APPENDIX A

# EcoAtlas

# The Bay Area EcoAtlas

## Visit the EcoAtlas at the SFEI website: www.sfei.org

The San Francisco Estuary Institute manages the Bay Area EcoAtlas as a growing assemblage of maps, images, scientific data, and information sources about the ecology of the bays, wetlands, and watersheds of the San Francisco Bay Area.

The EcoAtlas began in 1995 as a computerized Geographic Information System (GIS) to support the multi-agency Bay Area Wetlands Ecosystem Goals Project. Hundreds of volunteers worked with the regional community of environmental scientists to develop detailed views of past and present ecological conditions along the broad zone of transition between the open bays and local watersheds of the San Francisco Estuary, downstream of the Delta. The EcoAtlas includes maps of Bay Area watersheds and key sets of regional data about stream fishes, introduced species, and contaminants. Efforts will continue in the future to expand the EcoAtlas with the new information needed to understand and protect the natural resources of the Bay Area.

The hallmarks of the EcoAtlas are authenticity and accountability. The contents of the EcoAtlas reflect ongoing discussions among many interest groups. Federal and state agencies involved with resource management help prioritize the possible contents. Local agencies and non-governmental organizations assist with EcoAtlas design concepts and formats. The EcoAtlas staff at SFEI always consult with the sources of outside information to understand the limits of its applicability. All the contents are supported by detailed records of their development. SFEI works with many partners in and out of government to maintain the integrity of the EcoAtlas.

Current development of the EcoAtlas is focused on making it widely available to the private sector and the public. Earlier versions of the EcoAtlas were distributed to a test group of Bay Area resource managers. These tests showed the need for the EcoAtlas to be available in many formats, including paper maps and reports, overheads, photographic slides, and digital files suitable for graphics production or inclusion in a GIS. On-line access with interactive maps and information exchange services is also being planned. SFEI is focused on developing the EcoAtlas as a readily accessible source of authoritative information about the ecology of the Bay Area.

For more information on the EcoAtlas, or to request maps, please contact SFEI:

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# Past and Present Acreage for the San Francisco Bay, the Baylands, and Adjacent Habitats

## TABLE 1 Past and Present Habitat Acreage for the Project Area

| Habitat Type | Historical (ca. 1800) acres | Modern (ca. 1998) acres | % Change +/- |
|---|---|---|---|
| **Bays** | | | |
| Deep Bay/Channel | 99,529 | 82,410 | -17% |
| Shallow Bay/Channel | 174,442 | 171,818 | -2% |
| Total | 273,971 | 254,228 | -7% |
| **Baylands** | | | |
| Tidal Flat | 50,469 | 29,212 | -42% |
| Tidal Marsh | 189,931 | 40,191 | -79% |
| Lagoon | 84 | 3,620 | 4209% |
| Salt Pond | 1,594 | 34,455 | 2062% |
| Diked Wetland | - | 64,518 | |
| Agricultural Bayland | - | 34,620 | |
| Storage or Treatment Pond | - | 3,671 | |
| Undeveloped Bay Fill | 12 | 7,598 | 63217% |
| Developed Bay Fill | - | 42,563 | |
| Other Baylands | 254 | 1,951 | 668% |
| Total | 242,344 | 262,397 | 8% |
| **Adjacent Habitats** | | | |
| Moist Grassland | 60,487 | 7,474 | -88% |
| Grassland/Vernal Pool Complex | 24,070 | 15,038 | -38% |
| Riparian Forest/Willow Grove | 4,800 | 774 | -84% |
| Total | 89,357 | 23,286 | -74% |

## TABLE 2 Past and Present Habitat Acreage for the Suisun Subregion

| Habitat Type | Historical (ca. 1800) acres | Modern (ca. 1998) acres | % Change +/- |
|---|---|---|---|
| **Bays** | | | |
| Deep Bay/Channel | 16,746 | 11,584 | -31% |
| Shallow Bay/Channel | 24,095 | 22,428 | -7% |
| Total | 40,841 | 34,012 | -17% |
| **Baylands** | | | |
| Tidal Flat | 2,405 | 1,124 | -53% |
| Tidal Marsh | 65,358 | 13,562 | -79% |
| Lagoon | 2 | 6 | 200% |
| Salt Pond | - | 0 | |
| Diked Wetland | - | 49,873 | |
| Agricultural Bayland | - | 5,544 | |
| Storage or Treatment Pond | - | 720 | |
| Undeveloped Bay Fill | - | 762 | |
| Developed Bay Fill | - | 2,453 | |
| Other Baylands | 2 | 570 | 28380% |
| Total | 67,767 | 74,614 | 10% |
| **Adjacent Habitats** | | | |
| Moist Grassland | 6,529 | 936 | -86% |
| Grassland/Vernal Pool Complex | 14,178 | 9,153 | -35% |
| Riparian Forest/Willow Grove | 700 | 75 | -89% |
| Total | 21,407 | 10,164 | -53% |

## TABLE 3 Past and Present Habitat Acreage for the North Bay Subregion

| Habitat Type | Historical (ca. 1800) acres | Modern (ca. 1998) acres | % Change +/- |
|---|---|---|---|
| **Bays** | | | |
| Deep Bay/Channel | 20,139 | 10,362 | -49% |
| Shallow Bay/Channel | 55,120 | 53804 | -2% |
| Total | 75,259 | 64,166 | -15% |
| **Baylands** | | | |
| Tidal Flat | 13,351 | 9,118 | -32% |
| Tidal Marsh | 55,076 | 16,347 | -70% |
| Lagoon | 37 | 2,353 | 6259% |
| Salt Pond | 270 | 7,143 | 2545% |
| Diked Wetland | - | 7,622 | |
| Agricultural Bayland | - | 27,732 | |
| Storage or Treatment Pond | - | 1,266 | |
| Undeveloped Bay Fill | - | 1,648 | |
| Developed Bay Fill | - | 6,211 | |
| Other Baylands | 24 | 565 | 2254% |
| Total | 68,758 | 80,003 | 16% |
| **Adjacent Habitats** | | | |
| Moist Grassland | 15,416 | 5,841 | -62% |
| Grassland/Vernal Pool Complex | 3,502 | 3,263 | -7% |
| Riparian Forest/Willow Grove | 1,000 | 315 | -69% |
| Total | 19,918 | 9,419 | -53% |

## TABLE 4 Past and Present Habitat Acreage for the Central Bay Subregion

| Habitat Type | Historical (ca. 1800) acres | Modern (ca. 1998) acres | % Change +/- |
|---|---|---|---|
| **Bays** | | | |
| Deep Bay/Channel | 55,609 | 53,614 | -4% |
| Shallow Bay/Channel | 57,272 | 53,774 | -6% |
| Total | 112,881 | 107,388 | -5% |
| **Baylands** | | | |
| Tidal Flat | 13,532 | 4,014 | -70% |
| Tidal Marsh | 13,461 | 947 | -93% |
| Lagoon | 45 | 658 | 1363% |
| Salt Pond | - | - | |
| Diked Wetland | - | 1,314 | |
| Agricultural Bayland | - | 34 | |
| Storage or Treatment Pond | - | 57 | |
| Undeveloped Bay Fill | - | 3,420 | |
| Developed Bay Fill | - | 21,970 | |
| Other Baylands | 215 | 380 | 77% |
| Total | 27,253 | 32,794 | 20% |
| **Adjacent Habitats** | | | |
| Moist Grassland | 5,466 | - | |
| Grassland/Vernal Pool Complex | - | - | |
| Riparian Forest/Willow Grove | 800 | 87 | -89% |
| Total | 6,266 | 87 | -99% |

**TABLE 5** **Past and Present Habitat Acreage for the South Bay Subregion**

| Habitat Type | Historical (ca. 1800) acres | Modern (ca. 1998) acres | % Change +/- |
|---|---|---|---|
| **Bays** | | | |
| Deep Bay/Channel | 7,035 | 6,851 | -3% |
| Shallow Bay/Channel | 37,955 | 41,812 | 10% |
| Total | 44,990 | 48,663 | 8% |
| **Baylands** | | | |
| Tidal Flat | 21,181 | 14,955 | -29% |
| Tidal Marsh | 56,037 | 9,335 | -83% |
| Lagoon | - | 598 | |
| Salt Pond | 1,316 | 27,313 | 1975% |
| Diked Wetland | - | 5,709 | |
| Agricultural Bayland | - | 1,309 | |
| Storage or Treatment Pond | - | 1,628 | |
| Undeveloped Bay Fill | 12 | 1,768 | 14637% |
| Developed Bay Fill | - | 11,930 | |
| Other Baylands | 13 | 347 | 2570% |
| Total | 78,559 | 74,893 | -5% |
| **Adjacent Habitats** | | | |
| Moist Grassland | 33,077 | 696 | -98% |
| Grassland/Vernal Pool Complex | 6,391 | 2,622 | -59% |
| Riparian Forest/Willow Grove | 2,300 | 297 | -87% |
| Total | 41,768 | 3,615 | -91% |

# Compilation of Focus Teams and Hydrogeomorphic Advisory Team Recommendations



***Notice***

*The following is a compilation of the recommendations produced by each of the focus teams and the HAT. You will note that some of the terminology used in these reports differs from that used in the Goals Report. For example, some teams discuss regions and subregions that are defined differently, and some use different names for habitats. This is because the terminology used within the Project has evolved over time, and some has been developed specifically to facilitate presentation of the Goals.*

*In order to preserve the original intent of the focus team authors, no changes, other than minor formatting changes, have been made in the teams' reports. We believe the intent of their recommendations is made clear by the information contained in the reports.*

# Plants Focus Team

## Recommendations

The Plants Focus Team submits these recommendations regarding marsh restoration in the San Francisco baylands. Included is an introductory section on estuarine plant community objectives. Each recommendation includes descriptive background information and supporting rationale. For additional information regarding the plant communities of the baylands ecosystem, please refer to the community narratives that will be compiled in the Goals Project's Species and Community Profiles Report.

**1. Overall estuarine plant community objectives.** From the perspective of plant community conservation, the Plants Focus Team recommends the following objectives as the highest priorities for conservation of plant associations and rare plants in the San Francisco Estuary:

(1) protection of existing tidal marshes against further artificial losses and degradation;
(2) extensive restoration of *whole* tidal marsh systems (not just pocket marsh indentations within a matrix of levees that separate them from the historic Bay margin) and restoration of *associated ecotonal estuarine-margin plant communities* (e.g., freshwater riparian wetlands, vernal pool and swale grasslands, alluvial seasonal wetlands).

Tidal restoration of diked historic baylands (former marsh and mudflat) typically displaces non-tidal salt marsh, brackish marsh, freshwater seasonal wetland plant communities, and salt pans. While most diked wetland plant associations are less diverse and contain more exotic species than tidal marshes, some contain important populations of regionally rare plants which have been eliminated from their original communities in the ecosystem (e.g., subsaline vernal pools, alluvial terraces). The weedy character of much diked wetland vegetation is merely a contingent feature of past degradation from adverse land management practices (discing, ditching, filling), not an essential feature. Diked wetlands should therefore not be presumed to support entirely ruderal floras or degraded non-tidal salt marsh. They should be carefully assessed individually for regionally important plant associations before they are converted to tidal marsh, and some should be conserved and enhanced if they support scarce plant associations that cannot feasibly be replaced.

Tidal marsh restoration typically involves either passive sedimentation or engineered placement of dredged material to develop new marsh substrate in subsided diked baylands. These measures produce youthful marsh systems with little soil development, relatively little microtopographic differentiation, and usually support relatively low native plant species diversity. Well-developed and complex microtopography and marsh soils are often necessary for viable populations of rare tidal marsh plant species. Restoration designs should therefore be adapted to include structural features which will facilitate development of mature marsh features, while avoiding compromising natural marsh succession (e.g., gently sloping upland transition zones with suitable soils). This is particularly important along the upper marsh profile, where ponds, streams, alluvial deposits, and upland soils form complexes of ecotonal plant communities that naturally supported a high diversity of native plant species, which have declined significantly since most of the tidal marshes were diked.

The Plants Focus Team has chosen to use plant communities rather than species as the ecological units for conservation planning of the Estuary. This is partly because more is understood about the ecology of the habitat in which rare species occurred than about the species themselves, particularly for species which are now regionally extinct or reduced to minimal remnants of their original populations. It is also partly because many rare species are united by similar and related habitat requirements, often associated with the high marsh zone. For the plant communities considered, it would be arbitrary and unrealistic to prescribe specific acreage of plant associations as habitat goals at this regional level of planning. This is because plant associations and populations are highly dynamic in density, distribution, and area. Moreover, many rare plant populations, particularly rare annuals, are likely to exhibit fluxes of local extinctions and colonizations, often in concert with disturbances or environmental fluctuations. Instead, the Plants Focus Team is prescribing conservation priorities for the Bay ecosystem's plants which would apply to opportunities to acquire, manage or restore diked baylands and adjacent lands as they become available.

**2. Natural geographic variation in marsh structure and composition should be incorporated into marsh restoration designs and objectives.** In planning marsh restoration in the San Francisco Estuary, priority should be given to regenerating the full range of wetland types, local wetland habitats, and microenvironments within marsh systems. Much of the historic diversity of estuarine marsh was geographically embedded, reflecting local and subregional variations in substrate texture, wave energy, tidal energy, upland soils, upland drainages, etc. Some natural elements of the historic Estuary are either extinguished or drastically reduced or altered, such as sandy backbarrier marshes, lagoon-fringe marshes, natural salt pans and marsh ponds, natural levees along channels and bayfronts, and alluvial fan/terrace ecotones. Plant communities and species which are now locally extinct or in severe decline depended on natural variation in marsh structure and composition.

Therefore, the Plants Focus Team recommends that potential restoration sites be examined carefully for their potential contribution to restore geographically unique, atypical, or important local marsh systems. Geographically specialized marsh restoration plans, which fully consider opportunities to incorporate regionally scarce components of estuarine marsh systems, are preferable to generic marsh restoration plans.

**3. Restoration opportunities which link tidal marshes to upland and alluvial soils, seeps, and drainages should be given high priority in restoration planning.** Most tidal restoration sites are currently indented pockets in levee systems, separated from the historic margin of the Estuary by subsided diked lands. The upper edge of such restored marshes are typically steep, disturbed levee slopes on unnaturally elevated bay mud substrate which often supports weedy vegetation. Most floristic diversity in tidal marshes was concentrated along the upper marsh edge, where transitions between high tidal marsh and local soils, seeps, and drainages created ecologically important variation in environmental conditions. Many rare or locally extinct plant species had high affinity for, or ecological dependence on, these transitional and diverse environments.

Therefore, the Plants Focus Team recommends that opportunities to restore sites which connect tidal marshes to upland soils, creeks, seeps, and drainages be given at least as much priority as marsh restoration sites located adjacent to tidal sloughs.

**4. The ecological restoration design of the upper marsh transition zones (ecotone) should be given as much priority as intertidal marsh.** Upper marsh transition zones between high marsh and upland conditions are usually designed as buffer zones for wildlife, tidal refugia for wildlife, flood control components, public access and viewing areas, and maintenance access areas — predominantly pragmatic management considerations rather than ecological ones. In contrast, intertidal marsh is usually designed as wildlife habitat or ecosystem restoration for its own sake. Because most floristic diversity in tidal marshes would occur in the upper marsh transition zone, restoration plans should treat it as a high priority area for restoration based on natural models and reference sites.

**5. Exotic vegetation control and maintenance of existing native plant communities should be given consideration equal to restoration of marsh at new sites.** San Francisco Bay is subject to rapid invasion by exotic plant species which dominate whole marsh zones and displace native plant species (e.g., *Lepidium latifolium* and *Spartina alterniflora*). Some exotics displace rare and declining plant species and communities, such as upper marsh transition zones. Many newly restored marshes — perhaps most — are subject to rapid invasion and dominance by non-native marsh plants, significantly reducing the long-term ecological benefits of marsh restoration for biological diversity. Suppression of exotic plant invasion to newly restored marshes, which are less resistant to invasion than established marshes, is critical to the integrity of the plant communities they will support.

Therefore, the Plants Focus Team recommends that restoration efforts be directed not just to restoration of new tidal marshes in degraded diked baylands, but also to restoration, enhancement, and management of existing estuarine marshes, including systematic efforts to suppress the spread of invasive exotic marsh vegetation, and eventually reduce and control their abundance. Highest priority should be given to early eradication of small, local invasions before they require major control efforts after "latency" (e.g., *Spartina densiflora*, *S. patens*); eradication of outpost "guerilla" colonies of established invaders (e.g., isolated outlier populations of *Spartina alterniflora*); and large-scale population control in habitats supporting rare plants which are at risk of being excluded by the invasive species (e.g., *Lepidium latifolium* in habitats of *Cordylanthus mollis* or *Cirsium hydrophilum*)

Natural, passive recruitment of marsh vegetation is appropriate as a restoration tool only when local dispersal rates by exotic plant species to the restoration site are low. Where recruitment rates of exotic species are unavoidably high, planting of native vegetation to provide a competitive advantage to native species is often justified. No large-scale tidal marsh restoration should proceed before local infestations of invasive exotic plants are suppressed. Exotic plant control should be considered to be an integral component of site preparation for restoration projects, equal in priority to earthmoving.

**6. Reintroduction and introduction of rare plant species should be employed selectively as a restoration tool when appropriate opportunities arise.** Some plant species in San Francisco Bay have become locally extinct because of urbanization, such as California sea-blite (*Suaeda californica*, federally listed as endangered) and California saltbush (*Atriplex californica*), or have become very rare in the Estuary (e.g., *Lasthenia glabrata*, *Lasthenia platycarpha*, *Castilleja ambigua*, *Cordylanthus mollis*, *Cordylanthus maritimus*, *Lilaopsis masonii*).

Locally extinct plant species cannot disperse to potentially receptive restored habitats in San Francisco Bay from remote populations in a human time-scale. They should therefore be reintroduced from appropriate remnant populations outside the San Francisco Estuary when opportunities to restore receptive habitats for them arise. Furthermore, restoration projects should seek opportunities to establish receptive habitats for these species when feasible.

Rare plant species which still persist in the Bay may be limited by dispersal between artificially fragmented suitable habitats, as well as by scarcity of suitable habitat. Reintroduction is an appropriate tool to compensate for artificial fragmentation of rare plant populations in the Estuary. However, reintroduction should be designed to avoid adverse homogenization of genetically differentiated populations of rare species. Introduction of rare plant species to restoration sites which are not historically recorded to have supported them, but are within the ecological and geographic range of the species, is also appropriate for marsh restoration plans.

Attempted translocation of rare estuarine plant populations to restored marshes as compensatory mitigation for degradation or elimination of rare plant populations at impact sites is unacceptable and should not be permitted, since replacement of an established rare plant population by an uncertain and potentially unstable one is inherently adverse for the conservation of the species.

**7. Dredged materials should only be used selectively for marsh restoration.** Bay mud and other sediments dredged from the Estuary should be employed selectively in marsh restorations. Mineral-rich estuarine sediments should not generally be deposited at or above tidal elevations at which peaty organic material or adjacent upland soils would typically dominate the soil profile. Bay muds should not be deposited in the uppermost soil horizon of upper marsh transition zones unless used as a foundation material and are thickly capped with soil from terrestrial or alluvial (non-estuarine) sources. These restrictions are recommended because many rare marsh plants and associations of tidal marshes depend on the soil characteristics of peat-rich marsh soils and salinized, weathered upland mineral soils at the upland marsh edge, where soil texture and mineral composition is variable. Because marsh vegetation patterning is dependent on marsh drainage patterns, deposition of dredged materials above local Mean High Water, which inhibits differentiation of drainage patterns in subsequent marsh, should be discouraged (except where required for rapid development of endangered species habitat). Sites which historically supported relatively rare marsh substrates (e.g., sandy silts, sands, and interbedded alluvial sands, silts, clays) in the upper marsh zone should be restored with appropriate sediments. Levees used to contain dredged materials during filling operations should be removed to the greatest extent possible after placement of sediment, since levees screen out tidal litter that may be important in creating disturbance patches in tidal marsh.

**8. Dry-season fresh wastewater discharges should be discouraged and reduced over time.** Fresh wastewater discharges are a potentially useful resource for marsh restoration, but year-round high levels of discharges have contributed significantly to conversion of scarce salt marsh to brackish-fresh tidal marsh plant communities.

**9. Refugial floras of diked wetlands should be surveyed before tidal restoration is proposed.** While many diked wetlands are rich in exotic weedy species and poor in native species, some may (and do) act as refugia for species which were formerly found in tidal marsh edge environments, or adjacent seasonal wetlands, including species found in subsaline/alkaline soils of vernal pools. Since urbanization and agriculture have eliminated the original habitats of these species, their presence in diked wetlands may provide important refugia for geographically distinct populations. Diked wetlands should be subjected to careful seasonally timed surveys for spring flora species before diked wetland vegetation is presumed to be uniformly low in ecological value. Some diked baylands, particularly in the North Bay, should be conserved and artificially managed for hydroperiods that support surrogate grassland communities, including vernal pool plant species.

**10. Marsh restoration plans, designs, and objectives should be based on empirical data.** The use of generalized or arbitrary designs for plant community composition and vegetation structure should be discouraged. Plant community objectives should incorporate consideration of local geographic variability and historic conditions at the local and regional scale.

**11. Outboard levees should be graded down to marsh level** over long segments when tidal action is restored to diked basins, with some relict high fills left for tidal refugia used by marsh mammals and birds. This is to enable wave-driven debris (e.g., wracks, plant litter, peat rafts) to be dispersed across marsh plains during extreme tides, and to allow waves to propagate across shallow basins during brief periods of extreme inundation. These episodic disturbances — dispersion of tidal litter, drift-smothering of vegetation, and wave erosion of substrate at the high tide line — are important long-term cyclic processes for creating vegetation gaps, and regenerating natural disturbances on which some rare plant associations and species depend upon.

**12. Hypersaline microflora conservation** (specialized microalgal and bacterial flora adapted to hypersaline conditions) should be achieved in the absence of a large industrial salt production system by any of three alternative methods:

(1) construction, operation, and maintenance of small-scale salt production systems at the pre-modern geographic scale (early 20th century family operated system, a few hundred acres), established by sub-dividing portions of the salt pond system at feasible locations (e.g., portions of Alameda shoreline).

(2) construction and maintenance of "short-circuited" managed salt evaporators within a restored tidal salt marsh complex, designed to produce only moderately hypersaline brine before internal dilution by large bay water intake during dilute winter tides. This would require construction of new or upgraded levees set back from the erosional open bay edge, and installation of additional tidegates for water management.

(3) construction of naturalistic, unmanaged facsimiles of historic marsh pans and salt ponds at appropriate locations within restored tidal marsh complexes. These would depend on construction of very low berms (less than 0.3 m above MHHW) across shallow basin floors near MHW elevation, passive overtopping by spring tides, and evaporative concentration of brines. Topography within the large basins should be irregular, so that internal relief causes variation in pond depth and isolation of variable pockets of brine of different salinity during evaporative fall in pond levels. The concentration of brines would vary from hypersaline to crystallization in the largest basins. Such ponds would be constructed near the landward edge of restored tidal marsh in

Alameda County. These may be derived by construction of internal levees within existing salt ponds which are restored to tidal action, or they may be established in part by engineered placement of suitable dredged material. Pans equivalent to the smaller, mid-marsh depressions frequently flooded by spring tides ("drainage divide ponds") should be established artificially within some restored marshes to support near-marine salinity, to conserve viable populations of *Ruppia maritima*, and to support diverse macroalgae beds. Such pans would probably take many decades or more to form naturally.

To ensure adequate diversity of salinity regimes that control biological diversity of hypersaline microflora, the cumulative area of reconstructed salt ponds should be intermediate between the modern inflated extent, and the historic extent of the late 19th century. This is because the vast number of isolated, independent marsh pans that supported variability in hypersaline environments cannot be regenerated within the time-scale of restoration planning for tidal marshes.

**13. Pace and scale of tidal marsh restoration** should be regulated to avoid needless replication of design errors which become evident during monitoring, and to avoid excessive homogenization of even-aged restored marshes. Marsh diversity early in succession may reflect discontinuous, contingent events, such as rainfall variation, storm deposits of sediment, extreme tides, pulses of nutrients, freshwater flows, wrack deposits, variation in sediment supply or wind-driven sediment resuspension, etc. Results of large-scale pilot projects of tidal marsh restoration should be evaluated before regional conversion to tidal habitats is commenced in force. Such pilot projects, on the scale of 500 – 1,500 acres, should be initiated as soon as possible, and incorporate replicated variation in various restoration designs and techniques.

