Restoring and Enhancing Habitats: Things to Consider

Near the end of the process to develop habitat goals, the RMG decided that the final Project report should present more than just recommendations of habitat acreage and distribution — it should provide guidance to the project planners, agency personnel, and landowners that will implement the Goals recommendations. Thus, this chapter contains specific and general recommendations on a variety of technical and public policy issues.

This chapter is divided into three sections. The first section reviews several Bay Area habitat restoration and enhancement projects and some lessons that have been learned from them. The second section describes features of good habitat and presents recommendations on habitat design and management. The third section contains additional information and recommendations on a number of issues relevant to improving Bay Area habitats.

Habitat Restoration and Enhancement — Lessons Learned

At one of the Project's public workshops, several people voiced concerns about recommendations in the draft Goals report. Some stated that restoring large areas of tidal marsh would amount to little more than a big experiment. One person said that there have been no successful tidal marsh restoration projects in the Bay.

Project participants recognize that the science of habitat restoration is young (see Chapter 7). However, many wetland projects have been undertaken around the Bay during the past several decades and they have taught managers and scientists many important lessons. This section reviews some of these projects and describes some of what has been learned. Sharing this kind of information among the larger community will be important for successful regional habitat restoration and enhancement.

Wetland restoration and enhancement efforts of various kinds have been underway in the Bay Area since the late 1960s, and activities to enhance waterfowl habitat on managed wetlands have an even longer history. During this time, most wetland projects have been implemented as compensatory mitigation for development projects that destroyed or degraded wetlands. Even with several decades of experience, however, wetland restoration and enhancement remains controversial, and reviews of wetland creation projects have often been critical (Kentula et al. 1992, Race 1995). One of the most common shortcomings of tidal marsh restoration projects has been the inability to re-create all of the functions of a natural marsh (Zedler and Langis 1991).

Among the most detailed analyses of tidal marsh restoration in California are those from the Southern California coast (Zedler 1996). Some of the failures of Southern California tidal marsh restoration are due to specific restoration site conditions, predominately low-nutrient sandy substrates and low sedimentation rates, which are not typical of the San Francisco Estuary. Other factors, however, such as excess freshwater discharge and exotic plant invasions affect marsh restoration in this region as well. Generalizations about results or feasibility of tidal marsh restoration should be interpreted cautiously in appropriate regional contexts.

Several factors compromised the success of early wetland projects. One of the major factors was poor project design. Early projects that were developed to meet mitigation requirements tended to focus on specific habitat attributes and often incorporated unrealistic design, siting, and size constraints; far too often, this guaranteed failure, particularly for riparian restoration. Another factor was the requirement to undertake mitigation on the same site as the development impact, and to create the same type of wetland habitat. This often resulted in mitigation projects being sited in disturbed or marginally suitable locations. Also, a lack of clear or realistic objectives frequently made it difficult to determine whether a wetland project was a success or failure (BCDC 1988, Gahagan and Bryant 1994).

Over the years, restoration science has progressed substantially as scientists have learned from their early mistakes and have developed a better understanding of how natural wetlands function. Many articles and publications have been produced, particularly for tidal marsh restoration, and these provide a good basis for planning and implementing projects that have a high likelihood of success (Josselyn and Bucholtz 1984, PERL 1990, Zedler 1996). There has been substantial headway in restoring wetlands other than tidal marsh — particularly seasonal wetlands, vernal pools, riparian forest — and in developing planning protocols that can provide a high certainty of success. In all cases, most successes stem from selecting suitable sites and relying on natural processes for wetland evolution and long-term management.

Tidal Marsh

Mussels make a channel bed.

Josh Collins

A large number of sites have been restored to tidal influence within the Estuary, both purposefully and thorough natural processes. The most celebrated are the large mitigation projects, many of which have been accompanied by controversy and scrutiny. These projects include the Faber Tract in Palo Alto, Pond 3 in Hayward, Cogswell Marsh on the Hayward Shoreline, Muzzi Marsh in Corte Madera, and the Sonoma Baylands Project. All of these projects were highly designed and many incorporated the use of dredged material in their construction. Although they have had difficulty in meeting specific restoration objectives, as they develop and mature, they provide valuable wildlife habitat and a basis for the design of future projects. The older projects, such as Faber, Cogswell, and Muzzi marshes have developed many characteristics of adjacent natural marshes and support populations of endangered species. Muzzi Marsh has evolved for some 20 years and during this time the channel morphology, vegetative cover, and animal use have changed considerably (Josselyn, pers. comm.). In effect, these projects are part of an ongoing adaptive management program that will guide future bayland restoration.

Josh Collins

Brackish marsh goes to seed.

These projects demonstrate that dredged material can be useful in restoring subsided sites. This material may be particularly beneficial in re-creating habitat components, such as beach ridges and marsh/upland transition zones, on sites where they do not naturally occur and are unlikely to develop on their own. However, in most instances, one must be careful to allow natural sedimentation to establish final marsh plain elevations. Placement of fill material to elevations that are too high may inhibit channel formation and tidal circulation, and may produce less diverse habitats.

Another lesson learned from these projects is that sites must have unrestricted tidal connections to assure a full tidal range and timely development of target habitat components. Also, experiments in planting non-native marsh plants must be avoided (subsequent information in this chapter describes some of the problems caused by non-native invasive plant species).

Less well-known examples, but probably more important in guiding future restoration of tidal wetlands, are the large areas of the Bay where restoration has been left largely to natural processes. These include Outer Bair Island in Redwood City, Toy Marsh in Novato, White Slough in Vallejo, Whale's Tail Marsh in Hayward, Hoffman Marsh in Richmond, Petaluma River Marsh, and Pond 2A in the Napa Marsh. With the exception of Hoffman Marsh, which was a mudflat until the late 1940s (Haltiner, pers. comm.), these are previously diked areas where the levees have been breached purposely or through neglect. All of these sites, many highly subsided, have evolved over the course of many decades into productive marshes with characteristics similar to natural reference marshes.

These examples indicate that, in many parts of the Bay, the Bay water carries enough sediment to sustain the evolution of appropriate marsh elevations, even on highly subsided sites. Some sites, such as Pond 2A and Bair Island, have shown that remnant tidal channels may provide a template for channel formation. At Whale's Tail Marsh, well-developed marsh vegetation has formed in former salt crystallizers (Patrick and DeLaune 1990), and pans that are characteristic of large undisturbed and historic marshes have formed in the marsh plain. Natural re-vegetation occurs rapidly once appropriate conditions exist, and planting of dominant marsh species is generally not needed or effective in accelerating establishment of tidal marsh vegetation. Also, sites such as Toy Marsh have demonstrated that tidal scour can open small channels and that full tidal exchange develops with time. This also has been demonstrated at the Mini site in Napa County (Wilcox, pers. comm.).

Restored tidal marshes evolve over time, and sites that are initially lagoons or mudflats provide important habitat for fish and wildlife. For example, Sonoma Baylands and Upper Tubbs Island currently are microtidal lagoons, but they receive high use by dabbling and diving waterfowl, particularly in late fall and early winter, and by shorebirds. Monitoring at Sonoma Baylands indicates that the lagoons provide habitat for important fish species including juvenile Chinook salmon (USACE 1997; Heib, pers. comm.).

Some tidal marsh restoration projects have developed much faster than anticipated. Two recent examples are the Petaluma River Marsh Restoration Project and Pond 2A. The subsided 45-acre Petaluma River project, initiated in 1994, developed high mudflat, pioneer low marsh plant colonies on mudflats, and abundant peripheral low marsh vegetation in less than three years (Siegel 1998). The breaching of the 550-acre Pond 2A (an inactive salt pond) in 1995 resulted in greater than 80 percent brackish tidal marsh vegetation cover by 1998 (Wycoff, pers. comm.). Prior to these two projects, many scientists believed that native cordgrass was inherently slow to colonize restored sites.

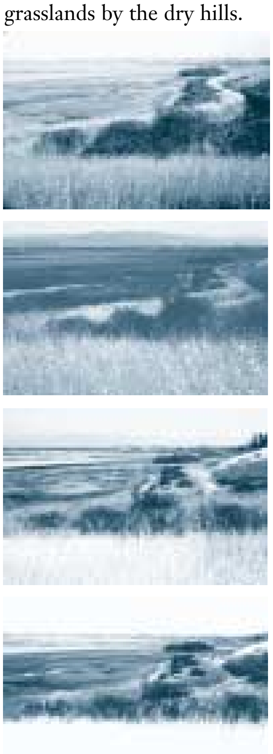
The Petaluma River Marsh Restoration Project also demonstrated that grading unneeded levees to about the marsh plain elevation facilitates rapid establishment of high tidal marsh vegetation. This minimizes habitat for non-native invasive plants and access for predators, while providing high-tide refuge for small mammals.

Additional information has been drawn from observations of the way tidal marsh features develop, or fail to develop, over time. For example, if a large site is to be restored in phases, restoration should proceed from upstream to downstream. Also, the initial channels should be designed large enough to assure full tidal excursion to the site's upstream portion; otherwise, the upstream location may never receive sufficient tidal flows and suspended sediment for natural marsh restoration. An oversized channel is better than an undersized channel, since the channel dimensions will tend to naturally decrease faster than they can increase.

Seasonal Wetlands

The science of seasonal wetland restoration and enhancement is not well developed. However, restoration ecologists have evolved techniques for restoring or enhancing some of these kinds of wetlands. Projects in the Central Valley and in the Santa Rosa area indicate that the most successful seasonal wetland projects are those that are sited in areas with suitable soils and that rely on natural hydrology (CH_2MHill 1995; Stromberg, pers. comm.). Although their design has been controversial, several projects in the Santa Rosa area mimic natural vernal pools in many respects and have maintained themselves for as long as ten years (Patterson, pers. comm.; Wilcox, pers. comm.). These results are promising for restoration and enhancement of seasonal wetlands adjacent to the baylands.

Groundwater wets the grasslands by the dry hills.



Josh Collins

In most of the diked baylands, seasonal ponds have been the products of farming or of passive neglect. An example of this sort of passive management is at Cullinan Ranch, a 1600-acre derelict farm north of Highway 37 in Napa County. When this site was producing oat-hay, it required extensive pumping to maintain dry conditions. When farming ceased, the site rapidly developed features of fresh and brackish seasonal marsh — with plants such as cattail, spikerush, brass-buttons, and fat hen — and deep ponds and mudflats. The site now attracts and supports nesting and feeding waterfowl and shorebirds (Takekawa, pers. comm.).

More recently, bayland restoration project designs have begun to incorporate shallow pond features that are maintained by infrequent tidal flooding or by rainfall. The designs for the Hayward Area Recreation District Marsh and the Baumberg Tract project included managing inactive salt ponds to enhance shorebird habitats during fall and winter and snowy plover breeding habitat during spring and summer (Woodward-Clyde 1998, RMI 1999). The Oro Loma Marsh Restoration Project design included habitat similar to backmarsh ponds, which provide fluctuating shallow water for shorebirds and waterfowl, particularly in late summer through early winter (Levine-Fricke 1993). The Martin Luther King, Jr. Shoreline Wetland Restoration Project design included seasonal ponds adjacent to a newly restored tidal marsh (Levine-Fricke 1996). Future plans for upland dredge disposal sites at Petaluma and San Leandro will include enhancing seasonal ponding for shorebirds and waterfowl.

Many of these projects have only recently been completed or are still in the planning and implementation phases, so it is too early to evaluate their effectiveness. However, monitoring at Oro Loma indicates high use by the target species (Didonato, pers. comm.).

In planning and constructing seasonal wetlands, it is imperative to consider seasonal water availability, site hydrology, site substrate permeability, and site topography. Inadequate assessment of these factors will decrease the chances of creating high quality habitat.

Freshwater Marshes

The creation of freshwater marshes in the baylands has been limited primarily to projects using treated wastewater, stormwater, or flood flows. The Hayward Treatment Marsh and Mountain View Sanitation District Marsh are examples of marshes created with wastewater. The Coyote Hills Demonstration Urban Treatment Marsh receives stormwater flows. The Ygnacio Pond and Hanna Ranch in Novato are examples of marshes designed as integral features of flood control projects. In addition, there are several small freshwater marsh enhancement projects in Napa Marsh that rely on seasonal rainfall.

All of these freshwater marshes support permanent emergent vegetation and open water habitat. The North Bay marshes provide habitat for breeding waterfowl and other water birds. The Hayward Treatment Marsh supports large numbers of wintering waterfowl, an egret rookery, and nesting habitat for resident shorebirds and terns (Taylor, pers. comm.). Additionally, the small wastewater ponds at the Redwood City Wastewater Plant at Redwood Shores receive substantial use for their size, and probably contribute to the heron and egret rookery there (Baye, pers. comm.).

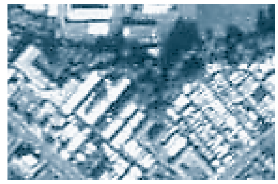
These freshwater marshes indicate that it is possible to use various sources of freshwater to create valuable wildlife habitat in and adjacent to the baylands and to provide other wetland functions. In using these kinds of water sources, however, it is critical to consider the seasonal nature of the water supplies and its effect on habitat functions. It also is important to assess potential contaminant effects.

Riparian Forest

Riparian forest restoration and creation has been underway in the Bay Area for many years, with limited success. Of all the wetland types, riparian forest may be the most difficult to restore because it must exist in proximity to a stream or on a flood plain. Success in restoring riparian habitats depends on imitating natural habitat (Baird 1989). Projects that ignore natural processes or that attempt to establish riparian vegetation at unsuitable sites are almost guaranteed to fail.

In rural parts of the Bay Area, streams are subject to rapidly changing conditions of erosion or sedimentation. Most are eroding along their banks and cutting down below their historical floodplains. As a result, their riparian forests

Some creeks have backyards.



NASA 1996/95

are being lost. Restoring them will require managing watersheds to reduce runoff and erosion.

Most of the region's urban streams have been channelized. This has severely limited their potential for restoration. Flood control levees may support some riparian trees, but only to the extent that this does not compromise the integrity of levees or other structures.

Objectives for flood control and riparian restoration have been met successfully on the lower reaches of Coyote Creek and Wildcat Creek (Riley 1998), and Novato Creek (Prunuske Chatham 1998). Plans are being developed to restore riparian functions along the lower Napa River in the context of flood management.

It is possible to design projects that provide flood control benefits and significant riparian functions. This requires careful planning by an interdisciplinary team of engineers, fluvial geomorphologists, and biologists. It also should involve extensive public input early in the process.

Many of the Bay Area's flood control districts are responsible for maintaining projects that were designed and constructed many decades ago, when there was much less appreciation for naturally functioning riparian systems. Today, several districts have efforts underway to repair some of the damage done by these projects, and these likely will continue for years to come. Perhaps the main lesson learned from recent experiences on local streams is that planning for flood control and riparian forest restoration must recognize the constraints and possibilities posed by activities throughout the watershed.

Site Assessment

One of the important lessons learned from past restoration and enhancement projects is the significance of complete site information. Each potential project site must be rigorously evaluated to determine its suitability for the proposed project. The major factors to assess include the site's historical and current conditions and its water and sediment supplies. To help ensure a successful project, the site should be assessed within a framework of well defined, quantifiable, ecological goals and objectives.

Site Conditions

A complete site assessment should consider a site's environmental history as well as its current conditions. It should assess current and historical land use, natural and unnatural disturbances (such as contaminant storage or leakage), levee failure and flooding, and sediment disposal. Evaluating site hydrology is particularly important and should include assessing water control structures such as tide gates, siphons, ditches, pumps, wells, storm drains or other outfalls, flood bypass channels, and remnant tidal marsh channels. For tidal marsh restoration, it is imperative to consider the site's historical drainage patterns, including the location of remnant channels and their confluences with adjacent tidal marsh channels, streams, or bays. Groundwater discharge should be considered for any site located at the base of a hill or downslope of a shallow aquifer.

A site evaluation should also consider existing and future uses of neighboring lands. If there are other potential restoration sites nearby, the planner should determine their possible physical and hydrological interactions with the proposed project. The project should be designed in the context of the future landscape.

Flood recedes and leaves debris.

Elise Brewster

Project planners should use site assessment information when designing and locating habitat components. For example, seasonal ponds in diked wetlands might be located adjacent to ditches to facilitate managing water levels, and levees might be breached where they cross historical tidal marsh channels in order to reestablish these features.

Water and Sediment Supplies

Site assessment must include an evaluation of water and sediment supplies that originate off site. As explained in Chapter 2, water and suspended sediment are key in controlling the initial formation and natural development of wetland habitats. In the context of restoration design and management, it should be kept in mind that tidal marsh depends on adequate sediment supply, whereas managed marsh, seasonal ponds, and tidal channels depend on adequate water supplies. Bayland restoration or enhancement projects must function within the limits and opportunities established by these natural controls.

The consideration of these controlling factors will involve determining site surface elevations relative to the tides, and the expected changes in tidal elevation due to sea level rise or ground subsidence. It also will entail evaluating the quantity and quality of water and suspended sediment supplies. Past professional experience, predictive models, and the study of reference sites are useful in estimating probable sediment deposition rates and other physical changes that the site will undergo as it evolves.

Habitat Design and Management

Implementing the Goals recommendations will require designing, constructing, and managing many kinds of habitats in and adjacent to the baylands. This section describes, for many of the habitats of the baylands ecosystem, the attributes of high quality habitat. It also presents recommendations on habitat design and management. The habitats are organized according to the Project's habitat typology.

Bay Habitats

Eelgrass

Eelgrass beds are the only Bay habitat for which Project participants made design and management recommendations. The distribution of eelgrass beds in the Bay is quite limited, and it is difficult to control the factors that determine where this habitat will thrive. Reducing turbidity is one of the most important factors that will allow an increase in eelgrass acreage.

High quality eelgrass beds are:

- Free of chemicals that are toxic to desired organisms.
- Geographically stable over the long term.
- Located in non-erosive environments.
- Rooted in a substrate of medium to fine sediment.

The design and management of eelgrass restoration projects should:

- Recognize that the local wave energy environment will determine sustainability.

Management Objectives and Project Design

When undertaking a project to restore or enhance a particular site, it is important to establish specific management objectives and to determine if the site can be designed and managed to meet these objectives.

Often, a primary management objective is to provide support for one or more particular species. In these cases, the project planner should identify the species for which habitat is to be provided and assess the species' habitat requirements. The planner should then carefully consider whether the selected site can support the desired habitat features.

It is much better to determine early on that a site is not suitable for a particular kind of habitat than to discover this several years after project construction.

- Minimize anthropogenic turbidity in order to increase transplanting success.
- Enhance beds by revegetating areas within bed margins.
- Restore beds only where key water quality features (e.g., low turbidity, well-oxygenated sediments) indicate a high likelihood of success.
- Schedule planting when water is warmer.

Bayland Habitats

Tidal Baylands

Project participants made design and management recommendations for three tidal bayland habitats: tidal flat, tidal marsh, and muted tidal marsh.

Tidal Flat

Resource managers have little control over the factors that determine the distribution of tidal flats in the baylands — this habitat occurs at the water's edge wherever there is suitable topography, sediment supply, and currents. They do, however, have some control over the way that tidal flat is managed. This section highlights the characteristics of high quality tidal flat and identifies several management considerations.

High quality tidal flat has:

- An absence of vascular vegetation, except for eelgrass.
- Diverse and abundant infauna and epifauna attractive to shorebirds at low tide and macroinvertebrates and fishes at high tide.
- No, or few, non-native invasive species.
- A range of particle sizes from sandy to clay.
- Salinities that are not subject to rapid fluctuation.
- Well-oxygenated sediments and low contaminant concentrations.
- A wide area with little shoreline disturbance.

Tide drains straight off flats.

NASA 95/96

The design and management of tidal flat restoration projects should:

- Maximize distance from adjacent upland edge.
- Ensure sediments free from chemical conditions toxic to desired organisms.
- Ensure absence of pilings, powerlines, and other artificial structures.

- Locate flats between subtidal and tidal marsh habitats.
- Minimize human disturbance.
- Regularly assess the level of human access.
- Ensure presence of immediately adjacent, protected roosting areas.

Tidal Marsh

There is great potential for large-scale tidal marsh restoration in the Bay, although much needs to be learned about restoring marshes that have a full complement of natural components. Restoring tidal marsh will directly affect the processes that form and maintain deep and shallow bays and channels, and tidal flats. As noted in Chapter 2 and in the next section of this chapter, large-scale tidal marsh restoration will affect tidal prism, sediment deposition and scour, and possibly salinity gradients.

There is significant natural geographic variation in tidal marshes throughout the Estuary, and tidal marsh restoration designs should vary according to local conditions. Depending on management objectives, a design may emphasize different amounts of natural restoration and habitat components. The components to consider are large and small tidal channels, natural and artificial levees, pans, and the vegetated plain. All of these components will evolve in some form on their own in the suitable setting, but they can also be created or nurtured through restoration design. The relative abundance of these components can also be controlled, at least through the early phase of marsh maturation.

