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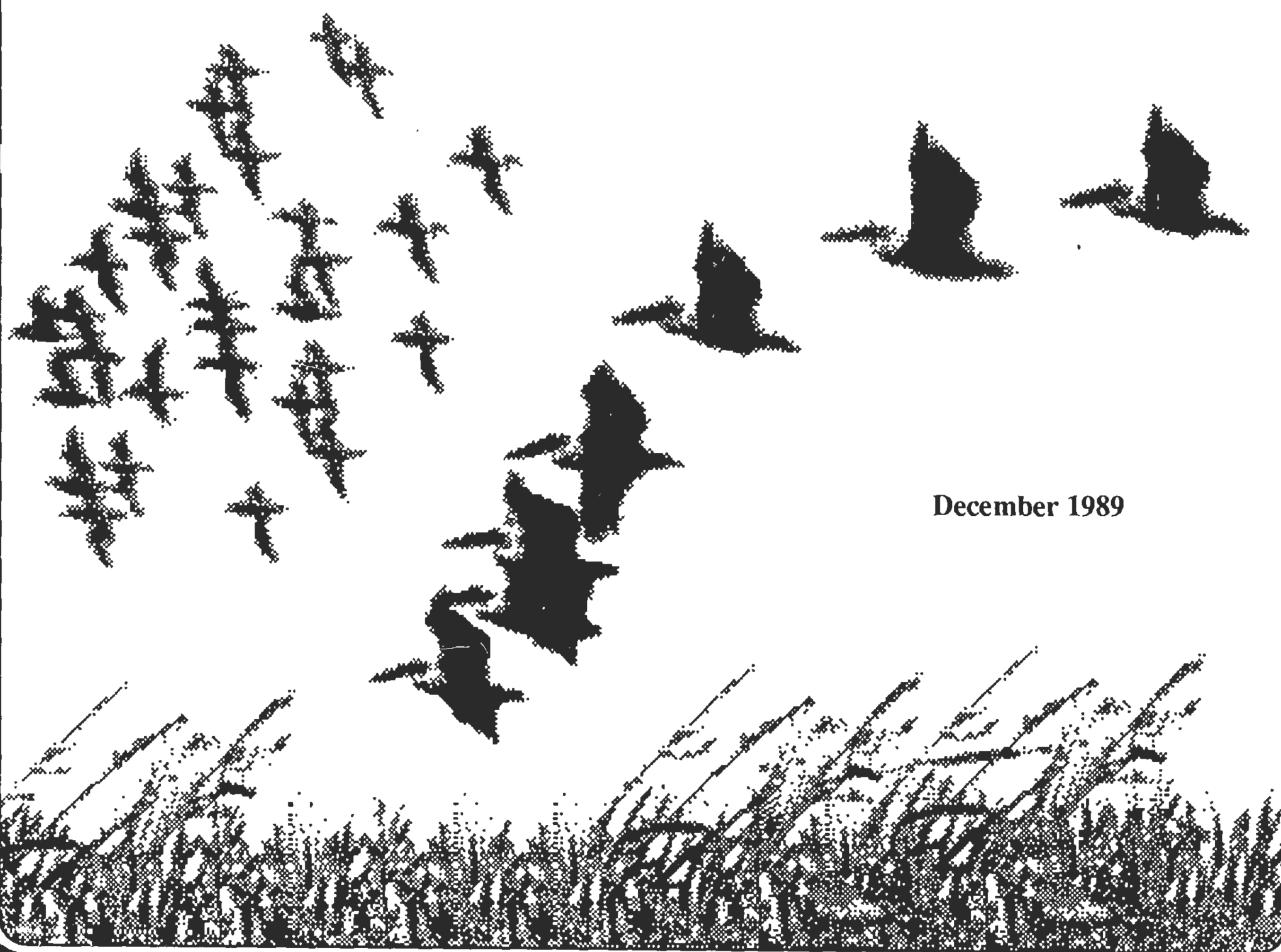
Environmental Research, Assessment and Planning

ELKHORN SLOUGH
WETLAND MANAGEMENT PLAN

Prepared for

California State Coastal Conservancy
&
Monterey County Planning Department



December 1989

Oblique aerial photo looking eastward from Moss Landing harbor mouth towards Elkhorn Slough Watershed.

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PREFACE

Elkhorn Slough is located at Moss Landing in North Monterey County and at the head of the Monterey Submarine Canyon (see Figure 1-1). Elkhorn Slough is the principal wetland complex in central California and called by the California Department of Fish and Game "one of the most ecologically important estuarine systems in California." Other connecting and adjacent slough systems to Elkhorn Slough include: Bennett, Parson's, Moro Cojo and McClusky Sloughs, the Old Salinas River Channel, and the salt pond complex. Wetland areas are environmentally sensitive habitat areas which contain varieties of plant and animal life and their habitats. These are especially rare or valuable due to their significant roles in ecosystems which can be (and in fact have, in North Monterey County been) disturbed or degraded by human activity and development. Wetland areas identified in the North County Coastal Land Use Plan (LUP) are the large sloughs and saltwater and freshwater marshes, each with different and changing degrees of salinity and each supporting unique communities of vegetation and wildlife. Wetlands provide feeding, resting and nursery areas for the many species of fish and wildlife that either reside in the area year-round or migrate through. Tidal flushing supplies nutrients and oxygen-rich water to support myriads of invertebrate animals that become food for fish, birds and mammals (some rare or endangered), and some ultimately supply humans with substantial important fishery resources. The marine habitat zone acts as a nursery for a variety of fish found in Monterey Bay, while the littoral zone (mudflats and marshes) provide organic matter, invertebrates and vegetation for food, breeding and nesting. The upland marine zone furnishes escape, resting, nesting and loafing cover for various estuarine birds. All three zones form the estuarine slough complex for which a restoration, and enhancement management program was recommended in the LUP.

The importance of Elkhorn Slough is demonstrated by its 1979 designation as an Estuarine Sanctuary pursuant to the provisions of the Federal Coastal Zone Management Act. Also, the Slough was identified by the California Department of Fish and Game as one of the nineteen wetlands requiring special protection. This special protection was qualified by the California Coastal Plan of 1976 designation as an environmentally sensitive habitat. Section 30240 of the Coastal Act provides a policy standard with which activities in and adjacent to environmentally sensitive habitats must comply:

<u>Section 30240</u>

(a) Environmentally sensitive habitat areas shall be protected against any significant disruption of habitat values, and only uses dependent on such resources shall be allowed within such areas.

(b) Development in areas adjacent to environmentally sensitive habitat areas and parks and recreation areas shall be sited and designed to prevent impacts which would significantly degrade such areas, and shall be compatible with the continuance of such habitat areas.

Further, the LUP, consistent with Section 30240 protects the slough complex with a "wetlands and coastal strand" land use designation which allows for low intensity recreational uses, research and education, and support facilities compatible with resource protection. The LUP establishes policies to protect, maintain, and where possible, enhance and restore. Policy 2.3.4 provides policy to prepare comprehensive wetland management plans. This management plan represents the first in a series of plans to enhance and restore the wetlands of Monterey County

A significant factor of importance concerning the Elkhorn Slough complex is its existence, as compared to over two-thirds of the coastal wetland in California which have been destroyed, primarily by filling. This, however, does not mean that the Elkhorn Slough complex has not been significantly altered. In fact, the historic, natural interface between the open, tidal waters and wetlands of North County has been systematically altered over the years by the construction of numerous levees or dikes, fills, the installation of structures, and the dredging of the harbor channel. These have served a number of positive or beneficial purposes, such as protecting agricultural lands, enabling aquaculture or waterfowl production to take place in otherwise inhospitable sites, and facilitating navigation and transportation. But they have also resulted in significant adverse environmental impacts, such as loss of valuable wetland and wildlife habitat. The enclosure of water bodies and marsh areas has also encouraged excessive production of mosquitoes, where such would have been previously less likely due to water circulation, and the presence of predatory fish. In many instances, land reclaimed for agriculture in this way has not proven to be of high value as farmland or pasture, due to resulting soil compaction and salinization.

The surface waters of the Slough complex have a variety of contemporary pollution problems that have resulted in degraded water quality. Land development, waste disposal, and agricultural practices contribute to the degraded water quality along with the presence of salts, heavy metals, and coliform bacteria. The Slough is also subject to sedimentation and erosion. Because of the above described conditions, the North County LUP contains Recommended Actions and Policies for the development of a comprehensive wetland management program. The following Elkhorn Slough Wetlands Management Plan sets forth an analysis of problems affecting the Slough and contains recommended actions for both the short-term and long-term. The Management Plan also provides wetland enhancement plans for five specific marsh areas and access to them.

Plan Preparation

In February, 1985 the Monterey County Board of Supervisors directed the Planning Department to begin preparation of a Wetland Management Plan for Elkhorn Slough. The County and the State Coastal Conservancy then agreed to joint-fund this important planning effort. The State Coastal Conservancy was created in 1978 as an implementation agency for the Coastal Act. As a primary mandate of its legislation, the Conservancy is responsible for planning and implementing habitat enhancement projects. State bond act provide funds for this program. In November of 1985, the County selected ABA Consultants to prepare the Management Plan. Technical review for the Management Plan was provided by the Elkhorn Slough Sanctuary Advisory Committee. Drafts of the Management Plan have been reviewed by numerous federal, state, and local agencies (see People and Agencies Contacted, pp.113-4).

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SUMMARY

Natural History of Elkhorn Slough

The natural history of Elkhorn Slough is divided into four major periods: Costanoan, Reclamation, Harbor and Enhancement Periods. Costanoan and other Indians probably had little effect on the slough, which was a shallow tributary of the Salinas and Pajaro Rivers for perhaps 3-5 thousand years before present. Freshwater runoff and springs had a strong influence on the slough, which was probably rarely brackish near its head. The shallow and probably clear water allowed a lush growth of eel grass almost as far as Kirby Park. Slough habitats and wildlife were first changed by human activities in the late 1880's during the Reclamation Period, when thousands of acres of wetlands were diked, ditched and drained to reclaim land primarily for agriculture. Over 90% of the coastal wetlands in the Monterey Bay area were lost during this period and Elkhorn Slough became an isolated survivor of a large historical complex of wetlands. The surviving wetlands harbored thousands of waterfowl and shorebirds instead of millions. The grizzly bear, wolf and tule elk were gone. Steelhead and salmon were no longer caught in the sloughs. There are no quantitative data on the habitat and wildlife changes caused by wetland reclamation, but they were probably the most significant ecological changes to local marshes caused by humans.

In 1947, the entrance to Moss Landing Harbor was opened at the mouth of the slough. The influence of freshwater was already markedly decreased by reclamation ditching and well pumping. Now the slough was exposed to daily tidal scour. Extensive mudflats were exposed in the slough for the first time in recorded history. The old mouth was less than 2 feet deep and only 2-5 feet deep in a narrow channel (15 feet wide). The entire mouth is now 25-30 feet deep and every major wetland habitat is being eroded at apparently high rates today. The once shallow, brackish river tributary is now a relatively deep-water tidal lagoon. While pickleweed was a dominant plant before the harbor opened and remains the dominant salt marsh plant, an abundant cover of brackish and freshwater plants was probably killed by the new salt water influence. Apparently the resulting turbidity destroyed almost all the previously extensive eel grass beds. A large variety and number of marine animals, which were largely restricted to the mouth of the slough before the harbor opened, now live throughout the slough. The tidal mudflats are major feeding grounds for many shorebirds. Marine and estuarine fishes also feed on the large numbers of benthic marine invertebrates. Dense clam beds cover the channel bottom and are the major prey of local sea otters.

In 1971, The Nature Conservancy purchased the first wetlands in Elkhorn Slough for conservation. This is the beginning of the Enhancement Period. Since then much of the slough's wetland and adjacent upland habitats have been acquired by public and private organizations and individuals for conservation purposes.

Erosion and Sedimentation

Two major erosional problems afflict the Elkhorn Slough watershed: the overall erosion of the marsh, and the erosion and subsequent deposition of soil from strawberry farms on the steep slopes surrounding the slough. The major environmental problem within the Elkhorn Slough is the erosion of marsh, mudflat and upland habitat since the construction of the harbor entrance at the mouth of the slough. This erosion is removing vegetated salt marsh, widening tidal creeks and channels, cutting back mudflats, undercutting upland habitat and dikes, and killing trees. The upland habitats and dikes near the mouth of the slough should be repaired at least temporarily. The erosion of all major slough habitats should be monitored to help determine future plans for erosion control within the slough. One area of important sedimentation into the slough is on several fans along the western pickleweed marsh. Agricultural runoff is eroding deep gullies along the steep uplands on the slough's west side.

The other major erosion problem in the Elkhorn Slough watershed is the loss of top soil from strawberry farms on steep slopes. The main environmental problem created by this erosion is the filling of freshwater wetlands above the slough. The main visual impacts of the erosion include large gullies and sediment deposits especially on roads. The Soil Conservation Service (SCS) has developed effective erosion control systems for local strawberry fields. Erosion can be reduced by discouraging strawberry production on steep slopes, requiring new farms to install SCS erosion control systems, making more matching money available to help install SCS systems on both small and large farms, and enforcement of the county's existing Erosion Control Ordinance. However, the best long-term strategy may be to replace agriculture on steep slopes around the slough with low density rural housing linked to revegetation with native plants.

Water Quality

The biggest water quality problem in the surface water of Elkhorn Slough and its watershed is the high levels of persistent pesticides moving through the system and exposed to aquatic organisms. The insecticides (DDT, dieldrin, toxaphene, aldrin, chlordane and chlorpyrifos) and the herbicide (dacthal) occur in sediment, fishes and shellfish from Elkhorn Slough. Since DDT was used in large quantities in the past and is highly persistent, its release from agricultural soils is a major pesticide problem. Since endosulfin is the last persistent chlorinated hydrocarbon pesticide still in use in the watershed, it is also a major concern. Pesticides are presently essential for local agriculture. Much of the pesticide input to the slough may come from the Salinas River and Moro Cojo Slough through the Moss Landing Harbor.

Coliform bacteria occur in high levels throughout the slough, especially after rains and particularly at the harbor mouth. While most of the bacteria appear to have a non-human origin, the contributions from domestic and wild animals are unknown and would involve very different management strategies.

The most significant groundwater problem around the slough is salt water intrusion of the surface, 180 ft. and 400 ft. aquifers. High nitrate levels also occur in some wells, especially the shallowest ones. Water and the application of nitrogen fertilizers are essential to agriculture. The salt water intrusion problem will be temporarily postponed by using the 900 ft. aquifer. Salt water may rapidly invade this aquifer. Regional water plans for supplemental water should be modified to include the slough area.

Wetland Enhancement Plans

Enhancement plans are recommended for five major wetlands in Elkhorn Slough: Blohm-Porter Marsh, Azevedo Marshes, Kirby Marsh, Lower Ranch Marsh and Calcagno Pond-ESNERR-Vierra Marsh. The most important environmental constraints to wetland enhancement in the slough are the extensive, slough-wide erosion, the sinking public roads, local flooding, and reduced influence of freshwater. The enhancement plans were generally designed to increase habitat heterogeneity and thus to attract a greater variety of wildlife, especially birds.

The Blohm-Porter Marsh is now a seasonal wetland with some cattle grazing. The enhancement plan lets salt water flush the main channel system while freshwater is impounded behind Elkhorn Road converting much of the remaining marsh into brackish wetlands. The marsh will be heavily bathed by freshwater during the rainy seasons and will be brackish the rest of the year when most water will recede into a continuous system of channels and large ponds flanked by islands. Causeways and trails will provide public access to a large wetland with salt and freshwater vegetation and many birds.

The enhancement plan for the Azevedo Marshes will increase tidal flushing in these relatively stagnant pocket marshes. The Kirby Marsh is also an abandoned pasture and seasonal wetland. There are two enhancement options here. The first returns limited tidal flow to the marsh if the low areas in Elkhorn Road are not raised. The second option depends on raising the elevation of Elkhorn Road and recommends using Kirby and the adjacent North Marsh for field experiments on the ecological importance of brackish or transitional wetland habitats. This area is part of the Elkhorn Slough National Estuarine Research Reserve. The pond, channel, and island systems are similar to those recommended for the Blohm-Porter Marsh, but are replicated to maximize their scientific potential. If the road is raised, the enhancement plan for the Lower Ranch Marsh will create a small freshwater marsh next to the larger Kirby and North Marshes.

Finally, the Calcagno Pond-ESNERR-Vierra Marsh is a freshwater system surrounded by salt marshes. The plan provides a limited tidal regime that flushes the salt marshes without causing significant erosion.

Since the largest enhancement sites can be dried before excavation of channels and ponds, the plans can be realized with considerable control and minimum expense. Preplanting wetland vegetation at the enhancement sites is possible and imperative to produce the desirable habitat heterogeneity.

Public Access

Public access trails are planned for most enhancement sites. There are also four major wetland areas in the slough where enhancement plans are not needed, but public access is considered. The Elkhorn Slough Estuarine Research Reserve and the Moss Landing Wildlife Area are managed by the Department of Fish and Game with excellent public access trails. The Packard Ranch can be connected to the wildlife area in the future if the Ranch is eventually open to public access. No general public access is recommended to The Nature

Conservancy Preserve and other marshes along the western slough. Access to the different wetland areas is not limited when they are adjacent to Highway One or Hall Road, but is limited along Elkhorn Road, which is a smaller scenic road.

Plan Implementation

The plan includes proposed implementation for each category of management problem in the slough. The Erosion and Sedimentation problems require two primary actions- investigation of measures to reduce tidal erosion in the slough and greater control of erosion in the slough watershed through complete implementation of the County Erosion Control Ordinance and possible public funding for installation of permanent erosion control systems on farmland.

The water quality problems in the slough primarily stem from transport of pesticides from the Salinas River drainage into the Moss Landing Harbor and Elkhorn Slough. The plan proposes the County identify other alternatives to managing the Salinas River flows than the present system. Controlling erosion will also reduce pesticide levels entering the slough system.

Implementation of the wetland enhancement plans will require acquisition or donating of private property by either a public agency or a non-profit organization. Complete design and construction work may follow once the land is secured, a source of enhancement funds is located, and long-term management is arranged. The responsible agencies, potential funding sources and preliminary cost estimates for the five enhancement projects are outlined.

Long-term Management Research

A number of long-term management problems require additional field research. They include in order of importance:

1. Determine the persistence and movement of pesticides in the watershed.
2. Develop fair and effective policies for preventing incremental loss, especially from agriculture, of wetland habitats .
3. Determine land preparation, irrigation and drainage techniques that minimize the mobilization of pesticides.
4. Determine the effects of pesticides on natural communities.
5. Establish a Task Force to assess water quality problems in the slough.
6. Recreate the wildlife history of future enhancement sites.
7. Assess the wildlife value of brackish or transitional wetlands.
8. Monitoring long-term patterns of wetland erosion.
9. Develop future groundwater plans.
10. Assess effects of new chemicals.
11. Determine the local effects of Organo-tin.
12. Develop regional management plans for the Salt Ponds and other ponds.
13. Monitor potential human health problems from consumption of contaminated shellfish.
14. Assess the effects of boat traffic on marine mammals and slough erosion.
15. Assess the habitat value of introduced species.
16. Determine the regional archaeological resources around the slough.
17. Assess impacts of increased automobile and recreational vehicle traffic from recreational use of the slough.

CHAPTER 1
NATURAL HISTORY
OF ELKHORN SLOUGH

1.1 INTRODUCTION

The management and enhancement of wetland habitats in Elkhorn Slough (Figures 1-1 and 1-2) depend on the existing knowledge of the slough's natural history. The present environment cannot be understood without considering the remarkable changes in wetland habitats caused by human activities. This chapter briefly describes the regional and local geological setting that led to the development of the wetland habitats first encountered by humans. Human influence on the slough is then considered and divided into four major periods:

1. Costanoan Period (>10,000 years before present to early 1800's)
2. Reclamation Period (mid 1800's to mid 1900's)
3. Harbor Period (1947 to present)
4. Enhancement Period (1971 to the future)

The major human activities and their effects on the landscape, hydrology and wildlife of the slough are briefly described for each period with a more detailed account of the present environmental conditions. This background in natural history is essential to the development of wetland enhancement plans for the slough (Chapter 4) and for defining and solving the significant problems in sediment erosion and deposition (Chapter 2) and water quality (Chapter 3).

1.2 GEOLOGICAL HISTORY

Elkhorn Slough now occupies a small portion of the much larger Elkhorn Valley, the landward extension of the Monterey Submarine Canyon (Figure 1-1). The Elkhorn Valley was apparently eroded by a large river draining the Santa Clara Valley and perhaps the Central Valley of California during low stands of sea level less than a million years ago (Beard 1941, Martin and Emery 1967, Jenkins 1974, Dupre 1975, Dupre et al. 1975). The Elkhorn Valley is cut by the San Andreas Fault near the Monterey and San Benito County lines. Apparently lateral movement along the fault changed ancient drainage patterns and diverted the large river flow away from the Elkhorn Valley. Although this early period is poorly known, the recent geological history of the slough is well described (Schwartz et al. 1986).

