] flood-tolerance plasticity, and; 5) examining geomorphology associated with *S. alterniflora* [hybrids] spread.

*How can it be determined that there is not a significant risk for S. alterniflora [hybrids] invasion into tidal salt marshes scheduled for restoration?* It is not known the extent that the Invasive Spartina Project will succeed in controlling *S. alterniflora* [hybrids] before restoration begins in the South Bay. It will be critical to devise a method of determining when it is 'safe' to restore an area, if *S. alterniflora* [hybrids] is still present in the South Bay. It is also important to devise empirical methods to determine that the native *S. foliosa* is not receiving *S. alterniflora* [hybrid] pollen, thereby not acting as a hybrid seed source. These methods should be developed in conjunction with the Invasive Spartina Project to ascertain if 'safe' distances from *S. alterniflora* [hybrid] exist, and with plant biologists to examine if *S. foliosa* plants are producing hybrid seed.

*What is the projected distribution of S. alterniflora [hybrids] in 2009-10, at the start of SBSP Restoration Project? What will be the effectiveness of the Invasive Spartina Project's control efforts?* This information will be important during development of restoration alternatives and assessment methods. This information can be acquired from the Invasive Spartina Project's evaluation of initial eradication efforts, and Invasive Spartina Project's information on *S. alterniflora* [hybrids] colonization in previously restored salt ponds.

### 8.2.2 Data-gaps to Fill During Adaptive Management and Monitoring

*What are the best control methods for* S. alterniflora *and hybrids?* This information will be important to adaptive management planning and can be acquired from the Invasive Spartina Project.

*Can the approvals of the herbicide Imazapyr, and the surfactant R-11, be expedited for use in California?* Glyphosate, the only herbicide approved for use in the estuarine environments in California, has been found to work most effectively on non-native *Spartina* spp. when applied with the surfactant, R-11. Imazapyr, another herbicide, can be even more effective than glyphosate to treat non-native *Spartina* spp. These management tools are currently unavailable in California. The schedule for approval of R-11 has been advanced and the Invasive Spartina Project may be using this tool soon. Obtaining approval of these tools is a priority for non-native *Spartina* species control (Olofson 2004).

*What changes in abundance of the endangered California Clapper Rail and other birds are due to effects of* S. alterniflora *[hybrid] invasion and control?* The Invasive Spartina Project will be working in Clapper Rail habitat. Research is needed on how *S. alterniflora* [hybrids], and control thereof, impacts the Clapper Rail. *S. alterniflora* [hybrids] can improve habitat quality initially, but as tidal channels become choked, and short-form *S. alterniflora* [hybrids] dominate tidal salt marshes, habitat quality decreases for the Clapper Rail. These data can be acquired by examining the long-term effects of *S. alterniflora* [hybrids], and control thereof, on Clapper Rail abundance.

*What changes in tidal waterbird habitat quality and abundance are caused by* S. alterniflora *[hybrid] marsh invasion? How will waterbirds respond to invasive* S. alterniflora *[hybrid] removal and treatment areas?* Current models of *S. alterniflora* [hybrids] impacts on waterbird habitat are based on lower tidal elevation limits, not effects on substrate of mudflats or invertebrate productivity, which are also important in determining waterbird habitat. This information can be acquired by 1) Conducting waterbird use surveys concurrently with benthic invertebrate samples including a variety of treatments for, and timeframes since, *S. alterniflora* [hybrid] removal, 2) Comparing nest site selection and reproductive success in South Bay tidal marsh breeding birds in *Spartina*-invaded and non-invaded areas.

*What is the impact of* S. alterniflora *on invertebrates in salt marshes?* This information is important to determine effects on bird use. Data can be obtained through field research.

*How will geomorphic structure and drainage patterns of salt marshes develop under the influence of dominant* S. alterniflora *[hybrids] in SF Bay?* Salt marshes formed by *S. alterniflora* [hybrids] may replicate drainage patterns similar to the Atlantic coastal plain, or may develop drainage patterns in response to local tidal patterns, regardless of growth habits of pioneer cordgrass vegetation. These data can be acquired by examining channel density and sinuosity of marshes developed under stands of S. alterniflora [hybrids].

*Are* S. alterniflora *invaded tidal flats likely to accrete sediments more rapidly and raise substrate surface elevations, increasing intertidal area suitable for further colonization?* Will estuarine beaches be stabilized and replaced by *S. alterniflora* [hybrids] marsh? Establishment of *S. alterniflora* [hybrids] may induce increased rates of sediment accretion and consequently raise mudflats, as well as stabilize naturally unvegetated, high-energy, sandy estuarine shorelines. These data can be acquired by examining if colonization of sandy foreshores by *S. alterniflora* [hybrids] is reversed by storm erosion.

*What is the projected distribution of* L. latifolium *in 2009-10, at the start of SBSP Restoration Project?* This information is important in restoration alternatives development, and to insure the success of the SBSP Restoration Project. *L. latifolium* has not been mapped in many areas of the South Bay (Albertson 2004). Information can, in part, be acquired using *L. latifolium* distribution maps developed by H. T. Harvey & Associates (H. T. Harvey & Associates 2002a; H. T. Harvey & Associates 2002b) combined with salinity and hydrology maps, to examine interactions between *L. latifolium* expansion and environmental variables. Also, clear delineation of populations is difficult early in the season while the *L. latifolium* is not in flower, thus managers often focus on known populations. These data can be acquired by developing methods to remotely identify populations, and by mapping current populations and monitoring their spread.

*What are the best control methods for* L. latifolium*?* There is little information on control of this species, how to link restoration with management, and how to limit spread in an estuary (Renz 2004a). Control and management methods can be developed using mechanistic studies of treatment and restoration.

*What factors limit the expansion of* L. latifolium*?* Many sites have dense infestations in one area and no plants invading into nearby locations. This indicates that *L. latifolium* spread is limited by environmental, physical, and/or geographical factors. Also, primary reproductive strategies are not fully understood. These data can be acquired through experimentation.

*What is the potential spread, and what are the potential impacts of* Salsola soda *in tidal salt marshes?* This is the only invasive non-native plant other than the *Spartina* sp. that grows in abundance in tidal salt marshes that have good tidal circulation. These data can be acquired by mapping and research on *S. soda*.

*What other species may become invasive in the restored areas?* Concerns about invasive species in the South Bay have focused on established species that are spreading. There is a potential for new invasive species to be introduced into the restored tidal habitats. A list of these potential invaders could be generated, and new invasive species searched for as part of the monitoring phase.

*What species may benefit from invasive plants?* Some native wildlife species may use invasive species as primary habitat. This would be important to plan for during invasive plant control. These data can be obtained through interviewing invasive plant, and wildlife, experts in the area and by conducting research.

# 9. TOPIC 7A WILDLIFE/HUMAN INTERACTIONS

## 9.1 Data Summary

Human activity can have deleterious effects on wildlife, from short-term behavioral impacts to long-term population effects (Knight and Cole 1991), and the SBSP Restoration Project will likely result in changes in the levels of human-wildlife interactions in the South Bay. However, not all recreational activities have negative effects (Burger 1981; Riffell and others 1996) and effects that do occur vary by type of activity, proximity, species, time of year, and many other factors. Disturbance of nesting areas and direct approaches (Burger 1981; Thomas and others 2003) have been well-documented as likely to cause significant impacts on birds. Several studies have found that human activity can alter behavior of foraging shorebirds, waterfowl, and other birds (Burger 1986; Burger 1991a; Korschgen and Dahlgren 1992; Lafferty 2001; Madsen 1995; Pfister and others 1992; Rodgers Jr. and Schwikert 2002; Schummer and Eddleman 2000). These changes in foraging behavior can affect energy budgets, and potentially have long-term affects on survival or reproductive success. Human disturbance can have a greater affect on breeding waterbirds, potentially resulting in nest loss or loss of chicks (Ruhlen and others 2003). Local studies on human/wildlife interactions are limited (Josselyn and others 1989; Taylor and others 2002).

Among federally listed species, there have been several studies on disturbance impacts to Snowy Plovers (Lafferty 2001; Ruhlen and others 2003), but few studies on California Clapper Rails. Clapper Rails have been documented nesting near human access points, but have also been documented abandoning nests as a result of human activity (U.S. Fish and Wildlife Service 2001). It should be noted that whereas a low level of human disturbance may have only a slight effect on some wildlife species, any activity that alters the normal behavior of a listed species (e.g., Snowy Plover or Clapper Rail) is considered “take” under the Endangered Species Act.

Harbor seals are also susceptible to human disturbance. Behavioral responses to different types of disturbance have been studied by Allen and others (1984) and Kopec and Harvey (1995). Little information is available on human interactions with other wildlife species, such as the salt marsh harvest mouse, or recreational impacts on salmonids.

The types and potential consequences of human disturbance in the San Francisco Bay area and related literature have recently been reviewed by the San Francisco Bay Conservation and Development Commission (2001). In addition, at least two studies are currently being conducted regarding the effects of human disturbance on waterbirds: one in South Bay Baylands (Lynne Trulio, San Jose State University) and one at Eastshore State Park (California State Parks). The results of the SJSU study should be available in 2004. These studies will add to our knowledge of bird responses (including habitat use and flushing distances) to human disturbance.

Although a number of studies have documented flushing distances and changes in habitat use of birds and harbor seals in response to different types of disturbance, the effects of disturbance with the greatest consequences are those that disrupt breeding or affect adult survival. Some studies are available analyzing affects of disturbance on nesting success, but studying the effects of disturbance on adult survival is very difficult.

## 9.2 Data-gaps

### 9.2.1 Data-gaps Essential to Fill for Restoration Planning

*What level of human disturbance causes a response in California Clapper Rails?* Very few data are available regarding the effects of human disturbance on Clapper Rails, primarily because of the difficulty of studying these secretive birds. Although it may be impossible to quantify the effects of human disturbance on adult survival in this species, it may be possible to study 1) the breeding distribution of the species relative to human activity in the South Bay, and 2) breeding success (i.e., hatching and fledging success) in areas of varying human use. It may be difficult to assess the effects of human use independently of potential confounding factors such as predator abundance.

# 10. TOPIC 7B. SPECIES RESPONSES DURING RESTORATION

## 10.1 Data Summary

Given the number of tidal marsh restoration projects implemented in the San Francisco Bay area, there are surprisingly few data on wildlife response to restoration. The best data on wildlife response are from salt marsh harvest mouse monitoring projects. As discussed under Topic 3 above, salt marsh harvest mice responded quickly to the restoration of tidal saltmarsh at the Concord Naval Weapons Station (H. T. Harvey & Associates 1997a) and the New Chicago Marsh (Padgett-Flohr and Isakson 2003). At Concord Naval Weapons Station, Black Rails were also monitored after restoration (H. T. Harvey & Associates 1999). Neuman (2003) presents data on waterbird use of restored tidal marsh and seasonal ponds near San Leandro Bay, and Spautz and others (2003) provide data on use of restored marshes bordering San Francisco Bay by songbirds and Black Rails. As discussed in Topic 3, few other data are available on bird use of restored tidal marshes of San Francisco Bay.

Connors (2003) provides information on shorebird response to loss of tidal mudflats to increased tidal scouring in Elkhorn Slough. This information relates to potential phased restoration, or use of dredge spoils to minimize sediment loss through increased tidal prism volume.

The response of invertebrates and fish to tidal salt marsh restoration has also received limited attention. Niesen (1981) quantified the colonization of Hayward Marsh by benthic invertebrates after restoration. Woods (1984) and Talley (2000) provide information on the response of fishes to tidal salt marsh restoration, and Hansen (Hansen 2003) reviews the potential impacts of the Initial Stewardship Plan on fishes. The response of fishes and other animals to restoration efforts in the North Bay and delta are currently being studied by USGS (http://sfbay.wr.usgs.gov/access/saltponds/, and the BREACH project http://depts.Washington.edu/calfed/breachii.htm).

The response of benthic invertebrates, fish, nutrient cycling, vascular plant community structure, and Light-footed Clapper Rail to tidal salt marsh restoration has been extensively studied at the Sweetwater Marsh Mitigation site in San Diego Bay (Langis and others 1991; Zedler 1993; Zedler and others 1999).

## 10.2 Data-gaps

### 10.2.1 Data-gaps Essential to Fill for Restoration Planning

Data gaps for this topic were covered under Topic 3.

### 10.2.2 Data-gaps to Fill During Adaptive Management and Monitoring

Although it is not a data-gap, it is important to consider now, how monitoring efforts might be initiated in a number of habitats, including tidal salt marshes, to provide pre-restoration control data for future analyses (e.g., before-after control-impact paired sampling) on the effects of conversion.

# 11. TOPIC 7C: PREDATION

## 11.1 Data Summary

Predation is an issue in the South Bay primarily for the Western Snowy Plover, California Clapper Rail, other nesting birds, and the salt marsh harvest mouse. Predators, primarily the non-native red fox (*Vulpes vulpes regalis*), and their impacts on California Clapper Rails have recently been studied recently in the South Bay (Harding and others 1998; Harding and others 2001). The biology and ecology of the red fox and other non-native predators has been summarized in a number of studies (Harding 2000; Jurek 1992; Lewis and others 1999). Effects of predators on Snowy Plovers and other wildlife have received less research effort attention in the South Bay, although some data are currently being collected by SFBBO and the Refuge. In addition, predation of Snowy Plover nests has been fairly well studied elsewhere (Neuman and others 2001). Predator management, focused on the red fox, is ongoing at the San Francisco Bay National Wildlife Refuge and Eden Landing Ecological Reserve.

Avian predation by native birds, especially the Common Raven, appears to be expanding and is an increasingly important issue for Snowy Plovers and California Clapper Rails (Albertson pers. comm.). Northern Harrier (*Circus cyaneus*), another predator of Snowy Plover chicks, will become more abundant with an increase in tidal salt marsh. The topic of corvid predation has been reviewed by Liebezeit and George (Liebezeit and George 2002). In addition, increasing numbers of California Gulls in the South Bay may pose a problem for other native wildlife species. During winter high tides, SFBNWR staff have observed heavy predation of salt marsh harvest mice by California Gulls (J. Albertson, pers. comm.). For species such as the Western Snowy Plover, that rely on the South Bay salt ponds for nesting habitat, reduction in available habitat could lead to density-dependent increases in predation rates.

