Turning SALT into Environmental GOLD

Wetland Restoration in the South San Francisco Bay Salt Ponds

SAVE THE BAY

MAP 1.

South San Francisco Bay Salt Ponds Proposed for Restoration

Cargill operates five salt production plants in the South Bay and is proposing to sell three of them. This map shows the area available for habitat restoration, other mitigation and restoration projects, and existing marsh.

Legend

Ponds available for habitat restoration and enhancement

- Baumberg Plant (4,760 acres)
- Alviso Plant (8,280 acres)
- Redwood City Plant (2,840 acres)

Ponds remaining in salt production

- Newark #1 Plant (3,930 acres)
- Newark #2 Plant (6,380 acres)

Ponds currently planned for restoration and not considered in this report

- Eden Landing, Hayward; Pond A4, Sunnyvale; and Bair Island, Redwood City (2,390 acres)

Regional features

- Marsh
- Deep bay, depths greater than 18 feet below mean lower low water
- Shallow bay, depths 0 to 18 feet below mean lower low water
- Tidal flats, depths range from lowest tide to mean tide level
- City boundaries
- Highways
- Railroad

0 1,000 2,000 4,000 Meters

0 1 2 4 Miles

Data Sources: EcoAtlas, Cargill, USGS
Map Projection: CA Stateplane III, NAD83
Map Version 1.10 | Produced on: 03/30/01

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Save The Bay has been working for four decades to protect and restore the San Francisco Bay and Sacramento-San Joaquin Delta and to improve public access to its shoreline. We are committed to keeping the Bay healthy, alive, and beautiful for future generations.

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Contents

Executive Summary

Tidal wetland restoration is desperately needed in the South San Francisco Bay, as it is throughout the San Francisco Estuary. The Estuary has lost nearly 95 percent of its historic tidal and riparian wetlands, and scientists estimate 100,000 acres of restored tidal marsh are needed to preserve estuary health for future generations. Acquisition and restoration of Cargill Salt's solar salt production ponds, located at the southern tip of San Francisco Bay in the vicinity of San Jose, California, would provide a significant portion of this acreage while preserving existing wildlife resources.

Working to reverse a century of degradation to the Estuary, Save The Bay analyzed the feasibility of restoring the South Bay salt ponds to tidal wetlands and related habitats. We found that all 26,190 acres of South Bay salt ponds are potentially restorable to a mix of tidal marsh, open water, and related habitats that will provide tremendous ecological benefit to the Estuary's fish, wildlife, and water quality. By acquiring 15,500 to 18,000 acres of salt ponds, state and federal resource agencies can dramatically increase the amount of special status species habitat in the South Bay and make cost-effective habitat decisions on a regional scale. To provide the best ratio of habitats, our feasibility analysis concurs with the *Baylands Ecosystem Habitat Goals Report* that approximately two-thirds of the South Bay salt ponds should be returned to tidal marsh. The remaining ponds should be retained as managed open water ponds to preserve existing waterfowl and shorebird habitat.

To determine restoration options and priorities, resource agencies must understand existing pond conditions because they will affect not only restoration options, but also the cost and speed with which restoration can occur. Based on these conditions, which are detailed in the report, we ranked the salt ponds by their relative ease of restoration and determined rough costs for tidal wetland restoration. High feasibility ponds have relatively few constraints and can be restored to tidal marsh in a rapid, cost-effective manner. Estimates for restoring high feasibility ponds range between $1,060 and $1,265 per acre. In contrast, low feasibility ponds exhibit a variety of constraints and cannot be easily restored to tidal marsh. Estimates for restoring low feasibility ponds to tidal marsh range between $4,900 and $90,445 per acre. The use of clean dredged sediment to overcome severe pond subsidence and accelerate the restoration process significantly increases costs toward the upper end of this range.

Because not every salt pond will be restored to tidal marsh, resource agencies have the flexibility to select restoration scenarios that optimize habitat benefits while minimizing restoration costs. Given the difficulty and high cost of restoring low feasibility salt ponds to tidal marsh, these ponds make excellent candidates for managed microtidal lagoons, decreasing overall restoration costs and providing valuable habitat for waterfowl and shorebirds. Crystallizer ponds can be quickly converted to habitat suitable for shorebirds, especially the threatened Western snowy plover, which will further reduce restoration costs for the salt pond complex. Applying this rationale to the acquisition area, we developed rough total restoration costs. Based on an acquisition area of approximately 15,500 acres, we estimate interim management and restoration costs for the South Bay ponds to be in the range of $148 to $228 million over a 20-year timeframe. This figure does not include acquisition costs.

Restoration of the South Bay salt ponds presents many opportunities and challenges. The complex's characteristics and substantial size offer unique benefits not found in many wetland restoration projects, such as creating large blocks of contiguous tidal marsh; accelerating restoration efforts through varied pond topography and antecedent channels; and reusing treated wastewater for pond desalination. While challenges to such large-scale restoration exist—including preservation of existing wildlife habitat, pond subsidence coupled with insufficient sediment supply, and pond desalination—our feasibility analysis finds that each can be overcome with careful planning, sufficient funds, and patience.

Public acquisition of the North Bay salt ponds in 1994 teaches us that interim operations and maintenance (O&M) costs will be significant and must be factored into any successful acquisition package. Problems that continue to trouble North Bay restoration efforts could have been avoided with adequate O&M funding to cover water management, levee maintenance, bittern removal, and other related costs. Creation of detailed hydrologic models should be the first step in the restoration process. These models will provide important guidance on key issues such as restoring tidal action to ponds; minimizing risks associated with levee breaches; predicting salt transport; and assessing sedimentation needs.

Several issues merit careful consideration during acquisition negotiations. In particular, decisionmakers must evaluate the failure to capture important restoration opportunities by allowing highly restorable ponds in the East Bay to remain in salt production, especially when doing so will lower the ponds' ecological value. Some of the best ponds for short-term tidal marsh restoration lie within the Newark #2 Plant, where Cargill plans to continue salt production. (Others are located in the Redwood City Plant, near the western end of the Dumbarton Bridge.) In some of these ponds, intensified salt production will increase salinity above current levels, eliminating useful habitat for birds and other species. A well-crafted acquisition agreement will address this and other management issues.

Save The Bay condenses two years of exhaustive research into this report, providing decisionmakers and the public with a clear yet concise picture of the opportunities and challenges to wetland restoration in the South Bay. More information is provided at our website, www.savesfbay.org, including maps depicting existing pond conditions. We believe this is the first time any organization has compiled and analyzed this vast array of interrelated data, adding new perspective to the public debate over salt pond acquisition and restoration.

Introduction

Wetlands play a vital and often overlooked role in maintaining a healthy ecosystem. They improve water quality, provide essential wildlife habitat, act as natural flood control, and prevent shoreline erosion. More productive than all ecosystems but tropical rainforests, wetlands feed and shelter countless species, support a diverse plant community, and form the foundation of the food web. They also provide other beneficial functions such as educational and recreational opportunities.

Unfortunately more than 90 percent of California's original wetlands have been destroyed by diking, draining, and filling. Many remaining wetlands are threatened by pollutant runoff and loss of freshwater flows caused by diversion projects. Riparian areas have been lost as creeks are routed underground or channelized for flood control and urban development. The San Francisco Bay Area—the nations' fourth largest metropolitan region—has suffered severe wetland losses due to urban development, agricultural conversion, and salt production. As a result, the Bay Area has lost nearly 95 percent of its historic tidal and riparian wetlands, particularly in the San Francisco and San Pablo Bays. Scientists estimate that a minimum of 100,000 acres must be restored to tidal marsh to keep the San Francisco Estuary vital and self-sustaining.

Determined to improve the health of the Bay and its inhabitants, many citizens, agencies, and organizations have set their sights on a 26,190-acre complex of solar salt production ponds located at the southern tip of San Francisco

Bay in the vicinity of San Jose, California (see Map 1 inside the front cover). The restoration potential of these ponds is enormous, and creating a combination of tidal marsh, managed ponds, and related habitats in this region will improve Bay water quality and greatly advance recovery of endangered species. Although Cargill Salt (Cargill) currently operates these ponds, it owns only 56 percent of the land (14,760 acres). Since 1974, the Don Edwards National Wildlife Refuge (Refuge) has owned the remaining 44 percent (11,430 acres), with Cargill retaining mineral rights for salt production. (See Figure 1 for specific land ownership.) The Refuge was established after the purchase of these lands from Leslie Salt, Cargill's predecessor.

After years of salt production in the San Francisco Bay Area, Cargill decided to consolidate its operations in October 2000. Negotiations with state and federal resource agencies are underway for sale of Cargill's mineral rights on lands owned by the Refuge (approximately 25 percent of the proposed acquisition area) and outright sale of other Cargill lands. The potential acquisition area totals between 15,500 and 18,000 acres, including 1,400 acres of former salt ponds north of San Pablo Bay along the Napa River and roughly 600 acres of submerged South Bay tidelands. After public acquisition of these areas, Cargill's salt production acreage will decrease to 10,310 acres and occur primarily on Refuge lands. Cargill will continue to own 2,800 acres of ponds along the southeastern shoreline near the City of Newark (se Map 1). This acreage represents 11 percent of the South Bay salt pond complex. Cargill's annual salt production will remain close to current levels because it plans to increase its per-acre yield through improved operational efficiency and modified salt harvest practices.

Regional Planning Efforts

The San Francisco Bay-Delta Estuary is an ecological treasure that supports enormous biodiversity. Approximately 120 fish species, 255 bird species, 81 mammal species, 30 reptile species, and 14 amphibian species live in the Estuary, relying on riparian and tidal wetlands for food, shelter, and breeding habitat. Nearly half the migrating birds on the Pacific Flyway and two-thirds of California's salmon pass through the Estuary each year.

Because of their biological importance, broad community support exists for protecting existing Bay wetlands from destruction and restoring degraded wetlands and diked, former tidal wetlands (known as "baylands") to productive ecosystems. Several regional efforts have addressed bayland restoration. The first such effort resulted in the *Comprehensive Conservation and Management Plan* (CCMP). The CCMP identifies 145 actions necessary to return the San Francisco Estuary to health, and it requires creation of an estuary-wide plan to protect, enhance, restore, and create tidal wetlands. By 1994, resource agencies had begun to develop a shared vision for Bay wildlife and wetlands. The San Francisco Estuary Institute (SFEI), the California Department of Fish and Game (CDFG), the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (USFWS), and many others collaborated on the Baylands Ecosystem Habitat Goals Project—a blueprint for future estuary restoration based on ecological principles.

The Bay Area has lost nearly 95 percent of its historic tidal and riparian wetlands, particularly in the San Francisco and San Pablo Bays. Scientists estimate that a minimum of 100,000 acres must be restored to tidal marsh to keep the San Francisco Estuary vital and self-sustaining.

The Baylands Ecosystem Habitat Goals Project was a four-year effort involving more than 100 Bay Area participants from public, nonprofit, academic, and private sectors. It focused on ecological restoration of the San Francisco Estuary, resulting in the *Baylands Ecosystem Habitat Goals Report.* The report identifies key indicator species for bayland habitats, evaluates those species' habitat needs, and provides recommendations for improving their habitats. The report also discusses how to connect these habitats with surrounding wetland-related habitats, such as intertidal mudflats, seasonal wetlands, streams, and uplands.

Despite the desperate need for tidal wetlands throughout the Estuary, the *Baylands Ecosystem Habitat Goals Report* notes the importance of providing a range of interconnected habitats in the South Bay, including tidal marsh, mudflats, seasonal wetlands, managed saline ponds, and buffer and transitional zones. For this reason, the report recommends restoring 16,000 to 21,000 acres of South Bay salt ponds to tidal marsh and managing 10,000 to 15,000 acres as shallow ponds for shorebird and waterfowl habitat. In other words, only 60 percent of the South Bay salt ponds should be restored to tidal wetlands. It also recommends that restored tidal marsh and managed salt ponds be interspersed and that wide corridors of similar habitat connect these areas. Natural transitions from mudflat through tidal marsh to adjacent uplands should occur wherever possible. Restored areas should be linked to each other and to existing or restored riparian corridors. Additionally, uplands, transitional habitats, and exiting wildlife resources should be protected, and the entire South Bay ecosystem buffered from urban development.