During the last glacial maximum and the resulting low stand of sea level (about 17,000 years before present), local drainage in the Elkhorn Valley cut a stream about 30 m below the present day sea level. This period had greater rainfall and local runoff than we experience today. As sea level rose, tidal water invaded the channel of the Elkhorn River. By 8000 years before present, the channel was a high-energy tidal inlet. The inlet gradually filled with fine sediment while vegetated salt marshes developed along its landward margins and advanced towards the center of the slough during the last 5000 years. A quiet water estuary, much larger than the present slough, covered the region less than 3000 years ago (Schwartz et al. 1986).

The degree to which this estuary was influenced by salt and freshwater is unknown. Freshwater peat deposits, 20 to over 50 feet thick, occur at the head of the slough near Blohm Road and below some major drainages such as the the Lower Ranch Marsh. Thick concentrations of roots probably from freshwater plants occur in narrow bands along parts of

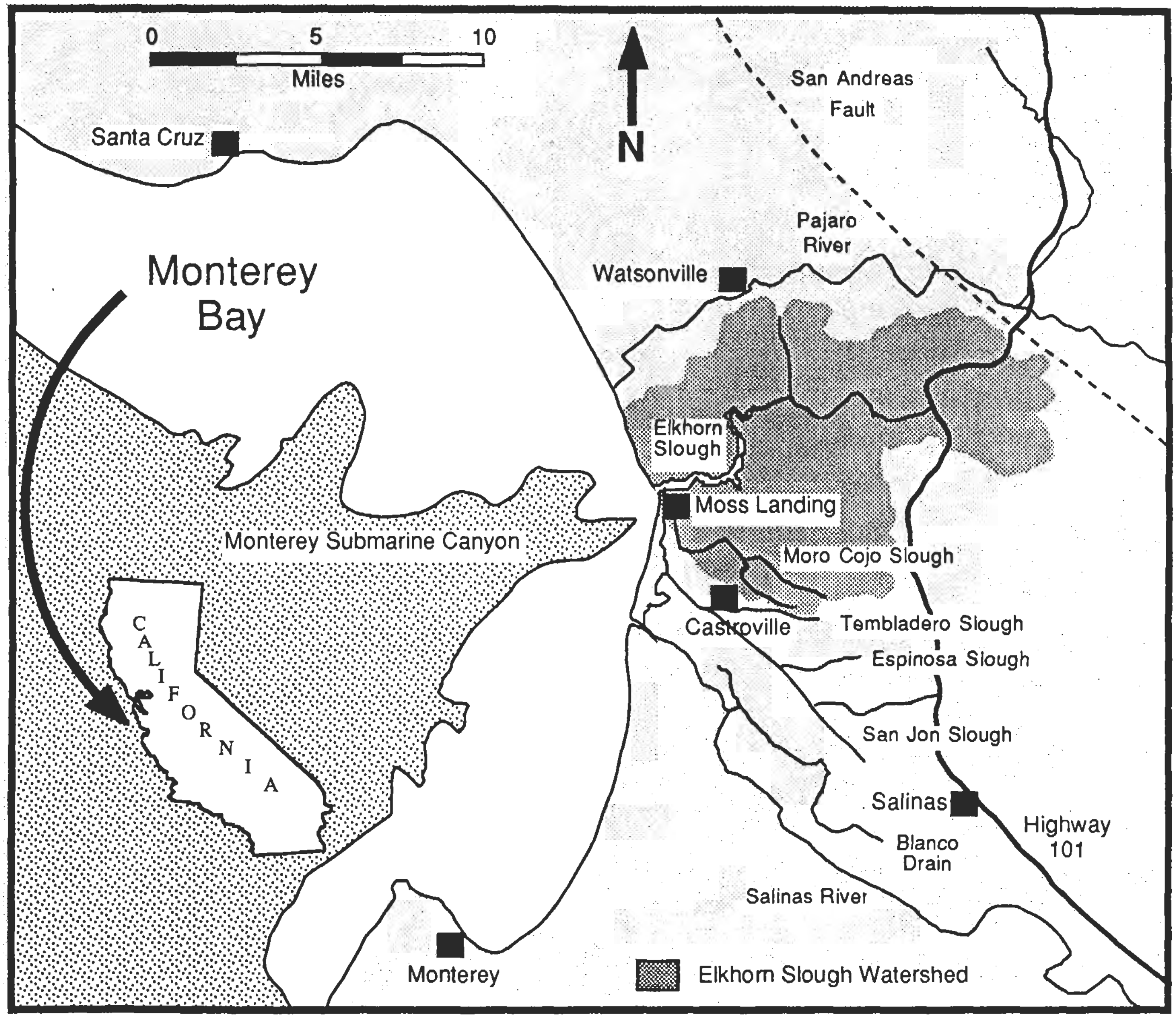


Figure 1-1. Monterey Bay area showing Elkhorn Slough and its watershed, the major rivers and sloughs in the central bay, and important place names.

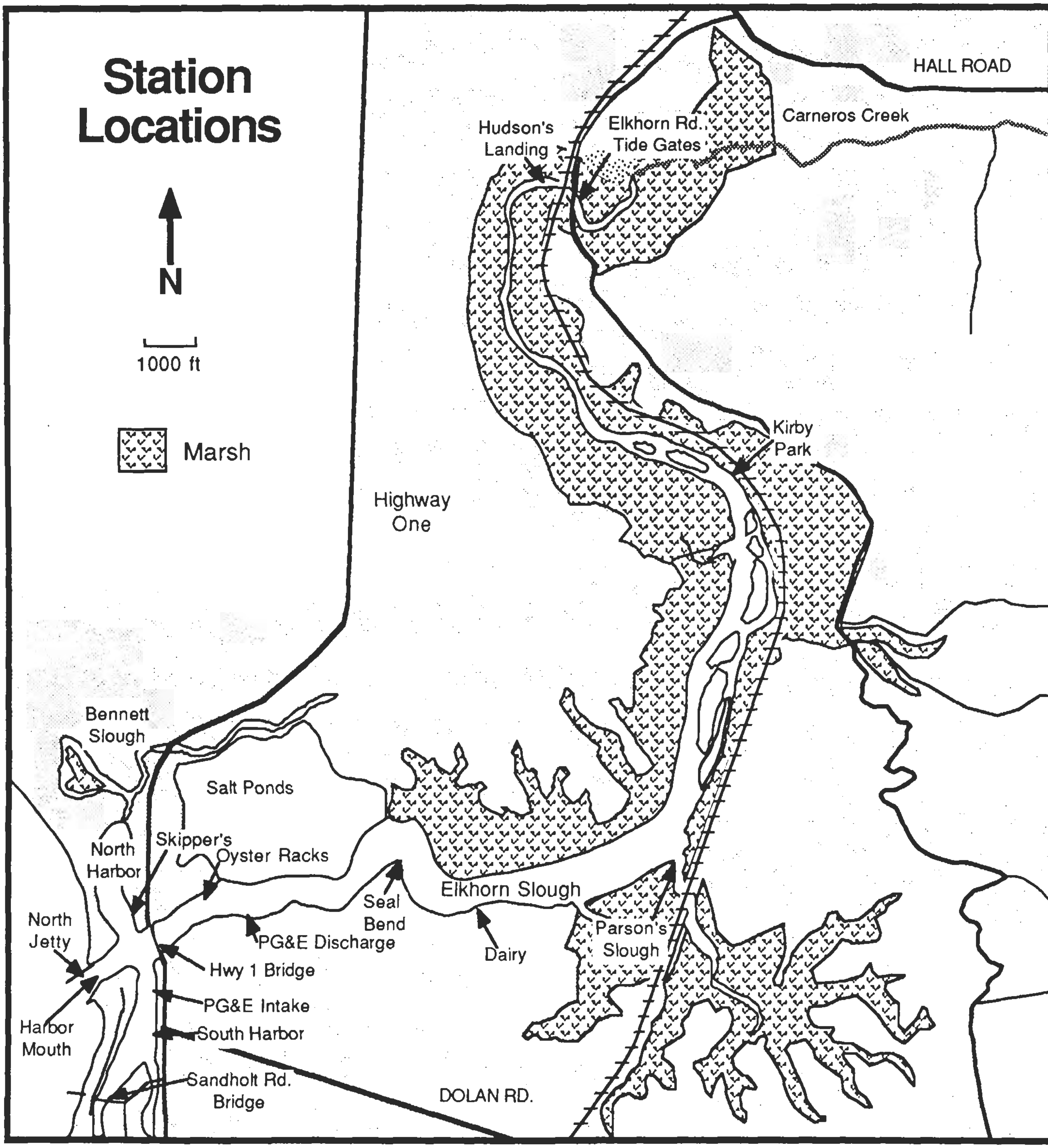


Figure 1-2. Elkhorn Slough showing important geographic locations.

the upper pickleweed marsh. None of these and other important deposits have been studied. This historical setting will be known much better when more deep sediment cores are taken for grain size, pollen, microfossil, root mat and age analysis. Nevertheless, the likely hydrologic and wildlife settings are described below in the first period of human occupancy (the Costanoan Period), when human effects on the slough were minimal.

1.3 HUMAN OCCUPANCY

1.3.1 Costanoan Period

1.3.1.1 Human Activities

The first native Indians migrated into the Monterey Bay area between 12,000 to 8,000 years before present. There is some evidence of native presence around the slough as early as 6000 years ago (Dondero et al. 1984). The Costanoan group was in place during the last 2000 years. Indian middens around the slough are full of the shells of marine invertebrates, especially clams, and the bones of birds and mammals. Indians fed on a wide variety of marine and coastal species. There is no evidence from existing studies that the Costanoan or earlier Indian groups depleted local marine populations to extinction (Dondero et al. 1984). Human-caused extinction was unlikely for most marine invertebrates since they probably maintined large subtidal populations as today and subtidal populations were not exploited by Indians. On the other hand, Indians may have dramatically reduced the numbers of some species in the intertidal zone. Populations of large intertidal clams may have taken several decades to fully recover from heavy Indian exploitation (e.g., Kvitek and Oliver in press). Local populations of marine mammals may have been eliminated as well, but again replacement by immigration from large coastal populations was likely. Therefore, although the Costanoan and other Indian groups fed heavily on slough animals, they probably had little long-term effects on the structure of marine communities. They collected animals and probably did not modify wetland habitats (Gordon 1977).

In contrast to the slough itself, the landscape around the slough was dramatically impacted by Costanoans. They extensively burned native vegetation. Gordon (1977) compiles an impressive number of historical accounts of extensive burning by Indians in order to obtain food. The burning also cleared land of heavy brush and trees and thereby favored the development and procurement of certain food items and probably facilitated travel. Since natural fires are not common along the coast, the most important effect of Indian burning was probably the maintenance of much larger areas of grassland habitats. Therefore, the coastal landscape was burned and extensively modified by human activities for thousands of years (Gordon 1977). In general, the burning activities of Indians probably had little influence on coastal wetlands. However, since Indian burning was usually done in the fall (Gordon 1977), heavy rainfall may have caused high rates of erosion from recently burned land next to wetlands resulting in locally high rates of wetland sedimentation. The old sediment fans located along the west side of Elkhorn Slough could have been caused by Indian burning along the adjacent plateau (Chapter 2).

1.3.1.2 Slough Hydrology

For several thousand years the Elkhorn Slough covered a much larger area than it presently covers (Schwartz et al. 1986). The Salinas River probably drained just north of the slough mouth for thousands of years, although during heavy rainfall the river may have broken through the dunes at its present mouth (Figure 1-3). The Pajaro River periodically meandered south along the inside edge of the dunes and drained at Moss Landing with the Salinas River (Gordon 1977). This was the only opening to the sea of the Elkhorn Slough. Tidal waters extended into the slough and caused the water elevation to rise at least several feet, allowing steam ship access to Hudson's Landing at the extreme head of the slough (Figure 1-2). Since the slough was only 1-2 feet deep except for a narrow channel, which was only 3-4 feet deep, there was little mixing of sea water with freshwater at the head of the slough. Tidal exchange was so restricted that there were no intertidal mudflats exposed in the slough except near its mouth (MacGinitie 1935).

Freshwater springs were common in the slough and all along its edges. Surface water was so plentiful that one artesian well flowed all year long in central Moss Landing into the 1930's (pers. comm. Bill Leeman). The earliest U.S. Coast and Geodetic Survey in 1854 describes an extremely wet landscape all along the coast of central Monterey Bay (Gordon 1977). Since the groundwater table was high most of the year and sources of freshwater were plentiful (Gordon 1977, per. comm. Bill Leeman), the head of the slough probably rarely experienced relatively high levels of salinity. Local residents recall swimming in only slightly brackish water some distance into the slough before the harbor opened (pers. comm. Burt Vierra and Louis Calcagno). The head waters may have been brackish during the late summer and fall when freshwater input was lowest and high tides may have advected some sea water into the back slough. However, during much of the year, the back slough was probably primarily freshwater.

In summary, for thousands of years the Elkhorn Slough was part of a much larger wetland system covering the mouth of the Pajaro Valley, the Salinas Valley, and the area in between including the present Elkhorn Slough. The slough was a large shallow embayment and quiet-water estuary with little tidal influence. Freshwater input was much greater than salt water. The slough was probably filled with freshwater for as much as half of the year and the head waters may have been brackish only rarely.

1.3.1.3 Slough Wildlife

The wildlife during the Costanoan Period must have been spectacular. Wetland plants probably covered thousands of acres of coastal land. At river mouths the plant assemblages were probably dominated by salt tolerant species such as pickleweed and salt grass. Rushes, sedges, tules, cattails, and willows covered much larger areas than the salt tolerant species (Gordon 1977). Freshwater springs were so common that they maintained patches of rushes or cattails in the middle of Elkhorn Slough (per. comm. Burt Vierra). Indians made rafts from the large reeds in these wetlands (Gordon 1977). Between the salt and freshwater marshes there were probably large areas of transitional wetlands, which were periodically covered with salt water during periods of very high tides or storms but usually were influenced by freshwater. These transitional wetlands probably harbored many salt tolerant species of plants and a rich insect and vertebrate fauna quite different from marshes with

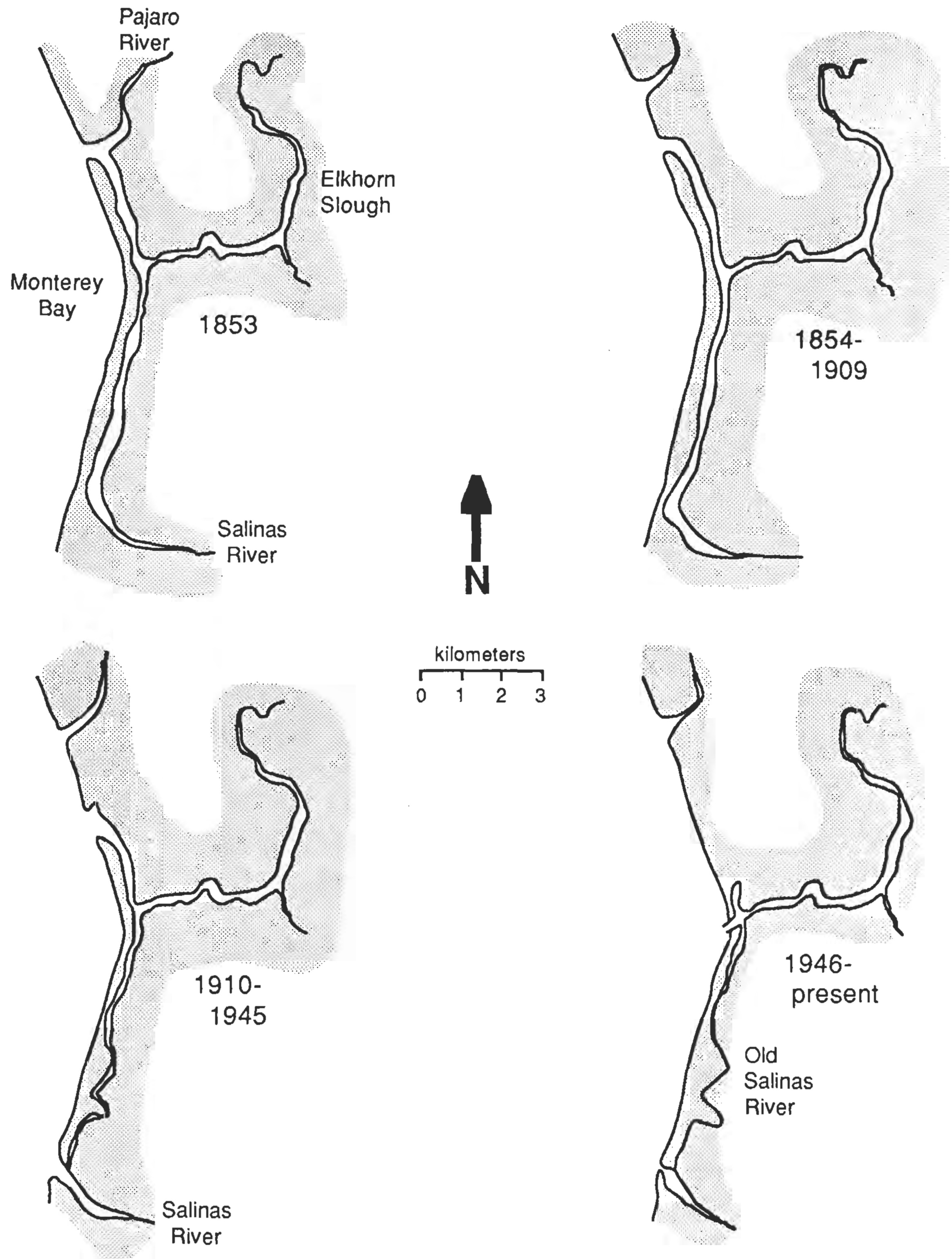


Figure 1-3. Historical changes in the connections between the Salinas River, Elkhorn Slough and Monterey Bay from 1853 to 1986.

regular tidal inundation.

There must have been many millions of waterfowl and shorebirds using the coastal wetlands of central Monterey Bay. Some of these early flocks were so dense that they blackened the sky (Gordon 1977). Early drawings and paintings suggest the same spectacle (e.g., Margolin 1978). While the tremendous numbers of birds must have been the most conspicuous wetland wildlife, tule elk, deer, wolves, coyotes and California golden grizzly bears were common (Gordon 1977). Coastal marine mammals, seals, sea lions and sea otters, may have been abundant around the mouth of the slough.

Salmon and steelhead were also abundant in Elkhorn Slough. They were caught with gill nets here in the early part of this century by local fisherman, along with the introduced striped bass which were sometimes as large as 50 pounds (per. comm. Bill Leeman). In the early 1900's Bill Leeman's father rented boats to hunters at Moss Landing. He tied the boats near the only major culvert that blocked Moro Cojo Slough at Moss Landing Road. Steelhead were so abundant and persistent in their leaping efforts to swim past the culvert that it was young Bill's job to remove trapped fish from the rental boats. Leeman also recalls catching salmon with other boys from the Moss Landing pier with bent nails attached to string (1900-1910). Although these observations were made during the Reclamation Period, the anadromous and freshwater fishes must have been extremely abundant throughout the Monterey Bay, and its rivers and wetlands for hundreds and probably thousands of years.

There is no indication that the hunting and gathering activities of local Indians had an important impact on any of the wetland plants and animals (Gordon 1977, Dondero et al. 1984).

1.3.2 Reclamation Period

1.3.2.1 Human Activities

The Reclamation Period began in the mid 1800's as American settlers moved into coastal California. The land use activities of Spanish and Mexican settlers primarily involved cattle grazing during the previous century. Widespread agriculture was first practiced by American settlers (Gordon 1977). Wheat, sugar beets and potatoes were important early crops and were developed earlier in the Pajaro Valley than in the Salinas Valley. This is reflected in the earliest U.S. Coast and Geodetic Survey map in 1854, when cultivated fields occurred only in the Pajaro Valley. The Chinese were among the first to dike, ditch and drain local wetlands for agriculture, especially sugar beets in the 1880's and 1890's (Lydon 1985). By the time of the next U.S. Coast and Geodetic Survey map in 1910, reclamation of coastal wetlands was widespread in central Monterey Bay. Wetland corridors persisted along major drainages such as the Salinas and Pajaro Rivers, Elkhorn and Moro Cojo Sloughs, and the Old Salinas River (the channel that runs from the present day mouth along the back dunes to Moss Landing Harbor) (Figure 1-1). However, even the major drainages were closely flanked by cultivated land. While the largest area of wetland habitat was reclaimed before 1900, additional large wetlands were reclaimed around Castroville and Moro Cojo and Elkhorn Sloughs into the 1930's and 1940's (Gordon 1977, Dickert and Tuttle 1980). Most of the Elkhorn Slough wetlands were reclaimed for cattle grazing or diked to make ponds for extracting salt or for duck hunting. Many dikes were constructed in the slough (Figure 1-4).

One of the most important reclamation projects was the diversion of the Salinas River to protect agricultural lands (primarily reclaimed wetlands) in the Salinas Valley and especially in the Castroville area. By 1910, the mouth of the Salinas River was permanently opened about five miles south of Moss Landing (Figure 1-3, Gordon 1977). The old opening just north of Moss Landing was maintained by tidal action and local runoff. Although the Salinas River periodically broke through the southern dikes and regained its old path through Moss Landing (MacGinitie 1935), most of the river water entered the Monterey Bay through its new opening (Gordon 1977).