**San Francisco Bay Area Wetlands Ecosystem Goals Project**

# Estuarine Fishes and Associated Invertebrates Focus Team

## Recommendations

This paper summarizes the Fish Focus Team's habitat recommendations and restoration principles. Information is presented for each of the key habitats that fish utilize. For additional information regarding the fishes that occur in the baylands and adjacent waters of San Francisco Bay, please refer to the individual species narratives that will be compiled in the Goals Project's Species and Community Profiles Report.

*Shallow Bay or Strait (unvegetated)*

**Recommendations:**
- Avoid any net loss of this habitat through solid bay fill.
- Restore shallow subtidal habitat in Suisun Bay (benefits Delta smelt, splittail, steelhead trout, etc.).
- Restoration of shallow subtidal habitat is encouraged in previously maintained and/or created artificial deepwater areas (e.g., former navigation channels or berthing areas).
- Maintain or create linkages to tidal marsh to maximize value for fishes.

**Restoration Principles:** (None advanced).

**Benefits:**
- In addition to those identified above, see **Table 1**.

*High/Mid-Tidal Marsh*

**Recommendations:**
- Preserve this habitat throughout the region, particularly in Central San Francisco Bay where the decline has been the most dramatic.
- Maximize restoration of this habitat throughout the remaining subregions (i.e., Suisun Bay, San Pablo Bay, and South San Francisco Bay), particularly in historic diked baylands where the best opportunities appear to exist.

**Restoration Principles:**
- Create large, continuous patches of high/mid-tidal marsh which will support a wide variety of channel orders (e.g., 3rd and 4th order for maximum edge), within an appropriate range of salinity, seasonality of water flow, and other features of the natural hydrograph. This will particularly benefit marsh resident species (e.g., longjaw mudsucker) and juveniles of seasonal residents (e.g., splittail, Chinook salmon, etc.).
- There should be significant linkages to low tidal marsh and adjacent upland habitats to maximize functional values for fish, invertebrates, and all marsh species, as well as promote a self-sustaining capability.
- There is a need for dead-end sloughs in Suisun Bay, particularly those with emergent and submerged vegetation. Beneficiaries include, splittail, Delta smelt, tule perch, and opossum shrimp.
- There should be potential for freshwater streams to connect within the marsh during high flow years — this promotes species diversity and genetic exchange.

- Encourage the presence and maintenance of high tidal marsh pans for the benefit of certain invertebrates (e.g., California horn snail).

**Benefits:**

- In addition to those identified above, see **Table 2**.

*Low Tidal Marsh*

**Recommendations**

- Preserve all existing low tidal marsh areas throughout all four subregions of the Estuary.
- Restoration efforts for low tidal marsh should be focused in areas of historical distribution or as transition zones in conjunction with high tidal marsh development plans.

**Restoration Principles:**

- Restore large, continuous patches (> 200 acres) of low tidal marsh in areas, particularly within the Suisun Bay subregion, where suitable land elevations exist near important rearing sites (i.e., shallow water areas of Suisun, Honker, and Grizzly bays) for juvenile fishes (e.g., Delta smelt, Chinook salmon, etc.). Tidal marshes adjacent to these open bays, especially the northern shore, are even more valuable to Chinook salmon and Delta smelt than are dead-end sloughs in the inner marsh.
- Low tidal marshes should occur at the mouths of all small streams and creeks entering San Francisco Bay. Marsh benefits include foraging and smolting and protective habitat for salmonid juveniles and adults.
- Linkages to high/mid-tidal marsh and intertidal flat should be maintained and/or created.
- Low tidal marshes should have an array of channel types, especially some within a short distance of the bay or strait which are not de-watered at low tide. Diverse and abundant native fish populations are found in these types of channels, as they probably function as refugia from major predators.
- Tidal marshes should be exposed to a full tidal range and not controlled by tide gates or muted with artificial or maintained structures. By controlling tidal range or amplitude, fish movements are limited, temperatures may increase, and some water quality parameters may decline. Former tidal marshes, which have subsided and are subsequently opened to controlled tidal action, may not develop to a more "natural marsh," including deeper channels which function as refuge from predators. Refuge is an important issue in areas which are maintained at relatively shallow depths, as predation, especially by birds, may be high in such areas.
- No actions should be taken that interfere with physical processes which may cause a transition to high/mid-tidal marsh.
- Restoration management plans for low tidal marsh should include eradication of deleterious invasive plant species (e.g., *Spartina alterniflora*).

**Benefits:**

- In addition to those identified above, see **Table 3**.

*Intertidal Flat*

**Recommendations:**

- Protect all intertidal flats at current levels and locations in Central San Francisco Bay where increases from historical levels are relatively low and, at a minimum, protect at historical levels in the other three subregions.
- We do not recommend restoration efforts for this habitat except as part of larger projects where it is a necessary transition zone between low tidal marsh and shallow bay (i.e., shallow subtidal), or as compensatory mitigation for direct losses of intertidal flat.

**Restoration Principles:**

- Since intertidal mudflats are an integral part of the channel system within tidal marshes, habitat characteristics advanced previously for those habitats (e.g., channel complexity) should be adhered to.
- Intertidal mudflat should be protected from low-growing eastern cordgrass, *Spartina alterniflora*.

**Benefits:**

- In addition to those identified above, see **Table 4**.

*Salt Ponds*

**Recommendations:**

- Relative to mature tidal marshes, salt ponds provide minimal habitat value to fishes and aquatic invertebrates; therefore, where possible, they should be converted to tidal marsh and other aquatic habitats by opening them to full tidal action. Depending upon the location of the restored ponds, different species and functions would be supported.

**Restoration Principles:**

- See tidal marsh and intertidal flats as described above.

**Benefits:**

- Same as above.

*Eelgrass*

**Recommendations**:

- Due to its unusually high value to fish and wildlife resources, all existing eelgrass beds within the region need to be identified and vigorously preserved.
- Eelgrass restoration efforts should be located within South San Francisco Bay, Central San Francisco Bay, and San Pablo Bay as a result of the apparent influence of fresh water on its distribution.

**Restoration Principles:**

- Restoration should take place only in those areas where key water quality features (e.g., water clarity, well-oxygenated sediments, etc.) indicate a high likelihood of success.
- Enhancement of existing eelgrass beds should be limited to the revegetation of unvegetated areas within the bed's margins.

**Benefits:**

- In addition to those identified above, see **Table 5**.

*Tidal Rivers, Creeks, and Streams*

**Recommendations:**

- Protect what we have region-wide.
- To the extent feasible, restore the area of dead-end sloughs to historical levels.

**Restoration Principles:** (None advanced).

**Benefits:** Maintenance of existing support values.

## TABLE 1 Functional Support for Target Species by Shallow Bay and Strait Habitat

| Species | Suisun Bay | San Pablo Bay | Central S.F. Bay | South S.F. Bay |
|---|---|---|---|---|
| **leopard shark** | | | spawning & forage | spawning & forage |
| **bat ray** | | | | forage & protection |
| **white sturgeon** | forage & movement | forage & movement | forage | forage |
| **Pac. herring** | | forage | spawning, forage, & movement | spawning, forage, & movement |
| **splittail** | forage & protection | forage & protection | | |
| **Delta smelt** | forage | | | |
| **longfin smelt** | forage | forage | | |
| **no. anchovy** | | | spawning & forage | spawning & forage |
| **steelhead trout** | forage & movement | forage & movement | forage & movement | forage & movement |
| **Chinook salmon** | forage & movement | forage & movement | forage & movement | |
| **topsmelt** | | forage | | forage |
| **jacksmelt** | | forage | forage | forage |
| **plainfin midshipman** | | | spawning, forage, movement, & protection | |
| **brown rockfish** | | | forage & protection | |
| **Pac. staghorn sculpin** | | forage & protection | forage & protection | forage & protection |
| **striped bass** | forage | forage | forage | forage |
| **white croaker** | | | spawning & forage | |
| **shiner perch** | | forage | forage | forage |
| **arrow goby** | | spawning, forage, & protection | | spawning, forage, & protection |
| **bay goby** | | | forage & protection | |
| **Ca. halibut** | | | forage & protection | |
| **starry flounder** | forage & protection | forage & protection | forage & protection | |
| **opossum shrimp** | forage | forage | | |
| **softshell clam** | | spawning, forage, & protection | spawning, forage, & protection | spawning, forage, & protection |
| **amphipods** | spawning, forage, & protection | spawning, forage, & protection | spawning, forage, & protection | spawning, forage, & protection |
| **Ca. bay shrimp** | forage & protection | forage & protection | spawning, forage & protection | forage & protection |
| **blacktail bay shrimp** | | | spawning, forage, & protection | |
| **Dungeness crab** | | forage, movement, & protection | forage, movement, & protection | forage, movement, & protection |
| **rock crabs** | | | spawning, forage, & protection | |
| **mud crab** | | spawning & forage | spawning & forage | spawning & forage |

## TABLE 2 Functional Support for Target Species by High/Mid-Tidal Marsh Habitat

| Species | Suisun Bay | SanPablo Bay | Central S.F. Bay | South S.F. Bay |
|---|---|---|---|---|
| **splittail** | forage & protection | forage & protection | | |
| **Chinook salmon** | forage & protection | forage & protection | forage & protection | forage & protection |
| **rainwater killifish** | spawning, forage, movement, & protection | | | spawning, foraging, movement, & protection |
| **topsmelt** | | | | forage |
| **three-spined stickleback** | spawning, forage, & protection | spawning, forage, & protection | | spawning, forage, & protection |
| **prickly sculpin** | forage & protection | forage & protection | forage & protection | forage & protection |
| **striped bass** | | | | forage |
| **tule perch** | spawning, forage, & protection | spawning, forage, & protection | | |
| **longjaw mudsucker** | | spawning, forage, & protection | | spawning, forage, & protection |
| **Assiminea californica** | spawning & forage | spawning & forage | spawning & forage | spawning & forage |
| **California horn snail** | | | spawning & forage | spawning & forage |
| **ribbed mussel** | | | | spawning, forage, & protection |
| **amphipods** | spawning, forage, & protection | spawning, forage, & protection | spawning, forage, & protection | spawning, forage, & protection |
| **mud crab** | | forage & protection | forage & protection | forage & protection |

## TABLE 3 Functional Support for Target Species by Low Tidal Marsh Habitat

| Species | Suisun Bay | San Pablo Bay | Central S.F. Bay | South S.F. Bay |
|---|---|---|---|---|
| **bat ray** | | | | forage & protection |
| **white sturgeon** | | forage & protection | forage & protection | forage & protection |
| **splittail** | forage & protection | forage & protection | | |
| **Chinook salmon** | forage & protection | forage & protection | forage & protection | forage & protection |
| **rainwater killifish** | | | | spawning, foraging, movement, & protection |
| **topsmelt** | | | | forage |
| **three-spined stickleback** | spawning, forage, & protection | spawning, forage, & protection | spawning, forage, & protection | spawning, forage, protection |
| **prickly sculpin** | forage | forage | forage | forage |
| **Pac. staghorn sculpin** | | forage | forage | forage |
| **striped bass** | forage | forage | forage | forage |
| **tule perch** | spawning, forage, & protection | spawning, forage, & protection | | |
| **arrow goby** | | forage & protection | | forage & protection |
| **longjaw mudsucker** | | spawning, forage, & protection | | spawning, forage, & protection |
| **starry flounder** | forage & protection | forage & protection | forage & protection | |
| **Ca. horn snail** | | | spawning & forage | spawning & forage |
| **opossum shrimp** | forage | | | |
| **amphipods** | spawning, forage, & protection | spawning, forage, & protection | spawning, forage, & protection | spawning, forage, & protection |
| **Ca. bay shrimp** | forage & protection | forage & protection | forage & protection | forage & protection |
| **Dungeness crab** | | forage | forage | forage |
| **mud crab** | | spawning & forage | spawning & forage | spawning & forage |

## TABLE 4 Functional Support for Target Species by Intertidal Flat (Mud and Sand) Habitat

| Species | Suisun Bay | San Pablo Bay | Central S.F. Bay | South S.F. Bay |
|---|---|---|---|---|
| **leopard shark** | | | forage | forage |
| **bat ray** | | | | forage & protection |
| **splittail** | forage & protection | forage & protection | | |
| **Chinook salmon** | forage & movement | forage & movement | forage & movement | |
| **jacksmelt** | | forage | forage | forage |
| **plainfin midshipman** | | | spawning, forage, movement, & protection | |
| **Pac. staghorn sculpin** | | spawning & forage | spawning & forage | spawning & forage |
| **striped bass** | forage | forage | forage | forage |
| **white croaker** | | | forage | |
| **shiner perch** | | forage | forage | forage |
| **arrow goby** | | spawning, forage, & protection | | spawning, forage, & protection |
| **longjaw mudsucker** | | spawning, forage, & protection | | spawning, forage, & protection |
| **Ca. halibut** | | forage & protection | forage & protection | forage & protection |
| **starry flounder** | forage & protection | forage & protection | forage & protection | |
| **Ca. horn snail** | | | spawning & forage | spawning & forage |
| **softshell clam** | | spawning, forage, & protection | spawning, forage, & protection | spawning, forage, & protection |
| **amphipods** | spawning, forage, & protection | spawning, forage, & protection | spawning, forage, & protection | spawning, forage, & protection |
| **Ca. bay shrimp** | forage & protection | forage & protection | forage & protection | forage & protection |
| **Dungeness crab** | | forage | forage | forage |
| **mud crab** | | spawning & forage | spawning & forage | spawning & forage |

## TABLE 5 Functional Support for Target Species by Eelgrass Habitat

| Species | Suisun Bay | San Pablo Bay | Central S.F. Bay | South S.F. Bay |
|---|---|---|---|---|
| **white sturgeon** | | forage | forage | forage |
| **Pac. herring** | | forage | spawning & forage | spawning & forage |
| **Chinook salmon** | | forage | forage | forage |
| **topsmelt** | | | | spawning & forage |
| **jacksmelt** | | spawning & forage | spawning & forage | spawning & forage |
| **Pac. staghorn sculpin** | | forage & protection | forage & protection | forage & protection |
| **shiner perch** | | spawning & forage | spawning & forage | spawning & forage |
| **amphipods** | | spawning, forage, & protection | spawning, forage, & protection | spawning, forage, & protection |
| **Ca. bay shrimp** | | forage & protection | forage & protection | forage & protection |
| **mud crab** | | spawning & forage | spawning & forage | spawning & forage |

# Mammals, Amphibians, Reptiles and Invertebrates (MARI) Focus Team

## Recommendations

This paper summarizes the MARI Focus Team's habitat recommendations. The recommendations are presented for each of the four Project subregions. For additional information regarding the MARI species that utilize the baylands and adjacent habitats, please refer to the individual species narratives that will be compiled in the Goals Project's Species and Community Profiles Report.

## Suisun Bay Region

While the taxa selected by the MARI Focus Team are genetically quite diverse, most are small and vulnerable to predation, disperse poorly, and have very limited tolerance for prolonged deep flooding. Therefore, while exceptional species will be discussed below, the following general recommendations are possible:

(1) Preserve and/or create large areas (at least several hundred acres) of dense vegetative cover, centered around known populations of target species;

(2) Connect these protected areas with corridors sufficient to allow periodic exchange of genetic material and re-population in the event of local extirpation;

(3) To minimize disturbance (especially by predators) from outside the protected areas, design the protected areas with central areas far from the borders and/or provide buffer strips between the protected areas and potential sources of disturbance (including residential areas); and

(4) Provide sufficient topographic relief within and/or adjacent to the protected areas to afford refuge during the highest flood water depths.

In addition, while high salinities are generally not detrimental to these taxa, as long as plant cover is not reduced, excessive freshness can be a problem if it promotes a mix of plant species (e.g., pepper grass, cattail, some *Scirpus* spp.) that displaces more favorable plant species (especially pickleweed and other mid- to high-elevation halophytes). Therefore, (5) restoration projects should be designed to promote hydraulic conditions, including salinity regimes, that encourage vigorous growth of upper elevation halophytes. To the extent possible, this recommendation should be balanced by a general preference for projects and management schemes that (6) require minimal ongoing application of external energy (e.g., pumping, levee maintenance).

Another consideration, which is harder to evaluate, is the significance of tidal hydrology as an independent variable, apart from its influence on vegetation. While the vegetarian salt marsh harvest mouse and California vole have been trapped in abundance in diked or muted tidal marshes with typically tidal marsh vegetation, the insectivorous Suisun shrew and salt marsh wandering shrew are apparently limited to "natural tidal salt and brackish marshes" (MacKay and Shellhammer, this project), and are not seen in diked marshes. It is not clear whether this is due to food availability or to other causes. In addition, although river otters have been observed in diked marshes with abundant crustaceans, sea otter, river otter, harbor seal, and California sea lion are all essentially aquatic animals, presumably supported by open water and unrestricted channels. Thus, it is generally recommended that (7) restoration of full tidal action to diked marshes is desirable, where such restoration will not unacceptably reduce other wetland functions and values.

These considerations are not essentially different from those noted in the recommendations for other regions, but their application in the Suisun Bay/Carquinez Strait region can differ for a number of reasons:

1. The generally fresher water conditions in the Suisun Bay area, compared to other Project regions, means that fully-tidal, mid-elevation marshes often do not produce the plant communities associated with high densities of our target taxa, especially in the southeastern reaches of this region. In addition, planning around salinity means and extremes is difficult, for salinity patterns depend not only on weather conditions, but also on legal decisions and the operation of specific pumps and dams. On the other hand, relatively low populations (i.e., little treated wastewater) and small local watersheds mean that there are few areas where local freshwater inputs are significantly affecting habitat.

   Desired plant communities, especially in the southeast, are often associated with high elevations relative to tidal datums and/or with muted tidal regimes, both of which encourage salt accumulation in soil.

2. Most of the historical tidal marshes of this region have been diked, and many have subsided as a result. In addition, the Carquinez Strait is a significant bottleneck to heavy winter flows in the Sacramento or San Joaquin rivers, and tidal elevations can be much higher than San Francisco or San Pablo bays. Thus, while the subsidence is not generally so extreme that tidal restoration will result in permanent lagoons, marshes "restored" by dike breaching alone are often so low that flood stages can eliminate mammal populations, especially in sites without connections to adjacent vegetated uplands.

   Sediment accumulation following reintroduction of tides can restore pre-diking elevations, but access to sediment supplies varies considerably through the region, and marshes at the headwaters of long channels may build up very slowly. Marsh surfaces can also be artificially raised with dredge spoils, and the Montezuma Wetlands Project on the southeast corner of the region is a major proposal of this type. Serious concerns about toxics and other potential problems have been aired, however, and it is unclear how widely this idea will spread.

3. While many of this region's marshes are very low, a relatively high number of them are associated with extensive, relatively undisturbed, adjacent uplands. This is a situation which can provide an unusually high potential for long-term survival of species, but only if these areas remain extensive and relatively undisturbed.

4. The diked marshes of Suisun Bay are far more likely to be managed for relatively dense marsh vegetation cover than in other regions, where diked marshes are usually managed for salt production, agriculture, flood control, and/or open water or mudflat habitats. While the current management regimes of Suisun Bay diked marshes are often not ideal to MARI target species, changes in water management can potentially promote MARI taxa without requiring complete restoration of free tidal action.

In light of these general recommendations and special conditions, we recommend the following habitat goals for the Suisun Major Subregion, based on promoting the long-term viability of the target taxa of the MARI Focus Team:

I. **Suisun Marsh Minor Subregion**

   A. Protect and enhance the existing populations of target species along the periphery of this subregion, by protecting, enhancing, and restoring appropriate hydrology and vegetation, in units of at least several hundred acres each, around the six known centers of small mammal population. This can be accomplished either by restoration of full tidal action or, in some cases, by modified water management on diked sites. By focusing initially on the areas outside Grizzly Island, we emphasize protection of areas with associated uplands, and we minimize risk to the central areas from future encroachment by residential or industrial development.

1. *Southwest Unit.* The Benicia/Moth Ball Fleet shoreline has known or suspected populations of salt marsh harvest mouse, California vole, ornate shrew, and river otter; the highest average salinity in this region; relatively low urban/industrial encroachment; and a large number of current restoration projects. These projects should be encouraged and additional tidal restoration/enhancement should occur to ensure the largest contiguous zone of tidal marsh possible. Where restoration on full tidal action is not possible, changes in water management to encourage halophytes is desirable.

   One priority for restoration planning in this area is responding to the relative lack of undisturbed uplands adjacent to the marshlands, especially where Interstate 680 runs just above the edge of the marsh. High water refugia are essential for small mammals, and where undisturbed transitions to extensive uplands no longer exist, island creation or other selective placement of fill on parts of the marsh may be appropriate.

2. *Northwest Unit.* The Cordelia Slough/Chadbourne Slough area has known or suspected populations of salt marsh harvest mouse, California vole, Suisun shrew, and river otter; significant areas of adjacent uplands; and sparse residential or industrial development in the vicinity. While most of this area is currently managed for ducks or other (dry land) hunting, significant areas of good habitat for mice, voles, and shrews have been observed. Both tidal restoration and improved water management should be encouraged in this area, with emphasis on creating a contiguous habitat area of 1,000 acres, with adjacent uplands.

   General restoration priorities in this area include improving water exchange under the Southern Pacific railroad line to maximize tidal exchange and minimize winter flooding, and restoring sufficient acreage to tidal action to maintain regional salinity in the face of projected increases in fresh water discharge into the head of Cordelia Slough.

3. *North Central Unit.* On the western side of Potrero Hills, Hill Slough, Rush Ranch, and Japanese Point, areas provide extensive acreage of known and suspected populations of salt marsh harvest mouse, California vole, Suisun shrew, and river otter, and some very good connections to undisturbed uplands. The proximity to rapidly developing areas around Fairfield makes protection of this areas a high priority.

   A restoration priority in this area is providing habitat continuity, given the steep topography and lack of marsh on the extreme western edge of Potrero Hills. Parcels northwest of Hill Slough and west of Suisun Slough should also be protected.

4. *Northeast Unit.* On the eastern side of Potrero Hills, Nurse Slough, and Denverton Slough are extensive areas with known and suspected populations of salt marsh harvest mouse, California vole, Suisun shrew, and river otter, and excellent connections to uplands, both in Potrero Hills and on Bradmoor Island. Ideally, this unit would be extensive enough to connect to the North Central Unit with a continuous habitat band along the southern side of Potrero Hills — this might require habitat protection on the extreme northern side of Grizzly Island. As with the North Central Unit, development pressures in adjacent areas make this a high-priority area.

   The channel water in this area has relatively low salinity. Therefore, a restoration priority is project design that encourages moderate salt accumulation in marsh soils.

5. *Southeast Unit*. On the eastern side of Montezuma Slough are known populations of most target mammals and good connections to adjacent uplands. Development pressure is lower here than in the more northerly units, although a serious future concern. The Montezuma Wetlands Project proposes restoration of over 1,000 acres of potentially high-value habitat in this area, using a combination of dredge spoils and natural sedimentation.

In addition to potential difficulties with toxics in the sediment, restoration challenges include low channel salinities and subsided sites, and steep slopes on the western flank of Kirby Hill, which apparently rule out a continuous habitat corridor east of Montezuma Slough. Restoration priorities should include encouragement of desired vegetation, and restoration and protection of appropriate habitat on the eastern side of Grizzly Island.

6. *Channel Islands Unit.* Most of Chipps, Ryer, and Roe islands currently appears to be good habitat for target mammals. While adjacent uplands are lacking, and channel salinity is low, the large acreage and near-complete protection from development pressure (Ryer and Roe, in particular, are owned by the Navy) makes these good candidates for protection and enhancement, though with lower priority than the units described above.

B. Provide for habitat corridors for small mammal movement between the units described above. While potential connections have already been described between the North Central and Northeast, and Northeast and Southeast units, it is less clear how best to connect the Southwest and North Central population centers. If extensive areas of mammal habitat are protected in the Cordelia Slough area, than these can potentially serve as stepping stones. Other options include Joyce Island or the northwestern side of Grizzly Island, either of which would require extensive new levees or the restoration of tidal marsh vegetation on large parcels.

C. Enhance the management of the Grizzly Island complex, including Wheeler Island, Simmon's Island, and Van Sickle Island, for mammals. Large-scale tidal restoration of the complex is not considered essential for preservation of the target species, and it is not clear that it would be desirable, given the subsidence and lack of adequate uplands on the islands, and the freshness of the surrounding water. On the other hand, relatively small-scale projects to enhance halophytic vegetation on site, to promote habitat corridors as discussed above, and/or to restore specific areas to tidal action should be supported.