Although large patches of tidal marsh should be restored at many sites around the Bay, not all marsh restoration projects need be large. Small patches (i.e., a few acres) of tidal marsh can be ecologically important and may provide especially valuable habitat to certain plants and animals. Even small wetlands may be very important in maintaining populations of wetland-associated animals (Gibbs 1993). Regardless of their size, tidal marshes should be designed and managed to provide a gradual transition zone from the marsh plain to the adjacent uplands.

Tidal wetlands take time to develop; when a site is restored, the initial set of habitat components will evolve for many years. After establishment, a tidal marsh with adequate sediment supply typically evolves in the following way: (1) the drainage network becomes less complex, (2) remaining channels become deeper and narrower, (3) salinity gradients across the marsh plain become more variable and steeper, (4) the amount of marsh plain that is not directly serviced by any channel increases, (5) surface drainage decreases, and (6) the amount of pans increases. Even at restoration sites where there is rapid sedimentation (e.g., Pond 2A in North Bay and the Petaluma River Marsh), it may take many years, even decades, before the marshes exhibit a full array of habitat features. Thus, tidal marsh restoration designs should take into account the probable changes that will occur over a long time period. They also should consider the eventual set of habitat components that is likely to exist when the site matures.

High quality tidal marsh has:

- A well-developed system of tidal channels.
- A natural transition to adjacent uplands.
- Wide upland buffers to minimize human disturbance.
- Connections with other large patches of tidal marsh that enable marsh-dependent birds and small mammals to move safely between them.

Channels wind around pans.

NASA 1995/96


Josh Collins

A pan holds water past low tide.

- Pans in the marsh plain and along the marsh/upland transition.
- Other wetland types and mudflats nearby.
- A dominance of appropriate species of native plants and animals.
- A minimum of uplands or structures intruding into or fragmenting the marsh to discourage predator access.

The design and management of tidal marsh restoration projects should:
- Assess the salinity regime (including artificial freshwater flows) and tidal range in the area where restoration is planned; there should be congruence between the physical parameters of the area (salinity, tidal range) and the expected habitat structure.
- Provide unrestricted tidal exchange, except where muted conditions are necessary or desired (see Muted Tidal Marsh discussion). Where full tidal exchange is not possible, encourage maximum tidal amplitude.
- Rely as much as possible on natural sedimentation processes. Natural sedimentation is preferable if adequate sediment supply is available for timely restoration of desired habitat.
- Utilize remnant natural channels (if present) as the template for channel formation. Fill borrow ditches when possible to keep them from capturing tidal circulation.
- Provide topographic variation to mimic natural conditions within the marsh. Provide small supratidal islands, at or slightly above MHHW, by leaving remnant levees or placing fill at appropriate elevations.
- Grade unneeded levees to marsh elevations (at or slightly above MHHW) when restoring diked baylands. Levee remnants will continue to reduce erosion and to provide high-tide roosting habitat, while discouraging predator access and invasion by weedy species.
- Design levees, where required as part of the restoration, to mimic naturally occurring transition zones (the slope should be as flat as possible).

Restoring Natural Salt Ponds

Historically, there was a large area of natural salt ponds and tidal salt marshes in the baylands near Hayward. It would be beneficial to re-create some naturalistic, unmanaged facsimiles of these ponds at appropriate locations within restored tidal marsh complexes. This could be achieved quickly by constructing very low berms (less than one foot above MHHW) across shallow basin floors near MHW elevation. Natural processes also could lead to the formation of salt ponds, but this likely would take many decades.

Natural salt ponds would provide conditions of near-marine salinity within a large marsh/pond complex, and this would help conserve viable populations of *Ruppia maritima* and unique pond fauna (Barnby et al. 1985). They also would encourage diverse macroalgae beds and provide unique feeding habitat for water birds. Based on historical and current conditions, it seems that natural salt ponds could be constructed near the landward edge of restored tidal marsh on the Bay shoreline in Alameda County.

- Provide for ongoing control of undesirable species including non-native invasive plants, undesirable predators, and mosquitoes. In the case of smooth cordgrass, undertake control as part of pre-construction.
- Rely in most instances on natural colonization by plants; however, there are some rare plant species that need to be reintroduced.
- Provide broad corridors (300 feet or wider) to connect neighboring marshes, except when the marshes are very small.
- Wherever possible, restore tidal marshes on sites that are contiguous with uplands and alluvial soils, seeps, and streams to facilitate establishment of natural transitions.
- Provide a buffer at least 300 feet wide between the upper edge of the marsh/upland transition and neighboring areas of developed use.

Muted Tidal Marsh

A muted tidal regime is required where a tidal marsh is desired, but where tidal flow must be limited to prevent site inundation. Muted marshes can provide many habitat functions for fish and wildlife that are similar to those provided by fully tidal marshes, and they should be considered where a fully tidal marsh would be unacceptable. Also, in some instances (e.g., the Cargill mitigation site near Whale's Tail Marsh), it may be preferable to create a muted tidal marsh as a first step in restoring full tidal action. This would enable sedimentation and would provide foraging habitat for shorebirds, but it would prevent the site from being completely inundated.

Restricting tidal flows can encourage specific tidal habitat features in subsided areas. It can enable the development of salt marsh habitat that mimics conditions of higher, fully tidal marshes. It also can help maintain tidal flats and open water habitat on sites that normally would become vegetated, a benefit for fish. Restricting tidal flows also can desynchronize tidal inundation, providing tidal flats that are available for shorebird foraging and roosting during high tides.

High quality muted tidal marsh has:

- Open water areas that are subject to restricted tidal influence and which provide important habitat for diving ducks, terns, and pelicans.
- Areas maintained as tidal flat with desynchronized tidal flooding to provide important high tide foraging and roosting habitats.

The design and management of muted tidal marsh should:

- Assess site constraints. A muted tidal regime should generally be considered for tidal marsh restoration only when full tidal action cannot be achieved due to flood control considerations or when it would not meet wildlife or habitat objectives.
- Consider elevating roads, rail lines, or transmission towers, especially when these structures are scheduled for upgrading. This would facilitate the eventual restoration of full tidal action to a site.
- Monitor hydrology and sedimentation to assure that there are desired conditions for healthy marsh vegetation.
- Consider developing muted tidal ponds or lagoons on subsided lands for waterfowl management. Such conditions would provide shallow water fish habitat without entrapment concerns.

A Note on Managing Habitats

Some habitats of the baylands ecosystem maintain themselves largely through natural processes, although they may require some management (e.g., control of non-native invasive plants) in order to provide maximum habitat functions. These are loosely referred to as "self-maintaining" habitats and include eelgrass bed, tidal flat, tidal marsh, some muted tidal marsh, riparian forest, and willow grove. Other habitats require more active and ongoing management in order to provide desired attributes or functions. These are referred to as "managed" habitats and include diked wetland, agricultural bayland, and salt pond.

The Goals recommend increasing the acreage of self-maintaining habitats. This will not eliminate the need for managed habitats (in some areas management will need to be very intensive), but overall it will help reduce it. The need for habitat management should be assessed as an integral part of any restoration or enhancement project; when management is necessary, it should be carefully planned and fully budgeted (see page 170 for more information regarding the costs of habitat restoration).

Within the diked baylands, managing lands specifically for wildlife — as at state wildlife areas, federal wildlife refuges, or duck clubs–usually results in the best wildlife habitat. However, management for other land uses, such as farming or salt production, also may provide valuable habitat.

Diked Baylands

Project participants made design and management recommendations for three of the four diked bayland habitats: diked wetland, agricultural bayland, and salt pond. They made no recommendations for treatment/storage ponds, as these are already subject to stringent management review. All of these habitats are managed to some degree for specific objectives, and past and present management actions influence their ability to support certain species of plants, fish, and wildlife. For example, the current farming practices of groundwater management, mowing, disking, or grazing strongly influence the conditions of agricultural baylands for various wildlife species. Converting any of these habitats to a different type of managed habitat will require careful planning and extensive long-term site management.

The habitat Goals call for restoring large areas of agricultural baylands to tidal marsh and managing the remaining areas primarily as diked wetlands, especially seasonal wetlands. They also call for managing some salt ponds in a manner that will make them more valuable for fish and wildlife. These changes should not be effected simply by discontinuing management practices; without adequate habitat design and ongoing management, the sites will not achieve their desired habitat functions.

In designing and managing diked bayland habitats, one should:

- Determine the site's elevation relative to a known tidal datum. If the site is subsided, can water be removed without pumping? Should the site be contoured to increase topographic variation?
- Determine if the quantity and quality (especially salinity) of available water are adequate.
- Determine if there are analogs or reference sites upon which to base the intended design and management. Assess the hydrology of the reference site and try to replicate it.
- Assess whether the site hydrology is appropriate to develop and maintain desired habitat functions without intensive management.

Levees cut across the marsh.

- Consider operation and maintenance issues such as water control structures, protection of adjacent properties from flooding, need for fish screens, and requirements for vegetation and invasive species control.
- Consult with the local mosquito abatement district to determine requirements for mosquito control.
- Assess the intensity of management that will be required to maintain the desired habitat; try to minimize the need for active management. (Management is costly and may be difficult to sustain in the long term.)
- Minimize the number and extent of levees. If levees are required for flood protection or water management, they should be wide enough to support maintenance equipment and should be designed and managed to discourage predator use.
- Consider removing or modifying overhead powerlines, berms, or boardwalks to reduce predation by raptors and small mammalian predators.
- Establish a 300-foot buffer of grasses or other native upland vegetation around periphery; if this is infeasible, maintain a buffer at least 100 feet wide.
- Manage to minimize disturbance from adjacent areas by humans and their pets.
- Inspect structures, water levels, and vegetation frequently to ensure the system is meeting its design criteria.
- Inspect for and control undesirable species (invasive plants, unwanted predators, and mosquitoes).

Diked Wetland

As noted in Chapter 4, the term "diked wetland" includes two types of bayland habitats: managed marsh and diked marsh. Because diked marsh, by the Project's definition, is not actively managed for wildlife purposes, Project participants did not develop design and management recommendations for this habitat type. They did, however, develop many recommendations for managed marsh, and these are presented below in two groups. The first group pertains to marshes that are managed primarily, although not exclusively, for waterfowl, and it is referred to as "managed marsh." The second group pertains to areas that should be managed primarily, although not exclusively, to provide large, very shallow seasonal ponds for shorebirds; this group is referred to as "managed seasonal pond."

In diked habitats, waterfowl generally prefer areas where there is ponded water that is 12 – 18 inches deep, some emergent vegetation, presence of food plants or seeds in the soil, and presence of preferred invertebrates. Shorebirds prefer shallower water (generally less than four inches deep), unvegetated edge with fluctuating water levels, presence of bare areas and minimal emergent vegetation, and close proximity to tidal mudflats. Both shorebirds and waterfowl prefer seasonal wetlands that pond consistently from year to year and continuously throughout the winter season, and which have a presence of preferred invertebrate food items.

Managed Marsh — Most managed marshes are designed to provide optimal habitat for waterfowl, but in many instances it is possible to design and manage these marshes to provide benefits for a wider variety of organisms. For example,


Ken Burger

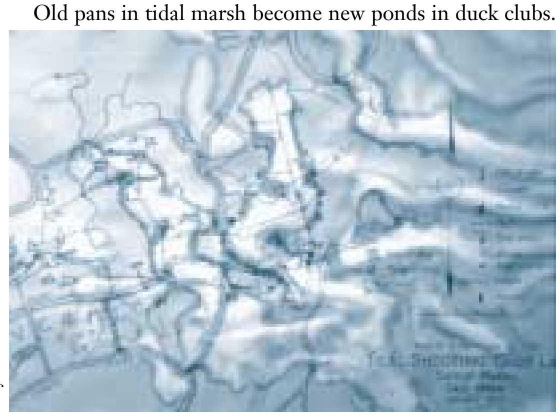
Some managed marshes serve as public parks.

marshes can be designed with deeper water for diving ducks and with shallower water for dabbling ducks and shorebirds.

In general, a high quality managed marsh has:

- Sufficient topographic variation to provide for a variety of water depths, wetland plant diversity, and high water refugia for small mammals.
- A diversity of habitat features to provide nesting, roosting, and foraging opportunities for a wide variety of species. These features include a mosaic of marsh vegetation, open water of varying depth, fluctuation zones with minimal vegetation (non-tidal mudflats), and areas of uplands within or adjacent to the wetland. Emergent vegetation provides cover for resting, nesting, and foraging habitat for a variety of marsh species including grebes, marsh wrens, waterfowl, egrets, and pond turtles. Open water ponds provide loafing and foraging areas primarily for waterfowl, but they are also used by foraging terns, grebes, and egrets. Water depth and duration are important in defining the kinds of wildlife that will utilize a marsh, and a variety of water depths helps to maximize species diversity. Providing deeper areas enables managers to maintain fish populations that diversify the prey base and aid in controlling mosquitoes.
- Provision for wetland habitat functions that are in short supply during certain seasons, years, and portions of the tidal cycle. These include non-tidal habitat for shorebirds and waterfowl during late summer and fall, foraging habitat for wintering waterfowl, drawdown conditions from late March through May to optimize shorebird foraging opportunities, and foraging and roosting habitat for shorebirds during high tide.
- Water level management to optimize wildlife utilization. The ability to vary water surface elevations aids in managing and controlling the types and amount of vegetative cover. This, in turn, determines habitat suitability for shorebirds and waterfowl. Shallow water areas (<4 inches) with exposed drawdown zones are extremely important to shorebirds, particularly in the spring.
- Well-maintained levees, preferably with some outboard marsh to help minimize erosion.
- A minimum impact on fish populations resulting from water diversions.
- An absence of contamination that adversely affects biota.

Old pans in tidal marsh become new ponds in duck clubs.


Tony Arnold

In addition to the general recommendations for diked baylands on pages 152 and 153, design and management of managed marsh habitat should:

- Consider whether site access will be adequate for management purposes in all seasons.
- Maximize a diversity of habitat functions in conjunction with the primary management objectives for a particular species or group of species.
- Provide and maintain water control structures (flood and drain capabilities) to manage the depth, duration, and timing of flooding. To operate most efficiently, the structures should be able to bring water on and off the site by gravity flow.
- Ensure the ability to prevent excessive soil salinity and the formation of acid sulfates in the soil of brackish or fresh water marshes. historical tidal marsh sediments are rich in sulfur, mostly as reduced sulfides bound to insoluble iron in the anaerobic conditions below the shallow root zone. When these soils are isolated from the tides, and permitted to dry, the abundant sulfides can be oxidized to sulfuric acid. If the soils are then wetted, the sulfuric acid can combine with organic acids from the oxidation of peat to acidify the surface sediments and overlying water. Such acidification greatly stresses the plant and animal communities of diked marshlands. Recovery from these conditions requires intensive management of surface hydrology, involving flushing of the acidified sediments.
- Emphasize the establishment of native plant species when feasible and consistent with management objectives.
- Install fish screens on water diversions where there is a potential to entrain endangered aquatic species.

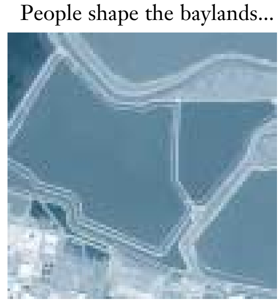
Managed Seasonal Pond — Much of the impetus for the Goals Project stemmed from disagreements among agency biologists regarding the ecological functions of shallow seasonal ponds. In the baylands, these ponds exist primarily in farm fields. Participants spent many hours discussing this kind of habitat and debating its functions for various key species. In the end, everyone recognized that these ponds and the surrounding lands are extremely valuable for many species. They also recognized that shallow seasonal pond habitat functions should be improved concurrent with tidal marsh restoration. Although the recommendations in this section pertain primarily to shallow seasonal ponds within the farmed baylands, they also may apply to the adjacent upslope areas.

The Goals call for enhancing seasonal ponds mostly to improve habitat for shorebirds and waterfowl. Although the general habitat needs of these two groups overlap, the needs of various species in each group differ considerably. Nevertheless, wherever possible, the design of managed seasonal ponds should consider the habitat needs of both groups.

High quality managed seasonal ponds have:

- Frequently or continuously inundated shallow ponds during waterfowl and shorebird migration and wintering periods (August through April) at depths suitable for waterfowl and shorebird foraging and roosting during high tides and storms. To achieve maximum value for shorebirds, inundation should be long enough to discourage dense ruderal cover, but short enough to prevent the establishment of emergent vegetation.

People shape the baylands...



NASA 1995/96

- Presence of ponds every year. Generally, seasonal wetlands that show the highest bird use are those that pond consistently from one year to the next, pond earliest, and remain ponded into late spring.
- Presence of well developed depressional topography, scattered shallow ponds that occur after heavy rains, and presence of short sparse vegetation with a significant component of native wetland vegetation.
- Location near tidal flats to minimize loss of energy by foraging shorebirds.
- No more than a minor component of tall, perennial wetlands vegetation, unless managed as a brood pond for waterfowl, where a fringe of dense, tall vegetation is desirable.
- Presence of unvegetated areas.
- Abundance of preferred plant and invertebrate food sources.
- Located within the baylands and on lands that are transitional with adjacent uplands.
- Few nearby obstructions and disturbances.

In addition to the general recommendations for diked baylands on pages 152 and 153, the design and management of managed seasonal pond habitat should:

- Select sites that do not have high ground water during the dry season to control the establishment of dense emergent vegetation.
- Retain or enhance depressional topography on the site.
- Use sites that are low enough to flood, but high enough to provide drainage using tidegates.
- Construct and maintain structurally sound levees at a 4:1 slope to maximize levee stability, minimize maintenance, and provide transitional wetland/upland habitat. Levee width and height should be based on impoundment size and expected depth. Place levees in areas that have limited exposure to wave action.
- For some areas within diked wetlands, design outboard levees that will episodically overtop with tidal flows to create high salinity and thereby minimize growth of woody, tall emergent vegetation. Alternatively, install adjustable water control structures to effect the same result.
- Manage for desired waterfowl and shorebird food sources through water manipulation to control moisture conditions and plant germination/seedling development.
- Provide a diversity of habitats by designing small impoundments within larger ones to allow for varied water depths, salinities, and other management practices.
- Control water depth unless the site has adequate topographic variation to maintain shallow areas with increasing water depth, and provide for gradual drawdown during the spring.
- Provide areas that consistently pond water when target species are present. For areas of seasonal ponding that are dependent solely on precipitation as a source of water, minimize drainage and encourage soil compaction to maximize ponding extent and duration. Ponding should occur as early in the season as possible. Flooding should be initiated in late summer or early fall for migrating shorebirds and waterfowl.

- Control vegetation to maintain large bare areas or areas of sparse low vegetation. Management techniques include grazing, mowing, disking, burning, and manipulating hydrology.
- Establish burning, mowing, and grazing regimes that favor native plant species.

The majority of diked bayland habitats that currently support seasonal ponds do not incorporate these design and management criteria. Improving seasonally ponded habitats will require changing land management practices.

Agricultural Bayland

As described in Chapter 5, Project participants recommended that agricultural baylands be restored to tidal marsh or be managed as diked wetlands to maximize wildlife habitat functions. However, they also agreed that farmers should continue to farm their lands for as long as they desire, and that landowner implementation of the Goals should be voluntary.

Agricultural baylands, especially portions that have seasonal ponds, provide habitat for several species of wildlife. Farmers that continue to produce crops in the baylands may be able to improve wildlife habitat by modifying their management practices. The kinds of actions they might consider include:

- Allowing ponding in field depressions for shorebirds and waterfowl.
- Creating small diked ponded areas adjacent to levees.
- Encouraging growth of vegetation along fence rows or field edges to provide habitat for small birds and mammals.
- Delaying spring harvest of oat-hay as late as possible to avoid nesting waterfowl.
- Fencing cattle from wetlands during wet periods.
- Increasing the practice of rotational grazing to encourage a more diverse grassland habitat.
- Avoiding farming in the more marginal areas.

Salt Pond

This section describes the habitat attributes of, and presents management recommendations for, salt ponds. It includes information for salt pond complexes that are actively producing commercial salt (active ponds) and for complexes that have been retired from active salt production (inactive ponds). The recommendations for active ponds apply primarily to South Bay ponds that currently are managed by the Cargill Salt Division. Those for the inactive ponds apply primarily to North Bay ponds that currently are managed by the California Department of Fish and Game. The recommendations for inactive ponds would apply to active ponds that are permanently removed from salt production.