Recently the USFWS began developing two regional plans for the recovery of threatened and endangered species whose survival depends on the region's tidal wetlands. These are the *Tidal Marsh Ecosystem Recovery Plan* and the *Snowy Plover Recovery Plan*. When completed, the *Tidal Marsh Ecosystem Recovery Plan* will incorporate recommendations developed in the *Snowy Plover Recovery Plan*, define ecological goals for South Bay salt pond restoration, and offer guidelines for achieving those goals. The plan will emphasize reestablishment of diverse wetland habitats within the South Bay, including the range of habitats that would be present under natural conditions. In addition, the plan is expected to recommend wetland restoration designs that minimize engineering and ongoing maintenance.

The San Francisco Bay Joint Venture (SFBJV) is a partnership that brings together public and private agencies, conservation groups, development interests, and others to collaborate in restoring wetlands and wildlife habitat in the San Francisco Estuary. The SFBJV strives "to protect, restore, increase, and enhance all types of wetlands, riparian habitat, and associated uplands throughout the San Francisco Bay region to benefit waterfowl and other fish and wildlife populations." The SFBJV recently prepared *Restoring the Estuary: Implementation Strategy of the San Francisco Bay Joint Venture.* The report outlines measures to achieve these goals, centering largely on habitat protection, enhancement, and restoration. It recommends several strategies for salt pond restoration, including: restoration of moderate and high salinity ponds to tidal marsh; preservation of low salinity ponds for diving and dabbling duck habitat; incorporation of large ponds into restoration design; and retention of some high salinity ponds for production of brine shrimp and brine flies.

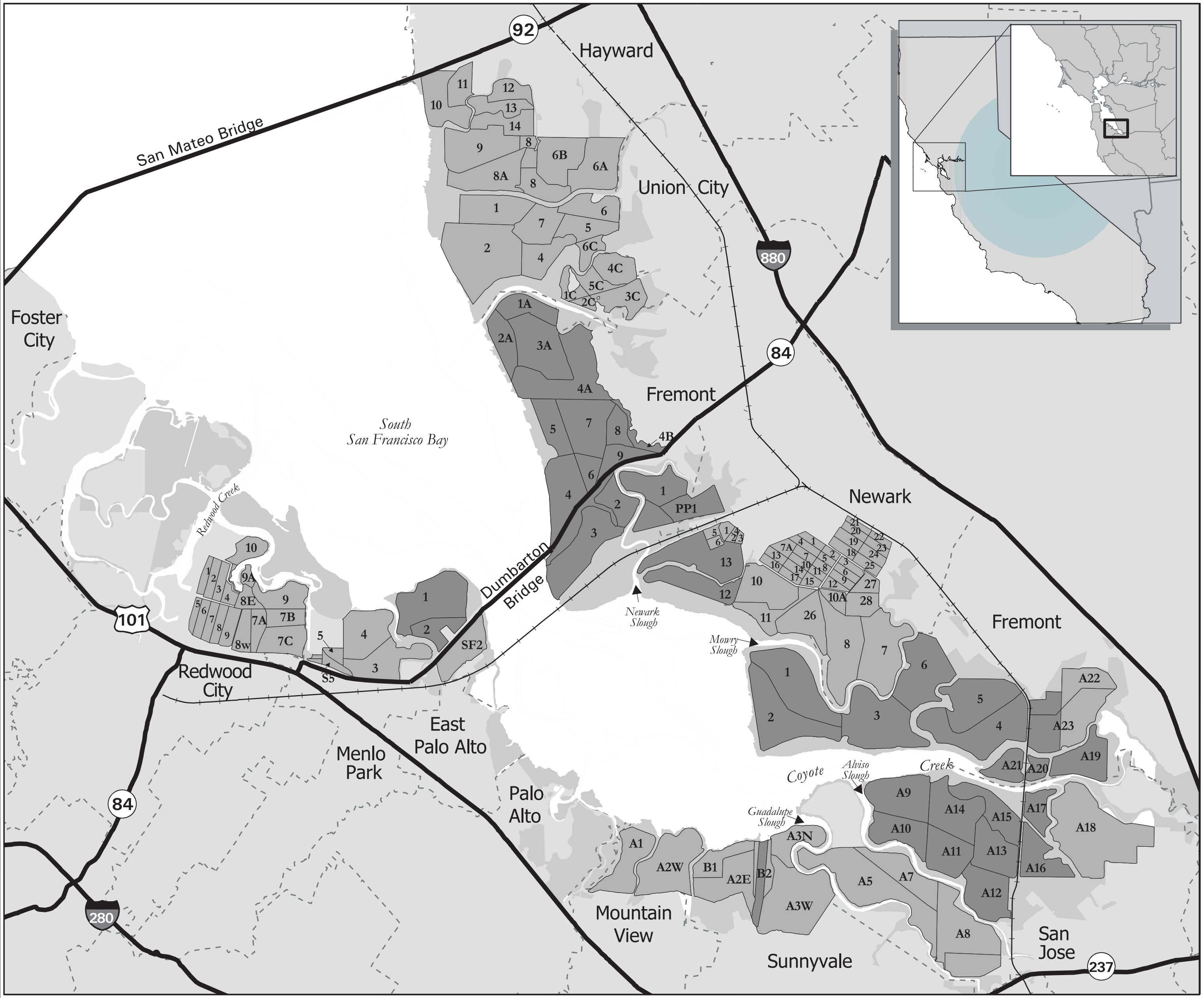

FIGURE 1.
Land Ownership of the South Bay Salt Ponds

Cargill produces salt on about 11,430 acres of publicly owned salt ponds. Cargill retained mineral rights on these lands under the 1979 purchase agreement that helped establish the Don Edwards San Francisco Bay National Wildlife Refuge.

Legend

- Ponds owned and operated by Cargill (14,760 acres)
- Ponds owned by Don Edwards San Francisco Bay National Wildlife Refuge, operated by Cargill for salt production (11,430 acres)
- City boundaries
- Highways
- Railroad

0 1,00 2,000 4,000 Meters

0 1 2 4 Miles

Data Sources: EcoAtlas, Cargill, USGS
Map Projection: CA Stateplane III, NAD83
Map Version 1.7 | Produced on: 03/30/01

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Existing Conditions in the South Bay Salt Ponds

To develop effective wetland restoration strategies, restoration planners must understand the salt production process and Cargill's system maintenance requirements. In the period between salt pond acquisition and restoration implementation, facilities such as channels, pumps, tide gates, levees, siphons, and pipelines must be maintained and operated to preserve system integrity and prevent problems such as those encountered in the North Bay salt ponds. (Lessons learned from the North Bay salt pond restoration effort will be discussed later in the report.) Restoration planners must also know the existing biological, physical, and environmental chemistry conditions found in the ponds to determine restoration options and priorities. These conditions also will determine the cost and speed with which restoration can occur.

The Solar Salt Production Process

Salt production in the San Francisco Estuary has occurred since the 1860s. The current network of South Bay salt production ponds has been operated for approximately 50 years, with Cargill acquiring the ponds from Leslie Salt in the late-1980s. Although its collective capacity is over 1 million tons, Cargill currently produces only 650,000 tons of salt per year on its 26,190-acre pond complex. Depending on the water's salinity during system intake, this requires approximately 40 million tons of Bay water annually.

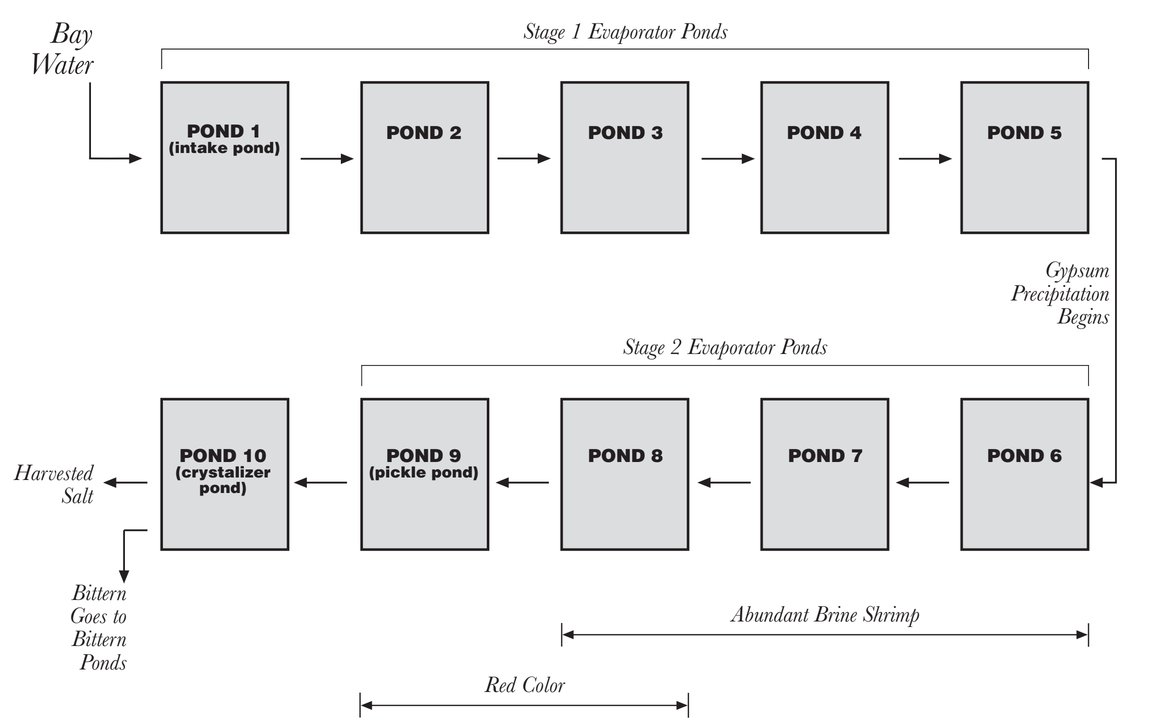
In the South Bay, five discrete "plants"—Alviso, Baumberg, Newark #1, Newark #2, and Redwood City—produce salt through solar salt production (see Map 1). Each plant consists of a series of salt ponds that concentrate and precipitate Bay water through solar evaporation. Final-stage processing plants currently are located in Newark and Redwood City. (The Redwood City Plant may be part of the acquisition.) Salt harvested from all five plants is processed at these two sites.

The solar salt production process begins when Bay water flows into eight intake ponds. The water enters the ponds through pumps or automatic tide gates that open at high tide and close when the Bay's water level drops below the pond's water level. Bay water is typically less salty than seawater because it is diluted by freshwater from the Sacramento and San Joaquin Rivers, local streams and creeks, and wastewater treatment plant discharges. This is particularly true in winter and early spring when rain and melting snow increase freshwater flows into the Bay. Therefore, Cargill normally takes Bay water into its pond system during dry months when the Bay's salinity is highest. The intake period begins in April or May and continues through the fall. Once in the salt pond system, Bay water is called "brine." It moves through the system by a combination of gravity feed and pumping. Prevailing summer winds also push the brine between ponds.

Brine begins its journey through the salt pond system in the evaporator ponds. (See Figure 2.) In Stage 1 ponds, the water volume is reduced by roughly 70 percent, brine salinity increases, and suspended matter settles to the bottom of the ponds. In Stage 2 ponds, salinity increases further and gypsum (calcium sulfate) precipitation begins. The final Stage 2 evaporator pond, called the "pickle pond," distributes concentrated brine (now called "pickle" due to its high salt content) to the crystallizer ponds. By the time pickle leaves the pickle pond each spring, 95 percent of the intake pond's original water volume has evaporated. In the crystallizer ponds, the pickle undergoes its final evaporation; here sodium chloride (common salt) precipitates at a rate of approximately 40 tons per acre. By September, the salt bed is five to eight inches deep and is ready for harvest.