1.3.2.2 Slough Hydrology

The major change in the slough's hydrology during the Reclamation Period was the diversion of the Salinas River. With the new opening maintained about five miles south of the slough, there was a dramatic decrease in the input of freshwater to the area. Our qualitative observations of old maps and photographs indicates that at least 90% of the coastal wetlands were ditched and drained during the reclamation period in Monterey Bay. In addition, the level of the groundwater table in the Moss Landing area decreased dramatically in recent years (see Chapter 3). Surface springs and shallow wells (< 10 feet deep) produced large volumes of freshwater in central Moss Landing until the 1930's or early 1940's (per. comm. Bill Lehman). The initial decrease in local freshwater was caused by ditching and draining wetlands, but over pumping of local wells probably caused most of the salt water intrusion problems (Chapter 3). Although the diversion of the Salinas River probably caused the greatest decrease in freshwater to Elkhorn Slough, all the local sources of freshwater input to the slough decreased markedly, particularly since the 1930's and 1940's when many local wetlands were thoroughly drained by reclamation and the water table was heavily tapped for extensive irrigation of row crops (Gordon 1977, Dickert and Tuttle 1980). The general reduction of freshwater to the slough must have been accompanied by greater advection of salt water into the slough.

1.3.2.3 Slough Wildlife

The general changes in wildlife caused by wetland reclamation were conspicuous. Extensive areas of wetland habitat were converted to crop or grazing lands. Salt ponds and duck ponds replaced relatively large areas of natural wetland in Elkhorn Slough, but these areas accounted for a very small amount of the total wetland area reclaimed in coastal Monterey Bay. Large open bodies of shallow water were drained and even larger areas of wetland plants were destroyed. The decrease in wetland vegetation and standing water eliminated habitat for all sorts of wetland animals. Wetland reclamation caused the most serious human impacts on birdlife throughout California (Grinnell 1922, Gordon 1977). Even into the 1930's and 1940's, Bill Leeman (a Moss Landing resident) recalls 50,000-100,000 mud hens or coots in a single flock on local wetlands. The regional decrease in wetland area must have eliminated millions of waterfowl and shorebirds from the bay and therefore prevented many birds from using Elkhorn Slough. Salmon, steelhead and striped bass probably disappeared from the slough and other local wetlands during the Reclamation Period (per. comm. Bill Leeman).

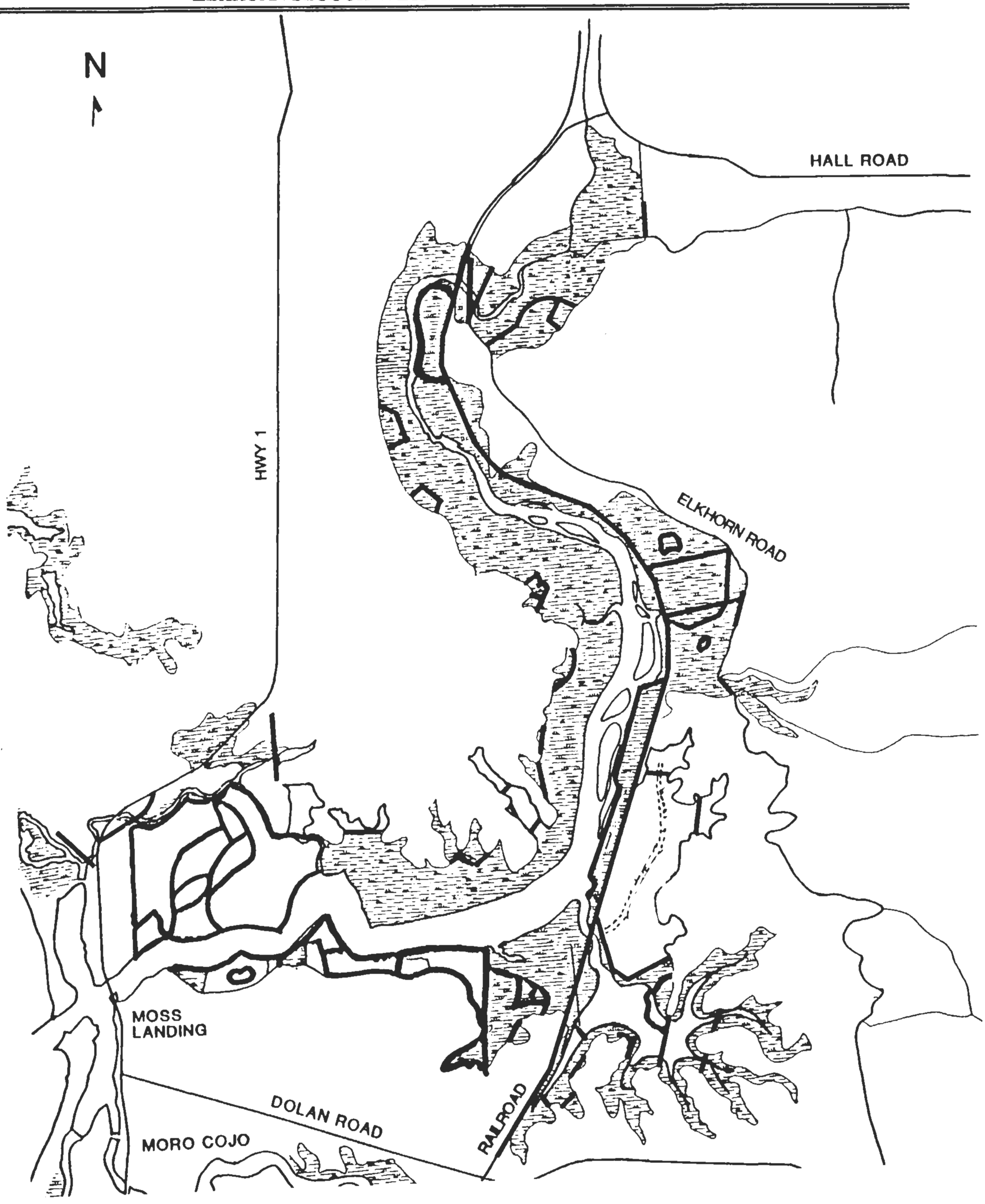


Figure 1-4. Location of dikes constructed in Elkhorn Slough from the late 1800's to 1986.

Although most of the larger terrestrial mammals were killed by American hunters (Gordon 1977), the decrease in wetland habitat must have influenced some of these species as well, especially the tule elk.

1.3.3 Harbor Period and Present Environmental Setting

1.3.3.1 Human Activities

The Moss Landing Harbor was constructed in 1946 and 1947. The harbor entrance was opened to Monterey Bay in 1947 (Figure 1-3). This event had the most significant known impact on the hydrology and wildlife of Elkhorn Slough. Before 1947, the slough was a shallow, quiet-water embayment. Tidal action was so restricted that the only intertidal mudflats occurred at the mouth of the slough near the old mouth of the Salinas River. This was the only opening of the slough into Monterey Bay and was located about one mile north of the slough (Figure 1-3). The new harbor entrance opened into the bay directly at the slough's mouth. The entrance was opened at a low tide and the effect on the slough was rapid and dramatic. The mouth of the slough drained within minutes, exposing shallow flats of eel grass and a narrow (about 15 feet wide), shallow (about 3-4 feet deep) channel. These habitats had always been underwater before the harbor opened (per. comm. Charlie Vierra). During the next tidal cycle, extensive tidal erosion began and continues today. Now the slough is a relatively deep coastal lagoon (over 20 feet deep at the mouth) and the main channel is a large dominant feature (see Chapter 2). Strong tidal currents scour every major wetland habitat and extensive intertidal mudflats cover large areas from the mouth to the head of the slough. Erosion of wetland habitat is now the most important environmental problem in Elkhorn Slough (Chapter 2). This artificial opening to the slough is maintained by dredging every 3-5 years (Oliver and Slattery 1976, Oliver et al. 1977).

The changes in the Blohm-Porter Marsh illustrate the complex effects of human activities on the Elkhorn Slough (Figure 1-5). Before the harbor opened, the hydrology and wildlife of this upper end of the slough were similar to the general descriptions given for the Costanoan and Reclamation Periods. By the time of the first aerial photographs in 1931, the Southern Pacific Company's railway trestle and Blohm Road had altered the movement of water in the marsh and most of the adjacent riparian wetlands had been reclaimed (Figure 1-5). When the Moss Landing Harbor opened in 1947, it opened the entire Blohm-Porter Marsh to direct flushing by tidal waters until 1951 when Elkhorn Road was constructed. As a result, the freshwater flora and fauna were largely replaced with salt marsh organisms as in the rest of the slough. Pickleweed probably dominated the marsh flora within 1-2 years as few other native aquatic plants tolerate the daily salt water emersion. A large number of willow trees were killed during this period of salt water innundation (1947-1951) (Figure 1-5). The culverts under Elkhorn Road were fitted with flaps to prevent tidal water from entering the marsh and allowed freshwater to exit rapidly. After 1951, the marsh became a highly seasonal wetland invaded by winter grasses where the Blohm ranch grazed 70-80 cattle for 8-9 months of the year into the 1960's (per. comm. Estelle Blohm). The Elkhorn Road culverts were replaced in the early 1980's after several years of salt water periodically leaking through the old culverts. The new culverts leaked heavily al

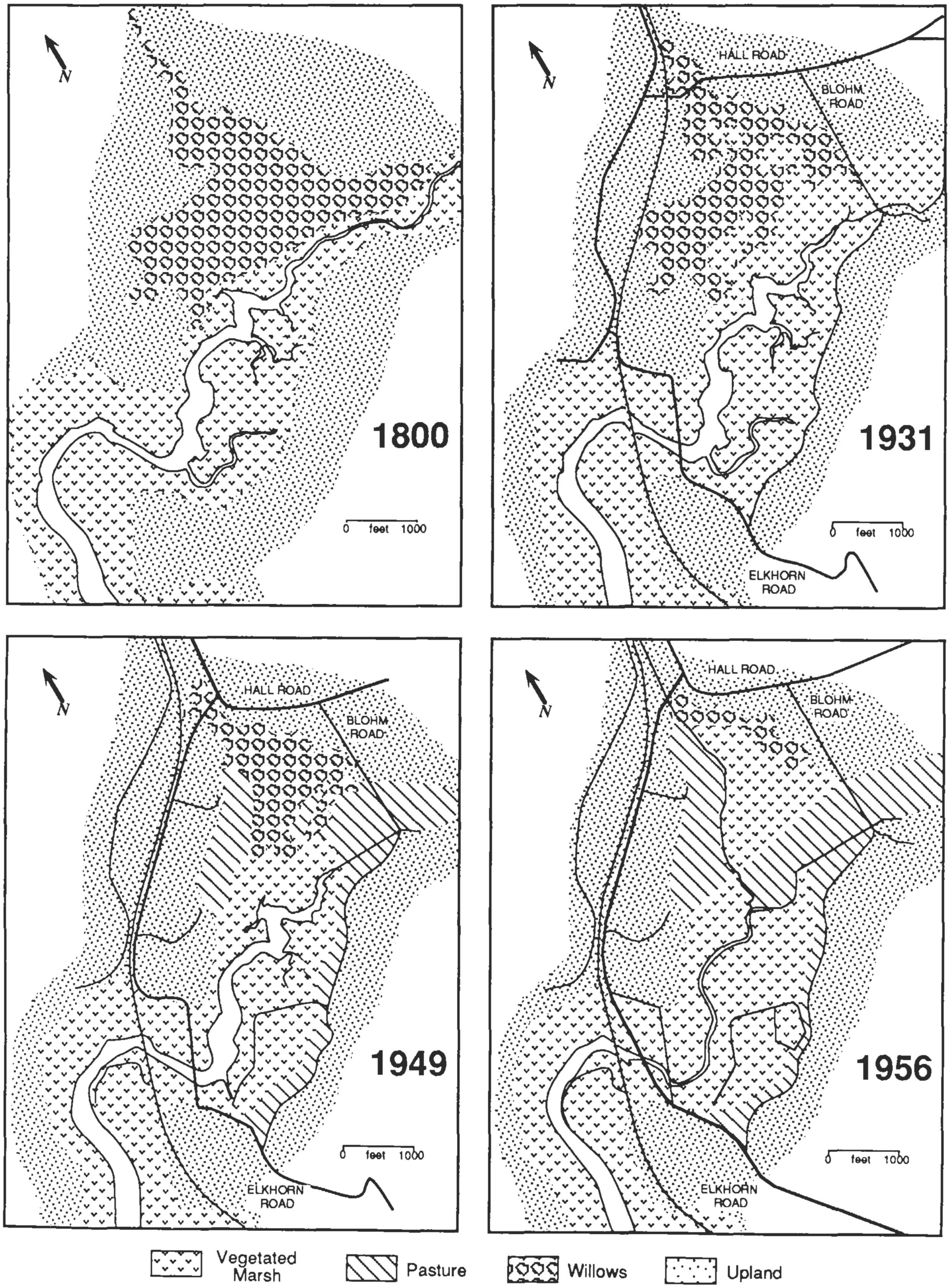


Figure 1-5. Historical changes in the Blohm-Porter Marsh from 1800 to 1956. The present seting (1986) is very similar to 1956 (see Chapter 4: Figure 4-2).

lowing as much as 3 feet of salt water to cover the marsh. This recent exposure killed several willow trees at the upper end of the marsh (the Porter Ranch and Reserve). Since the culverts still allow winter rain to exit rapidly, there is no freshwater buffer against the tide and the marsh is now influenced by periodic salt water flows when the culvert flaps are held open by debris. The main reason the culverts leak more now than in the past is that Bob Blohm is no longer alive to keep them free of debris. He maintained the culverts regularly from 1951 until his death. As a result of the recent leaking, salt plants (particularly pickleweed and salt grass) are much more common than they were from the 1950's into the 1970's and cattle gazing has decreased markedly on the marsh (Figure 1-5).

1.3.3.2 Slough Hydrology

1.3.3.2.1 Water Movements and Salinity

Today the Elkhorn Slough is a tidally flushed estuary with little fresh water input. The majority of freshwater enters into the north end of the slough through Carneros and Watsonville Creeks, two intermittent creeks with substantial flows during the winter and virtually none during the summer. Direct runoff from surrounding hills in the winter and agricultural return flows from irrigated fields contribute additional freshwater. A potentially important amount of freshwater may enter the slough from the Salinas River via the Old Salinas River channel and the Moss Landing Harbor. There are tide gates under Elkhorn Road at Hudson Landing to prevent the incursion of high salinity slough water into the pastures and agricultural land to the east of Elkhorn Road. These tide gates worked well until the late 1960's and early 1970's when they began to leak (per. comm. Estelle Blohm). In March of 1986 we found salinities of 32 ppt (parts per thousand) on the slough side of the gate and 30 ppt on the landward side of the gate.

Smith (1973) and Broenkow (1977) divided the slough into three sections, upper slough, lower slough, and harbor based on salinity, temperature, and nutrients in the water. The upper slough extends roughly from Kirby Park to Hudson Landing. This water mass "varies seasonally depending on evaporation, precipitation and runoff rates. During periods of maximum rains, lowest salinities in the upper slough were about 17 ppt, while yearly maximum salinities of 35.7 and 37.4 ppt were found in September 1975 and June 1976" (Broenkow 1977). Water beyond the mean tidal prism in the upper slough is generally isolated from exchange with the Monterey Bay and so has a residency time in excess of 300 days (Smith 1973). The lower slough waters extend from Kirby park to the slough entrance. These waters are almost completely exchanged on every tidal cycle, and are essentially marine in character. Salinity at the Highway One bridge was between 33.2 and 34.0 ppt from July 1974 to June 1976. Waters of the lower slough tend to be homogeneous and unstratified because of tidal mixing.

The salinity of the Old Salinas River and the Moss Landing Harbor is generally lower than water from offshore. The water is a mixture of tidally driven Monterey Bay water and freshwater from rainfall, agricultural runoff and the Salinas River. In the past, the Castroville Sewage Treatment Plant discharged significant amounts (174.3 million gallons in 1983) of treated wastewater into Tembladero Slough, which then mixed with the water coming down the Old Salinas River. This discharge ceased in May, 1984, when the plant was connected with the offshore outfall near Marina. Rain runoff from the Tembladero, Espinosa, and San Jon Sloughs drains into the Old Salinas River and then into the harbor. Moro Cojo Slough drains directly into the harbor.

Water from the Salinas River can enter the Old Salinas River through a 4 foot diameter culvert through the levee (capacity 120 cubic feet per second). During times of high river flow, a bulldozer is used by personnel of the Monterey County Flood Control District to open the mouth of the Salinas River, the levee gate to the Old Salinas River is closed at this time, and the Salinas River flows directly into the Bay. However, when river flow is low, the mouth of the Salinas River is closed by sand, the levee gate is opened, and the entire flow of the Salinas River goes into the Old Salinas River and eventually into the harbor mouth. The levee gate may be opened and closed several times per winter, and the amount of time that the levee gate is open (and the river mouth closed) is variable. During the period from April, 1981 to March, 1986, the levee gate was open for 1059 days, or 59% of the time. Unfortunately, there are no flow data for the levee gate. However, the effects of Salinas River water can be seen in salinity data from the harbor (Figure 1-7). During February of 1975, at a time of high rainfall (Figure 1-6), the salinity at the Portrero Road tide gate was the same as seawater, because the levee gate was closed and the river mouth was open. In June of 1975, despite no rainfall, the salinity at the tide gate was reduced to 20 ppt by a flood control release of water from Nacimiento Reservoir, which came down the Salinas River and through the levee gate.

1.3.3.2.2 Water Exchange Between the Harbor and Slough

The exchange of water between the harbor and the slough may be important in advecting chemical contaminants into the slough (Chapter 3). There are two possible mechanisms for transporting harbor water into the slough. At low tide, low salinity water comes down the Old Salinas River to the harbor mouth and could enter the slough on a flooding tide. Smith (1973) thought the harbor and slough water masses were isolated from each other except under "unusual conditions". Smith detected a plume of low salinity surface water extending out the harbor mouth, but found no plume extending into the slough. However, all his samples were collected at high tide. If low salinity water enters the slough from the harbor, it must do so during a flooding tide and may be well mixed by the time of high tide.

Water could also be transported up the slough by the PG&E power plant cooling intakes. There are two sets of intakes. Units 6 and 7 intake water from the mid harbor and discharge it offshore. Units 1-5 intake water near the entrance to the harbor and discharge it 0.5 km up the Elkhorn Slough. Between them, the two intakes pump a substantial quantity of water, about 10 times the low water volume of the south harbor daily. Approximately one third of the pumped water goes through the slough discharge (Figure 1-8). The constant pumping maintains a flow of bay water in through the harbor mouth, which mixes with the harbor water and may even improve harbor water quality (Pacific Gas & Electric Co. 1979). The top of the water intakes for units 1-5 are located at a depth of about 3 ft. below mean sea level. Since the freshwater from the Salinas River

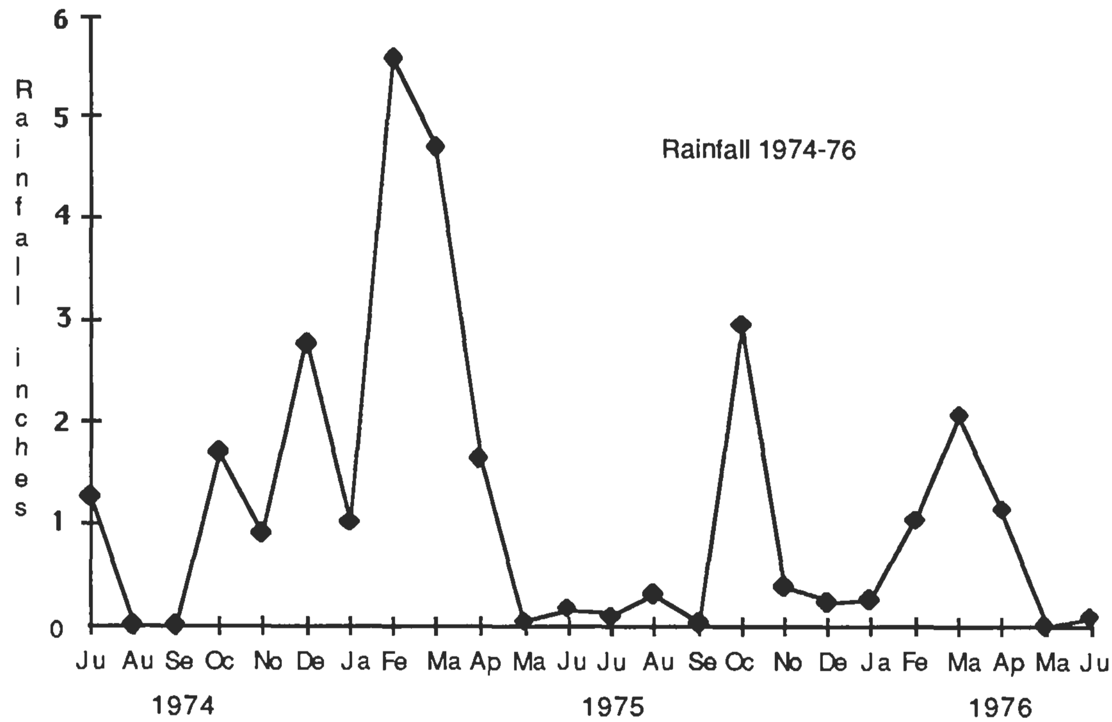


Figure 1-6 : Monterey County monthly rainfall for 1974-76. Data from Monterey County Flood Control District.