II. **Contra Costa North Shoreline Minor Subregion**

A. Protect and enhance existing habitats and population centers, including restoration of tidal action as feasible. The degree of industrial, military, transportation, and residential development adjacent to these marshlands is high. On the other hand, the early development of industrial and military facilities on rocky zones along the coast probably discouraged residential expansion or management of wetlands for agriculture or waterfowl; therefore, the mammal populations of many of these marshes are high.

1. *West (Peyton/Pacheco) Unit.* Abundant populations of salt marsh harvest mouse and river otter are known from the marshlands between I-680 and Pacheco Slough; adjacent uplands are available with minimal disturbance; and the mean annual salinity is relatively high. Therefore, the potential for maintaining viable mammal populations justifies additional efforts to restore the undeveloped diked marshes in the vicinity to tidal action.

2. *West Central (Point Edith/Hastings Slough) Unit.* Abundant populations of salt marsh harvest mouse are known or suspected in much of this area, and the presence of ornate shrew is suspected. Some adjacent upland is available, salinities are moderate, and extensive restoration efforts are underway. Restoration priorities include responding to subsidence, rail lines with insufficient drainage, buried contaminants, and flood risk to adjacent structures.

3. *East Central Unit.* The area from Port Chicago (Seal Bluff) to the Pittsburg power plant contains known and suspected populations of salt marsh harvest mouse, California vole, ornate shrew, and river otter. Protection from further development is strong, adjacent uplands are available, residential impacts are slight, and the feasibility of connecting the marshes is high.

Constraints to restoration, which should be addressed, include buried contaminants, railroad lines, and existing land use (industry and a harbor). Protection of existing marshlands and adjacent uplands and buffers is important throughout the unit. In addition, tidal enhancement is feasible in areas, and where infeasible, improved water management can improve vegetation.

4. *East Unit.* A relatively small area of shoreline between Pittsburg and Antioch support known populations of salt marsh harvest mouse, California vole, and ornate shrew. While these populations should be protected, extensive enhancement is not justified, given the small acreage and the lack of adjacent undeveloped land.

5. *Channel Islands Unit.* Brown's and Winter islands are both large expanses of potentially good habitat for salt marsh harvest mouse, California vole, and ornate shrew, with low development risk. Brown's Island is undiked and has not subsided; protection is probably adequate. Winter Island is diked and managed for waterfowl. Given its subsidence, the lack of uplands, and the freshness of the surrounding waters, enhancement for halophytes is a higher immediate priority than tidal restoration.

B. Provide for habitat corridors for small mammal movement between the units described above. The Peyton and Point Edith units are probably well-enough connected as long as the marshlands at the mouth of Pacheco Slough are protected. The most important corridors to promote would connect the Point Edith and East Central Units, across the relatively sparsely developed tidal area of the Concord Naval Weapons Station. In addition, the connection should be improved within the East Central Unit between the marshlands west and east of the General Chemical plant. The connections north of McAvoy Harbor and across Mallard Slough should be protected. Connecting the marshes west and east of Pittsburg is not feasible.

**III. Carquinez Strait Minor Subregion**

While mammal populations are known from Southampton and Martinez Waterfront marshes, neither area is large enough and free enough of development to justify elaborate efforts to promote mammals. In addition, the steep rocky shorelines and the railroad along the Contra Costa shore argue against creation of wetland habitat corridors along the Strait.

## North San Francisco Bay Region (San Pablo Bay)

The North Bay region begins on the western side of the Bay at Point San Pedro in Marin County and extends north to include the Petaluma River and associated marshes north to the City of Petaluma. This region extends east to include the Napa River and associated marshes south of the City of Napa. Turning south, the region includes the lands west of the Carquinez Bridge and continues to Point San Pablo. The majority of the development in this region is concentrated along the Highway 101 corridor, in Vallejo at the mouth of the Napa River, and in Contra Costa County. This region has a large amount of undeveloped land and has the greatest opportunities for marsh restoration of any of the Bay regions.

After a great deal of discussion among the members of the MARI team, it was decided that we would designate only parcels we believed were the minimum necessary to provide for the needs of the target species. Since the majority of the mammalian target species inhabit tidal salt marsh, parcels designated for restoration are generally adjacent to San Pablo Bay or to tidally influenced reaches of rivers that flow into the Bay. Undesignated parcels on our maps were left to allow the other focus teams flexibility to provide for the needs of their target species. Although we recognize the value of these undesignated parcels to the overall health of the North Bay marshes, we felt that specific habitat designation by the MARI team was not necessary to achieve our goals.

The areas we selected in North Bay were based upon several assumptions that the MARI team believed would best preserve the target species in perpetuity. A basic assumption that guided the recommendations was that large continuous patches of tidal salt marsh with existing populations of salt marsh harvest mouse should be preserved. Where an existing salt marsh is insufficient to support viable mouse populations in perpetuity, it should be expanded to provide a large block of tidal marsh. Parcels were selected that would be large enough to develop the dendritic slough channel pattern and salt pans characteristic of historic bay marshes. The wetlands should be large enough to require little or no maintenance once restored. Although corridors connecting the various tidal salt marsh blocks were discussed, it was decided that, in North Bay, the need for corridors was not paramount due to the large amount of existing salt marsh and the potential for restoration of large self-sustaining blocks. Small, isolated wetlands in areas where a large block of tidal marsh does not exist and could not be restored were not recommended to be connected with corridors because we felt they were too small, even with connections, to sustain salt marsh harvest mouse populations in perpetuity. Additional considerations included the current land use and amount of existing infrastructure in the area, resulting in only areas that could reasonably be restored to tidal action being recommended for restoration. The presence of adjacent uplands or the potential to create and preserve adjacent upland refuge habitat was another important consideration for the team when selecting the blocks of salt marsh for preservation and/or restoration. The transition habitat that provides refugial habitat during high tide events is extremely important to the long-term viability of a tidal salt marsh for small mammal species. This upland transition/buffer habitat can also provide seasonal wetland values for other target species, and its value cannot be overstated. We also included parcels that were already being restored or would soon be restored (Sonoma Baylands and Tolay Creek wetlands) whether we believed these parcels to be essential to the area or not.

Originally, the North Bay was divided into five separate areas that we believe could independently sustain viable populations of salt marsh harvest mouse, Suisun shrew, and San Pablo vole. The five areas were, beginning in Marin County and moving around the North Bay in a clockwise direction:

1. The Hamilton/Bel Marin Keys wetlands, an area roughly north of Las Gallinas Creek to Novato Creek.
2. The Petaluma Marshes extending from the mouth of the Petaluma River north to just south of the City of Petaluma on both sides of the Petaluma River.
3. The south Napa Marshes extending from Sonoma Creek to the Napa River and bounded to the north by Napa Slough, South Slough, and Dutchman Slough.
4. The Napa River wetlands including Coon Island, Fagan Slough wetlands, and the lands on the west side of the Napa River south of the Newport North development.
5. The Point Pinole wetlands extending from Wilson Point southwest around Pinole Point to Point San Pablo.

After discussions with several of the other focus teams, particularly the Other Baylands Birds team and the Shorebirds and Waterfowl team, we modified a portion of one of the areas — the south Napa marshes, to preserve specific parcels with high existing values for several bird species. Pond 1, Pond 1A, and the West End Club originally proposed for restoration to tidal action are now recommended for preservation. The new description for the Napa marshes now includes the existing marshes south of Highway 37 between Sonoma Creek and the Napa River as well as the Cullinan Ranch and Guadalcanal Village north of Highway 37. In addition, Pond 3 (Knight Island), Pond 2A (south half of Pond #2), and Pond 4 (the southern half of Russ Island) are now included with these wetlands. The result of this modification is that the south Napa wetlands and the Napa River wetlands are connected and are combined into one large tidal wetlands complex, leaving four, not five distinct areas.

The Hamilton/Bel Marin Keys wetlands currently support good pickleweed marsh outboard of the levees at the south end of Hamilton Army Air Base (AAB) property and the Silvera and St. Vincent properties. These marshes are valuable and must be preserved. To ensure the long-term viability of salt marsh harvest mice in Marin County, however, it will be necessary to expand this wetlands complex and provide for areas of upland refugial habitat. The Hamilton AAB site is being considered for restoration to tidal action as part of the base closure/clean up process. The western edge of Hamilton should be restored to an upland buffer that gradually changes from tidal marsh to the existing inboard levee. The adjacent State-owned antenna field could be included as part of the Hamilton AAB tidal restoration. There is currently little or no marsh outboard of the levee along most of the Bel Marin Keys property. Existing mouse populations around the mouth of Novato Creek are isolated from populations immediately to the south. The restoration of at least the eastern portion of the Bel Marin Keys site would provide continuous tidal marsh extending from Las Gallinas Creek to Novato Creek. Upland buffer should also be provided along the western edge of the Bel Marin Keys parcel as a necessary component of the restoration.

The marshes along the western side of the Petaluma River north of San Antonio Creek are the largest block of tidal salt marsh remaining around San Francisco Bay. Although these marshes have been ditched for mosquito abatement purposes, and levees constructed along portions of the eastern edge for an unrealized filling of the marsh, this wetland complex remains the least disturbed tidal marsh in North Bay. The restoration of tidal wetlands south of San Antonio Creek to the mouth of the Petaluma River is considered vital to the future health of the salt marsh harvest mouse populations in this area and important to the vitality of the marsh system as a whole. We recommend restoration of significant amounts of former tidal marsh on the eastern side of the Petaluma River to create a block of tidal marsh large enough to provide for genetic variability and population stability of salt marsh harvest mouse populations in this area.

The lands along the eastern side of the Petaluma River should provide a transition from tidal wetlands into uplands resulting in needed refugial habitat. It is not possible to create this upland habitat on the western side due to the existing railroad line at the western boundary of the existing wetlands. Another component of this marsh complex extends from the mouth of the Petaluma River to Tolay Creek. Portions of this area are already tidal marsh or are being restored to tidal action (Sonoma Baylands and Tolay Creek south of Highway 37). However, the most benefit will be realized when the steep levees that presently separate the tidal marsh from adjacent lands are removed and a buffer established that gently slopes from salt marsh to upland.

The Napa marshes include the existing tidal marshes south of Highway 37 between Sonoma Creek and the Napa River. Portions of these marshes around Mare Island support some of the highest densities of salt marsh harvest mice in the entire North Bay. For this reason, some of the former military lands of Mare Island are proposed for restoration to tidal action. The remainder of the Napa marshes wetlands are on the western side of the Napa River and extend upriver to just south of the City of Napa. Much of this acreage is former Cargill Salt Division salt ponds presently owned by the California Department of Fish and Game (CDFG). CDFG currently has plans to restore a number of the salt ponds to tidal action, as does the U.S. Fish and Wildlife Service on the Cullinan Ranch, which it owns. The restoration of the parcels along the western side of the Napa River will provide a solid tidal salt marsh block on the northeastern side of North Bay and up the lower Napa River that should support healthy populations of salt marsh harvest mouse independent of other populations.

The Point Pinole wetlands constitute the best opportunity to support a viable population of salt marsh harvest mouse in the East Bay. This area is also extremely important because the San Pablo Creek marsh is the only locality for the endemic San Pablo vole. Restoration and enhancement of this area will protect this subspecies and should provide sufficient habitat for its continued survival. The possibility of restoring large tracts of tidal salt marsh in the East Bay is limited due to extensive fill and development. Although a number of small, healthy unconnected patches of wetlands can be found along the Contra Costa shoreline in North Bay, we believe that they are too small and too isolated for long-term mouse viability. The MARI team recognizes that this area is considerably smaller than the other three recommended areas and may be too small to support target species without some maintenance efforts in the future. However, these wetlands represent the best opportunity to preserve/restore a block of tidal marsh with uplands on the eastern side of the Bay in this region. In addition to the four major wetland complexes recommended in North Bay, there are a number of specific areas that our Focus Team believed merited special protections:

1. The marshes near San Clemente Creek at Corte Madera and south of San Rafael Creek in Marin County are important because they support a small population of the southern subspecies of salt marsh harvest mouse. This is the only area where this subspecies is known to occur north of the San Mateo Bridge and is the northern-most extent of the range of this subspecies.
2. The Corte Madera Marsh is also important because it serves as a harbor seal haul-out and pupping site. This site has deteriorated over the past few years from shoreline erosion and would be greatly enhanced if wave action were reduced and the haul-out site stabilized.
3. There is a small area near Sears Point that supports a healthy population of red-legged frog that warrants protection and enhancement.
4. The slough channels throughout the marshes and salt ponds between Sonoma Creek and the Napa River provide habitat for river otter and the enhancement of adjacent marshes could benefit this species.

## Central San Francisco Bay Region

The Central Bay region extends on the western side of the Bay from Point San Pedro (Marin County) in the north to Burlingame (San Mateo County) in the south. On the eastern side, it begins at Point San Pablo (Contra Costa County) and goes south to Mulford Landing, just north of the flood control channel in San Lorenzo (Alameda County). Thus, the northern boundary coincides with the narrowest stretch of San Pablo Strait, while the southern boundary is an arbitrary line drawn about 4 1/2 miles north of the San Mateo Bridge. The Bay margins in this region carry the highest human densities in the entire San Francisco Bay Area, and correspondingly sustain the greatest anthropogenic impacts.

Historically, the Central Bay region had only 7% of the estimated acreage of tidal marsh in the Bay system, although it had 27% of the intertidal mudflats (EcoAtlas version 1.021). Proportionally, it has suffered greater losses in both of these habitat categories than has the Bay as a whole: 94% of its tidal marshes (82% in the entire Bay), and 71% of the mudflats (59% in the entire Bay) (EcoAtlas version 1.021). Those remaining habitat patches are small and widely scattered. A few hundred acres of tidal marsh pans are estimated to have been present originally within the tidal marsh habitat. This represents 2.5 to 4.5% of the total estimated acreage of pans in the Bay system (EcoAtlas version 1.50). Presently, no significant pan habitat remains in the Central Bay region.

The habitats of greatest concern to the MARI team are the tidal marshes, adjacent uplands (including freshwater sites), and riparian corridors. In addition, salt (intertidal) pans probably represented unique habitat for some terrestrial invertebrates. Because these critical habitats survive in Central Bay only in small, isolated fragments, we have few site-specific recommendations for this region. Our general recommendations are:

1. In general, the remaining wetland fragments are too small and isolated to support secure source populations for our target species.
2. Surviving wetlands should be protected and where possible enhanced, because (a) they serve as important stepping stones for the movements of organisms within the Bay system; (b) such sites can at least temporarily support populations of the target species and hence contribute to overall metapopulation survival; (c) small populations can contribute to maintaining genetic variability within the Bay system and as refuges from unanticipated disasters in the source populations (disease, predation, pollution); (d) even small wetlands can serve as temporary feeding or resting sites for more mobile species (such as birds); and (e) Central Bay wetlands are important esthetic and educational resources.
3. When opportunities arise, enhancement and enlargement of existing wetlands should be pursued. An example of such an unanticipated opportunity is the current 71.5-acre restoration project in San Leandro Bay adjacent to Arrowhead Marsh (Martin Luther King, Jr. Regional Shoreline Wetlands Project). Significantly, this project will create two islands and an adjacent uplands buffer zone. The marsh-upland ecotone has all but vanished from the Bay Area, and yet is of critical

importance to a number of our target species. Other feasible enhancements include the cleaning up of marshes (e.g., Emeryville Crescent), the provision of corridors to connect small existing wetlands (e.g., East Bay Shoreline Park in Richmond and Albany), and the restoration of creeks flowing into the Bay.

**Site-specific recommendations:**

1. A small existing freshwater marsh in Millbrae along the western side of the San Francisco airport should be preserved, and if possible, enhanced for the benefit of the San Francisco garter snake and red-legged frog. Enhancements should include expansion of adjacent upland habitat.
2. The Strawberry Spit area in Richardson Bay (Marin County) has been used as a haul-out site for harbor seals, and this could be enhanced by reducing human disturbance.
3. The Corte Madera marshes could be greatly increased in value if upland buffers were established on its periphery. It can also serve as a haul-out and pupping site for harbor seals.
4. The San Rafael Bay Marsh should be maintained as a source habitat for other wetlands, current or future, along the Marin County bay edge.
5. The Castro Rocks near the Richmond-San Rafael Bridge are an important haul-out and pupping site for harbor seals, and should be protected.
6. A small marsh (now in private ownership) at the end of the Tiburon Peninsula (Keil Pond, near Bluff Point) should be preserved and enhanced for the benefit of red-legged frogs.
7. We support the development of tidal marshes in association with Crissy Field in San Francisco, and any other similar projects within the city.
8. It would be highly desirable if the existing Arrowhead Marsh (Alameda County) could be connected to upland habitat while preferably maintaining its isolation from red fox and other predators.

## South San Francisco Bay Region

We subdivide the South San Francisco Bay region into seven sectors starting from the northeast and swinging around to the northwest aspect of the South Bay: (1) (Landings Sector) the area from Highway 92, i.e., the San Mateo Bridge highway, north to the San Leandro Marina or Mulford Landing and named after Johnson, Hayward, and Robert's Landings along its edge, (2) (Baumberg/Alameda Flood Control Sector) the area between Highway 92 and Coyote Hills Slough, the second of the large flood control channels south of Highway 92, (3) (Coyote Hills Sector) the area between Coyote Creek Slough and Highway 84, the Dumbarton Bridge road, (4) (Refuge Central Sector) the area between Highway 84 and Mowry Slough, (5) (Alviso Sector) the area between Mowry Slough and Stevens Creek just west of Moffett Field, (6) (Palo Alto Sector) the area from Stevens Creek to Highway 84, and finally (7)(Bair/Greco Islands Sector) the area from Highway 84 to Highway 92. A simplified table follows:

| Geographic location | Name of Sector |
|---|---|
| North of Hwy. 92, East side | Landings |
| Hwy. 92 to Coyote Hills Slough | Baumberg/Alameda Flood Control |
| Coyote Hills Slough to Hwy. 84 | Coyote Hills |
| Hwy. 84 to Mowry Slough | Refuge Central |
| Mowry Sl. to Stevens Creek | Alviso |
| Stevens Creek to Hwy. 84 | Palo Alto |
| Hwy. 84 to Hwy. 92, West side | Bair/Greco Islands |

There are some important and fairly large marshes still present in South Bay. They include the string of marshes that make up the Landings Sector; the Baumberg Tract within the Baumberg/Alameda Flood Control Sector; the Dumbarton, Mowry, and Calaveras marshes in Refuge Central Sector; Bair and Greco islands in Bair/Greco Islands Sector; and to some degree the Palo Alto Educational Center Marsh in the Palo Alto Sector. Many of the marshes within the Alviso Sector, with the exception of the Calaveras Point Marsh, have been or are being converted rapidly from saline to brackish vegetation that does not support salt marsh harvest mice and to some extent either salt marsh wandering shrews or California voles. The loss of much of the Alviso Sector has resulted not only in the loss of many salt marshes, but has produced a major barrier to gene flow between the populations of mice, shrews, and voles on the eastern and western sides of the southern end of the South San Francisco Bay (hereafter, we will call it South Bay). Indications are that parts of the large Calaveras Point Marsh are also beginning to become brackish; its loss would be a tragedy because it appears to contain the largest single population of the southern subspecies of the salt marsh harvest mouse.

Aside from the few remaining large blocks, most of the tidal salt marshes of South Bay are narrow, strip marshes (many two meters wide or less) with little to no upper edge of peripheral halophytes (the escape cover salt marsh harvest mice need and without which such marshes often lose their harvest mice). The poor quality of most of the salt marshes in South Bay makes the pre-existing large marshes listed previously extremely important to the long-term survival of the southern subspecies of the salt marsh harvest mouse, especially since any long-term conversions of salt ponds to tidal salt marshes may take five to 25 years or more.

**Recommendations without major conversions of salt ponds.**

Here are our recommendations for marsh enhancement before the many salt ponds we have identified are returned to tidal action.

1. Connect the large, protected tidal or muted tidal marshes of the Landings Sector with corridors of at least 100 yards wide and composed of halophytic (salt tolerant) vegetation appropriate for the salt marsh harvest mouse and the shrews. Protect the upper edges of the present marshes, as well as corridors, if possible, with areas of marshy, ruderal, and/or grassland vegetation at least 100 yards deep to act as buffer zones for them. We think that corridors need "edges" as much as, if not more than, larger marshes.

2. Expand the areas of salt marsh within the Baumberg area within the Baumberg/Alameda Flood Control Sector by at least twice the size that is presently under restoration.

3. Enhance the Alameda Flood Control "marshes" just north of Coyote Hills Slough and running from the Bay towards the south Union City area, and then south and west towards the hill just north of the Slough and the Coyote Hills to the south of that hill, and manage them for year-round use by small rodents (not just winter flood control use). These marshes need better connections between units, and the total area of salt marsh needs to be expanded by at least one-third. We have no short-term recommendations for the salt ponds of the Coyote Hills Sector. Long-range plans involve opening some or most of them to tidal action.

4. The Dumbarton Point Marsh and the marshes along Newark Slough west of the refuge headquarters hill in the Refuge Central Sector need expansion and increased protection. Marshes along Newark Slough east of the hill, i.e., south of Thorton Avenue and west of Newark (the Jarvis Landing Area), need to be expanded and protected from urban build-out. Part of the eastern end of this area is within the City of Newark. Enhancement includes better water management, adding a 100-yard buffer of marsh or grassland vegetation and conversion of adjacent salt ponds to tidal action and connecting them to existing units wherever possible.

5. The Calaveras Point Marsh within the Alviso Sector needs to be expanded by opening the two outer salt ponds between Mowry Slough and Coyote Creek to tidal action. The Calaveras Point

Marsh extending eastward along Coyote Creek is extremely important to the harvest mouse, and the Mowry Slough marshes are important to the mouse, shrew, vole, and harbor seal.

6. The "Triangle" Marsh, north of Alviso and west of the railroad tracks and bordering Coyote Creek within the Alviso Sector, has been virtually lost to the harvest mice and shrews by the effects of brackish waters. The only salvation of this former highly productive salt marsh is saltier water. This area has almost completely turned into brackish vegetation because of non-saline sewage water entering the Bay from the San Jose-Santa Clara Water Treatment Control Plant. Many of the marshes of the Alviso Sector (Albrae Slough, Mud Slough, Upper Coyote Creek, and Artesian Slough) are similarly dependent on increased salinities for re-conversion back to saline marshes. They also need to be expanded from their present narrow, strip-like character to be of much value to mammals; however, to increase the width of these strip marshes will require the conversion of some to many adjacent salt ponds, as there is no intermediate step possible in the most southern South Bay.
7. The New Chicago Marsh, in the Alviso Sector and within the San Francisco Bay National Wildlife Refuge Complex, has some water management, but additional funding is needed for management and pump improvements. The Refuge Complex needs more biologists and better funding from the U.S. Fish and Wildlife Service, in general, to manage the enormous variety and size of their holdings, especially if many to most of the salt ponds in South Bay are eventually converted to tidal action.
8. The marshes between Charleston Slough to Cooley Landing in the Palo Alto Sector, including the Palo Alto Education Center Marsh, need more upland buffers, better protection from illegal entry, more alien predator management and better marsh corridors or connections between present marshes. Again, the 100-yard minimum rule and appropriate vegetation rule applies to both buffers and upper edges. The Palo Alto Marsh continues to change in vegetation (for the worse) and the upland edge of the marsh is very abrupt and needs modification.
9. Bair Island (Bair/Greco Islands Sector) needs to have more marsh habitat now that it looks like it will be protected.
10. The strip marsh along Ravenswood Point (Bair/Greco Islands Sector) needs to be expanded to the south by opening the adjacent salt ponds to tidal action.
11. Greco Island (Bair/Greco Islands Sector) needs better protection by opening up areas south of Westpoint Slough to tidal action.

**Recommendations for major conversions of salt ponds to tidal action.**
We think it is important to preserve, expand, and improve the existing marshes previously identified wherever and however possible. But to ensure the long-term survival of the southern subspecies of the salt marsh harvest mouse and probably the salt marsh wandering shrew and California vole in South Bay, as well as many species of birds, other vertebrates, and invertebrates, we recommend that most of the salt ponds of South San Francisco Bay be opened to tidal action. We assume commercial salt production will cease some day in the South Bay, either when the salt company stops making salt and sells its assets or if it is bought out as mitigation for other modifications within the Bay. Unless the salinity of the waters of the southern part of South Bay is increased (i.e., returned more towards historical salinity), marsh development in many of these areas will result in brackish rather than saline marshes. There are plans to open the Knapp Property, the bayward "thumb" of the former salt ponds between Alviso and Guadalupe sloughs in the Alviso Sector, to tidal action. While it will be an important conversion, it will do little by itself for the endangered and threatened small mammals of the southern end of South San Francisco Bay.