High quality salt pond habitat has:

- A series of ponds with salinities varying from low to mid-salinity (<180 ppt), with few high-salinity ponds.
- Water depths that vary from shallow (<3 feet) to very shallow. For shorebirds, water depth should be less than 4 inches, with 2 inches ideal. Water deeper than three feet in lower salinity ponds provides habitat for diving ducks. Within a pond complex, water depth should be spatially variable to increase habitat diversity.

...and reshape the baylands.

NASA 1995/96

- Barren islands within the ponds and/or remote, undisturbed parts of dikes between ponds to provide roosting and nesting sites for shorebirds and terns.
- Proximity to tidal flats to minimize energy losses for shorebirds moving from tidal flats to peripheral foraging habitat.
- Limited nearby obstructions and disturbances.

The design and management of *active* salt ponds should:

- Include islets within ponds suitable for shorebird roosting and for nesting by least tern and snowy plover.
- Ensure that pond islands used by nesting birds are not inundated during the breeding season.
- Allow for drawdown of intake/low salinity ponds during April and early May to enhance shorebird foraging.
- Include sandy beaches on the levee edges along the leeward shore of ponds.

In addition to the general recommendations for diked baylands on pages 152 and 153, the design and management of *inactive* salt ponds should:

- Provide optimal habitat for shorebirds, waterfowl, other water birds, invertebrates, and plant species that typically occur in salt ponds. This is best achieved in a complex where the ponds are linked hydrologically.
- Provide a complex of ponds with various salinities (up to 180 ppt) and water depths.
- Include islets with little or no vegetation to provide roosting habitat for a variety of shorebirds and nesting habitat for terns, avocets, stilts, snowy plovers, and other birds.
- Ensure that each pond complex has access to tidal saltwater. Systems should have the capability to bring in low-salinity water to dilute the concentrated salt water before discharging it back to the Bay.
- Allow drawdown during early spring to optimize foraging habitat for migrating shorebirds.
- Construct nesting islands from levee remnants or by placing fill. Islands should be barren (dry mud is fine) and at least one foot above the maximum water surface elevation.
- Manage ponds so that islands will not eventually cover with salt marsh vegetation. This may require removing vegetation or drowning islands for three to six months during the non-nesting season.
- Manage ponds to provide appropriate conditions for nesting. Some species (e.g., Forster's tern) prefer to nest in low-salinity ponds, while others will nest in low-salinity and mid-salinity ponds. Prevent drainage or flooding of ponds when nests are present.
- Regularly inspect areas to ensure correct water levels are maintained for desired plant germination and growth.
- Provide deeper water depths in some ponds during the winter for diving ducks.
- Minimize maintenance requirements and move towards natural systems where possible. Designs should be tested to develop ponds that mimic historically occurring salt ponds or pans.

Adjacent Habitats

Project participants recommended protecting and improving many kinds of habitats adjacent to the baylands. However, riparian forest and willow grove are the only adjacent habitats for which they made design and management recommendations.


Elise Brewster

A riparian forest leans downstream.

Riparian Forest

Riparian forest habitat has been eliminated or extensively degraded on most of the Bay's small and large tributaries. It is in need of major restoration and repair.

High quality riparian forest habitat:

- Extends in a continuous corridor along a stream course.
- Extends laterally from the stream channel across an unimpeded floodplain.
- Forms a natural transitional ecotone with the adjacent uplands.
- Is free of domesticated animals and human disturbance.
- Supports a diversity of native understory and canopy plant species, and is free of invasive plants.

The design and management of riparian forest should:

- Incorporate setback levees into flood control planning to restore or maintain floodplain and riparian habitats.
- Allow natural stream processes to maintain channel form, provide flood flow passage, and maintain riparian vegetation.
- Control or remove non-native invasive species (giant reed, German ivy, eucalyptus, and Himalayan blackberry).
- Provide buffers at least 100 feet wide beyond the outer edge of the riparian vegetation.
- Minimize trails, grazing, and other disturbance within the riparian corridor.
- Utilize native plant species from the local area.
- Establish appropriate hydrological regime to ensure long-term persistence of native species.

Willow Grove

Willow groves, although never widely distributed, were abundant in South Bay and should be restored wherever possible. They should be incorporated into site designs associated with drainage ditches or flood detention basins.

High quality willow grove:

- Has hydrological conditions (including water quality) suitable to ensure long-term support of grove vegetation.
- Has a natural transitional ecotone with the adjacent uplands.
- Is free of domesticated animals and human disturbance.

Willows grow around a pond.


Josh Collins

The design and management of willow grove should:

- Establish appropriate hydrological regime to ensure long-term persistence of native species.
- Utilize native willow and other plant species from the local area.
- Provide buffers of at least 100 feet in width beyond the edge of the grove.

- Minimize trails, grazing, and other disturbance nearby.
- Control or remove non-native invasive species (giant reed, German ivy, eucalyptus, and Himalayan blackberry).

Other Important Considerations

This section describes several issues that arose during the development of the Goals. The issues range from very specific to very general; some are technical and others pertain more to policy. The RMG provided some guidance on each of the issues, but many will need to be discussed further and resolved in other forums. The intent of this section is to make the reader aware of these issues so that they can be factored into the earliest phases of restoration planning at the regional and local level.

Phasing

In this report, phasing refers to the timing of restoration and enhancement projects in and near the baylands. It is one of the key issues that led to the initiation of the Goals Project. At the heart of this issue is the recognition that tidal marshes and diked baylands cannot occupy the same places at the same time; increasing the acreage of one kind of habitat means decreasing the acreage of the other. In recent years, this issue arose primarily when tidal marsh was restored in agricultural baylands. In the future, it will arise in similar instances and also when tidal marsh is restored in salt ponds and in managed diked wetlands. Proper phasing will be necessary to ensure no overall loss of bayland ecological functions.

Phasing should occur within each subregion. Within a subregion, extensive restoration of tidal marsh should be undertaken, whenever possible, when there is significant progress in enhancing diked wetlands or salt ponds in the same subregion. Ideally, seasonal wetland enhancements would precede tidal marsh restoration. Alternatively, tidal marsh projects would include efforts to enhance diked habitats. In this way, there would be progress toward attaining all of the habitat goals, not just the goal of restoring tidal marsh. However, it will be difficult to attain this ideal unless habitat restoration and enhancement is undertaken on a large scale (i.e., thousands of acres) or within the context of a regional plan or subregional plans. Requiring each and every tidal marsh restoration project to enhance diked habitats as a condition of agency approval may defer endangered species recovery and overall improvement of the Estuary.

One of the more critical aspects of phasing will involve making decisions about habitats for threatened and endangered species — increasing habitat area for some species may reduce it for others. For example, restoring tidal marsh at a salt pond to benefit the California clapper rail and the salt marsh harvest mouse could reduce habitat for the least tern or snowy plover. Planning habitat restoration on a regional scale will minimize this kind of detrimental habitat trade-off. Fully implementing the Goals Project's recommendations should provide adequate habitat for all of the existing protected species.

Given the importance of phasing projects, it is appropriate for the resource and regulatory agencies to develop written agreements, perhaps phasing plans, for each subregion. This would help ensure that tidal marsh restoration occurs only with concomitant restoration and enhancement of other habitat types. It also would minimize short-term adverse impacts to protected species.

Contaminants

Contaminants such as lead, copper, mercury, petroleum, and pesticides may be found throughout the baylands and their concentrations vary greatly in water and in sediments. The design of wetland restoration and enhancement projects must, therefore, examine potential sources and loadings of contaminants to the project site and evaluate the potential problems that contaminants may pose to biota. The kinds of projects in which contaminants must receive especially careful consideration include those that use: (1) dredged material for restoring intertidal habitat and tidal marsh, (2) sewage sludge in diked wetlands, (3) wastewater to create or restore marshes, and (4) wastewater for streamflow augmentation.

Some segments of the baylands are generally more contaminated than others, based on past or current land use. The more contaminated areas include the highly industrialized parts of Central Bay, especially the western shoreline between San Francisco and the San Mateo Bridge, and along portions of some of the East Bay shoreline between Richmond and San Leandro. Wetland restoration projects planned in these areas, especially at sites with a history of industrial activity or use as formal or informal landfills, should include careful assessments for contaminants.

Use of Dredged Material for Wetlands Restoration

Much of San Francisco Bay is naturally very shallow and must be dredged to enable the safe passage of modern, deep-draft vessels in navigation channels, turning basins, and marinas. During the past four or five decades, an annual average of some six million cubic yards of sediment was dredged from the Bay.

Dredged material is disposed of in the ocean, at in-Bay sites, and at some upland sites, particularly landfills. In recent years, dredgers and the agencies that regulate the discharge of dredged material have given attention to expanding the beneficial uses of some of this material. There is much interest in using dredged material to restore tidal wetlands in portions of diked baylands. The Final EIS/EIR for the Long-Term Management Strategy for dredged material disposal proposes that about 40 percent of clean Bay Area dredged material be used for beneficial re-use in a variety of ways, including wetland habitat restoration (LTMS 1998).

Many areas of diked baylands have subsided substantially since they were isolated from tidal waters decades ago. This has been caused by soil decomposition, wind erosion, and compaction of organic matter. Groundwater pumping has contributed to subsidence of some diked areas, especially in South Bay. Restoring tidal marsh or creating shallow ponds for wildlife in subsided areas may require elevating the bottom substrate. Using dredged material is a way to accelerate this process, especially where the suspended sediment supply is limited. Dredged material also may be used to restore a full range of marsh, beach ridge, roosting island, and other habitat that may not develop through natural processes (see page 142).

A dredger clears a creek crossing.

Elise Brewster

In certain locations, and in order to meet specific project design objectives, the use of dredged material may be an appropriate adjunct to natural sediment deposition. Where dredged material is used to raise elevations of subsided baylands for tidal marsh restoration, care must be taken to avoid potentially negative effects such as overfilling, burying historic slough traces, and inhibiting proper slough channel formation. Also, the risk of adverse effects of contaminants on water quality and biota must be addressed. It is particularly important to rely on natural sedimentation processes to the maximum extent possible when establishing the final substrate of the marsh plain.

The decision to use dredged material for wetland restoration or enhancement must be made on a project-specific basis. The LTMS Final EIS/EIR lists specific factors that should be evaluated for any wetland project that proposes to use dredged material.

Given the concerns regarding the use of dredged material in the Bay Area for habitat restoration, the RMG recommends that dredged material be used very selectively and only when it is of suitable quality. All restoration projects that have used or are proposing to use (e.g., Montezuma Wetlands, Hamilton Field) dredged material should be monitored intensively. This would provide a better understanding of the long-term effects of this material on marsh evolution and ecological functions.

Wastewater Re-use

Each day, more than 40 municipal wastewater treatment plants discharge some 600 million gallons of treated wastewater to the Bay. These flows affect the condition of the baylands and some offer potential for improving its habitats.

Most Bay Area municipal wastewater treatment plants discharge effluent to deepwater areas of the Bay, and these discharges do not significantly affect the plant composition of bayland habitats. However, discharges of treated wastewater to sloughs and shallow areas may affect bayland habitats by making them fresher. An example of this is in South Bay, where discharges from the City of San Jose's treatment facility into Artesian Slough have caused large areas of nearby tidal salt marsh to become brackish. This has degraded the habitat of several salt marsh dependent species, and the resource agencies and City staff have spent considerable effort trying to improve the situation.

Treatment facilities that discharge closer to the bayshore, rather than into sloughs, may have more options for avoiding marsh conversion. For example, the East Bay Regional Park District operates the Hayward Treatment Marsh by mixing wastewater from the Union Sanitary District wastewater treatment plant with Bay water before discharging it to the Bay. In doing this, it has avoided significant adverse impacts.

Although wastewater discharge may cause unwanted changes in the baylands if managed incorrectly, it also offers opportunities to create or improve habitats. Most treatment facilities have ponds in which water is stored before being discharged, and waterfowl and other water birds use some of these ponds. Also, some treatment plants use marshes to remove, or polish, pollutants from wastewater before discharging it to the Bay. The Hayward Treatment Marsh and the wetland at the Mountain View Sanitary District facility in Martinez are examples of the kinds of habitats that can be created using wastewater.

Although it may be feasible to create or improve habitats with treated wastewater, the effects of discharging wastewater to wetlands and other areas must be carefully considered beforehand. Flows should be free from potentially harmful contaminants and the receiving wetland or stream should be carefully monitored for long-term effects. Care is also needed to avoid inadvertently converting seasonal wetlands to perennial habitat, causing bioaccumulation of contaminants, or adversely affecting anadromous fishes by discharging water from one watershed into another.

As the population of the Bay Area grows, there will be increased interest in re-using wastewater for many purposes. Given its potential for both positive and adverse effects on the baylands, wastewater re-use should be addressed on a region-wide basis. Efforts underway by the U.S. Environmental Protection Agency, the San Francisco Bay Regional Water Quality Control Board, and others should continue.

Stormwater

During the wet season, large volumes of stormwater enter the baylands. Stormwater flows originate in urban areas and rural settings and, by the time they reach the baylands, they contain a variety of pollutants including suspended solids, trace elements, oil and grease, and pesticides. It is important to remove these pollutants from flows before they cause environmental harm.

Created wetlands can be effective at removing pollutants from stormwater. Perhaps the best local example is the 55-acre Coyote Hills Demonstration Urban Stormwater Treatment Marsh. Although treatment efficiency fluctuates between seasons, between storms, and even within the same storm, this marsh removes several kinds of pollutants from stormwater, including suspended solids, nutrients, and trace elements (Meiorin 1986). The marsh has vegetated and unvegetated areas, as well as islands constructed for nesting birds, and it provides habitat for wintering waterfowl, nesting egrets and terns, and resident shorebirds.

The use of created wetlands to treat stormwater runoff requires careful planning and design. It also requires monitoring of soils and biota to assess long-term effects.

Although wetlands are able to improve water quality, using them to treat highly polluted stormwater may involve some risks. Accordingly, urban stormwater should not be applied to natural wetlands until the risks are more clearly understood.

Salt Pond and Bittern Discharges

Disposing of concentrated waste products is a major management issue of salt ponds. In pond systems where salt is harvested commercially, the waste product is known as bittern, and it contains the magnesium-potassium salts that remain after sodium chloride has been harvested from Bay water. In inactive salt ponds, the waste product that forms when Bay water evaporates is referred to as hypersaline brine.

The San Francisco Bay Regional Water Quality Control Board regulates the disposal of bittern and hypersaline brines in Bay waters. It prohibits bittern disposal because this substance is acutely toxic to aquatic organisms if discharged in a concentrated form (toxicity is a result of high biological oxygen demand, hypersalinity, and specific ion toxicity). It prohibits the disposal of hypersaline brines because these liquids exceed background salinity requirements and, depending on their salinity, may be toxic.

Successfully restoring bittern and brine ponds to tidal marshes will require removal of bittern and brines. Disposal most likely will involve diluting these waste products before discharging them to the Bay. The Bay is one potential source of dilution water, and discharges from wastewater treatment facilities are another. At pond complexes that continue to produce salt, it may be possible to dilute bittern enough to allow its discharge to the Bay; without the need for bittern storage, existing bittern ponds possibly could be restored to tidal marsh.

Resolving this issue will require establishing criteria to determine how, and under what circumstances, these liquids can be discharged safely to the Bay. This should involve careful evaluation of a wide array of potential disposal alternatives for bittern and hypersaline brines. It also should involve the development of validated models to help predict the effects of salt pond restoration in the context of adjacent bayland habitats and restoration efforts. The current scientific investigations of the Napa-Sonoma Marsh Restoration Group, which is working to resolve this issue for the inactive salt ponds of North Bay, should be examined as a possible approach that could also be applied to South Bay.

Buffers

Project participants strongly agreed that existing and restored wetlands must be protected from factors that diminish wildlife habitat quality. It makes little sense to expend private or public funds to restore a site, only to have its biological functions compromised by residential and industrial activities, dogs and cats, unrestricted entry, and illegal dumping. One of the best ways to help ensure that the baylands provide maximum benefits for wildlife is to incorporate buffers into project design and management.

As used in this report, a buffer is a zone of transitional or upland vegetation that abuts a bayland or stream. Its purpose is to minimize the negative effects of adjacent land uses on the bayland or stream. The optimal dimensions of a buffer will vary from locale to locale as a function of local environmental constraints and the ecological objectives of restoration projects.

To develop recommendations for buffers, the RMG and the focus teams integrated the recommendations for many species and habitats. They recommended a minimum buffer width of 300 feet. Where existing land uses or other factors such as steep terrain preclude this, wetland buffers should be no narrower than 100 feet. For riparian habitats, the recommended minimum buffer width is 100 feet beyond the outside boundary of the riparian vegetation.

Most buffers should be fenced to prevent entry of humans, dogs, and livestock. However, there may be some instances where fencing may not be required. Buffers also should be free of human disturbance (e.g., tennis courts, swimming pools, trails) and non-native invasive vegetation.

Buffers should be considered an integral part of every wetland restoration or enhancement project. Funds for their acquisition, design, and long-term maintenance should be provided along with other project funding.

Public Access

In recent years, the public has become increasingly interested in gaining access to the Bay's shoreline for recreational enjoyment. In response to this demand, cities, counties, and several state agencies are facilitating recreational uses of the baylands. For example, the legislation that established the Bay Conservation and Development Commission mandates that agency to require maximum feasible public access as an integral part of shoreline development projects.

Agencies that encourage or require public access to the shoreline are fulfilling a part of their public trust responsibility as they enable people to use a public resource. They also are helping to ensure long-term Bay protection, as people who can use the Bay likely will seek to protect it. On the other hand, agencies that discourage public access because of concerns regarding impacts to wildlife are also fulfilling their public trust responsibilities. Balancing public access and natural resource protection clearly is one of the more difficult arenas of public policy.

Public access has been found to disturb many species of wildlife. Studies have shown that human disturbance can have significant adverse impacts on the feeding and breeding behavior of water birds (Anderson and Keith 1980, Burger 1981). For example, human disturbance may cause a decrease in the duration and intensity of foraging activities by migratory shorebirds, thereby resulting in decreased energy reserves necessary for successful migration and breeding. One study in the Bay Area showed that human activities on a trail reduced the number of birds in adjacent, suitable habitat (Josselyn et al. 1989). Increased human access to wetlands also provides access for foxes, dogs, cats, and other predators, which often follow the same trails used by the public. Due to these impacts, and given the small amount of natural bayland habitats that exist at this time, resource agencies responsible for protecting wildlife consider uncontrolled public access to many baylands incompatible with wildlife protection.

Recognizing the need for more research on this topic, the Bay Trail Project (a regional effort to establish a system of recreational trails around San Francisco Bay) is funding an investigation into the impacts of recreational trails on wildlife. Researchers at San Jose State University are conducting the study, which will assess the effects that trail users have on the immediate behavior of birds and on bird species abundance and diversity. The study will collect data on the effects of typical Bay Trail users — walkers, dog walkers, bicyclists, photographers, birdwatchers, and in-line skaters — on salt marsh and brackish marsh birds (Sokale and Trulio 1998). The results of this study may help project sponsors design trails with fewer adverse impacts to wildlife.

To balance the need for natural resource protection with the increased demand for public access, a thorough assessment of opportunities and constraints for public access should be conducted during the design phase of all restoration, enhancement, and recreational use projects in the baylands. Agencies responsible for authorizing, planning, or requiring public access should:

- Limit or prohibit public access in areas of high biological value during nesting seasons or other appropriate times of the year.
- Provide limited access for compatible wildlife-dependent activities, such as fishing, wildlife observation, or environmental education in areas of higher biological value that can support such activities.
- Provide interpretive signs along trails and focus access on a destination, such as a pier or overlook deck, to limit intrusion into wetlands.
- Minimize construction of extensively improved "loop" trails.
- Emphasize high-quality wildlife viewing experiences that minimally affect wildlife.

- Place heavy-use recreational trails whose primary purpose is not wildlife-dependent (e.g., hiking, biking trails) at inland locations or along the upland edge of buffers, as far as possible from wetlands.
- Actively enforce access restrictions.
- Where necessary, establish and enforce appropriate restrictions on dogs to protect wildlife.
- Provide animal-proof trash receptacles at trailheads and do not allow trash to accumulate.
- Prohibit feeding of wildlife or feral animals.
- Develop a program to educate the public about the many benefits of wetlands. This will foster public awareness of, and appreciation for, wetlands and will encourage voluntary compliance with wetland conservation efforts.

Many of these restrictions on public access are necessary because of the extensive losses of tidal marsh and transitional habitat along the Bay edge. But, as restoration and enhancement projects increase the amount and quality of these habitats, and as populations of marsh-dependent threatened and endangered species rebound, public access impacts to wildlife may become less significant.

Control of Non-native Invasive Plants

There are several species of non-native invasive plants in the baylands ecosystem. These species have the potential to alter the ecosystem by dramatically affecting habitat structure or seriously reducing populations of endemic plants and animals. Thus, their control is of special concern.