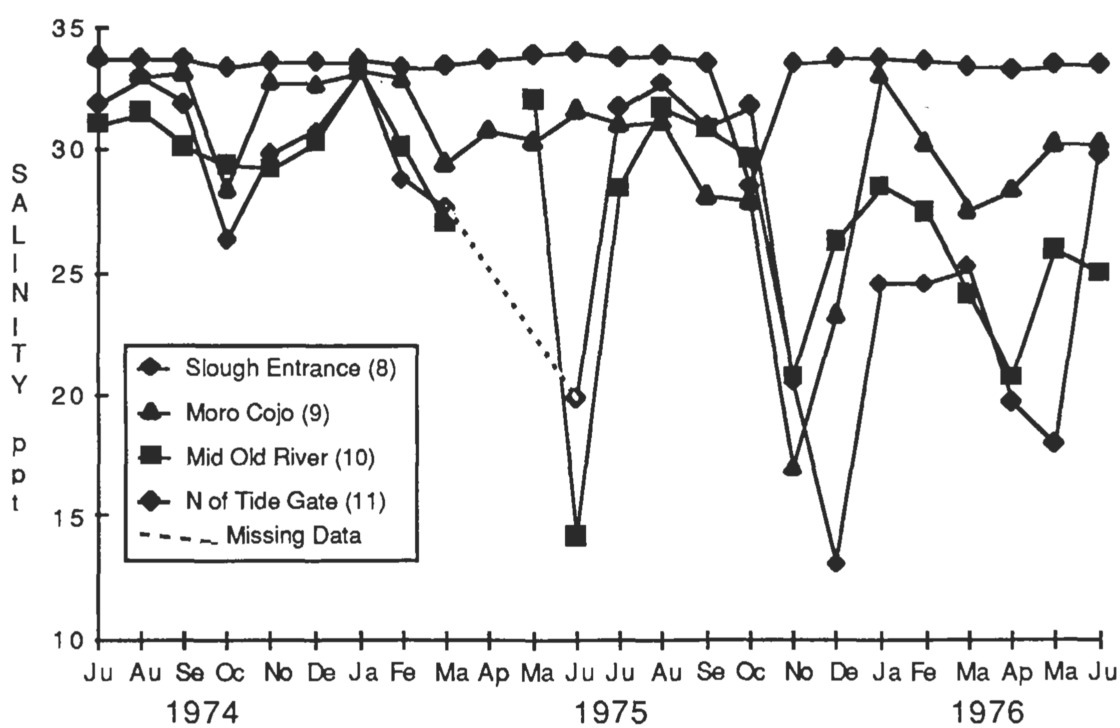


Figure 1-7: Salinities from four stations in the Old Salinas River Channel, collected from a depth of 1 m. Data modified from Broenkow (1977).

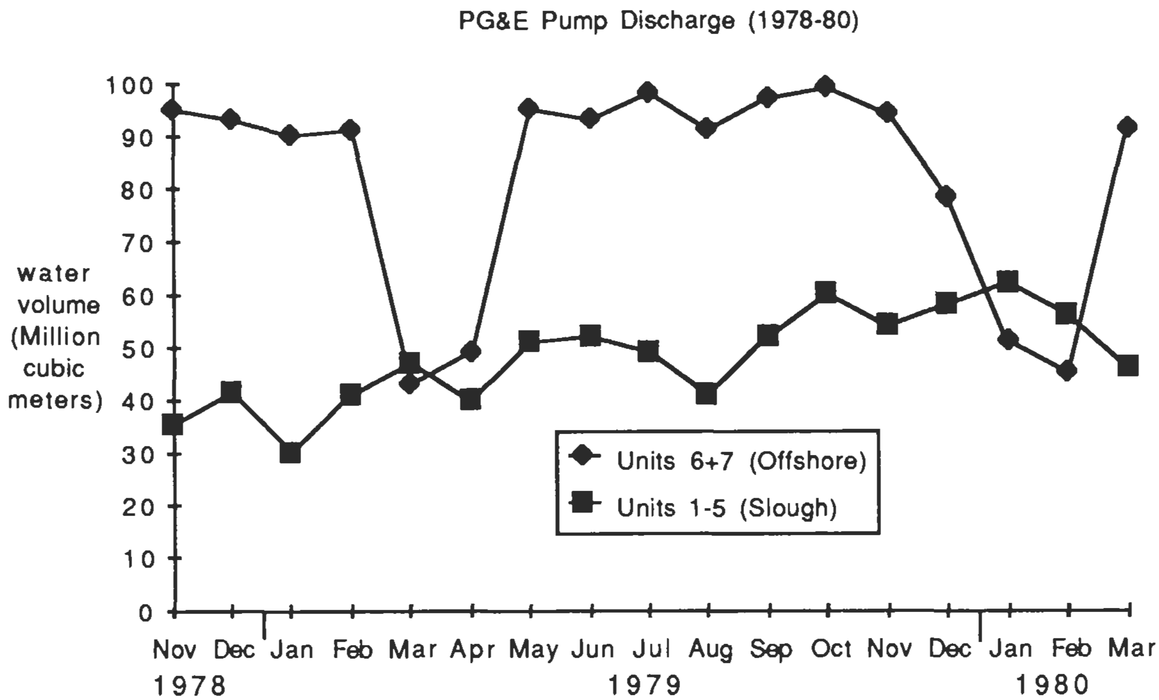


Figure 1-8. Amount of water pumped through the PG&E cooling intakes in the Moss Landing Harbor. Units 1-5 discharge into Elkhorn Slough and units 6-7 discharge offshore into Monterey Bay.

generally forms a surface layer on top of the denser sea water, under normal circumstances it should not enter the intakes. However, if there were localized mixing caused by small-scale eddies, or if the water column stratification were broken down by low temperatures or wind-driven downwelling, water from the Salinas River could be pumped into the slough. None of the available salinity data allow a critical test of this hypothesis. There is secondary evidence from pesticide distribution in the slough that significant amounts of water from the Old Salinas River do enter the slough. However, until more data are available, the importance of transporting water and chemical contaminants from the harbor into the slough will remain unknown.

1.3.3.3 Slough Wildlife

1.3.3.3.1 Plants

1.3.3.3.1.1 Coastal Salt Marsh

The largest wetland habitats in Elkhorn Slough are covered with salt marsh plants. Pickleweed (*Salicornia virginica*) accounts for over 90% of the plant cover. The other common salt marsh plants are salt grass (*Distichilis spicata*), alkali heath (*Frankenia grandifolia*), the succulent (*Jaumea carnosa*) and fat hen (*Atriplex patula*). These other species are located primarily at the upper edge of the pickleweed marsh in Elkhorn Slough (Mayer 1986). The construction of the harbor entrance directly (by erosion) or indirectly (by marshes subsiding into eroded channels) caused the cover of pickleweed to decrease by as much as 50% after strong tidal currents were introduced into the slough (Chapter 2). Nevertheless, the broad green zone of salt marsh, which is present today, was probably present throughout at least the lower and middle slough for thousands of years (Schwartz et al. 1986). The upper end of the slough harbored a similar broad zone of wetland plants, but freshwater plants rather than pickleweed were the dominant species before the harbor opened (unpublished core data, David Schwartz). Now much of the upper slough (Blohm-Porter Marsh) is covered with pickleweed, salt grass, mixed winter grasses and willow trees (Figure 1-5). Cord grass (*Spartina*) is conspicuously absent from the slough.

The other conspicious plants in the salt marsh are macroalgae. Dense mats of green algae (primarily *Enteromorpha* spp.) often cover the upper mudflats at the edge of the pickleweed marsh. They form a green band from spring to early fall. The brown algae, *Gracilaria sjoetsedtii*, occurs in dense patches during the fall and winter on intertidal mudflats and in subtidal habitats (King and Oliver in review). Large quantities of macroalgae also drift along the subtidal channels (Oliver and Slattery 1976, Oliver et al. 1977) and strand during high tides at the upper edge of the pickleweed marsh. This wrack zone is colonized each year by fat hen. Debris deposition and infestation by a parasitic plant (dodder) are two of the most frequent and probably important natural disturbances to the pickleweed marsh. Nevertheless, pickleweed usually recolonizes these disturbed patches even when they are first invaded by other plants (Oliver and Mayer in prep.).

There are only small patches of eel grass (*Zostera marina*) near the mouth of the slough. Before the harbor opened, eel grass covered large areas of the slough around the mouth and inland along the channel where the water was clear and shallow. Long-time local residents recall that dense beds of eel grass or a related species were present even at the head of the slough (per. comm. Bill Lehman and Burt Vierra). Now that the water is much deeper and highly turbulent due to the scouring action of strong tidal currents (Chapter 2), eel grass is limited in distribution.

1.3.3.3.1.2 Riparian and Upland

Rich riparian corridors grow along many of the relatively small freshwater drainages into the Elkhorn Slough. The largest of these drainages are the Watsonville and Carneros Creeks (Figures 1-2 and 1-5). Watsonville Creek is now primarily a drainage ditch and, although the riparian vegetation has been largely removed along the Carneros Creek, this is the largest and richest riparian corridor into the slough. Most of the larger riparian trees (alder, sycamore, box elder and cottonwood) were cut down during the last century. Willow is the only common tree in the riparian habitats. There are a number of small drainages along the steep slopes of the west slough. They are usually lined with willows. Near the upper edge of the salt marsh, there are small patches of cattails, tule, rush and sedges. These riparian habitats are invading the relatively new and old depositional fans that are spreading into the pickleweed marsh on the western slough. While the erosion of upland soil is not a sound mechanism for habitat creation, the extension of the riparian corridors along the depositional fans has some positive ecological value

(Chapter 2).

Coast live oak was and still is the most common tree in the upland habitats around the slough. Before human occupancy, extensive live oak woodlands were probably mixed with areas of oak-bush and oak-grassland. Indian burning undoubtedly created more grassland and later Spanish, Mexican and especially American cutting dramatically reduced the cover of oak trees around the slough (Gordon 1977). On thin-soiled ridge tops oak forest is replaced by chaparral assemblages that are dominated by manzanita.

1.3.3.3.2 Invertebrates

Marine invertebrates are extremely abundant in Elkhorn slough. Before the harbor opened, these groups were probably limited to the mouth of the slough where tidal action insured a constant source of salt water (MacGinitie 1935). Today a species-rich and abundant marine invertebrate fauna even inhabits the channels, mudflats and salt marshes at the head of the slough near Elkhorn Road (Figure 1-2). There are two major faunal zones which correspond to the two water masses in the slough. The upper or back-bay invertebrate fauna is dominated by infaunal species that brood their young. Species with pelagic larvae are much less abundant. The lower water mass has many fewer brooding species and most species have pelagic larvae (Nybakken et al. 1977, Jong et al. in prep.). Apparently the brooders do well in the isolated back-bay water mass because their young are more easily retained here than species with pelagic larvae (Dayton and Oliver 1980). Like the benthic invertebrates, the two abundant species of planktonic copepods (*Acartia* spp.) are also separated by the two water masses in the slough (Pace 1978).

Distinct invertebrate faunas inhabit the channels, mudflats and salt marshes of the slough. Several species of large infaunal clams are abundant along the main channel (Nybakken et al. 1977, Kvitek et al. in press). They are largely restricted to the lower slough water mass and have a distinct zonation here. The gaper clam (*Tresus nuttallii*) and the Washington clam (*Saxidomus nuttalli*) are most abundant near the slough's mouth, and are replaced by dense beds of the rough piddock clam (*Zirfaea pilsbryi*) around Seal Bend and the Calcagno Dairy (Figure 1-2). These clams also live in the intertidal zone where they are not as abundant as in the subtidal channel. In addition to the large clams, there are many small infaunal invertebrates in the sandy and muddy channel bottoms. Many of the same polychaete worms that live in the intertidal zone also live in the subtidal channels (Oliver and Slattery 1976, Oliver et al. 1977, Nybakken et al. 1977).

The intertidal mudflats harbor very dense assemblages of small tube-dwelling and mobile infaunal invertebrates. These include polychaete worms (e.g., *Armandia brevis*, *Platynereis bicanialculata*, *Prionospio* spp., *Streblospio benedicti*, *Capitella capitata*, and *Polydora socialis*), amphipod crustaceans (e.g.,*Corophium* spp., *Allorchestes angustus*, and *Eogammarus confervicolus*), and bivalve molluscs (e.g.,*Macoma* spp. and *Gemma gemma*). Dense tube mats of the phoronid worm, *Phoronopsis viridis* , occur near the mouth of the slough. The most abundant invertebrates in the vegetated salt marsh are the mud crab, *Hemigrapsus oregonensis*, the semi-terrestrial amphipod, *Traskorchestia traskiana*, and the snail, *Batillaria zonalis* . Mud crabs are probably the most conspicuous marine invertebrates in Elkhorn Slough. MacGinitie's (1935) classic study of intertidal animals was done at the mouth of the Elkhorn Slough. All the species of invertebrates that he studied are still present in the slough, but their distribution and relative abundances are surely very different today.

The dense mats of macroalgae on intertidal mudflats harbor an abundant crustacean fauna when water and air temperatures are not too hot. Several species of amphipods and benthic copepods are much more abundant in the mats compared to under the mat or in channel bottoms without an algal mat. During hot weather and low tides, many infaunal invertebrates die from the anoxic conditions under algal mats (King and Oliver in review).

A wide variety of insects use the upper pickleweed marsh and especially the riparian habitats. Several species of mosquitoes breed around the edges of the slough. However, in general, the insect fauna accounts for a small fraction of the invertebrates that live in Elkhorn Slough because the daily tide floods potential habitats with high salinity waters.

1.3.3.3.3 Fishes

There is a rich fish fauna in Elkhorn Slough (Kukowski 1972, Talent 1975, Ambrose 1976, Cailliet et al. 1977, Antrim 1981, Barry 1983, Small 1986). It is dominated by marine and estuarine species. Unlike the invertebrate fauna, the larval and adult fishes (Cailliet et al. 1977) do not have distinct assemblages that live in the upper and lower water masses of the slough. Although there are changes in the composition and especially the relative abundance of fishes along the main channel, the greatest faunal changes occur between the main channel and the tidal creeks that meander into the vegetated salt marsh (Barry 1983). The fish fauna at the upper end of the slough is more similar to the tidal creek fauna than it is to the fauna from the lower main channel (Cailliet et al. 1977, Barry 1983).

There is a peak in the number of species and individuals of fishes in the spring and summer in the slough (Cailliet et al. 1977, Barry 1983, Small 1986). The most common species are the staghorn sculpin (*Leptocottus armatus*), English sole (*Parophrys vetulus*), starry flounder (*Platichthys stellatus*), and several species of perches. Large leopard sharks (*Triakis semifasciata*) and several species of rays are also frequently caught by local fisherman. The diets of several species of local fishes have been documented in the slough (Talent 1975, Cailliet et al. 1977, Antrim 1981, Barry 1983). In general, the fish consume a wide variety of benthic invertebrates.

Onuf et al. (1979) argue that California coastal wetlands are not important nursery grounds for marine fishes compared to east coast estuaries. Although some fish species recruit in high densities into the slough, the same species also probably recruit along the much larger area of the nearshore coastal marine shelf. Since the shelf is so much larger than the slough and similar systems, tremendously greater recruitment is likely to occur along the shelf. Onuf et al. (1979) suggest that the major value of the high recruitment into the slough is to feed other species. The patterns of recruitment into the slough differ among different species of fish. Gravid females of the staghorn sculpin and English sole are rare in the slough, but there is high seasonal recruitment of immigrant larvae or juveniles from offshore populations. Unlike the staghorn sculpin and English sole, sharks and rays (Talent 1975) and shiner perch (Antrim 1981, Terry and Stephens 1976, Odenweller 1975, Shaw et al. 1974) migrate into the Elkhorn Slough and similar wetlands as gravid females, spawn there and then return offshore.

1.3.3.3.4 Birds

The shorebirds in the Elkhorn Slough are similar to those observed in other coastal wetland and salt marsh habitats along the California coast (Ramer 1985). The 10 most abundant shorebirds along the main channel of Elkhorn Slough are (from most to least abundant): western sandpiper (*Calidris mauri*), dunlin (*Calidris alpina*), least sandpiper (*Calidris minutilla*), marbled godwit (*Limosa fedoa*), dowitchers (*Limnodromus griseus* and *L. scolopaceus*), willet (*Catoptrophorus semipalmatus*), american avocet (*Recurvirostra americana*), black-bellied plover (*Pluvialus squatarola*), sanderling (*Calidris alba*), and long-billed curlew (*Numenius americanus*). The small western sandpiper is the numerical dominant accounting for at least 75% of the shorebird individuals present in each season. Unlike number of individuals, the seasonal patterns of biomass are not dominated by a single species and the larger birds account for the same total biomass as the small birds (Ramer 1985).

Shorebird migrations from summer breeding habitat to winter feeding grounds are responsible for the general seasonal patterns in shorebird abundance and biomass. Most of the shorebirds winter in Elkhorn Slough. Summer populations are comprised mainly of large shorebird species. Except for the American avocet, these are non-breeding populations. The dunlin is the only species with a peak abundance in the fall. All other species are most abundant in the winter. These general seasonal patterns have been documented in similar habitats along the California coast (Ramer 1985).

Intertidal mudflats are the primary feeding grounds for all the common shorebirds in Elkhorn Slough (Ramer 1985). Most species feed on the exposed mudflats. Fewer species and individuals feed near the water edge or wading in the water. The salt ponds and salt marsh are the major roosting areas in the slough. Most shorebirds move between roosting and foraging sites in response to tides, roosting at high tides and feeding at low tides. However, several species of shorebirds that are less abundant in the slough roost and feed exclusively in the salt ponds. Phalaropes are the most common of these species. In addition, when a major dike broke and a large salt pond was exposed to tidal action, many shorebirds began to feed in the new intertidal mudflat. However, in general, salt ponds are not exposed to tidal action and roosting is their major habitat value (Ramer 1985). The only common shorebird that feeds in large numbers and regularly in the vegetated salt marsh is the willet. Its diet is dominated by mud crabs that are most abundant here and are much larger than the infaunal prey consumed by birds such as the western sandpipers and marbled godwits which feed on the intertidal mudflats (Ramer 1985).

Waterfowl are also abundant in parts of the slough (Ramer 1985). Their seasonal patterns of abundance are similar to the shorebirds with highest numbers in the winter, although some species breed in the slough during the summer. Few species of waterfowl feed at low tides on the intertidal mudflats and their foraging habits from other parts of the slough are poorly known. Many shorebirds and waterfowl use upland and riparian habitats adjacent to the slough for roosting, feeding and sometimes breeding. Upland species also forage and roost in and around the marsh. However, the interactions between wetland and upland animals and the utilization of alternate habitats in the slough are poorly known.

1.3.3.3.5 Mammals and Other Vertebrates

Several marine mammal species use Elkhorn Slough. Harbor seals (*Phoca vitulina*) haul out on mudflats around Seal Bend and the Calcagno Dairy. Groups often contain more than 20 individuals. Unfortunately, harbor seals are wary of boat traffic and are easily disturbed by this and other human activities. They feed in the slough, but hauling out is probably their main activity there. Sea lions *(Zalophus californianus)* periodically haul out on boat docks and sandflats (probably when sick) at the mouth of the slough, but are not nearly as common as the harbor seals.

In recent years, sea otters (*Enhydra lutris*) have become increasingly abundant in the slough (Kvitek et al. in press). As many as 20-30 animals use the slough during the spring to late summer, and a few animals are now present throughout the year. Otters use the slough for resting and feeding. Their main prey are benthic invertebrates from the slough channel. The gaper and Washington clams are the most important of these prey. Otters dig clams from the sediment with their forelimbs. Although otters have had dramatic and rapid impacts on benthic prey in other habitats, they have not caused a significant decline in slough clams because these prey have a deep refuge in the sediment. However, eventually (perhaps over 10 years) otters may deplete the dense clam beds in the slough (Kvitek and Oliver 1987). Fortunately, their arrival was documented and their foraging activities are being monitored to document the actual pattern of exploitation of this newly exploited feeding ground (Kvitek et al. in press). Although this is the first coastal wetland that sea otters have recolonized since their population recovered after the heavy commercial killing in past centuries, sea otters probably rested and fed in most of the wetlands along the California coast in the past. Therefore, sea otter use of the slough will probably increase in the future and teach us much about the feeding ecology of this threatened species (Kvitek and Oliver in press).

A number of terrestrial mammals forage along the slough including raccoons, muskrats, and opossums. Raccoon scat found near the slough are often full of mud crab parts. Other mammals are active at the edge of the slough including striped skunk, longtailed weasel, red and gray fox, brush rabbit, blacktail jackrabbit, California ground squirrel, and various rodents.