Salt harvesting begins in early October and continues 24 hours per day until the end of December. The ponds are drained and harvested one at a time to minimize the time the salt is left uncovered. Mechanical harvesters break up the salt bed with a rotating "pickroll," scrape the pieces up with a blade, and deposit the salt into hopper cars. The harvester cuts a swath thirteen

FIGURE 2. **The basic salt production process** (based on the ten-pond model in Ver Planck 1958).



feet wide and four to six inches deep. Diesel locomotives pull the hopper cars along a temporary track laid on the crystallizer pond floor. Each hopper car holds approximately two tons of salt. The harvested salt is then washed and processed for industrial and commercial use.

After harvesting ends in late December, the crystallizer ponds are flooded with a weak brine solution to dissolve any remaining sodium chloride. This brine solution is returned to intermediate evaporator ponds to reclaim the sodium chloride. In April when the rainy season ends, the crystallizer ponds are dried, leveled with scrapers, and pumped full of new pickle.

Bittern, the hypersaline byproduct of solar salt production, is stored in bittern ponds located near the processing plants in Newark and Redwood City. Salinity in these ponds can reach 447 parts per thousand, which is nearly 13 times more saline than seawater. Bittern's high salinity and ionic imbalance—due to precipitation of carbonates, calcium, sulfate, chloride, and sodium from the brine—is toxic to aquatic species.

Once bittern is produced, few options exist for its disposal. Prior to 1970, bittern that was not sold was discharged into San Francisco Bay. By the early 1970s, the federal Clean Water Act (33 USC 1251, *et seq.*) and the state Porter-Cologne Water Quality Control Act (Cal. Water Resources Code 13020, *et seq.*)—both implemented by the San Francisco Bay Regional Water Quality Control Board (RWQCB)—prohibited bittern discharge to the Bay. This marked the beginning of long-term, onsite bittern storage in bittern ponds. While some bittern continues to be sold for use in dust suppressants and de-icers, much of the bittern produced since the 1970s is stored within the South Bay salt pond complex. Recent operational changes have reduced bittern production, but the backlog of stored bittern remains. Bittern disposal is therefore an important consideration when assessing the feasibility of salt pond restoration.

As part of its operations, Cargill conducts numerous maintenance activities in the South Bay salt pond complex, but the most common is levee maintenance. Throughout the pond complex, extensive levee maintenance is required due to erosion, subsidence, and soil compaction. Cargill uses a floating dredge and a system of access channels entered through dredge locks to maintain the levees. Most of Cargill's regulatory requirements stem from levee maintenance and dredge lock use.

Biological Conditions

Salt ponds dramatically altered the South Bay ecosystem. The creation of these shallow ponds in a region characterized by broad stretches of tidal marsh changed the Bay's hydrology, degraded water quality, and reduced wildlife habitat, resulting in severe impacts to many tidal-marsh-dependent species. But the shallow salt ponds, coupled with the Bay's abundant prey of fish and invertebrates, began providing valuable waterfowl habitat. South Bay salt ponds now provide important habitat for many bird species, as well as other flora and fauna.

Successful salt pond restoration must accommodate a range of biological conditions that will impact restoration feasibility. The three most significant biological conditions are: (1) special status species, (2) preservation of existing biological resources, and (3) invasive non-native species.

Special Status Species

Numerous special status species reside in the South Bay salt ponds, including 2 plants, 1 invertebrate, 25 birds, 2 fish, and 3 mammals (see Table 1). The presence of these species will complicate restoration planning and probably increase restoration costs. Federal and state laws protect these species and their habitats and will strongly influence restoration design and implementation. Ponds that satisfy (or could satisfy) the specific requirements of special status species should be identified and assigned a high priority for restoration.

Although salt pond restoration will benefit some special status species (e.g., salt marsh harvest mouse and California clapper rail), other species, such as the Western snowy plover, may be negatively impacted by a loss of salt pond habitat (see last column in Table 1). The dependence of many species on South Bay habitats, combined with the dramatic loss of historic tidal marsh, mandates careful planning and a willingness to make tradeoffs between habitat types. Our primary goal must be to benefit those species most at risk, while minimizing impacts to other species that rely on existing salt pond habitat.

Preservation of Existing Biological Resources

Preservation of existing biological functions is a constraint to salt pond restoration. The most significant impact of reducing salt pond habitat is

TABLE 1. **Special status species found in the South Bay salt ponds.**

Common Name	Scientific Name	Status[1]	Reproduces in salt ponds[2]	Probable impact of tidal marsh restoration[3]
PLANTS				
California sea blite	*Suaeda californica*	FE, EX	X	+
Pt. Reyes bird's beak	*Cordylanthus maritimus palustris*	FSC, EX	X	+
INVERTEBRATES				
California brackish water snail	*Tryonia imitator*	FSC	X	-
BIRDS				
Alameda song sparrow	*Melospiza melodia pusillula*	FSC, SSC	X	+
Aleutian Canada goose	*Branta canadensis leucopareia*	FT		0
American peregrine falcon	*Falco peregrinus anatum*	FD, SE		0
American white pelican	*Pelecanus erythrorhynchos*	SSC		-
Barrow's goldeneye	*Bucephala islandica*	SSC		0
Black skimmer	*Rynchops niger*	SSC	X	-
Black tern	*Chlidonias niger*	FSC, SSC		-
Burrowing owl	*Athene cunicularia hypugea*	FSC, SSC	X	0
California brown pelican	*Pelecanus occidentalis californicus*	FE, SE		-
California clapper rail	*Rallus longirostris obsoletus*	FE, SE	X	+
California gull	*Larus californicus*	SSC	X	-
California horned lark	*Eremophila alpestris actia*	SSC	X	0
California least tern	*Sterna antillarum browni*	FE, SE	X	-
Double-crested cormorant	*Phalacrocorax auritus*	SSC	X	0
Elegant tern	*Sterna elegans*	FSC, SSC		-
Long-billed curlew	*Numenius americanus*	SSC		+
Northern harrier	*Circus cyaneus*	SSC	X	0
Salt marsh common yellow-throat	*Geothlypis trichas sinuosa*	FSC, SSC	X	+
Short-eared owl	*Asio flammeus*	SSC	X	+
Tri-colored blackbird	*Aegelaius tricolor*	FSC, SSC	X	0
Western least bittern	*Ixobrychus exilis hesperis*	FSC, SSC	X	+
Western snowy plover	*Charadrius alexandrinus nivosus*	FT, SSC	X	-
White-faced ibis	*Plegadis chihi*	FSC, SSC		0
White-tailed kite	*Elanus leucurus*	SSC	X	0
Yellow warbler	*Dendroica petechia brewsteri*	SSC	X	0
FISH				
Coho salmon	*Oncorhynchus tshawytscha*	FT		+
Steelhead	*Oncorhynchus mykiss irideus*	FT		+
MAMMALS				
Pacific harbor seal	*Phoca vitulina richardsi*	MMPA	X	0
Salt marsh harvest mouse	*Reithrodontomys raviventris halicoetes*	FE, SE	X	+
Salt marsh wandering shrew	*Sorex vagrans halicoetes*	FSC,SSC	X	+

[1] Acronyms: federal endangered species (FE), federal threatened species (FT), federal species of concern (FSC), federal delisted species (FD), state endangered species (SE), state threatened species (ST), state species of special concern (SSC), protected under Marine Mammal Protection Act (MMPA), and locally extinct (EX).

[2] This includes species that currently reproduce, historically reproduced, or could potentially reproduce in the area.

[3] Symbols: positive impact (+), negative impact (-), and unknown or negligible impact (0).

the potential reduction in migratory bird health and population. Many species depend on the salt ponds and adjacent tidal marsh for breeding, foraging, over-wintering, and migratory habitat. Some of these species were not historically abundant in San Francisco Bay, but because their historic habitats were greatly reduced (e.g., Central Valley wetlands), these species now rely on the salt ponds.

To balance the needs of various species and provide the best ratio of habitats, the *Baylands Ecosystem Habitat Goals Report* recommends returning roughly 60 percent of the South Bay salt pond complex to tidal marsh. Based on our analysis, we concur with this finding. The remaining ponds should be enhanced and managed as other wetland-related habitats, particularly shallow open water areas of varying salinity and depth.

Phasing salt pond restoration will optimize habitat benefits for all species. Other restoration projects have taught us that interim conditions—those existing from the time tides are reintroduced to the site until the emergence of tidal marsh—provide varied and significant ecological functions, especially for shorebirds and waterfowl. For example, a deeply subsided salt pond progresses from a tidal lagoon to a low intertidal mudflat to a high intertidal mudflat before becoming a vegetated and fully channelized marsh. During this evolution, the site provides dabbling and diving duck habitat that transforms into and coexists with wading bird and probing shorebird habitat. Fish use also changes over time, especially as invertebrates colonize these areas. These varied functions are important to a variety of wildlife and should be enhanced through phased restoration.

Because restoration on this scale has never been attempted in the Bay Area and wildlife use of the salt ponds varies from year to year, we must adapt our plans as the restoration effort proceeds. Resource agencies must make ongoing adjustments to ensure adequate protection of all wildlife resources. In other words, adaptive management will be essential to the restoration process. This is particularly true in the case of invasive plant and animal species.

Invasive Non-Native Species

Salt pond restoration may provide new habitat for invasive non-native species, which can be extremely harmful to native species. The most serious invaders in the South Bay are smooth cordgrass, Norway rat, and red fox.

Smooth cordgrass (*Spartina alterniflora*) is an aggressive non-native plant that poses a serious threat to the success of future tidal marsh restoration throughout the San Francisco Estuary. The plant was introduced to the Estuary in the 1970s as part of a tidal marsh restoration project in Pond 3, located on Coyote Hills Slough near the Alameda Creek flood control channel. Smooth cordgrass is now well-established in the South San Francisco Bay, impacting about 1,000 acres located south of the Bay Bridge. The East Bay shoreline between the San Mateo and Dumbarton Bridges is heavily infested with *S. alterniflora*.

To balance the needs of various species and provide the best ratio of habitats, the Baylands Ecosystem Habitat Goals Report recommends returning roughly 60 percent of the South Bay salt pond complex to tidal marsh.

Newly restored wetlands are especially vulnerable to invasion by smooth cordgrass. Seeds migrating on tidal currents germinate easily in areas with disturbed soil and limited competition from other vegetation. Three East Bay restoration sites—Cogswell Marsh, Oro Loma Marsh, and the Martin Luther King, Jr. Shoreline—were quickly colonized by *S. alterniflora* in the initial stages of restoration.

Control of this highly invasive species is being studied by a multi-agency task force called the Invasive Spartina Project. Currently no satisfactory control measure has been identified. Consequently, resource managers have suggested that tidal marsh restoration along the heavily infested East Bay shoreline occur later in the restoration process, allowing scientists more time to develop and implement effective control measures for

S. alterniflora. If control measures fail, resource agencies must re-evaluate the ecological implications of tidal restoration in this area.

The Norway rat (*Rattus norvegicus*) and red fox (*Vulpes vulpes*) are predators of ground nesting birds,

Ponds that are less feasible for tidal marsh restoration should be strongly considered for preservation as managed open water ponds or other habitats.

including California clapper rail and Western snowy plover. They often gain access to nesting sites via salt pond levees, and restoration activities may provide new predator corridors. Restoration efforts must strive to limit dispersal of predators. Existing levees can be breached in strategic locations to limit predator access. Restoration of large tracts of tidal marsh will also hinder predator access to the marsh interior.

Physical Conditions

Successful wetland restoration depends on our understanding and accommodation of physical conditions that directly affect the feasibility of restoring salt ponds to tidal marsh. Six physical conditions will determine the ease with which each pond can be restored to tidal marsh: (1) the absence or presence of antecedent channels; (2) the absence or presence of borrow ditches; (3) the pond's hydrologic connection to tidal waters (i.e., its remoteness from the Bay or slough channels); (4) the sediment deficit created by subsidence; (5) the surrounding landscape's topography and its potential for flooding; and (6) various infrastructure impediments. These physical conditions will influence, and to some extent direct, restoration planning efforts. Ponds that are less feasible for tidal marsh restoration should be strongly considered for preservation as managed open water ponds or other habitats.