Among the several non-native invasive plant species that are causing problems in the Bay, smooth cordgrass perhaps gives the greatest cause for alarm. This is because its spread could effect large-scale impacts to the Bay ecosystem by converting valuable mudflats and small tidal channels to dense marsh of relatively low habitat value for many species. Another species, pepper grass, is displacing native plant species on levees and is spreading into brackish marshes. Giant reed threatens riparian habitats as it displaces native vegetation and reduces habitat quality. These successful, non-native invasive plants are able to out-compete native species that have similar habitat requirements. The regional distribution of introduced tidal marsh plants is reviewed in Grossinger et al. (1998).

There needs to be a major commitment to control the spread of smooth cordgrass before it becomes established throughout South Bay. Control should begin immediately; unless this is done, tidal marsh restoration will likely lead to the spread of this exotic plant species, and the resulting large stands of smooth cordgrass on tidal flats and in channels probably will undermine restoration objectives. Some suggest that planting native cordgrass may help slow the spread of smooth cordgrass into restored marshes; however, recent research indicates that the two species hybridize where they are in proximity, and thus, even planting efforts may be insufficient (Strong and Ayres 1998).

For any tidal marsh restoration project between the San Francisco-Oakland Bay Bridge and the Dumbarton Bridge, a systematic and coordinated program of smooth cordgrass control should be developed and implemented at least two years prior to restoring tidal action. Local colonization pressures by smooth cordgrass must be reduced to insignificant levels before extensive tidal restoration takes place. The goal is to prevent dispersal of smooth cordgrass into the restoration area. A plan should also be in place prior to restoring tidal action to monitor the restoration site for smooth cordgrass invasion and to control any infestations. There should be efforts to control other invasive plant species including dense-flowered cordgrass (currently limited to Richardson Bay, Corte Madera Creek, and Point Pinole), pepper grass, and giant reed.

Introduced Animal Species and Predator Control

Over a period of many years, a variety of introduced estuarine fish and invertebrates have become established in the Estuary; the Bay's history is filled with a litany of successful introductions. In recent years, scientists and managers have become increasingly concerned about introduced animal species and their effects in the Estuary. Many of the introduced species that have been studied are aquatic (Cohen and Carlton 1995), and some of these, such as the mitten crab and the Asian clam, have received considerable media attention.

Many of the introduced species were transported to the Bay in ship ballast water. It is probably not possible to control the species that have already been introduced, but efforts should be directed toward preventing the introduction of additional species. The most effective way to accomplish this is by prohibiting the discharge of untreated ship ballast water in the Bay.

Terrestrial animals are also of concern, especially those that are effective predators on native species. With many of the Bay Area's natural habitats disturbed or lost, predation by mammalian predators on several endangered species has become a crucial management issue.

The red fox is an introduced predator that threatens the survival of the endangered California clapper rail and severely reduces populations of other native ground nesting birds (Jurek 1992, Lewis et al. 1992). Red fox predation on the clapper rail is especially severe because the two species did not evolve together. Also, the rail's tidal salt marsh habitat is greatly reduced in area and is highly fragmented by levees that provide easy access for foxes. Cats are another especially effective mammalian predator on bayland wildlife, particularly on the California least tern. Cat control near tern colonies is critical for this species' survival in the Bay.

Urban development and its associated infrastructure contribute to predator problems. Developments in close proximity to marshes and other bayland habitats provide conditions suitable for terrestrial predators such as red fox, dogs, cats, rats, raccoons, and opossums. The presence of power poles, lighting fixtures, and unnatural landscaping in or near wetlands enhances habitat for avian predators, such as raptors and ravens which prey on snowy plovers, terns, and other bird species. Measures to minimize predator habitat should be an integral part of each restoration project.

Habitat restoration that increases tidal marsh area, reduces its fragmentation, and removes predator travel corridors will reduce the vulnerability of native species to predation by exotic predators. This could lessen the amount of active predator control needed to protect endangered, threatened, and other vulnerable species. However, it is expected that predator control will continue to be necessary to maintain wildlife species, given the proximity of urban areas to the baylands, the need to maintain existing flood control channels and levees (features that provide habitat for predators), and the difficulty in eliminating exotic predators.

One possible management technique that could augment existing predator control programs in South Bay is the reestablishment of coyote populations. Coyotes may help control red fox and other similar predators; however, this technique should be pursued very carefully in order to be certain that it would not adversely affect other wildlife species and people.

Mosquitoes

Mosquitoes are one of the many groups of animals that occur in the baylands ecosystem. Certain bayland mosquito species transmit diseases, the most important of which are those caused by encephalitis viruses. Although clinical cases of encephalitis have rarely been reported in recent years, the virus is still detected annually in wild birds, in sentinel chickens, and in mosquito populations. The primary goal of mosquito abatement efforts is to keep mosquito populations below threshold levels for disease transmission to humans, and to reduce nuisance problems that can impact recreational, economic, and agricultural activities and create public distress.

Mosquitoes rarely occur in significant numbers in tidal marshes that have full tidal action. But they can occur in large numbers in seasonally ponded wetlands with inadequate water control engineering or poor water management practices, and in densely vegetated tidal areas that hold water between tides.

The design of wetland restoration and enhancement projects should include input from the local mosquito abatement district in order to prevent or discourage the build-up of mosquito populations. Where mosquitoes are a potential problem, designs should incorporate features to help discourage and control mosquitoes. Appropriate designs include: (1) deep water, especially on the down-wind side, (2) open water with little or no vegetation, (3) long fetch for waves, (4) permanently flooded areas for mosquito predators, and (5) water control capacity. In addition, designs should incorporate a wide buffer between wetlands (especially seasonal ponds) and residential areas, and provide access points for mosquito surveillance and control.

Once a project is constructed, the site manager should maintain good communication with the mosquito abatement district regarding water levels, predator abundance, and observations of mosquito larvae or adults. The manager should also budget funds for mosquito control, especially for lands which do not contribute funds to the local mosquito abatement district, for projects with habitat types that are especially conducive to mosquitoes, and for projects near residential areas.

Freshwater Flows

Freshwater inputs to the Bay are critical to the healthy functioning of the baylands ecosystem. These flows influence salinity gradients, affect shallow bay habitats, contribute sediments to maintain the marsh plain, and provide energy to the aquatic ecosystem. Changes in the volume and timing of freshwater flows have dramatically affected the baylands in measurable ways since about the 1920s, when diversions from the Sacramento and San Joaquin rivers began to increase markedly. While the effects of diversions are Estuary-wide, the most obvious changes in the baylands have been upstream of Carquinez Strait.

The overall effect of altered seasonal flows from the Central Valley has been to increase salinity in Suisun Bay during spring and summer and to decrease it during the fall and winter. In dry years, relatively high salinities now occur yearlong (SFEP 1992). As noted in Chapter 2, this has caused the tidal marshes in the Suisun subregion to become more brackish. On a smaller scale, hydrological changes in local streams have altered the salinity gradients and salinity regimes where they flow into the Bay, and this has affected the plant communities and habitat functions of tidal marshes.

Some of the water that is diverted from the Bay's streams returns to it in the form of large inputs of year-round freshwater flows from municipal wastewater treatment plants. These flows are changing the tidal marsh habitat types and functions on a local scale.

To the extent possible, the volume and timing of freshwater flows to the Bay should reflect historical or natural conditions under which the bayland habitats and animals developed. Appropriately timed increased freshwater flows in tributaries as large as the Sacramento River and as small as the intermittent streams of South Bay would improve bayland habitat diversity and function.

Wetland Success Criteria

Establishing widely accepted project success criteria is one of the more controversial areas of habitat restoration. Over the years, criteria have evolved from simple measures of vegetation to sophisticated indicators of habitat structure and function. Frequently, restoration projects fail to meet many of their success criteria, but still provide valuable habitat. Conversely, projects that produce low value habitat sometimes are labeled "successful" because they met some inappropriate criteria. The San Francisco Bay Regional Water Quality Control Board, U.S. Army Corps of Engineers, and others have begun work to develop uniform guidelines for evaluating restoration success (DeWeese 1994, Pavlik 1996, Simenstad and Thom 1996, Breaux et al. 1997, Thom 1997, SFBRWQCB 1998).

Project participants offered the following observations and suggestions regarding the measuring of restoration project success:

- The time frame for determining project success needs to be carefully considered. Many types of restored habitats evolve slowly over a period of years, or even decades. A typical five-year monitoring period is not sufficient for evaluating most projects.
- Reference sites for a variety of tidal and diked habitats should be used to help measure project success. To reduce cumulative adverse impacts from repeated monitoring excursions, monitoring of these sites should be coordinated and controlled.
- The relative success of a project should be evaluated in light of natural, external variables, such as drought and flood cycles, regional invasion by non-native species or diseases, and sea level rise. Project design should also address other variables, such as natural subsidence and sediment supply and deposition.
- Success criteria should be uniform to the extent possible, but they also need to be flexible to accommodate changes in understanding.
- A project may not result in the exact type of habitat or condition initially designed for, but it may still be a "success" if it provides good habitat that improves the overall health of the Estuary.

Case Study: A Hypothetical Wetland Restoration Project — Where the Money Goes

The costs of wetland restoration projects vary considerably. It is instructive to see what the money is spent on in a typical project. The following is a case study for a hypothetical medium-sized project at a site with moderate constraints and management requirements. It includes many of the kinds of costs that real restoration projects incur.

Acquisition: *$5 million*. Purchase 500 acres of baylands, which are a mix of uplands, inactive salt ponds, and agricultural baylands. The site has moderate flood protection and infrastructure constraints. Flood protection requires only upgrading of existing perimeter levees. Some powerlines and a pipeline for recycled wastewater will require minimal modification to accommodate restoration.

Project Planning and Permitting: *$250,000 and 18 months*. Conduct site survey, hydrologic study, biological assessments, and historical site assessment. Prepare public access plan. Prepare restoration plan based upon studies and input from public and regulatory and resource agencies. Prepare environmental documents (California Environmental Quality Act/National Environmental Protection Act) and circulate for public and agency review; respond to concerns. Apply for and obtain authorizations: Section 404 of the Clean Water Act, State Waste Discharge Requirements/Section 401 Certification, BCDC permit, compliance with State and Federal Endangered Species Acts.

Project Construction: *$1.3 million and five months*. Dredge 150,000 cubic yards to clear tidal channels ($5 per cubic yard), construct 5,000 linear feet of new levee ($7 per foot), upgrade 8,000 linear feet of existing levee ($3.50 per foot), relocate access roads and construct 100-foot bridge ($200,000), protect existing power and sewer lines onsite ($75,000), install four 36-inch culverts with control gates ($36,000), construction administration and oversite ($100,000), contingencies 10% ($120,000).

Project Monitoring: *$125,000 and five years*. Includes monitoring hydrology, vegetation, and fish and wildlife at $25,000 per year.

Ongoing Operation and Maintenance: *$35,000 per year*. Maintain levees, water control structures, fences, gates, signs, and trails (including prorated replacement costs), $12,000 per year. Other costs associated with management, patrol, inspections, operation of water controls, predator control, and site administration, $23,000 per year. This cost does not include biological surveys or interpretive activities.

In this example, total project cost for the first five years is approximately $7 million. On a *per-acre basis*, the total cost is $14,000. Beyond the fifth year, annual project cost drops to $35,000, the cost for operation and maintenance. Ongoing monitoring costs would be additional.

This example demonstrates that wetland restoration can be an expensive proposition, both in the short-term and in the long-term.

Costs of Habitat Restoration

Restoring bayland habitats will cost millions of dollars. Private and public interests will bear these costs over many decades. There are several aspects of this issue that warrant review.

The cost of restoring wetlands varies widely, and it is influenced primarily by site characteristics, by the complexity of design and construction, and by the type of desired habitat. In recent years, there have been some tidal restoration projects that entailed little or no planning — they were effected by natural or artificial breaching of levees. Examples of these kinds of restorations are at White Slough near Vallejo and at Pond 2A in the Napa Marsh. Although these projects were essentially cost-free or inexpensive, they certainly do not represent the norm. Most restoration projects require substantial funding over a period of many years.

Land Value — A Perspective

Implementing the Goals will require significant land acquisitions. Beyond having adequate funding, one obstacle to acquiring lands for wetland restoration and enhancement is arriving at land valuations that meet the expectations of the buying agency and a willing landowner. In recent years, disagreements regarding land value have prevented some public agencies from acquiring private lands. Further, some landowners and members of the public have questioned the prices that agencies have paid for wetland parcels.

Much of this controversy centers around the work of the appraiser and the assumptions that he or she makes about the opportunities and constraints on property. Some people believe that properties with wetlands should be valued according to current use and fully recognizing regulatory constraints; this tends to minimize the property value. Others, usually landowners, believe that valuations should consider the wildlife benefits provided by the land, not just its commercial potential.

Recent valuations indicate considerable variation in land values from one part of the baylands to another. For example, in South Bay, land valuations for wetland parcels have ranged from $6,000 to $15,000 per acre during the last several years. In North Bay, most of the baylands have been valued much lower, typically in the range of $2,000 to $3,000 per acre. Suisun Marsh property values are similar to those in North Bay. This wide range in valuations has led some to believe that their land is worth more than an objective appraisal would indicate. A review of the appraisal process should help everyone understand this issue better and to appreciate its complexity.

The Appraisal Process

There are many distinct steps in the process of appraising property. The first steps are to identify the property to be appraised, and to determine the property rights that are involved, the use the client will make of the appraisal, a definition of market value, the effective date of the appraisal, and any underlying assumptions and limiting conditions that apply.

Next, the appraiser makes a plan to collect and analyze general information about the market and the government regulations and environmental forces that affect the value of the property. This provides the background against which the specific data are analyzed. Specific data include information about the subject property site and improvements (the land and buildings or other structures), and the comparable data on properties which have sold, rented or are listed for sale (comparable sales, comparable rentals, or comparable listings). The appraiser must consider the effect on use and value of the following factors: existing land use regulations, reasonably probable modifications of such land use regulations, economic demand, the physical adaptability of the real estate, neighborhood trends, and the highest and best use of the real estate.

An analysis of the highest and best use is an important step in the process of estimating the value of any property. The appraiser must first estimate the highest and best use of a property, regardless of whether the site is unimproved and vacant, or is improved and occupied. They identify that use which, in their opinion, would be the best development of the property in terms of its total economic worth. They do a second highest and best use analysis of the property as it is actually improved to identify what could be done to the existing improvements to make the property more valuable. Highest and best use is defined as: "the reasonably probable and legal use of vacant land or an improved property, which is physically possible, appropriately supported, financially feasible, and that results in the highest value. The four criteria the highest and best use must meet are legal permissibility, physical possibility, financial feasibility, and maximum profitability." (AIREA 1989). To determine the highest and best use, the appraiser needs to analyze:

- What are the possible physical uses of the site?
- What legal restrictions or limitations are being imposed as a result of zoning and/or deed restrictions?
- What uses would feasibly produce the highest present value for the site?
- What is the highest and best use from among the feasible uses?

Three Approaches to Value

In appraising real estate, there are three separate methods that are customarily utilized for the purposes of determining the economic value of any given property. The nature of the property determines which one or more of these methods is utilized and which receives the greatest emphasis in the reconciliation. While the appraiser generally bases his/her valuation of the land on sales of comparable

(continued on next page)

Land Value — A Perspective (continued)

lands, a general definition of the three approaches to value is as follows:

Cost Approach

The value concluded via the Cost Approach is comprised of two components: the value of the underlying land as if vacant and available for development, and the estimate of the reproduction replacement cost of the improvements. An aggregate amount reflecting the decrease in utility brought about by various forms of physical, functional, and economic depreciation is then subtracted to arrive at the calculated value. This method typically receives the greatest emphasis when valuing special purpose or newer properties for which relative construction costs can be determined. Because many of the lands appraised for public agencies, particularly land acquired for wetland preservation and restoration, are vacant lands, the Cost Approach is not utilized.

The Market or Sales Comparison Approach

This approach requires several distinct steps. It compares the property being appraised to other similar nearby properties that have recently sold or are currently listed for sale. When good data are available, the results obtained by this approach are the most satisfactory and also the easiest to understand. Since no two properties are exactly alike, the appraiser must make adjustments for significant differences between the comparable sales and the subject property. Keeping in mind that a sales comparison value estimate decreases in reliability if there are many differences between the subject property and any of the comparable sales, the four general categories of adjustments are as follows:

- Time adjustment, to reflect market differences between the date of the appraisal and the comparable's date of sale.
- Location adjustment, to reflect value differences between the location of the subject and the location of each comparable sale.
- Adjustments for differences in physical characteristics between the subject and the comparable sales, such as size, condition, special features, amenities, etc.
- Adjustments, if needed, for special conditions or special financing that might have influenced the selling price of the comparable.

In general, restoration projects incur costs for five different kind of activities. These activities include site acquisition, planning and permitting, construction, monitoring, and maintenance. The cost of each of these five activities varies considerably from project to project. Accordingly, the total long-term per-area cost for wetland restoration or enhancement varies substantially. The following four examples demonstrate the range of costs:

- **Pond 2A in Napa Marsh** — the total cost to restore an acre of wetland was only about $1,000. This inexpensive project restored tidal action to an inactive salt pond using explosives to blast a hole in a levee.
- **Baumberg Tract in Hayward** — the total cost per acre of restored wetland will be about $18,000. This project to restore seasonal and tidal wetlands requires constructing levees, installing water control structures, and relocating power lines.
- **Tolay Creek in North Bay** — the total cost per acre of restored or enhanced wetland was about $27,000. This tidal marsh restoration project required levee construction and repair, and extensive channel dredging.
- **Martin Luther King Jr. Shoreline Wetland** — the total cost per acre of restored wetland was about $56,000. This project to restore tidal marsh and to establish seasonal wetlands was highly engineered; it involved moving large volumes of soil, excavating channels, and creating low berms.

The main factors that account for the large range in the costs of these projects are land acquisition costs and design complexity. Although there are economies of scale associated with larger restoration projects, even very large projects may be relatively costly if they are in areas where land is expensive. Based on several recent examples of restoration projects, one may reasonably expect that a typical bayland project will cost somewhere between $5,000 and $50,000 per acre of restored wetland. Most projects probably will be in the range of $10,000 to $20,000 per acre of restored wetland.

An important aspect of restoration project funding is long-term maintenance. As anyone who has had to take care of land knows, maintenance costs can be substantial. Maintenance activities include tasks such as fixing water control structures, repairing eroded levees, removing trash, repairing fences, controlling predators, replacing signs, and paving and grading roads. It is important to recognize that long-term maintenance does not come cheaply, and its costs must be an integral part of any wetland restoration budget. Because much of the habitat

Land Value — A Perspective (continued)

Reconciliation Approach — The Final Value Estimate

In instances where the cost approach and the market approach produce substantially different valuations, the appraiser will reconcile these differences. In this reconciliation approach, the appraiser considers all of the available data and uses his or her knowledge, experience, and professional judgment to estimate a final value for the subject property.

Appraisal Report

The final step of the valuation process is the preparation of the appraisal report. Complete appraisal reports are usually in narrative format and contain, in addition to the estimated value, many details about how the appraiser arrived at the value as well as supporting maps, charts, and photographs.

Professional Ethics and Standards

The Appraisal Foundation, through its Appraisal Standards Board, has been mandated by Congress to develop a code of ethics, which is called the Uniform Standards of Professional Appraisal Practice. Appraisers follow this code or similar professional standards enforced by various independent appraisal organizations which also have their codes of ethics.

All states require that real estate appraisers who are licensed and/or certified comply with these standards. All of the various independent appraisal organizations also have their codes of ethics that are enforced by internal committees on professional standards.

Conclusion

The key to the appraisal process is recognizing that every piece of real estate is unique, and that the type of value to be estimated must be determined by the needs of the client. Tens of millions of acres of environmentally significant real estate worth perhaps billions of dollars need to be appraised for acquisition and protection in coming years. How this property will be valued, and values that may be estimated, will be based on fair market appraisals by independent appraisers. Government agencies, historically the most frequent purchasers, will undertake acquisitions from willing landowners. Also, these agencies typically have standards requiring appraisers to evaluate the real property rights acquired, based on a traditional market value definition, premised on a highest and best use determination, that permits an estimate of market value, arrived at using comparable sales.

The evaluation of lands in Suisun Marsh, around San Pablo Bay, and in South Bay will be pivotal to the ultimate implementation of the Goals recommendations. Many landowners consider the prices currently offered for their lands a pittance compared to the open space and habitat values that society seems to place on them. Resolving this issue immediately and fairly must be a high priority of the agencies.

changes envisioned in the Goals ultimately will occur on public lands, it is imperative that the managers of these lands receive the funding necessary to maintain habitat and to meet their responsibilities as good neighbors.