1.3.3.3.6 Introduced Species

Many species of plants and animals have been introduced into the slough and the adjacent riparian and upland habitats. Some of the most abundant species of marine invertebrates are not native species (Carlton 1975). Particularly abundant species include the polychaete worm, *Streblospio benedicti*, the small clam, *Gemma gemma*, and the snail, *Batillaria zonalis* . Among the fishes, the predacious striped bass was abundant along the coast and in the slough during the early part of this century. The most conspicuous introductions among the mammals are domesticated animals, which have had important impacts on many local wetland and upland habitats (Gordon 1977).

Introduced plants have greatly modified the local and regional landscape. Introduced annual plants in our grasslands are such a long-time and persistent component of the flora that they are sometimes referred to as the "new native annuals". The eucalyptus tree characterizes the widespread and prominent place of many introduced species. While it clearly occupies the habitat of native species and harbors a much less rich flora and fauna than the native live oak forests (Gordon 1977), eucalyptus forests and the birds that use them have considerable appeal to many naturalists.

There are several important introduced species of salt marsh plants that have become abundant in the slough. These include fat hen (*Atriplex patula*), rabbitfoot grass (*Polypogon monspeliensis*), and brass buttons (*Cotula coronopifolia*). The colonization of the slough by brass buttons is an excellent example of the prominent role of many introduced species. Brass buttons was a rare species in the slough during the 1970's. By 1979, it was only conspicuous in one patch near Elkhorn Road and Campagno Way (Figure 1-2) in a small transitional wetland, an area influenced by freshwater runoff and periodic tidal action. Today this species has spread to all the major wetlands along the east side of the slough and onto several of the depositional fans along west slough. It is abundant along the road side where Highway One meets local wetlands and in low wet areas in many local agricultural fields, which are largely reclaimed wetlands. In addition, it has spread along the Salinas and Pajaro Rivers and all along the Moro Cojo Slough and Old Salinas River during this same period (unpublished data, John Oliver). Brass buttons is now an abundant and widespread wetland species in Monterey Bay.

1.3.3.3.7 Threatened, Endangered or Unique Species

Six threatened or endangered species occur in the slough: 1) California brown pelican, 2) California least tern, 3) California clapper rail, 4) Santa Cruz long-toed salamander, 5) southern sea otter, and 6) peregrine falcon. The clapper rail is rare in the slough (Harvey 1980). Several thousand brown pelicans once roosted in the salt ponds. Because of dike breaks there, many pelicans now roost at other sites in the slough, but feed primarily offshore. Least terns also roost in the salt ponds and sometimes nest there. The long-toed salamander occurs in small numbers in several riparian, freshwater and transitional wetlands around the slough. The recent colonization pattern of sea otters indicates that they will become more abundant in the slough.

In addition, there are a number of unique native species in the adjacent uplands. The most important are the black shouldered kite and the endemic manzanita, *Arctostaphylos pajaroensis*. A federal candidate threatened species is the Santa Cruz tarweed (*Holocarpha macradenia*), which has been seen in the slough's watershed. Another candidate, the Monterey ornate shrew, may also live in freshwater wetlands in the watershed. The recommended enhancement plans will improve potential habitat for all these species (see Chapter 4).

1.3.4 Enhancement Period

1.3.4.1 Wetland Values

There has been a dramatic decrease in the area and quality of wetland habitats throughout the state (e.g., Atwater et al. 1979) as well as in the Elkhorn Slough and other wetlands in Monterey Bay. The rarity of coastal wetlands has caused their value to increase greatly. Wetland values are determined by the structure and function of natural systems and by the recreational interests of society. Onuf et al. (1979) recognize four major values of California coastal wetlands:

1. Habitat for endangered species.
2. Stopping places for migrating birds on the Pacific flyway.
3. Education and research.
4. Aesthetics.

Clark and Clark (1979) recognize five functional values of wetlands:1. habitat, 2. food chain, 3. hydrologic and hydraulic, 4. water quality maintenance, and 5. use: harvest and heritage. While these functional values are clearly important in California wetlands, the values listed by Onuf et al. are more appropriate to California wetlands and integrate natural functional values with the broad concerns of human society.

The Elkhorn Slough provides a heterogeneous habitat for feeding, breeding and resting of many animals (1.3.3.3: Slough Wildlife). The hydrographic setting is the result of historical human manipulations of wetlands and their watersheds (1.3: Human Occupancy). The major values of the present physical and biological setting are the four values listed by Onuf et al (1979). The aesthetic value of the slough is the greatest concern to local and regional human society. While there has been some commercial use of the slough for shellfish, the recreational uses are much greater. Each year thousands of persons visit the Elkhorn Slough National Estuarine Research Reserve. When public access is developed for the salt ponds and the wetland enhancement areas discussed in Chapter 4, the slough will probably be visited by several thousand more persons each year. The high aesthetic value of the slough depends on maintaining a rich wetland environment.

In general, the best strategy for wetland restoration is to increase the area of wetland habitat. There is a well documented positive correlation between habitat area and the number of species (Connor and McCoy 1982). The usual explanation for this increase in species number is a likely increase in habitat heterogeneity (complexity) as habitat area expands. Therefore, in addition to increasing habitat area, species number can be increased by increasing habitat heterogeneity in a particular wetland restoration site. The variety of habitats allows many species of plants and animals to coexist. The values listed by Onuf et al. (1979), especially the aesthetic value, are optimized by enhancing the abundance and variety of wildlife through increasing habitat heterogeneity.

1.3.4.2 Trends in Wetland Ownership

The trends in wetland ownership insure that the Elkhorn Slough will be conserved and enhanced in the future (Figure 1-9). The Enhancement Period begins with The Nature Conservancy's first land purchases in Elkhorn Slough in 1971 and 1972 (Table 1-1). They are the pioneer land conservation organization in the slough. Their activities focused new atten

Year	Acquired By	Land Area	Method
1971	The Nature Conservancy	Azevedo marsh	sale
1972	The Nature Conservancy	Slough Preserve	sale
1972	The Nature Conservancy	Rodgers et al. marsh	gift
1974	The Nature Conservancy	North & Lower Ranch Marsh	gift/sale *
1975	The Nature Conservancy	Porter Ranch	gift
1975	The Nature Conservancy	Warner Lake	gift
1980	NOAA/Fish & Game	Main Sanctuary	sale
1982	Fish and Game	Eucalyptus forest/marsh	sale
1982	The Nature Conservancy	Struve Pond	sale
1984	David Packard	Rubis Ranch	sale
1984	Fish and Game	Salt Ponds and marsh	sale
1984	The Nature Conservancy	Salt Ponds to F&G	gift/sale
1985	Fish and Game	Avila Marsh	sale
1985	The Nature Conservancy	Porter/Cooley easement	gift

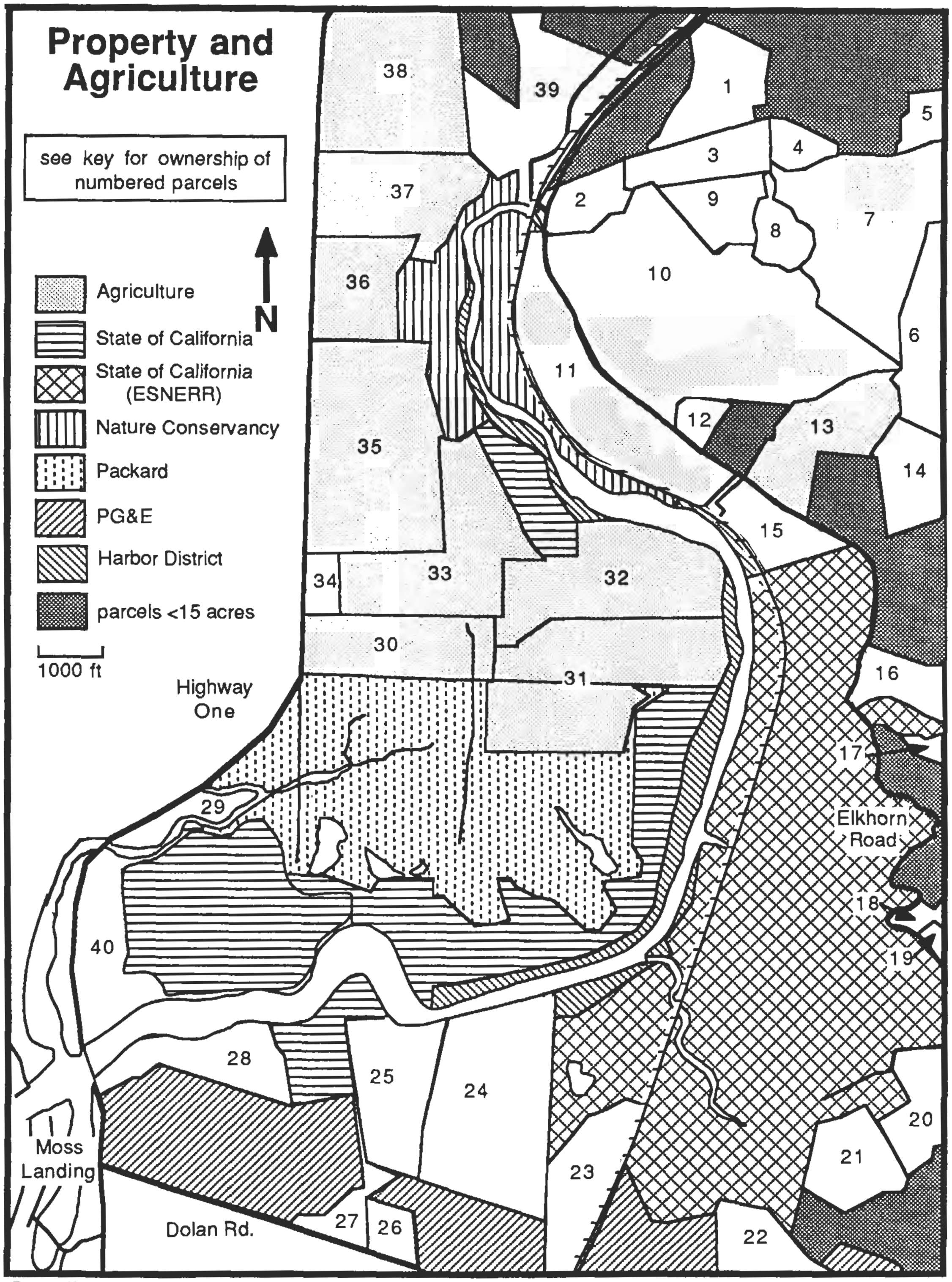
* First land donated to the Elkhorn Slough National Estuarine Research Reserve

Table 1-1. Major wetland and important wildlife land acquisitions in the Elkhorn Slough during the Enhancement Period.

tion on the slough's conservation, restoration and enhancement. They purchased or were given wetlands throughout the slough. The Nature Conservancy provided the first land acquisition for the National Estuarine Research Reserve by placing the North and Lower Ranch Marshes in the sanctuary. Federal and State government purchased most of the land for the Elkhorn Slough National Estuarine Sanctuary in 1980. Since then the Department of Fish and Game, which manages the sanctuary, acquired additional parcels for the sanctuary as well as the salt ponds and the adjacent wetlands for wildlife conservation (Figure 1-9). The Nature Conservancy also provided $500,000 towards the purchase of the salt ponds and retained ownership of small mud islands along the central slough. In 1984, David Packard purchased the Rubis Ranch insuring the conservation and enhancement of another large area of slough watershed and wetlands. Hundreds of additional acres of slough wetland may be gifted or purchased in the near future for conservation and enhancement (Chapter 4). A considerable amount of wetland and other wildlife habitat was given to land conservation organizations by local landowners (Table 1-1).

1.3.4.3 Trends in Land Use

The trends in land use in and around the slough also reflect the recent pattern of conservation and enhancement of wetland habitats. The earliest plans to develop the Moss Landing Harbor included a branch into the main channel as far east as the present Research Reserve (Figure 1-9). Today there are no plans to extend the harbor into Elkhorn Slough (Local Coastal Plan 1981). Much of the land around the slough is used for agriculture (Figure 1-9). The major long-term change in agricultural lands is an increase in row crops, especially strawberries around the slough (Table 1-2). The present local coastal plan recommends the removal of agriculture from steeper slopes around the slough, replacing it with low density rural housing (Local Coastal Plan 1981). Gordon



1) Bernice Porter (for Nature Conservancy)
2) Harold Hermansen
3) Barbara Kilduff
4) Wilson Wang
5) Ray Kirby
6) Charles King
7) El Chamisal Associ
8) Robert Harris
9) Roberta Thomas
10) Estelle Blohm
11) Minnie Azevedo
12) Dean Sanders
13) David Vasquez
14) Sauliage Renteria
15) Haro Estrada
16) Charles Saludo
17) Thomas Landess
18) George Witham
19) Manuel Salazar
20) Ada Wells
21) Willis Wells
22) Benedictine Fathers
23) John Dolan
24) Manuel Minhoto
25) Louis Calcagno
26) Mearle Corp.
27) Granite Rock
28) Charles Vierra
29) Augustus Giberson
30) Edward Campinotti
31) Josephine Costa
32) Opal Viau
33) Joseph Piini
34) U.S. Government
5) John Rogers
36) Sunset Farms
37) Bruno Imazio
38) Acme Farms
39) BC&CR (Golf Course)
40) Monterey Bay SaltCo

Figure 1-9. Land ownership around Ellkhorn Slough.

Land Use	1931 Acres	1931 % of watershed	1980 Acres	1980 % of watershed	% change	% change watershed
Brush	5,765	12.8	3,395	7.6	-46	-5.3
Pasture	24,334	54.2	20,674	46.0	-15	-8.2
Oak woodland	4,838	10.8	6,280	13.9	30	3.2
Row crops	1,975	9.4	5,194	11.6	163	7.2
Strawberries	0	0	2,358*	5.2	----	5.3
Orchards	2,556	5.7	182	0.4	-93	-5.3
Tree plantations	794	1.8	1,609	3.6	103	1.8
Urban	45	0.1	572	1.3	1,171	1.1
Industrial	123	0.3	300	0.7	144	0.4
Commercial	10	0.02	517	1.2	5,070	1.1

* Soil Conservation Service (1984) also estimates 1,250 acres of strawberry fields are fallow.

Table 1-2. Changes in upland land use from 1931 to 1980 in the Elkhorn Slough watershed, showing the percent change for each land use catagory and the change as a percentage of the total watershed (70.2 square miles). From Dickert and Tuttle (1985).

(1977) argued that low density housing and thoughtful revegetation of the adjacent uplands will have a highly positive impact on native plants and animals in the slough and the watershed. Dickert and Tuttle (1985) show that most bare ground in the watershed, which is very susceptible to erosion, is associated with agricultural lands (Table 1-3). The implications of this erosion are considered in Chapter 2 on Erosion and Sedimentation. Wetland habitats were extensively diked in the past (Figure 1-4) and widely used for hunting, grazing and salt production. The trends in wetland ownership directly reflect the recent trend to conserve and enhance wetlands for wildlife. The main use of these wetlands is now passive recreation, comprising primarily aesthetic activities and education and research.

1.3.4.4 Government Jurisdictions and Policies

Federal, state, and local governments each have important and often overlapping jurisdictions in the Elkhorn Slough. The U.S. Army Corps of Engineers has jurisdiction over dredge and fill operations in navigable waters and adjacent wetland areas under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act. The U.S. Coast Guard also has jurisdiction over navigable waterways, particularly obstructions, abutments, weirs and other navigation hazards. The U.S. Fish and Wildlife Service is responsible for rare and endangered species in the slough, and the National Marine Fisheries Service is responsible for marine fish and water quality. The Environmental Protection Agency oversees wetlands and water quality effects, especially from dredging, filling and runoff. The Soil Conservation Service and Food and Drug Administration are concerned with erosion and pesticide problems in the slough watershed. These are the primary federal agencies with important jurisdiction in the slough or its watershed.A number of state agencies also have jurisdiction in Elkhorn Slough. The State Lands Commission determines the extent of state ownership in wetlands and tidelands and grants leases for certain operations such as aquaculture. The State Coastal Commission has jurisdiction for planning and development in the coastal zone. The State Water Resource Control Board is responsible for implementation of water quality standards. Department of Fish and Game is responsible for rare and endangered species, fisheries, wetlands, and aquaculture. The Wildlife Conservation Board purchases lands for the Department of Fish and Game. The Department of Health Services has jurisdiction over pesticide and mosquito problems.Among local agencies with jurisdiction in the slough, the Moss Landing Harbor District oversees some state lands and develops and maintains harbor facilities. The Regional Water Quality Control Board is responsible for implementing water quality standards in the central coast region. Monterey County has jurisdiction over many activities in the slough and its watershed. The Public Works Department has responsibility for public street and road maintenance, and maintenance of culverts under those roads. The Environmental Health Department oversees water quality and public health. The Planning Department is responsible for development permits and the Agricultural Commission oversees pesticide use and other agricultural land use practices.

1.3.4.5 Study Area Boundary

The preceding discussion of the slough's natural history was not limited to a particular geographic area, often covering the entire central bay or the other sloughs and wetlands that connect directly with Elkhorn Slough. In general, this plan is restricted to the Elkhorn Slough east of the Highway One bridge, and does not include the Moss Landing Harbor, the Moss Landing Wildlife Area (old salt ponds), Moro Cojo Slough, Bennett Slough and the Old Salinas River (see Figures 1-2 and 1-2). These other wetland habitats are considered in Harbor District (Moss Landing Harbor and adjacent areas), Monterey County (Moro Cojo and Old Salinas River), and Department of Fish and Game plans (salt ponds). The upper boundaries of Elkhorn Slough are considered the historical and present wetland habitats under the influence of tidal waters. The slough's watershed and larger geographic areas are considered whenever they are important in defining, understanding and solving problems within the slough study area.

1.3.4.6 Purpose and Need for Plan

This plan was mandated and given a high priority in the North Monterey County Land Use Plan. It is consistent with state and federal legislation for wetland management and enhancement, particularly Section 30240 of the California Coastal Act, concerning use and development in environmentally sensitive areas such as coastal wetlands.

LAND USE	Percent Area in Impervious Surface	Percent Area in Bare Ground
Chapparal	0.0	6.0
Oak woodland	0.3	1.1
Eucalyptus	0.0	3.2
Pasture & grassland	1.3	6.5
Rowcrops- artichokes	0.2	63.1
Strawberries	0.2	69.5
Orchards	0.3	93.2
Commercial	33.1	51.4
Industrial	22.3	48.2
RESIDENTAL USE		
51- acre parcel & greater	0.6	9.6
31- to 50- acre parcel	0.6	7.9
15.5- to 30- acre parcel	2.9	13.2
10- to 15.4- acre parcel	0.5	8.1
5- to 9.9- acre parcel	1.9	9.9
2.4- to 4.9- acre parcels	9.2	3.8
1- to 2.3- acre parcels	9.6	14.2
0.5- acre parcel and less	15.7- 59.1	0.8- 51.4

Table 1-3. The percent area of each parcel type (land use category) covered with impervious surfaces (including roofs and pavement) and bare ground in the upland watershed of Elkhorn Slough. From Dickert and Tuttle (1985).

CHAPTER 2. EROSION AND SEDIMENTATION

2.1 INTRODUCTION

Coastal wetlands are usually dominated by depositional processes rather than erosion. River valleys are invaded by rising sea level and salt marshes commonly grow seaward over adjacent mudflats as the sea continues to rise (Redfield 1972, Atwater et al. 1979, Schwartz et al. 1986). As sea level stabilizes, the new embayments and wetlands trap sediment and fill with fine deposits. This is the history of the Elkhorn Slough during the last 8 to 12 thousand years (Schwartz et al. 1986). In California, a number of human activities especially lumber operations in watersheds greatly increased erosion and the subsequent deposition into some coastal wetlands (Mudie and Byrne 1979). Deposition is also enhanced by diking wetlands and restricting water flow over large areas. Elkhorn Slough would certainly follow this depositional pattern if the Moss Landing Harbor had not been constructed (Chapter 1). Because the harbor entrance is stabilized and maintained at the mouth of the slough, strong tidal currents scour Elkhorn Slough every day and the system is dominated by erosional processes, not deposition.

Nevertheless, in recent years there has been a large increase in soil erosion by strawberry farming in the slough's watershed. This erosion and deposition has been a major concern for county planners, soil conservation groups and local residents (Edwards 1984, Eisenman 1984). The most serious sedimentation problems within the slough are actually caused by large volumes of water eroding slopes with natural vegetation below agricultural fields. This chapter describes the erosion and deposition within the watershed and within Elkhorn Slough, relates the watershed to the wetlands, identifies the important environmental problems, and recommends solutions.

2.2 WATERSHED EROSION

A number of historical land use patterns probably caused limited erosion directly adjacent to the slough. Native Indians apparently burned the plateau to the west and north of the slough to improve deer hunting and food gathering (Gordon 1977). Since this is not steep ground and native vegetation undoubtedly recovered rapidly from these burns, the resulting erosion was probably small or highly localized. Before the turn of this century, several fans were formed along the western side of the slough which indicate locally high rates of erosion off the western plateau. Oak trees were removed for firewood and to produce grassland for grazing cattle throughout the watershed. However, this cutting produced little erodable bare ground. During the 1940's, manzanita was excavated for the large burl (root nodule) to make pipes and decorative flame burl wood pieces. The burls varied in size from 15 to 1000 pounds, but only 15-20% of the wood was adequate for making the Nissen Briar Burl pipes. While the excavation process removed vegetation and exposed bare ground, the total area of disturbed ground was very small.