Antecedent Channels

Tidal marshes have channels that carry water, sediments, nutrients, and biological organisms into and out of the marsh with the ebb and flow of tides. If a salt pond retains remnants of the original tidal marsh channel network (called antecedent channels), restoration feasibility is increased because antecedent channels provide a template for reestablishing channel networks in the restored marsh. The easier it is to restore these networks, the simpler and less costly the restoration effort.

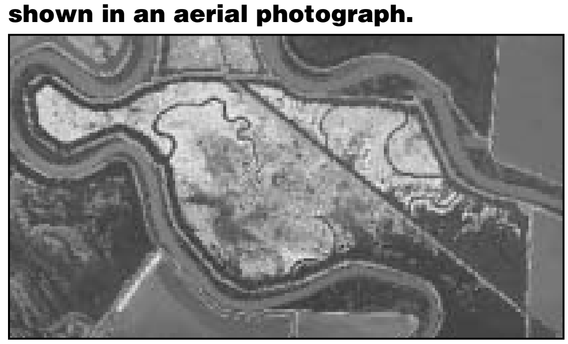
Antecedent channels are present in every South Bay evaporator pond, but not in the crystallizer ponds. Aerial photographs reveal that these channels are more intact in some evaporator ponds than in others. Typical antecedent channels can be seen in an aerial photograph of Alviso Ponds A5 and A7 in Sunnyvale (see Figure 3).

Borrow Ditches

Sediment removed from borrow ditches was originally used to construct the salt pond levee system, and levee maintenance activities over decades have continued to mine sediment from these ditches. For this reason, borrow ditches up to 200 feet wide run alongside most salt pond levees. Figure 2 shows typical borrow ditches adjacent to levees in Alviso Ponds A5 and A7 in Sunnyvale.

Borrow ditches can affect the outcome of restoration efforts for two reasons. The most significant concern is the decreasing ability of borrow ditches to provide material for ongoing levee maintenance. While this need will decline as marsh restoration occurs, some ongoing levee maintenance will always be needed, especially near ponds retained as open water areas. Nevertheless, the presence of borrow ditches may be beneficial because the variable water depth provides a range of forage opportunities.

FIGURE 3. **Typical antecedent channels as shown in an aerial photograph.**



A second concern is the way borrow ditches affect a pond's hydrology, sedimentation, and ecology. Once a pond is returned to tidal action, borrow ditches will significantly alter the channel network's hydrology and sedimentation pattern by short-circuiting the flow paths. This will not only impact water velocity, but will transport sediment in an atypical manner. A new technique may prevent borrow ditches from capturing tidal flows. By constructing a series of "cutoff berms" at strategic locations in the borrow ditch network, restoration scientists hope to prevent the ditches from siphoning off flows in the restored marsh.

Hydrologic Connection to Tidal Waters

The character of each pond's hydrologic connection to the Bay fundamentally affects its ability to be restored. Two factors determine how easily tidal action can be restored: (1) the distance from or proximity to tidal waters, and (2) the existence or absence of tidal marsh on the Bay or "outboard" side of pond levees. In the first factor, a pond's distance from tidal waters determines the ease with which tidal action can be brought to it. A pond can have an open Bay edge, a tributary channel edge, or no tidal edge. A pond that fronts directly onto the Bay provides the most effective tidal connection and is often the easiest to restore. A pond that fronts a tidal channel, such as a creek or flood-control channel, might be more difficult to restore depending on the tributary channel's width, which can vary from a few to several hundred feet. Narrow tributary channels reduce a pond's restoration feasibility because the channels require enlargement to bring sufficient water to the restored pond. A pond with no tidal edge must be combined with other ponds in a multi-pond restoration scenario. Approximately 20 percent of the salt pond acreage has no tidal edge. A case-by-case analysis is needed to determine how this impacts restoration feasibility.

In the second factor, the existence of tidal marsh on the Bay side of salt pond levees (known as "outboard marsh") poses special problems for the return of tidal action to that pond. These small, fragmented marshes must be preserved for the endangered species that depend on them. Breaching levees in these areas is challenging because the breach may alter salinity or otherwise disturb habitat in the outboard marsh. Thus, the existence of outboard marsh significantly decreases a pond's restoration feasibility.

Based on this information, the optimal hydrologic connection for tidal marsh restoration is an open Bay edge without outboard marsh. Approximately 11 percent of the South Bay salt pond acreage meets this criterion. The most challenging hydrologic connection for tidal marsh restoration is a tributary channel edge with outboard marsh. About half of the pond acreage falls into this category.

Pond Subsidence

Existing pond bottom elevations are the result of decades of subsidence. Subsidence occurs for two reasons: soil oxidation and groundwater withdrawal. Soil oxidation occurs when wetlands are isolated from tidal action and drained. As the soil dries, oxidation results in soil compaction. In ponds drained as part of ongoing salt production activities, soil oxidation may cause limited subsidence. However, most South Bay salt ponds are continuously flooded, so oxidation is probably not significant. Groundwater withdrawal, on the other hand, has caused considerable South Bay subsidence. Aquifer overdraft between 1912 and 1969 resulted in as much as 13 feet of subsidence, with increasing severity towards the south. The effect on salt ponds and adjacent land is readily visible from Mountain View to San Jose. Consequently, many salt ponds require sedimentation to create bottom elevations suitable for tidal marsh.

The closer existing pond bottom elevations are to that at which marsh plants begin to colonize (mean tide level [MTL] to mean high water [MHW]), the more rapidly colonization will occur after tidal action is restored. Where pond elevations are substantially lower than MTL, it will take considerable time for sedimentation to create suitable elevations. If shorter timeframes are desired, subsided ponds will need sediment augmentation with suitable fill, such as clean dredged sediment.

Based on our review, approximately 60 percent of the complex's pond bottom elevations are between MTL and MHW. In these ponds, plant colonization should occur quickly during restoration, assuming other necessary factors are present. Approximately 20 percent of the salt ponds have moderate subsidence and will take longer to restore to tidal marsh. The remaining 20 percent of the ponds have significantly subsided. Extending from Mountain View to San Jose, most of these ponds have bottom elevations well below

MTL. One pond—A3W in Sunnyvale—will require 7.9 feet of sediment to reach optimal tidal height (mean higher high water [MHHW]). For these ponds, existing elevations are far too low to support intertidal marsh vegetation. If these areas were opened to unrestricted tidal exchange, they would function as open Bay water for decades.

Surrounding Topography and Flood Control

Flooding from high tides is a fundamental risk for much of the Bay Area. Salt pond levees provide the primary flood protection for large amounts of South Bay property. Many (but not all) of these areas have no other means of flood control. Therefore, an important consideration when selecting which ponds to restore to tidal marsh will be the extent and cost of levee reconstruction.

Public agencies currently maintain 17 miles of flood control levees within the salt pond complex. In contrast, Cargill maintains 201 miles of levees, 21 miles of which separate salt ponds from adjacent uplands. If the upland edge is sufficiently high, flooding is not a major concern, although erosion and related issues must still be addressed. If the upland edge is not high enough to protect adjacent land from flooding, a properly engineered flood control levee must be strengthening or constructed. Salt pond levees, particularly the internal berms, were not designed for flood protection, so full reconstruction often will be needed to meet current seismic safety and flood control standards. Conversion of these levees entails more than raising levee height and will be costly.

Based on review of existing levees, about 21 miles of interior pond levees must be converted to flood control levees. Ideally, the restoration plan will create the maximum acreage of restored tidal marsh at a minimum cost for levee reconstruction. For example, Newark #2 Ponds 1, 2, and 3 (located between Mowry Slough and Coyote Creek) could be restored to tidal marsh by constructing a small flood control levee between Ponds 3 and 6. In this instance, a single half-mile levee would yield 1,500 acres of restored marsh. Additionally, techniques to better integrate these new levees into the surrounding landscape—such as building levees with gentler slopes and using native vegetation for erosion control—should be adopted, rather than the traditional engineering approach of steep levee slopes with rock or concrete rubble rip rap for shoreline protection.

Infrastructure Impediments

Existing infrastructure can pose a barrier to wetland restoration. Examples of infrastructure impediments include overhead utilities, above- and below-ground pipelines, rail crossings, roads and bridges, structures, and flood control facilities. To develop cost-effective restoration strategies, comprehensive infrastructure information is needed. Unfortunately, research on existing infrastructure is complicated by the large number of entities with potentially pertinent facilities, the various formats used to store relevant information, and the lack of a centralized database of such information. While our research identified many infrastructure impediments, we also determined that a number of other facilities may exist, but were not investigated. These facilities include storm drain systems, petroleum pipelines, and fiber optic cables.

Infrastructure impediments within the salt pond complex must be addressed during restoration planning. Several types of structures could increase restoration costs. Electrical towers generally require vehicular access, concrete footings, and minimum line-sag clearance. As a result of restoration, some towers must be raised because their concrete footings lie below the increased water level or they no longer provide minimum sag line clearance from the ground or water surface. The solution in both cases is to increase the height of the tower's concrete footings. Another type of structure that will increase restoration costs is underground utilities that cannot be abandoned but that lie at elevations that interfere with unrestricted tidal exchange. Road and rail crossings, as well as flood control facilities, can also limit or interfere with tidal exchange. In addition, several structures that may qualify for historic preservation are located within the pond complex. For these reasons, strategies to accommodate infrastructure impediments can be difficult to design and costly to build.

Environmental Chemistry

Salt production over the past century has affected water quality and sediment chemistry within the South Bay salt ponds. Restoration efforts will be constrained by these factors. For example, in the North Bay salt ponds, insufficient water inflows decreased sediment pH (i.e., acidified the sediments) and made ponds inhospitable for plant colonization. Similar issues could pose a problem for the South Bay salt ponds.

Water Quality

As brine passes through the salt pond system, it becomes concentrated and increasingly saline. Exact salinity levels at a given pond vary seasonally and annually due to climatic and operational conditions, affecting pond water quality characteristics such as ionic imbalance, suspended solids, nutrient concentrations, temperature, dissolved oxygen, and acidity. These characteristics affect the ponds' habitat value, but should be transitory conditions once tidal flow resumes.

The water quality impacts most directly related to salt production are salinity and ionic imbalance. As brine evaporates, precipitation removes ions from solution and alters the ionic balance. The resulting ionic imbalance may be toxic to fish. As salinity increases in subsequent ponds, different biotic communities establish themselves. For instance, water boatmen (*Trichochorixa reticulata*) are found at low to moderate salinity levels, and brine shrimp (*Artemia franciscana*) are found in ponds with higher salinity. Populations die off when salinity increases above the suitable range. For instance, brine shrimp die-offs occur when salinity exceeds 200 parts per thousand, resulting in potential odor problems. In general, as salinity increases, habitat value decreases.

Pond Sediments and Gypsum

Salt production has also altered the chemistry of pond sediments, although in some cases for the better. Contaminant levels in evaporator pond sediments are expected to be lower than those found in surrounding tidal marshes. While suspended sediments are a transport mechanism for many contaminants, including mercury, polychlorinated biphenyls (PCBs), and dichloral diphenyl dichloroethane (DDT), two factors suggest that contaminant accumulation within the salt ponds is less than that of surrounding marsh soils. First, detention times are relatively long in each pond (e.g., weeks or months). This water management regime minimizes the import of suspended solids into the salt ponds. Second, biomass growth in the intake ponds can be relatively high. Macroalgae growth and subsequent settling may increase the sediment organic content and essentially dilute the contaminants in these soils. For these reasons, sediment contamination in the salt ponds is presumably lower than in adjacent marshes.

Crystallizer pond sediments, in contrast, are typically altered for the worse. In these ponds, approximately 95 percent of sodium ions and 80 percent of chlorine ions precipitate from solution. Therefore, pond sediments will be hypersaline. Even after flushing, residual salts are left behind in the sediments.