## 11.2 Data-gaps

### 11.2.1 Data-gaps Essential to Fill for Restoration Planning

*How do characteristics of tidal salt marsh, salt pond, and managed pond habitats affect levels of predation by terrestrial mammals (e.g., fox, raccoon) and birds (e.g., raven)? How can tidal salt marshes and managed ponds be designed or managed to minimize predation?* Studies of causes and levels of predation in different habitats could address this question.

### 11.2.2 Data-gaps to Fill During Adaptive Management and Monitoring

*What is the level of predation on special-status wildlife in the South Bay?* Although there has been some research on this topic, causes of nest loss of Snowy Plovers have not been systematically studied. No studies have been carried out on the effects of predation on salt marsh harvest mice, in part because they are so difficult to do, and because the impact of predation on Clapper Rails was so obvious and serious that is has occupied the primary attention of resource managers.

*How can avian predators be controlled?* Will management of local landfills help reduce local populations of California Gulls and Common Ravens? To what extent do Common Ravens use PG&E towers for nesting? Which South Bay habitats are preferred by ravens? Determining the nesting and foraging preferences of Common Ravens may aid in developing deterrence strategies.

*What will be the projected annual costs of predator control techniques when expanded to a Bay-wide scale?* Reasonably successful techniques exist for removing, preventing the use of, and discouraging the use of tidal marshes and transition zones by mammalian predators such as the red fox, and domestic and feral cats, mainly through a continuing trapping program.  These techniques may be scaled up if economically feasible.

# 12. TOPIC 7D. CONTAMINANTS IN WILDLIFE

## 12.1 Data Summary

### 12.1.1 Distribution and Concentrations of Contaminants in the Bay

Extensive data are available on the distribution and concentration of contaminants in Bay water and sediments, including characteristics of various wetland types that affect mercury methylation and methylmercury degradation, and uptake into the food web. Such information includes, but is not limited to: (Abu-Saba and Flegal 1997; Anderson and others 1990; Belanger 1986; Conaway and others 2003; Custer and Myers 1990; Cutter 1989; Davis 2004; Dillon and Moore 1991; Donat and others 1994; Flegal and others 1990; Flessel and others 1991; Hunt and others 2001; Jarman and others 1997; Johnson and Looker 2003; Kozelka and others 1997; Kuwabara and others 1989; Lion and others 1982; Lion and Leckie 1982; Long and others 1990; Luoma and others 1988; Luoma and Presser 2000; Maruya and others 1996; Marvin-DiPasquale and Agee 2003; Marvin-DiPasquale and others 2003; Miles and Roster 1999; Modin 1969; Nichols 2004; Olson and Cooper 1976; Pinza and others 1996; Rivera-Duarte and Flegal 1997; San Francisco Estuary Institute 2003; Sandberg and others 1971; Squire and others 2002; Swartz and others 1994; Thomas and others 2002; Thompson and others 1999; Topping and others 2001; Wang and others 1993; Wiener and others 2003a; Word and others 1991; Zawislanski and others 2001).

Some studies provide pertinent information from mercury-bearing sites elsewhere (Benoit and others 1998; Fink 1993; Gilmour and others 1998; Hurley and others 1998; Miles and Fink 1998)

### 12.1.2 Contaminants in Wildlife

The literature on contaminants in wildlife falls into two major categories, studies reporting tissue concentrations, and studies reporting toxic response, or effect. For contaminants found in San Francisco Bay, studies with residue data include: (Clark and others 1992; Davis 2004; Davis and others 1997; Davis and others 2002; Gates and Tjeerdema 1993; Hothem and others 1998; Hothem and others 1995; Hothem and Zador 1995; Hui and others 2001; Johns and Luoma 1988; Johns and others 1988; Knezovich and others 1988; Lonzarich and others 1992; Maruya and others 1997; Ohlendorf and others 1988a; Ohlendorf and Fleming 1988b; Pereira and others 1994; Purkerson and others 2003; Schwarzbach 1993; Stegeman and others 1988; Young and others 1998a). Much of these data come from on-going monitoring programs such as the SFEI's Regional Monitoring Program, so this knowledge base can be expected to continue to grow.

A recently funded USFWS/USGS-BRD study of contaminant impacts on birds, with an emphasis on mercury, will provide more comprehensive data on a wider range of species, than has previously been available, and will contribute significantly to filling this data-gap (Suchanek and others).

The USFWS and the San Francisco Bay Bird Observatory are currently conducting a study of environmental contaminants (including Hg and PCBs in bird eggs) and seabird ecology of the San Francisco Bay. The results of this study will help determine if existing exposure to mercury and PCBs will cause population-level effects on birds (SFBBO, unpubl. data).

Information on mercury impacts on birds in San Francisco Bay has been reported (Schwarzbach and Adelsbach 2003; Schwarzbach 1993). Species-specific toxicity information from studies conducted at sites other than San Francisco Bay is also useful. There is a modest fund of toxicity data from other sites for species found in San Francisco Bay, or closely related species, including: (Beyer and Heinz 1996; Braune and Norstrom 1989; Brix and others 2001a; Brix and others 2001b; Burger and Gochfeld 1994;

Cain and Luoma 1990; Chasko and others 1984; Davis and others 1997; Elbert 1996; Fernandez and Beiras 2001; Franson and others 2002; French and others 2001; Geret and others 2002; Grue and others 1984; Gunther and others 1997; Hamilton and others 2002a; Hamilton and others 2002b; Hamilton and others 1986; Heinz 1976; Heinz 1979; Heinz and others 1983; Henny and others 1991a; Hoffman and others 1996; Hoffman and Moore 1979; Hoffman and others 1998; Hoffman and others 1986; Hopkins and others 2002; Hyne and others 2002; Jordan and Bhatnager 1990; Lemly 1993; Prati and others 2002; Rao and others 1989a; Rao and others 1989b; Rattner and others 1996; Reish 1993; Stegeman and others 1988; Stehr and others 1997; Strong and Luoma 1981; Subba Rao and Saxena 1981; Takayanagi 2001; Walker 1989; Wayland and others 2002).

The most valuable studies are those that report both tissue concentration and toxic response, or effect, in a dose-dependent manner (Adams and others 2003; Baron and others 1997; Barr 1986; Blus and others 1985; Burger and Gochfeld 1994; Burger and Gochfeld 2000; Dieter and others 1983; Elliott and others 1989; Finley and others 1979; Henny and Herron 1989; Hoffman and Moore 1979; Hoffman 1998; Hopkins and others 2002; Hopkins and others 2003; Hyvarinen and Siipila 1984; King and others 1991; Landrum and others 1993; Marigomez and others 1996; Monteiro and Furness 2001; Newton and Haas 1988; Pelletier and Audet 1995; Spies and others 1984; Thompson and others 1991; Watanabe and others 1999; Wayland and others 2002; Wolfe and others 1998).

### 12.1.3 Factors Influencing Bioavailability and the Potential of Contaminants to Bioaccumulate in Wildlife

The ability of contaminants to bioaccumulate in wildlife is a function of the toxicokinetics (the rate of uptake and transformation of potentially toxic substances) and toxicodynamics (the way in which toxicants exert their effects) of each particular contaminant. Other factors such as exposure and life history stage are also important in understanding the likelihood of toxicity and bioaccumulation. The following studies provide information on bioaccumulation pertinent to the SBSP Restoration Project: (Allen-Gil and others 1995; Amiard-Triquet and others 1993; Atwell and others 1998; Barkay and others 1992; Baron and others 1997; Besser and others 1996; Bodaly and others 1997; Braune and Norstrom 1989; Bryan and others 2003; Bryan and Langston 1992; Clark 1987; Clarke and others 1995; Doyon and others 1998; Fan and others 1997; Finerty and others 1990; Fischer and others 1995; Flessel and others 1991; Gerrard 2001; Gunther 1991; Hoffman 1994; Hope 2003; Hopkins and others 2003; Hurley and others 1998; Inza and others 1998; Johns and Luoma 1988; Johnston and others 2003; Lemly 1996a; Lemly 1997a; Lemly 1997b; Luoma and Bryan 1978; Luoma and others 1992; Marigomez and others 1996; Maruya and others 1997; Mason and others 2000; Mason and others 1995; McFarland and others 1994; Monteiro and Furness 2001; Morel and others 1998; Ohlendorf and others 1989; Pasternak and Bielak 2002; Patronek 1998; Pelletier and Audet 1995; Pereira and others 1992; Plourde and others 1997; Ponce and Bloom 1991; Reinhold and others 1999; Reish 1993; Scheuhammer 1990; Thompson and others 1991).

### 12.1.4 Monitoring Contaminants in Wildlife, Bioindicators and Biomarkers

A *bioindicator* may be defined as an organism (biological unit or derivative) that responds predictably to contamination in ways that are readily observable and quantifiable (Beyer and Heinz 1996; Frederick and others 2002; Hawkes and others 1992; Hodson 1990; Jenkins and Sanders 1990; Kucera 1983; Landrum and others 1993; Leonzio and Massi 1989; Long and others 1991; Luengen and others 2004; Monteiro and Furness 1995; Petrucci and others 1995; Ruelle 1986; Wade and others 1998; Wolfe and others In Press; Zillioux and Newman 2003). Particularly useful insights on strategies for long-term avian monitoring are reported in the recently published study from the Great Lakes (Hebert and Weseloh 2003).

Subcategories of bioindicators at suborganismal levels are generally referred to as *biomarkers*. Biomarkers may reflect exposure, effect or susceptibility; of these, biomarkers of effect are both more valuable and more difficult to find (Akesson and others 1997; Bartell and others 2000; Burnett 1997; Cossu and others 2000; Cossu and others 1997; Custer and others 1997; Fossi and others 1996; Fossi 1998; Ip and others 2000; Jenkins and Sanders 1990; Kreps and others 1997; Leonzio and others 1996; Regoli and Principato 1995; Snyder and Valle 1991; Trust and others 2000; Werner and others 1998; Wolfe and others In Press; Woods 1996).

The desired knowledge endpoint for the present effort is to evaluate the potential hazard of contaminants in the SBSP Restoration Project area. Therefore, selected risk assessment protocols must include consideration of multiple exposures, including possible interactive effects, such as antagonism, in the case of selenium and mercury (Allen 1996; Baron and others 1999; Cain and Luoma 1990; Chandy and Patel 1985; Constantinou and others 1995; Custer and others 2001; Duvall and Barron 2000; El-Demerdash 2001; Fan 1993; Fernandez and Beiras 2001; Frisk and others 2001a; Frisk and others 2001b; Gordon and others 1995; Hamilton 2003; Hamilton and others 2002a; Hamilton and others 2002b; Hunt and others 2001; Inza and others 1998; Jacobson 2001; Jak and others 1996; Jongbloed and others 1996; Jordan and others 1990; Jordan and Bhatnager 1990; Kagi and Hapke 1984; Karustis and Brewer 1995; Koller and Roan 1980; Lemly 1996a; Lemly 1996b; Lemly 1997a; Lemly 1997b; Lemly 1997c; Lemly 1998; MacIntosh and others 1993; Meyer 2001; Moore and others 1999; Patel and others 1988; Rao and others 1989a; Rao and others 1989b; Ribeyre and others 1995; Rumbold 2000; Sample and others 1996; Sappington 2002; Scheuhammer 1990; Spencer and others 2001b; Timmer and Thompson 1994; Trabalka and Garten 1983; U.S. Environmental Protection Agency 1993b; U.S. Environmental Protection Agency 1993c; Wolfe and Norman 1998; Wolfe and others 1998).

Risk assessment and risk management guidelines specific to mercury are set forth in several USEPA publications (U.S. Department of the Interior 1996; U.S. Environmental Protection Agency 2001b) and elsewhere (Baron and others 1999; Duvall and Barron 2000; Jacobson 2001; Moore and others 1999; Rumbold 2000). Some considerations of risk assessment in wetlands are also provided (Fan 1993; Lemly 1996a; Lemly 1997b). The importance of tailoring risk assessment protocols to the conditions and characteristics of particular locations is discussed by a number of investigators (Lemly 1996b; Lemly 1998; Sappington 2002; Shipp and others 2000; Wolfe and Norman 1998).

Management of the risk of contaminants to wildlife would include potential for bioremediation. Available information suggests that, for selenium at least, the prospects for using constructed or restored wetlands for bioremediation are promising. There is less data on remediation of mercury-bearing sites, but research in this area has increased in the last few years, so additional information is forthcoming (Banuelos 2001; Barkay and others 1992; Boyd and Carlucci 1996; D'Itri and others 1993; Frankenberger and Arshad 2001; Garbisu and others 1997; Garbisu and others 1995; Gbondo-Tugbawa and Driscoll 1998; Gilmour and Bloom 1995; Hansen and others 1998; Heaton and others 1998; Jenkins and Sanders 1990; Losi and Frankenberger 1997; Macy and others 1993; Manning and Burau 1995; Vaz and others 2000; Wu and others 2003; Ye and others 2003; Yu and others 1997). Results and recommendations specific to mercury in San Francisco Bay are provided in Churchill (2003).

## 12.2 Data-gaps

### 12.2.1 Data-gaps Essential to Fill for Restoration Planning

*How should restoration be designed to incorporate the potential for bioremediation?* Most mercury remediation studies focus on either mine remediation, to reduce loading (Churchill and Clinkenbeard 2003), or experimentally varying methylation rate parameters (King and others 2000). The potential for integrating remediation measures into restoration design should be modeled, and then examined in small pilot projects. Helpful information will be available in the future from studies currently underway (U.S. Geological Survey 2004c).

### 12.2.2 Data-gaps Essential to Fill later During Adaptive Management and Monitoring

*What are the best terrestrial species to monitor as bioindicators of contaminant exposure?* The USFWS/USGS-BRD study cited above will probably identify the most suitable avian species to monitor, but no current studies address this question for mammals. The SBSP Restoration Project will likely restore and enhance suitable habitat for a number a wetland mammal species including the harbor seal (a piscivorous mammal), the salt marsh harvest mouse (an herbivorous small mammal), and the salt marsh wandering shrew (an insectivorous small mammal). However, the susceptibility of these species to contaminant exposure in the project area is unknown. Therefore, work on wetland mammals should be supported.