Restoring Wetlands Outside of the Baylands

Many valuable wetlands used to exist outside the baylands, particularly vernal pools and other seasonal features in moist grasslands and riparian vegetation adjacent to streams. Although agriculture, flood control, and other kinds of development have affected many of these wetlands, some are intact, and new wetlands have recently developed on altered landscapes. There are many sites that could be restored or enhanced and improving them could help replace some of the habitat functions that will be lost as diked areas within the baylands are restored to tidal marsh.

All wetlands and riparian corridors outside of the baylands should be fully protected to prevent their further degradation or total loss. In addition, there should be a detailed inventory of these resources, with attention focused on vernal pools and other seasonal wetlands, as many of these support unique plant and animal species. Projects to enhance and restore these valuable resources should be undertaken in tandem with projects in the baylands.

Baylands Science — History and Needs

Developing the Goals required a large body scientific information. The Goals Project itself was part of a rich history of scientific investigation about the San Francisco Estuary. The Project participants collectively represented hundreds of years of baylands field and laboratory experience. The institutions they represent have long histories of both bayland science and management. While it is certainly true that much is known about the estuary and the baylands, much remains to be learned.

The first half of this chapter presents an overview of past and present bayland studies, and provides some perspective on the breadth and depth of current scientific knowledge. The second half of this chapter presents the Project's recommendations for future studies and urges the implementation of a region-wide research and monitoring program.

History of Baylands Science

The history of science and management of the baylands begins with the native peoples that lived near the baylands for at least 30 centuries. Their survival depended upon a detailed understanding of the ecological structure and functions of the baylands (Milliken 1995). To the extent possible, the available fragments of this native knowledge have been incorporated into the Project through the historical view of the Bay Area EcoAtlas, which is based in part on Native American accounts of habitats and wildlife. It is well documented that the Native Americans used the tidal marshes for salt production and waterfowl hunting (Ver Planck 1958, Brown 1960). The emerging picture of native land management may provide some guidance for managing the baylands in the future.

Beginning in the mid-1700s with the earliest Spanish explorers, people began to record the physical features of the region's landscape on maps, and later to describe its physical and biological characteristics in journals and reports. The

Tules are turned into houses.

Elise Brewster

A Wealth of Baylands Knowledge

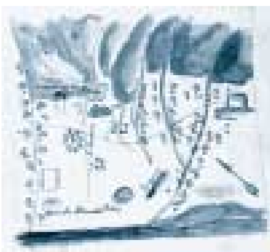
Over the last hundred years, there has been a rapid increase in the amount of scientific information about the baylands. In the 1980s, more than 350 technical reports and articles about the baylands were produced; nearly twice as many as were produced in the 10 previous decades. These figures do not include the numbers of environmental impact reports and monitoring reports.

Since the 1980s, the number of baylands researchers has increased, with the universities, colleges, and government agencies in the region contributing more to baylands science than ever before. The amount of scientific information about the baylands continues to grow. And yet, much of the more current information has not been published; it exists in the field notes and collective experience of the regional community of wetland scientists and managers.

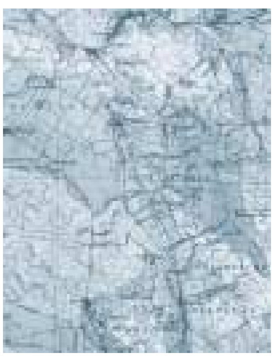
By bringing together these regional experts, the Goals Project was able to draw not only from many decades of published information, but also from the greater wealth of professional scientific experience.

following three sections trace the evolution of baylands knowledge through mapping, physical science, and ecological science.

No map shows all.



Bancroft Library



USDA 1914

Whitney 1873

Mapping

Various maps of the estuary and its immediate environs have been produced in the last two centuries. Juan Crespi drew the first published map in 1772, during the expedition of Pedro Fages. Other Spanish explorers produced no fewer than seven maps during the late 1700s. From 1827 to 1839, the English expedition led by Frederick Beechey made five separate maps of the estuary and some of its harbors. All of these maps include considerable detail of the bathymetry of the bays and straits, and features in the baylands, including lagoons, and local streams.

Early maps of the Spanish ranchos and Mexican land grants were sketched by the landowners to support their claims. These maps, which date between about 1830 and 1850, show appreciable detail of tidal marshlands and riparian forests. In 1841, Charles Wilkes created a detailed map of Suisun, the Delta, and the lower reaches of the Sacramento River for the U.S. Navy. The U.S. Hydrographic Office (Harlow 1950) revised this map in 1850.

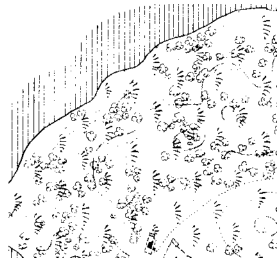
The most detailed and well-documented maps of the baylands were produced by the U.S. Coast Survey in two sets, the T-sheets and H-sheets, beginning in 1852. Although these maps vary in quality among the surveyors, they remain some of the most detailed shoreline maps ever made (Grossinger and Collins 1999).

Other maps made during the late 1800s and early 1900s can be used to confirm the details of the T-sheets and H-sheets, and in some cases to add local information. Examples of these kinds of maps include historical county maps, local soil surveys by the Bureau of Soils of the U.S. Department of Agriculture, the first topographic maps produced by the U.S. Geological Survey, and the regional geomorphic maps produced by Josiah Whitney as the first State Geologist.

Since the beginning of this century, the number and kinds of maps of the Bay Area has increased. However, until the last few decades, most modern maps disregarded the baylands. The navigational charts produced by the Coast and Geodetic Survey, and later by the National Oceanographic and Atmospheric Administration, focused on the bathymetry of the bays and straits, and the foreshore between the baylands and the open bays. The second and third generations of topographic maps made by the U.S. Geological Survey tended to only show the levees and roads of the baylands and some of the largest tidal marsh channels.

It was the advent of computer-based cartography that greatly improved mapping of the baylands. During the last few decades, global positioning systems, which use satellites to determine the geographic coordinates of the ground surface, have been combined with digital imaging technologies (e.g., radar, infra-red, and other spectral themes) in geographic information systems to create electronic maps. Digital terrain models and high-resolution digital images from airplanes and satellites are fundamental elements among these technical mapping systems. The U.S. Geological Survey recently produced a new set of digital terrain models for the Bay Area, and the National Oceanographic and Atmospheric Administration and the National Atmospheric and Space Administration are developing high-resolution imagery of the baylands.

A cooperative venture between the National Ocean Survey and National Geodetic Survey has produced a new array of global positioning system control stations in the North Bay and in Suisun (BCDC and NOAA 1998) to improve the spatial registration of baylands images. Bay Area maps are moving onto the Internet as interactive references to spatial data and their sources (e.g., the Regional Environmental Geographic Information System at the University of California, Berkeley; Bay Access at the U.S. Geological Survey in Menlo Park; and Comprehensive Monitoring Assessment Research Inventory at the Estuary Institute). The Bay Area has become a center for new information technologies, including state-of-the-science cartography.


USCS 1860

Oaks dot a map...

Physical Science

The earliest known studies of the physical nature of the estuary dealt with the tides and currents. The early explorers recorded the strengths of the currents and the depths of the bays relative to tidal stage. There has been a nearly continuous record of the tides at Fort Point since 1868. Another permanent gage was later installed at the Alameda Naval Base. This gage provides a record that is more indicative of tidal patterns in the estuary.

The National Ocean Survey is responsible for measuring the tides. It periodically computes the tidal datums for permanent and temporary gages around the Estuary, and these computations are used to adjust the datums for sea level rise (Gill et al. 1998). The National Ocean Survey has conducted regional studies of the spatial variations in tidal datums (NOAA 1980 and 1983), and both the U.S. Army Corps of Engineers (USACE 1984) and the California State Lands Commission have analyzed the frequency of different tide heights. The California Department of Water Resources has tide gages in Suisun that are referenced to the National Ocean Survey tidal datums. Some cities have their own gages and use their own datums. Field studies have revealed natural, local variations in average tide height among tidal marsh channels that are ecologically significant (Collins and Evens 1992). Recent studies of tidal marsh geomorphology suggest that these spatial variations in tidal datums also have a significant effect on the natural maintenance of tidal marsh channels (Siegel 1993). The ongoing measurements of the tides and currents are an essential part of the basic information about the baylands.

...of oaks on a hillside.


NASA 1995/96

There are few early records about the physical nature of the baylands, except with regard to the tides. The earliest explorations provide some accounts of the sources of fresh water around the edges of the estuary, but these accounts mainly focus on plants and other wildlife. Some of the written records of extreme events, such as Brewer's observations of the great flood of 1862 (Farquhar 1966), or the descriptions by Crespi of natural salt ponds in the South Bay (Bolton 1930), help to visualize the historical, natural variability in weather and landscape.

There have been far fewer studies of the physical nature of the baylands than of their ecology. Gilbert's study of currents and sedimentation (Gilbert 1917) is the "nearest thing we have to a base line analysis of the physical characteristics of San Francisco Bay" (Hedgpeth 1979). This study marked the start of a continuing investigation into the hydro-dynamics of the estuary (Miller et al. 1928, Young 1929, Fischer 1976, Conomos et al. 1979, CDWR 1986, Ogden Beeman and Associates 1992, Cheng et al. 1993, McDonald and Cheng 1993) and sediment transport (Krone 1966, Buchanan and Schoelhammer 1995), which has lead to increasingly useful numerical models.

Until very recently (Schoelhammer 1998), the hydrologists who study the open bays and straits had not studied the baylands. Past analyses of sediment fate and transport within the estuary has disregarded the baylands (Krone 1979 and 1985). Hydrological studies of the baylands did not begin until the 1960s. Studies undertaken at this time focused on the form and function of small tidal marsh channels (Pestrong 1965, Holland 1976, Collins et al. 1987, Haltiner and Williams 1987a, b, Siegel 1993, Leopold et al. 1993) and local patterns of sedimentation (Pestrong 1972, Wells and Goman 1995). The most recent field studies in the Napa-Sonoma marshes (USACE 1998), and the estuarine hydro-dynamic modeling for South Bay have begun to elucidate the hydrological interactions between the bays, the baylands, and local watersheds.

Chronic subsidence of the baylands has been addressed from two perspectives. Subsidence due to groundwater extraction has been measured and mapped by the U.S. Geological Survey (Helley et al. 1979) for the Santa Clara Valley and adjoining baylands of South Bay; groundwater levels in this area are intensively monitored by local agencies. Local subsidence of diked baylands due to wind erosion and the oxidation of peaty soils has been studied in the Delta (Hastings 1998), with findings that apply to diked baylands elsewhere in the region. Bayland farmers and duck club members understand the influence of local subsidence on surface water management. Their practical experience in water management can be applied to the enhancement of diked baylands.

Until recently, water quality studies have focused almost exclusively on the open bays and local watersheds (Miller et al. 1928, Filice 1959, Luoma and Cain 1979, RMP 1998). Studies of the distribution and the ecological effects of contaminants are now being extended into the baylands (Lee et al. 1995, RMP 1998). The potential use of dredged sediments to nurture tidal marsh restoration (LTMS 1998) has also nurtured the study of intertidal sediment toxicity (Lee et al. 1995). Ongoing studies of the fate and transport of estuarine contaminants within the baylands will help to quantify their regional function as a water filter.

Ecological Science

The journals of naturalists that accompanied the earliest Spanish explorers are the oldest written ecological surveys of the Bay Area. The naturalists that traveled into the region more than 200 years ago with Gasper de Portola, Pedro Fages, Don Fernando Rivera, Juan Manuel de Ayala, and Juan Bautista de Anza (Bolton 1930) made notes about the plants and animals that they encountered near the estuary, and about the landscapes around them. These accounts of local settings collectively provide a rough sketch of the native landscapes of the region. They were followed in the late eighteenth and early nineteenth centuries by other explorers, most notably George Vancouver, who made maps and recorded the natural history (Vancouver 1798), and F.W. Beechey (Beechey 1941). Perhaps the first substantial biological survey of the estuary and its adjacent uplands was made in 1824 (Hedgpeth 1979) by scientists accompanying the Russian explorer, Otto von Kotzebue (Essig 1933).

These and other early accounts were later combined with anthropological studies of contemporary Native American culture in technical references about the historical ecology of the region (Cooper 1926, Skinner 1962). These records have since been compiled and augmented with more recent findings to create the current set of references (Mayfield 1978, Atwater 1979, Harvey et al. 1992). The historical view of the EcoAtlas that was developed for the Goals Project is one of the most detailed regional maps of native landscapes ever produced.

There was a long hiatus in regional ecological studies of the baylands between the early 1800s and the mid-1900s. Voyages of the U.S. Fisheries Commission steamer Albatross within the estuary beginning in 1912 yielded a variety of technical articles on the estuarine water and their biota, but almost nothing about the baylands (Hedgpeth 1979). Researchers at Stanford University and at the University of California, Berkeley made significant collections of the fauna and flora of some locations. However, these were not compiled into a regional view until a few decades ago. Reverend Edward Greene conducted botanical surveys through much of the region in the late 1800s, but his collections are not comprehensive for the baylands. The longest running ecological records for the region are the U.S. Fish and Wildlife Service's and the California Department of Fish and Game's mid-winter waterfowl surveys, and the California Department of Fish and Game's annual mid-water trawls. The waterfowl surveys began in 1955, and the trawls began in 1967. Of these studies, only the waterfowl surveys pertain directly to the baylands.

Environmental legislation enacted in the early 1970s created a need for scientific information about the baylands. A new industry of environmental science was built on the need to inform regulatory decisions. The sudden growth in ecological information about the baylands, and its variable quality, warranted a series of regional and subregional reviews during the late 1970s (CDFG 1977, Harvey et al. 1977, Atwater 1979, Jones and Stokes Associates et al. 1979, Josselyn 1983).

These reviews identified gaps in understanding that began to be addressed by a growing number of baylands scientists in government, academia, the private sector, and not-for-profit scientific institutions. Ecologists and hydrologists at the University of California, Davis; University of California, Berkeley; San Jose State University; Hayward State University; and San Francisco State University developed new lines of baylands research. The U.S. Fish and Wildlife Service, California Department of Fish and Game, Point Reyes Bird Observatory, and San Francisco Bay Bird Observatory began regular field surveys of baylands birds and other wildlife. Field data began to flow from baylands restoration projects.

Science for Baylands Restoration

A large amount of scientific information about the estuary has been developed during the past century. Although much is known about the baylands, there is much to learn. Throughout the course of the Goals Project, participants frequently noted a scarcity of data on many important bayland issues. They identified many research needs in their focus team recommendations and in their species profiles. At the five-day integration workshop, Project participants agreed that future efforts to restore the baylands ecosystem should be supported by an integrated program of research and monitoring. Such a program is needed to provide better information on habitats and their functions and on the effects of restoring and enhancing these habitats. It also is needed to track progress towards achieving the Goals.

Perspective on the Science of Wetlands Restoration

The science of wetland restoration is still in its infancy — active restoration has been underway for less than three decades. Achieving the ambitious vision presented by the Goals Project will require rapid advancements in the state of this science. We must learn from past and present efforts — gathering, interpreting, and sharing information so that each generation of restoration projects is more predictable and cost effective.

How does a new science typically develop? We can obtain some historical perspective by considering advances in other fields, such as space exploration, electronics equipment and data processing, and water resources engineering. In each of these cases, advancements stemmed from nationally recognized public mandates. Spurred by public sentiment, elected officials and government agencies provided support through legislation and resources. Public interest and government support resulted in integrated programs of fundamental research, extensive laboratory-scale experimentation, carefully monitored pilot projects, and large-scale project implementation. All phases of these efforts were monitored and evaluated, so that the designs could be refined and the success measured.

Similarly, the field of wetland restoration had its beginning when ecologists and the public, recognizing the value of wetlands, directed the government to halt their continued widespread destruction. In response to public pressure, elected officials passed laws restricting unnecessary wetlands destruction and requiring mitigation for permitted losses. The government also established funding to purchase and restore wetlands in some areas. Although the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, and the U.S. Fish and Wildlife Service are conducting some research on many aspects of wetlands ecology, much remains to be done to develop a coordinated program of research, experimentation, and monitoring. Most wetlands restoration projects continue to be monitored solely to verify compliance with permit requirements, and this limited monitoring information is typically not widely disseminated. Inadequate attention is typically given to evaluating these individual projects holistically to determine how they support overall ecosystem health, or to glean new knowledge from the effort.

Despite this disorganized beginning, the current state of the science of wetlands restoration is starting to resemble the early stages of advancement in other scientific fields — there are national and state mandates to protect and restore wetlands, most government agencies concerned about the baylands recognize that a comprehensive program is needed, and the public broadly supports the idea of protecting and restoring wetlands as a part of a larger movement to preserve the environment. It is now reasonable to envision that, given adequate funding and more integrated federal and state agency support, wetlands restoration might advance into a more mature science, with appropriate levels of research, monitoring, and implementation.

— By Jeff Haltiner, Hydrogeomorphic Advisory Team

Many endeavors, in addition to the Goals Project, have recognized the need for a regional program of baylands science. Such a program was called for in the National Oceanographic and Atmospheric Administration's proposed San Francisco Bay Estuarine Research Reserve System (NOAA 1992), in the Estuary Project's *Comprehensive Conservation and Management Plan* (SFEP 1993) and its *Regional Monitoring Strategy* (SFEP 1993), and in the CALFED Bay-Delta Program's Comprehensive Monitoring and Research Program (CALFED 1998a).

Suggested Program Objectives

A regional program of baylands science should focus on meeting the scientific needs of baylands managers. To do this, there must be a critical look at each existing and new restoration or enhancement project, and a series of questions must be asked: Is the project successful? How is "success" defined? Are there any negative effects of the project? What are the combined effects of this and other projects on regional conditions? Does the project bring us closer to the regional habitat goals? What should be done differently with the next project?

The breadth of these issues underscores the need for a comprehensive science program that includes the following objectives:

- **Increase understanding of baylands habitats and ecological functions.** The capability to restore or enhance the baylands is linked to an understanding of their function as ecological systems. Much of the ecological function of wetland systems results from complex interactions among physical and biological factors that are not well understood. Increased understanding of these complex systems will enable improvements in the planning, designing, and management of restoration and enhancement projects.
- **Build upon existing science and monitoring experience.** Although there is much to learn about baylands restoration and enhancement, past projects provide important lessons. The exchange of ideas among local and regional experts should be encouraged and facilitated.
- **Obtain useful information from each restoration and enhancement project and use projects to test new ideas.** Much can be learned about baylands restoration and monitoring through projects that are designed to help meet research needs. Controlled scientific experimentation should be supported as a way to rapidly improve the ability to create functional systems.
- **Monitor to measure progress towards the Goals.** The Goals provide a yardstick by which to measure progress towards a healthy and sustainable baylands ecosystem. This information can be used to prepare a "report card" to Congress, legislators, the public, and other stakeholders, and to inform the Estuary Project's continuing State of the Estuary updates.
- **Monitor some mitigation projects.** Wetlands restoration projects frequently occur because of requirements associated with dredge or fill permits, and they must be monitored to assure compliance with permit conditions. In some circumstances, it may be beneficial to include monitoring of these sites as part of a regional program.

- **Make information readily available to agencies and the public.** Policy makers and other planners can make better decisions based on up-to-date, accurate information on the health and status of restoration of the baylands.

To help meet these objectives, the Estuary Institute has begun to develop a program for baylands science, focusing on the baylands downstream of the Delta (Collins 1999). In a somewhat parallel fashion, CMARP has begun developing a plan to assess the ecological health of shallow water habitats in the Sacramento/ San Joaquin River watershed, including the Delta and Suisun Marsh (Collins, J. 1998). Coordination of these efforts is required for them to address the needs for baylands science throughout the estuary.

Suggested Program Framework and Elements

The wetland science program should be developed within a logical framework. This framework could possibly consist of a set of conceptual models about the baylands and their ecological functions. The conceptual models could help the regional experts generate hypotheses and identify critical gaps in understanding or information. A draft set of conceptual models has been developed (Collins 1999), but these are very preliminary and will need further review and revision.

Project participants and others have identified many of the needed elements of a baylands science program. The following sections briefly describe these elements and some priority topics that should be addressed. Additional and more detailed research and monitoring recommendations are in the focus team recommendations (Appendix C) and in the species and community profiles (Goals Project 1999).

Please note that the suggested program elements and topics presented here are incomplete and preliminary. Designing the bayland science program will require a thorough and systematic assessment of these and other elements and topics. During that assessment, it may be helpful to organize each program element according to a hierarchy similar to the one presented in the next section.

Research

Research is needed to expand scientific understanding of the baylands ecosystem. Agencies should establish priorities to help focus this research toward key topics of interest to bayland managers. Within this framework of priorities, researchers should be encouraged to explore new ideas and confirm new discoveries. This approach would link research to practical management needs.