The very large tidal salt marsh complexes that will be created if most of the ponds are opened to tidal action are expected to be multiple-use, in that levees and saline pans can be left within them to support resting and feeding sites for various species of birds. Small ponds or areas of open water can be included, as long as the salinity levels of such areas of water do not have to be maintained. The large marshes can have complex shapes and surround or otherwise be integrated with other types of saline plant or water environments. What is paramount to save the various species of mice, as well as the California clapper rail, is that the new complexes be tidal salt marshes, not brackish marshes. The marshes need to be very large ones (1,000 acres or more) with extensive and wide margins of both peripheral halophytes and grassland buffers of at least 100 yards, but preferably more than 200 yards in width. And where corridors are needed to connect isolated marshes to increase the overall size of the connected marshes (such as are needed between the marshes of the Landings Sector), the corridors should be wide (at least 100 yards), be composed of appropriate salt marsh vegetation, have gently-sloping edges of approximately 100 yards, and be at least partially protected from intrusion by humans and non-native predators, such as the red fox, and be managed to control such predators on a continual and perpetual basis. We recommend large corridors be established or maintained between large marshes, but that corridors much less than 100 yards be established or maintained between small marshes of one or two to ten acres. The wider the corridor and the more appropriate the vegetation, the more likely the corridor will facilitate movement between marshes, but in the short run, just connecting small marshes is a very important first step. We recommend smaller connections, but think that the recovery effort should proceed beyond them as more land for both corridors and marshes becomes available.

**Studies needed prior to major salt pond conversions.**

We think it is imperative that a series of studies be carried out before many of the large salt ponds, especially those in the most southerly and most subsided portion of South Bay, are breached and returned to tidal action. These studies need to identify such things as how long it will take for restoration to occur in various parts of South Bay, and how the ponds and levees can be engineered to provide the greatest benefit to the most species and at the lowest maintenance costs. We need to determine whether mudflats and ponds will be created in ways to help support various species of waterfowl and wading birds, as well as other vertebrate species, many of which are dependent on and often endemic to the tidal marshes of San Francisco Bay.

More money needs to be provided to the California Department of Fish and Game (CDFG) to allow them to actively manage the salt ponds and newly developing marshes of the San Pablo Bay. The CDFG can provide valuable information about marsh restoration around the entire Bay if they can proactively manage those marshes. Several other marshes are being restored in South San Francisco Bay, i.e., parts of the Baumberg Marsh on the eastern side and several marshes between Charleston Slough and Highway 84 on the western side. None of these “experiments” are in the deeply subsided southern tip of the Bay. Marsh restoration in this latter area needs to be modeled by physical and biological scientists working together.

South San Francisco Bay was once filled with marshes and mudflats, as well as smaller salt pans and tidal ponds. We think it should be returned to that general condition, but not before studies are done to model the effects of converting salt ponds to tidal action, especially in the most subsided portions of the Bay. Such studies need to be carried out soon. And increased funding sources need to be identified, as the management of South Bay will become more costly in the future no matter what scenario takes place.

# Shorebirds and Waterfowl Focus Team

## Recommendations

This paper summarizes the Shorebirds and Waterfowl Focus Team's habitat recommendations. Included are our focus team tenets, some brief information regarding each of the key species, and habitat recommendations. We also have included some of the research needs that we believe need to be addressed. For additional information regarding the shorebirds and waterfowl species that utilize the baylands and adjacent habitats, please refer to the individual species narratives that will be compiled in the Goals Project's Species and Community Profiles Report.

## Introduction

Shorebirds and waterfowl are characterized by their mobility and strong dependence on aquatic and wetland habitats. The San Francisco Estuary is renown as a major North American refuge for many species of shorebirds and waterfowl during their migration and wintering (August through April) periods, and it provides breeding habitat during the summer for a few species (e.g., snowy plover and mallard). The Estuary is recognized as a Western Hemisphere Shorebird Reserve Network site of international importance for more than a million shorebirds and as the winter home for more than 50% of the diving ducks in the Pacific Flyway (Accurso 1992), with one of the largest wintering populations of canvasbacks in North America.

The current populations of shorebird and waterfowl species are a reflection of alterations in the development of the Estuary (see Nichols et al. 1986) which may have resulted in increased numbers of some of these species while other populations have decreased. We do not know how many distinct populations depend on the habitats of this ecosystem and contribute to diversity and stability of continental populations. For example, northern pintails in South Bay have little interchange with birds in the Central Valley, and they may represent a distinct subpopulation (Miller, pers. comm.). Western sandpipers show strong site fidelity to small areas in South Bay and do not leave that subregion during the winter (Warnock and Takekawa 1996).

The loss of more than 90% of the wetlands in the Estuary have greatly altered the ecosystem, which has resulted in the proposed listing or protection of more than one hundred species, many associated with tidal salt marsh habitats. Many projects to rehabilitate or restore wetlands in the Estuary, especially tidal salt marsh, have been proposed to benefit listed species. However, results of wetland restoration efforts are highly variable (Race 1985), and the efforts to complete successful salt marsh restorations for certain species may come at the expense of shorebird and waterfowl populations that use the existing habitats, including salt evaporation ponds. We lack specific information relating abundance of current populations to the amount of their habitats (for more specific information, see the individual narratives). Thus, we are unable to predict how reduction of present wetland habitat used by these species may affect their populations. We advise care in implementing large scale changes and encourage further study of critical habitats and better delineation of the regional populations present in the ecosystem.

## Focus Team Principles

1. There should be no net loss of shorebird and waterfowl resources and populations in the ecosystem.
2. The San Francisco Bay ecosystem has been altered, and we will not be able to return it to historic conditions, nor is that necessarily desirable. Some habitats have actually increased from historic levels in some areas.

3. Shorebirds and waterfowl species are unlikely to benefit from tidal marsh conversions when the conversion is from another wetland type. As conversions do occur, we must enhance the remaining habitats for shorebirds and waterfowl.
4. Engineered tidal marsh and non-tidal wetland and salt pond restorations have unpredictable outcomes. In fact, this field is very young and few restorations have been deemed to be successful.
5. No large conversions should be undertaken without pilot projects in advance. These pilot projects should include testing habitats and elements of habitats which replace lost habitat values for shorebirds and waterfowl.
6. San Francisco Bay is a crucial area within the Pacific Flyway. The region is as important to continental shorebird and waterfowl species, as are specific parcels to endemic populations within the Estuary.
7. Critical habitats for shorebirds and waterfowl include tidal flats, sparsely vegetated wetland elements (levees, islets, beaches), managed wetlands, salt evaporation ponds (which are not inherently bad as wildlife habitat and have increased some species while preserving areas from development), large, persistent seasonal ponds with lots of open water, and inactive salt ponds.
8. Managed wetlands (water control, predator control, muting tidal flows) may be more beneficial than natural wetlands in some cases.
9. Disturbances and flight obstructions (e.g., power lines) between feeding and roosting areas should be minimized.
10. Seasonal wetlands have important habitat values for shorebirds and waterfowl, but are poorly quantified or understood. More research is needed to clarify how the habitats are used and how much is needed for sustaining populations.

## Shorebirds

Shorebirds are aquatic birds with cylindrical bills varying considerably in length and curvature among the 31 species encountered regularly on San Francisco Bay. These species, which range from the sparrow-sized least sandpiper to the duck-sized long-billed curlew, feed primarily on invertebrates obtained on tidal flats, salt ponds, managed wetlands, and other habitats. Recent survey information collected by Point Reyes Bird Observatory indicates that San Francisco Bay supports very high numbers of shorebirds of most species during migration and winter, compared to other wetlands along the U. S. Pacific Coast. San Francisco Bay has been recognized as a site of hemispheric importance to shorebirds by the Western Hemisphere Shorebird Reserve Network.

### Key Species

We selected seven "key" species as a basis for defining regional wetland habitat goals for shorebirds and provide detailed information on these species in the species accounts. Five species represent groups of shorebirds that use specific habitat types, one (snowy plover) is federally listed as a threatened species, and one (red knot) is especially dependent on San Francisco Bay as a wintering area.

**Western Sandpiper (*Calidris mauri*) —** The western sandpiper represents small sandpipers and plovers, including least sandpiper, dunlin, and semipalmated plover. The western sandpiper is the most abundant shorebird in the Bay at all seasons. The least sandpiper and dunlin are also abundant. All four species breed in Arctic or sub-Arctic regions and occur in San Francisco Bay both as migrants and winter residents. On the Bay, tidal flats are their most important feeding habitat. At high tide these birds are forced from the tidal flats to roosting and auxiliary feeding areas including salt ponds, managed wetlands, and seasonal wetlands.

**Marbled Godwit (*Limosa fedoa*) —** The marbled godwit was the selected representative for the large sandpipers and plovers which include willet, long-billed curlew, whimbrel, black-bellied plover and American avocet. These species breed in Arctic, sub-Arctic, or temperate regions and occur in San Francisco Bay both as migrants and winter residents. Hundreds of avocets also breed in San Francisco Bay, primarily in salt ponds. Tidal flats are the most important foraging habitat for all these species except, possibly, the avocet which also forages extensively in salt ponds. At high tides these birds move from the tidal flats to roost in salt ponds, managed wetlands, seasonal wetlands, and other habitats above the high tide line.

**Red Knot (*Calidris canutus*) —** Although not abundant, the red knot was selected as a key species because San Francisco Bay is one of only three wetlands on the Pacific coast of North America supporting as many as several hundred wintering individuals. Red knots are Arctic breeders which occur in the Bay during migration and in winter. They often associate with black-bellied plovers and short-billed dowitchers, but are more restricted than these species in their distribution within the Bay. Tidal flats of Central Bay and South Bay are the knots' primary foraging habitats and salt ponds serve as the primary high tide roosting habitat.

**Long-billed Dowitcher (*Limnodromous scolopaceus*) —** The long-billed dowitcher was selected because of its use of fresh and brackish habitats. In addition to tidal flats, managed wetlands and seasonal wetlands are important foraging habitats for long-billed dowitchers and its associates. The other species associating with long-billed dowitchers in managed and seasonal wetlands are greater and lesser yellowlegs, dunlin, black-necked stilt, and American avocet. This group of shorebirds was singled out as potentially deriving more benefit from managed brackish water wetlands and seasonal wetlands than other shorebirds. Managed wetlands also are used by two members of the group, black-necked stilt and American avocet, for nesting. Although not closely associated with any of the above species, because of its more solitary nature and preference for more vegetated habitats, the common snipe is the other shorebird which makes heavy use of the managed and seasonal wetlands as foraging and roosting habitat during winter.

**Black Turnstone (*Arenaria melanocephala*) —** The black turnstone represents shorebirds that make the most use of gravel to rocky intertidal habitat. Also included in this group are ruddy turnstone, American black oystercatcher, wandering tattler, surfbird, and spotted sandpiper. None of these species are abundant in the Bay, numbering at most in the tens to low hundreds of individuals at any time. Small numbers of American black oystercatchers regularly nest in the Bay, as does an occasional pair of spotted sandpipers.

**Snowy Plover (*Charadrius alexandrinus nivosus*) —** The Pacific Coast population of western snowy plover was selected as a key species because it is federally listed as a threatened species. About 10% of the listed population has been recorded breeding on San Francisco Bay, primarily in South Bay salt evaporation ponds. Although there is no evidence this species bred in the Bay prior to the construction of the evaporation ponds, playas that existed on the inboard margins of the salt marshes may have supported nesting snowy plovers.

**Wilson's Phalarope (*Phalaropus tricolor*) —** The Wilson's phalarope was chosen to represent those shorebirds that, in addition to the snowy plover, are most dependent on the salt ponds for foraging habitat. Some members of this group, including the Wilson's and red-necked phalarope, occur only during spring and fall migration, while the others, including black-necked stilt and American avocet, are present year-round. The latter two species also nest in the Bay, primarily in South Bay salt ponds, but also in other areas of ponded water such as the managed wetlands of Suisun Bay. Surveys conducted by the U.S. Fish and Wildlife Service indicate that occurrence in salt ponds by these species is related to salinity, with the highest use by foraging stilts and phalaropes in ponds with salinities ranging from 130–180 ppt. Anecdotal historical information suggests that numbers of American avocets, black-necked stilts, and Wilson's phalaropes have increased significantly since salt pond construction.

**Habitat Considerations**
Except for anecdotal information suggesting an increase in use of the Bay by shorebird species using salt ponds as their primary foraging or breeding habitat, there is no historic information on changes in abundance of shorebirds in the Bay during the past 150 years when most human-induced habitat alterations have occurred. The most recent mapping of historic and current Bay habitat by the San Francisco Estuary Institute (SFEI) indicates that tidal flats outboard of salt marsh have increased in the north and south subregions of the Bay, but that the total amount of tidal flat has decreased in all subregions, primarily due to loss of tidal flat along slough channels in salt marsh. Since the majority of the shorebirds in the Bay use tidal flat as their primary foraging habitat, foraging conditions in the Bay may have declined for these species — unless gains in secondary foraging habitats, such as salt ponds and managed wetlands, have compensated for the tidal flat losses. Thus, the shorebird populations in San Francisco Bay may have declined commensurably.

For the majority of shorebirds that forage primarily on tidal flats, loss of subsidiary foraging areas, such as salt ponds and managed wetlands, might be mitigated (by an unpredictable degree) by creating wide, gently-sloped tidal flats along large channels in restored tidal marsh. Tidal salt marsh and slough channels do not, however, provide high tide roosting habitat for most shorebird species, which require barren to sparsely vegetated sites above the high tide line. Thus, suitable roosting areas will need to be constructed to replace roosting areas that are converted to tidal marsh. Roosting areas must be in reasonable proximity to tidal flat foraging areas.

For the salt pond specialists, substantial areas of salt pond habitat should be maintained in the northern and southern regions of the Bay. If portions of the salt pond systems of the north and south regions of the Bay are converted to tidal marsh and managed salt ponds, it will not be feasible to set aside ponds with important shorebird habitat in a piecemeal fashion. Instead smaller salt pond systems should be retained and re-engineered to produce salinities and water depths most favorable to shorebirds and the other aquatic species targeted for protection. Low, wide, barren to sparsely vegetated internal levees with fine scale topographic relief should be incorporated into the pond design as nesting and roosting substrate. In addition, salt marsh restoration efforts should attempt to re-create playas that occurred in historic salt marshes.

Since the success of marsh restoration efforts are likely to be highly unpredictable and the value of slough mudflats and salt marsh playa for shorebirds is not well understood, incorporation of these habitats into restored marshes should not be counted as replacement habitat for shorebirds. Further research must be undertaken to estimate the amount of salt pond habitat that should be managed for shorebirds and other target species. The maintenance of at least the current numbers of shorebirds relying extensively on salt pond habitat will require an adequate acreage of suitable ponds for 25,000 wintering American avocets, 5,000–7,000 wintering black-necked stilts, tens of thousands of migrating Wilson's and red-necked phalaropes in fall, and 500 breeding snowy plovers.

## Waterfowl
The San Francisco Bay region is identified as one of the 34 waterfowl habitat areas of major concern in the North American Waterfowl Management Plan (U.S. Fish and Wildlife Service 1989). More than 30 species of waterfowl are found in the San Francisco Bay ecosystem. These species are commonly divided into dabbling ducks, which feed at the surface or in shallow water to the depth of their body length, diving ducks, which forage underwater to 5 m in depth, and swans and geese, which feed on plants by grubbing in sediments of wetlands or fields. Mid-winter waterfowl surveys conducted by the U.S. Fish and Wildlife Service on San Francisco Bay and in the Delta include more than 700,000 waterfowl, and surveys of the open bays and salt ponds (Accurso 1992) include more than 300,000 individuals, a 25% decrease from the earliest surveys in the 1950s. In 1988–1990, dabbling ducks comprised up to 57,000 of the waterfowl in the open bays and ponds of the Estuary, while diving ducks comprised up to 220,000 of the total. For this review, we selected six species as representative taxa of the waterfowl and the habitats they use in the San Francisco Bay ecosystem.

**Northern Pintail (*Anas acuta*) —** The northern pintail historically has been the most common dabbling duck in the ecosystem. Continental population declines have been severe, but even larger declines (90% in Suisun

Marsh) have been recorded in the San Francisco Bay region. In addition, birds in the South Bay subregion may represent a distinct population that interchanges little with birds in the Central Valley (Miller, pers. comm.). Peak numbers usually occur in October when dabbling ducks account for 50% of the waterfowl in the open waters of the San Francisco Bay. Nearly 9,000 northern pintails have been reported in October, with 5,000 ducks observed in mid-winter; maximum counts have exceeded 12,000 individuals. Pintails use a wide variety of habitats, including managed marsh, seasonal wetlands, open bay, and salt ponds. Species commonly found in similar habitats are green-winged teal (*A. crecca*), the northern shoveler (*A. clypeata*), and American wigeon (*A. americana*). American wigeon peak abundance includes 6,000 individuals or 1–2% of waterfowl in the open bays and salt ponds, but northern shovelers are the third most abundant species in the open bays and represent 13% of the waterfowl. Total dabbling ducks peak at over 50,000 birds, and represent 8–30% of total waterfowl.

**Mallard (*Anas platyrhynchos*) —** Mallards are dabbling ducks with large economic and recreational importance as a hunted species and are commonly found in managed marshes. The mallard was selected as a representative of dabbling ducks such as Cinnamon teal (*Anas cyanoptera*) and Gadwall (*Anas strepera*) which migrate to the San Francisco Bay ecosystem during the winter. Gadwall numbers peak at 3,000 individuals, <1% of the waterfowl in the Estuary (excluding Suisun Marsh). All three of these species represent resident breeding populations in the San Francisco Estuary as well. The largest population of mallards occurs in the Suisun Marsh subregion. Mallards have also been recorded as the most abundant dabbling duck in diked baylands of the San Pablo Bay and South San Francisco Bay subregions, most often using seasonal wetlands habitats and low salinity salt ponds.

**Canvasback (*Aythya valisneria*) —** The canvasback is a diving duck that forages on aquatic plants or benthic invertebrates in mouths of rivers or channels, on large wetlands, or in brackish marshes. Sixty thousand individuals were counted in the mid-1960s, though historic populations were thought to be much higher. While the continental population of canvasbacks has not increased greatly in the last 20 years, based on mid-winter surveys (U.S. Fish and Wildlife Service 1955 – 1998) its population in the Estuary has continued to decline. However, San Francisco Bay supports the largest population of canvasbacks (nearly 30,000 birds) on the Pacific Flyway and represents one of the three largest wintering areas in North America. Associated species that use similar habitats in the Estuary include: common goldeneye (*Bucephala clangula*), greater and lesser scaup (*A. marila* and *A. affinis*), and very small populations of redhead (*A. americana*) and ring-necked ducks. San Francisco Bay is a major wintering area for scaup which have shown an unexplained continental decline in the past decade. Scaup comprised more than 40% of the open bay and salt pond waterfowl counted (Accurso 1992), up to 140,000 birds.

**Ruddy Duck (*Oxyura jaimaicensis*) —** The smaller diving ducks of the Estuary include the ruddy duck and bufflehead (*Bucephala albeola*), which use a variety of managed marsh areas and salt ponds in the baylands. The ruddy duck is widespread, but the population found in the San Francisco Bay ecosystem during the winter is one of the largest in North America. The maximum population has been estimated at about 28,000 birds. It is the fourth most abundant waterfowl species in the Estuary, representing 7–8% of the total. As many as 7,000 bufflehead also are found in the Estuary.

**Surf Scoter (*Melanitta perspicillata*) —** Surf scoters are the least studied of the North American waterfowl. San Francisco Bay appears to be the most important inshore habitat in the eastern Pacific, south of the Straits of Georgia and Puget Sound. This species is representative of sea ducks that primarily use deeper, open-water, marine habitats. Associated species are white-winged scoters (*M. fusca*), black scoters (*M. nigra*), and red-breasted mergansers (*Mergus serrator*). Surf scoters are the second most numerous species in the ecosystem, with estimates as high as 73,000 birds in 1991 (Trost 1997, unpublished data).

**Tule Greater White-fronted Goose (*Anser albifrons gambeli*) —** Tule geese were chosen as the key species to represent the geese and swans group, which also includes Pacific greater white-fronted goose (*Anser albifrons* *frontalis*), Canada goose (*Branta canadensis*), Aleutian Canada goose (*B.c. leucopareia*), lesser snow goose (*Chen caerulescens*), and tundra swan (*Cygnus columbianus*). Tule geese are associated primarily with managed wetlands and agricultural lands. The Suisun Marsh subregion is one of the few wintering areas in California and North America for tule geese. The geese and swans are of economic and recreational importance as four of the six members of this group are hunted, and overpopulation of geese may cause large urban and agricultural damage. Formerly, geese were present in the ecosystem in larger numbers, but are now down to a remnant few, primarily in Suisun Marsh. For example, a population of what was perhaps a few hundred greater white-fronted geese, which may have been the tule subspecies, now number less than 20 individuals in North Bay (Allen, pers. comm.). Greater white-fronted geese are found primarily in Suisun and North Bay; Canada geese, all sub-regions; Aleutian geese, Suisun and Central Bay; snow geese, all sub-regions; and tundra swans, Suisun and North Bay.

### Habitat Considerations

**Salt Evaporation Ponds —** In 1988–1990, salt evaporation ponds supported 30–41% of the waterfowl in the ecosystem, 9–14% in the former North Bay ponds, and 21–27% in the South Bay ponds. Many of the birds found in the Estuary during migration (September–October, March–April) were found in these areas.

In the North Bay ponds, up to 42,000 diving ducks have been counted, including 30% of the ruddy ducks in the Estuary, 59% of the canvasbacks, and 38% of the bufflehead. As many as 15% of the dabbling ducks were also found in these ponds, including 19% of the northern pintail and 47% of the mallards. Eighty-three percent of waterfowl were found in 54% of the salt pond area with salinities of 20–93 ppt, with most birds preferring 20–33 ppt areas. Pond size explained much of the variation in counts, with less than 2% of the use on small ponds < 150 ha, and most diving duck use on ponds 200 to 550 ha.

South Bay salt ponds supported up to 76,000 or 27% of the Estuary's total waterfowl. This area provided the largest haven for ruddy ducks (up to 67% of the population), and supported 17% of the canvasbacks, 50% of the bufflehead, and up to 86% (47,000) of dabbling ducks, including the majority (90%) of northern shovelers. Waterfowl were concentrated in lower salinity (20–63ppt) ponds, with few birds present in ponds above 154 ppt. Most waterfowl used ponds of moderate size, from 50 to 175 ha.

**Open Bay Areas —** Up to 50% or 140,000 of the diving ducks surveyed in the Estuary during the winter were counted in the North Bay subregion. Densities were as high as 653 birds/100 ha. The populations include up to 35% of the scoter, 26% of the canvasbacks, and 12% of the scaup. Most of the use was in water depths < 4 m, although much of the open bay area was less than 6m. The Central Bay supported 17% of the waterfowl, or up to 53,000 birds, including 20% of the diving ducks. This area was important for scoter (up to 50%), scaup (16%), and bufflehead (13%), but only 1% of the dabbling ducks. The South Bay supported 9–11% or 36,000 of the waterfowl in the Estuary, and was important for scaup (18%) and scoter (16%). The open waters of Suisun Bay supported only 12% of waterfowl in the Estuary, including up to 15% of the diving ducks (17% of scaup, 16% of scoter, and 16% of canvasbacks).