*What monitoring methods, e.g. tissue residue versus sub-organismal biomarker, will yield the most sensitive data about the change in health status of wildlife populations?* Design of mercury monitoring programs is the subject of a current USEPA/SETAC-sponsored project. Wildlife indicator species and monitoring endpoints for the SBSP Restoration Project should be designed with reference to those guidelines (Wolfe and others In Press). A recently developed mercury egg injection method will help to evaluate the relative sensitivities of bird species (Heinz 2003).

*How should the risk of contaminants to wildlife be assessed and managed?* Risk assessment should be probabilistic to maximize sensitivity to the dynamics of the South Bay. Various risk management models should be evaluated for applicability to the SBSP Restoration Project, and modified as necessary for the particular conditions of the South Bay.

## 13. TOPIC 7E. SALT POND FOOD RESOURCES

### 13.1 Data Summary

Salt ponds provide abundant food for a variety of waterbird species. The most abundant prey in higher salinity ponds (100-150 ppt) include franciscan brine shrimp (*Artemia franciscana*), reticulate water boatman (*Trichocorixa reticulata*), and brine flies (*Ephydra* sp. and *Lipochaeta slossonae*). Biology, ecology, and distribution of these species are discussed in the Goals Project's Species and Community Profiles (Goals Project 2000).

As discussed under Topic 1, invertebrate and fish populations of the South Bay salt ponds have been studied by a number of researchers (Carpelan 1957). Also under Topic 1 is a current study by the USGS on invertebrate and fish populations in fifty three (53) South Bay salt ponds. These data, which have not yet been fully compiled and analyzed, will provide information on abiotic factors affecting the abundance and distribution of these prey species. Food web response to restoration activities are also currently being studied by USGS and the BREACH project (see Topic 7b).

### 13.2 Data-gaps

None—USGS will fill data-gaps.

## 14. TOPIC 8. WATER AND SEDIMENT QUALITY

Numerous investigations and monitoring programs have been conducted on the San Francisco Bay and Sacramento-San Joaquin Delta ecosystem. A particular contaminant of concern identified through these studies is mercury. A brief summary of some of the key studies conducted, with an emphasis on mercury distribution and methylation is presented below.

### 14.1 Topic 8a. Physical Distribution of Mercury/Other Contaminants

#### 14.1.1 Data Summary

Water and sediment quality in the San Francisco Bay has been monitored through both one-time and ongoing sampling programs by federal, state and local public and private institutions and agencies. Key agencies participating in monitoring programs adjacent to the SBSP Restoration Project area include the USGS, the USFWS, the CDFG, the RWQCB, the Alameda County Public Works Agency (ACPWA), the SCVWD and the City of San Jose. The principal private agency working closely in conjunction with these public agencies is the SFEI. The San Francisco Bay Clean Estuary Partnership (CEP) is a collaborative program established through a memorandum of understanding between the RWQCB, the Bay Area Clean Water Agencies (BACWA), and the Bay Area Stormwater Management Agencies Association (BASMAA). The California Bay-Delta Authority (CBDA, previously CALFED) funded an assessment of mercury and methylmercury in sediments throughout the San Francisco Bay, including South Bay sites and sites along creek mouths and marginal areas, and will fund a similar assessment beginning in 2005 (Heim and others 2003).

Five major sources of available data from the USGS have been identified. Two online databases provide information on the continuous monitoring of suspended solids concentrations, temperature, salinity, and water levels at fixed stations throughout the San Francisco Bay and Delta since 1989 and on a long-term monitoring program collecting various general water quality parameters in the San Francisco Bay since 1969 (U.S. Geological Survey 2004a; U.S. Geological Survey 2004b). The USGS also produced a report that provides seasonal and year-to-year data trends for trace element concentrations in sediments and clams in receiving waters near the Palo Alto Regional Water Quality Control Plant for the years 1977 through 2001 (U.S. Geological Survey 2004d). Another report by the USGS provides historical trends of metals in the sediments of San Francisco Bay, which includes core data from San Pablo Bay, Grizzly Bay, Richardson Bay and Central Bay. The sediment core samples were collected from multiple locations and analyzed for aluminum, chromium, copper, lead, mercury, nickel, silver, vanadium and zinc (Hornberger and others 1999). A report summarizing science support for salt pond restoration and management and evaluating short-term data collection needs for the SBSP Restoration Project was also produced by the USGS. This report includes baseline characterization of the physical and biological aspects of fifty-three (53) salt ponds within the SBSP Restoration Project area. Sediment samples were collected from ponds and sloughs and analyzed for salinity, organic matter and particle size distribution (U.S. Geological Survey 2004c).

The California Department of Fish and Game and the U. S. Fish and Wildlife Service produced the ISP, Environmental Impact Report/Environmental Impact Statement (California Department of Fish and Game and U.S. Fish and Wildlife Service 2003). Some ISP data are collated in a Report of Waste Discharge (ROWD) submitted to the RWQCB. In addition, more detailed mercury data have been collected subsequently, based on a monitoring program managed by Lisa Stallings of Life Sciences Inc. The ROWD provides water quality and inorganic sediment data for individual ponds that will be managed under the ISP within the project area. Because the collated data came from a multitude of agencies & consultants, there are some questions about the quality and consistency of the data (e.g., selenium and arsenic concentrations obtained by Inductively Coupled Plasma Spectroscopy). Baseline monitoring information known to be useful includes:

- Mercury concentrations in bird eggs – Steve Schwarzbach, USGS, is lead author, draft report produced in August, 2003.
- Mercury concentrations in sediments, snails, and key prey fish for avian species (e.g., terns) monitored at part of the environmental site assessment in 2002. This is in a report available from Thomas Maurer, USFWS.
- Replicated, research-quality mercury and methylmercury in sediments of 12 ponds (6 in Alviso, 2-3 each in Redwood and Baumberg tracts) as part of ISP monitoring in 2004. Raw data were recently received from the laboratory and data synthesis and summary are in process; USGS (Keith Miles) is lead agency; study was designed by Lisa Stallings in collaboration with Tom Maurer and Mark Marvin-DiPasquale.
- Sediment sampling and analysis in Ponds A8 including total and methylmercury in 2004. Study was conducted by Light, Air and Space Construction for the Santa Clara Valley Water District.

The RWQCB has produced two significant reports that detail total maximum daily loads (TMDLs) for mercury and polychlorinated biphenyls (PCBs). The mercury TMDL provides a description of mercury sources and target concentrations and the relationship between the two in the San Francisco Bay (Regional Water Quality Control Board 2003b). The PCB TMDL provides a description of PCB sources and target concentrations and the relationship between the two in the San Francisco Bay (Regional Water Quality Control Board 2003a).

ACPWA has established a multi-year plan for monitoring and assessment. This report details current status of watersheds within Alameda County and the impact of stormwater runoff from these watersheds into San Francisco Bay. Contaminants analyzed through the historical monitoring efforts include cadmium, copper, lead, zinc, polynuclear aromatic hydrocarbons (PAHs), and organochlorine pesticides. Current monitoring includes diazinon, copper, mercury, nickel, selenium, chlordane, DDT and dieldrin (Regional Water Quality Control Board 2003b).

Two relevant sources of information from the SCVWD have been identified. The SCVWD produced a report for the Guadalupe River watershed mercury TMDL project, which provides a description of mercury sources and target concentrations and the relationship between the two in the Guadalupe River watershed (Tetra Tech Inc. 2003a; Tetra Tech Inc. 2003b; Tetra Tech Inc. 2003c; Tetra Tech Inc. 2003d; Tetra Tech Inc. 2003e). The SCVWD has also undertaken the restoration of Pond A4 (Santa Clara Valley Water District 2003a; Santa Clara Valley Water District 2003b).

The City of San Jose maintains a surface water-monitoring program, for which data can be accessed by submitting a written request to Randolph Shipes, deputy director of the City’s Environmental Services Division. Surface water sampling and monitoring has been historically conducted throughout the watershed at approximately 12 locations. Data collected includes total and dissolved trace metals, total suspended solids (TSS), salinity, nutrients, and other ancillary parameters (Hayes 2004).

San Francisco Estuary Institute manages the Regional Monitoring Program for Trace Substances (the RMP). This discharger-funded program has been collecting contaminants data in water, sediments, and biota since 1993 (San Francisco Estuary Institute 2004). Budget priorities for regular monitoring and special studies are approved by a steering committee with representatives from the San Francisco Bay Regional Water Quality Control Board, dischargers, and environmental groups.

The SFEI maintains a regional monitoring program. This approximately 10-year-old monitoring program is a collaborative effort between SFEI, the RWQCB, the USGS and other local agencies. The program monitors contaminants within the water, sediment and biota of the San Francisco Bay (San Francisco Estuary Institute 2004).

Two important references are provided by the Clean Estuary Partnership. One is a conceptual model and impairment assessment report for mercury in San Francisco Bay, which provides a summary of evidence for impairment, conceptual model for mercury linkages to beneficial uses, and assessment of key uncertainties (Tetra Tech Inc. 2004). The other resource is the conceptual model and impairment assessment report for selenium in San Francisco Bay, which provides a summary of evidence for impairment, conceptual model for selenium linkages to beneficial uses, and assessment of key uncertainties. The report notes extremely high water column selenium concentrations in Alviso Slough, and the need for selenium data from salt ponds (Grieb 2004).

CALFED provides useful references. An assessment of mercury and methylmercury in San Francisco Bay sediments (2000 survey) was performed and summarized (during a public meeting at Moss Landing Laboratories) by Mark Stephenson (Stephenson 2003). An upcoming study of mercury and methylmercury in water, sediments, and biota of San Francisco Delta and its tributaries is expected to begin in 2005 (Stephenson and others 2002). Another large project was recently funded by CALFED for work on trophic transfer of mercury (Marvin-DiPasquale and others 2002). Also, a recently funded project will look at mercury methylation and bioaccumulation in salt marsh environments in the North Bay (Yee and others 2002).

Since the SBSP Restoration Project may rely on natural erosion and sedimentation processes to restore tidal marsh topography, there is concern about the potential for contaminants (especially mercury) buried in existing tidal mudflats, to be re-mobilized. Contaminant resuspension could increase the exposure to biota. Information on the potential for contaminants to be released into the water column during restoration, and strategies to prevent release is found in a number of references (Wagner and others 1990; Wentworth 1997; Youd and House 1978). Extensive information specific to San Francisco Bay, including recommendations for necessary further studies, is available (Wiener and others 2003b). The Wiener Mercury Strategy includes an excellent synthesis of mercury-related issues concerning investigations needed to build a scientific foundation for ecosystem restoration and the assessment and reduction of mercury–related risks to biota in the San Francisco Bay-Delta (Wiener and others 2003b). The Mercury Strategy emphasizes that the primary issue with mercury is the exposure of aquatic biota to methylmercury, and restoration designers and managers must focus on this critical link to control mercury contamination in biota in the San Francisco Bay-Delta.

The Long Term Management Strategy (LTMS) for beneficial re-use of dredged sediments established guidelines for the concentrations of contaminants in dredged sediments, including total mercury in sediments. These guidelines are incorporated by reference in the Water Quality Control Plan for San Francisco Bay (the Basin Plan) (California Regional Water Quality Control Board San Francisco Bay Region 1995). The guidelines were not developed by considering linkages between total mercury in sediments and mercury bioaccumulation. Therefore, refinements to the guidelines for mercury may be necessary over time. Because the Montezuma Wetlands restoration project was one of the first major projects to implement the LTMS cover/no cover guidance, the Montezuma monitoring and adaptive management strategy may help to inform this question.

Two ongoing activities that could impact the restoration effort should be tracked by the Project Team. The data collection program was the first focused analysis of mercury and methylmercury in the South Bay Salt Ponds. RWQCB staff has indicated that additional sampling is being planned. This process needs to be tracked by the Project Team since there may be an opportunity to influence the new data collection program to inform data-gaps presented below. In addition, the State Water Resources Control Board (SWRCB) is currently developing sediment quality objectives, which may affect the design alternatives. This process also needs to be tracked by the Project Team.

### 14.1.2 Data-gaps

**Data-gaps Essential to Fill for Restoration Planning**

*What are the spatial gradients for contaminants, especially mercury, within the South Bay salt ponds?* We need to better characterize concentrated mercury areas within the salt ponds and within adjacent sloughs and tidal mudflats to help inform decisions about where to locate various habitat types (e.g., tidal marsh versus salt pond), and where wetland soil-cover might be needed. Sediment mercury data collected under the ISP, described above and currently under review by the USGS, may cover this data gap for within the ponds.

*How will spatial gradients of contaminants within the greater San Francisco Bay, outside of the SBSP Restoration Project area, affect sediment quality of restored tidal habitats?* Other programs, such as the Regional Monitoring Program and the Clean Estuary Partnership, are collecting data that documents gradients in the concentrations of contaminants (e.g., PCBs, mercury) in sediments. Additional monitoring of the horizontal and vertical distribution of contaminants at strategic locations will also be needed, particularly in areas that are expected to be eroded and mobilized as a result of the restoration (e.g., existing tidal mudflat outside of the salt ponds). This data will assist any effort to predict sediment quality in restored areas and assess the risk to biota from contaminant exposure for tidal habitat restoration alternatives.

**Data-gaps to Fill During Adaptive Management and Monitoring**

*How might future mercury contamination affect restored tidal habitats?* Future mercury loadings from upstream sources (e.g., Guadalupe River) and/or the Bay could re-contaminate restored tidal habitats. The potential timing and location for significant mercury sources needs to be characterized to help inform decisions about location and phasing of restoration efforts, as well as long-term operation.

*How might future mercury loads affect restored tidal habitats?* In addition to predicting the mercury concentration in sediments of restored project areas, consideration should be given to how mercury loads to the project area could change over time. Mercury can enter restored project areas from four different pathways: fluvial loads transported by the Guadalupe River, tidal exchange of Bay sediments, stormwater runoff from adjacent urban areas, and direct atmospheric deposition. Some of these loads may increase over time (e.g., atmospheric deposition), some are expected to decrease (e.g., mercury in Bay sediments). The effect of these long-term changes on mercury loading to the food web should be considered when evaluating project design and management alternatives.