An effort to prioritize research topics has already begun, as Project participants identified many questions relating to their particular interests. Others, too, have identified research topics (SFEP 1995, Collins, J. 1998 and 1999). In general, there seems to be a need to better understand the nature of the baylands as habitats for native and introduced fish and wildlife, and as transitional landscapes between the open bays and the local watersheds. These topics can be further separated into a larger number of more specific questions according to their physical or biological aspects and the scale to which they pertain. It should be recognized that research priorities will change.

On a regional scale (i.e., whole estuary), research should be conducted to answer the following types of questions:

Physical Sciences

- What are the effects of tidal marsh on the sediment budget and tidal prism?
- How does the form of tidal marsh channels vary with salinity?
- What is the availability of sediment for tidal marsh restoration?
- What is the appropriate scale to measure shoreline loss or gain?
- What factors affect the evolution of mudflats and tidal marsh features?

Biological Sciences

- What is the effect of tidal marsh on nutrient supplies to the bays?
- What is the tidal marsh fish community?
- What are the patterns of migration of waterfowl and shorebirds through the baylands?
- For which species of fish and wildlife is the baylands ecosystem fragmented?
- Where do birds go if their habitat is converted to another habitat type?

On a subregional scale (Suisun, North Bay, Central Bay, South Bay), research should be conducted to answer the following types of questions:

Physical Sciences

- How do the relative influences of watersheds and bays on sediment supply and contaminant loading vary with distance along the tributaries, such as Nurse Slough, Suisun Slough, Napa River, Petaluma River, or Coyote Creek?

Biological Sciences

- What controls the distribution and abundance of California clapper rail, salt marsh harvest mouse, and other resident species — what are the roles of dispersal, food, nesting resources, and salinity?
- Where do tidal marsh birds and tidal flat birds go at high tide?
- What support functions are provided by salt ponds, seasonal wetlands, and managed marsh?
- What is the long-term effect of waterfowl management practices on marsh soils and vegetation?

On a local scale (projects and wetland patches), research should be conducted to answer the following types of questions:

Physical Sciences

- What is the relationship between tidal marsh patch size or shape and natural channel maintenance?
- How do marshes act as chemical or sediment filters; what is the relationship between loading, distance from channel, and plant architecture?
- How does tidal marsh affect local watershed drainage, including flood frequency?
- How are mature, high tidal marsh conditions restored quickly, especially in subsided baylands?

Biological Sciences

- What causes plant zonation in a tidal marsh?
- What is the relationship between habitat patch size and production of waterfowl or shorebirds in managed and unmanaged diked marshes?
- How can non-native plant and animal species be monitored and controlled, and how can new introductions of invasive species be prevented?

Pilot Projects

Because most of the restoration efforts over the past 30 years have been mitigation projects, they have been designed and monitored primarily to meet permit requirements. Consequently, these efforts have focused little on expanding restoration science or our technical understanding of the baylands ecosystem. Pilot projects are needed now to answer the high priority questions about baylands restoration. Depending on the kind of information needed, pilot projects typically may range in size from a few hundred square feet to many hundreds of acres, or even larger. Pilot projects looking at natural habitat controls or large-scale tidal marsh design issues should be very large, from 500 to 1,500 acres.

Project participants suggested that pilot projects should be undertaken on many topics that fit into the general outline of needed research. Topics that should be addressed through one or more pilot projects include:

- Optimal design, configuration, and management of salt ponds to support shorebirds and waterfowl in the absence of commercial salt production.
- Effective and affordable methods for controlling non-native invasive plants, such as smooth cordgrass.
- The effect of smooth cordgrass on habitat function.
- Techniques for incorporating naturalistic high marsh pans and other features as integral components of large-scale tidal marsh restoration projects.
- Methods for restoring tidal marsh in the deeply subsided areas in South Bay.
- Options for using organic, rather than strictly mineral, sediment for restoring tidal marsh elevations.
- Possible non-traditional water management methods to provide good waterfowl habitat.

Monitoring

Monitoring is a repeated set of systematic observations designed to measure change over time. It is essential for determining the success of restoration projects, the effects of management decisions and practices, and progress toward the Goals. Monitoring is required by regulatory agencies for mitigation projects and for most restoration projects. However, the existing approach to monitoring is piecemeal and should be improved to enable comparisons of projects and to measure regional conditions.

One of the first steps in improving the approach to monitoring should be an assessment of existing baylands monitoring efforts. This assessment should lead to the development of standard monitoring methods that would enable short-term and long-term project comparisons. These methods should include practical monitoring parameters and protocols that would provide useful information at a reasonable cost.

The performance of wetland projects must be evaluated relative to the natural variability of the baylands. This requires establishing a network of reference sites that can be used to monitor background variation in populations of key species of fish and wildlife and their habitats. Although there are no sites within the baylands ecosystem that have remained pristine, there are less-disturbed sites or portions of sites which still provide a useful basis for comparison. The proposed San Francisco Bay Estuarine Research Reserve of the National Oceanographic and Atmospheric Administration can help provide a large part of the needed network of reference sites (Vasey 1995).

Jack Feminella

A biologist learns the ropes.

In addition to monitoring done for individual research projects, pilot projects, and restoration projects, information is also needed on a broader scale. The distribution, abundance, and health of populations of key fish, wildlife, and plant species should be monitored on an ongoing basis. The status of endangered species may be of greatest concern, but this should not reduce the need for comprehensive and routine monitoring of other fish and wildlife populations.

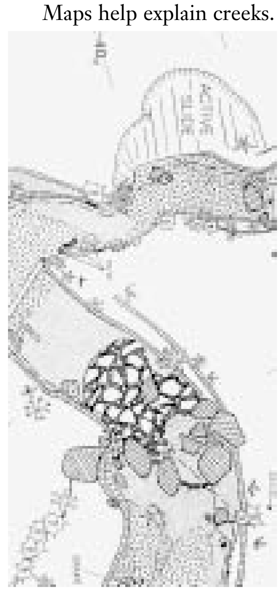
The program will need to provide quality control and assurance for monitoring data and their interpretation. The methods of data collection must be repeatable, and the data must be defensible and address the monitoring issues or objectives with adequate accuracy and precision. There should be protocols for data storage and transfer that maintain the integrity of the data and minimize their misuse.

Monitoring results must be made available to those who can use them to improve the next generation of restoration projects. Also, the information derived from projects should be used to adjust the regional Goals according to new understanding. In this way, new projects will continue to make progress towards the overarching goal of restoring the physical, chemical, and biological health of the estuary.

Mapping

Mapping is an important tool for effectively relaying many kinds of information obtained through research and monitoring. Paper or "hardcopy" maps are useful to display simple concepts. A computerized geographic information system (GIS) is an extremely powerful form of mapping that can be used to create and update maps of any combinations of landscape features at any scale. Data, reports, other maps and images can be electronically "linked" to maps in a GIS, creating a visual, geographic index to information. New technologies are being developed that enable an on-line GIS, so that maps and related information can be accessed over the Internet.

Maps help explain creeks.



Laurel Collins

There will also be a need to track changes in the distribution, quantity, and quality of key bayland habitats. This will require careful mapping of changes in the baylands landscape. The EcoAtlas could be a useful tool for tracking and visualizing such changes.

Project participants identified many mapping needs, including:

- Current distribution and abundance of the key habitats. Resolution of the maps may need to increase for habitats of some key species of plants and some animals that occupy small habitat patches. Ideally, the regional maps of key habitats would indicate the variation in habitat quality between habitat patches, relative to the desired support functions for the key plant communities and fish and wildlife species. These would need to be updated periodically.

- Topography and tidal elevations of the diked baylands. This information is needed to estimate the amount of tidal prism and sediment that might be required to achieve the tidal marsh restoration called for by the Goals.
- Distribution and abundance of many key species of fish and wildlife, particularly threatened and endangered species.
- Rocky intertidal habitats and significant feeding and roosting areas for rocky intertidal shorebirds.
- Salinity and moisture gradients within habitats.

Information Management Systems

Information about the baylands is distributed among many documents and libraries. For example, there are scientific journals, environmental impact reports and statements, and monitoring reports for compensatory mitigation projects. Many studies have never been reported. Very few organizations subscribe to more than a few of the dozens of scientific journals that are likely to contain information relating to the baylands. Most of the existing reports for baylands restoration projects are located in government agencies, universities and other research institutions, private companies, or non-profit environmental organizations. Very few reports are widely distributed. A large body of valuable information also exists in the form of casual observations of local conditions by landowners, scientists, and other resource managers.

There are several ways, from simple to quite sophisticated, that information about the baylands could be made more accessible. The first, and simplest, approach would be to create a comprehensive bibliography of research and monitoring information. It would be possible, for example, to create an on-line bibliography that is updated frequently. Portions of the initial contents of such a bibliography already exist in various offices and could be readily assembled.

A more advanced approach would involve creating and maintaining a dedicated web site to enable anyone with Internet capability to access information about the baylands. Information could be accessed through a set of written menus and a map of the baylands. The kinds of information that could be available are almost unlimited; they include pictures, movies, graphs, maps, reports, tabular data, and commentary. Information could be accessed for a particular baylands site, subregion, or for the entire baylands ecosystem. There could be an on-line GIS for making custom maps and viewing the distribution of data. It is possible to create an on-line information system that enables people to correspond, even to send email with attached files, through an interactive map of the baylands.

"Perhaps there will always be more information about the baylands than can be made available to any one person or organization. ...The challenge is to provide as much useful information to as many people as possible."
— J. Collins, SFEI

The most beneficial information system will meet the variable technical capabilities of its users. This means that there should be access to information through CD-ROM and other portable electronic media, and there should be paper products like conventional maps and reports, as well as interactive maps on-line. The EcoAtlas includes many of these features and has the potential to become a comprehensive information management system for the Bay Area.

Conclusion

There has been considerable scientific information compiled about the estuary and the baylands in the past decades. In recent years, the volume of information has grown exponentially. Increased information promotes a better understanding of this complex environment and will help improve habitat restoration design and management. However, access to the information needs to be improved, and even with all of the information that is available, there is still a need for more.

The RMG warned that there is a significant ecological risk in undertaking region-wide bayland restoration efforts without an adequate program of science support. This chapter has identified many aspects of the science program that is needed. Appropriate steps should be taken immediately to establish a regional science program to support the management of the baylands ecosystem. The first tasks should be selection of reference sites to monitor background conditions, development of uniform data collection and interpretation protocols, and creation of a system for managing information. The initial emphasis should be placed on making existing and new information more available for those who can use it to improve restoration planning, design, and management decisions.

Local scientists and other experts should develop the baylands science program. This should involve regional experts in population biology, community and ecosystem ecology, hydrology and geomorphology, toxicology, and information technologies. The Estuary Institute should coordinate the effort as part of the Regional Monitoring Strategy that was recommended by the *Comprehensive Conservation and Management Plan* (SFEP 1993). The agencies and programs that should participate in developing this program include:

- CALFED Bay-Delta Program
- California Coastal Conservancy
- California Department of Fish and Game
- California Department of Water Resources
- California Environmental Protection Agency
- California Resources Agency
- California Water Resources Control Board
- National Atmospheric and Space Administration
- National Geographic Survey
- National Marine Fisheries Service
- National Oceanographic and Atmospheric Administration
- National Ocean Survey
- San Francisco Bay Conservation and Development Commission
- San Francisco Bay Regional Water Quality Control Board
- U.S. Army Corps of Engineers
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service
- U.S. Geological Survey

Developing and implementing an adequate bayland science program will require considerable resources. The agencies and other entities that develop the program will need to consider both short-term and long-term costs and should take steps to ensure adequate funding.

"A program of wetlands science should accompany any region-wide restoration effort. However, science should not be pursued in lieu of restoration, and it should not be extravagantly funded. Both efforts must be undertaken concurrently."
— P. Baye, RMG

Next Steps

Sponsors of the Goals Project anticipate that several agencies and other entities will immediately begin to implement the recommendations in this report. This chapter identifies some of these groups and describes how each one will likely use the Goals. It also highlights some of the incentives that are available to private landowners that are considering restoring or enhancing bayland habitats. And it describes an effort that will begin in spring 1999 — the development of a regional wetland strategy.

Regional Planning Efforts

There are several agencies and other groups that have begun, or soon will begin, to undertake specific, large-scale wetlands planning efforts in the Bay Area. These include CALFED, California Coastal Conservancy, San Francisco Bay Conservation and Development Commission, San Francisco Bay Joint Venture, San Francisco Bay Regional Water Quality Control Board, and U.S. Fish and Wildlife Service. Although the purpose, geographic scope, and products of these planning efforts vary considerably, the Goals recommendations should help all of them develop or fund useful habitat restoration and enhancement projects.

CALFED

The CALFED Bay-Delta Program is a collaboration among state and federal agencies and the state's leading urban, agricultural, and environmental interests. These groups are seeking to address and resolve the environmental and water management problems associated with the Bay-Delta system and ultimately to develop a long-term comprehensive plan for restoring ecological health and improving water management. The primary issues for which specific actions will be developed are ecosystem restoration, water supply reliability, water quality, and levee system integrity. Although the geographic scope of the CALFED problem area includes the Delta, Suisun Bay, and Suisun Marsh, the scope of its solution area reaches well beyond. It includes the Central Valley watershed, parts of Southern California, San Pablo Bay, San Francisco Bay, and near-shore portions of the Pacific Ocean (CALFED 1998b).

Within CALFED, the program to address ecosystem health is known as the Ecosystem Restoration Program. Its goals are to improve and increase aquatic and terrestrial habitats, and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species. The Ecosystem Restoration Program Plan (ERPP) establishes a framework for implementing long-term, ecosystem restoration efforts over several decades.

Since 1995, CALFED has been a major source of funding for environmental projects in the solution area, including some limited parts of the Bay. For the near future, projects funded through the ERPP likely will emphasize improving aquatic resources. When CALFED staff consider proposals for ecosystem restoration, the Goals should help them decide where, and for what kinds of projects, to expend funds in the Bay Area, particularly in the Suisun and North Bay subregions.

California Coastal Conservancy — San Francisco Bay Area Conservancy Program

The California Coastal Conservancy administers many programs to improve natural resources along the California coastline. In 1997, under legislative mandate, it established the San Francisco Bay Area Conservancy Program. This program is the Conservancy's primary effort to identify and adopt long-term goals for resource protection and outdoor recreation in the nine-county Bay Area. It involves governmental agencies, nonprofit land trusts, and other interested parties. The goals developed in this program will guide the Conservancy's priorities for undertaking projects and awarding grants. Although the program's scope includes all lands within the immediate Bay watershed, the Conservancy will base its resource and recreational goals for the baylands on the Goals Project's habitat recommendations.

San Francisco Bay Conservation and Development Commission — Bay Plan Update

The San Francisco Bay Conservation and Development Commission was established by the McAteer-Petris Act of 1965. It implements a comprehensive plan, referred to as the *San Francisco Bay Plan*, for the conservation of San Francisco Bay waters and regulation of shoreline development. The Commission updates the Bay Plan periodically, and the last update was in 1988.

In 1999, the Commission will begin a five-year process to update the Bay Plan. Its staff will use information developed by the Goals Project to assist in revising sections on Fish and Wildlife, Marshes and Mudflats, and Salt Ponds and Managed Wetlands. In addition, they will use Goals Project products in developing Bay Plan policies to minimize conflicts between bayshore public access and sensitive wildlife populations. They also may refer to Goals Project materials as they complete the North Bay Wetlands and Agricultural Protection Program. This program is designed to provide local governments with the tools and information they need to protect, enhance, and restore North Bay wetlands, and to protect agriculture and allow compatible uses to continue.

The Commission uses the EcoAtlas maps developed for the Goals Project as base maps for the San Francisco Bay Plan. These maps also provide the Commission's planning and regulatory staff with site information about the location and extent of various wetlands and transitional habitats along the Bay edge, a great aid in land use planning.

San Francisco Bay Joint Venture

The San Francisco Bay Joint Venture was initiated in 1996. It is a public-private partnership that seeks to promote the acquisition, restoration, and enhancement of Bay Area wetlands and associated habitats. It is one of 15 joint ventures that operate under the auspices of the *North American Waterfowl Management Plan*, which was signed by the United States, Canada, and Mexico. It includes partners from public agencies, environmental organizations, hunting and fishing groups, the business community, local government, and landowners.

Joint Venture partners currently are preparing an implementation strategy that is scheduled for release in spring 1999. The strategy will guide the Joint Venture as it undertakes specific wetland projects, and it will include habitat goals that are derived from the Goals Project recommendations.

San Francisco Bay Regional Water Quality Control Board — Basin Plan Triennial Review

The San Francisco Bay Regional Water Quality Control Board is the State agency responsible for regulating surface water and groundwater quality in the nine-county San Francisco Bay Area. The *Water Quality Control Plan for the San Francisco Bay Basin* (Basin Plan) is the Regional Board's master policy document. It describes the legal, technical, and programmatic bases of water quality regulation and defines programs to preserve and enhance water quality and protect the beneficial uses of the waters of the State. The Basin Plan identifies the protection, preservation, and restoration of the baylands' tidal marsh system as essential for maintaining the ecological integrity, and hence water quality, of San Francisco Bay.

In order to keep current with technological, hydrological, political, and physical changes within the region, the Regional Board reviews and revises its Basin Plan about every three years. Board staff have begun the preliminary stages of revising the Plan and expect to complete the process in 2000. The Regional Board will consider the Goals Project's recommended habitat changes and other technical information as they update the Basin Plan's wetlands protection strategy.

U.S. Fish and Wildlife Service

Endangered Species Recovery Plans

The U.S. Fish and Wildlife Service is preparing two endangered species recovery plans that will affect the restoration and enhancement of bayland habitats. These plans are the *Recovery Plan for Tidal Marsh Ecosystems of Central and Northern California* and the *Recovery Plan for Western Snowy Plover, Pacific Coast Population*. The tidal marsh plan will revise and expand the existing recovery plan that was prepared several years ago for the California clapper rail and salt marsh harvest mouse; it will include recovery actions for these species and for several others. The western snowy plover recovery plan will include recovery actions for this species along the U.S. Pacific Coast, including the San Francisco Bay recovery unit. Each of these recovery plans will identify actions necessary to achieve self-sustaining, wild populations of listed species so they will no longer require protection under the Federal Endangered Species Act. These recovery plans are scheduled to be available for public review in 1999. Also, the Fish and Wildlife Service has begun to revise the recovery plan for the California least tern, which was originally completed in 1980.

Many members of the Goals Project have participated, or are currently participating, on recovery teams. As a result, recovery plans likely will reflect the concepts and general recommendations in this report. However, it is important to note that the recovery plans are aimed at restoring a limited number of species, while the Goals seek to describe the habitat conditions necessary for a much larger and more diverse group of organisms. Accordingly, while recommendations in these recovery plan actions may be consistent with the general intent of the Goals Project to protect, enhance, and restore the estuary's ecosystem, specific recommendations may differ. For federally listed species, specific recovery plan recommendations will take precedence over general recommendations in this report.

San Francisco Bay National Wildlife Refuge Complex Comprehensive Conservation Plan

Soon after 2000, the U.S. Fish and Wildlife Service is scheduled to begin preparing a Comprehensive Conservation Plan (CCP) for the San Francisco Bay National Wildlife Refuge Complex. Through a process of public involvement and consultation with wildlife biologists and wetland scientists, the CCP will identify wildlife management objectives, amounts and types of wetlands to be restored, and specific restoration projects to accomplish these objectives. The CCP will provide site-specific analysis and will incorporate funding realities and engineering considerations that are beyond the scope of the Goals Project. As a result, the configuration, location, and types of wetlands to be restored on Refuge lands in North Bay and South Bay may differ from the site-specific recommendations presented in this report.

Use of the Goals by Non-governmental Organizations

There are many non-governmental organizations in the Bay Area that actively seek to protect or improve wetlands and other valuable areas. Some of these organizations also undertake environmental restoration and enhancement projects. The organizations that likely will help implement some of the Goals recommendations, or that will have an interest in ensuring that the recommendations are implemented carefully, include the eight Bay Area Audubon Society chapters, Bay Area Open Space Council, California Waterfowl Association, Citizens Committee to Complete the Refuge, Ducks Unlimited, Nature Conservancy, Save San Francisco Bay Association, Sierra Club, The Bay Institute, Trust for Public Lands, Urban Creeks Council, and many smaller groups with more local focus.

Landowner Incentives

Private lands around the estuary provide valuable habitat for fish and wildlife. This report recommends enhancing habitats on many of these lands. For other lands, it recommends restoring habitat, mostly to tidal marsh. Project participants recognized that the majority of lands around the estuary are privately held, and agreed that habitat changes should occur only with landowner consent. Therefore, attaining the Project's long-term vision will require cooperation of private landowners, resource agencies, and other interests.