Another ramification of salt production is the formation of calcium sulfate (gypsum) on pond bottoms. The presence of gypsum may pose a challenge during restoration because it can form a hard, relatively insoluble layer on pond bottoms. This layer inhibits tidal channel formation, sediment redistribution, and plant colonization. Gypsum impacts approximately 6,300 acres or 24 percent of the salt pond complex. It will hinder establishment of tidal marsh in one 310-acre pond (Baumberg 8A) and could hinder marsh establishment in another 2,140 acres of ponds scattered throughout the complex.

Before restoration can occur, ponds with hypersaline brines and sediments must be flushed. This flushing will also help dissolve accumulated gypsum. In lower salinity ponds, dissolution is not generally an issue because gypsum remains in solution. In higher salinity ponds, gypsum precipitates from solution and dissolution probably will be necessary. Gypsum dissolution depends on five factors: (1) the amount of gypsum in the sediments; (2) the volume of water exchanged over time; (3) the surface flow velocity; (4) the pond's water chemistry, including salinity and trace metal concentrations; and (5) the inundation period. Of the first four factors, salinity and water velocity are the most important. Gypsum dissolves rapidly at low salinity levels and high water velocities (above 0.5 meters per second) if ponds are permanently inundated. Under these optimal conditions, gypsum in the pond complex could be dissolved in as little as four months. Intermittent inundation dramatically extends gypsum dissolution time by a factor of ten. High salinity levels and low water velocities further extend gypsum dissolution times.

The extent to which gypsum can impede tidal marsh restoration is largely a function of pond elevation. In lower elevation ponds in which significant accretion is needed (about 60 percent of ponds affected by gypsum) Bay sediment will bury the gypsum layer. In these ponds, the presence of gypsum will have a negligible effect on restoration efforts. In mid- to high-elevation ponds where elevations are closer to targeted levels, gypsum may persist for years, especially in ponds with a consolidated gypsum layer. In these ponds (about 40 percent of ponds affected by gypsum), gypsum could hinder tidal channel formation, sediment redistribution, and plant colonization, slowing marsh restoration and recovery. For these ponds, rapid flushing with freshwater in a manner that maintains pond inundation will be imperative to quickly remove this constraint and enhance marsh restoration.

Restoration Feasibility and Costs

Based on existing conditions found in the South Bay salt ponds, we ranked ponds by their relative ease of restoration and determined rough costs for tidal wetland restoration. As shown on Map 2 (located inside the back cover), we classified each South Bay salt pond into one of three categories of tidal marsh restoration feasibility: high, medium, and low. (We had insufficient data to classify 1,830 acres of ponds located primarily in the Newark #2 Plant.) Our classifications reflect a cost-benefit analysis between the money that must be spent to restore a given pond to tidal action and the ecological gains achieved.

Restoration Feasibility

Restoration feasibility varies from pond to pond and depends on many site-specific factors. Factors we considered include the pond's ecological characteristics, its restoration constraints, and major structural elements. We also considered the ecological benefits and costs incurred by individually restoring ponds to tidal marsh or by combining contiguous ponds for restoration as a large tract. (In cases where it is easier to restore ponds in conjunction with adjacent ones, our feasibility ranking is based on joint restoration.) Due to the large number of feasibility criteria, ponds within a single classification do not necessarily share identical reasons for their classification.

High Feasibility Ponds

A high feasibility pond requires minimal work to restore it to tidal marsh and provides considerable ecological benefits. Because pond bottom elevations are relatively high, marsh vegetation will quickly establish itself. A tidal source is readily available, and antecedent channels remain intact. The pond also lies in proximity to existing marsh and its restoration will aid endangered species recovery efforts. All that is required for tidal marsh restoration in high feasibility ponds is modest levee alterations, closure of borrow ditches, and—if outboard marsh is present—excavation of a pilot channel before breaching the levee. These ponds have the highest likelihood of meeting our ecological goals in a cost-effective and rapid manner.

Restoring low feasibility ponds to habitats other than tidal marsh will reduce overall restoration costs and provide a range of interconnected habitats, optimizing benefits for all species. . .

Our application of these criteria to the South Bay salt ponds yielded a total of eight ponds representing 2,690 acres—only 10 percent of the salt pond complex (see green ponds on Map 2). These ponds, due to their lack of restoration constraints, will provide the quickest habitat. Acquisition of as many high feasibility ponds as possible will reduce overall restoration costs by shrinking the average cost per acre for tidal marsh restoration and lowering interim maintenance costs.

Medium Feasibility Ponds

A medium feasibility pond requires a moderate amount of work to restore it to tidal marsh. Restoration criteria for these ponds lie between those for high feasibility and low feasibility ponds and yield a total of 49 ponds representing 13,240 acres. Fifty-one percent of the salt pond ponds within the South Bay complex fall into this category (see yellow ponds and green/yellow striped ponds on Map 2). These ponds can be restored to tidal marsh, but require more time, effort, and cost than high feasibility ponds.

Low Feasibility Ponds

A low feasibility pond requires considerable work to restore it to tidal marsh. These ponds typically face one or more constraints: the need for new flood control levees; severe subsidence; infrastructure that interferes with unrestricted tidal exchange; and residual high salinities in pond sediments. Subsided ponds could be restored to intertidal elevations by natural sedimentation, which is time-consuming, or through the reuse of dredged sediment, which would speed the process but is very costly.

These criteria define a total of 40 evaporator ponds and all crystallizer ponds. Their total area is 8,430 acres—32 percent of the salt pond complex (see blue ponds and yellow/blue striped ponds on Map 2). These ponds have the lowest likelihood of meeting ecological goals in a timely, sustainable, and cost-effective manner. Because these ponds will be difficult to restore to tidal marsh, we recommend using them for other types of habitat such as managed open water ponds and salt pannes (flat, unvegetated, hypersaline areas with seasonal ponds).

The **Spartina alterniflora** *Constraint*

Smooth cordgrass (*Spartina alterniflora*) presents a major challenge to quick and cost-effective tidal marsh restoration. Several ponds located on the East Bay shoreline between the San Mateo and Dumbarton Bridges are in close proximity to existing tidal marshes that have been invaded by *S. alterniflora*. For this reason, we downgraded the restoration feasibility classification for 3,420 acres of ponds. Of this total, 79 percent would have been classified as high feasibility if *S. alterniflora* were not present. Absent this constraint, the high feasibility acreage would increase by 2,690 acres (an additional 10 percent of the salt pond complex).

Restoration Costs

Because not every salt pond will be restored to tidal marsh, resource agencies have the flexibility to select restoration scenarios that optimize habitat benefits while minimizing restoration costs. Restoring low feasibility ponds to habitats other than tidal marsh will reduce overall restoration costs and provide a range of interconnected habitats, optimizing benefits for all species. Given the difficulty and high cost of restoring deeply subsided evaporator ponds to tidal marsh, these ponds make excellent candidates for managed open water ponds and microtidal lagoons, decreasing overall restoration costs and providing valuable habitat for waterfowl and shorebirds. Crystallizer ponds can be quickly converted to salt panne habitat suitable for shorebirds, especially the threatened Western snowy plover, which will further reduce restoration costs for the salt pond complex. Phasing restoration over time will optimize habitat benefits for a variety of species.

Applying this rationale to the proposed acquisition area, we developed a restoration framework as well as rough costs associated with that framework. The South Bay salt ponds included in the acquisition area total 13,610 acres. Because 4,696 acres of low feasibility ponds are scattered throughout this area, we determined that retention of these ponds for management as open water areas was the most cost-effective option. This left 1,170 acres of high feasibility ponds and 7,744 acres of medium feasibility ponds, for a total of 8,914 acres, to restore to tidal marsh. Dividing the acquisition area in this manner complies with the recommendations of the *Baylands Ecosystem Habitat Goals Report* to restore only 60 percent of the salt ponds to tidal marsh and satisfies half of the report's restoration objectives for the South Bay.

Our next step was to develop rough restoration costs for the South Bay salt pond acquisition area within the context of our restoration framework. The total cost of restoring all or a portion of the pond complex involves several components. These components include: restoration planning, operations and maintenance during the planning period, restoration construction, interim operations and maintenance for ponds restored to tidal marsh, permanent operations and maintenance for ponds retained as open water, and monitoring. Based on our restoration classification for each pond, we developed the rough cost estimates outlined below.

Restoration Planning Costs

We assumed a budget of $10 million for restoration planning activities, to be used over a five-year planning period.

Operations and Maintenance Costs during the Planning Period

We calculated operation and maintenance (O&M) costs for the proposed acquisition area. We estimate it will require an annual O&M budget ranging between $3.8 and $9.1 million, or $278 to $670 per acre to desalinate the system, maintain low salinity levels, and prevent degradation of the system's ecological functions. These figures are consistent with the California Department of Fish and Game's estimated O&M costs of $286 per acre for the North Bay salt ponds. (See the "Lessons Learned" chapter for more details.) For the five-year planning period, total O&M costs will range between $19 and $46 million.

. . . Dividing the acquisition area in this manner complies with the recommendations of the Baylands Ecosystem Habitat Goals Report to restore only 60 percent of the salt ponds to tidal marsh and satisfies half of the report's restoration objectives for the South Bay.

Tidal Wetland Construction Costs

To help determine tidal wetland construction costs, we developed two marsh restoration case studies. The first case study involves a group of high feasibility ponds. The second case study examines tidal marsh restoration of a group of deeply subsided medium feasibility and low feasibility ponds.

Based on the case studies, we determined rough costs for tidal wetland creation in the South Bay salt ponds. Estimates for restoring high feasibility ponds range between $1,060 and $1,265 per acre.

In contrast, estimates for restoring medium feasibility and low feasibility ponds to tidal marsh range between $4,900 and $90,445 per acre. Subsided ponds at the low end of this cost range rely on natural sedimentation (explained later in this report) to raise pond bottoms to intertidal marsh elevations suitable for plant colonization. While this approach is cheaper, it could take 100 years to obtain a fully functioning tidal marsh. The use of clean dredged sediment to overcome pond subsidence (explained later in this report) accelerates the restoration process, but significantly increases restoration costs toward the upper end of this range.

Interim Operations and Maintenance for Ponds Restored to Tidal Marsh

High and medium feasibility ponds restored to tidal marsh will require O&M funds for the interim period prior to their restoration. Once restoration implementation begins, these ponds will incur decreasing O&M costs until marsh vegetation is sufficiently established to prevent levee erosion. Because these costs will eventually decline to zero, we cut our estimated O&M costs in half. Therefore, we estimate it will cost $139 to $335 per acre each year to maintain these ponds. Assuming a 15-year restoration implementation period, this will result in a total cost ranging between $19 and 45 million.

Permanent Operations and Maintenance for Ponds Retained as Open Water

Although low feasibility ponds retained as shallow open water habitats do not require restoration construction funding, they will require permanent O&M funding to cover water control infrastructure, salinity management, and levee maintenance. These costs will remain steady over time at an annual rate of $278 to $670 per acre. For the 15-year restoration implementation period, total O&M costs for these ponds will range between $20 and $47 million.

Based on a 20-year timeline, we estimate total restoration costs for the proposed acquisition area to be in the range of $148 to $228 million.

Monitoring

We assumed an annual cost of $2 million for monitoring, to be used over the 5-year planning period as well as the 15-year restoration implementation period. This will result in a total cost of $40 million spread out over 20 years.

Estimated Total Restoration Costs for the Proposed Acquisition Area

Based on the rough cost estimates provided above, we calculated the total restoration costs for the proposed acquisition area. Based on a 20-year timeline, we estimate total restoration costs for the proposed acquisition area to be in the range of $148 to $228 million. This figure does not include a contingency fee or the acquisition costs of approximately $100 million.

Restoration Opportunities

Although numerous opportunities exist, the primary opportunity in restoring the South Bay salt ponds is the area's large size. By acquiring an area ranging from 15,500 to 18,000 acres, resource agencies can evaluate the "big picture" and make habitat decisions on a regional rather than a local scale. This should ensure more cost-effective restoration approaches. Additionally, tradeoffs between habitat types should be easier to make because there will be significantly more habitat for all species.