## 14.2 Topic 8b. Mercury Methylation

### 14.2.1 Data Summary

The understanding of mercury cycling in San Francisco Bay and its margins is a key part of the alternatives analysis for wetland restoration. To address these concerns, several mercury studies have been conducted to fulfill regulatory drivers (i.e., total maximum daily loads). The primary objectives of these studies have been to quantify mercury sources, identify the speciation of the mercury sources, and determine the most important factors affecting methylmercury production and bioaccumulation. The results of these studies are summarized in a conceptual model for mercury in the San Francisco Bay (Grieb 2004).

The CALFED Mercury Project (http://loer.tamug.tamu.edu/calfed) undertook a major three-year assessment of factors affecting mercury risks to people and wildlife that eat fish. The study had many facets, including source assessment, assessment of mercury in the food web, and feasibility of mine site restorations. The aspects most relevant to the SBSP Restoration Project are studies of mercury cycling in wetlands, and the conceptual model for mercury in the Bay-Delta ecosystem (Gill and others 2002).

Through review of the CALFED study and other reports, we have identified the following key issues that the SBSP Restoration Project should address with regards to mercury methylation and wetland restoration. Sources and bioavailability of mercury to the project area need to be determined: 1) Avoiding and minimizing increased methylmercury loads from the project area to the Bay is important. Factors affecting net methylation and bioaccumulation rates within the restored tidal habitats will need to be determined. Previous studies have identified wetland areas that exhibited high methylation rates, but that also yielded low bioaccumulation rates (Slotton and others 2002). Therefore, even though the restored wetlands may be net producers of methylmercury, the methylmercury may not enter the aquatic food chain at an elevated bioaccumulation rate. It will be necessary to identify factors that affect net methylation rates and overall bioaccumulation in the South Bay tidal habitats and salt ponds, and whether those factors can be related to tidal habitat restoration and managed pond design or operational decisions.

### 14.2.2 Data-gaps

**Data-gaps Essential to Fill for Restoration Planning**

*Are there existing spatial gradients for methylmercury and net methylation rates within the salt ponds and within adjacent sloughs and tidal mudflats?* These data would likely help inform restoration design to minimize exposure of biota to methylmercury. Sediment methylmercury data collected under the ISP, described above and currently under review by the USGS, may partly inform this data gap for the ponds, but methylation rates have not yet been directly evaluated to date.

*How does mercury methylation differ throughout the continuum of habitat types pertinent to the SBSP Restoration Project?* Radio-isotope data are needed to characterize the kinetics of mercury methylation in the habitats targeted for restoration and management: tidal mudflats, tidal marshes, and managed ponds.

**Data-gaps to Fill During Adaptive Management and Monitoring**

*Will the restoration alternatives affect bioaccumulation by altering the food web?*

## 14.3 Topic 8c. Water Quality

### 14.3.1 Data Summary

The water quality of the Bay is also affected by municipal wastewater treatment plants that discharge more than 600 million gallons of treated wastewater to the Bay each day (Goals Project 1999). Most of this is discharged to deep-water areas; however, treated wastewater is also discharged to sloughs and shallow areas, which has adversely affected wetland marsh areas causing the conversion of tidal salt marsh to brackish marsh, particularly near Artesian Slough. To avoid this problem, the city of Hayward mixes Bay water with treated wastewater in the Hayward Area Recreation District Marsh (Goals Project 1999). Freshwater ponds are also used by the treatment plants to store wastewater before it’s discharged to the Bay, and some treatment plants use marsh vegetation to remove, or polish, additional pollutants (Goals Project 1999). An example of this kind of facility is at the Demonstration Urban Stormwater Treatment Marsh in Hayward.

### 14.3.2 Data-gaps

**Data-gaps Essential to Fill for Restoration Planning**

*How will SBSP Restoration Project impact phytoplankton levels in South Bay? Will the ponds as act net sources or sinks of phytoplankton and nutrients?*

# 15. TOPIC 9. EFFECTS OF LIKELY LONG-TERM OPERATIONS BY CARGILL

## 15.1 Data Summary

The process of salt making with particular details on Cargill Salt Company's historic operations is summarized in chapter 3 (Siegel and Bachand 2002). This description provides background on traditional solar salt production methods (i.e., the Ver Planck Ten-Pond Salt Production Model) and Cargill modifications thereof. Salinity ranges associated with the progressive stages of salt production are outlined in Table 3-3 (Siegel and Bachand 2002) feasibility study, and range from 20 to 315 ppt for concentrator ponds, 350-400 ppt for crystallizer ponds, and 400-450 ppt for bittern desalting and storage ponds (Siegel and Bachand 2002).

Cargill has historically produced approximately one million tons of salt per year on about 30,000 acres of South Bay salt ponds (Ransom 2004). The area was historically broken into five discrete plants - Redwood City, Baumberg, Newark #1, Newark #2, and Alviso (Maps 1 and 2; (Siegel and Bachand 2002). Approximately 700,000 tons of the salt was produced at the final processing plant located in Newark and the remaining 300,000 tons was produced at the plant in Redwood City (Siegel and Bachand 2002). In March 2003, Cargill transferred ownership of the Baumberg complex to the California Department of Fish and Game, (U.S. Fish and Wildlife Service and California Department of Fish and Game 2003a). Remaining portions of the Alviso complex and the West Bay ponds, which comprise the eastern portion of the Redwood City plant, were transferred to the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service and California Department of Fish and Game 2003a). Cargill retained ownership of portions of the Newark #2 complex (crystallizer ponds and ponds 7, 8, 10, 10A, 11, 26, 27, 28) and reserved salt making rights on the USFWS land in Newark #1 and Newark #2 (U.S. Fish and Wildlife Service and California Department of Fish and Game 2003b).

Chapter 12 of (Siegel and Bachand 2002) also provides an overview of proposed system modifications as a result of the property transfer, based on Cargill maintenance reports and work plans that were prepared shortly before the transfer (2000 and 2001). The proposed modifications are related to Cargill's efforts to maintain efficient salt making operations on a smaller, reconfigured system with less than half the area of original salt ponds. In general, two historic intake locations will be replaced by one location off Alameda Creek. The direction of flow will continue south, but will integrate the lower ponds in Newark #2 as final concentrator ponds (Map 5; (Siegel and Bachand 2002). Existing salt concentrations in the ponds in Newark #1 and Newark #2 will change as a result of system modifications and some ponds (e.g., Mowry Ponds 1, 2, and 3) will become more concentrated (Siegel and Bachand 2002).

Cargill intends to continue producing salt at their Newark facility into the foreseeable future (Ransom 2004). Cargill will continue to operate the salt ponds in Newark #1 and #2 complexes, which total approximately 12,000 acres, including the plant site, and will produce approximately 650,000 tons/year of salt (Ransom 2004). Pond salinities and depths will vary depending on salt-making needs. Salinity levels and pond depths associated with the Newark operation are generally not predictable on a pond-by-pond basis, because it is a salt production system. This system is expected to stay within the traditional range for salt production, described above, and will continue to include many ponds at the mid- to high-concentration range.

In consolidating their operations, Cargill will transition over the next 5-10 years, moving higher concentration brines from geographically outlying areas (i.e., Alviso, Baumberg, and Redwood City) toward the Newark facility. Compliant with the Phase Out Agreement, saline waters in the Baumberg complex are expected to be transferred to Newark by August 2004 (U.S. Fish and Wildlife Service and California Department of Fish and Game 2003a). Cargill also intends to eventually phase out salt production at their Redwood City facility, after processing and harvesting existing salt on-site (Ransom 2004).

In consolidating their operations, Cargill will transition over the next 5-10 years, moving higher concentration brines from geographically outlying areas (i.e., Alviso, Baumberg, and Redwood City) toward the Newark facility. Cargill also intends to eventually phase out salt production at their Redwood City facility.

The salinity management of the salt ponds recently acquired by the federal and state government (i.e., Baumberg, Alviso, West Bay) is detailed in the ISP. The ISP outlines the interim management plan for each of the three salt pond complexes (U.S. Fish and Wildlife Service and California Department of Fish and Game 2003b). Cargill's role in implementing the plan is specified in the Phase Out Agreement between Cargill and U.S. Fish and Wildlife and California Department of Fish and Game (U.S. Fish and Wildlife Service and California Department of Fish and Game 2003a).

### 15.2 Data-gaps

*How will management of retained Cargill ponds affect population numbers and distribution of birds in the South Bay?* Cargill ponds will provide various different habitats for birds. How these ponds are managed could affect bird populations in adjacent restoration sites.

# 16. TOPIC 10. SEASONAL POND/GROUNDWATER INTERACTIONS

## 16.1 Data Summary

In characterizing the seasonal pond/groundwater interactions, several factors need to be considered, including soil types, infiltration rates, geology, and groundwater levels. Infiltration rates within the (SBSP Restoration Project) area are a function of soil type. Soil surveys were obtained from the U.S. Department of Agriculture Natural Resources Conservation Service (USDA NRCS) for the ponds in the southeast portion of San Mateo County (U.S. Department of Agriculture Soil Conservation Service and University of California Agricultural Experiment Station 1991), in Northern Santa Clara County (U. S. Department of Agriculture Soil Conservation Service and University of California Agricultural Experiment Station 1958), and in the western portion of Alameda County (U.S. Department of Agriculture Soil Conservation Service and University of California Agricultural Experiment Station 1980). Soil types are generally defined as fine-grained, and corresponding soil attributes including infiltration rates for the ponds are described as poorly drained with low permeability.

The geologic framework for the area is provided by the USGS report (Atwater and others 1977) and Society for Sedimentary Geology report, (Society for Sedimentary Geology and Pacific Section 1995). Fine-grained distal alluvial and Bay Mud deposits predominate in the SBSP Restoration Project area.

According to the State of California Department of Water Resources (DWR), the San Francisco Bay hydrologic region is divided into several basins and subbasins (Society for Sedimentary Geology and Pacific Section 1995). The entire project lies within the Santa Clara Valley Basin. The Alviso complex of the SBSP Restoration Project is located in the Santa Clara Subbasin, while the Baumberg complex is in the Niles Cone Subbasin. The West Bay complex lies within the San Mateo Plain Subbasin. DWR does not monitor any wells within the project area.

Groundwater level monitoring is required to define the seasonal relationship between the salt ponds and groundwater. The USGS has a regional monitoring network with several wells near the ponds in each of the subbasins, as identified in (Fio and Leighton 1995).

The SCVWD also collects groundwater elevation data for the three subbasins within the county. The SCVWD records depth-to-water measurements monthly from fifty-six wells, quarterly from 132 wells, and periodically from 184 wells (operated by other agencies). Depth-to-water well measurements are maintained in a database by the District, and serve as data points for groundwater level contour maps (Whitman and others 1995). A request has been placed with Beth Dyer of the District to obtain such data.

According to personal communications with Jim Ingle of the Alameda County Water District (ACWD), the District does monitor groundwater levels in the salt ponds area (Ingle 2004a). A written request has been submitted to obtain the data, which will cover the Baumberg complex. According to Ingle, monitoring and abandoned wells within the salt ponds would need to be capped prior to restoration. A request for the locations of such wells has been submitted to the ACWD, and the information may be received pending proper authorization.

The West Bay salt ponds in San Mateo County have groundwater elevations within one foot of sea level (Fio and Leighton 1995).

Both the Santa Clara Valley and the San Mateo Plain Groundwater Basins have deep confined aquifers from which most groundwater production occurs and shallow aquifer zones (above approximately 150 feet depth) that are under unconfined (water table) conditions (Groundwater Committee of the California

Regional Water Quality Control Board San Francisco Bay Region and others 2003). Most regional water level monitoring is in the deep, confined zones, which will not be representative of water table conditions beneath the salt ponds. Either water table monitoring wells in the immediate area of the salt ponds or groundwater modeling would be necessary to evaluate the interaction between the salt ponds and the water table.

## 16.2 Data-gaps

### 16.2.1 Data-gaps Essential to Fill for Restoration Planning

None.

### 16.2.2 Data-gaps to Fill During Adaptive Management and Monitoring

*What is the seasonal vertical gradient between the salt ponds and the water table, and how much interaction is there?* The low permeability soils may effectively limit significant vertical migration of water on a seasonal time frame. Simultaneous and frequent monitoring of both salt pond and adjacent shallow well water levels would be needed to evaluate the water table response and to ensure limited losses of surface water to the aquifer.

*What unique factors may influence salt pond/groundwater interactions?* Spatial variations may have some effect on infiltration due to the precipitation of salt in salt ponds that are not harvested frequently, thereby decreasing permeability of the surface layer and creating a unique scenario.

## 17. TOPIC 11. SOUTH BAY INFRASTRUCTURE

### 17.1 Data Summary

The identification of existing infrastructure in the SBSP Restoration Project area is essential for restoration planning. Ideally, previously compiled infrastructure data will be obtained from existing sources. The sources below have been identified as having significant GIS information pertaining to the infrastructure immediately adjacent to and within the boundaries of the SBSP Restoration Project. In a GIS data listing distributed by EDAW, the Bay Area Open Space Council and the Cargill Salt Company were identified as potentially having GIS information related to existing infrastructure within the project area. A request for existing GIS data was submitted to the SFEI. Comprehensive lists of infrastructure facilities are provided in Stuart Siegel and Philip Bachand (2002) and in Moffatt and Nichol Engineers and California State Coastal Conservancy (2003a). Obtaining the GIS data used in the above mentioned reports is imperative to evaluate outstanding infrastructure data-gaps.

#### 17.1.1 Significant GIS Data Sources

**The Bay Area Open Space Council (BAOSC)** has assembled a large amount of GIS infrastructure information. BAOSC has information including roads/highways, county lines, and transportation lines. These types of information will help construct the base map for this project upon which the pertinent infrastructure information will be overlaid. This information has been obtained (Appendix A) and Brown and Caldwell has requested a copy of the files to validate the accuracy or extent of the information.

**The Cargill Salt Company** also has GIS information on PG&E utility locations, nearby buildings, levees, pond locations, and pump locations. These data have also been obtained (Appendix A) and Brown and Caldwell has requested a copy of the files to validate the accuracy or extent of the information.

**The Siegel and Bachand "South Bay Salt Pond Feasibility Analysis"** includes information on wastewater discharge points, sewer mains, PG&E facilities, road and railroad, and the Hetch Hetchy aqueduct (Siegel and Bachand 2002). Information requests have been placed to Stuart Siegel by Adam Parris of PWA.