There are many incentives available to landowners who are interested in improving wetlands and other habitats. These incentives include conservation easements, land purchase and lease-back programs, funding for maintaining infrastructure, such as levees and water control structures, and funding to pay for reduced crop production. **Table 8.1** presents some of the voluntary landowner incentive programs that may be used to improve wetlands on private lands. Information about each program is available from the respective agency or organization.

Some landowners have indicated they would be more interested in improving wetland habitats if the regulatory procedures were less complex and more streamlined. They also want to be offered fair market value for lands that are desired for tidal marsh restoration or that are managed primarily for wildlife.

There are many ways that the public and private sectors will need to collaborate to improve habitats in the coming years. One of the first steps could be for landowners to assess their short-term and long-term interests and to identify the kinds of restoration actions that are acceptable on their lands. For areas that

TABLE 8.1 Voluntary Landowner Incentive Programs for Wetlands

Program	Agency/Organization
Acquisition Program	U.S. Fish and Wildlife Service
California Waterfowl Habitat Program	California Department of Fish and Game and California Waterfowl Association
Conservation Reserve Program	Natural Resources Conservation Service
Environmental Quality Incentives Program	Natural Resources Conservation Service
Partners for Wildlife	U.S. Fish and Wildlife Service
Permanent Wetland Easement Program	California Department of Fish and Game and Wildlife Conservation Board
Resource Enhancement and Agricultural Programs	State Coastal Conservancy
Wetland Reserve Program	Natural Resources Conservation Service and U.S. Fish and Wildlife Service
Wildlife Conservation Board Program	Wildlife Conservation Board
Valley/Bay CARE	Ducks Unlimited

they do not want restored, landowners could identify acceptable enhancement actions. Agencies should work closely with landowners to identify the financial and regulatory tools that may facilitate these improvements.

Regional Wetland Strategy — A Framework for Coordination

The Goals establish a very flexible vision for restoring bayland habitats. Because they are not a blueprint of specific projects, implementing the Goals recommendations will require close coordination among landowners, agencies, and others. Restoration and enhancement projects will need to be tracked so everyone will know who is doing what, and as projects are monitored and as research is undertaken, the results will need to be made readily available. Without some kind of framework to ensure better coordination among restoration entities, appropriate research and monitoring, and improved agency policies and procedures, effectively restoring bayland habitats will be extremely difficult.

Poor coordination of restoration efforts could result in many kinds of problems. For example, planning for a particular tidal marsh project might not take into account the need for concomitant enhancement of nearby seasonal wetland habitat. Or, several tidal marsh projects might be undertaken concurrently in a segment of the Bay where there is insufficient suspended sediment. Or, two groups of scientists might unknowingly and unnecessarily duplicate research or monitoring work.

From the outset of the Goals Project, and in keeping with the Estuary Project's *Comprehensive Conservation and Management Plan*, the RMG envisioned that the agencies and the public would develop a framework for implementing the Goals. This framework would be developed after completing the Goals, as part of a regional wetland plan.

In spring 1998, at the request of the Estuary Project's Implementation Committee, staff of the U.S Environmental Protection Agency and the San Francisco Bay Regional Water Quality Control Board began a dialogue with the public and with other resource and regulatory agencies to determine the most appropriate way to develop a regional wetland plan. They discussed this issue with several landowners, with the San Francisco Estuary Project's Wetlands Subcommittee, and with the Bay Area Wetlands Planning Group. (The California Resources Agency initiated the Bay Area Wetlands Planning Group in 1994. Its members include the state and federal resource and regulatory agencies that are involved in wetland issues in the Bay Area. Its purpose is to improve regional wetlands planning and regulation.)

Most everyone agreed it would be beneficial to develop a wetland plan and expressed interest in participating, provided the process were limited in scope. Several people stated that, rather than trying to resolve each of the many wetland issues described in the CCMP, it would be preferable (and much quicker) to identify the most critical issues pertinent to implementing the Goals, and then to establish a brief framework or strategy for addressing them. Such a strategy would build upon and complement ongoing wetland planning efforts and could be completed relatively quickly and cheaply.

Based on these discussions, the California Resources Agency, which the *Comprehensive Conservation and Management Plan* designates as the lead agency for developing a regional wetland plan, agreed that the Bay Area Wetlands Planning Group should take the lead in developing the plan as a regional wetland strategy. This past winter, group members drafted a general scope for this effort. The tasks in the draft scope include forming a stakeholder committee, holding technical workshops, preparing a draft strategy, seeking public comments on the draft strategy, and preparing a final strategy. The stakeholder committee will include landowners, business interests, environmental groups, and local governments. Initial stakeholder meetings are scheduled to begin in spring 1999, and the process to develop the wetland strategy is expected to take six to twelve months.

At this time, it is difficult to predict exactly what the wetland strategy will include. At a minimum, it should (1) contain a plan (or plans) for implementing the Goals in each of the four subregions; (2) identify restoration projects (including pilot projects) and their short-term and long-term costs; (3) establish a wetland monitoring framework; and (4) include written agreements among the parties that will be funding, regulating, or undertaking projects.

Updating the Goals

The Goals are long-term recommendations that will take decades to implement. In preparing them, Project participants developed a detailed view of the estuary's historical and existing habitat conditions and a better understanding of the habitat needs of the baylands ecosystem key species. In the future, as additional ecological planning work is done, as wetland projects are undertaken, and as scientific information on restoration techniques and species needs improves, the Goals will need to be reviewed and possibly revised periodically. This should be done by the Resource Managers Group or its successor on a regular basis, perhaps every five years or so, and the regional wetland strategy should establish the procedures for doing this.

REFERENCES

AIREA. 1989. The dictionary of real estate appraisal. American Institute of Real Estate Appraisers. 2nd ed.

Allen, J., M. Cunningham, A. Greenwood, and L. Rosenthal. 1992. The value of California wetlands; an analysis of their economic benefits. Produced for and published by: The Campaign to Save California Wetlands. August. Oakland, Calif. 15 pp. and refs.

Anderson, D.W. and J.O Keith. 1980. The human influence on seabirds nesting success: conservation implications. Biol. Conserv. 18:65 – 80.

Anderson, R. and M. Rockel. 1991. Economic valuation of wetlands. Discussion paper #065, published by the American Petroleum Institute, April.

Antilla, C.K., C.H. Daehler, N.E. Rank, and D. Strong. 1998. Greater male fitness of a rare invader (*Spartina alterniflora*, *Poaceae*) threatens a common native (*Spartina foliosa*) with hybridization. American Journal of Botany 85:1597 – 1601.

Arnold, A. 1996. Suisun Marsh history. Hunting and saving a wetland. Monterey Marina Publishing Company. Marina, Calif. 253 pp.

Arthur, J.F. and M.D. Ball. 1979. Factors influencing the entrapment of suspended material in the San Francisco Bay-Delta estuary. *In:* T.J. Conomos (ed). San Francisco Bay: the urbanized estuary. Pages 143 – 174. Pacific Division, American Association for the Advancement of Science. San Francisco, Calif.

Arthur, J.F., M.D. Ball, and S.Y. Baughman. 1985. Summary of federal and state water project environmental impacts in the San Francisco Bay-Delta estuary, California. *In:* J.T. Hollibaugh (ed). San Francisco Bay the ecosystem. Pages 445 – 495. American Association for the Advancement of Science. San Francisco, Calif.

Atwater, B.F. 1979. Ancient processes at the site of southern San Francisco Bay: movement of the crust and changes in sea level. *In:* T.J. Conomos (ed). San Francisco Bay: the urbanized estuary. Pages 31 – 45. Pacific Division, American Association for the Advancement of Science. San Francisco, Calif.

Atwater, B.F. and C.W. Hedel. 1976. Distribution of seed plants with respect to tide levels and water salinity in the natural tidal marshes of the northern San Francisco Bay estuary, California. U.S. Geological Survey Open-File Series 76-389, U.S. Geological Survey, Menlo Park, Calif. 41 pp.

Baird, K. 1989. High quality restoration of riparian ecosystems. Restoration and Management Notes 7:60 – 64.

Barnby, M.A., J.N. Collins, and V.H. Resh. 1985. Aquatic macroinvertebrate communities of natural and ditched potholes in a San Francisco Bay salt marsh. Estuarine Coastal and Shelf Science 20:331 – 347.

Bay Institute. 1987. Citizens' report on the diked historic baylands of San Francisco Bay. The Bay Institute of San Francisco, Sausalito, Calif. 196 pp.

BCDC. 1982. Diked historic baylands of San Francisco Bay: findings, policies, and maps. San Francisco Bay Conservation and Development Commission, San Francisco, Calif.

BCDC. 1988. Mitigation: an analysis of tideland restoration projects in San Francisco Bay. San Francisco Bay Conservation and Development Commission, San Francisco, Calif. 78 pp.

BCDC and NOAA. 1998. Location 3 the San Francisco Bay/Delta GPS network. San Francisco Bay Conservation and Development Commission and National Oceanographic and Atmospheric Administration. Symposium held 17 June 1998, San Francisco, Calif.

Beechey, F.W. 1941. An account of a visit to California, 1826 – '27. Grabhorn Press, San Francisco, Calif.

Blanchfield, J.S., R. Twiss, S. McCreary, and J. Sayer. 1991. The effects of land use change and intensification on the San Francisco Estuary. Draft report. June. Prepared by the Bay Conservation and Development Commission for the San Francisco Estuary Project. U.S. Environmental Protection Agency. San Francisco, Calif.

Bolton, H.E. 1930. Anza's California expeditions. University of California Press, Berkeley, Calif. 609 pp.

Breaux, A., F. Serefiddin, and M. Carlin. 1997. Wetland reference sites in San Francisco Bay. Chapter 133 in California and the World Ocean '97, eds. O. Magoon, H. Converse, B. Baird, and M. Miller-Henson. Conference Proceedings, March 24 – 27, 1997, San Diego, Calif.

Brown, A.K. 1960. Salt for the scraping: origin of the San Francisco Bay salt industry. California Historical Society Quarterly 34(2):117 – 120.

Buchanan, P.A. and Schoelhammer, D. 1995 (and others in this series). Summary of suspended sediments concentrations data, Central and South San Francisco Bays, California, water years 1992 and 1993. U.S. Geological Survey Open-File Report 94-543. 15 pp.

Burger, J. 1981. The effect of human activity on birds at a coastal bay. Biol. Conserv. 21:231 – 241.

Byrne, R.A. 1997. The influence of climate and sea level rise on wetlands. Proceedings of the 1996 State of the Estuary Conference, San Francisco Estuary Project, San Francisco, Calif. 64 pp.

CALFED. 1998a. Recommendations for the implementation and continued refinement of a comprehensive monitoring, assessment, and research program. Leo Winternitz (ed). Comprehensive Monitoring, Assessment, and Research Program, CALFED Bay-Delta Program, Sacramento, Calif.

CALFED. 1998b. Proposal solicitation package. Ecosystem restoration projects and programs. CALFED Bay-Delta Program. Sacramento, Calif. 104 pp.

Casazza, M.L. 1995. Habitat use and movement of northern pintail wintering in the Suisun Marsh, California. Masters Thesis, Humboldt State University, Arcata, Calif.

CDFG. 1977. The natural resources of Napa Marsh. California Department of Fish and Game, Sacramento, Calif.

CDFG. 1998. California natural diversity data base, California Department of Fish and Game, Sacramento, Calif.

CDWR. 1986. DAYFLOW program documentation and DAYFLOW data summary user's guide. California Department of Water Resources, Sacramento, Calif.

CH2MHill. 1995. Phase 1 Final Report. Santa Rosa Plain Vernal Pool Preservation Plan, Appendix G Assessment of Compensation Techniques. Prepared for the Santa Rosa Plain Vernal Pool Task Force.

Cheng, R.T., V. Casulli, and J.W. Gartner. 1993. Tidal, residual, intertidal mudflat (TRIM) model and its applications to San Francisco Bay, California. Estuaries, Coastal and Shelf Science 36:235 – 280.

Cloern, J.E. and F.H. Nichols. 1985. Temporal dynamics of an estuary: San Francisco Bay. Dr. W. Junk Publishers, reprinted from Hydrobiologia Vol. 129 (1985). 237 pp.

Cohen, A.C. and J.T. Carlton. 1995. Nonindigenous aquatic species in a United States estuary: A case study of the biological invasions of the San Francisco Bay and Delta. U.S. Fish and Wildlife Service and National Sea Grant Report No. PB96-166525. 246 pp.

Collins, J.N. 1998. Bay-Delta shallow water habitats. *In*: L. Winternitz (ed). Draft recommendations for the implementation and continued refinement of a comprehensive monitoring, assessment and research program, Appendix A2. Comprehensive Monitoring, Assessment and Research Program, CALFED Bay-Delta Program, Sacramento, Calif.

Collins, J.N. 1999. Draft plan of science bay area regional wetlands monitoring program. San Francisco Estuary Institute, Richmond, Calif. 38 pp.

Collins, J.N. and J.G. Evens. 1992. Evaluation of impacts of naval riverine forces training operations on nesting habitat of the California clapper rail at Napa River, California. Navy Western Division, Naval Facilities Engineering Command, San Bruno, Calif. 19 pp.

Collins, J.N. and T.C. Foin. 1993. Evaluation of the impacts of aqueous salinity on the shoreline vegetation of tidal marshlands in the San Francisco estuary. *In*: J.R. Schubel (ed). Managing freshwater discharge to the San Francisco Bay/Sacramento-San Joaquin Delta estuary: the scientific basis for an estuarine standard. Pages C1 – C34. San Francisco Estuary Project, San Francisco, Calif.

Collins, L.M. 1998. Sediment sources and fluvial geomorphic processes of lower Novato Creek watershed. Marin County Flood Control and Water Conservation District, San Rafael, Calif. 75 pp. plus appendices.

Collins, L.M., J.N. Collins, and L.B. Leopold. 1987. Geomorphic processes of an estuarine marsh: preliminary results and hypotheses. *In*: V. Gardner (ed). International Geomorphology 1986 Part I. Pages 1049 – 1072. John Wiley and Sons Ltd., London.

Conomos, T.J., R.E. Smith, D.H. Petersen, S.W. Hager, and L.E. Schemel. 1979. Processes affecting seasonal distribution of water properties in the San Francisco Bay estuarine system. *In*: T.J. Conomos (ed). San Francisco Bay: the urbanized estuary. Pages 115 – 142. Pacific Division, American Association for the Advancement of Science. San Francisco, Calif.

Cooper, W.S. 1926. Vegetational development upon alluvial fans in the vicinity of Palo Alto, California. Ecology 7: 1 – 30.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31. U.S. Fish and Wildlife Service, Office of Biological Services. Washington, D.C. 103 pp.

Dedrick, K.G. 1989. San Francisco Bay tidal marshland acreages: recent and historic values. *In*: O.T. Magoon et al. (eds). Proceedings of the sixth symposium on Coastal and Ocean Management. Omni Hotel. Charleston, South Carolina, July 11 – 14, 1989. Volume 1. 383 pp.

Dedrick, K.G. and L.T. Chu. 1993. Historical atlas of tidal creeks San Francisco Bay, California. *In*: O.T. Magoon (ed). Proceedings of the eighth symposium on coastal and ocean management (Coastal Zone 93). American Society of Civil Engineers, New York, NY.

DeWeese, J. 1994. An evaluation of selected wetland creation projects authorized through the Corps of Engineers Section 404 program. U.S. Fish and Wildlife Service, Sacramento, Calif.

Einarsen, A.R. 1965. Black Brandt: Sea goose of the Pacific Coast. University of Washington Press, Seattle, Wash.

Essig, E.O. 1933. The Russian settlement at Ross. California Historical Society Quarterly 12:191 – 209.

Fancher, L.E. and D.J. Alcorn. 1982. Harbor seal census in South San Francisco Bay (1972 – 1977 and 1979 – 1980). Calif. Fish Game 68(2):118 – 124.

Farquhar, F.P. 1966. Up and down California in 1860 – 1867. The journal of William H. Brewer, etc. University of California Press, Berkeley, Calif. 583 pp.

Fiedler, P.L. and R.K. Zebell. 1993. Restoration and recovery of Mason's lilaeopsis: phase I. Final report to the Shell Oil Spill Litigation Settlement Trustee Committee and California Department of Fish and Game, San Francisco State University, San Francisco, Calif. 47 pp.

Filice, F.P. 1959. The effect of wastes on the distribution of bottom invertebrates in the San Francisco Bay estuary. Wasmann Journal of Biology 17(1):1 – 17.

Fischer, H.B. 1976. Mixing and dispersion in estuaries. Annual Review Fluid Mechanics 8:107 – 133.

Fritts, H.C. and G.A. Gordon. 1980. Annual precipitation for California since 1600: reconstructed from western North American tree rings. California Department of Water Resources, Sacramento, Calif. 45 pp.

Gahagan and Bryant. 1994. A review of the physical and biological performance of tidal marshes constructed with dredged materials in San Francisco Bay, California. Prepared for U.S. Army Corps of Engineers, San Francisco District.

Gibbs, J.P. 1993. Importance of small wetlands for the persistence of local populations of wetland-associated animals. Wetlands, Journal of the Society of Wetland Scientists. Vol 13 (1): 25 – 31. March.

Gilbert, G.K. 1917. Hydraulic-mining debris in the Sierra Nevada. U.S. Geological Survey Professional Paper 105. 154 pp.

Gill, S.K., J.R. Hubbard, and W.D. Scherer. 1998. Updating the national tidal datum epoch for the United States. Center for Operational Oceanographic Products and Services, National Ocean Survey, National Oceanic and Atmospheric Administration, 4 pp.

Gleick, P.H., P. Williams, J.N. Collins, and R. Grossinger. 1999. Proposed integrated assessment of the impacts of climate change and variability for San Francisco Bay. Pacific Institute for Studies in Development, Oakland, Calif.

Goals Project. 2000. Baylands ecosystem species and community profiles: Life histories and environmental requirements of key plants, fish and wildlife. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. San Francisco Bay Regional Water Quality Control Board, Oakland, Calif.

Gobalet, K. 1990. Fish remains from nine archive sites in Richmond and San Pablo, Contra Costa County, Calif. California Department of Fish and Game 76(4):233 – 243.

Gosselink, J.G., E.P. Odum, and R.M. Pope. 1974. The value of the tidal marsh. Center for Wetland Resources, Louisiana State University, Baton Rouge. LSU-SG-74-03. 30 pp.

Graham, S.E. and R.J. Pike. 1997. Shaded-relief map of the San Francisco Bay region, California. Open-File Report 97-745 B, U.S. Geological Survey, Menlo Park, Calif. 8 pp.

Grossinger, R. 1995. Historical evidence of freshwater effects on the plan form of tidal marshlands in the Golden Gate Estuary. Masters Thesis, Department of Marine Sciences, University of California at Santa Cruz, Santa Cruz, Calif. 130 pp.

Grossinger, R. and J.N. Collins. 1999. Variability in mapping of tidal marshland by surveyors of the United States Coast Survey in the San Francisco Estuary, 1850 – 1860. Manuscript submitted to Journal of Coastal Research. 9 pp.

Grossinger, R., J. Alexander, A.N. Cohen and J.N. Collins. 1998. Introduced tidal marsh plants in the San Francisco Estuary: regional distribution and priorities for control. San Francisco Estuary Institute. Richmond, Calif. 52 pp.

Haltiner, J. and P. Williams. 1987a. Slough channel design in salt marsh restoration. *In:* K.M. Mutz and L.C. Lee (eds). Wetland and riparian ecosystems of the American west. Pages 125 – 130. Proceedings of the Eighth Annual Meeting, Society of Wetlands Scientists, Wilmington. NC.

Haltiner, J. and P. Williams. 1987b. Hydraulic design in salt marsh restoration. *In:* J.A. Kusler and G. Brooks (eds). National symposium: wetland hydrology. Pages 293 – 299. Association of State Wetland Managers, Berne, NY.

Hammer, D.A. 1989. Constructed wetlands for wastewater treatment. Lewis Publishers, Inc. Chelsea, MI. 831 pp.

Hammer, D.A. and R.K. Bastian. 1989. Wetlands ecosystems: natural water purifiers? *In*: D.A. Hammer (ed.). Constructed wetlands for wastewater treatment: municipal, industrial, and agricultural. Pages 5 – 19. Lewis Publishers, Inc., Chelsea, Mich.

Harlow, N. 1950. The maps of San Francisco Bay from the Spanish discovery in 1769 to the American occupation. The Book Club of California, San Francisco, Calif. 140 pp.

Harvey, H.T. and M.L. Torok. 1994. Movements, dive behaviors, and food habits of harbor seal *(Phoca vitulina richardsi)* in San Francisco Bay, California. California Department of Water Resources, Sacramento, Calif. 89 pp.