Another significant opportunity is the chance to dramatically increase the amount of special status species habitat in the South Bay. Increasing habitat for these species provides the best chance for their recovery. Habitat features critical to species survival during extreme high tides or other seasonal fluctuations can also be created.

Additionally, creation of large blocks of tidal marsh provides habitat continuity and facilitates species colonization of what are now isolated habitat islands. Connecting these areas to form contiguous habitat will result in larger populations of special status species due to higher recruitment among young adults seeking new territories. Contiguous habitat also protects wildlife from upland-based predators such as the red fox. Combining ponds to create large tracts of tidal marsh is also desirable because it reduces construction costs and allows restoration of ponds that are difficult to restore as stand-alone ponds.

Other significant biological opportunities include:

- Enhancing existing salt pond habitat through water level management, predator and vegetation control, and creation of artificial islands within the ponds. These enhancements will benefit both special status wildlife and wintering birds.
- Converting crystallizer ponds to salt pannes suitable for shorebird habitat, especially the threatened Western snowy plover. Because they need relatively little modification, these ponds provide quick and cost-effective habitat.
- Connecting tidal marsh to adjacent habitats to create ecologically valuable ecotones. The ability to provide a range of interconnected habitats is stressed in the *Baylands Ecosystem Habitat Goals Report.*
- Buffering sensitive wildlife and plant populations from urban development, human encroachment, and predators. Larger blocks of habitat will help do this, as will creation of buffer and transitional zones along the upland edge. Attention must be paid to this issue when identifying public access locations and restricted areas for wildlife viewing.
- Upgrading existing infrastructure and maintenance access for facilities such as PG&E towers, roadways, and flood-control channels. Replacing traditional methods with more ecologically sensitive practices will reduce wildlife disturbance.
- Monitoring existing and restored habitats over a long period of time to refine management goals and further define species habitat requirements. Monitoring during early phases of restoration implementation will identify the most successful restoration measures.

Since most baylands in the San Francisco Estuary have been diked and drained, resource agencies typically do not have the advantage of utilizing antecedent channels when restoring tidal wetlands. In a restoration scenario that allows natural sedimentation to raise subsided ponds back to tidal marsh elevation, antecedent channels will exert a strong influence on channel network formation. Even when several feet of sedimentation are needed, channel networks persist as the pond bottom rises, imprinting themselves into the restored marsh's geomorphology and enhancing wetland restoration. These benefits will not occur if fill is used to augment the sediment deficit because antecedent channels will be lost.

The primary opportunity in restoring the South Bay salt ponds is the area's large size.

Lastly, the San Jose/Santa Clara Water Pollution Control Plant (SCWPCP) pumps large quantities of effluent into the South San Francisco Bay. This daily source of freshwater did not exist historically and has converted extensive tracts of salt marsh in the Bay's southern reaches to tidal brackish and tidal freshwater marsh.

Using SCWPCP effluent to desalinate decommissioned ponds and dilute hypersaline brines and bittern will improve water quality, lower effluent levels, and provide a ready source of freshwater without tapping into municipal supplies. Wastewater discharges also originate from the cities of Sunnyvale and Palo Alto. Although smaller in volume than the SCWPCP discharge, these flows also could prove useful in pond desalination and bittern dilution along the western shoreline.

Restoration Challenges

Restoring the South Bay salt ponds to tidal marsh and related habitats will be an enormous and complicated undertaking requiring careful planning and adequate funds. While the acquisition area's large size presents an enormous opportunity, it also presents a challenge: overlapping governmental and regulatory jurisdictions, including cities, counties, flood control districts, and state and federal entities. Stakeholder involvement in the restoration process will require long review periods and much compromise. However, the opportunity to focus people's attention on South Bay ecology will clarify community needs and emphasize the value of our natural resources. By protecting and enhancing these resources, the community helps ensure the health of an ecologically rich and diverse region.

Several important constraints to salt pond restoration exist: the dependence of shorebirds and waterfowl on existing salt pond habitat; subsidence and the resulting sediment deficit; flood control issues; the presence of a gypsum layer (particularly in higher elevation ponds); pond desalination; the presence of freshwater discharges from wastewater treatment plants; bittern disposal; and the proximity to sites invaded by *Spartina alterniflora*. The following sections discuss the most serious challenges to salt pond restoration and various approaches to overcoming them.

Subsidence and the Resulting Sediment Deficit

A fully functioning tidal marsh typically occurs in the MHW to MHHW elevation range. Yet subsidence below these elevations is typical of South Bay salt ponds, hindering restoration because marsh plants cannot colonize until pond elevations reach MTL. Successful restoration efforts will need to overcome this constraint without destroying existing biological resources. Of particular concern is the potential destruction of existing mudflats caused by regional shifts in sediment deposition. The resulting decrease in available habitat must be avoided if we are to achieve our ecological goals.

> ***Roughly 88 million cubic yards (±10 to 20 percent) of sediment would be needed to return ponds in the acquisition area to optimal tidal height. . . .***

Estimating the Sediment Deficit

Restoring large areas of the South Bay to tidal action will significantly alter local sediment dynamics—the erosion, transport, and deposition of sediments. An understanding of these dynamics is necessary to evaluate options for resolving the sediment deficit found in the South Bay salt ponds because these processes determine the size and elevation of deep-water channels, mudflats, and tidal wetlands. They also determine the amount of sediment potentially available to restore subsided baylands. This in turn affects the timeframe in which natural processes can restore baylands to the critical elevations for vegetative colonization.

The South Bay consists of shallow tidal flats with a large deep-water channel (see Map 1). Sediment is deposited on these flats from external and internal sources, known as the “sediment supply.” External inputs come from the Sacramento-San Joaquin Delta, San Pablo Bay, and local watersheds. Internal supply consists of resuspended sediments.

The Sacramento-San Joaquin Delta provides 80 to 90 percent of the Estuary’s total sediment load, transporting sediment from the Sacramento and San Joaquin Valleys to the Bay. The Sacramento River supplies most of this sediment. Local watersheds, including creeks and rivers, contribute the remaining 10 to 20 percent of the sediment load. Most sediment enters the Estuary during winter and early spring, the periods of maximum freshwater flows.

Despite the Delta’s prominent role in providing sediment to the Estuary as a whole, its role in sediment supply to the South Bay is less certain. Studies suggest that the South Bay’s primary sediment supply is local watersheds, *not* the Delta. Whereas historic levels of sediment flow from the Delta have significantly decreased as a result of upstream dam construction and other diversions, such structures are not prominent features in the South Bay watershed. For this reason, South Bay sediment supply may not have decreased significantly from historic levels. Since 1955, South Bay sediment has accumulated at an average rate of 0.89 million cubic meters per year.

While a relatively small amount of new sediment enters the South Bay annually, a great volume of sediment is continually resuspended and redeposited. Resuspension of South Bay sediment occurs when tidal flow velocities high enough to overcome the sediment’s resistance to erosion. Four mechanisms contribute to such flow velocities: tidal currents, winds, freshwater inflows, and salinity-induced density differences. Tidal currents and winds contribute more to South Bay sediment resuspension than the other two factors.

We estimated the sediment deficit for the South Bay salt ponds based on marsh elevations of MHHW. We found that roughly 88 million cubic yards (±10 to 20 percent) of sediment would be needed to return ponds in the acquisition area to optimal tidal height. If the entire pond complex were raised to these elevations, over 100 million cubic yards are needed. In general, the ponds Cargill is offering to sell have the greatest sediment deficit. These ponds constitute 83 percent of the total sediment deficit even though they represent only 61 percent of the pond area.

Our sediment deficit estimate does not account for sea level rise, which has varied between 0.8 and 2.1 millimeters per year along the Pacific Coast. Near San Francisco, current sea level rise is estimated at 1.3 millimeters per year, but a recent review of global climate change has increased predicted sea level rise to 3.0 feet over the next century, or roughly 10 millimeters per year. If these predictions hold true, our estimated sediment deficit estimate is far too low.

This sediment deficit represents the most significant constraint to wetland restoration in the South Bay. Severely subsided ponds are some of the most difficult to restore. They also take the longest time to restore. A comparison of the current sediment deposit rate (0.89 million cubic meters/year) with the estimated sediment deficit (88 million cubic yards) illustrates the magnitude of the problem. It will take decades to rectify a sediment deficit this large, and future sea level rise will exacerbate the problem. For this reason, we recommend that resource agencies retain many of the severely subsided ponds as managed ponds to simplify the restoration process.

There are three possible approaches to restoring tidal marsh elevations: relying on natural sedimentation, importing dredged sediment, or retaining the most subsided ponds as managed open water habitat. We discuss each approach in the following three sections.

Natural Sedimentation

The primary issue with natural sedimentation is whether the approach will sustain mudflats at their current elevation or cause them to erode. Tidal currents and the Bay's bathymetry (depth and topography) determine how sediment is transported and distributed. These natural processes continually resuspend and redistribute sediment on the mudflats, but create a bathymetric equilibrium that sustains mudflats at their current elevations.

If tidal marsh restoration in the South Bay salt ponds were implemented too quickly (i.e., sediment demand exceeded net sediment input), sediments would be transported and eventually deposited on the deeper areas awaiting restoration rather than on the shallower mudflats, effectively disrupting the equilibrium. The subsided salt ponds would act as a "sink" for the suspended sediments, preventing them from redepositing on the mudflats. Over time, the existing mudflats would erode.

If all South Bay salt ponds were opened to the tides immediately, the ponds would reach intertidal marsh elevation in 15 to 50 years. However, a massive redistribution of sediments from existing mudflats to the salt ponds would occur, effectively scouring the mudflats of their sediment and causing tremendous loss of mudflat habitat for shorebirds and waterfowl. This impact of the natural sedimentation approach can be avoided by phasing restoration efforts over time. Phasing restoration in this manner will balance sediment demand created by the restoration effort with the available South Bay sediment supply. Assuming that sediment supply is adequate and restoration is phased slowly enough to avoid mudflat scour, our research indicates it will take 100 to 150 years to raise pond elevations to MHHW.

> ***. . . This sediment deficit represents the most significant constraint to wetland restoration in the South Bay.***

Dredged Sediment Importation

The second approach for restoring subsided salt ponds to tidal marsh elevations is the use of imported dredged sediment. Dredged sediment has been used in several Bay Area tidal marsh restoration projects: Pond 3 in Hayward, Faber Tract in Palo Alto, Muzzi Marsh in Corte Madera, and Sonoma Baylands. Use of dredged sediment shortens the restoration timeframe without causing mudflat erosion. When dredged sediment is used to enhance salt pond restoration, the timeframe depends on two factors: the time needed to obtain and place the dredged sediment in the ponds, and the time required for natural sedimentation to provide the final one to two feet of tidal substrate. Assuming typical time periods for these two factors, our research indicates use of dredged sediment would shorten the salt pond restoration timeframe to 45 to 60 years. Shorter restoration timeframes will significantly reduce interim pond maintenance costs.

The primary issues associated with the imported material approach involve economics, logistics, and practicality. Use of dredged sediment is contingent on several factors:

- Availability of sufficient quantities of suitable material.
- Loss of antecedent channels unless costly preservation measures are taken.

- Movement and placement of dredged sediment.
- Cost of obtaining dredged sediment when compared to natural sedimentation.

Each of these factors presents significant drawbacks to this approach. While import of dredged sediment can accelerate the restoration process, there is a high price associated with this speed. Rough cost estimates for importing dredged sediment to restore the entire salt pond complex to intertidal marsh elevations range from $660 million to over $1 billion. For this reason, dredged sediment reuse must be applied sparingly.

Retention as Managed Ponds

For many of the deeply subsided ponds in the South Bay complex, the best approach may not involve natural sedimentation or dredged sediment importation. It is possible to retain most or all of these ponds as managed open water areas. If these ponds are managed as non-tidal or micro-tidal wetlands with flexible water levels and salinity, they will provide valuable habitat for salt marsh harvest mice, Western snowy plover and other shorebirds, and waterfowl.