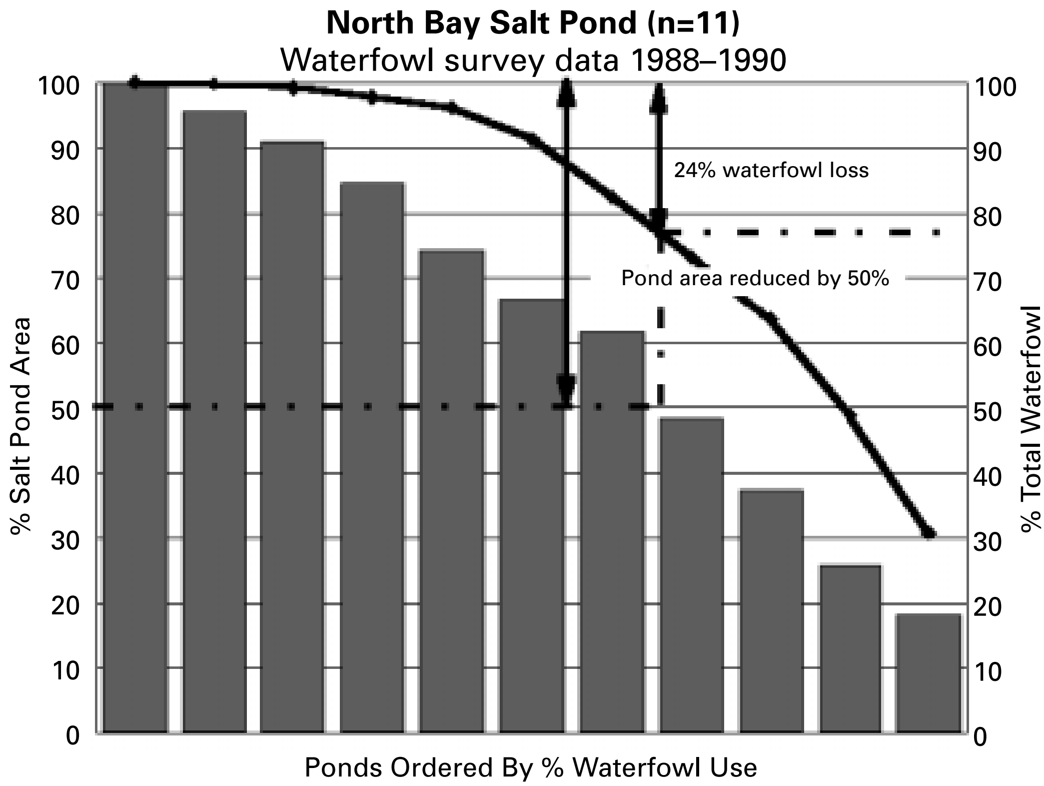
## General Recommendations

It is important to maintain existing populations of shorebirds and waterfowl in the Bay while increasing habitat for other species that are dependent on salt marsh. Increasing the acreage of salt marsh will come at the expense of other habitats, especially salt ponds and managed wetlands that are important for shorebirds and waterfowl. Maintaining current shorebird and waterfowl populations will thus require increasing the carrying capacity of remaining salt ponds and managed wetlands or re-creating their function in new locations.

### Subregions

**Suisun Bay —** Although these wetlands are managed primarily for waterfowl habitat by private land owners, populations of one of the major target species, northern pintail, have decreased by as much as 90%. Thus,

**FIGURE 1 Waterfowl Use of Salt Ponds in the North Bay Ordered from Most to Least Waterfowl Use.**



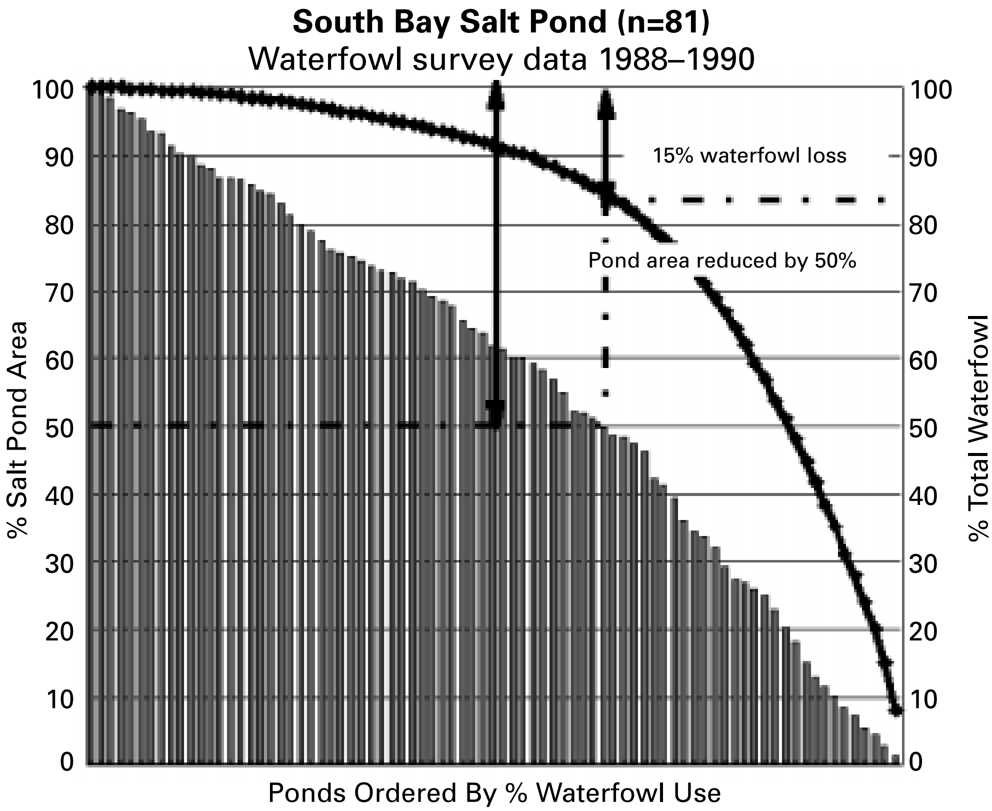

Reduction in the total salt pond area is related to the estimated decrease in waterfowl numbers. For example, a 50% reduction in salt pond suggests a 24% reduction in waterfowl.

despite the best management efforts, populations of waterfowl in the Suisun Marsh have decreased. Any conversion of managed wetland habitats will result in a loss of waterfowl. Conversion of this area should proceed gradually to provide time to evaluate population changes and the effects of the loss of habitat. Conversion or loss of this habitat type must be offset by enhanced management of existing areas or mitigation with alternative areas. Shorebirds are present in the tens of thousands. Management should be promoted to improve areas for their populations.

**North Bay —** The former salt evaporation ponds in this region are a critical area for shorebirds and waterfowl. Ongoing conversion should be linked to enhanced management of existing areas or mitigation. In this subregion, conversion of 50% of the former salt ponds may result in loss of 24% of the 42,000 waterfowl that are counted in these ponds (**Figure 1**; Takekawa, pers. comm.). Change in salt pond areas may already be resulting in reduction of waterfowl numbers. Thus, there is an immediate need to develop alternative managed marsh areas in this subregion. Although mudflat habitats seem abundant in the North Bay, shorebird roosting habitats may be limiting and should be increased.

**Central Bay —** This subregion is highly urbanized and is used least by both shorebirds and waterfowl. Any additional roosting habitat that can be protected from disturbance would be beneficial in maintaining or improving existing populations. Restoration of any large, shallow ponds would likely benefit shorebirds and waterfowl. Wetland rehabilitation in urban areas should be encouraged.

**FIGURE 2 Waterfowl Use of Salt Ponds in the South Bay Ordered from Most to Least Waterfowl Use.**




Reduction in the total salt pond area is related to the estimated decrease in waterfowl numbers. For example, a 50% reduction in salt pond suggests a 15% reduction in waterfowl.

**South Bay —** The majority of the shorebirds and waterfowl in the South Bay use the salt evaporation ponds for roosting or feeding habitat during the winter. Conversion or loss of this habitat type must be offset by enhanced management of existing areas or mitigation with alternative areas, including created salt ponds, managed wetlands, and seasonal wetlands. For example, analysis of waterfowl survey data from 1988–1990 (Takekawa, pers. comm.) suggests that if 50% of the salt ponds are converted, 15% of the 76,000 waterfowl may be lost (**Figure 2**). An increasing number of waterfowl would be displaced if more area was converted.

Although mudflat foraging habitat seems adequate, with salt pond conversion, suitable roosting habitat for shorebirds may become limiting. Little is known about how salt ponds and seasonal wetlands provide food for shorebirds and protected microclimate areas during adverse weather. Thus, we recommend not more than 50% or 15,000 acres of salt ponds in South Bay be converted to other habitats without careful planning for habitat mitigation for shorebird and waterfowl populations. We also recommend an increase in seasonal wetlands as migration habitat and roosting areas.

## Enhancing Tidal Marsh Restoration Projects for Shorebirds and Waterfowl

Shorebirds and waterfowl may use several elements in tidal salt marshes. As restoration or rehabilitation is undertaken, these elements should be provided when possible.

1. Larger channels with large mudflats are often used by shorebird and waterfowl species and should be encouraged in tidal marsh design.
2. Muted tidal areas provide temporal diversity which may provide good habitat, especially for diving ducks.

3. Unvegetated levees and islets with gradual slopes that are durable, and bare areas that remain unvegetated with limited management should be constructed as roosting sites.
4. A diverse mix of pans and ponds should be retained in marsh plains for high tide roosting and foraging areas.
5. Designs should be made to minimize disturbance by people, pets, and predators.
6. Surveys of shorebirds and waterfowl should be conducted prior to restoring areas to tidal salt marsh so losses may be evaluated and suitably mitigated.

## Research Needs

Relationships among habitat change and change in populations of waterbirds have been studied in other estuaries (see Goss-Custard et al. 1997). We should learn from these efforts and develop a research program in the San Francisco Estuary to examine questions raised in the Goals process, including the following topics:

1. Determine the feasibility of designing ponds or systems from the existing salt evaporation ponds which can support the current populations of shorebirds and waterfowl.
2. Evaluate what constitutes a good roosting area for different species of shorebirds, including distance from feeding areas. Areas used within tidal salt marshes should be included.
3. Estimate the size and composition of shorebird populations in Suisun Bay subregion.
4. Determine the importance of non-mudflat habitats, such as salt ponds and seasonal wetlands, as foraging areas, especially during inclement weather.
5. Examine seasonal wetland use and extent (not available in the EcoAtlas), including diked farmland, grazed baylands, diked marsh, managed marsh, and ruderal baylands through wet and dry years.
6. Test differences in shorebird and waterfowl response to different actions in managed wetlands by measuring use-days and numbers.
7. Relate diving ducks use of wetlands by area size and water depth.
8. Quantify shorebird foraging and roosting in wetlands other than intertidal flats, including intertidal pans, low and medium salinity ponds, managed marsh, diked marsh, muted tidal, and seasonal ponds. Include factors such as tidal cycle, salinity, vegetation, and distance to intertidal flats.
9. Describe use of wetlands by salinity and prey differences for shorebirds and waterfowl.
10. Provide more information about the effects of disturbance on shorebirds and waterfowl to develop suitable habitat buffer zones.
11. Determine the effects of channelization, levee alteration, and use of dredged-spoil on mobilization of contaminants sequestered in soils or sediments and bioaccumulation in shorebirds and waterfowl.
12. Characterize hydrology, biology, and chemistry of salt ponds heavily- and lightly-used by shorebirds and waterfowl to examine the differences.
13. Determine habitat values and use by waterfowl and shorebirds of managed wetlands versus tidal wetlands.
14. Investigate the effect of non-native invertebrates and plants (e.g., *Potamocorbula amurensis*, *Spartina alterniflora*) on shorebirds and waterfowl.

15. Evaluate methods to reduce effects of non-native predators on shorebirds and waterfowl.
16. Examine the effects of contaminants on breeding birds.
17. Pilot Projects — encourage monitored experiments in wetland restoration or mitigation:
    a. Include repeatable waterbird surveys before and after project actions.
    b. Examine maintenance or creation of salt pond systems, including low- to mid-salinity ponds in the absence of commercial production. Habitat values and use should be maximized while minimizing maintenance costs.
    c. Test methods of constructing habitat elements with low maintenance requirements, such as bare roosting islands, intertidal pans, and non-tidal seasonal ponds.
    d. Examine differences in use of different wetland unit sizes.
    e. Test methods of increasing shorebird and waterfowl use of managed marshes.
    f. Increase monitoring efforts on existing projects with habitat elements valuable for shorebirds and waterfowl.
    g. Employ adaptive management by applying earlier findings to change design elements through time.
    h. Preliminary sampling for contaminants of areas designated for salt marsh restoration.
    i. Preliminary sampling of salt ponds for invertebrate community, salinity, and other water quality characteristics.

## Literature Cited

Accurso, L. M. 1992. Distribution and abundance of wintering waterfowl on San Francisco Bay 1988–1990. Unpubl. Master's Thesis. Humboldt State Univ. Arcata, CA. 252 pp.

Goss-Custard, J. D., R. Rufino, and A. Luis (eds.). 1997. Effect of habitat loss and change on waterbirds. ITE Symposium No. 30 and Wetlands International Publ. No. 42. The Stationary Office, London.

Nichols, F. H., J. E. Cloern, S. N. Luoma, and D. H. Peterson. 1986. The modification of an estuary. Science 231:567–573.

Race, M. S. 1985. Critique of present wetlands mitigation policies in the United States based on an analysis of past restoration projects in San Francisco Bay. Environ. Manage. 9:71–82.

Trost, R.E. 1997. Pacific Flyway 1996–97 Fall and Winter Waterfowl Survey Report. U.S. Fish & Wildlife Service, Migratory Bird Management Office, Portland, OR. unpubl. data.

United States Fish and Wildlife Service. 1955–1998. Mid-winter waterfowl survey data. Sacramento National Wildlife Refuge. Willons, CA.

United States Fish and Wildlife Service. 1989. Concept plan for waterfowl habitat protection. North American waterfowl management plan, category 27. U. S. Dep. Int., Fish Wildl. Serv. Rep., Portland, OR.

Warnock, S.E. and J. Y. Takekawa. 1996. Wintering site fidelity and movement patterns of Western Sandpipers *Calidris mauri* in the San Francisco Bay estuary. Ibis 138:160–167.

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**San Francisco Bay Area Wetlands Ecosystem Goals Project**

# Other Bayland Birds Focus Team

## Recommendations

## Introduction

The baylands of the San Francisco Bay support a diverse assemblage of bird species. The Goals Project has divided these species into two groups: (1) shorebirds and waterfowl, and (2) other baylands birds. Representatives of the other baylands birds group include gulls, terns, grebes, pelicans, egrets, raptors, rails, and many species of songbirds. This report presents the recommendations of the Other Baylands Birds Focus Team, which was formed to address the needs of this group of birds, and the term "other birds" will be used throughout when referring to them.

The U.S. Fish and Wildlife Service's *Diked Baylands Wildlife Study* and the San Francisco Estuary Project's *1992 Status and Trends Report on the Wildlife of the San Francisco Estuary* identify 184 other bird species. The baylands provide important support for many of these species during migration and during the winter (warblers, grebes, and raptors), and support breeding during the summer, particularly for resident species (clapper rail and song sparrows).

The abundance and distribution of other birds using the Estuary is a reflection of the habitat changes which have occurred in the baylands over the last 150 years. These changes have resulted in dramatic declines in some species (clapper rail) and increases in other species (eared grebe or meadowlark). Changes are most pronounced in species which are dependent on tidal marsh and those which have been able to exploit new habitats resulting from diking and filling of the Bay. From the historic record and inference about how species use the existing baylands, we are able to identify changes in abundance. Unfortunately, little information is available to allow us to fully understand the range of support functions provided in the historic condition.

The changes which have occurred over the last 150 years have altered the mix, abundance, and distribution of habitats within the baylands and adjacent uplands significantly. The habitat most affected has been tidal marsh, which has been reduced by 80 percent. Much of what remains today is recently formed, fragmented, and poorly developed and does not provide the levels of support which could have been expected in the historic marshes. This can be inferred by comparing current tidal marshes to mapping of the baylands in the mid-1800s. With the exception of the Petaluma Marsh, today's tidal marshes are a shadow of the historic marshes which were a diverse mixture of channels, flats, marshes, permanent ponds, salt ponds and pan, areas of seasonal ponding, and ecotones with various upland habitats.

Uplands adjacent to the Bay have also been greatly altered or eliminated, particularly in the South and Central Bay subregions. Based upon historic information developed as part of the EcoAtlas, the uplands surrounding the baylands supported extensive areas of potential seasonal ponding. Examples of these can be seen at the Warm Springs area in South Bay and at areas surrounding Suisun Bay. In many cases, diking of the baylands has created habitats suitable for many upland species which historically occupied adjacent uplands (burrowing owl and meadowlark). These habitats include levees, diked marshes, managed marshes, farmed and grazed lands, and areas of undeveloped fill.

Diking of the baylands has also provided for the establishment of other types of wetlands that were of limited extent or found primarily in the adjacent uplands surrounding the Bay. These include salt ponds, managed marshes, and seasonal ponds. The presence of these habitats in the baylands has been beneficial for many other bird species which prefer these habitats and have been able to exploit them (eared grebe, terns, gulls, and white pelican).

These changes in the baylands have set up a natural tension between species in developing recommendations for the Goals Project. The Other Baylands Birds Focus Team selected evaluation species to represent the habitats of the entire Estuary as a means of identifying needed habitat support functions.

Although the recommendations for restoration of particular features of the ecosystem may benefit some evaluation species and their proxies, there will always be conflicts between the needs of the various evaluation species, and management goals must seek to balance these conflicts.

## Tenets

The process of making recommendations for other birds focused on looking outward from the baylands. The emphasis was on making recommendations for species which depended upon the baylands for their primary support. To aid in this process, an attempt was made to place evaluation species in context with their regional and flyway populations. Since the area of the baylands is limited, compared to the distribution of some evaluation species, emphasis was placed on making recommendations for those species whose life requires or local occurrence depend on the support functions provided by the baylands. The focus team agreed that its recommendations should:

1. Emphasize sensitive species endemic to the Estuary over species which have become more abundant or colonized the Bay as a result of habitat alterations.
2. Maintain or restore habitat gradients to express the full range of biodiversity within the Estuary.
3. Strike a balance between the habitat needs of species using the baylands ecosystem. A return to historic conditions may not be possible nor desirable given the alterations which have occurred.
4. Provide large patches of diverse habitat that contain large populations, as these are superior to small patches with small populations. Small habitat patches can provide important connections between larger patches.
5. Use umbrella or keystone species to represent habitat types and larger assemblages of species.
6. Minimize habitat fragmentation.
7. Emphasize restoration of self-maintaining systems. Some degree of management will be needed to maintain populations of species which depend upon habitats created by past alteration of the baylands.
8. Protect and enhance native species.

## Evaluation Species

The selection of evaluation species used the following criteria:

1. Requires large, well developed tidal marsh habitat.
2. Uses salt pond or shallow saline pond habitat.
3. Uses higher part of tidal marsh and upland transition.
4. Represents a particular habitat type, including: riparian, seasonal ponds, freshwater marshes, adjacent uplands, channels, open bay, or rocky shores/islands.
5. Relies on a variety of bayland habitats and adjacent areas for nesting and foraging.

7. Represents a broader group of species which use the baylands.
8. Is locally or regionally limited in number and distribution (listed species, species of special concern).

Twenty-seven evaluation species were initially selected from the species identified in the Diked Baylands Study and the Status and Trends Report. The selected evaluation species represented the full range of habitats found within the baylands, as well as the support functions they provided (foraging, roosting, migration, wintering, breeding).

Upon selection, the evaluation species were evaluated for their dependence on the baylands and their regional, statewide, and flyway populations and trends. Additionally, an evaluation was made of what their specific conservation needs were and what the limiting factors to their persistence within the baylands and the region were. This review resulted in a thinning of the evaluation species to 14 species which provided the basis for recommendations made for the other birds.

The recommendations of the Other Baylands Birds Focus Team focused upon those species which represented habitat features present only in the baylands.

**Eared Grebe *(Podiceps nigricollis).*** This species uses the Bay primarily for wintering habitat. Historically, it was present in the Bay in low numbers; presence of salt ponds has resulted in higher wintering populations. This species represents other bird species which rely on low- to mid-salinity salt ponds.

**Western/Clarks Grebe (*Aechmophorus occidentalis* and *A. clarkii*).** These species frequent the Bay during the fall and winter. They characteristically utilized the open bay and larger tidal channels, as well as ponded habitats in the diked baylands, where fish are present.

**Brown Pelican (*Peleanus occidentalis*).** The brown pelican is a summer and fall visitor to the Bay. This species is representative primarily of the open bay habitat of the Central Bay. It requires disturbance-free roost sites, such as Breakwater Island at the Alameda Naval Air Station.

**Snowy Egret (*Egretta thula*).** The snowy egret is a year-round resident of the Estuary. It is a generalist in its use of wetland habitats within the Bay. The species breeds within the baylands and is representative of other associated species and island nesting species in the Bay. The primary limiting factor for this species is the availability of nesting sites isolated from predation and disturbance.

**Northern Harrier (*Circus cyaneus*).** The harrier is a resident raptor which inhabits the baylands. This species uses all the current habitats of the baylands and adjacent open uplands. The species is used to represent other raptor species which utilize the baylands.

**California Black Rail (*Laterallus jamaicensis*).** The State listed threatened black rail is a resident of high tidal marshes of the San Pablo and Suisun bays. The species is representative of brackish tidal marsh species.

**California Clapper Rail (*Rallus longirostris*).** The State and Federally listed endangered clapper rail is a resident of the tidal marshes of the Estuary. The species characteristically inhabits the more saline marshes of the Bay. Highest populations are found in large tidal marshes with well-developed channel systems.

**Forster's Tern (*Sterna forsteri*).** This is a resident tern of the baylands. It uses salt ponds and managed wetlands with islands or appropriate structures for nesting. It forages in both managed wetlands and the open Bay and channels. It is representative of species which rely on salt ponds for nesting habitat.

**California Least Tern (*Sterna antillarum browni*).** This State and Federally endangered species breeds in the Bay, nesting on bare open sites in close proximity to areas of shallow open water. The species historically nested on beaches, but has been displaced to areas of unvegetated fill adjacent to the Bay. The species also relies on low-salinity salt ponds for post fledging foraging.

**Burrowing Owl (*Speotyto cunicularia hypugaea*).** The burrowing owl is a species of special concern. It is characteristic of open grasslands adjacent to the Bay. Much of its historic habitat particularly in the South Bay has been lost to development. It represents species which inhabit the upland grasslands adjacent to the baylands. In many cases the species is found in diked baylands predominated by annual grasses.

**Yellow Warbler (*Dendroica petechia*).** The yellow warbler is both a resident and migrant in the riparian habitats at the edge of the Bay. The species is used as a representative for those species which depend upon riparian and willow thicket habitats.

**Salt Marsh Yellowthroat (*Geothlypis trickas sinuosa*).** The yellowthroat is found in fresh and brackish marshes, tidal marshes, swampy riparian thickets, and weedy fields and grasslands bordering wet habitats. Yellowthroat territories frequently include the ecotones between these communities.

**Savannah Sparrow (*Passerculus sandwichensis*).** The savannah sparrow is found in the transition zone between tidal marsh habitats and adjacent open uplands. This species is representative of species found in the grasslands within the baylands and transitions from marsh habitats to open uplands.

**Song Sparrow (*Melospiza melodia*).** Three subspecies of song sparrows are found in the tidal marshes of the San Francisco Bay. All are considered species of special concern due to their limited distribution and loss of habitat. These species are characteristic of tidal marshes and depend upon adjacent uplands for refugia.

Based upon the tenets identified above and the selected evaluation species, the following recommendations are made concerning future management and restoration of the baylands. From the discussion above, the emphasis of the recommendations is on restoration of tidal habitats, particularly tidal marsh, due to the substantial reductions of this habitat and the number of listed or sensitive species they support. While the recommendations of the Other Baylands Birds Focus Team emphasized tidal habitats, it is recognized that diked habitats provide support functions for some other bird species, but more so for shorebirds and waterfowl. Consequently, maintenance and enhanced management of retained diked baylands will be an important feature for insuring that competing species needs are balanced. Additionally, it is important to provide upland habitats contiguous with the baylands as refugia and buffers from disturbance.

## Recommendations

A. Increase the amount of tidal marsh in all subregions of the Bay. Tidal wetland acreage within the Bay has been reduced by approximately 82 percent. Much of the tidal marsh that remains is recently developed and often linear with a high perimeter-to-area ratios. These tidal marshes in many cases are poorly developed, lacking topographic variation, extensive tidal channels and pannes. Consequently, they are of reduced value to many species which depend upon them. Evaluation of current tidal marshes within the Bay indicates that approximately 50 percent of the current acreage is of good habitat quality for other bird evaluation species which depend upon this habitat type.

- Create large blocks of tidal marsh with a minimum of upland within the marsh. The ratio of upland edges to marsh area should be minimized. Restoration of tidal marsh in areas of higher salinity should be a priority for recovery of the California clapper rail. In areas where tidal marshes are restored, flood control levees should be removed.
- Provide connections between tidal marshes (corridors), particularly in Suisun Marsh for Suisun song sparrows, and in South Bay for clapper rails and Alameda song sparrows.

- Reduce or eliminate unseasonable freshwater inflows to the Bay (e.g., wastewater discharges).
- Provide high tide refugia by developing supratidal marsh features (e.g., vegetated channel levees) and retaining levee remnants and other artificial features where possible. These features should be at or slightly above MHHW.

B. Connect tidal marshes to uplands in natural gradients in all subregions of the Bay. Where possible, site marsh restorations at locations where such connections can be restored naturally. Restoration of such connections will be important for accommodating a rise in sea level.