The general changes in land use patterns in the watershed have been well documented since 1931 when aerial photographs are available for direct measurements (Chapter 1: Table 1-2). The overall pattern has been a marked increase in row crops such as artichokes and strawberries, especially directly adjacent to Elkhorn Slough. The ground is 60-70% bare of vegetation in these row crops (Chapter 1: Table 1-3).

Land Use	Total Acres	Erosion tons/ year
Bushberry	36	540
Dairy	70	280
Nursery	650	1,625
Orchard	797	3,190
Grain & pasture	1,237	3,715
Row crops (not berries)	9,000	45,000
Native vegetation	40,175	42,000
Industry & residential etc.	4,354	870
Strawberry sheet & rill erosion	3,900	38,900
Strawberry gullies (field roads)	---	90,000
Strawberry total	3,900	128,900
Total for Watershed	60,219	226,120

Table 2-1. Tons of sediment eroding each year from different types of land use in the Strawberry Hills Target Area of the Elkhorn Slough watershed (target area includes most of the watershed). From Soil Conservation Service (1984).

About 75% of the watershed's erosion is caused by human activities and 75% of this is caused by strawberries. Most of the sediment eroding from strawberry fields comes from gullies along farm roads (70%). The present rates of erosion are 8-145 tons/acre/year from strawberries and 15-12 tons/acre/year from flower production. Natural rates of erosion are about 1 ton/acre/year (Soil Conservation Service 1984).

Row crops were first established on the flat ground south of the Pajaro River (this area drains into the upper slough; Chapter 1- Figure 1-1) and on the plateau to the west and north of the slough. The first crops were potatoes and especially sugar beets which were widespread by the late 1880's (Lydon 1985). Artichokes were introduced during the 1930's and irrigation began shortly after. Presently, row crops such as artichokes occur on relatively flat land and cover over twice as many acres as strawberries. However, there is almost three times as much erosion from strawberry fields (Table 2-1). Strawberries first became an important local crop in the early 1950's, but the market collapsed in the mid 1950's. They became important again in the 1970's and are now well developed on the steep hillsides along the east side of Elkhorn Slough. The most conspicuous erosional features in the watershed occur here. Large gullies have the greatest visual impact being easily seen from roads and local homes. One of the largest gullies in the watershed is adjacent to the recreational area at Kirby Park. This gully is formed by runoff from strawberry fields on steep slopes. The largest and most conspicuous depositional fan in the watershed is at the base of the gully. The largest gullies have been cut in the steep slope along the west slough forming the deposition fans discussed in section 2.4.3.2: West Slough.

It is important to emphasize the variation in sediment erosion from strawberry fields. There is a great variation among growers in reducing erosion. The difference is related to a number of factors. The most important cause of variation is the slope of the rows. Ever a slight slope causes major erosion problems. The Soil Conservation Service has an excellent program to reduce soil erosion from strawberry fields (Soil Conservation Service 1984, 1985). Their recommendations are considered in a later section (Problems and Recommended Solutions).

The Soil Conservation Service estimates that annual erosion and sedimentation damages in the watershed are about $3,000,000 per year or $791 per acre of strawberry land. Damages include $100,000 for cleaning up county roads, $1,667,500 for installing on-farm emergency measures (some farmers spend as much as $1,000 per acre), $37,700 for replanting strawberries, and $1,214,400 net income loss due to land going permanently out of production (Soil Conservation Service 1984). None of the environmental damages have been assigned a monetary value.

2.3 SLOUGH EROSION

The Elkhorn Slough was a depositional system until the Moss Landing Harbor was constructed from June 1946 to September 1947. The slough was a shallow embayment with water depths of 1-2 feet except in a small channel where depths were about 3-4 feet or less. The natural history of the early slough is described in Chapter 1. This setting was dramatically changed when the harbor jetties were constructed and the mouth of the slough opened directly into Monterey Bay. The harbor opening was first cut at a low tide so the slough was drained of most of its water, revealing a broad flat bottom and a narrow (about 15 feet) steep sided channel only 3-4 feet deep at the mouth (per. comm. with Charlie Vierra). The entire slough became severely eroded. The new channel scoured rapidly and is now over 20 feet deep and 300 feet wide at the slough mouth.

The rapid erosion of the main channel is indicated further by the loss of Round Island which was located off Seal Bend at the first major bend in the slough. A small boy could jump from the point to the island before the harbor opened (per. comm. with Charlie Vierra). Aerial photographs and local residents document the rapid decrease in island size, the opening of the gap between the island and the point, and the eventual disappearance of the island in the early 1950's.

Today tidal currents suspend and transport large quantities of sediment from the slough into Monterey Bay during each low tide. The previously clear waters of the slough (per. comm. Bill Lehman: Chapter 1) are now laden with sediment and murky.

The tide exposed large areas of mudflats throughout the slough which had not been exposed before the harbor opened. Today mudflats end abruptly in steep erosional features at the channel edge. These mudflats are probably remnants of the large, flat and shallow bottom of the pre-harbor slough. Because the aerial photographs were taken at different tidal heights, it is impossible to measure the erosion of mudflat habitat since the harbor opened. Nonetheless, the existing erosional features indicate that intertidal mudflats are probably eroding today, but at unknown rates. Local residents, Charlie Vierra and Louis Calcagno, have also observed mudflat habitat disappear near their lands (shown in Figure 1-9).

The total area of the vegetated salt marsh decreased dramatically from 1931 to 1980 in the Elkhorn Slough (Dickert and Tuttle 1980 and 1985). The reduction was not caused by erosion or sedimentation, but by diking, ditching and draining wetlands (Chapter 1). The reduction was much greater in the Moro Cojo Slough and around the Salinas and Pajaro Rivers (Gordon 1977).

Within the Elkhorn Slough, the widths and borders of salt marshes were not destroyed and remained relatively unchanged. Measurements from aerial photographs show little change in the position of the outer edge of the salt marsh or in its total width before and after the harbor opened. Marsh widths were measured at 10 sites from aerial photographs taken between 1931 to 1980 and only average 1% change. However, major internal erosion within vegetated habitat, which is continuing today, is indicated by measurements of the pickleweed marsh. In 1931, most of the salt marsh was covered with a thick growth of pickleweed (over 60%). The area of bare ground (tidal creeks and mud pans) increased from less than 10% to over 50% from 1931 to 1980 and the change continues into recent years (Figures 2-1 and 2-2). All the major tidal creeks that drain the marsh have increased steadily in width since the harbor opened. Even in the last decade rates of tidal creek erosion are almost 1 foot/ year (Table 2-2, Oliver et al. in prep.).

The reduction in plant cover may be caused by the salt marsh dipping slightly into the deep channel eroded by the tide. If the marsh habitat subsided as much as several inches to a foot, the additional tidal immersion time for pickleweed may kill the plant or reduce its cover so erosion is more effective. Eventually this idea can be tested by measuring the elevations of salt marsh habitats with contrasting densities of plant cover.

The accuracy of estimating plant cover from aerial photographs was tested by comparing locations which are still covered by dense pickleweed. Measurements from aerial photographs show little change in plant cover from 1931 to 1980 at sites where independent field observations show little change. Most of the sites with little temporal change in plant cover were diked to make ponds for hunting waterfowl. Although some dikes were breached by the tide, the intact ones apparently prevented erosion of the enclosed marshes by reducing tidal currents (Figures 2-1 and 2-2).

In general, erosional features predominate along the main channel of the slough. Vertical cliffs (often several feet high) calve from the salt marsh along the main channel and many tidal creeks. The extensive burrowing activities of numerous mud crabs probably hasten this erosion (Sliger 1981). Even at the head of the slough at Hudson's Landing, there are no depositional features where the culverts drain under Elkhorn Road. The slough side of the road is a nearly vertical face and the rock rubble near the culverts is clear of sediment. One of the most severely eroded and modified portions of the salt marsh is located almost seven miles from the mouth of the slough near Hudson Landing (Figure 2-2).

The erosion along the main channel is also reflected in the loss of upland habitat near the mouth of the slough. Just east of the Highway One bridge, a large tidal eddy continues to erode the upland edge killing pine and cypress trees next to the Vierra homestead. The rem

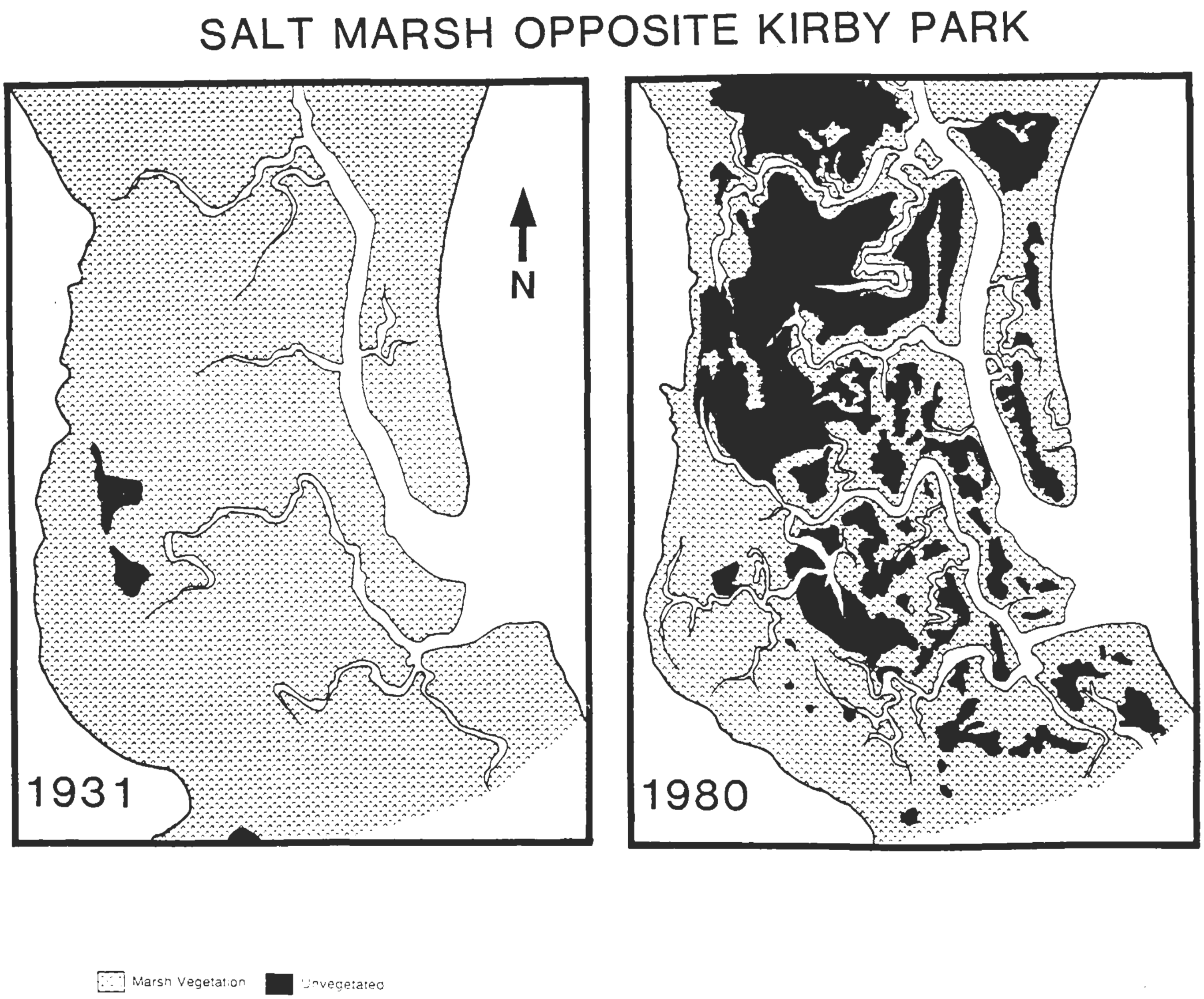


Figure 2-1. Changes in the area of vegetated and unvegetated salt marsh caused by erosion between 1931 and 1980 in the mid slough (from Bruhn et al. in prep.).

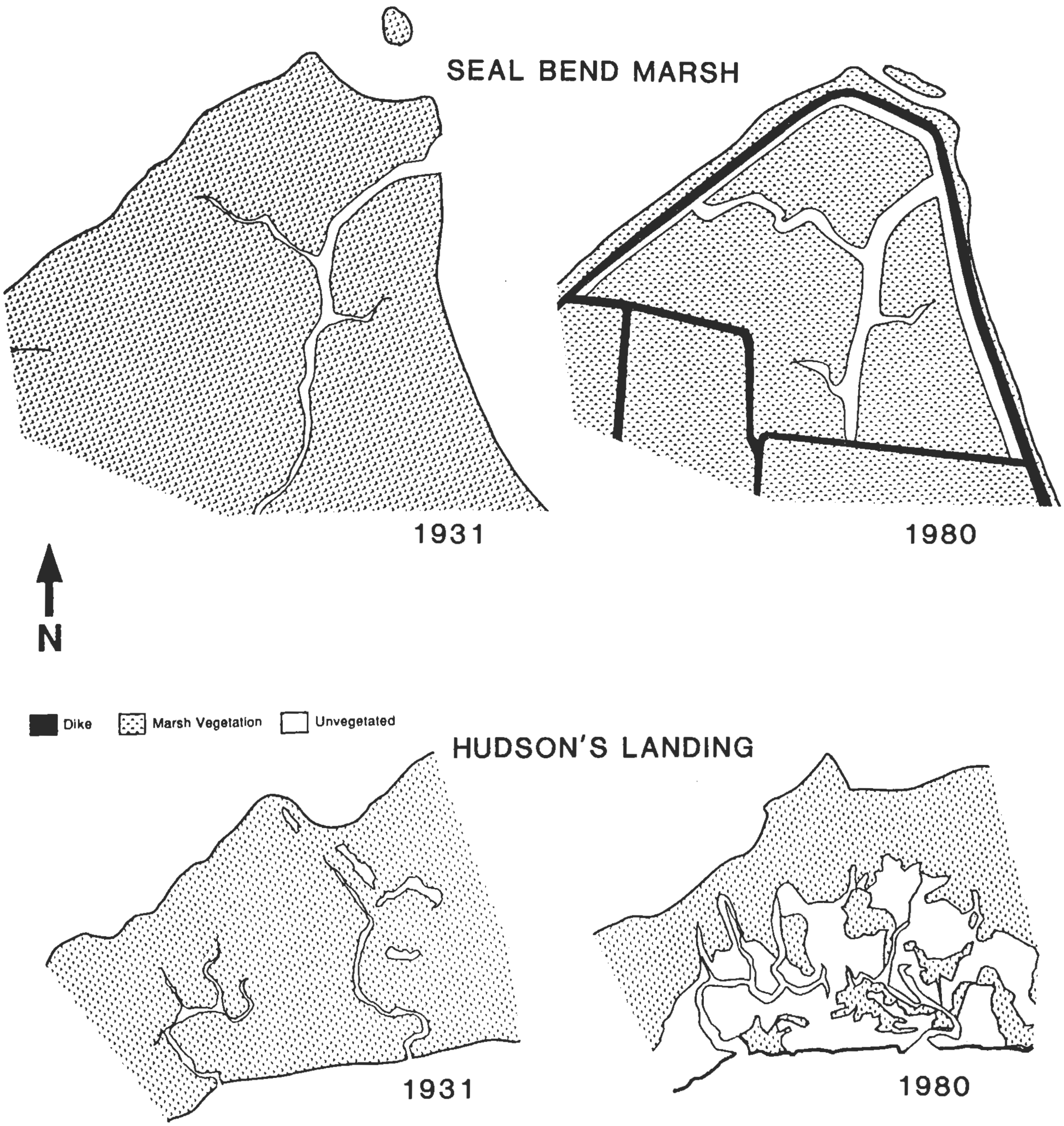


Figure 2-2. Changes in the area of vegetated and unvegetated salt marsh caused by erosion between 1931 and 1980 at the mouth (the diked Seal Bend Marsh) and head of the slough. Note the loss of Seal Bend island after the harbor opened.

Marsh Area	Channel Width in Feet 1931	1949	1966	1980	% change 1931-80
The Nature Conservancy	20	29	32	43	109%
Kirby Park	47	43*	46*	53	13%
Mid Slough	51	65	64*	71	39%
Packard Ranch	29	32	55	67	135%

* Within measurement error (<5%) from older black and white photographs

Table 2-2. Changes in the widths (feet) of major tidal creeks draining the *Salicornia* salt marsh along the west and north side of Elkhorn Slough from 1931 to 1980. The harbor entrance channel was opened in 1947 between the 1931 and 1949 aerial photographs (from Oliver et al. in prep.).

nants of 6 dead trees that were killed in the last decade are still present here. Just up-slough from this site, the same eddy has deposited considerable new sand and created a narrow, low sand dune that was not present 10 years ago. The source of this sand is probably the dunes along Moss Landing State Beach, although recent dune improvements by the State Department of Parks will surely decrease dune sand erosion. The remaining south side of the slough is diked from the Vierra property to the Calcagno dairy. When these dikes were constructed in the late 1940's and early 1950's, there was a high mudflat border present, more than 50 feet wide. Today the borders are gone and the dikes are being eroded directly. The dikes protecting the Vierra Marsh are presently threatened by erosion.

2.4 SEDIMENTATION

Where does eroded sediment go in the watershed? The Soil Conservation Service estimated the quantities of sediment delivered, retained and passed through various upland and wetland habitats (Table 2-3). The salt water wetland estimates are suspect because they do not account for the erosional processes in Elkhorn Slough discussed in the preceding section. During a single rain storm, large quantities of sediment from the watershed are deposited on local roads around the slough. No deposition is more conspicuous. Over the past several years, most local growers have become effective at removing road deposits before the county road department, which charges the grower for the price of sediment removal from county roads. Much sediment is also deposited at the base of hillsides below strawberry fields.

Dickert and Tuttle (1985) show the location of a number of sediment fans around the slough based on a 1980 aerial survey. Since their map does not indicate if the fans are in the slough or not, we re-examined the same photographs to determine if the depositional fans were located directly in the pickleweed marsh, in pickleweed marsh that was diked, in freshwater ponds or wetlands, or in non-wetland habitat (Figure 2-3). While erosion of upland soil is a problem

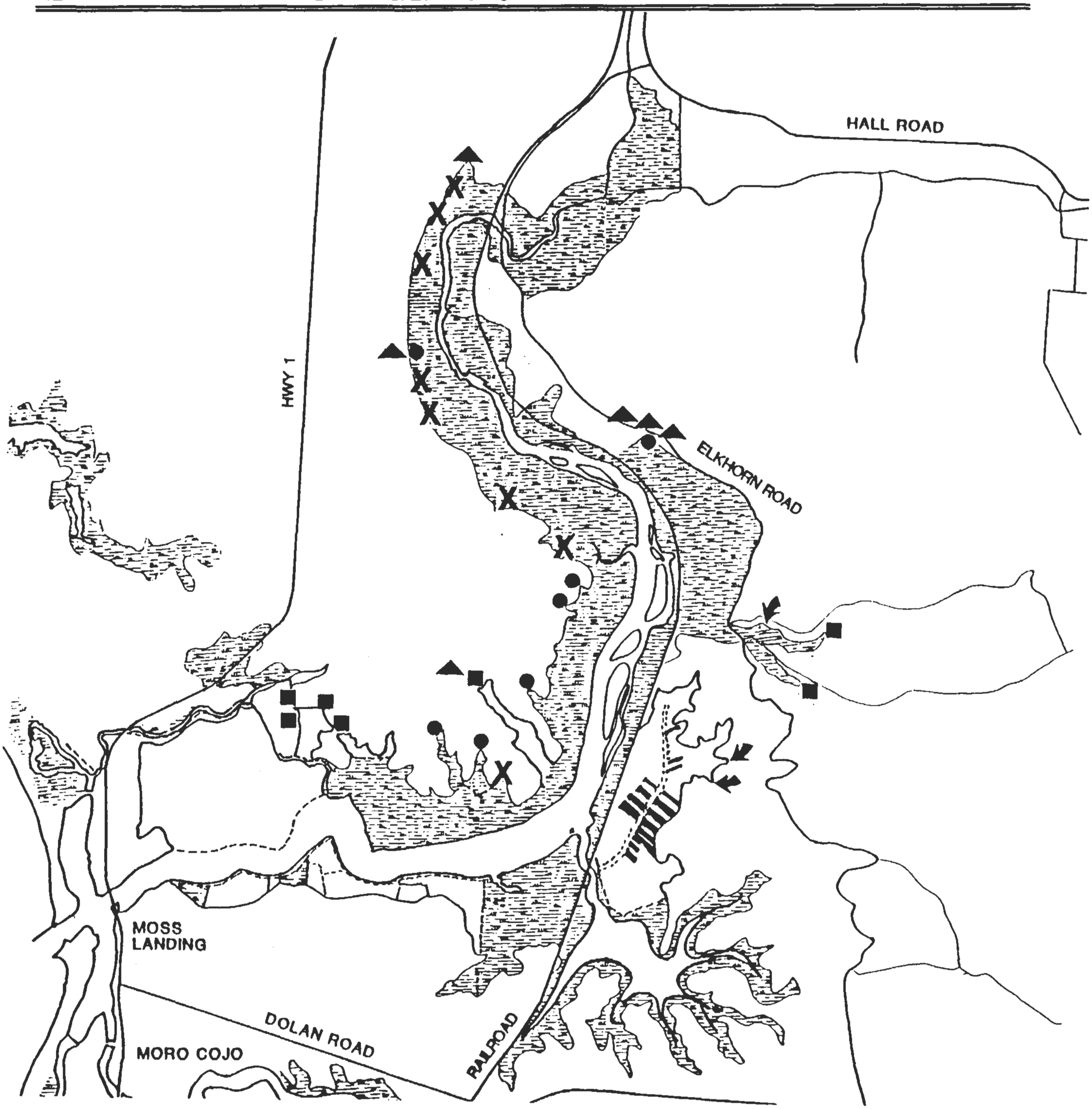


Figure 2-3. Sites of sediment deposition around and in Elkhorn Slough from Dickert and Tuttle (1985). Triangles= fans on non-wetland; Squares= fans in freshwater ponds; Circles= fans on diked pickleweed marsh; Crosses= fans on undiked pickleweed marsh; Arrows= fans measured by SCS in Table 2-4.