**The Moffatt and Nichol "Inventory of Water Conveyance Facilities South Bay Salt Pond Restoration"** also lists important infrastructure information. This report identifies and pinpoints control structures, stormwater, treated wastewater, and industrial dischargers and discharge points. Information requests have been made to Dilip Trevedi at Moffatt and Nichol through Shawkat Ali at PWA (Moffatt & Nichol Engineers 2003a).

**The San Francisco Estuary Institute** compiled information for the "SBSP Restoration Project" map dated February 13, 2004. They will be joining the Project Team and will provide large amounts of GIS mapping information potentially including water, storm, and sewer lines; storm and treated wastewater outfalls; PG&E tower locations; and base map information including aerial photographs.

Some of the information attained may be redundant, but until the project area infrastructure is fully mapped, it is best to obtain as much information as is available to assure maximum coverage and accuracy.

Outstanding data and information still to be collected include further investigation of what infrastructure information is available in GIS format and how much of it has already been attained. Currently, insufficient GIS information has been attained with regard to infrastructure. Initially, the attempt was made to contact individual cities to determine the availability of GIS infrastructure data. Some cities are wary to release information on the respective City's infrastructure due to security reasons, while other cities were only willing permit the review of and copy maps at the respective city halls. The cities of Palo Alto and Fremont were willing to release GIS data with the receipt of a written request, while some other cities have yet to return multiple phone calls. The data search has been redirected to broader sources of information in hopes of expediting the GIS data acquisition process.

Brown and Caldwell has redirected efforts to obtain previously accumulated information from SFEI, BAOSC, Cargill Salt Company, the Siegel and Bachand Report, and from Moffatt and Nichol Engineers. Data requests have been placed with SFEI (through EDAW), Stuart Siegel, and Moffatt and Nichol (through PWA) based upon the information in their reports. Information from BAOSC and Cargill Salt Company has been obtained (Appendix A), so no further effort has been put forth to acquire data from those sources.

Assuming information from the aforementioned sources will be released for use in this project, all areas of concern have been covered in our data search including base mapping, pipelines, outfalls, utilities, and water control structures. The potential for obtaining useful information is great, but the biggest data-gap will likely be the difference between the information we anticipate being provided to us, and what information is actually provided. Brown Caldwell anticipates that there may be portions of the data we collect that will not be complete, and that slight redundancy in the data requests will help reduce future data-gaps once the GIS information is obtained.

SFEI is currently identifying sources for the outstanding GIS data. At this time it is not possible to predict the quality or completeness of the data, as it is still in the collection process. The accuracy of infrastructure GIS data is unknown at this time; however, the accuracy of other data obtained by SFEI as part of the project ranges from highly accurate to unverifiable.

Some key information still to be collected by the consultant team includes:

**The Locations of the Existing PG&E Towers.** This information may be available through Cargill or through Stuart Siegel. These structures are located throughout the ponds and will be major obstacles to avoid and/or engineer around during the restoration process.

**The Locations of Existing Stormwater and Treated Wastewater Outfalls.** This information has been requested from Stuart Siegel and Moffatt and Nichol. We do not anticipate obtaining all outfall information, but significantly large outfalls should be identifiable and data should be available. These outfalls may affect the dredgeable area along the bay coast, the water quality along certain portions of the bay, and other factors that may play a significant role in the overall restoration design.

**Additional Infrastructure Elements within the Limits of the Salt Ponds.** Of significant concern in this assessment is the location of any underground utilities within the salt ponds. In addition to all sewer and stormwater outfalls being identified, it is just as important to be able to find the infrastructure that conveys those flows to avoid inadvertent disturbance of the pipelines during future dredging. It is unclear whether this information is available and to what extent it is available.

### 17.2 Data-gaps

None.

# 18. TOPIC 12. SEDIMENT

## 18.1 Topic 12a. Imported Sediment Supply and Quantity

### 18.1.1 Data Summary

In 2001, BCDC amended the Bay Plan to adopt the Long-Term Management Strategy (U. S. Army Corps of Engineers and others 2001). At that time, BCDC and the other agencies hoped to be able to utilize 40% of the anticipated annual amount of dredged material for beneficial uses, while disposing of the rest in offshore sites (40%) and within San Francisco Bay sites (20%). Therefore, it is possible that up to 3 million cubic yards of dredged material may still be available annually for beneficial uses.

Both the Bay Planning Coalition (BPC) and the U.S. Army Corps of Engineers (US ACOE) maintain very detailed lists of pending and past dredging projects, respectively. These lists capture nearly all dredge activity occurring within the San Francisco Bay and are generated as part of the dredging permitting process. However, these lists do not capture dredging projects more than a year or two into the future. To supplement these data, a series of personal interviews of the dredging community was undertaken to further identify potential sources of dredge materials as well as to determine the corresponding volume, frequency, quality, physical characterization, and typical disposal destination (Blake 2004; Bonebakker 2004; Braganolo 2004; California State Coastal Conservancy and U. S. Army Corps of Engineers 2002; Cermignani 2004; Chan 2004; Chase 2004; Farr 2004; Ferrari 2004; Fetzer 2004; Goulart 2004; Isley 2004; Kistie 2004; Martinez 2004; Maudlin 2004; Moorhead 2004; Nybakken 2004; Pederson 2004; Rhoads 2002 amended 2003; Schurman 2004; Snodgras 2004; Timothy 2004; Walters 2004; Weaver 2004; Woods 2004).

Only sources south of the San Rafael-Richmond Bay Bridge were considered in the study. Transporting materials from sources beyond this limit was generally considered not to be cost-effective for South Bay sites. In addition, many of the North Bay sites are already being incorporated into the planning of the Hamilton restoration project (California State Coastal Conservancy and U. S. Army Corps of Engineers 2002). As would be expected, maintenance dredging activities are the most predictable sources of future dredging. Maintenance dredge materials are also the best understood in terms of cleanliness and physical properties of the material, with little changes over time. The best data for these projects are usually provided by the owners/operators of the sites. One time (or “new works”) projects, on the other hand, by their nature tend to be especially difficult to predict more than a few years into the future. Similarly, the information regarding the dredge material for these types of projects is generally non-specific.

The Santa Clara Valley Water District and other agencies in the East Bay and Peninsula remove significant amounts of sediment from rivers and creeks tributary to the Bay each year (Santa Clara Valley Water District 2002). The amount of sediment potentially available from riverine sources has been estimated at 80,000 cubic yards for regular annual maintenance. The quality of riverine-source sediments from some areas could be a limitation, given the high levels of mercury present.

Based on the data developed to date, a little over one million cubic yards of dredge materials are excavated annually on average as part of regular dredge maintenance activities for the sources considered. This quantity excludes one-time, project specific dredging, which may significantly increase the amount of materials available during any one year. In general, dredged materials are mostly characterized as silty sands and silts. The Alcatraz (SF-11) disposal site is by far the most common disposal site for the dredging activities reviewed. A few sources (about 13% of the annual total) use special disposal sites such as wetland placement, surcharging, or drying ponds. Based on the requirements for these disposal sites, it can be generally inferred that the dredge materials are relatively clean and most likely suitable for wetland disposal (U. S. Army Corps of Engineers and others 2001).

The spatial distribution of dredge material sources with regard to the project area will be determined at a later time. This task will require mapping of the potential dredge sources consistent with GIS systems being developed for the SBSP Restoration Project. This mapping is beyond the current scope of work for data collection.

#### 18.1.2 Data-gaps

**Data-gaps Essential to Fill for Restoration Planning**

None.

**Data-gaps to Fill During Adaptive Management and Monitoring**

*How accurate is dredge material data (such as quantities, material characteristics, and cleanliness) given the delay between dredge material data collection and actual dredging?* As potential dredge material sources are targeted, the suitability criteria for the sediment's use can be measured against available data, and additional chemistry and geophysical analyses can be performed as necessary. Biological components, including presence of invasive species propagules, can also be assessed.

### 18.2 Topic 12b. In-place Sediment Quality

#### 18.2.1 Data Summary

Sediment quality (contaminant concentrations and presence/absence of invasive plant species) in the San Francisco Bay has been monitored through both one-time and ongoing sampling programs by federal, state and local public and private institutions/agencies. Key regulatory agencies participating in monitoring programs adjacent to the project area include the USGS, the CDFG, the RWQCB, the ACPWA, the SCVWD and the City of San Jose. The principal private agency working closely in conjunction with these public agencies is SFEI. Sediment quality data available from the above agencies are summarized above in Topic 8A.

Information remaining to be collected about this topic includes further research of the data that currently exists in GIS layers. The voluminous data produced through the above listed studies, and other related studies, was not organized into a database that could be incorporated as GIS layers. However, it is expected that most, if not all of the data generated by these studies have been compiled into GIS layers by SFEI. Once this transfer of data from SFEI is accomplished, we will be able to identify if any additional GIS layers will be required.

#### 18.2.2 Data-gaps

Same as Data-gaps identified above for Topic 8A.

### 18.3 Topic 12c. Imported Sediment Characteristics that Foster Establishment of Target Biota

#### 18.3.1 Data Summary

**Imported Sediment Characteristics (Dredged Material).** The RWQCB has developed contaminant screening guidelines for selection and beneficial reuse of dredged sediments for wetland restoration, including total mercury in sediments (Regional Water Quality Control Board 2000b). Contaminant screening concentration criteria are used by the RWQCB "…when evaluating the suitability of dredge material for beneficial reuse projects…" page 2; (Regional Water Quality Control Board 2000a). These screening criteria are differentiated according to wetland surface (cover) and wetland foundation (non-cover) materials. This report provides guidance on "…appropriate sediment testing to support suitability determinations". In practice, these guidelines have been modified on a site-specific basis. In addition, the adaptive management strategy applied to the Montezuma Wetlands restoration project also provides useful guidelines for selection of dredged sediments for wetland restoration.

The US Environmental Protection Agency, RWQCB, and the Bay Conservation and Development Commission (BCDC) drafted an EIS/EIR for the "Long Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region" (Long Term Management Strategy 1996). This document developed and compared alternative management strategies for placement of dredged material. It presents an overview of dredged material characteristics in the San Francisco Bay Area, including contamination and associated risks depending upon destination habitat. Parameters for reuse are summarized by destination habitat along with an analysis of the potential environmental impacts of reuse. A companion volume of appendices (Long Term Management Strategy 1996) contains dredge material quantity estimates, cost estimates and biological concerns.

There are several tidal wetland restoration projects that have or will use dredged material in San Francisco Bay, including the Sonoma Baylands (Hostettler and others 1996), Concord Naval Weapons Station (H. T. Harvey & Associates 1997a), Montezuma Wetlands (Siegel 1993), and Bair Island (H. T. Harvey & Associates and Philip Williams and Associates 2004). These projects range from completed, to under construction, or planned for the near future.

**In-situ Sediment Characteristics (Soil Amendments)**. We found no source of information or data that address invasive species issues in tidal habitats in relation to characteristics of imported sediments. However, there are a number of studies that have characterized the soil fertility characteristics within natural tidal salt marshes and tidal salt marshes restored with dredged material in California (Boyer and others 2000; Gibson and others 1994; H. T. Harvey & Associates 2002b; Langis and others 1991). The younger marshes of the South Bay, those that have formed since the creation of the salt ponds in the last 40 years, generally have low organic content (H. T. Harvey & Associates 2002b). However older marshes contain significantly more organic content, and as noted by (Cooper 1926) they can exhibit a stratum of "pure peat" on top of the bay mud. It is documented that tidal marsh restoration with dredged material low in organic matter content, results in lower vascular plant productivity and lower plant height and habitat quality compared to natural marshes (Boyer and others 2000; Gibson and others 1994; Langis and others 1991). In addition, there are a number of papers on the response of wetland vegetation to amending soils with organic matter. The consensus among these papers is that there is little long-term increase in plant productivity from organic and inorganic amendments to coarse-textured dredged material placed in restored tidal wetlands (Boyer and others 2000). There are some interesting hypotheses and experimental techniques being explored currently (Gibson and others 1994; H. T. Harvey & Associates 2003c; Langis and others 1991). Therefore, data on texture and fertility of existing target tidal marshes should be collected and used to craft specifications for the selection of appropriate dredged material to foster establishment of productive target plant communities. Other amendments to tidal marshes can include iron to sequester sulfides that are toxic to vegetation (Mitsch and Gosselink 2000).

As stated above in topics 1 and 3, restoration of high tide refugial habitat (broad higher elevation tidal marsh/upland transition zones) will be important to meet the project's goals to restore habitat for special-status tidal salt marsh plant and animal species. Imported soil used to build levees for flood control could be used to restore this broad transition zone. Some data are available to guide the design of soil selection, soil amendment, soil preparation, and revegetation techniques to reduce weed colonization and foster native plant establishment in high marsh/upland transition zones built with imported soil. The ecology of invasive plants is well studied and there have been many advances in the understanding of this problem. For example, the role played by disturbance in the breakdown of soil ecology and subsequent invasion of native plant communities is being studied (Riefner and others 2000). Also, attempts to restore soil ecology using land imprinting technology with mycorrhizal inoculation have had significant positive impacts establishment of coastal sage scrub and grassland communities (Allen and others 2000; H. T. Harvey & Associates 2002b; Riefner and others 2000).

### 18.3.2 Data-gaps

#### Data-gaps Essential to Fill for Restoration Planning

*What is the range of textures, organic matter content, pH, and macro and micronutrient content in existing high quality tidal marsh reference sites of the South Bay?* This information would be important to prepare specifications for the selection of dredged material to foster establishment of productive target vegetation.

#### Data-gaps Essential to Fill During Adaptive Management and Monitoring

*What is the response of tidal wetland plant communities to variable organic content in sediments?* Although there is little a project of this size can do to amend naturally deposited sediments, predictions of wetland plant community development and the resultant habitat created for wildlife will be limited without this information.