C. Maintain low- and mid-salinity salt ponds in the absence of salt production, (e.g., intake ponds and adjacent evaporators), as well as other open water habitats. Several ponds operating in series are needed to provide concentration of brines to provide the array of salinities preferred by species using salt ponds. Siting of several such pond complexes around the Bay should be located so that the discharge point could be used to add salinity to large wastewater discharges.

- Manage salt ponds of low- and mid-salinity to provide important habitat for species, such as terns, eared grebes, and white pelicans. Ongoing salt production maintains these important habitat attributes.
- Allow for discharge of medium salinity brines back into the Bay, i.e., to areas where they exceed background levels.
- Develop nesting islands for terns and other avian species within retained salt ponds. Such features are also important for shorebirds.
- Consider muted tidal regimes when managing intake ponds.

D. No special emphasis should be placed on managing for primarily upland species within the baylands (e.g., meadowlark). Protection and enhancement of transitional and adjacent uplands and seasonal and managed wetland areas will provide an appropriate habitat.

E. Development of permanent freshwater emergent wetlands should not be a priority where it would preclude restoration of tidal wetlands or convert existing wetlands within the baylands. Development of such habitats should be focused in upland areas adjacent to the Bay. Development of fresh to brackish marshes using treated wastewater can provide important habitat for other bird species, such as egrets and waterfowl (e.g., Hayward Treatment Marsh). Such wetlands should be carefully sited and designed to avoid direct and indirect impacts to existing wetlands.

F. Riparian and willow thicket (sausal) habitats should be enhanced and developed where possible around the Bay to provide habitat for migrants and resident species. These habitats should be distributed as evenly as possible. Use of treated effluent could be used to enhance flows in streams tributary to the Bay which would help to expand and maintain riparian habitats. Setback levees should be encouraged in flood control planning to restore or maintain flood plain and riparian habitats where possible.

G. Within the historical extent of the Bay, farmed and grazed lands can be maintained as long as they are in ongoing production. Farming practices that enhance wildlife and which are compatible with agricultural production should be encouraged, particularly enhancement of seasonal ponding. These lands provide support for many species, although the level of support varies widely depending upon the agricultural practices and climatic factors which affect the degree of ponding and quality of habitat for wildlife.

H. Opportunities to protect and enhance upland transitional habitats should be identified and given priority. Development of upland transitions should be incorporated into tidal marsh restorations where possible. They should be incorporated as they would naturally occur. For tidal marsh restorations where levees will be required, the levees should be constructed to mimic naturally occurring transition zones between tidal marshes and uplands. The levee slopes should be designed with gradual slopes. Where feasible, areas of seasonal or high tide ponding should be incorporated into the transition zone.

I. In areas now largely developed, remaining wetland parcels should be retained and/or enhanced where possible, especially where such parcels are adjacent to larger wetlands, to function as dispersal corridors for wetland birds moving between larger intact wetlands and other native habitats.

**Table 1** displays current and recommended habitat acreage.

## Table 1. Other Bayland Birds Focus Team Recommended Habitat Acreage. (Recommendations made in early 1998 based on EcoAtlas version 1.0.)

| | Current | Future |
|---|---|---|
| **Tidal Marsh (acres):** | | |
| Estuary: | 40,403 | 112,656 |
| South Bay: | 9,345 | 30,769 |
| Central Bay: | 949 | 949 |
| North Bay: | 16,334 | 44,793 |
| Suisun: | 13,775 | 36,202 |
| **Uplands/tidal marsh transition (linear):** | | |
| Estuary: | minimal | increase |
| South Bay: | | |
| Central Bay: | | |
| North Bay: | | |
| Suisun: | | |
| **Salt Pond (acres):** | | |
| Estuary: | 37,210 | 10,038 |
| South Bay: | 28,643 | 8,515 |
| Central Bay: | -0- | -0- |
| North Bay: | 8,567 | 1,523 |
| Suisun: | -0- | -0- |
| **Managed Marsh (acres):** | | |
| Estuary: | 53,815 | 38,656 |
| South Bay: | 1,309 | 1,309 |
| Central Bay | 29 | 29 |
| North Bay: | 4,718 | 9,130 |
| Suisun: | 47,759 | 28,188 |
| **Diked/Farmed Baylands (acres):** | | |
| Estuary: | 44,224 | 15,863 |
| South Bay: | 4,100 | 2,610 |
| Central Bay: | 1,400 | 1,400* |
| North Bay: | 31,296 | 6,910 |
| Suisun: | 7,428 | 4,943* |
| **Riparian (acres):** | | |
| Estuary: | limited | increase |
| South Bay: | | |
| Central Bay: | | |
| North Bay: | | |
| Suisun: | | |

Tidal marsh = all tidal marsh types.
Salt pond = all salt pond types, inactive and crystallizer.
Diked/Farmed Baylands = diked marsh, ruderal bayland, grazed bayland, farmed bayland.
*subject to further review.

## Hydrogeomorphic Advisory Team

# Integrating Abiotic Factors in the Goals Project: Tenets of the Hydrogeomorphic Advisory Team

This paper presents information regarding some of the physical considerations associated with restoring bayland habitats. It includes the HAT's organizing principles and other summary points. It also includes questions posed by the focus teams and our brief answers to them.

The information we are providing here is very limited, and we recognize that any large-scale effort to restore the baylands will require substantial regional and site-specific investigation.

## I. Organizing Principles

1. The preferred approach to implementation of the Goals should be the restoration of natural, self-sustaining systems that can adjust to changes in physical processes, with minimum ongoing human intervention.
2. In those cases where the restoration of natural, self-sustaining systems is not possible or is not preferred, a phased eventual transition to such systems should be considered. For example, some salt ponds may be maintained to support species currently using this type of habitat. However, it would be preferable to eventually replace these with natural, self-sustaining habitat types, such as mudflats, tidal marshes, salt pans, etc., if this can be accomplished.
3. Restoration planning and design should be based on expected regimes and variability of physical processes, including hydrology, sediment, salinity, water quality, and biogeochemistry.
4. Restoration planning and design should account for both natural causes of variability, such as drought, and anthropogenic causes of variability, such as alteration of freshwater flows.
5. Restoration planning and design should recognize the range of temporal scales. This applies both to the rate of evolution of a restored site in providing wetland functions, such as transition from an intertidal mudflat to a vegetated tidal wetland, and potential changes in the controlling physical factors, such as expected changes in the bay sediment budget.
6. Restoration planning and design should recognize the spatial scale (size and location) of restoration sites. Key examples include uniform sedimentation rates across small sites versus higher sedimentation rates near a levee breach at larger sites, and greater sedimentation rates in South Bay than in Central Bay.
7. Restoration planning and design should consider its effects on regional physical processes, such as sediment transport.

## II. Links to External Influences

1. Restoration planning should be conducted in recognition of the links to major and local influences that are external to the Bay itself. These primarily include the oceanic influence, watershed input from the Sacramento/San Joaquin river system, and the local river and creek contributions.
2. The restoration of the Bay ecosystem must be tied to the restoration and maintenance of these external links.

## III. Planning and Design Guidance

1. Site design should be focused on the creation of an appropriate “template” which will evolve towards a dynamic equilibrium within the shortest time to provide the range of ecosystem function and complexity characteristic of appropriate reference sites.
2. Preference should be given to the restoration of large sites, capable of providing the complexity of habitat, highest channel order, and ecosystem resilience.
3. Preference for habitat type should recognize those ecosystems which are limited in their potential extent by controlling abiotic factors. For example, intertidal wetlands should be given preference where conditions are suitable because of the extremely limited opportunities for creation.
4. It is recognized that at some sites it will be infeasible to develop a self-sustaining system, and that artificial control structures may be required. Based on experience with these systems, there is a greater uncertainty in site evolution and a greater need for oversight. Therefore, an adequately funded maintenance and management organization is needed to ensure that restoration goals are met in perpetuity.

## IV. Advancing Restoration Science

1. The goal of advancing restoration science is to improve the ecological effectiveness of restoration projects.
2. Advancement of restoration science should come from a comprehensive program linking academic research, numerical and physical modeling, pilot projects, monitoring, restoration success evaluation, and information exchange between researchers, practitioners, regulators, and interest groups.
3. This comprehensive program should incorporate natural reference systems, previous restoration projects, and new restoration projects.
4. Principles of adaptive management should be incorporated into all restoration projects. Adaptive management would include both incorporating project-specific monitoring results into ongoing site management, as well as exchanging information for other restoration efforts.

## V. Evaluating Restoration Success

1. Adaptive monitoring and maintenance of the systems should be based on conformance to the expected evolutionary trend and to reference conditions rather than specific conditions at any given time.

## RMG/Focus Team Questions and HAT Responses

The questions shown below in bold type were submitted to the HAT by the RMG on 3 November 1997, and the HAT members worked together to develop the following responses:

**1. How long would it take for marsh “restoration” to take place in areas of subsidence?**

As for most of the questions, the response to this depends on the definition of “restoration,” as well as a consideration of temporal and spatial scales. The question reflects the understanding that restoration requires raising the subsided marsh plain back to an appropriate elevation in the intertidal zone and restoring the range of functions a tidal marsh provides. A brief review of these will provide some insights regarding the process.

**Process**

In subsided San Francisco Bay tidal wetlands, restoration will proceed primarily by deposition of suspended sediment (as opposed to the accumulation of organic matter), since most of the marsh plain rise will occur at elevations below that suitable for vegetation. Our observations indicate that deposition will continue until the marsh plain reaches a steady elevation relative to the Mean Higher High Water (MHHW), supporting primarily a pickleweed vegetation cover under saline conditions, or a more diverse cover of pickleweed and other plant species under brackish-saline conditions.

It is important to remember that the processes vary through time and space in ways that preclude any exact equilibrium or steady-state.

**Depth of Subsidence**

The depth of subsidence in the diked wetlands varies dramatically around the Bay, depending on the various subsidence properties. In the South Bay, maximum subsidence has been about 15 feet (New Chicago Marsh in Alviso), due to both groundwater withdrawal, soil compaction, and oxidation of the organic faction by microbial actions in part. The nearby salt ponds (adjacent to Alviso Slough) appear to have subsided about eight feet. Another salt pond (100-acre site at Cooley Landing in East Palo Alto adjacent to the Dumbarton Bridge) has only subsided one to two feet. In North Bay, subsidence of three feet to six feet appears common in sites studied.

**Rate of Deposition**

The rate of sediment deposition is affected by numerous parameters; major factors include suspended sediment concentration, depth of water column, local wave climate, salinity regime, presence of vegetation, and others. Some simple models are available incorporating the first two factors for prediction of sediment accumulation rates. Reasonably good field information is available on the rates of deposition at a number of locations around the Bay to predict deposition rates for small to moderate size (up to about 200 acres) subsided sites. These include the Alviso Marina site, Warm Springs Marsh Restoration, and Baumberg Tract in South Bay, and some Petaluma River marshes and other sites in North Bay. These indicate fairly rapid rates of accretion under present conditions for most of the Bay.

For example, the Alviso Marina (about a five-acre site) was last excavated (for boat use) to a depth of about minus 15 feet NGVD (vertical datum that corresponds approximately with mean sea level) in 1976. The Marina accumulated silt rapidly, and was only marginally functional by the early 1980s. By 1990, it had accumulated about 16 feet of sediment, and vegetation began encroaching. By 1995, it was mostly covered with brackish marsh vegetation. This corresponds with monitoring in the Warm Springs Marsh (a 200-acre site), in which initial deposition rates have been extremely rapid (up to five feet per year), and an overall rapid pace of deposition.

Initial rates of over two feet of accretion per year are common in deeply subsided sites. These rates decrease as the marsh plain rises (smaller water column and associated sediment above). Using local data for calibration, it has been predicted that about 10 to 15 years would be required for sediment deposition in a subsided South Bay salt pond (marsh plain elevation currently about minus three feet NGVD) to raise the marsh plain to an elevation where native vegetation would become established. While the amount of sediment available for deposition decreases as the marsh plain rises, the establishment of vegetation accelerates the rate of rise towards steady elevation relative to the tides by reducing turbulence and adding organic matter. This estimate of 10 to 15 years is probably applicable to similar small to moderate sites in South Bay, which has the highest rates of deposition. In North Bay, there are reports of initial cumulative deposition rates of about 1.5 feet per year at the Petaluma River Marsh restoration site. Based on a series of site comparisons, there are estimates that it would require about 35 years for the Sonoma Baylands site to reach a steady elevation relative to the tides.

**Temporal Considerations**
The above observations are based on the historical and existing suspended sediment concentrations and rates of sea level rise. While these are not likely to change quickly, it is important to recognize that the long-term future sediment supply to, and sediment loss from, the Bay system may change and that the rate of sea level rise may increase. These topics are described more fully in the response to Question 7.

**Spatial Considerations**
The restoration sites monitored to date have been small (generally less than a couple hundred acres). Concurrent opening of large numbers of subsided sites will require consideration of the regional sediment supply. As an example, at its maximum depth, the 200-acre Warm Springs site aggraded at a rate of almost five feet per year, corresponding to an annual accumulation of perhaps 1.0 to 1.7 million cubic yards. This represents a significant fraction of the total net Bay sediment available of about five million cubic yards per year.

**Restoration Process**
It is probably clear to all the participants that the term "restoration" is a controversial topic, which covers a wide range of functions and values. As applied to this question, we recognize that the subsided site will evolve through the states of:

- subtidal, unvegetated
- low intertidal (mostly mudflats, unvegetated)
- mid-intertidal (vegetated by lower marsh vegetation)
- high intertidal (mature marsh plain vegetation)

From a process perspective, we can state with some assurance that the evolution will proceed through the above states at a predictable time frame. However, these represent only the broadest categories, and do not reflect the complexity that we see in an ancient marsh compared with a recently restored site. For example, it is unlikely the slough channel system will achieve the multiple channel orders and sinuosity in a recently restored site compared with an unaltered reference site. Likewise, the amount of organic matter and nutrients in the marsh sediments will be less in a site which has undergone extremely rapid rates of mineral soil deposition (such as a subsided marsh reopened to tidal circulation), and the organic matter would be mainly in the uppermost soil layer. Whereas, in the case of a marsh plain that has evolved gradually over thousands of years, the organic matter would be distributed throughout the vertical soil profile down to the contact with ancient mudflat sediments. In view of this, we should not expect recently restored marshes to include this level of complexity for decades or perhaps even centuries. The goal of the restoration plan should be to create the optimum "template" such that the site will evolve towards a condition of maturity and complexity in the shortest time frame, recognizing that some functions can be restored more quickly than others. The monitoring process should be focused on whether the site is evolving along the desired path rather than the specific state at any one time. This approach is emphasized in the HAT guiding principles and recommended research.

**2. Can we create and maintain large slough channels in restoration (which provide mudflat foraging habitat for shorebirds)?**

Marsh slough channels evolve as nature's most "efficient" way of exchanging water and dissipating energy within the intertidal landscape. At any location within the marsh plain system, the slough channel cross section dimensions and shape reflect a balance between erosion (scour) forces exerted by the tidal flow, which tend to expand the channel bed/banks, and the tendency for deposition of suspended sediment to decrease the channel dimensions. At the most basic level, the maximum channel "order" within a marsh complex, and size of the slough channels at a particular location, are determined by the size (areal extent) of the intertidal zone. Quite simply, to support large slough channels or complex networks of channels of varying order, we need large marshes. Slough channels hundreds of feet wide, with maximum depths of 25 to 30 feet and broad expanses of unvegetated mudflats, were common features of the historical Bay marshes which covered thousands of acres. This image is apparent in the historical view of the EcoAtlas.

The areal extent of restored tidal marsh required to support a given width/depth dimension of a slough channel can be approximated by using the "hydraulic geometry" approach developed in large part by Bay Area wetlands scientists. There is also extensive data collected on how rapidly channels respond to changes in tidal area or tidal prism: In response to decreases in marsh plain area, the channels decrease rapidly in depth to a new equilibrium level, and more slowly in width. The rate of enlargement of channels with increased tidal exchange depends primarily on the erodibility of the underlying sediment (highly consolidated clay material is relatively resistant to erosion and may require excavation).

**3. Does marsh restoration decrease mudflat habitat? Will restoring tidal marsh areas reduce bayside tidal mudflats used by shorebird and waterfowl species?**

The seat-of-the-pants consensus of the HAT seems to be "not much, if any."

**4. Can you estimate the decrease in mudflat area with the increase in tidal marsh at a specific site? For a region?**

To check this, some simple calculations were made assuming the following:

1. All sediment to fill a pond comes from mudflats from MHHW to minus six feet MLLW, a depth at which bottom sediments can readily be re-suspended by wind waves.
2. The longshore distance that contributes sediment to a salt pond is equal to the frontage of the pond on the Bay.
3. The pond bottom must be raised three feet (gross estimate from Napa River ponds).
4. No sediment comes from the local watershed.
5. The slope of the resulting mudflat will be the same.
6. The mudflat can not migrate landward.

These assumptions are probably the worst case for mudflats. In reality, some if not most of the sediment that would deposit in the ponds would come from further away in the Bay (or more distant sediment would replenish sediment that moved from the mudflat to the pond) or from the local watershed. These assumptions can be used to calculate the distance the minus six-foot contour will migrate landward. This is the cross-shore distance of mudflat lost.

$$\text{Volume of fill} = AH = L\, dh\, dx\, (1 - dx/x)$$

where A=area of pond, H=depth of pond, L=Bay frontage of pond, dh=distance from -6 ft MLLW to MHHW, dx=distance -6 ft MLLW contour moves toward shore, and x=cross-shore distance from -6 ft MLLW to MHHW.

This approach was tried for two randomly selected salt ponds along the shore of South Bay: the pond east of Mountain View Slough and the pond south of Coyote Hills Slough. For each pond, about 10–15% of the habitat from MLLW -6 feet to MHHW ($dx/x \sim 0.1$ to $0.15$) would be lost for this worst case scenario.

**5. How should salt ponds be restored through phasing of pilot projects, i.e., which ponds should be restored first, and how long should one salt pond or pond complex take to develop before another is attempted?**

Some of the decisions that would have to be made and some of the factors that would affect these decisions can be listed. If a large area of salt ponds were to be restored, a study would be required to answer this question specifically and in appropriate detail for making resource management decisions. So far, as best we know, restoration projects have been small enough where this question has not arisen.

Spatial decisions (what order?):

- Napa or South Bay first (depends on ecological benefit on baywide scale)?
- Restore ponds adjacent to the bay/river shoreline or furthest away from shoreline first?
- For South Bay, restore closer to San Francisco or San Jose first?

Phasing decisions (when?):

- What criteria should be used to decide when to open up additional ponds to tidal action (seasonal, deposition in previous pond, time)?

Hydrologic factors influencing decisions:

- Sediment supply: Is seasonal and varies from year to year.
- Salinity: In and around the ponds should be maintained at an ecologically safe level. This will also be dependent on freshwater flow, which also varies seasonally and annually.
- Tidal currents: May be altered near a restored pond.
- Pond plumbing: The ponds have extensive plumbing to transfer water and produce salt. Restoring tidal action to one pond could affect the flow of water between ponds and thus water quality in the remaining ponds.

Other factors:

- Opportunity: What ponds are available at any given time for restoration.
- Levees: If a levee breaks during a flood, the pond is restored to tidal action.

**6. Can you maintain the variation in salinity in salt ponds without continuing to operate the ponds as a evaporative system?**

No. In order to produce hypersaline water from seawater, water ($H_2O$) must be removed (evaporated). An alternative to solar evaporation would be a desalination (reverse osmosis) plant that would produce drinking water and hypersaline water.

**7. Comment on the implications of sea level rise in relation to long-term management of both tidal and diked wetlands.**

Atwater and others have described the history of the San Francisco Bay on a geologic time scale. Sea level rose rapidly prior to 8,000 years ago and progressively invaded the valleys, creating the San Francisco Bay system. The rate of rise slowed between 8,000 and 6,000 years ago to approximately the present rate. At this slower rate, soil eroded from the land and was transported to the bays, accumulated along the shores, and supported the proliferation of marsh plants. The plants accelerated the rate of deposition of suspended sediment in their midst, as they do today, and continuing accumulation of sediment and plant material raised the surface. As sea level continued its rise, sediment was added to the surface and the rising marsh invaded the land and created the extensive tidal marshes found by the forty-niners.

Sediments enter the bays suspended in the waters of winter freshets. For the Bay system as a whole, the Central Valley drainage provided in excess of 80 percent of the sediment entering the bays, with the remainder contributed by local streams. The importance of local sediment supplies probably increased closer to local sources. For example, it is possible that the relative contribution of sediment from the Napa Creek watershed increased upstream from Mare Island. The material from the Central Valley drainage deposits initially where it enters the broad bays. Onshore breezes generate waves during spring and summer days that suspend the newly deposited material, and tidal currents circulate it throughout the bays. During a year, most of the material either deposits in locations where it is not further suspended by currents or waves, including deposition on marshes, or exits the Golden Gate.

Human activity wrought large changes in the Bay system. Sediment and water inflows have been altered drastically, and most of the marshlands have been diked and drained. Present evidence indicates that prior to 1849, the limited supply of suspended sediment brought into the bays was not quite sufficient to maintain water depths, and the bays slowly deepened. Hydraulic mining contributed 1.4 billion cubic yards of mud deposit in the bays and on the marshes during the period from the early 1850s to the late 1870s.

Vallejo Bay and Northampton Bay became mudflats with the Carquinez Strait channel through them. Large deposits filled the upper bays and added large amounts of material to San Pablo Bay. Most of the marsh south of Highway 37 and the marsh along the western shore evolved on these deposits. Agriculture in the valleys and mountain slopes added to the sediment supply then and since.

The suspended sediment input continued to be higher than natural pre-1850 levels until the water projects began to divert sediment-laden river waters for irrigation and municipal supplies. Total annual input to the system averaged 10.5 million cubic yards during the period 1923 to 1950, and averaged 7.9 million cubic yards during the period 1955 to 1990. The CALFED activities suggest that there will be no further reduction. Water diversion is subject to political and legal forces and to the pressures of population growth; however, the long-term prognosis is uncertain.

The upper bays and San Pablo Bay are now so shallow that suspension by waves and tidal currents move all of the annual winter deposit, except that needed to compensate sea level rise, further down into the system. It circulates and deposits where hydraulic conditions permit. North San Francisco Bay is now slowly filling with accumulating sediment, and there is a plentiful supply to South Bay. About 40 percent of the annual supply exits the Golden Gate.

The central roles of sea level rise and sediment supply in maintaining the elevation of mature marshes is apparent from this description. As long as the sediment supply is sufficient to maintain the elevation relative to MHW, as sea level rises, the marshes will endure. It appears that the present supply of suspended sediment is sufficient for a modest rate increase. An excessive increase in the rate of sea level rise or decreases in sediment supply, however, will lower marsh elevations relative to the tides or submerge them.

Restoration requires higher suspended sediment concentrations than does marsh maintenance. Suspended sediment concentrations are highest where there is wave action on mudflats. Planning restoration of diked former marshlands requires attention to the local supply and to the impacts of nearby large restoration projects on depletion of suspended sediments. Evaluation of such impacts can be made using numerical hydraulic and sediment transport models.

In order to sort out immediate and long-term effects of restoration projects, it will be useful to complete the bay-wide evolution of the bathymetric history, as this integrates variations over time scales of interest. Then we could develop whole bay sediment transport model(s) with resolution on the order of 150–300 feet in conjunction with the bathymetric change surfaces at the same resolution. Higher resolution models of individual restoration projects will be useful in predicting an immediate (one to five years) response, but for long-term stability analysis, a full bay transport model will be required.

Once a model is functional and verified with bathymetric change, for it to be useful in predictive scenarios, we will need accurate estimates of sediment delivered to the Bay including major local streams and elevation maps for potential restoration sites.

**8. In the southernmost South Bay, inflows from San Jose may be creating a brackish system. Would large scale restoration in this area work for tidal marsh species? If not, could a marsh system be used to keep the freshwater farther from the Bay?**

The answer is yes, but it will be expensive and will require maintenance.

There will always be brackish water where treatment plant effluent having low concentrations of dissolved salts mixes with the more saline South Bay water. The location and configuration of this mixing zone can be changed, and from the question it appears that it would be desirable to locate the mixing zone far from the Bay and have tidal marshes colonized with salt-tolerant plants on the margins of the Bay. It might be noted that the historical condition included some amount of brackish marshland associated with the inflows from local creeks. It might also be noted that there are some historical data to suggest that the historical mean daily flow from South Bay creeks combined was about equal to the allowable mean daily sewage effluent, although the historical natural flow was seasonally much more variable. The ongoing occurrence of some amount of brackish tidal marsh in the far South Bay, in conjunction with salt marsh restoration, would reflect historical conditions.