Sediment Site	Tons of Sediment per year Delivered	Retained	Passing	Remarks
Upland basins	226,400	77,900	148,500	65% passing
Roads & roadslides	98,000	49,000	49,000	$105,000 removal/ yr.
Streams	99,500	20,300	79,200	
Mudflats and wetlands	18,300	18,300 *	0 *	1 ft./ 54 yr. *
Elkhorn Slough	26,200	5,200	21,000	3 acre feet retained
Moro Cojo Slough	17,600	17,600	0	empties to Elk. Slough
Old Salinas River	17,100	8,600	8,500	empties to Elk. Slough
Pacific Ocean	29,500 *	29,500 *	0	13% sed. delivery ratio

* These numbers are probably incorrect. Less sediment is retained on mudflats and wetlands and more passes into the ocean because of intense erosion within the slough.

Table 2-3. Tons of sediment delivered to, retained in, and passing through different habitats in the Strawberry Hills Target Area of the Elkhorn Slough Watershed (target area includes most of watershed). From Soil Conservation Service (1984).

	Total Area (sq. ft.)	Deposition Thickness (feet)	Deposit (tons)	Time to Develop	Rate (tons/yr.)
Hidden & Strawberry Valley (freshwater wetland)	10,500	0.8	450	1958- 78	21
Hidden & Strawberry Valley (freshwater wetland)	39,150	0.5- 4.0	2,923	1980- 84	730 *
Elkhorn Dairy Road (freshwater wetland)	165,000	2.0- 4.3	51,560	1950- 84	1520 **
Upper South Marsh (saltwater wetland)	50,000	1.0- 2.0	3,950	1950- 84	110

* 30 to 60 years to fill wetland depending on the level of fill.
** 22 years to fill wetland.

Table 2-4. Deposition of sediment into three wetlands in the Elkhorn Slough National Estuarine Research Reserve. Location of the fans is shown in Figure 2-3. Data from an unpublished field survey made by the Soil Conservation Service.

throughout the watershed, the deposition of this eroded sediment is a much greater problem in some habitats than in others.

2.4.1 Freshwater Ponds

Half of the sediment fans around the slough are in non-wetland sites or in freshwater wetlands and ponds. The most important deposition within the upland watershed occurs in freshwater ponds and wetlands. Some of these wetlands are filling with eroded sediment at a rapid rate (Table 2-4). The Soil Conservation Service measured the deposition into three freshwater wetlands on the Elkhorn Slough National Estuarine Research Reserve. At the present rate, one of these wetlands may fill within 20 years (Table 2-4). These are not isolated examples. At the corner of Elkhorn Road and Walker Valley Road, the area of freshwater wetland has decreased at least 50% since strawberries were planted in the Long Valley, which drains into the wetland. Many freshwater ponds also receive eroded sediment (Figure 2-3). In several cases legal action was necessary to stop sediment eroding from a neighbor's land. Except for the sanctuary wetlands, there is no information on the rates of deposition into other freshwater wetlands and upland habitats that can be degraded or destroyed by sediment deposition.

All the freshwater ponds on the Packard Ranch (Figure 2-3) were constructed before 1931 by diking old salt marsh. The 1980 fans on the ranch are all located in drainage areas that probably supported smaller freshwater wetlands grading into the adjacent salt marsh. Since cattle grazing was the cause of this erosion and has been reduced on the ranch, the erosion around these ponds is likely to decrease sharply as gullies and other bare areas are re-vegetated. Freshwater plants are now being planted in the ponds for waterfowl habitat and general plans for terrestrial planting are being discussed. None of these upland sediment fans have any effect on the existing salt water wetlands of the slough.

2.4.2 Carneros Creek

Carneros Creek is the major creek draining into Elkhorn Slough (Figure 1-2). It flows along a drainage ditch in a highly modified riparian corridor. After the rainy season, some adjacent lands are plowed and cultivated right to the channel edge. There are major inflows of eroded soil ino the channel and the adjacent flats flanking the channel. In the past the channel has filled with sediment and vegetation and was dredged for flood control in 1957.

Today the sediment is primarily eroded from steep slopes where strawberries are grown along Hall Valley (Dickert and Tuttle 1980). While much of the sediment enters the creek channel, much more is deposited along the broad flats next to the channel. The channel depth varies considerably as sediment is deposited and transported down the creek (Dickert and Tuttle 1980). While no comprehensive survey of sediment deposition on Carneros Creek has been completed, limited field observations show deposition of sand in the channel and on adjacent flatlands. Lighter sediments (silts and clays) either deposit in the Blohm marsh or are carried out into the slough. Further documentation of sediment deposition on the Carneros Creek floodplain is needed. Depositional fans are not evident in the Blohm-Porter Marsh (Figure 1-5), where the Carneros Creek empties before entering Elkhorn Slough.

Development, including filling, grading and construction, with the exception of necessary utility lines and appurtenant facilities are prohibited in the 100-year floodway of Carneros Creek. Further, flood control projects to protect new development are prohibited. If flood control projects are proposed, natural stream bed maintenance shall be preferred over channelization, trenching or construction methods. Natural streambed maintenance, including broad, low-angle contouring, is the environmentally preferred method of stream maintenance over channelization.

2.4.3 Salt Marshes

2.4.3.1 East Slough

The other half of the sediment fans occur on the natural pickleweed marsh or on pickleweed marsh that has been diked. Fans along the eastern side of the slough occur in old marsh that was first diked for hunting and later to create pasture land. When salt marsh is diked, ditched and drained for pasture, the elevation of the marsh subsides 2-4 feet because of a re-orientation of clay particles as the marsh soil dries and compacts (Krone 1969). This is an irreversible process which occurred in the back arms of Parson Slough, the Reserve's North and South Marshes, the Kirby Marsh, and the wetlands on the east (up slough) side of Elkhorn Road. A remarkable number of dikes have been constructed in the Elkhorn Slough (Chapter 1: Figure 1-4). When tidal action is returned to these subsided pastures, the land elevation is several feet too low to support the vegetated salt marsh that once lived there. As a result, deposition of soil eroded from the adjacent watershed is actually producing high areas where marsh plants can re-establish. This sediment deposition occurs at the expense of local top soil and leads to aesthetically undesirable gullies and unvegetated sediment fans. It is unwise to raise subsided salt marshes by eroding farm land. However, the deposition of sediment into these large areas of diked and subsided former marsh does not threaten the slough.

2.4.3.2 West Slough

The remaining sediment fans occur along the western side of the slough at the upper edge of the existing salt marsh (Figure 2-3 and 2-4). Some of these sites were also diked for hunting, but were not dried and thus did not subside. Aerial photographs and field surveys indicate significant expansion of several sediment fans along the western slough in recent years, probably within the last two decades and especially since 1940 when irrigation of row crops became common.

These fan deposits are primarily eroded from the steep slopes below the agricultural fields where agricultural drainage water has cut large gullies with vertical sides. Rain and irrigation water runs off the relatively flat fields where over 60% of the ground is bare (Table 1-3). This water does not carry much sediment, but is channeled into drainages down the steep slopes flanking the west slough. Although these slopes are heavily vegetated with native and introduced upland plants, strong water flows have cut large and deep gullies and deposited this slope sediment on the upper pickleweed marsh.

Some fans are more active and thus larger than others (Figure 2-4, Table 2-5). Assuming that most fan growth occurred since 1940, when irrigation became widespread, the rate of deposition on the most active fan is 219 tons per year (Fan #7, Table 2-5, Oliver et al. in prep.). This rate is comparable to the depositional rates in the freshwater marshes along the east slough (Table 2-4). Rates of deposition are much less on the smaller fans along the west slough: 13 tons/year on fan #2 and 42 tons/year on fan #4 (Table 2-5). Fan size and depositional rate are clearly related to the size and depth of gullies eroded in the adjacent slopes (Oliver et al. in prep.). The biggest canyon is above the largest sediment fan (Fan #7, Figure 2-4). Different rates of sedimentation are also illustrated by changes at the fan surface (Table

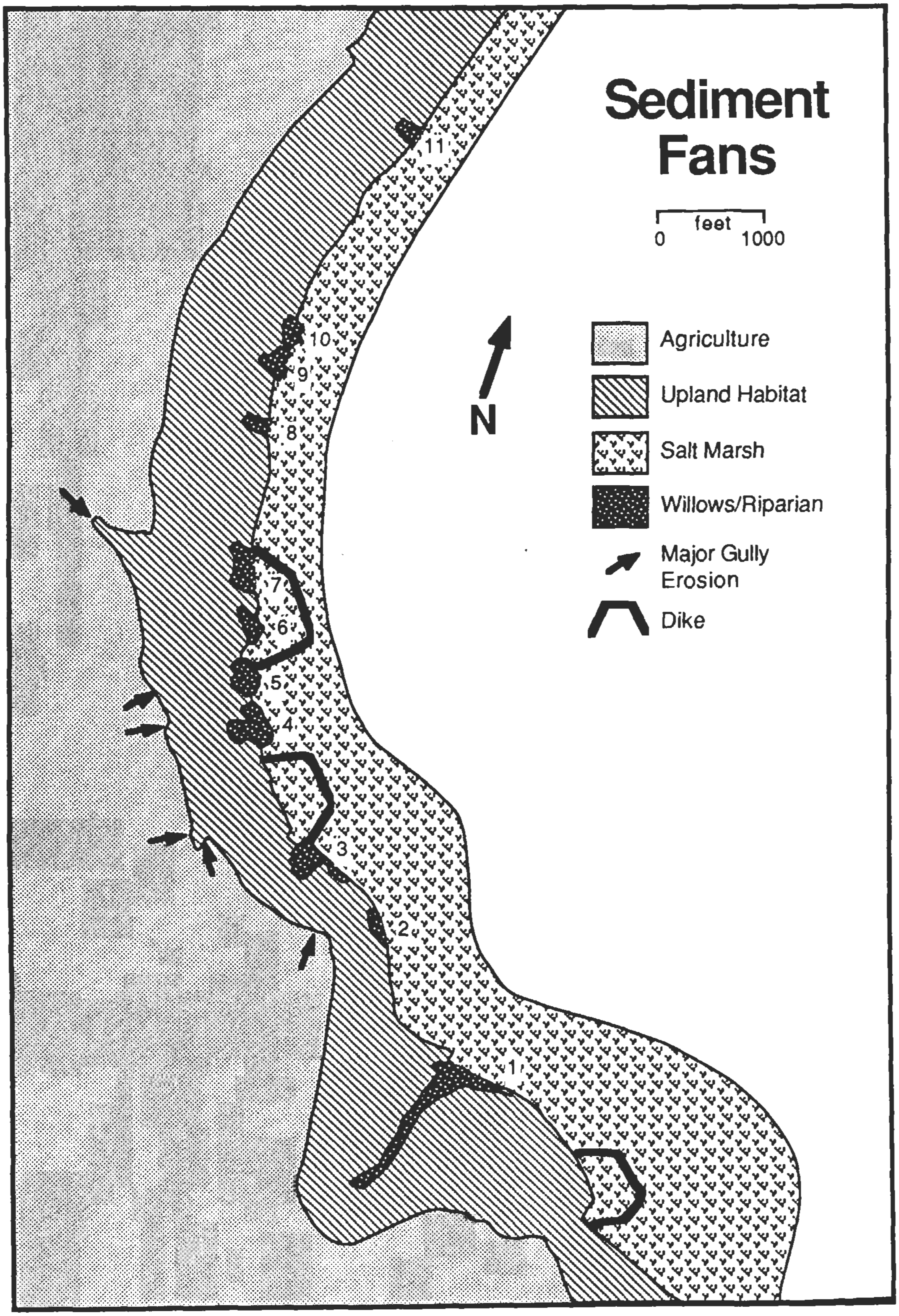


Figure 2-4. Location of sediment fans on salt marsh along the western side of Elkhorn Slough.

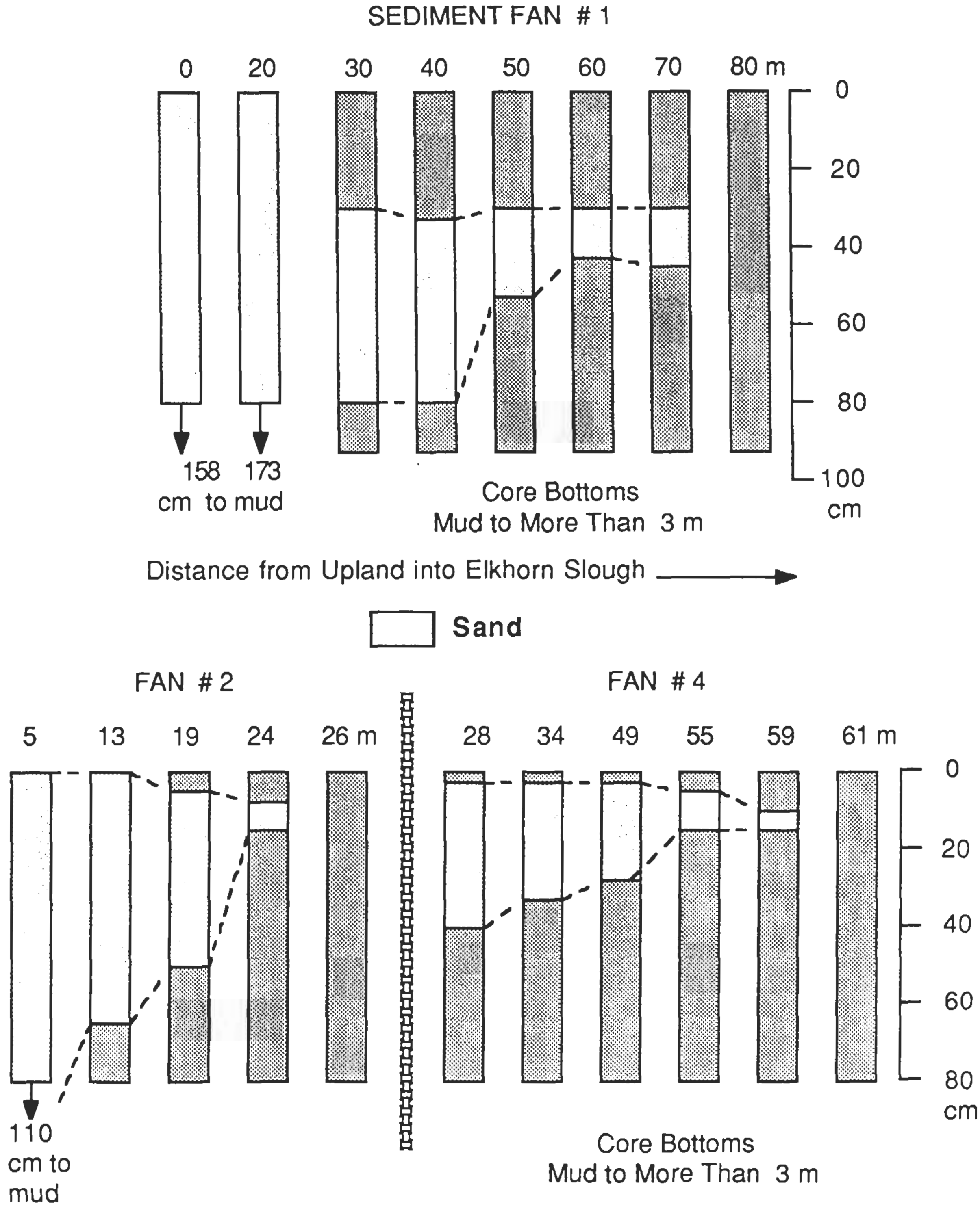


Figure 2-5. Vertical profiles of three sediment fans on the salt marsh along the western slough. Fan #1 is older and buried. See Figure 2-4 for locations.

2-6). However, these short-term measurements are highly variable from one rain storm to another. They are also confounded by the erosion of drainage channels through the fan, which undercut and rework the existing fan deposits.

In contrast to sedimentation on the diked and subsided pastures along the eastern slough, sediment deposition into the diked and undiked salt marsh along the western slough has obvious impacts on the pickleweed marsh. These ecological effects are similar for the diked and undiked marsh along the western slough. All of the sediment fans originate below gullies that drain the adjacent, broad western plateau. The fans bury pickleweed and raise the marsh elevation allowing freshwater plants to invade over 50 feet into the salt marsh. Some of the fans are simply recolonized by pickleweed.

Upland sediment occasionally slumps into the marsh leaving conspicuous slump scars in the upland bank. One large slump spread more than 50 feet into the upper marsh just north of the The Nature Conservancy barn in 1982-83. The slump was probably caused by agricultural drainage from the adjacent, steep hillside. This is the only part of the steep hillside in cultivation. The rest is well vegetated (Figure 2-4). The slump was rapidly invaded by willows at the upper edge and by pickleweed on most of the resulting fan.

Finally, field surveys revealed two old sediment fans of coarse sand buried beneath about one foot of fine marsh deposit (Figure 2-5). These buried fans are not the result of erosion from row crops on the adjacent plateau. They were deposited well before 1940 (Oliver et al. in prep.), perhaps during a period of heavy rainfall after local areas were burned by Indians removing vegetation and exposing bare ground (Chapter 1).

2.5 PREVIOUS SLOUGH PLAN

Dickert and Tuttle (1980, 1985) developed a plan linking the cumulative impacts of watershed development to Elkhorn Slough. The plan makes valuable contributions to local planning, but provides an incomplete impression of the role of erosion and sedimentation in the slough. Since the plan continues to influence county and regional planning and these problems are central to future planning, we briefly consider its strengths and weaknesses.

Dickert and Tuttle examine how land use patterns have changed in the subwatersheds of the slough from aerial photographs beginning in 1931. They measure changes in the area of bare ground and ground covered with impervious surfaces such as roads (see Tables 1-2, 1-3). They call attention to the problem of soil erosion from strawberry fields on steep slopes which is a major focus of the Soil Conservation Service (Edwards 1984, Eisenman 1984, Soil Conservation Service 1984, 1985). They develop a planning approach that regulates land development by restricting the area of bare ground exposed by a new development.

Their planning approach is sound and realistic: In future development, do not expose any more bare ground than the maximum amount of bare ground present between 1931 and 1980. These dates are selected because there are good aerial photographs since 1931. Therefore, changes in bare ground can be estimated. Bare ground is used as an index of watershed impact because it can be related to erosion susceptibility. Using the maximum exposure of bare ground as the "land disturbance target" insures that future development is no worse than the past.

Fan Number	Number of Cores	Buried Fan	Active Fan	Rank By Depositional Activity
1	11	yes	yes	6
2	4	no	yes	5
3	2	no	yes	2
4	5	no	yes	4
5	4	no	yes	3
6	12	yes	no	7
7	11	no	yes	1*

* 1= most active

Table 2-5. Depositional fans cored along the west side of Elkhorn Slough during July 1986. Fan locations shown in Figure 2-4 (from Oliver et al. in prep.)

Deposition on *Salicornia* marsh	Erosion (inches)	Deposition (inches)	Activity (sum)	
The Nature Conservancy (5) *	.15	.35	.50	Freshwater Fan
The Nature Conservancy (6)	1.88	5.27	7.15 * *	Freshwater Fan
Packard Ranch (10)	.54	1.51	2.05	Freshwater Fan
Packard Ranch (11)	.02	.14	.16	Freshwater Channeled
Natural Vegetation (1,2,3,4,7,8,9,26,27)	.06	.06	.12	Average of Nine Sites

* transect numbers from Dickert and Tuttle (1985) in parenthesis and do not relate to numbers in Figure 2-4.
* * this high value may be caused by channel movement.

Table 2-6. Deposition and erosion of sediment on the upper *Salicornia* marsh where freshwater drains into the west side of Elkhorn Slough compared to deposition and erosion in sites covered with natural vegetation in the upland watershed. From Dickert and Tuttle (1980).

Obviously, bare ground is not the only measure of land disturbance. Water pumping, septic tank drainage, wildlife changes, and any number of other factors can be equally or more important, but none of these can be measured as easily as bare ground, which can be related to other disturbances besides erosion (e.g., visual impacts, wildlife changes, roads and traffic).