## 19. TOPIC 13. VECTOR CONTROL-FOCUSED ON MOSQUITOES

### 19.1 Data Summary

An extensive body of literature exists on the mosquitoes associated with the tidal and seasonal wetlands of the South San Francisco Bay region and can be found in the summaries of (Bohart and Washino 1978; Durso 1996; Maffei 2000a; 2000b; 2000c; 2000d; 2000e). Five species, *Aedes dorsalis* (Summer Salt Marsh Mosquito), *Aedes squamiger* (Winter Salt Marsh Mosquito), *Aedes washinoi* (Washino's Mosquito), *Culex tarsalis* (Western Encephalitis Mosquito) and *Culiseta inornata* (Winter Marsh Mosquito) are routinely controlled by the mosquito and vector control agencies that exist within each of the counties of South San Francisco Bay. The following agencies have been responsible for managing the populations of mosquitoes for their respective communities since their formation: Alameda County Mosquito Abatement District, Santa Clara Vector Control District, and San Mateo Mosquito Abatement District. Not all of these mosquitoes breed specifically in tidal marsh habitat; however the following four species are significant for tidal salt marsh habitat restoration planning: Summer Salt Marsh Mosquito, Winter Salt Marsh Mosquito, Winter Marsh Mosquito, and Washino's Mosquito. The Winter Salt Marsh and Summer Salt Marsh Mosquitoes can breed in tidal wetlands as well as adjacent uplands and can tolerate salinities of 35 ppt and 120 ppt, respectively. The Winter Marsh Mosquito breeds in adjacent upland areas with water salinities that can reach 26 ppt. Washino's Mosquito tends to prefer sausal habitats, which were historically present in the South Bay.

The biology and ecology of these mosquitoes, including preferred habitats, salinity tolerances, reproductive rates, flight characteristics, adult hosts and vector/nuisance potential were summarized in detail for the Goals Project's Species and Community Profiles (Maffei 2000a; 2000b; 2000c; 2000d; 2000e). Therefore, no further discussion concerning the biology of these organisms will occur here. It is important to note that the specific breeding sites for these mosquitoes do vary from year to year due to both natural (weather, changes in vegetative cover, salinity, tidal flushing, etc.) and manmade environmental changes. Detailed records are maintained by the local mosquito and vector control districts about mosquito breeding areas, population densities and techniques and materials used to control them.

The salt ponds do not produce mosquitoes, although no refereed publications discussing mosquito production and salt ponds were identified. The pickleweed tidal marsh fringes associated with some of the salt ponds and those abandoned salt ponds that have vegetated areas, which can collect winter rainwater, do breed mosquitoes. The vector control districts do have records in their files indicating past and present mosquito breeding for these sites.

Although mosquito production may have been a concern for some tidal wetland restoration projects, specific peer reviewed, published, research on this topic appears to be lacking. A limited number of research projects have examined the effects of salt pond and tidal marsh restoration on mosquito abundance (Christie 1996; Scheirer 1994). Projects that integrate marsh restoration design, adaptive management and mosquito control have been implemented on the east coast of the United States. These projects have occurred in Rhode Island, Connecticut, Delaware, New Hampshire and Florida (Burdick and Diers. 2003; Christie 1996; DEP's Tidal Wetland Restoration Program 1997; Florida Coordinating Council on Mosquito Control 1998; Meredith and others 1985; Scheirer 1994).

### 19.2 Data-gaps

#### 19.2.1 Data-gaps Essential to Fill for Restoration Planning

*Can the Winter Salt Marsh Mosquito and Washino's Mosquito harbor and effectively transmit West Nile Virus in the South Bay?* There are not sufficient data to answer this question for these species, and no research proposals to study this topic were identified. Recent research indicates that the Winter Marsh Mosquito and Summer Salt Marsh Mosquito can harbor and transmit West Nile Virus (Goddard and others 2002). We recommend that the local mosquito abatement districts and the SBSP Restoration Project perform a coordinated study, including cost sharing, to answer this question for the Winter Salt Marsh Mosquito and Washino's Mosquito. The local abatement districts would likely be very interested in such a project and they have the necessary equipment and scientific staff.

#### 19.2.2 Data-gaps to Fill During Adaptive Management and Monitoring

*What provisions will be made (access, equipment, control agents, etc.) for the control of mosquitoes while still maintaining the integrity of the developing wetland (flora, fauna, geomorphology)?* Mosquitoes can utilize any available water source that remains for more than a week. When wetlands are restored or created there is a potential for mosquito problems. The sensitivity of this habitat to disturbance is usually more significant than a mature or well-established wetland. The SBSP Restoration Project should establish communications with the vector control districts during the design process to handle this issue.

*How significant will local and transient bird populations be in the transmission cycle?* It is known that West Nile Virus can affect certain waterfowl {Bernard, 2001 #1669;Centers for Disease Control and Prevention, 2004b #1672}, which may serve as reservoirs of the virus.

*What are the long term impacts in the South Bay associated with continual control of mosquitoes using current methodologies and materials (methoprene, surfactants, adulticides, ditching and use of all terrain vehicles)?* Federal, State and local agencies monitor mosquito control activities on sensitive wetlands. There is an extensive body of literature on the non-target effects of chemical and biological control agents used for mosquito control (Legner 1995; Maffei 1997; Scientific Peer Review Panel of the Metropolitan Mosquito Control District 1996; Washino and Dritz 1995). The long-term food web effects have not been well studied (Niemi and others 1999).

*Who will be responsible for obtaining any and all necessary Federal and State permits to allow mosquito management practices in the project area? What agencies will cover the cost for obtaining them? How will funds be allocated? Other than the Mosquito Abatement Districts and landowners, who will be involved with the engineering and design of mosquito control ditches and water control structures? Where will the funds come from for long-term mosquito management?* Long-term mosquito management practices utilize ditching, vegetation control, and water control structures. These types of activities usually require various Federal and State permits that sometimes take a number of years to acquire.

# 20. TOPIC 14. FLOOD PROTECTION

## 20.1 Topic 14a.1 Flood Control Issues

### 20.1.1 Data Summary

The South Bay salt pond complexes are located in three geographically distinct areas: the Baumberg complex in Alameda County comprises 23 salt ponds covering 4,800 acres; the Alviso complex in Santa Clara County includes 24 salt ponds covering 7,500 acres, and the West Bay complex in southern San Mateo County includes 7 salt ponds covering 1,500 acres (Moffatt & Nichol Engineers 2003a; Siegel and Bachand 2002). A combination of salt ponds, existing levees and adjacent marshlands comprise the SBSP Restoration Project area.

USACE (1992) details flood management needs, opportunities and constraints in the SBSP Restoration Project area under the 1992 (pre-restoration) condition while Siegel and Bachand (2002) and Moffatt & Nichol (2003) identify potential opportunities and constraints associated with post-restoration flood management.

Extensive areas along the San Francisco Bay shoreline are lower in elevation than the extreme high tides in the Bay (U.S. Army Corps of Engineers 1988; U.S. Army Corps of Engineers 1992). The San Francisco Bay Shoreline Study (U.S. Army Corps of Engineers 1988; U.S. Army Corps of Engineers 1992) details potential tidal flooding issues in the South Bay area, identifying areas where significant tidal flooding may occur. The study is currently being re-evaluated by a US ACOE Reconnaissance Investigation to determine updated flood hazards and damages.

Levee failure is not the most likely mode of tidal flooding in the South Bay area; rather, most historical flooding has been due to high fluvial runoff that typically occurs with moderate high tide. In some cases, high tides have induced fluvial flooding. The influx of bay water into the channel reduces the available channel capacity. Many of the flood control channels also have reduced capacity due to sedimentation.

The levees and the flood storage of the salt ponds themselves act as limited flood control structures. The levees are not engineered and do not meet flood defense criteria, but have been effective through frequent maintenance by Cargill. Many of the berms and levees associated with the salt ponds will require improvement, or replacement, if they are to provide the level of flood protection required for FEMA flood standards. When levees are breached or overtopped and ponds restored to tidal action, shoreward levees will be required to protect upland areas from tidal flooding. Siegel (2002) developed GIS plots of the existing salt ponds, including area, bottom elevations, tidal prism estimates, and existing levees and perimeter levee heights. The updated GIS data is available from the San Francisco Estuary Institute (SFEI). Life Science (2003) and Moffatt & Nichol (2003) presented the information relevant to the salt pond control structures.

The major water conveyance facilities within the SBSP Restoration Project project area include rivers, flood control channels, tidal sloughs, and creeks. Moffatt & Nichol (2003) provided detailed descriptions of three streams in the Baumberg complex (Coyote Hills Slough, Alameda Creek, and Mt. Eden Creek); ten streams in the Alviso complex (Mud Slough, Coyote Creek, Artesian Slough, Alviso Slough, Guadalupe Slough, Stevens Creek, Mountain View Slough, Palo Alto Flood Basin, Charleston Slough, and San Francisquito Creek), and three streams in the West Bay complex (San Francisquito Creek, Ravenswood Slough, and West Point Slough). Moffatt & Nichol (2003) provide a general description of these channels and tributaries, including the contributing watershed area, channel width, mean tidal level, sediment transport patterns, and flood control facilities. The channels discussed in the report do not represent an exhaustive compilation of all channels in the vicinity of the SBSP Restoration Project, but rather provide descriptions of the larger, primary drainages.

**Baumberg Complex.** The Alameda Creek Flood Control Channel (ACFCC) (a.k.a. Coyote Hills Slough) is the primary flood control channel for the Alameda Creek Watershed. Although the designed capacity is 52,000 cfs (500-yr recurrence interval), the maximum current capacity is 29,000 cfs (100-yr recurrence interval) due to significant levels of sedimentation. 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 with a cost of over $3 million. URS (2002a; 2002b) studied the ACFCC to determine the extent of flood inundation below Decoto Road. Alameda County is currently investigating the potential for levee reconfiguration to route flood flows through the adjacent salt ponds. This would be completed in conjunction with restoring the Baumberg complex to tidal action, and could provide a source of sediment due to channel scour. SBSP Restoration Project efforts in the Baumberg complex will be closely linked with potential levee reconfiguration efforts for the ACFCC

Old Alameda Creek and Mt. Eden Creek also provide limited flood protection for Alameda County. Alameda Creek is experiencing similar sedimentation problems as the ACFCC. Mt. Eden Creek is part of an ongoing restoration project sponsored by the California Department of Fish and Game that will restore and enhance tidal marsh habitat. SBSP Restoration Project coordination with the Mount Eden Creek and Old Alameda Creek restoration efforts will be required to ensure that the projects are mutually beneficial.

**Alviso Complex.** The Santa Clara Valley Water District (SCVWD) acts as the flood protection agency in Santa Clara County, which includes most of the Alviso complex. Tidal exchange with the bay is minimized by the use of flap gates, although some tidal exchange is allowed by permanently opening a portion of one flap gate. Levees enclose the flood basin to protect the surrounding areas from flooding, however, several floods have occurred in the 80s and 90s. 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.

Guadalupe Slough drains approximately 81 square miles within San Jose and Sunnyvale. SCVWD staff indicates that the tidal influence extends upstream near Highway 237. Flooding has occurred in the areas of Calabazas Creek and Sunnyvale West Channel.

Guadalupe River, which becomes Alviso Slough near the City of Alviso, has experienced ongoing flooding problems (Santa Clara Basin Watershed Management Initiative 2003). The channel was first modified in 1866 to address the flooding issues with the development of a canal. In 1975, approximately 3,000 ft of the channel were moved to accommodate the Almaden Expressway. Concurrent with the channel relocation, the channel was widened. Recent flooding events have occurred in 1955, 1958, 1980, 1982 and 1983. In 1995, the Guadalupe flooded San Jose communities with estimated flows of 11,000 cfs (30-yr recurrence interval). The Lower Guadalupe Flood Control Project plans to increase the channel capacity to convey the 100-yr design flow (Stokes 2001b). CH2MHill (2001) investigated water resource-related problems in the Lower Guadalupe River, including existing and potential flooding, erosion, and sedimentation problems.

Coyote Creek, one of the largest creeks in the South Bay, is under the jurisdiction of both Alameda County and SCVWD. The creek drains a watershed of approximately 320 $mi^2$. Flooding has occurred seven times over the past 50 years, with severe flooding in 1982 resulting in damages in excess of $6 million. Recent improvements to the lower reaches, including bypass channels and levee setbacks, have proven effective at protecting the area from record flows. The creek receives a freshwater influx prior to entering the Bay as a result of discharge 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.

**West Bay Complex.** The San Mateo County Flood Control District provides flood control in the vicinity of the West Bay complex. Ravenswood Slough is subject to tidal flooding in the vicinity of the Bayfront Canal. San Francisquito Creek has also experienced periodic flooding. The largest flood of record, and the worst flooding damage, occurred in 1998 (Santa Clara Basin Watershed Management Initiative 2003). Flood protection was installed in 1958 in response to the 1955 flood event, however flooding has continued and the current capacity of the creek is below designed capacity. The 100-year flow event on the San Francisquito Creek is estimated to be 6,100 cfs. The San Francisquito Creek Joint Powers Authority have been working with the US ACOE to investigate the potential for a flood control project in the lower reach, as well as the impact of the removal of the Searsville Dam.

### 20.1.2 Data-gaps

**Data-gaps Essential to Fill for Restoration Planning.** *What is the upstream boundary of tidal influence in the tributaries and sloughs under existing conditions?* The outfalls of numerous stormwater and wastewater systems discharge into the major tributaries that drain to the Bay. The inverts (minimum elevation of a pipe interior) of the stormwater and wastewater outfalls are designed under the existing hydraulic conditions of the streams. SBSP Restoration Project may likely extend the tidal boundary further upstream, which may affect designed operation of the gravity drainage facilities. Existing upstream tidal boundaries and water levels are the basis for evaluation of the altered hydraulic conditions induced by restoration alternatives and therefore an accurate representation of existing tidal influence is essential. Data required include stormwater and wastewater discharge locations, pipe sizes, invert elevations, and flap gate operations.

**Data-gaps to Fill During Adaptive Management and Monitoring.** *What is the implication of restoration-induced short- and long-term sediment processes on flood management?* Consideration of short- and long-term effects of erosion/deposition processes on flood management is important for both restoration planning and adaptive management.

## 20.2 Topic 14a.2 Hydrology and Floodplains

### 20.2.1 Data Summary

Historical hydrologic information pertaining to tributary and wastewater inflows, as well as tidal benchmarks is necessary to delineate floodplains and determine the potential impacts of the SBSP Restoration Project on flooding and existing flood control structures.