A portion of the most bayward salt ponds, leveed to protect them against the highest tides and storm waves, can be used for mixing the effluent with saltier tidal water, before release into the Bay environment. In essence, what is required is a forebay. The pond or forebay should be sufficiently deep to prevent the establishment of brackish water plants and should be connected directly to the Bay with a channel dimensioned to maintain itself by flows created by the tidal prism of the mixing pond. Maintenance of the water depths in the mixing pond will require periodic dredging, because the high concentrations of suspended sediment in South Bay waters, combined with the tranquillity of the mixing pond waters, will cause rapid rates of sedimentation. For some years, the dredged material can be used to accelerate the restoration of neighboring marshes.

Dimensions and configuration of the mixing pond and the connecting channel can be determined with the aid of hydraulic and salinity models and specification of acceptable salinities at the discharge. Patterns and rates of sedimentation in the pond can be determined with the use of a sediment transport model.

The large tidal range in South Bay may be sufficient to provide the necessary mixing in the Bay *itself*. A pipeline from the San Jose Wastewater Treatment Plant and a diffuser, possibly located north of the Dumbarton Bridge, would avoid local low salinities. Evaluating this solution and determining the location of the diffuser could easily be completed with conventional models.

The HAT would like to take this opportunity to emphasize the need for the simulation of hydraulics and sediment transport in the design of restoration projects. Even the simple breaching of levees requires that their locations and dimensions be optimized to achieve desired deposition patterns and water circulation. Every project has unique conditions, including shape and elevations of the site and suspended sediment and salt concentrations in the flooding water. Model studies are very inexpensive, compared with construction costs or the costs of an unsuccessful project. The HAT is considering how it might help bridge the gap between modelers (the scientists that develop and test models, but may know too little about their operational application in natural resource management) and managers (the people in government who make decisions based upon model outputs, but who may know too little about their assumptions and uncertainties).

**9. Given that shorebirds and waterfowl need certain elements that are contained in artificial salt ponds and managed marshes (e.g., open water, roosting sites within a kilometer of feeding areas, etc.), are there particular sites with restoration potential, or particular design features that could be incorporated into tidal restoration projects, that will provide the elements required by shorebirds and waterfowl?**

At this time the HAT will defer discussion of particular sites. We can discuss some of the assumptions about restoration projects.

**Some Assumptions**

Large-scale tidal marsh restoration on diked historic baylands will occur either through the "natural sedimentation" model or the "dredged sediment/backfill placement" model. This assumption guides the approaches available during and following restoration construction to achieve desired elements.

The desired landscape elements sought within tidal marsh restoration projects are open water areas within the tidal marsh of both shallow (for shorebirds) and deeper (for waterfowl) depths.

Any restoration project proceeds through an evolutionary process from the initial unvegetated (or in some cases submerged vegetation) intertidal or subtidal landscape to early vegetation colonization and ultimately to a vegetated marsh plain dissected with a tidal slough system. The time over which this process occurs can vary widely from site to site and in general cannot be predicted with a high degree of accuracy.

Restored wetlands will be subject to regional sea level rise conditions that will influence the inundation regime of tidal wetlands.

**Tidal Marsh Pans as Open Water Areas**

At least two types of ponds ("pans" in the Goals Project typology) existed historically in tidal wetlands in the San Francisco Estuary: drainage divide pans located within the vegetated marsh plain between tidal drainage networks, and transitional pans located at the upland boundary of the tidal wetland. Few examples of drainage divide pans remain. Petaluma Marsh is probably the best location to find numerous extant pans of this kind. Hoffman Marsh in Richmond adjacent to Highway 580 had such pans, but they were drained as part of an enhancement project in the mid 1980s. Virtually no historical transitional pans remain, as these areas have been overtaken by land use conversion. Only where tidal wetlands still have a natural upland edge that is not too steep are these pans found. Rush Ranch in the Suisun Marsh is one such example, though mosquito control ditches have taken their toll. The pans along the uplands edge of marshland at the Emeryville Crescent may be analogous to the historical transitional pans.

Drainage divide and transitional pans are characterized as small depressions in the landscape that have some type of topographic containment that defines the top elevation of the water surface. Containment features can be small berms, in which case the pond could be partially or wholly perched atop the marsh plain, with the pond bottom below or at the height of the adjacent marsh plain, respectively. Containment features can also be the marsh plain itself, in which case the pond bottom is below the marsh plain (i.e., a simple depression).

There may be three water sources for drainage divide pans. Most prevalent are tidal inputs, the magnitude and frequency of which are related to the height of the pond containment feature relative to the tides. Typically, it is the higher spring tides that reach these ponds. Consequently, the seasonal variability of ponding relates directly to the seasonal variability of the higher spring tides each year, with the June–July and December–January spring tide series being of particular significance. Direct rainfall can also supply water to these ponds. Finally, emergent groundwater can contribute to surface ponding. Surface water is lost by surface drainage out of pond, groundwater infiltration, and evaporation. Likely the most important characteristic affecting surface water loss is substrate type; the more impervious the substrate (e.g., more clay), the longer the duration of ponding (vernal pools are a good analogy).

Water sources for transitional pans can include all those described for drainage divide pans plus runoff from adjacent upland areas. Consequently, these ponds can have a greater freshwater influence relative to drainage divide pans and, depending on annual climatic variability, they may support greater duration of ponding. Surface water is lost in the same manner as for interior ponds.

The HAT presumes that both types of ponds or pans offer habitat for benthic and aquatic invertebrates as food sources for shorebirds and waterfowl.

**Tidal Marsh Channels as Open Water Areas**

Channels within tidal marshes are open water areas. Water depth varies with the daily tidal flows and with channel bottom elevation. Minor channels drain at lower tide levels offering exposed channel bottoms through a portion of the tidal cycle, depending on their bottom elevation. Major channels either remain submerged throughout all tides (for the largest channels) or may be drained at some of the lowest tides (for the moderately large channels). The HAT presumes that channels can provide a variety of foraging opportunities for shorebirds and waterfowl, including habitats for benthic and aquatic invertebrates and fish.

**High Marsh as Roosting Sites**

The HAT presumes that roosting sites are needed for passerines and raptors, as well as for shorebirds and waterfowl. Tidal marshes support roosting sites for passerines and raptors on the tall emergent vegetation along channels and especially along natural levees. Roosting sites are also available along the upland perimeter of tidal wetlands, though such availability is strongly affected and defined by adjacent land use. For moderately high tides that do come out of the channels, the tidal marsh plain covered with low vegetation may serve as a roosting site for shorebirds and waterfowl. The shallow pans of high tidal marsh might also serve as roosting sites for shorebirds and waterfowl.

**Creating Shorebird and Waterfowl Habitat in Tidal Marsh Restoration Projects**

No built projects we know of have included drainage divide pans in their design and construction. Two proposed projects have included such features (Montezuma Wetlands Project and Redwood Landfill Wetland Restoration) and one planned project may include them (Hamilton Army Airfield). The only built projects we know of that have included transitional pans are Arrowhead Marsh, currently under construction by the Port of Oakland, and Oro Loma Marsh under construction by the East Bay Regional Park District. Both projects include a variation of the transitional pan idea that does not quite replicate the historic condition, but seeks to provide shorebird and waterfowl foraging habitat. The basic issue with pond creation is how to generate the appropriate elevations, perimeter containment features, and substrate, and how to exclude unwanted vegetation colonization.

Under the natural sediment restoration model, ponds may form naturally, but as yet we do not have sufficient understanding about how they form or under what time scale formation may occur. Pond formation probably involves some influence of stagnant water (tidal water entrained in the peats or isolated on the marsh surface) on plant survival. Drainage divide ponds could be created within restoration sites after the appropriate elevations have been reached (i.e., return to the site some number of years after construction and do some follow-up construction work). Though restoration strategies have yet to be developed, what they might entail could be determined through experiments in any existing tidal marsh with appropriate elevations.

Under the dredged sediment/backfill placement restoration model, ponds could be built at the outset by creating the required elevations, containment features, and substrate with the dredged sediment or backfill. Strategies to achieve ponds in this manner have been proposed, but not yet field tested.

Restoration projects can incorporate some flexibility with respect to channel density and size within some constraints. These constraints include providing adequate amount of tidal circulation throughout a restoration site and the natural processes of sediment transport that form and maintain tidal marsh channels through erosion and deposition. Natural marshes exhibit a wide range of combinations of channel density (defined hydrologically as the total length of channel per unit of marsh surface area [though an ecologist might be interested in the total surface area of channel per marsh surface area or the amount of channel edge]) and channel size. For example, Rush Ranch in Suisun Marsh comprises relatively few channels (i.e., low channel density), but these channels are generally fairly large, whereas Petaluma Marsh comprises numerous channels (i.e., high channel density), but these channels are generally not as large. These differences may have to do with several factors that are specific to regions with the Estuary, such as tidal range, degree of riverine influence, and salinity.

**10. What is the relationship between natural maintenance of tidal channels large and small, including mudflats along the edges of large channels, and the tidal prism provided by tidal marsh restoration?**

As pointed out elsewhere, the form of tidal marsh channels in plan view, profile, or cross section is a result of interactions among the erosional and depositional actions of the flowing tides. In a very general way, channel cross-sectional area increases with tidal prism. For example, channels get larger downstream, toward their tidal source. For smaller channels, say first-order to third-order, the increase in channel size is due more to gains in depth than width. For larger channels, the increase in channel size is due more to width than depth. It is therefore also commonly observed that smaller tidal marsh channels tend to be u-shaped in cross section, whereas the larger channels are more v-shaped. In other words, the banks of the larger channels are less steep. The large channels, therefore, tend to have more area of mudflats, despite the fact that the smaller channels are more likely to completely de-water at low tide.

The relationship between channel form and the tidal prism of the channel has been described for some channels in some areas of the Estuary. The relationship is better described for channels of small to moderate size in saline marshlands. The relationship is not well described for very large channels in any area, or for any size channels in freshwater areas. Historical soundings in tidal marsh channels could be assembled to help describe the relationship between channel size and tidal prism for very large channels, but original field work would be required to explore the relationship for smaller channels in non-saline areas.

A rather crude prediction of the relationship between the size of a tidal marsh restoration project and the amount of channel-associated mudflat could be developed based upon an assumed height of the project plain relative to a local tidal datum, the estimated area of the plain, the expected equilibrium form of the channel in cross section (i.e., the slope of the banks and channel depth relative to the tides) as evidenced by existing data, and the expected plan form (i.e., sinuousity and length) or density (area of channel per unit area of marsh plain) as evidenced by existing data. Another approach would be to quantify the mudflat associated with different size natural marshes as historically mapped by the U.S. Coast Survey.

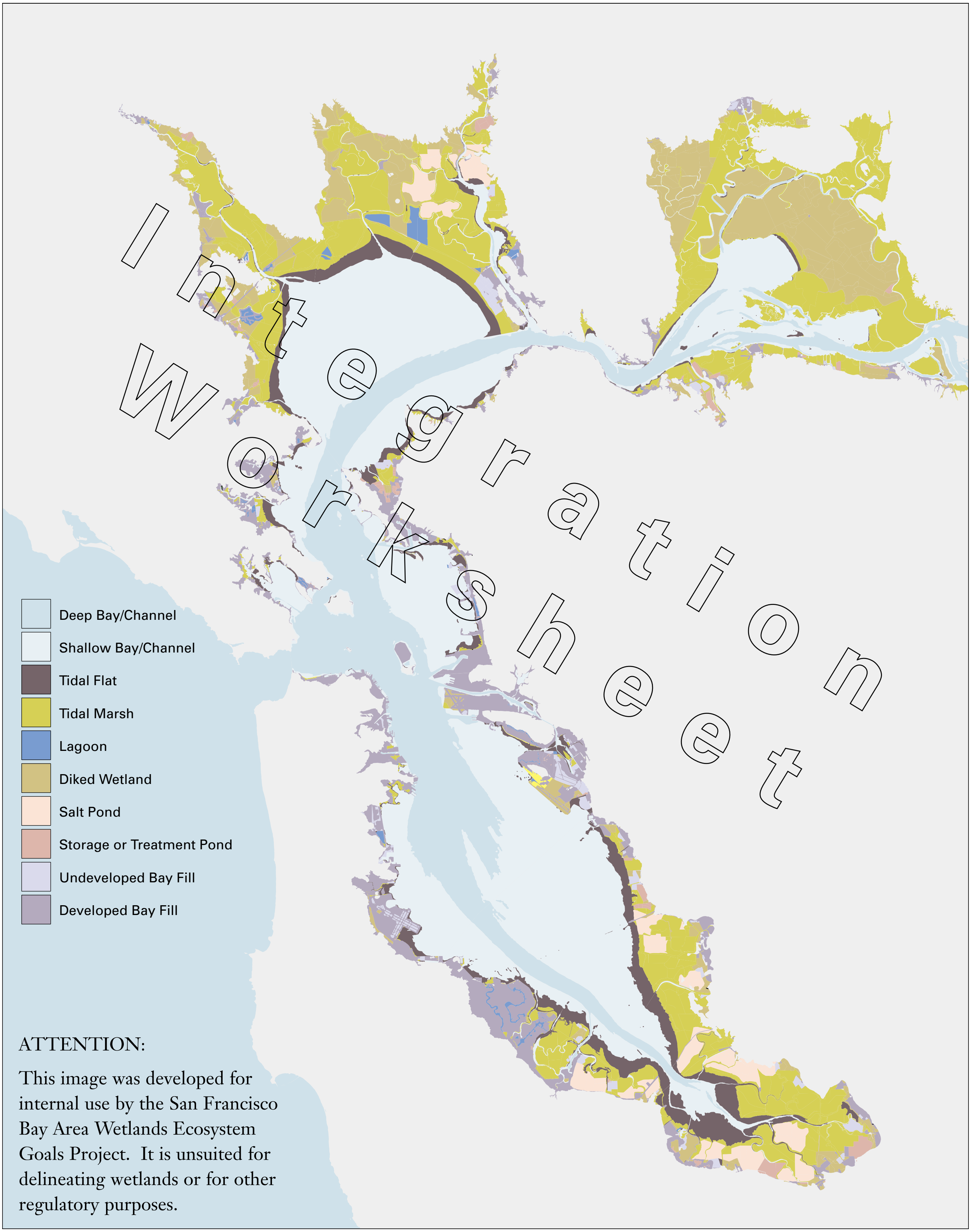
**11. What are the local physical controls, including soil characteristics, for seasonal ponding on diked baylands, including farm lands and ranch lands?**

The primary control is the distribution and abundance of surface water, as affected by rainfall, levee weep or leakage, groundwater discharge, and on-site water management. For diked baylands, it is generally true that surface water exists only until it infiltrates the soil, or while the groundwater rises above the soil surface. There are variations within and among sites due to the interactions among weather (timing, intensity, and duration of rainfall, evapotranspiration), soil conditions (depth, field capacity and related parameters), depth to groundwater, distance to tidal influence and/or uplands, and water management practices (i.e., types and conditions of water control structures and their methods and timing of use). However, a few basic patterns are self-evident. These are:

- For any given set of weather conditions, the amount of seasonal wetlands tends to be inversely related to the amount of drainage.
- The lack of drainage, or the amount of management to provide drainage, tends to be related to the amount of ground subsidence. Simply stated, lower land is more difficult to drain. Therefore, the potential for seasonal wetlands increases with subsidence.
- Subsidence tends to be greater for organic soils than mineral soils, and greater for deep soils. The most subsidence is observed for deep peaty soils.
- Within the diked historical marshlands, the mosaic of organic and mineral soils reflects the historical distribution of tidal marsh channels, with the organic faction increasing with distance from historical channel banks.
- Within a site, in the absence of land management practices that level the land surface, the mosaic of organic and mineral soils produces differential rates of subsidence, which in turn produce topography, and this topography helps control the distribution of surface water and seasonal wetlands.
- In diked baylands, seasonal wetlands are mainly due to local infiltration of irrigation water or rain that causes the near-surface groundwater level to rise above the ground surface. The influence of the tides and groundwater from hillsides tends to be restricted to areas very near the Bay, perimeter levees, or adjacent to steep upland terrain.

# Integration Map

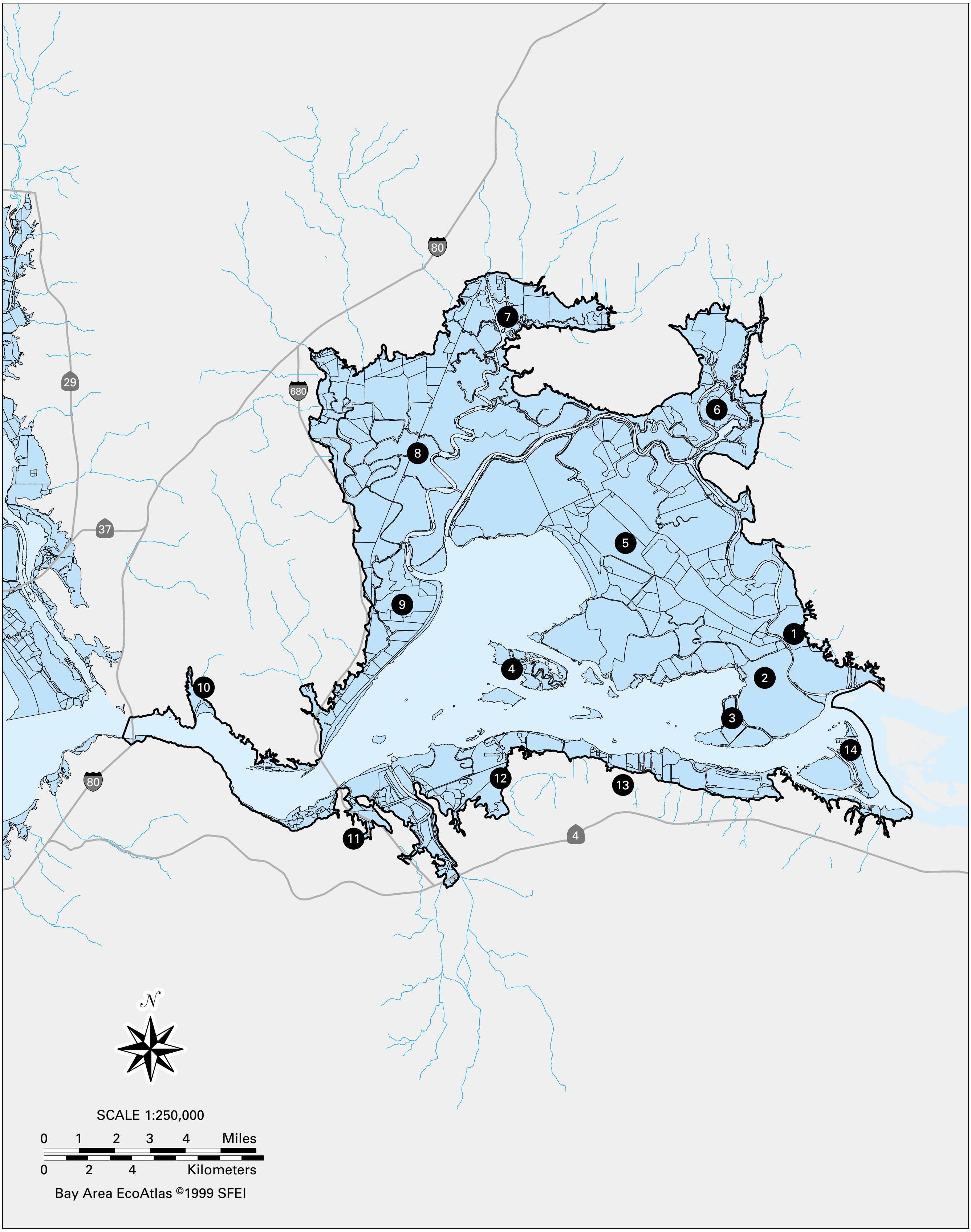
This map, also referred to as the integration worksheet, represents one possible future arrangement of bayland habitats. It was used to derive the habitat acreage recommendations presented in Chapter 5.


Integration Worksheet
Deep Bay/Channel
Shallow Bay/Channel
Tidal Flat
Tidal Marsh
Lagoon
Diked Wetland
Salt Pond
Storage or Treatment Pond
Undeveloped Bay Fill
Developed Bay Fill
ATTENTION:
This image was developed for internal use by the San Francisco Bay Area Wetlands Ecosystem Goals Project. It is unsuited for delineating wetlands or for other regulatory purposes.

APPENDIX E

# Potential Restoration Sites and Projects

## Suisun Potential Restoration Sites and Projects



# Potential Restoration Sites and Projects

The sites listed in this table and shown on the accompanying figures have potential for habitat improvement. Some of these improvements would be simple and relatively inexpensive to effect. Others would be more complicated and costly. This list does not include all possible habitat improvement sites, but it is offered as a starting point for those seeking to undertake habitat projects.

**Site # Recommendation**

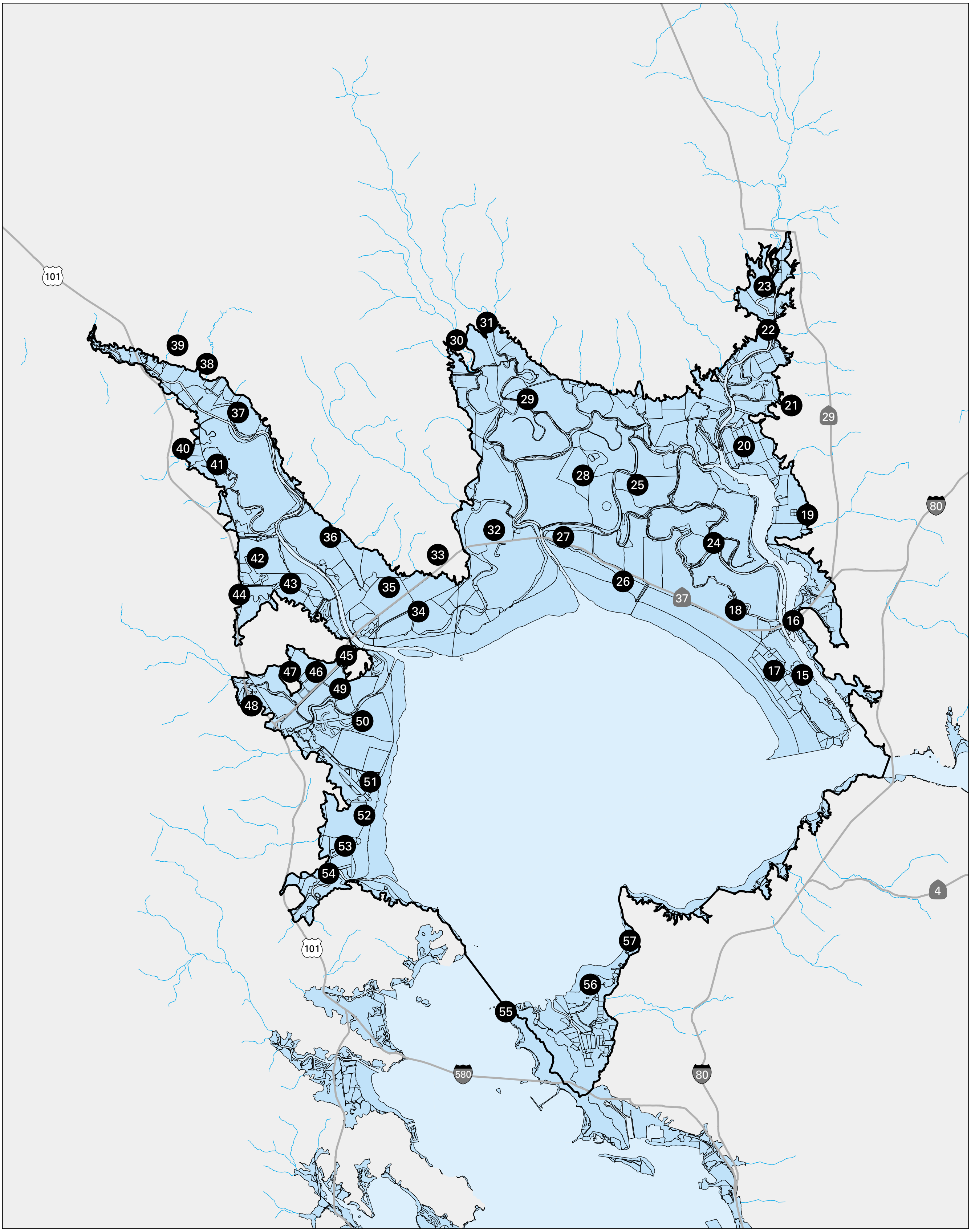
**Suisun Subregion**

1. **Montezuma Slough:** Restore to tidal marsh a wide band along the eastern side of the Slough from Sacramento/ San Joaquin rivers to Nurse Slough. Provide a natural transition to adjacent uplands, and protect vernal pools and other seasonal wetlands.
2. **Roaring River Area:** Restore tidal marsh south of Roaring River on Simmons, Wheeler, and Van Sickle islands, especially to enhance fish habitat.
3. **Chipps Island:** Restore the muted tidal area to tidal marsh.
4. **Ryer and Roe Islands:** Protect existing tidal marsh and enhance tidal action.
5. **Grizzly Island Area:** Enhance managed marsh to improve waterfowl habitat.
6. **Nurse Slough Area:** Restore a large area on both sides of the Slough to tidal marsh, and provide natural transitions to adjacent uplands. Provide protective buffers on Potrero Hills and other adjacent lands, and protect vernal pools, including those on the north of Potrero Hills.
7. **Suisun and Hill Slough Area:** Restore a large area on the north and west sides of Potrero Hills to tidal marsh, including some areas west of the railroad tracks. Provide a natural transition to uplands and buffers.
8. **Goodyear Slough to Boynton Slough:** Provide a tidal marsh corridor connecting the new tidal marsh in the Suisun/Hill slough area to the new tidal marsh in the Morrow Island area. Provide and protect natural transitions to adjacent uplands.
9. **Morrow Island Area:** Restore to tidal marsh a large, continuous band from the confluence of Goodyear Slough and Suisun Slough southward along Suisun Bay.
10. **Southampton Bay:** Protect existing tidal marsh, remove trash, and restore tidal marsh.
11. **I-680 to Pacheco Slough:** Restore diked marshes to full tidal action.
12. **Point Edith and Hastings Slough Area:** Restore a large area of existing diked marsh to tidal marsh.
13. **Port Chicago to Pittsburg Power Plant:** Enhance tidal action and improve water management in existing marshes. Enhance least tern nesting site at the power plant. Protect and expand adjacent buffers where possible.
14. **Winter Island:** Enhance water management.