Retaining most or all of the deeply subsided ponds as managed open water areas will significantly reduce the sediment deficit. While these ponds constitute 21 percent of the salt pond complex, they account for over half the estimated sediment deficit. However, retaining subsided ponds as managed open water and wetland areas presents two drawbacks. First, the flood control levees and water control structures for these ponds must be permanently maintained. Because these ponds are deeply subsided, their levees are presumably the tallest, and therefore the most difficult and costly to maintain. These levees will also be more prone to failure during catastrophic events such as earthquakes and intense storms. Sufficient funds must be allocated to cover these costs in perpetuity.

Second, the ecological goals stated in reports such as the *Baylands Ecosystem Habitat Goals Report* envision a relatively uniform distribution of tidal marsh and managed open water habitats throughout the South Bay. However, the deeply subsided ponds are clustered together from San Jose to Mountain View. Furthermore, these ponds tend to border the Bay, so retaining all of them as open water ponds precludes creation of a continuous band of tidal marsh around the shoreline. This problem can be remedied by dividing some of the ponds to create narrow bands of bayfront tidal marsh contiguous with the large, open water areas.

Resource managers must determine which ponds are most appropriate for natural sedimentation, dredged sediment importation, or retention as managed open water ponds. We believe utilizing all three approaches in a balanced and deliberate manner will provide the most cost-effective and optimal solution to the sediment deficit problem.

Salt Pond Desalination

Decommissioning South Bay salt ponds will require careful planning. Nearly every pond will need water level and salinity management during the restoration planning and implementation period. Ponds retained as managed open water areas will need permanent management. In addition, many ponds will require desalination before restoration can occur.

Two questions are crucial to evaporator pond desalination: Which ponds require desalination? Are additional actions needed to deal with ionic imbalance? Salinity levels determine which ponds require desalination; low salinity ponds require little if any desalination. For moderate to high salinity ponds, desalination may be required, depending on the salinity discharge level authorized by the San Francisco Bay Regional Water Quality Control Board (RWQCB).

Ionic imbalance in the brine is caused by the precipitation of non-commercial salts such as gypsum. Ionic imbalances can vary in intensity; those associated with bittern are known to be toxic to aquatic organisms. It is not known whether less-severe ionic imbalances will pose toxicity concerns. The RWQCB will consider this issue when permitting brine discharge into South San Francisco Bay.

At its most fundamental level, the desalination process involves nothing more than repeatedly diluting large quantities of hypersaline brine with large volumes of freshwater (also called “flush water”). The greater the volume and speed of the flush water, the shorter the desalination period. Increasing desalination rates, however, may not increase restoration speed because other factors influence restoration rates. The most significant factor identified in this report is the sediment deficit, which could hinder restoration rates far more than pond desalination. For this reason, resource agencies must explore various approaches to overcome each restoration challenge and select solutions that work together to provide optimal results.

There are four steps in the desalination and brine disposal process for evaporator ponds: (1) removing high salinity brines from targeted ponds (desalination); (2) evaluating whether to use the brines in Cargill's salt production system or discharge it into the Bay; (3) if discharge is selected, obtaining authorization for Bay discharge; and (4) diluting brines to meet the authorized salinity threshold. Three strategies exist for this process: rapid desalination, desalination to optimize salt production, and desalination with Bay discharge. Each of these approaches will solve the desalination issue, but involve varying degrees of cooperation from and impacts to Cargill.

Rapid Desalination

This strategy flushes ponds rapidly to maximize desalination rates. Cargill accepts all brine into its salt production process, maximizing pond depths at all salinity levels to increase its capacity. This results in large decreases in salt production in the short-term, but eventually unusually high salt production rates occur. Cargill's interim operation and management responsibilities are minimized, placing a greater burden on the Refuge to manage ponds during this period.

Desalination to Optimize Salt Production

This strategy involves conducting pond desalination in conjunction with Cargill's salt production cycle. While Cargill continues to accept all brine into its salt production process, ponds are flushed at a rate that maintains optimal salt production. Upstream pond depths may exceed normal levels, and production efficiencies are reduced slightly in the short-term as less concentrated flush waters are introduced into the system. Cargill's interim operation and management responsibilities are likely to continue for two to five years, and its costs may increase due to a more complicated water transfer system. Ponds are also taken out of production more gradually than under Strategy 1, reducing the Refuge's burden for pond management during the interim period.

Desalination with Bay Discharge

This strategy is similar to the second strategy except that Cargill only accepts brine that exceeds the salinity discharge threshold. This strategy utilizes Bay discharges to minimize the amount of brine Cargill must accept. Ponds are flushed at a rate that maintains optimal salt production, and the discharge threshold maximizes benefits to Cargill while minimizing impacts to the Bay. Cargill's interim operation and management responsibilities are likely to continue for two to five years, and its costs may increase slightly. Ponds are taken out of production more gradually than under Strategy 1, reducing the Refuge's burden for pond management during the interim period.

Bittern Disposal

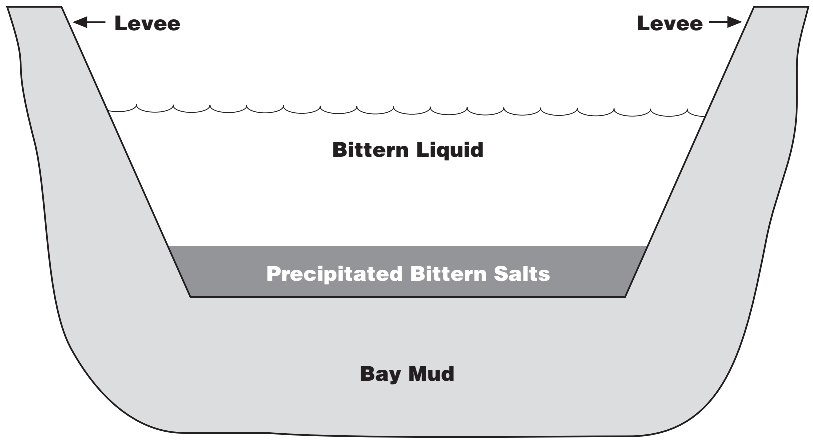
Bittern, the hypersaline byproduct of solar salt production, occurs as both a liquid and a solid. It is composed primarily of chloride, magnesium, sulfate, potassium, and bromide, plus any remaining sodium chloride that did not precipitate in the crystallizer ponds. Although it is composed of the same minerals found in Bay water, at the time it leaves the crystallizer ponds, bittern differs greatly from the original brine. The brine volume is reduced 97 to 98.4 percent, and salinity can reach 447 parts per thousand. Bittern's high salinity and ionic imbalance are toxic to aquatic species.

Because the byproduct has both a solid and a liquid phase, the term bittern is ambiguous and may not mean the same thing to all stakeholders. Figure 4 shows a cross-section of a bittern pond.

Addressing the bittern problem for the South Bay salt pond complex involves desalinating the bittern ponds so they can be restored, and disposing of the bittern and all flush water. In the short term, Cargill plans to transfer all Redwood City bittern to Newark, but it is not known where it will stockpile the additional bittern. In the long term, bittern disposal is more complex. Although Cargill estimates that the current bittern market equals the current bittern production rate, this estimate only applies to liquid bittern. As stockpiles of both liquid bittern and precipitated bittern salts accumulate in the bittern storage ponds, this excess must be disposed of in some way. If Cargill ceases salt production altogether in the Bay Area, the Refuge will be forced to deal with this problem unless Cargill has sold all the stockpiled bittern or disposed of it.

Although bittern ponds are more difficult to desalinate than evaporator ponds because of the

FIGURE 4. **Cross section of a bittern storage pond.**



accumulation of precipitated bittern salts, it is substantially the same process as the one described in the previous section. There are two methods for desalinating bittern ponds: the "push method" and the "pull method." Under both methods, bittern must be diluted at a ratio of 100:1 to allow Bay discharge without harmful effects. The basic difference between the two methods is the point in the process at which the bulk of this dilution takes place. In the push method, dilution occurs within the bittern pond as new water is pumped into the pond, and only limited dilution occurs in the dilution ponds. In the pull method, most dilution occurs in the dilution ponds; in later stages of removal, some dilution occurs in the bittern ponds. The dilution pond must be at least two times the size of the bittern pond to allow for proper dilution.

Each method has it advantages and disadvantages, although both will desalinate bittern ponds. Selecting which method to use will depend on a pond's specific characteristics, such as levee height and integrity, pump needs, and proximity to a slough channel or the Bay. It is important to note that the presence of precipitated salts in bittern ponds will greatly extend the desalination period, increase the water volume needed to flush the ponds, and produce hypersaline outflow brines for an extended period. In the bittern storage ponds, approximately one-third of the salts have precipitated from solution. Thus, these ponds require desalination to remove both liquid bittern and bittern salts, increasing desalination time. Bittern desalting ponds contain relatively small amounts of precipitated salts, minimizing their effect on desalination time.

Lessons Learned from the North Bay Salt Ponds

In 1994, the State of California purchased 10,000 acres of Cargill's North Bay salt pond complex on the northern shores of San Pablo Bay for $10 million. A 7,500-acre portion of the site contains ten salt evaporator and two bittern storage ponds. The remaining 2,500 acres contain tidal marsh and open water adjacent to the salt ponds. The California Department of Fish and Game (CDFG) now manages these lands and intends to restore them to a combination of tidal marsh and managed open water ponds.

The former North Bay salt ponds are similar to the South Bay salt ponds in that both contain large expanses of contiguous bayland habitat and both have a long history of salt production. The tidal wetlands and diked ponds located in the North Bay complex provide vital habitat for migrating and wintering waterfowl and shorebirds, as well as for resident species.

Three significant problems have plagued restoration in the North Bay salt ponds: (1) insufficient data and conflicting ecological goals for the site's restoration; (2) insufficient funds for interim maintenance and management of levees, water control structures, and salinity levels; and (3) presence of hypersaline brines and bittern. These problems have resulted in two serious consequences. First, the system's ecological functions have declined due to inadequate water pumping and management. Second, serious deterioration of the system's levees has occurred due to inadequate maintenance. These consequences have increased the risk of a catastrophic release of hypersaline brines and bittern into the Napa River and San Pablo Bay. As time passes, the risk of such releases increases.

A multi-agency effort has been underway for several years to plan the North Bay salt pond restoration. At the time of the purchase, insufficient data existed to develop restoration alternatives because state resource agencies could not identify antecedent channels, assess water quality effects, anticipate erosion, or quantify levee breach impacts. There was also significant controversy over tradeoffs between restoration of historic, tidal marsh habitats and preservation of existing salt pond habitats for shorebirds and waterfowl. Partially as a result of the *Baylands Ecosystem Habitat Goals Report,* consensus now exists that increased habitat for *all* species is essential and that an effective restoration strategy must be based on a hydrologic model. Efforts are underway to develop such a model.

Due to the long delay in restoration planning, the transitional period continues for the North Bay salt ponds. To date, management efforts have attempted to simply maintain the status quo. It has become increasingly apparent that no provision was made for adequate operation and maintenance (O&M) funds. Prior to purchase, Cargill's annual O&M budget for the North Bay salt ponds was approximately $500,000. In contrast, the state allocates approximately $60,000 annually for this purpose. This funding shortfall has critically hampered a broad range of O&M activities: water pumping and management; repair and replacement of water control structures; levee repair and maintenance; bittern management; and habitat enhancement. Although this problem has been partially mitigated by creative management strategies, alternative funding, and water management assistance from Cargill, it remains an issue that must be resolved before wetland restoration can occur.

After eight years of inadequate water management, the North Bay salt ponds have become increasingly saline and have begun to dry out for the first time since their construction. Approximately two to four tons of residual salts remain in the ponds, decreasing their habitat value for waterfowl and other species. To further complicate the situation, the acquisition agreement did not include a feasible bittern disposal or reuse plan. Unlike the proposed South Bay acquisition, Cargill did not remove or dispose of this material. As a result of these two issues, a large quantity of hypersaline brines and bittern remains in the ponds. The state resource agencies have developed a preliminary strategy to dilute these brines. Nonetheless, as the North Bay salt ponds continue to "make salt," salt accumulation continues and intensifies the disposal problem.