**Tributary Flows.** The tributary creeks and sloughs discharge freshwater into South Bay primarily in the form of winter and spring runoff. Moffatt & Nichol (2003) documented the 100-yr flow rates of the large streams that cross the Baylands and drain into the Bay. Tudor and others (1973) also documented the 100-yr design flows of nine streams used in their study; however, these flow rates might underestimate the actual 100-yr flow rates because of the substantial development that has occurred in Santa Clara County since the 1970s. The Federal Emergency Management Agency's (FEMA) Flood Insurance Study (FIS) reports include riverine flow data and water surface profiles (10-, 50-, 100-, and 500-yr) for the studied streams around the South Bay; however, the data in the FIS reports should be updated with recent data if available from flood protection agencies. FEMA's existing condition flood profiles can be used to evaluate the impact of SBSP Restoration Project alternatives, by comparing the existing profiles with simulations of potential post-restoration scenarios.

Limited data are available on historical water levels near the mouths of the tributaries to the South Bay. The Santa Clara Valley Water District (SCVWD), the City of Palo Alto, and the USGS collect river stage and flow for the tributaries upstream of the salt pond levees. The USGS maintains stations on Guadalupe

River, Alameda Creek, Alameda Flood Control Channel, Matadero Creek, and San Francisquito Creek, and most stations contain historical records dating back to the 1950s. The City of Palo Alto maintains flow gauges in San Francisquito Creek, Matadero Creek, and Adobe Creek, although historical archiving did not begin until August 2003. Wastewater flows from the treatment plants are monitored and available. Moffatt & Nichol (2003) has compiled a comprehensive inventory of tributary and wastewater inflows for the South Bay. Much of the data will require manipulation to tie benchmarks to a uniform datum.

Moffat and Nichol undertook recent data collection efforts, deploying stand alone pressure transducers at the mid-point of the Guadalupe Slough Channel, the mouth of Stevens Creek, the mid-point of Stevens Creek, and the mouth of Ravenswood Slough; and Conductivity, Temperature and Depth (CTD) in Coyote Creek at the Railroad Bridge, the mouth of Alviso Slough, the mid-point of Alviso Slough, the Dumbarton Bridge, and the Coyote Hills Slough. Stanford University also collected CTD data in Coyote Creek, Artesian Slough, and Old Coyote Creek in early 2000.

**Stormwater and Wastewater Discharges.** There are numerous stormwater and wastewater discharge facilities within the South Bay. Moffatt & Nichol (2003) focused on discharges to the lower reaches of the pond complexes within the US ACOE -defined 100-year tidal boundary. Most of the stormwater runoff from the Bay uplands is pumped into the creeks via lift stations because land subsidence in the lower South Bay makes gravity discharge impossible (Moffatt & Nichol Engineers and Conservancy 2003). The inverts of the stormwater and wastewater outfalls are designed under the existing hydraulic conditions of the streams. The SBSP Restoration Project may likely extend the tidal boundary further upstream, which may affect designed operation of the gravity drainage facilities. However, small variations in tidal stage should not affect the operation of the lift stations. There are other discharge facilities that exist within the SBSP Restoration Project area, such as runoff from the state right-of-way by Caltrans, which discharge into adjacent ponds (for example Hwy 92 discharges into Pond 10 and 11). Some of the outfalls of these discharges may be affected by the tidal restoration of the salt ponds. Detailed data, such as location, capacity, and invert of the outfalls will be necessary to evaluate the effects of restoration on their operations.

**Tidal Datums and Benchmarks.** Moffatt & Nichol (2003) tabulated tidal benchmark data at 18 locations around the South Bay, including: period of measurement, duration of measurements, USACE estimated 100-yr tide level, highest observed water level (HOWL), mean higher high water (MHHW), mean high water (MHW), mean tide level (MTL), mean low water (MLW), mean lower low water MLLW, and lowest observed water level (LOWL). USACE (1984) published tidal data from 50 stations San Francisco Bay, including MHHW, and highest estimated tide (HET). The study also presented 10-, 100-, and 500-yr tide elevations at each station. The computations were based on a frequency analysis of the recorded highest annual tide over a span of 129 years (1855 – 1983) at the Presidio. The effects of astronomical forces, barometric pressure fluctuations, and wind set-up were included in the computation. Due to the limited data, the frequency of the HET and MHHW at the Presidio were scaled appropriately around the Bay.

**Floodplain Delineation.** The SBSP Restoration Project area is subject to riverine and/or coastal flooding. Riverine or fresh water flooding is the consequence of overtopping or breaching of a levee by fresh water or storm ponding due to inadequate drainage facilities subjected to severe storm conditions (Tudor Engineering Company 1973; U.S. Army Corps of Engineers 1988). Historical flood events in the major streams within the project area are documented within USACE (1983) and (1988), and also within Moffatt & Nichols (2003a). Coastal flooding occurs due to high tides that exceed ground elevations or overtop levees (Tudor and others 1973). Streams with tidal influence are associated with both riverine and coastal flooding.

FEMA had several different floodplain designations for the upland areas surrounding the South Bay. The Flood Insurance Rate Map (FIRM) delineates the potential flooded area subjected to 100- and 500-yr floods. FIS delineates floodplains using MHHW as the downstream tidal boundary, coupled with 10-, 50-. 100-, and 500-yr flood events for the upstream flow conditions (Federal Emergency Management Agency 1998). FEMA's National Flood Insurance Program (NFIP) uses the tidal floodplain associated with a 100-yr tide as the base floodplain in areas which are not protected by levee systems meeting FEMA's levee standard (U.S. Army Corps of Engineers 1988).

The USACE (1988) delineated a potential 100-yr tidal floodplain for San Francisco Bay. The analysis included a tidal stage versus frequency study at several locations in the Bay, as well as the determination of the maximum extent of tidal flooding which could occur using the contour of the computed tidal elevations (e.g., 100-yr) 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.

The Bayland Salt Water Flood Control Planning Study considered the 100-yr flood as the designed flood event (Tudor and others 1973). This study used a rainstorm event with a 25-yr recurrence interval for the purpose of designing drainage facilities to handle internal storm water. Moffatt & Nichol (2004b) included FEMA's Special Flood Hazard Area (100-yr floodplain) in the SBSP Restoration Project area, assuming all levees not certified by FEMA would fail, and all areas behind the levees would be flooded.

It appears that the *San Francisco Bay Shoreline Study* (U.S. Army Corps of Engineers 1988) is the basis of the current delineations of 100-yr tidal floodplain in the South Bay. The delineation of the floodplain did not consider the protection by the existing levees since they do not meet FEMA or US ACOE flood protection standards. However, the absence of history of significant tidal flooding in the South Bay indicates that these levees do provide a substantial amount of protection (U.S. Army Corps of Engineers 1988) Therefore, a more accurate analysis is required to determine the actual extent of flooding which is most likely to occur. The *Shoreline Study* presented a detailed method of tidal flooding analysis, which used a refined method of estimating levee degradation due to overtopping, the coincident frequency analysis of tide and wind combinations, and the multiple tide peak series.

**Infrastructure.** The existing infrastructures in the SBSP Restoration Project area include Pacific Gas and Electric (PG&E) above- and below-ground electrical transmission and distribution lines, PG&E natural gas pipelines, sewer force mains and outfall pipes, roads and railroads, the Hetch Hetchy Aqueduct, storm drain systems, petroleum pipelines, and fiber optic cables (Siegel and Bachand 2002). Siegel (2002) documented and mapped the known locations of existing infrastructure, and discussed possible sources of information with respect to some missing elements.

**Economic Impacts.** Benefits of flood risk reduction can be estimated by an economic analysis. The US ACOE has addressed the economic impacts associated with tidal flooding, and previous estimates of flood damage were assessed at $34.5 million (in 1981 dollars) (U.S. Army Corps of Engineers 1988) However, there has been considerable development in the area since then, therefore continued flooding could have greater financial impacts. The US ACOE uses risk-based analysis procedures for formulating and evaluating flood damage reduction measures (U.S. Army Corps of Engineers 1996). The procedures include quantifying uncertainty in discharge-frequency, stage-discharge, stage-damage functions and incorporating the uncertainty into economic and performance analyses of alternatives (Benjamine and Cornell 1970). This process applies Monte Carlo simulation, a numerical-analysis procedure that computes the expected value of damage while explicitly accounting for the uncertainty in the basic function (Benjamine and Cornell 1970). The uses and implications of the Corp's risk-based analyses are discussed by several authors (Davis 1997; Eiker 1997; Moser 1997; National Research Council 2000; Schaaf 1997; Wild 1997). An overview of the flood damage analysis program (HEC-FDA) is presented in

Burnham (1997). An overview of the flood damage analysis program (HEC-FDA) is presented in Burnham (Burnham 1997).

FEMA considers base flood flow (1% median probability event) and computed flood elevation for that flow to delineate floodplains for flood insurance purpose. Floodplains delineated by the US ACOE for the flood benefit calculations are based on expected flood stage, either from flow developed using 'expected probability' and computed flood elevation for the flow, or expected flood stage directly as results from the RBA (Davis 1997).

### 20.2.2 Data-gaps

**Data-gaps Essential to Fill for Restoration Planning**

*Which project areas (and vicinity) with identified flood risk are flood sensitive and must not experience any increase in water level or flood frequency?* The primary flood management objective of the SBSP Restoration Project is to maintain existing levels of flood protection in the South Bay. However, it is necessary to identify the flood sensitive areas, e.g., developed /developing areas, where the existing levels of flood protection must be maintained.

*What should be the basis for the delineation of flood hazard areas?* Moffatt & Nichol (2004b) and SCVWD produced maps showing FEMA designated flood Hazard areas around the South Bay. The US ACOE (1988) also mapped areas subject to potential 100-yr tidal flooding. They all assume that the inundation results from breaching of levees or overtopping due to wind-driven waves. It is necessary to identify an appropriate method for the delineation of potential flood hazard areas for both existing condition and post-restoration alternatives.

**Data-gaps to Fill During Adaptive Management and Monitoring**

None.

## 20.3 Topic 14b. Construction Methods of Levees; Levee Materials, and Subsurface Conditions beneath Levees

### 20.3.1 Data Summary

As of April 9, 2004, four major reports have been collected and reviewed to assess: 1) the levee construction method, 2) levee materials, and 3) subsurface conditions beneath the levees. The reports were prepared by Tudor Engineering Company (1973), the U.S. Army Corps of Engineers, San Francisco District (U. S. Army Corps of Engineers 1988), and (Moffatt & Nichol Engineers 2004a).

The reports indicate that the existing levees have not been designed to provide specific levels of flood protection. The levees are frequently referred to as being either outboard levees or inboard (shoreline) levees. The outboard levees (i.e., bayfront and slough/creek levees adjacent to tidal waters) are salt pond levees which were built to enclose evaporation ponds on former tidal marshes and mudflats. These levees are typically constructed with Bay Mud dredged from adjacent borrow ditches or pond areas. The outbound levee fill likely received little or no compaction. Bay Mud fill has been added to these levees in the past to compensate for land subsidence and to compensate for erosion and settlement resulting from consolidation and/or displacement of the compressible levee fill material and weak underlying Bay Mud deposits. Some of these levees are protected by riprap. These levees were not constructed or maintained following a well-defined standard.

The inboard (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. Some have been modified/raised to improve flood protection but, as with the outboard levees, the inboard 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 also has 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).

Significant subsurface data is available for the study area. For the ponds located in Santa Clara County alone, (Tudor Engineering Company 1973) compiled 148 water wells and 478 boring logs. This data is presented in a separate report volume that has yet to be obtained from the Santa Clara Valley Water District. A significant amount of data also was compiled by Moffatt & Nichol Engineers (2004a; Moffatt & Nichol Engineers 2004b). As with the Tudor data set, the Moffatt & Nichol data is presented in a separate volume that has not been obtained by the project team.

Maps, publications, and reports pertinent to the project area also are available from various sources (Bonaparte and Mitchell 1979; Bortugno and others 1991; California Division of Mines and Geology 2001; California Division of Mines and Geology 2002a; California Division of Mines and Geology 2002b; California Division of Mines and Geology 2002c; California Division of Mines and Geology 2002d; California Division of Mines and Geology 2002e; California Division of Mines and Geology 2002f; Dibblee 1972a; Dibblee 1972b; Ellen and Wieczorek 1988; Federal Emergency Management Agency 1988; Geomatrix Consultants 1992a; Geomatrix Consultants 1992b; Helley and Graymer 1979a; Helley and Graymer 1979b; Helley and others 1979; Jennings 1994; Knudsen and others 1997; Knudsen and others 2000; Moffatt & Nichol Engineers 2004b; Nichols and Wright 1971; Pyke 1989; Santa Clara County 1977; Santa Clara County Planning Office 2002; Tudor Engineering Company 1973; U. S. Army Corps of Engineers 1997; U.S. Army Corps of Engineers 1988; U.S. Army Corps of Engineers 1989; Wagner and others 1990; Wentworth 1997; Youd and House 1978). A partial reference list is provided at the end of this data summary. These maps and reports are being compiled for use by the project team. More references likely will be compiled as specific project needs are identified.

Proposed and completed levee maintenance is documented in Cargill's annual "maintenance work plan" and "completed maintenance" reports, respectively. Cargill reports, which date back to 1995, were obtained from BCDC. The reports include information about regular levee maintenance as well as special projects, on an annual basis. There is currently no comprehensive summary of Cargill's maintenance activity over the last several years or any clear indication of which levees, if any, have had recurring problems. A comprehensive evaluation of the reports to summarize historic levee performance and maintenance/repair activities would help to identify problematic levees and the potential for future problems with the levees. In addition to reviewing work plans, a meeting with Cargill maintenance staff would be beneficial to gather information regarding first-hand experience with the levees and levee condition over time.

### 20.3.2 Data-gaps

#### Data-gaps Essential to Fill for Restoration Planning

*What are the subsurface soil conditions underneath the levees?* Subsurface soil conditions in the project area must be reasonably assessed to evaluate:

- levee stability and performance under loading conditions stipulated in FEMA/US ACOE guidelines
- long-term settlement
- control of seepage / under seepage
- potential restrictions on levee construction related to foundation stability and compressibility
- It is likely that significant additional data (consisting of borehole logs, cone penetration test probes, well logs, and laboratory test results) exist from the following sources:

  - Santa Clara Valley Water District
  - Alameda County Water District
  - U.S. Geologic Survey
  - California Geologic Survey
  - Corps of Engineers
  - Cargill
  - East Bay Discharges
  - City of Mountain View
  - City of Sunnyvale
  - City of Milpitas
  - City of Alviso
  - City of Fremont
  - City of Hayward
  - City of Union City
  - City of San Jose
  - Caltrans
  - Town of Menlo Park
  - BFI/other waste disposal companies
  - PG&E
  - San Francisco Public Utilities Commission
  - Other consultant files

These possible sources of data will be contacted during subsequent tasks. The data will be cataloged and presentation on plans and profiles for use by the project team. Additional data may be needed as the project concepts are developed and specific needs are identified.