**North Bay Subregion**

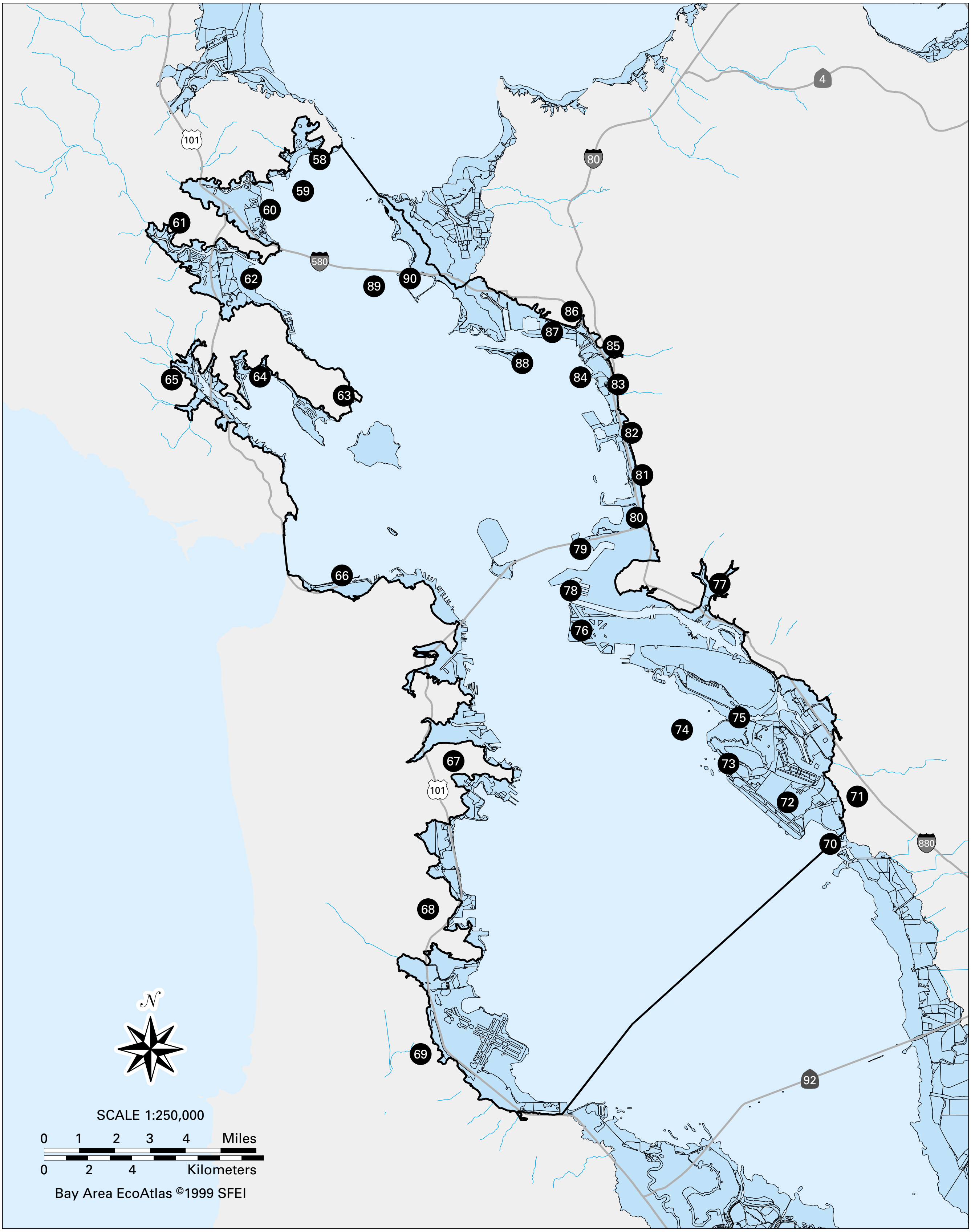
15. **Mare Island Strait:** Enhance habitat for Mason's lilaeopsis.
16. **River Park:** Restore tidal marsh and enhance seasonal pond habitat.
17. **Mare Island:** Enhance seasonal ponding at the dredged material disposal ponds.
18. **Cullinan Ranch:** Restore to tidal marsh.
19. **American Canyon:** Restore tidal marsh and enhance and protect seasonal pond habitat in adjacent uplands.
20. **Crystallizers:** Manage as salt panne and open water habitat.
21. **Green Island Area:** Enhance and protect seasonal pond habitat.
22. **Napa River at Baylands Boundary:** Restore tidal marsh and enhance seasonal ponds at several sites on west side.
23. **South Napa:** Restore tidal marsh and enhance and protect seasonal pond habitat.
24. **West Side of Napa River:** Restore a large area of inactive salt ponds to tidal marsh.
25. **Western Area of Inactive Salt Ponds:** Manage a large complex as salt pond/open water habitat.
26. **Salt Pond Intake Channel:** Remove spoil berm on both sides of channel to enhance tidal marsh habitat.

## North Bay Potential Restoration Sites and Projects



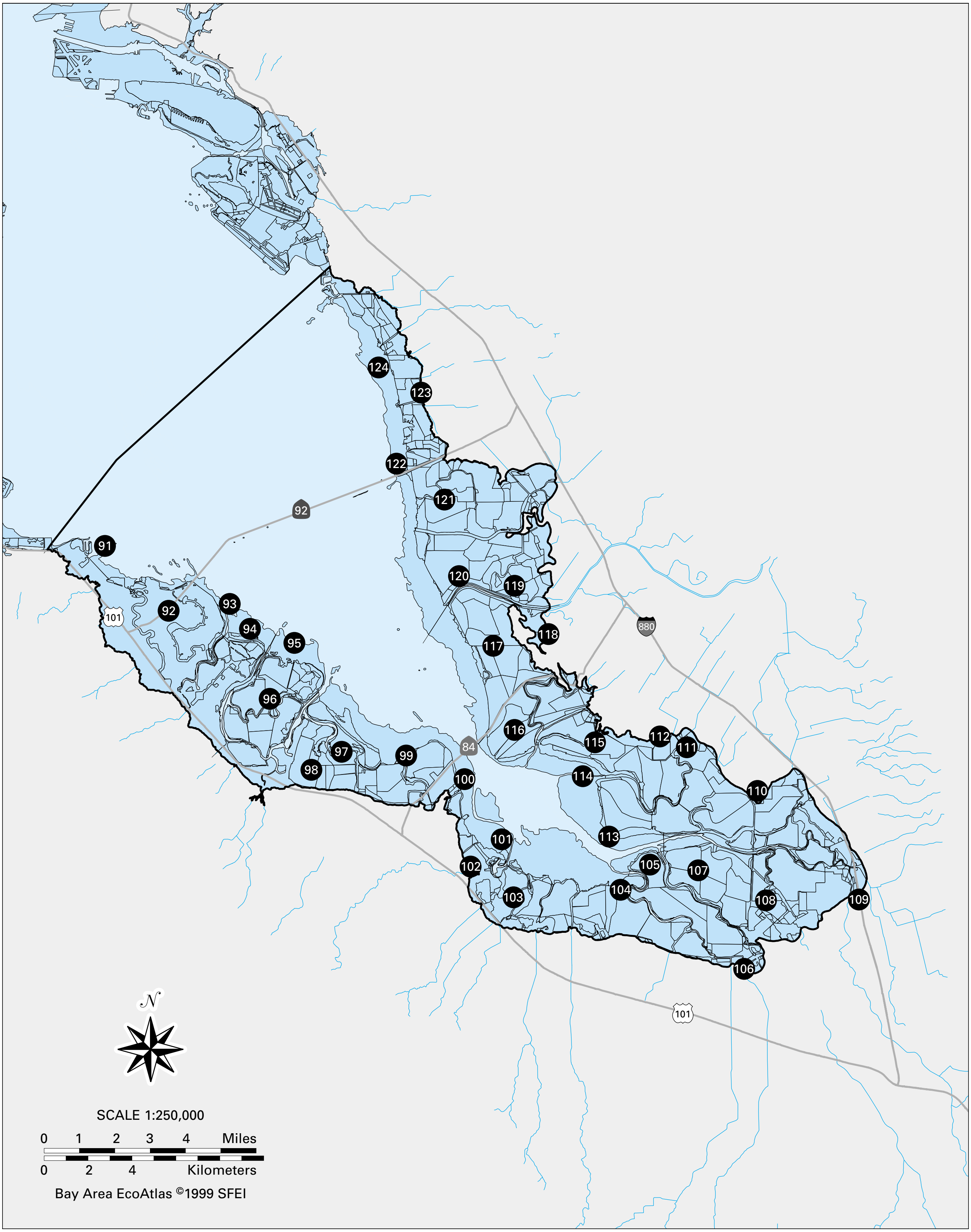
| Site # | Recommendation |
|---|---|
| **North Bay (continued)** | |
| 27. | **West End/Deetjen's Duck Clubs:** Enhance management for shorebirds and waterfowl. |
| 28. | **Skaggs Island:** Restore portion west of Skaggs Island Road to tidal marsh and enhance seasonal pond habitat on remainder of Island. |
| 29. | **Camps Area:** Restore all or part of Camp 3 to tidal marsh. Enhance seasonal pond habitat on Camps 2, 4, and 5. |
| 30. | **Sonoma Creek Upstream From Camp 2:** Restore tidal marsh on west side of railroad tracks. |
| 31. | **Schellville Area:** Enhance riparian vegetation along Sonoma Creek and seasonal pond habitat in grazed lands. |
| 32. | **West of Sonoma Creek:** Enhance seasonal pond habitat on lands north of Highway 37. Restore to tidal marsh lands south of Highway 37. Protect and restore Tolay Creek. |
| 33. | **West of Sears Point:** Manage existing stock ponds and adjacent lands to protect red-legged frog. |
| 34. | **Tolay Creek to Petaluma River:** Restore the area south of railroad tracks to tidal marsh. |
| 35. | **Highway 37:** Enhance seasonal pond habitat on both sides of Highway 37. |
| 36. | **East Side of Petaluma River:** Restore a large area between the River and the edge of the baylands to tidal marsh, and ensure natural transition into the three small watersheds. Also include some seasonal wetlands. |
| 37. | **Cloudy Bend:** Enhance for seasonal ponds. |
| 38. | **City of Petaluma Sewage Treatment Facility:** Restore tidal marsh on one-half of site and ensure mix of seasonal ponds and marsh on remainder. |
| 39. | **City of Petaluma Marsh Restoration Site:** Enhance the dredged material disposal site with seasonal ponds. |
| 40. | **San Antonio West of Railroad Tracks:** Restore the area adjacent to San Antonio Creek to tidal marsh, with enhanced transition to seasonal ponds. |
| 41. | **North of Redwood Landfill:** Restore tidal marsh and ensure natural tidal marsh transition to upland. Include some seasonal wetlands. |
| 42. | **Gnoss Airfield Area:** Enhance with seasonal wetlands the areas surrounding the airport complex. |
| 43. | **West Side of Petaluma River:** Restore the Central and Western Lowlands at Bahia to tidal marsh. |
| 44. | **Rush Creek and Cemetary Marshes:** Improve water management and water quality in the managed marshes. |
| 45. | **Black Point to Bahia:** Protect the unique oak woodland and mixed evergreen forest and hillslope, and the upland/wetland ecotone at base of slopes. |
| 46. | **Highway 101 to Black Point:** Enhance with seasonal ponds the areas on both sides of Highway 37. |
| 47. | **Deer Island:** Protect oak woodland and mixed hardwood forest. |
| 48. | **Hanna Ranch:** Protect oak woodland on hill near Highway 101. |
| 49. | **North Side of Novato Creek:** Restore the area from the bayfront to Highway 101 to tidal marsh, emphasizing restoration upstream of Highway 37 between Deer Island and Novato Creek. |
| 50. | **Bel Marin Keys:** Restore a wide band of tidal marsh along bayfront, and enhance seasonal ponds on remaining areas. |
| 51. | **Hamilton Field:** Restore primarily to tidal marsh and restore/create an upland buffer with managed seasonal ponds. |
| 52. | **Silveira and Saint Vincent's:** Restore a wide band of tidal marsh on about one-half of the area between railroad tracks and bayfront. Protect and enhance seasonal wetlands and transitional uplands between this new marsh and the railroad tracks. Enhance seasonal ponding west of the railroad tracks and protect seasonal wetlands and oaks. |
| 53. | **Gallinas Creek Wastewater Facility:** Enhance seasonal ponding and transitional uplands north and south of the treatment plant. |
| 54. | **Gallinas Creek:** Restore tidal marsh along north side. |
| 55. | **San Pablo Peninsula:** Protect lagoon on east side of the Peninsula. |
| 56. | **Richmond Landfill:** Restore tidal marsh corridor along eastern edge of landfill to connect Wildcat Marsh and San Pablo Marsh. |
| 57. | **Bruener Property:** Protect and restore to tidal marsh with a connection to Giant Marsh, and restore vernal pools in transitional area. |

## Central Bay Potential Restoration Sites and Projects



| Site # | Recommendation |
|---|---|
| **Central Bay Subregion** | |
| 58. | **McNear Quarry:** Restore diked marsh to tidal marsh. |
| 59. | **East and West Marin Islands:** Enhance for colonial nesting birds. |
| 60. | **San Rafael Marshes:** Protect, enhance with seasonal ponds, and improve upland transition area. |
| 61. | **Corte Madera Creek:** Eradicate non-native cordgrass and protect adjacent seasonal wetlands. |
| 62. | **Corte Madera Marshes:** Establish upland buffers on periphery, and enhance seasonal ponding in upland transition zones. Stabilize the shoreline to protect habitat for harbor seal haul-out and pupping. |
| 63. | **Tiburon Peninsula:** Preserve and enhance the small marsh at the end of the Peninsula (Keil Pond, near Bluff Point) for the benefit of red-legged frog. |
| 64. | **Strawberry Spit Area:** Enhance as a haul-out site for harbor seals by reducing human disturbance and protect and enhance habitats on nearby islands. |
| 65. | **Richardson Bay:** Restore and enhance fringing marsh along northwest edge for Point Reyes bird's-beak. |
| 66. | **Crissy Field:** Restore tidal marsh and sand dune habitats. |
| 67. | **San Francisco Shoreline, from China Basin south:** Restore tidal marshes, especially at China Basin, Hunters Point, and along Yosemite Creek, using sandy berms and barrier beaches. Reestablish California sea-blite and associated high salt marsh plant species on sandy edges. |
| 68. | **Oyster Cove/Shearwater:** Restore tidal marsh in subtidal area. |
| 69. | **West of Bayshore Parcel near San Francisco Airport:** Expand and enhance the small existing freshwater marsh for the benefit of the San Francisco garter snake and red-legged frog. Protect adjacent upland habitat. |
| 70. | **San Leandro Marina:** Protect small island at entrance to marina for roosting waterbirds and California sea-blite and other plants. |
| 71. | **Oyster Bay Regional Park:** Enhance burrowing owl habitat. |
| 72. | **Oakland Airport:** Protect and enhance seasonal ponds and snowy plover and least tern nesting habitat. |
| 73. | **Bay Farm Island:** Enhance least tern and snowy plover habitat. |
| 74. | **S.F. Bay near Bay Farm Island:** Protect and enhance existing eelgrass beds. |
| 75. | **Alameda Island:** Restore beach dune and marsh in Elsie Roemer Sanctuary. Eradicate smooth cordgrass. |
| 76. | **Alameda Point (formerly Naval Air Station):** Enhance and protect suitable habitat for least tern, snowy plover, brown pelican, and other species. Protect Breakwater Island from human disturbance. |
| 77. | **Lake Merritt:** Enhance habitat value of lake and slough channel by improving tidal action and restoring tidal marsh, especially along both sides of channel that connect the lake to the Estuary. Consider other shoreline enhancements, including moving or removing public walkways around the lake, as opportunities arise. Reestablish tributary streams and restore riparian habitat. |
| 78. | **Oakland Middle Harbor:** Restore shallow bay, intertidal mudflat, and eelgrass beds. |
| 79. | **Oakland Outer Harbor:** Protect the shorebird roosting sites along the shoreline on south side of toll plaza area. |
| 80. | **Emeryville Crescent:** Protect and enhance shorebird roosting sites by removing debris and restoring native vegetation. |
| 81. | **Berkeley Aquatic Park:** Expand and enhance wetland habitat. |
| 82. | **Berkeley Meadows:** Enhance area between Marina and the freeway with seasonal ponds, provided the fill is of suitable quality. |
| 83. | **Codornices Creek:** Expand salt marsh at mouth of creek. |
| 84. | **Albany Landfill Peninsula:** Enhance roosting habitat at tip of landfill and restore pocket beach on south edge of Peninsula. |
| 85. | **Albany Crescent:** Restore tidal marsh near Central Ave. and create shorebird roosting habitats. |

# South Bay Potential Restoration Sites and Projects



| Site # | Recommendation |
|---|---|
| **Central Bay (continued)** | |
| 86. | **Liquid Gold Site:** Restore tidal marsh to connect Hoffman Marsh with the rest of the shoreline. |
| 87. | **Richmond Field Station Marsh:** Clean up (may include remediation of contaminated sediments) and enhance tidal marsh and seasonal wetlands. |
| 88. | **Brooks Island:** Preserve and enhance eroding beach. |
| 89. | **Red Rock:** Protect as seabird and egret roosting habitat and harbor seal haul-out. |
| 90. | **Castro Rocks:** Protect as important haul-out and pupping site for harbor seals and daytime roost for cormorants. |
| **South Bay Subregion** | |
| 91. | **Coyote Point Marina:** Restore the dredged material disposal lagoons to tidal marsh. |
| 92. | **Foster City:** Consider improvements in the Foster City canal system that would enhance fish and wildlife habitat. |
| 93. | **Foster City and Redwood Shores Peninsula:** Enhance oyster shell ridges in supratidal zone. |
| 94. | **Redwood Shores Peninsula:** Protect Bird Island from human disturbance, restore tidal marsh in Area H, and enhance diked marsh near radio tower and around the sewage treatment plant. Also, enhance seasonal ponds on Redwood Shores Ecological Reserve. |
| 95. | **Bair Island:** Enhance oyster shell ridges in intertidal zone. |
| 96. | **Bair Island:** Restore Inner Bair, Middle Bair, and most of Outer Bair Island to tidal marsh. |
| 97. | **Westpoint Slough:** Restore the salt ponds adjacent to the Slough to tidal marsh. |
| 98. | **Crystallizer and Adjacent Salt Ponds:** Manage as saline pond habitat. |
| 99. | **Ravenswood Point:** Provide a continuous tidal marsh corridor along bayfront, from Greco Island to Dumbarton Bridge. Manage remainder of area as saline pond habitat. |
| 100. | **Pond Adjacent to Dumbarton Bridge:** Protect and manage as saline pond habitat. |
| 101. | **Cooley Landing to Charleston Slough:** Provide a continuous tidal marsh corridor along bayfront, provide more and wider upland buffers, and improve management to reduce human intrusion and predators. |
| 102. | **San Francisquito Creek:** Reestablish native vegetation in riparian corridor. |
| 103. | **Palo Alto Flood Control Basin:** Enhance management to improve diked marsh habitat. |
| 104. | **Charleston Slough to Alviso Slough:** Restore a continuous band of tidal marsh along bayshore and enhance management of several ponds to create one or two salt pond complexes for shorebirds and waterfowl. |
| 105. | **Knapp Parcel:** Restore to tidal marsh. |
| 106. | **Sunnyvale Baylands:** Enhance seasonal wetlands and burrowing owl habitat. |
| 107. | **Alviso Slough to Mud Slough:** Establish a large managed saline pond complex and restore the remainder of the area to tidal marsh. |
| 108. | **New Chicago Marsh:** Improve habitat through better water management or restore to tidal marsh. |
| 109. | **Coyote Creek:** Enhance and reestablish native vegetation in riparian corridor. |
| 110. | **Mud Slough to Albrae Slough:** Restore to tidal marsh, emphasizing a natural transition between tidal marsh and grassland/vernal pool complex. Establish buffer zone to protect this area from disturbance from development in adjacent uplands. Enhance vernal pools in Warm Springs area. |
| 111. | **Mowry Slough:** Protect and enhance the tidal marsh/upland transition at the upper end of Mowry Slough. |
| 112. | **Pintail Duck Club:** Restore tidal influence, reestablish tidal marsh/upland transition, and improve seasonal wetlands. |
| 113. | **Calaveras Point:** Protect tidal marsh for well established population of salt marsh harvest mouse. |
| 114. | **Lower Mowry Slough:** Protect tidal marsh for well-established population of salt marsh harvest mouse and for harbor seal haul-out. |
| 115. | **Mowry Slough to Newark Slough:** Manage a salt pond complex for shorebirds and waterfowl near and including the crystallizer complex, and restore the remaining area to tidal marsh. |

| Site # | Recommendation |
|---|---|
| **South Bay (continued)** | |
| 116. | **Dumbarton Point to Alameda Flood Control Channel:** Establish a large complex of managed saline ponds and restore the remainder of the area to tidal marsh. |
| 117. | **Coyote Hills, west side:** Restore large area at the base of the Hills to tidal marsh and enhance tidal marsh/upland transition. |
| 118. | **Coyote Hill, east side:** Protect, enhance, and expand muted tidal areas with improved water management. Protect and enhance existing willow grove and seasonal wetlands. |
| 119. | **Turk Island:** Establish a large complex of managed saline ponds. |
| 120. | **Alameda Flood Control Marshes:** Enhance and improve management to support wildlife, including small mammals. |
| 121. | **Old Alameda Creek to Highway 92:** Establish a large complex of managed saline ponds in the Baumberg Tract area, including the southern Oliver Brother's ponds. Create shallow pannes for snowy plover nesting. Restore remainder of site to tidal marsh. |
| 122. | **Northern Oliver Brothers Salt Ponds:** Establish a small complex of managed saline ponds adjacent to and north of Highway 92. Create shallow pannes for snowy plover nesting. |
| 123. | **West Winton Avenue Landfill Area:** Establish natural salt ponds in the diked marshes adjacent to the landfill, and in the old oxidation pond to the south. |
| 124. | **San Leandro Shoreline Area:** Investigate the potential for restoring sandy berms and barrier beach along the shoreline to facilitate reintroduction of California sea-blite and other associated high marsh plant species. |

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Aerial photography: Joice Island, 1998, Herb Lingl/Aerial Archives
Inset: Diseño, San Leandro, 1840, Bancroft Library
Topographical map: Petaluma River, 1860, US Coast Survey

Front cover
Aerial photography: Turk Island, 1997, and Bair Island, 1999, Herb Lingl/Aerial Archives
Inset drawing: "East Bay shoreline, still there," 1997, Elise Brewster

Teams of Bay Area environmental scientists have assessed the past and present conditions of the baylands ecosystem and recommended ways to improve its ecological health. This report presents the Baylands Ecosystem Goals.