Several lessons can be learned from restoration efforts at the North Bay salt ponds and are directly applicable to restoration of the South Bay salt ponds. First—and most importantly—O&M funding must be made available immediately upon purchase and it must be sufficient to cover levee maintenance, water management, bittern removal, and other related costs. Tardy and inadequate O&M funding will compromise the short-term ecological value of the salt ponds; increase the risks of uncontrolled hypersaline releases and other catastrophic events; allow salt production to continue; increase the cost of water management; and complicate future restoration efforts.

Second, creation of detailed hydrologic models should be the first step in the restoration process. These models will provide important guidance on key issues such as restoring tidal action to ponds; minimizing risks associated with levee breaches; predicting salt transport; and assessing sedimentation needs.

Other lessons include:

- Consensus must exist among resource agencies and stakeholders on the ecological goals and the tradeoffs between habitat types before restoration can proceed.
- Special status species complicate restoration planning and increase restoration costs.
- The Reyes soils underlying most salt ponds are unsuitable for use as fill material because they provide poor conditions for upland vegetation.
- Per-acre restoration costs increase as salinity levels increase.
- Hypersaline brines and bittern ponds will be the most difficult and time-consuming to restore because of high residual salt concentrations.
- Disposal of hypersaline brines and bittern is a critical restoration component that will impact long-term restoration costs.
- Salt pond restoration is a complex and lengthy process requiring adaptive management.

Issues to Consider during Aquisition Negotiations

While it is critical that we publicly acquire a large block of the South Bay salt ponds as quickly as possible, it is also imperative that the public is protected by a sound acquisition agreement. As discussed earlier, the Don Edwards National Wildlife Refuge was established in 1979 after purchase of a block of salt ponds from Leslie Salt, Cargill's predecessor. Leslie retained mineral rights for salt production on these ponds, and the purchase agreement has not provided the level of resource protection desired by the Refuge. We should not repeat past mistakes. To help craft a sound acquisition agreement, decision makers must consider several issues during acquisition negotiations.

Prioritize pond acquisition to capture the best marsh restoration opportunities.

Based on our feasibility analysis, some of the best ponds for short-term tidal marsh restoration lie within the Newark #2 Plant, where Cargill plans to continue salt production. Others are located in the Redwood City Plant, near the western end of the Dumbarton Bridge (see Map 2). If state and federal acquisition focuses on ponds where restoration is most feasible, progress toward the goals stated in the *Baylands Ecosystem Habitat Goals Report* will be greatly advanced. The October 2000 acquisition proposal requires resource agencies to focus their tidal marsh restoration efforts on ponds in the Redwood City and Alviso Plants, where salinity, subsidence, and sediment deficit issues are more challenging.

Acquisition funding must be accompanied by funds for restoration planning as well as funds to maintain and operate the ponds while planning occurs.

Without restoration planning funds, restoration cannot take place. Given the size and complexity of the South Bay salt pond restoration effort, interim management of the ponds will be necessary. Detailed information on current operation and maintenance (O&M) costs—preferably from Cargill—is essential so that adequate funding can be provided for these functions as part of the acquisition. Without sufficient funds, proper interim management will not be possible, and restoration efforts will be hampered as they have been for the North Bay salt ponds. Adequate funds for restoration planning and O&M must be allocated if salt pond restoration is to succeed in the South Bay. Additional funding for the lengthy restoration effort must be available as well.

Agreement must be reached on how to dispose of hypersaline brines and bittern.

For ponds where salt production ceases, all concentrated brines and bittern (both liquid and solid) as well as other toxic contaminants must be removed as rapidly as possible. Wetland restoration cannot begin until this occurs. Agreement on the best way to capture and dilute hypersaline brines without causing damage to the Bay ecosystem is crucial.

It is our understanding that recent pond real estate appraisals make numerous assumptions regarding the level of cleanup required for habitat restoration. However, fewer assumptions mean less taxpayer risk. Therefore Cargill should commit to as much site cleanup as possible to minimize assumptions and potential taxpayer liability. The acquisition agreement should include careful evaluation of costs to remove toxic contamination and who will pay them.

For salt ponds not acquired in the proposed acquisition, ecological functions must be protected to the degree possible.

In many of the ponds Cargill intends to continue operating for salt production, salinity will increase above useful habitat levels. This will adversely affect birds and other species that have grown dependent on these ponds. Of particular concern is increased salinity in Mowry Ponds 1, 2, and 3 in the Newark #2 Plant. These low salinity ponds currently provide immense habitat value that will be lost as Cargill alters its pond operations to increase productivity. Additionally, increased pond water levels will reduce available levee habitat for nesting and roosting birds. Since it is not contemplated at this time to take the entire complex out of salt production, these adverse impacts to wildlife should be minimized or mitigated to the greatest extent possible.

Conclusion

After a century of degradation, tidal wetland restoration is a top priority for improving the health of San Francisco Bay, and one of the most promising restoration sites is the South Bay salt ponds. Acquisition and restoration of these ponds represents an important act of land stewardship that will benefit not only the Bay and its wildlife, but also future generations of Bay Area residents.

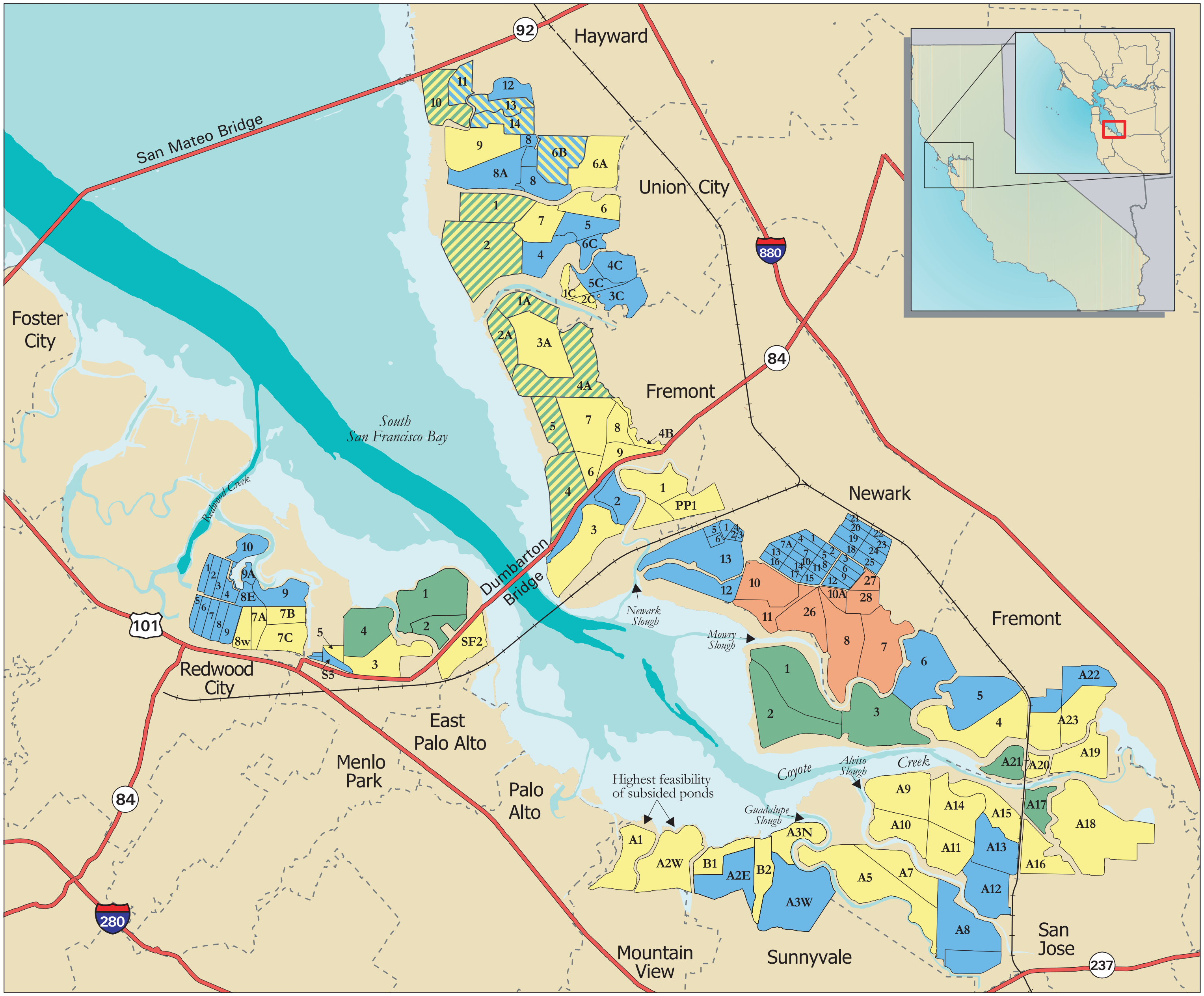
As we have shown in this report, all 26,190 acres of South Bay salt ponds are potentially restorable to a mix of tidal marsh, open water, and related habitats that will grant tremendous ecological benefits to the Estuary's fish, wildlife, and water quality. Restoration of these ponds will provide a significant portion of the minimum acreage scientists say the Estuary's fish and wildlife need. To reduce restoration costs and optimize habitat benefits for all species, we recommend restoring two-thirds of the pond complex to tidal marsh, phased over time. All high feasibility ponds and many moderate feasibility ponds can be restored to tidal marsh with relative ease. Deeply subsided evaporator ponds should be retained and managed as microtidal lagoons. Hypersaline crystallizer ponds can be converted to salt pannes for quick, cost-effective shorebird habitat. The challenges of comprehensive and integrated wetland restoration on a regional scale can be overcome with careful planning, sufficient resources, and patience.

Now is the time to turn salt into environmental gold for the San Francisco Estuary. Acquisition and restoration of the South Bay salt ponds is a unique, once-in-a-lifetime opportunity that is unparalleled in Bay Area history. In the midst of a densely urban area, we have a chance to restore estuary health, permanently protect open space, and recreate thriving, vital wildlife habitat. We need to seize this priceless opportunity and run with it. Our estuary deserves nothing less.

Why are the salt ponds different colors?

Salt pond colors reflect a complex interaction of plants, animals, and varying salinity.

- Low to mid-salinity ponds: Green algae creates the color.
- Moderate salinity ponds: Dunaliella algae proliferates and turns the ponds a lighter shade of green.
- High salinity ponds: High salt concentrations cause the Dunaliella to produce a red pigment. Halophilic bacteria contribute to the red and purplish-red hues. Millions of tiny brine shrimp in mid-salinity ponds add an orange cast.
- In choppy conditions, the colors appear murkier. Heavy rain can even turn the water clear.



MAP 2.
South San Francisco Bay Salt Ponds Ranked by Ease of Tidal Marsh Restoration

This map ranks salt ponds by their feasibility for tidal marsh restoration based on the following attributes: subsidence, tidal connection, flood hazard, infrastructure impediments, salinity levels, gypsum, and *Spartina alterniflora*. Ponds classified as low feasibility for tidal marsh restoration should be retained as managed open water ponds or other types of habitat.

Legend

- High feasibility for tidal marsh restoration (2,690 acres)
- Medium feasibility for tidal marsh restoration (10,550 acres)
- Low feasibility for tidal marsh restoration; good candidate for managed pond or other habitat (7,700 acres)
- Medium feasibility; increases to high feasibility without *Spartina alterniflora* constraint (2,690 acres)
- Low feasibility; increases to medium feasibility without *Spartina alterniflora* constraint (730 acres)
- Insufficient data to determine feasibility (1,830 acres)
- City boundaries
- Highways
- Railroad

0 1,000 2,000 4,000 Meters

0 1 2 4 Miles

Data Sources: EcoAtlas, Cargill, USGS
Map Projection: CA Stateplane III, NAD83
Map Version 1.5 | Produced on: 04/23/01

SAVE THE BAY

' Stuart Siegel, 2001
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