*What will be the future levee maintenance needs?* A comprehensive assessment of historic levee performance and maintenance/repair records would provide valuable understanding of the need for future maintenance. Future levee maintenance needs will eventually be evaluated based on their current condition and documentation of what problems have been experienced historically. The US ACOE (1988) report describes a levee and shoreline condition survey that was performed between March and May 1984 (U.S. Army Corps of Engineers 1988). The information collected for each levee segment reportedly included: the width and condition of the levee crest; the lengths, angles, and condition of the embankment slopes; the type and condition of slope protection; the embankment soil type; and other pertinent information including evidence of slumping, cracking, erosion, or seepage. At the time this data report was prepared, the detailed findings of the US ACOE survey had not been found in the US ACOE archives; this detailed information may not be available for the project team's review. A visual reconnaissance survey also was performed and reported (Moffatt & Nichol Engineers 2004a). However, the survey was only performed on some of the inboard project levees.

A detailed survey of all project levees will be required to establish current baseline conditions. Provided the findings of the US ACOE survey can be made available to the project team and a new survey is performed, modifications and changes to the levees that have occurred over the past 20 years can be documented. This information will be used to help assess future maintenance requirements. A detailed review of aerial photographs also may provide an understanding of the modifications that were made, the effect of past flooding events, and the maintenance that has been performed over the time period for which high-quality aerial photographs are available.

# 21. TOPIC 15. RECREATION AND PUBLIC ACCESS

## 21.1 Data Summary

### 21.1.1 Overview

The PWA Team is currently collecting data on recreation and public access in the three categories outlined below. Additionally, geographic-based recreation and public access data are listed here, with more detailed descriptions of the GIS shapefiles presented in Appendix A. The topic of recreation and public access for the SBSP Restoration Project area has not been previously studied, nor have data been collected or compiled. Although there have been many local and regional recreation planning efforts around the project area, the volume and depth of the resultant reports, documents and maps require that data collection be ongoing and iterative. The data summary below provides an overview of the general topics, why they are important, and the current status of the data collection effort.

### 21.1.2 Management

This sub-topic defines the plans, laws, policies and other regulatory constructs that will affect public access and recreation in the SBSP Restoration Project area. Specifically, the CDFG Code and all applicable laws of the USFWS and associated regulations will be reviewed to determine the land-owning agency requirements for recreation and public access on project lands. (The respective agencies have summarized and presented this information to the Recreation and Public Access Work Group, but further review will yield more detailed documentation.) The BCDC, through the *San Francisco Bay Plan* ("Bay Plan"; (San Francisco Bay Conservation and Development Commission 1998) and its authorizing legislation, the McAteer-Petris Act, regulates certain activities in and around the Bay. Specifically, for public access, the Bay Plan states that the "Commission should ensure that each new shoreline development increases public access to the Bay to the maximum extent feasible, in accordance with the policies for Public Access to the Bay." Further review of the Bay Plan is required to ascertain and understand the jurisdiction of the BCDC and how it relates to the project area.

The Association of Bay Area Governments (ABAG) administers the nonprofit San Francisco Bay Trail Project. In 1989, ABAG published *The Bay Trail – Planning for a Recreational Ring Around San Francisco Bay* (Association of Bay Area Governments 1989) and, pursuant to Senate Bill 100, mandated that the Bay Trail "provide connections to existing park and recreation facilities, create links to existing and proposed transportation facilities and be planned in such a way to avoid adverse effects on environmentally sensitive areas."

Other regulatory, planning and policy information related to recreation and public access exists through many of the municipalities in the project vicinity. Local jurisdictions that own or manage public recreation lands in and around the project area are being contacted to ascertain how these managed lands will interact with recreation and public access in the project area. These entities include the East Bay Regional Park District, Hayward Area Recreation and Park District, City of Mountain View, City of Palo Alto, City of Redwood City, Mid-Peninsula Regional Open Space District, City of Sunnyvale, and others.

### 21.1.3 Recreation Use (Social)

Studies on visitor use and demand are limited for the project area lands. However, there are many regional and national sources that may provide useful information to determine historical recreational use trends, define future demand and user trends, and quantify the value of recreation and carrying capacity related to visitor use and experience. Several sources for this information that have been used for recreation and public access analysis for other projects have been identified. These are being reviewed to determine the key components of these types of data that are essential for the project; however, no conclusions or summaries are currently available for these data.

#### 21.1.4 Wildlife Compatibility (Biological)

This sub-topic includes research and studies (within the region and nationwide) related to visitor use and resource protection. Existing research summaries and data are being reviewed to ascertain how this information can inform and assist in developing the recreation and public access concept plans in the form of guiding principles. Pertinent studies identified to date were summarized above in Topic 7A. In addition, our literature review has included studies that address the issue of beach use by humans and their pets, potentially disturbing nesting and wintering shorebirds (particularly Western Snowy Plovers). The most applicable information comes from southern California near Santa Barbara, and is focused primarily on the Western Snowy Plover, which is listed as threatened due to loss of suitable nesting habitat from disturbance and predation. There are also some earlier studies on shorebird-related disturbance from the east coast. This information is being extracted to provide focused statements that can assist in informing recreation and public access planning. This effort does not duplicate data collection under Topic 7A, Wildlife/Human Interaction Effects.

#### 21.1.5 GIS Data

GIS data collected and mapped to date are summarized in Appendix A.

### 21.2 Data-gaps

#### 21.2.1 Data-gaps Essential to Fill for Restoration Planning

*What is the social and physical carrying capacity of the project area lands based on different restoration alternatives to sustain recreation and public access, and where and to what intensity should it exist in the project area?* Documenting carrying capacity is challenging particularly when there has not been any previous baseline information collected. Baseline data for recreation and public access planning includes physical conditions of trails and facilities where visitors “experience” the place. It also includes social conditions such as the number of visitors, where they go and what they do. For the project area, the lack of these data may inhibit the ability to determine carrying capacity. However for planning at this scale, this data is not essential to be able to proceed, but it could be required before future recreation and public access concepts are finalized. To solve the question of carrying capacity there has been a planning framework established by the National Park Service as well as others. The challenge will be how to engage in this focused planning effort within the larger restoration planning context.

#### 21.2.2 Data-gaps to Fill During Adaptive Management and Monitoring

*To what extent does the existing condition and use of trails over project area lands inform the future needs and potential impacts of new trails?*

*To what extent does the lack of visitor use and demand data inhibit the ability to plan and provide new recreation uses and facilities for future users?* Some recreation and public access physical data for project area lands may be missing, such as trail alignments over USFWS lands and the current condition and degree of use. Planning and analyzing new recreational facilities and uses in the project area is important for determining costs and potential environmental impacts as well as the ultimate need and functionality of these facilities.

The consultant team should be able to document that there is a need, and "best location" based on more than anecdotal data and obvious constraints. As the consultant team is still researching data availability this question may be answered by other such data collected for nearby locations, namely Bair Island. The consultant team will review this work before determining an absolute need for project specific data. This will also help to further define what data are needed and how best to collect it.

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Josh Collins, San Francisco Estuary Institute
Edward Gross
Bruce Herbold, U. S. Environmental Protection Agency
Michael Josselyn, Wetlands Research Associates
Jessie Lacy, US Geological Survey
Mark Marvin-DiPasquale, U. S. Geological Survey
Frederic Nichols
John Takekawa, U. S. Geological Survey
David Schoellhamer, U. S. Geological Survey
Mark Stacey, University of California, Berkeley
Cheryl Strong, San Francisco Bay Bird Observatory
Dilip Trivedi, Moffatt and Nichol
Nils Warnock, Point Reyes Bird Observatory

**APPENDIX A.**
**GIS Data Compilation List**

**GIS Data: South Bay Salt Pond Restoration Project**

**GIS Data Obtained**

HT Harvey – Mark Lagarde, GIS Specialist

*Shapefiles / Layer Files*

*2003 Data*

- alviso dominant.lyr
- alviso_reach03.shp
- full_merge03.shp
- lower dominant.lyr
- lower_reach03.shp
- transition dominant.lyr
- transition_reach03.shp
- upper dominant.lyr
- upper_reach03.shp

*2001 Salinity*

- alviso.shp and .lyr
- lowerreach.shp
- salinity2.shp and .lyr
- transition.shp and .lyr
- upperreach.shp and .lyr

*1989 Data*

- alviso.shp and .lyr
- lower.shp and .lyr
- transition.shp and .lyr
- upper.shp and .lyr

*Imagery*

- 2003 CIR Aerials

City of San Jose Environmental Services Department – Timothy Hayes, GIS Specialist II

*Imagery*

- 2003 IKONOS
- 2002 LIDAR

*Shapefiles / Layer Files*

- South Bay Landfills_UTM.shp

*South Bay Marsh Studies 2002-2003*

- 2002 Entire South Bay Marsh Study Area.shp
- 2003 Entire South Bay Marsh Study Area.shp
- IKONOS Coverage Area.shp
- LIDAR Coverage Area.shp
- Salt_Ponds_S_Bay.shp
- South_Bay_Marsh_Studies_Grid.shp
- WPCP_Boundary.shp

*Riparian Restoration Action Plan 1999*

- Classification_Code_Description.dbf
- Riparian Vegetation Outside San Jose.shp
- RRAP Channel Classification.shp
- RRAP Land Use Classification.shp
- RRAP Vegetation Classification.shp

Cargill (via Tim Hayes)

*1998 Mr.SID Imagery* – 1ft resolution true color aerials (of all ponds)

*Geodatabase Layers*

- Buildings
- Ditch
- Flow
- Grid
- Levee
- Marsh
- PGE
- Ponds
- Pond1
- Pumps
- Riprap
- Road
- Selections
- Street
- Subsurface
- Water

Bay Area Open Space Council – John Woodbury, Director

*Shapefiles*

*Transit Outdoors 2000*

- Bafarm96.shp
- Bartline.shp
- Bartstat.shp
- Bayareacounties.shp
- Baywater.shp
- Buslines.shp
- Caltrainline.shp
- Caltrainstations.shp
- Ferrylines.shp
- Highways.shp
- Intersections.shp
- Lightraillines.shp
- Openspace.shp
- Raodac.shp
- Roadcc.shp
- Roadma.shp
- Roadnapa.shp
- Roadsc.shp
- Roadsf.shp
- Roadsm.shp
- Roadsol.shp
- Touchup.shp (and 2 and 3 … not sure what are)
- Trailsee.shp
- Transferstations.shp
- Underlayer.shp

*Regional Trails Oct 2001*

- Cities.shp
- Baycounties.shp
- Calcounties.shp
- Bafarmnew.shp (2000 and 2001)
- Openspace.shp (2000 and 2001)
- Pknames.shp
- Contours.shp
- Sfunderlayer.shp
- Surround.shp
- Yolounderlayer.shp
- Baywater.shp (2000 and 2001)
- AlamedaTrails.shp
- CcTrails.shp
- MarinTrails.shp
- NapaTrails.shp
- SCTrails.shp
- SFTrail.shp
- SMTrails.shp
- SolanoTrails.shp
- SonomaTrails.shp

GreenInfo Network – Brian Cohen, GIS Manager

*Shapefiles*

- OpenSpace_ProtectedLands.shp

ABAG – Laura Thompson, Bay Trail Planner

*Shapefiles*

- BayTrail.shp

BCDC- Caitlin Sweeney, Senior Planner

Shapefiles

- BayTrail.shp

PRBO – Diana Stralberg, Landscape Ecologist / GIS Manager

- Mudflat_abundance.shp (shorebird abundance)
- Mudflat_biomass.shp (shorebird biomass)
- Mudflat_density.shp (shorebird density)

**GIS Data Requested**

Invasive Spartina Project – requested by HT Harvey

- Spartina distribution
- Current and historical ortho rectified aerial photos used to map and treat Spartina alterniflora

SFEI – Eric Wittner, GIS Manager (data coming by end of next week)

- Bay Area County Boundaries
- Average PCB Concentrations in Sediment (ppb)
- Dredging Disposal Sites
- Work Windows for Dredging
- Modern Roads
- Rainfall in millimeters
- 24k NHD – Coyote CU and SF Bay
- Streams
- Historic Rivers and Streams, Circa 1800
- Pannes (Historic 1800 and Modern 1997)
- Seasonal Wetland Soils within 3 miles of Bay (Historic 1800 and Modern 1997)
- Watershed Habitats (Historic 1800 and Modern 1997)
- Baylands (Historic 1800 and Modern 1997) and updated version est. March, 31st, 2004
- Bay Segments
- Detailed and Simple Bay Bathymetre
- Land Use Types, Circa 1995 (I'll call ABAG to request 2000)
- Watershed Boundaries (DRAFT)
- Ocean
- Shaded Relief
- DOQ's (Alameda, Contra Costa, San Mateo, Santa Clara)
- NIMA 1' true color imagery – available est. April/June 2004
- City of San Jose's IR imagery, reprojected to UTM
- City of San Jose's plans and wetland types, reproject to UTM

Requested by Brown and Caldwell

- Outfalls from Water Treatment Plants
- Potable waterlines within/near the project area
- Sanitary Sewer waterlines within/near the project area
- Storm Sewer waterlines within/near the project area
- Water control structures (gates, levees)
- Railroad locations near the project area
- Bridges
- Flood Control Channels near/within the project area
- Lined Creeks near/within the project area
- Trails near/within the project area
- Landfills near/within the project
- Spatial distribution of pollutants in sediment and/or water column of any ponds in project area including (but not limited to):
    - Mercury levels (total and methylmercury)
    - Mercury levels in biota
    - Other metals (As, Cr, Cu, Ni . . .)
    - Selenium
    - DDTs
    - PCBs
    - PAHs

Requested by PWA

Bathymetric data and tide gauge data from Moffatt and Nichols report (Dilip Trevedi)