Harvey, H.T., H.L. Mason, R. Gill and T.W. Wooster. 1977. The marshes of San Francisco Bay: their attributes and values. San Francisco Bay Conservation and Development Commission, San Francisco, Calif. 154 pp.

Harvey, T.E., R.W. Lowe and D. Fearn. 1988. The value of salt ponds for waterbirds in San Francisco Bay and considerations for future management. National Wetland Symposium, June 26 – 29, 1988, Assoc. of State Wetland Managers. Oakland, Calif.

Harvey, T.E., K.J. Miller, R.L. Hothem, M.J. Rauzon, G.W. Page and R.A. Keck. 1992. Status and trends report on wildlife of the San Francisco Estuary. Prepared by the U.S. Fish and Wildlife Service for the San Francisco Estuary Project. U.S. Environmental Protection Agency. San Francisco, Calif. 283 pp. and appendices.

Hastings, L. 1998. Evaluation of carbon fluxes in flooded organic soils in the Sacramento-San Joaquin Delta. Project description, http://water.wr.usgs.gov/projects/ca496.html (11 November 1998). 2 pp.

Hedgpeth, J.W. 1979. San Francisco Bay — the unsuspected estuary: a history of researches. *In:* J.T. Hollibaugh (ed). San Francisco Bay the ecosystem, American Association for the Advancement of Science, San Francisco, Calif. Pages 9 – 29.

Helley, E.J., K.R. Lajoie, W.E. Spangle, and M.L. Blair. 1979. U.S. Geological Survey, professional paper 943.

Herbold, B., P.B. Moyle and A.D. Jassby. 1992. Status and trends report on aquatic resources of the San Francisco Estuary. Prepared by U.C. Davis for the San Francisco Estuary Project, U.S. Environmental Protection Agency. San Francisco, Calif. 257 pp. and appendices.

Holland, M.D. 1976. Hydrogeology of the Palo Alto baylands, Palo Alto, California, with emphasis on the tidal marshes. Masters Thesis in Department of Geology, Stanford Univesity, Palo Alto, Calif. 138 pp.

Hutchinson, I. 1992. Holocene sea level change in the pacific northwest: a catalogue of radiocarbon dates and an atlas of regional sea level curves. Institute for Quaternary Research Occasional Paper No. 1, Simon Fraser University, Burnaby, British Columbia, Canada. 100 pp.

Ingram, B.L., J.C. Ingle and M.E. Conrad. 1996. Isotopic records of pre-historic salinity and river inflow in San Francisco Bay Estuary. *In:* J.T. Hollibaugh (ed). Pages 35 – 61. San Francisco Bay the ecosystem, American Association for he Advancement of Science, San Francisco, Calif.

Jaffe, B., R. Smith and L. Zink. 1998. Sedimentation changes in San Pablo Bay. Proceedings of the 1996 State of the Estuary Conference, San Francisco Estuary Project, San Francisco, Calif. 64 pp.

Jensen, D.B., M. Torn and J. Harte. 1990. In our hands: a strategy for conserving biological diversity in California. Published by California Policy Seminar. Berkeley, Calif. 184 pp. and appendices.

Jones and Stokes Associates, Inc., Harvey and Stanley Associates, Inc., and John Blayney Associates. 1979. Protection and restoration of San Francisco Bay fish and wildlife habitat, v. II habitat description, use and delineation. 39 pp., plus maps and appendices.

Josselyn, M. 1983. The ecology of San Francisco Bay tidal marshes: a community profile. FWS/OBS-83/23. U.S. Fish and Wildlife Service, Division of Biological Services, Washington, D.C.

Josselyn, M.N. and J.W. Buchholtz. 1984. Marsh restoration in San Francisco Bay: a guide to design and planning. Technical Report #3, Tiburon Center for Environmental Studies, San Francisco State University. 104 pp.

Josselyn, M., M. Martindale and J. Duffield. 1989. Public access and wetlands: impacts of recreational use. Tiburon, Calif. Romberg Tiburon Center.

Jurek, R.M. 1992. Nonnative Red Foxes in California. California Department of Fish and Game, Nongame Bird and Mammal Section. Report 92-04.

Kelley, R.L. 1989. Battling the inland sea: American culture, public policy and the Sacramento Valley, 1850 – 1986. Univ. Calif. Press. 395 pp.

Kentula, M., R.P. Brooks, S.E. Gwin, C.C. Holland, A.D. Sherman, and J.C. Sifneos. 1992. Wetlands: an approach to improving decision making in wetlands restoration and creation. Edited by Ann J. Hairston. Island Press. Covelo, Calif. 151 pp.

Kimmerer, W. 1998. Report of the 1994 entrapment zone study. Technical Report 56, Interagency Ecological Program for the San Francisco Bay/Delta Estuary. 136 pp.

Kopec, A.D. and J.T. Harvey. 1995. Toxic pollutants, health indices, and population dynamics of harbor seals in San Francisco Bay, 1989 – 1992. Moss landing marine laboratories, Moss Landing, Calif. 138 pp. plus appendices.

Krone, R.B. 1966. Predicted suspended sediment inflows to the San Francisco Bay system. Report to Central Pacific River Basins Comprehensive Water Pollution Control Administration (Southwest Region). 33 pp.

Krone, R.B. 1979. Sedimentation in the San Francisco Bay system. *In:* T.J. Conomos (ed). San Francisco Bay: the urbanized estuary. Pages 85 – 96. Pacific Division, American Association for the Advancement of Science. San Francisco, Calif.

Krone, R.B. 1985. Recent sedimentation on the San Francisco Bay system. *In:* J.T. Hollibaugh (ed). San Francisco Bay: the ecosystem. Pages 63 – 67. Proceedings of the Seventy-fifth Annual Meeting of the Pacific Division/ American Association for the Advancement of Science, San Francisco, Calif.

Lee, C.R., J.W. Simmers, D.L. Brandon, H.E. Tatum, J.G. Skogerboe, R.A. Price, and S. Miner. 1995. Field survey of contaminant levels in existing wetlands in San Francisco Bay area. Miscellaneous paper EL-95, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MI.

Leopold, L.B., J.N. Collins and L.M. Collins. 1993. Hydrology of some tidal channels in estuarine marshland near San Francisco. Catena 20:469 – 493.

Levine-Fricke. 1993. Draft enhancement plan, Oro Loma Marsh, Hayward, California. Prepared for East Bay Regional Park District, Oakland, Calif. 32 pp. and appendices.

Levine-Fricke. 1996. Revised Preliminary Design Report, Port of Oakland, Arrowhead Wetland Restoration Project. Prepared for the Port of Oakland, Oakland, Calif., 52 pp. and appendices.

Lewis, J.C., K.L. Sallee, and R.T. Golightly, Jr. 1992. Introduced Red Fox in California. Final Report to the California Department of Fish and Game.

Logan, S.H. 1990. Global warming and the Sacramento-San Joaquin Delta. Calif. Agric. 44(3):16 – 18.

LTMS. 1998. Long-term management strategy (LTMS) for the placement of dredged material in the San Francisco Bay region. Final policy environmental impact statement/programmatic environmental impact report. Prepared for LTMS Management Committee by U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, San Francisco Bay Conservation and Development Commission, San Francisco Bay Regional Water Quality Control Board, and State Water Resources Control Board. Volume 1. October.

Luoma, S.N. and D.J. Cain. 1979. Fluctuations of copper, zinc, and silver in tellenid clams as related to freshwater discharge — South San Francisco Bay. *In:* T.J. Conomos (ed). San Francisco Bay: the urbanized estuary. Pages 231 – 246. Pacific Division, American Association for the Advancement of Science. San Francisco, Calif.

Madrone Associates, B.E. Jones, D.W. Kelly, Storm Engineering and J.R. Arnold. 1980. Sacramento/San Joaquin Delta wildlife habitat protection and restoration plan. Prepared for Calif. Dept. Fish and Game and U.S. Fish and Wildlife Service.

Mayfield, D. W. 1978. Ecology of the pre-Spanish San Francisco Bay area. Masters thesis, San Francisco State University. 173 pp.

McDonald, E.T. and R.T. Cheng. 1993. Issues related to modeling the transport of suspended sediment in northern San Francisco Bay, California. Proceedings of 3rd International Conference on Estuarine and Coastal Modeling, ASCE, Oak Brook, Illinois.

Means, T.H. 1928. Salt water problem, San Francisco Bay and delta of Sacramento and San Joaquin rivers. Prepared for Association of Industrial Water Users of Contra Costa and Solano counties. 75 pp.

Meiorin, E.C. 1986. Urban stormwater treatment at Coyote Hills Marsh, Fremont, California. Association of Bay Area Governments. Oakland, Calif.

Meiorin, E.C., M.N. Josselyn, R. Crawford, J. Calloway, K. Miller, T. Richardson and R.A. Leidy. 1991. Status and trends report on wetlands and related habitats in the San Francisco Estuary. Prepared by the Association of Bay Area Governments for the San Francisco Estuary Project. U.S. Environmental Protection Agency. San Francisco, Calif. 209 pp.

Miller, A.W., R.S. Miller, H.C. Cohen and R.F. Schultze. 1975. Suisun Marsh Study, Solano County, California. U.S. Department of Agriculture, Soil Conservation Service. June. 186 pp.

Miller, G.T. 1985. Living in the Environment. An introducion to environmental science. 4th edition. Wadsworth Publishing Company. Belmont, Calif. 468 pp. and appendices.

Miller, R.C., W.D. Ramage and E.L. Lazier. 1928. A study of physical and chemical conditions in San Francisco Bay especially in relation to the tides. University of California Publications in Zoology 31(11):201 – 267.

Milliken, R. 1995. A time of little choice. The disintegration of tribal culture in the San Francisco Bay area 1769 – 1810. Ballena Press, Menlo Park, Calif. 364 pp.

Mitchell, A. 1869. On the reclamation of tide-lands and its relation to navigation. *In:* Report of the Superintendent, U.S. Coast Survey. Page 7. 41st Congress, 2nd Session, House Executive Document No. 206, Appendix 5.

Mitsch, W.J. and J.G. Gosselink. 1993. Wetlands. 2nd ed., Van Nostrand Reinhold, New York. 722 pp.

NASA. 1995/96. Color infra-red aerial photography, flight numbers 96052, 96053.

NCDC. 1998. Bay Area climatic data summaries. National Climatic Data Center, National Oceanic and Atmospheric Administration, Asheville, NC.

Nichols, F.H. and M.M. Pamatmat. 1988. The ecology of the soft-bottom benthos of San Francisco Bay: a community profile. U.S. Fish and Wildlife Service Biological Report 85(7 – 23). 73 pp.

Nichols, F.H. and J.E. Thompson. 1985. Persistence of an introduced mudflat community in south San Francisco Bay, California. Mar. Ecol. Prog. Ser. 24:83 – 97.

NOAA. 1980. The relationship between the upper limit of coastal wetlands and tidal datums along the Pacific Coast. National Ocean Survey, National Oceanic and Atmospheric Administration, Rockville, MD. 37 pp. plus appendices.

NOAA. 1983. California marine boundary program final report. State of California/National Ocean Survey Cooperative Program, Tides and Water Levels Division, Office of Oceanography, National Ocean Survey, National Oceanic and Atmospheric Administration, Rockville, MD.

NOAA. 1992. San Francisco Bay National Estuarine Research Reserve site nomination proposal. Prepared for the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration, by R. Crawford, M. Vasey, J. Kelley, and P. Fonteyn. San Francisco State University. November, 1992.

Odum, E.P. 1971. Fundamentals of Ecology. W.B. Saunders Company, Philadelphia, PA. 574 pp.

Ogden Beeman and Associates, Inc. 1992. Sediment budget study for San Francisco Bay. Portland, OR.

Patrick, W.H. and R.D. DeLaune. 1990. Subsidence, accretion, and sea level rise in south San Francisco Bay marshes. Limnology and Oceanography 35(6): 1389 – 1395.

Pavlik, B. 1996. Defining and measuring success. *In:* D. Falk, C. Millar, M. Olwell (eds.). Restoring diversity: strategies for reintroduction of endangered plants. Pages 127 – 155. Island Press, Washington, D.C.

Perkins, J.B., S. Potter and L. Stone. 1991. Status and trends report on land use and population. Prepared by the Association of Bay Area Governments for the San Francisco Estuary Project. U.S. Environmental Protection Agency. San Francisco, Calif. 186 pp.

PERL. 1990. A Manual for Assessing Restored and Natural Coastal Wetlands. Pacific Estuarine Research Laboratory, California Sea Grant Report No. T-CSGCP-021. California Sea Grant, La Jolla, Calif.

Pestrong, R. 1965. The development of drainage patterns of tidal marshes. Stanford University Publications in Geological Sciences 10(2):1 – 87.

Pestrong, R. 1972. San Francisco Bay tidelands. California Geology 25:27 – 40.

Prunuske Chatum. 1998. Novato flood control project mitigation status and plan, 1998 year-end report. Prepared for Marin Flood Control and Water Conservation District. 32 pp. and appendices.

Race, M.S. 1995. Critique of present wetlands mitigation policies in the United States based on an analysis of past restoration projects in San Francisco Bay. Environmental Management Vol. 9, No. 1, pp. 71 – 88.

Rantz, S.E. 1971. Precipitation depth-duration-frequency relations for San Francisco Bay region, California. *In:* Geological Survey research 1971: U.S. Geological Survey Professional Paper 750-C. pp. C237 – C241.

Riley, A.L. 1998. Restoring streams in cities. A guide for planners, policy makers and citizens. Island Press, Covelo, Calif. 423 pp.

RMI. 1999. Restoration and management plan for the Baumberg Tract, Hayward, California. Prepared for the California Department of Fish and Game, Yountville, Calif.

RMP. 1998 (and others in this series). Regional monitoring program for trace substances annual Report for 1997. San Francisco Estuary Institute, Richmond, Calif. 299 pp. plus appendices.

Rollins, G.L. 1981. A Guide to waterfowl habitat management in Suisun Marsh. State of California. The Resources Agency, California Department of Fish and Game.

SFBRWQCB. 1998. Performance criteria and success of mitigation projects (1988 – 1995). Final Report prepared by A. Breaux, M. Martindale, and F. Serefiddin for the San Francisco Bay Regional Water Quality Control Board, Oakland, Calif.

SFEI. 1994. Potential environmental impacts of tidal marsh restoration in the North Bay of the San Francisco estuary. San Francisco Estuary Institute, Richmond, Calif. 138 pp.

SFEP. 1992. State of the Estuary: a report on conditions and problems in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Prepared by M.W. Monroe and J. Kelly, Association of Bay Area Governments, for the San Francisco Estuary Project, Oakland, Calif. 269 pp. and figures.

SFEP. 1993. Regional monitoring strategy. Prepared by the San Francisco Estuary Institute for the San Francisco Estuary Project, Oakland, Calif. 143 pp.

Siegel, S.W. 1993. Tidal marsh restoration and dredge disposal in the San Francisco Estuary, California: selected scientific and public policy principles for implementation of the Montezuma wetlands project. Masters Thesis in the Department of Geography, University of California at Berkeley, Berkeley, Calif. 242 pp.

Siegel, S.W. 1998. Petaluma River Marsh monitoring report, 1994 – 1998. Prepared for Sonoma Land Trust. May. 37 pp.

Simenstad, C. and R. Thom. 1996. Functional equivalency trajectories of the restored Gog-Le-Hi-Te estuarine wetland. Ecological Applications 6 (1):38 – 56.

Skinner, J.E. 1962. An historical review of the fish and wildlife resources of the San Francisco Bay area. Water Projects Branch Report No. 1., California Department of Fish and Game, Sacramento, Calif. 226 pp.

Smith, R.L. 1980. Ecology and Field Biology, 3rd ed., Harper and Row, New York. 835 pp.

Sokale, J. and L. Trulio. 1998. San Francisco Bay Trail Project. Wildlife and public access study: site selection report. July 1. 13 pp.

Strong, D. and D. Ayres. 1998. Smooth and California cordgrass and their hybrids in San Francisco Bay. Univ. Calif. Davis Bodega Marine Lab.

Thom, R.M. 1997. System-development matrix for adaptive management of coastal ecosystem restoration projects. Ecological Engineering 8:219 – 232.

Thompson, J. and E.A. Dutra. 1983. The tule breakers: The story of the California dredge. Stockton Corral of Westerners, University of the Pacific. Stockton, Calif. 368 pp.

USCS. 1852. Topographic sheet T-352. U.S. Coast Survey, Washington, DC.

USCS. 1857. Topographic sheet T-676. U.S. Coast Survey, Washington, DC.

USCS. 1860. Topographic sheet T-817. U.S. Coast Survey, Washington, DC.

USCS. 1860. Topographic sheet T-818. U.S. Coast Survey, Washington, DC.

USCGS. 1921. Topographic sheet registration no. 4014. U.S. Coast and Geodetic Survey, Washington, DC.

USACE. 1974. San Francisco Bay: tidal stage vs. frequency study. United States Army Corps of Engineers, San Francisco District, San Francisco, Calif.

USACE. 1997. Annual monitoring report, Sonoma Baylands wetlands demonstration project. United States Army Corps of Engineers, San Francisco District, San Francisco, Calif., 16 pp. with appendices.

USACE. 1998. Project study plan: Napa River salt marsh restoration Napa and Solano Counties, California. United States Army Corps of Engineers, San Francisco District, SF, Calif. 29 pp.

USDA. 1914. California soil map, reconnaissance survey, San Francisco Bay sheet.

Van Royen, W. and C.O. Siegel. 1959. Future development of the San Francisco Bay area, 1960 – 2020. Report prepared for U.S. Army Corps of Engineers, San Francisco District, San Francisco, by Business and Defense Services Administration, U.S. Dept. of Commerce.

Vancouver, G. 1798. A voyage of discovery to the north Pacific ocean, and around the world. Printed for G.G. Robinson, J. Robinson, and J. Edwards, London.

Vasey, M. 1995. San Francisco Bay national estuarine research reserve draft environmental impact statement and draft management plan. San Francisco State University, San Francisco, Calif.

Ver Planck, W.E. 1958. Salt in California. Bulletin 175. State of California Department of Natural Resources, Division of Mines. 168 pp.

Wells L.E. and M. Goman. 1995. Late holocene environmental variability in the upper San Francisco estuary as reconstructed from tidal marsh sediments. *In*: C.M. Isaacs and V.L. Tharp (eds). Proceedings of the eleventh annual Pacific Climate (OACLIM) Workshop, April 19 – 24, 1994. Pages 1 – 14. Interagency Ecological Program, Technical Report 40. California Department of Water Resources, Sacramento, Calif.

Whitney, J.D. 1873. Map of the region adjacent to the San Francisco Bay. State Geological Survey of Calif., Sacramento, Ca.

Woodward-Clyde. 1998. Enhancement plan for the former Oliver Brothers salt ponds, HARD Marsh, Interpretive Center Marsh, and the Salt Marsh Harvest Mouse Preserve. Prepared by URS Greiner Woodward-Clyde Consultants for Hayward Area Recreation District, Hayward, Calif. 45 pp. and appendices.

WRA. 1998. Cargill Salt Company salt evaporator pond B-1 tidal marsh restoration. Annual monitoring report, Year 3. Prepared by Wetlands Research Associates, San Rafael, Calif., for Cargill Salt Division, Newark, Calif.

Young, W.R. 1929. Report on the salt water barrier below confluence of Sacramento and San Joaquin Rivers, California. California Division of Water Resources Bulletin 22(1): 667 pp.

Zedler, J.B. 1996. Tidal wetland restoration: a scientific perspective and Southern California focus. Published by the California Sea Grant College System, University of California, La Jolla, Calif. Report No. T-038. 129 pp.

Zedler, J.B. and R. Langis. 1991. Comparisons of constructed and natural salt marshes of San Diego Bay. Restoration Management Notes 9:21 – 25.

Personal Communication:

Peter Baye, U.S. Fish and Wildlife Service, Sacramento.

Joe Didonato, East Bay Regional Park District, Hayward.

Helene Hagen, Institute of Archetypal Ethnology, Larkspur.

Kathy Heib, California Department of Fish and Game, Stockton.

Jeff Haltiner, Philip Williams and Associates, Ltd., Corte Madera

Michael Josselyn. San Francisco State University, San Francisco.

Gary Page, Point Reyes Bird Observatory, Stinson Beach.

Charlie Patterson, wetlands consultant, Lafayette.

Paul Sheffer, Southern Sonoma County Resource Conservation District, Petaluma.

Lawrence Stromberg, wetlands consultant, San Rafael.

Jim Swanson, California Department of Fish and Game, Yountville.

John Takekawa, U.S. Geological Survey, Mare Island.

Mark Taylor, East Bay Regional Park District, Hayward.

Carl Wilcox, California Department of Fish and Game, Yountville.

Larry Wycoff, California Department of Fish and Game, Yountville.