This planning approach is not arbitrary. The area of bare ground can be related to the probability of erosion. Erosion from strawberry fields is one of the major environmental problems in the watershed adjacent to the slough. The selection of the actual "land disturbance target" is conservative. Cumulative impacts are assessed by considering bare ground changes throughout the watershed for each new development.

The prevention of impacts to Elkhorn Slough is the primary reason for developing past watershed plans. Dickert and Tuttle (1985) relate "impacts of watershed development to coastal wetlands", asserting that "protection of coastal resources, such as wetlands, requires better methods for assessing the cumulative impacts of land development". Their plan is based on the erroneous assumption that sedimentation is the main ecological and planning problem in the slough. However, erosion is the major process degrading every major habitat in the slough (2.3 Slough Erosion). Moreover, Dickert and Tuttle do not distinguish sedimentation in the freshwater wetlands above the slough from the severe tidal erosion within the slough. In summary, Dickert and Tuttle present practical recommendations for planning development in the uplands surrounding the slough.

Gordon (1977) provides the best general strategy for future planning in the slough's watershed. He clearly recognizes the major upland problem as erosion from strawberry fields on steep slopes and recommends replacement of berries with low density rural housing where native vegetation can be restored. This general strategy fits well with Dickert and Tuttle's (1985) land disturbance targets in the watershed.

2.6 MANAGEMENT PROBLEMS

The major erosion problems in Elkhorn Slough and its watershed are:

1. Erosion of the wetland habitats within Elkhorn Slough from tidal currents.
2. Erosion of soil from strawberry fields on steep slopes.
3. Erosion of large gullies along the steep, vegetated slopes above the west slough.
4. Visual impacts of erosion scars and unvegetated fans.

The major sedimentation problems in the slough and its watershed are:

1. Deposition of sediment into small freshwater ponds and wetlands above the slough.
2. Deposition of sediment in the Carneros Creek.
3. Deposition of sediment at the upper edge of the pickleweed marsh along the west slough.
4. Deposition of sediment along Elkhorn Road and other public and private roads.

See Chapter 6 for recommendations on these erosion and sedimentation problems and their implementation.

CHAPTER 3. WATER QUALITY

3.1 INTRODUCTION

The water quality of Elkhorn Slough has been changed dramatically by various human activities. The diversion of the Salinas River, diking and draining of surrounding freshwater wetlands, heavy use of groundwater and the opening of Moss Landing Harbor dramatically reduced freshwater input to the slough. The strong tidal currents changed the shallow and clear water of the pre-harbor slough into a deep lagoon bathed with muddy water. At low tides, the muddy plume reaches a mile or more into the Monterey Bay. It is essential to remember these important historical changes caused by freshwater diversion and the harbor when considering the present water quality problems. Elkhorn Slough is a highly modified system (see Chapter One). Today there are a variety of water quality problems in the slough and vicinity involving salinity, nutrients (nitrogen), bacteria, heavy metals and pesticides. Bacteria and pesticides are the major problems in surface waters, and salinity and nitrogen are the primary concerns in groundwater. Since there is probably little direct exchange between the surface waters of the slough and the major groundwater reservoirs (see Groundwater), the surface and groundwater problems are discussed separately.

3.2 SURFACE WATER

3.2.1 Nutrients in Surface Water

The ecologically most important nutrients in Elkhorn Slough are the several forms of nitrogen: nitrate, nitrite, and ammonia. Nitrate is the most abundant form. Nutrients enter surface water in the slough from agricultural runoff, sewage discharge, and sea water. The main ecological problem caused by nutrient enrichment is increased aquatic plant growth (eutrophication) (Carter and Bondurant 1976). Algal blooms can clog waterways, decrease flow rates, produce undesirable odors, and during decomposition decrease oxygen available for many animals. Eutrophication is a major periodic problem in the Salinas River (Engineering Science 1980).The major source of nitrogen in Elkhorn Slough is sea water, and the primary factor controlling local nitrogen concentrations is the tide. Concentrations of all nutrients are well correlated with the tidal curve (Smith 1973). Seasonal fluctuations in nitrate are linked to rain runoff in the winter. These pulses do not persist because of the strong mixing and flushing action of the tide. Nitrate values are usually low, ranging from 0.07 to 0.21 ppm in the lower slough and offshore waters, and 0 to 0.658 ppm in the upper slough (Smith 1973, Jagger 1981). Although Smith (1973) found high levels of ammonia near the Moonglow Dairy in 1970-1972, they were not present in 1975 (Broenkow 1977). However, Smith and Broenkow both found ammonia levels several times higher in the harbor and Old Salinas River Channel compared to Elkhorn Slough. These high values were attributed to the Castroville Treatment Plant, which now discharges into the Monterey Bay, and agricultural runoff. In 1980, the Regional Water Quality Control Board found low (<0.1 ppm) nitrate levels in Elkhorn Slough and thus no enrichment problems (Jagger 1981). Phosphate, another nutrient, is present in Elkhorn Slough in low concentrations, and tends to parallel nitrate, although there are significant diurnal variations in oxygen and phosphate caused by mudflat algal production (Smith

1973). No nutrient data are available since 1980.

3.2.2 Bacteria in Surface Waters

The major historical water quality problem in Elkhorn Slough is coliform bacteria. As described below, it was the primary cause of the demise of commercial oyster harvesting in the slough.

3.2.2.1 Commercial Shellfishing History

Commercial shellfishing in Elkhorn Slough began in 1923, when the Consolidated Oyster Company of San Francisco planted eastern oysters. The highest production was in 1931 and 1933, when 45% and 31% respectively of the state's total shellfish harvest came from this area (Bureau of Sanitary Engineering 1967). From the middle 1930's to the late 1970's, oysters were planted in the slough only intermittently. Coliform levels began to increase in the early 1960's. The last commercial oyster bed was closed by the State Department of Public Health early in 1967, after high levels of bacteria were found in 1966. Based on these data, public officials concluded that "no area within the estuary system is safe for harvesting shellfish for human consumption" (Bureau of Sanitary Engineering 1967). They recognized several sources in their order of importance to public health:

a. Castroville Sanitation District Sewage Discharge
b. Dairy wastes discharging into Elkhorn Slough
c. Onshore residences, fish processing plant, and commercial establishments with unsatisfactory sewage disposal.
d. Camping or other recreational areas without toilet facilities.
e. Boats which have onboard toilet facilities.

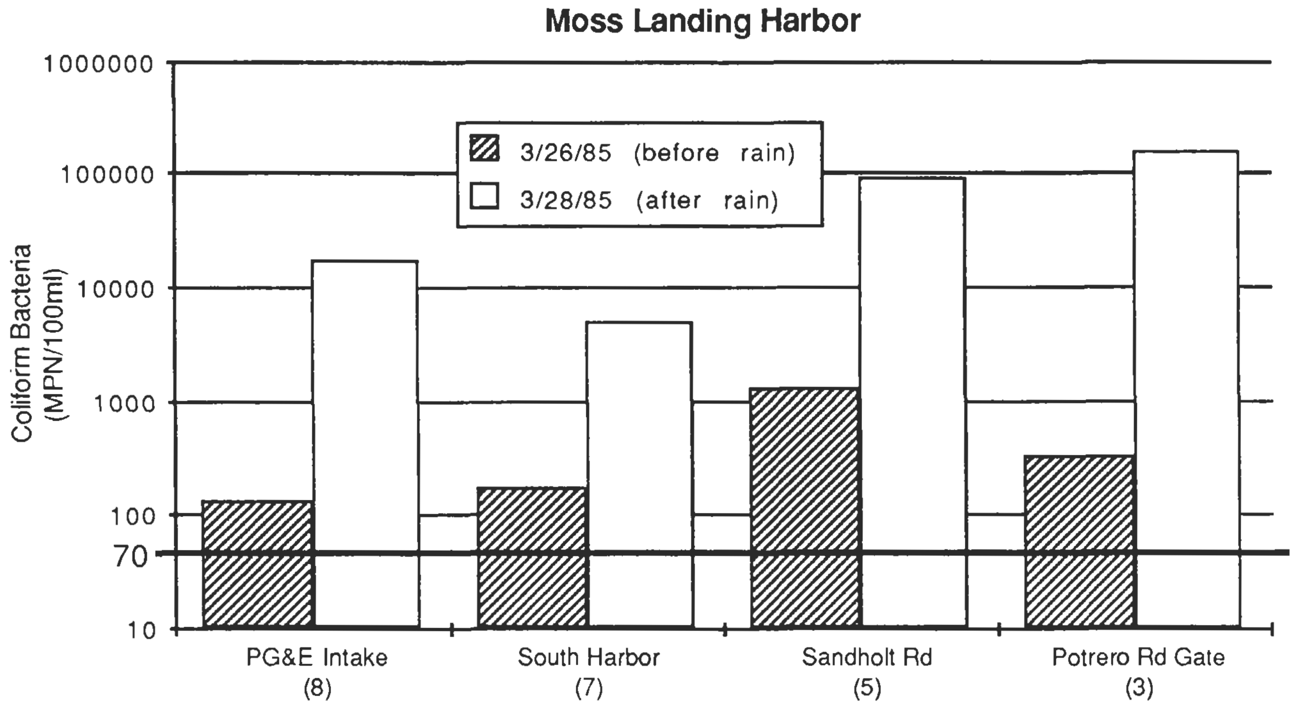
In 1969, the County Health Department posted signs warning against eating local clams.High levels of coliform bacteria were the basis for denying a permit to International Shellfish Enterprises (ISE) for raising oysters in Elkhorn Slough in 1974[1] . ISE found that the highest coliform levels occurred during and after rain and argued that the water quality was improving (ISE 1978). Although ISE started to raise many oysters in the slough, their marketing permit was denied in 1978, 1979, and 1980[2] . The Health Department granted a provisional marketing permit in 1981 with the condition that all oysters were depurated for 30 days in ultraviolet-treated water before sale[3]. ISE ceased operations in Elkhorn Slough in December 1983 without completing a depuration facility at Pescadero and with many marketable-sized oysters in the slough[4]. No commercial oyster operations use the slough for growing adult oysters today. As a result of high pesticide levels in mussels (see Pesticides), in 1985 the Monterey County Health Department issued a "health advisory" against eating shellfish from the slough. Because there is no actual quarantine on shellfish from Elkhorn Slough, the California Regional Water Quality Control Board has classified shellfish harvesting as an "existing

1) Memorandum from Daniel Chen, California Department of Health to Richard J. Hee, California Regional Water Quality Control Board, April 29, 1974.

2) Letters from California Department of Health to Paul Davis, ISE.

3) Letter from Richard McMillan, California Department of Health Services, to Dave Streig, ISE, dated August 11, 1981.

4) File Note by C.L. Bowen, California Department of Health Services, December 23, 1983.



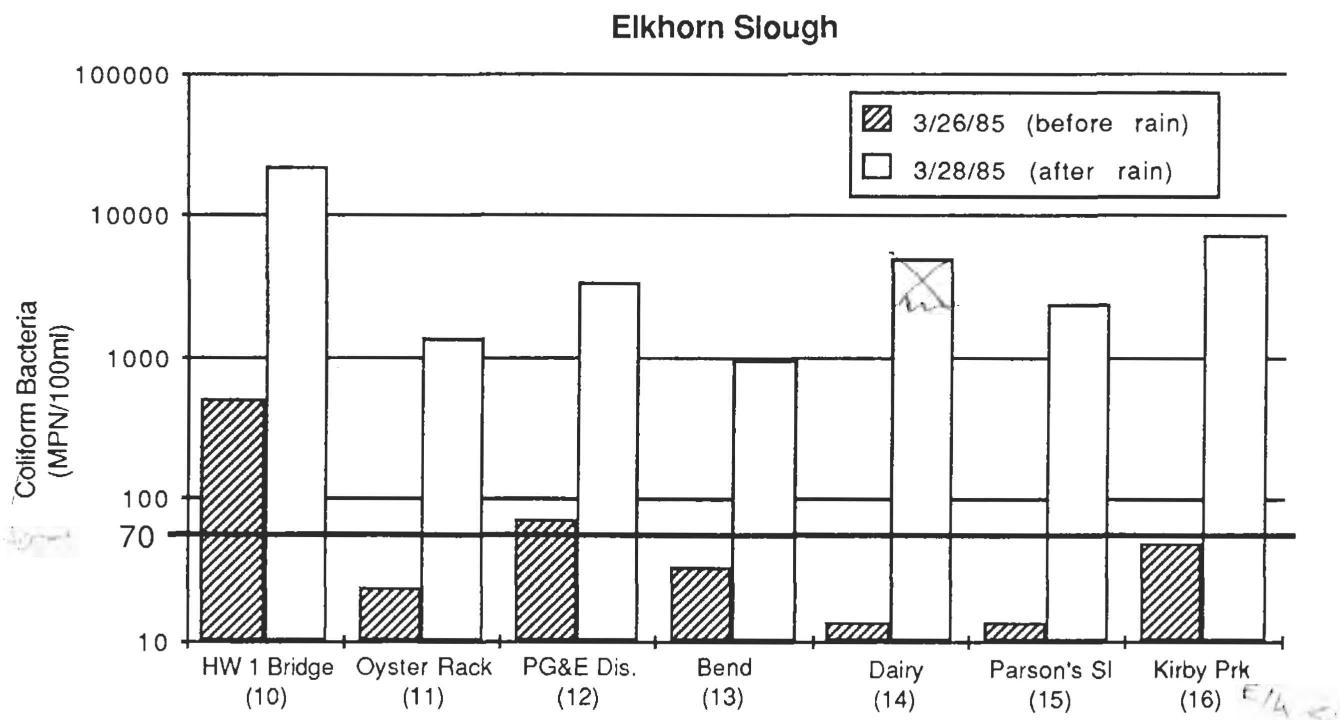


Figure 3-1: Coliform Bacteria Concentrations in Most Probable Number (MPN) per 100ml for 7 stations from Elkhorn Slough and 4 stations from the Moss Landing Harbor. Numbers in parenthesis are USFDA station numbers. Samples were taken on two days,one before and one after rainfall. Water with an MPN of over 70 is considered unsafe for human recreational activities and commercial shellfish harvesting Unpublished data from the US Food and Drug Administration.

Date	Station Location	Shellfish Type	Total Coliform	Fecal Coliform
3/20/85	PG&E Intake	Mussel	23,000	790
3/21/85	Parson's Slough	Mussel	230	130
3/22/85	Parson's Slough	Oyster	330	230
3/24/85	Seal Bend	Oyster	490	490
3/25/85	Seal Bend	Oyster	13,000	4,900
3/26/85	Seal Bend	Oyster	33,000	1,300
3/27/85	Seal Bend	Oyster	4,600	790
3/28/85	Seal Bend	Oyster	49,000	7,900

Table 3-1: Total and fecal coliform bacteria counts (in Most Probable Number (MPN)/100 grams meat) in shellfish tissue from Elkhorn Slough. Shellfish with fecal bacteria counts of greater than 230 MPN/100 grams are considered unfit for human consumption. Unpublished data from US Food and Drug Administration.

Coliform Bacteria (MPN/L)

Station	10/2/85	10/23/85	11/20/85	1/27/86	2/24/86	3/24/86
Hudson's Landing	91	>24000	36	170	210	16000
Kirby Park	36	<30	<30	40	16000	9200
PG&E Discharge	36	>24000	<30	230	490	4300
HW 1 Bridge	<30	>24000	36	<20	2400	720
Harbor Mouth	91	>24000	<30	170	340	490
North Jetty	<30	150	91	<20	490	330
Island	<30	>24000	<30	<20	310	0

Table 3-2: Water concentrations (Most Probable Number (MPN) per liter) of coliform bacteria from 7 stations in Elkhorn Slough and the Moss Landing Harbor. Unpublished data from the Monterey County Health Department.

	Spring		Fall	
	Mean	S.D.	Mean	S.D.
Aluminum	410	40	370	80.6
Arsenic	NA	--	5.9	.10
Cadmium	11	1.6	10	.35
Chromium	ND	--	1.6	.29
Copper	7.6	1.9	6.8	1.1
Lead	2.5	.5	1.3	.55
Manganese	8.9	.79	7.7	1.3
Mercury	.15	.043	.12	.009
Selenium	NA	--	1.7	.39
Zinc	110	15	67	6.7

NA= Not Analyzed ND=Not Detected

Table 3-3: Heavy metal concentrations in mussels (*Mytilus edulus*) transplanted to the Dairy in Elkhorn Slough in 1980-81. Shown are means and standard deviations in ppb wet weight for 6 month spring and fall transplants. Data from Stephenson et al (1981).

beneficial use" of Elkhorn Slough and Moss Landing Harbor[5].

3.2.2.2 Coliform Bacteria

The most recent comprehensive survey of coliform bacteria in the slough was conducted by the Federal Food and Drug Administration in March, 1985. Twenty stations were sampled in Elkhorn Slough, the Moss Landing Harbor, and the Old Salinas River once or twice a day over a 10 day period (Figure 3-1). The harbor usually contained levels of coliform bacteria considered unsafe for shellfish harvesting and human recreational activities. The slough waters usually had safe levels except during rainy periods. Coliform levels in both oysters and mussels from the slough were generally unfit for human consumption (Table 3-1). The ratio of total bacteria to fecal bacteria suggests that most of the coliform bacteria originate from non-human sources. These data were collected before the completion of the Moss Landing sewer system which diverted all Moss Landing septic tank discharge to the Monterey Bay Regional outfall near Marina. Nonetheless, samples collected by the Monterey Health Department in 1986 after these regional changes show a similar pattern (Table 3-2).

3.2.3 Heavy Metals in Surface Waters

Heavy metals were last measured in Elkhorn Slough during 1980-81, when the State Mussel Watch examined levels in the tissues of mussels (Table 3-3). The metal concentrations found in the slough are low and similar to levels in control mussels from Bodega Bay. Although there are no recent data available from slough sediments, the mussel watch data are usually correlated with changes in the surrounding environment and clearly suggest that heavy metals are not a problem in the slough.

Tributyl tin (TBT) is a potentially worrisome synthetic organo-tin compound used in antifouling paint for commercial and private vessels, and is often found in harbor areas. It is highly toxic to aquatic organisms, especially shellfish (Beaumont and Budd 1984). Recent water samples (April and May, 1986) analyzed from the Moss Landing Harbor contained 180 and 230 ppt of TBT, concentrations which could pose a hazard to marine life (Stallard and Goldberg, unpublished). No sediment samples have been analyzed from the harbor, and there is no information on TBT levels in local shellfish. The hazard of TBT is probably not bioaccumulation, but is in the depletion of shellfish stocks through mortality, reducing their availability to sport fishermen and natural predators such as sea otters, leopard sharks, and bat rays. Fortunately, another highly toxic component of anti-fouling paint, copper, does not occur in high levels in the slough (Table 3-3).

3.2.4 Pesticides in Surface Waters

Agriculture is the largest, most valuable industry in Monterey County, and at the present time is entirely dependant on insecticides, herbicides, and fungicides (pesticides) for its maintenance (R. Nutter, pers comm). These pesticides reach Elkhorn Slough by runoff, wind transport, percolation and advection from systems that interact with the slough such as the Moss Landing Harbor, Old Salinas River and Moro Cojo Slough. The role of atmospheric transport in determining pesticide distributions is poorly understood but may be significant (R.

5) CRWQCB, Resolution No. 85-04.

Risebrough, pers comm.). Since much of the cultivated land in Monterey County is drained by the Salinas River and this water can eventually enter Elkhorn Slough (see Chapter 1 for a discussion of water movements in the slough), regional patterns of pesticide use and probable movements must be considered.

DDT, toxaphene, dieldrin, endrin, aldrin,and endosulfan are major persistent pesticides which have been used in this region. They are halogenated hydrocarbons which are mostly insoluble in water but highly soluble in lipids. Therefore, they readily concentrate in the fatty tissues of animals. In water and soil, these chemicals are usually bound to sediment particles or organic-mineral aggregates. In addition, a number of other chemicals are in use, which while presumably less persistent, have also been detected in sediment, water, and animal tissue.

A generic problem in environmental protection is that different agencies often have different standards for the same chemical. Sometimes two or more standards for the same chemical can exist within the same agency. For example, the US Food and Drug Administration, the National Academy of Sciences, and the Environmental Protection Agency (two levels) all have different action levels for toxaphene. Another difficulty is that action levels are calculated on a wet tissue weight basis, whereas results of analyses are usually standardized for dry weight or lipid weight, making the analytical results not comparable to the standards.

3.2.4.1 Pesticide Monitoring

3.2.4.1.1 Previous Monitoring

The California Mussel Watch Program monitors the levels of worrisome chemicals in the tissues of mussels which concentrate chemicals from the environment. Mussels are planted into test areas and later collected for tissue analysis. This monitoring does not indicate what levels of chemicals actually occur in a habitat nor does it usually allow statistical inferences to be made about differences among locations. However, the Mussel Watch program is useful in identifying problem areas, which can then be examined in detail using other techniques. Most of the pesticide data from Elkhorn Slough were collected by Mussel Watch.

The first systematic study of pesticides in Elkhorn Slough was made during the winter of 1978, when mussels contained detectable levels of heptachlor epoxide, dieldrin, and endrin, and the highest levels of the p,p' isomers of DDD and DDT known in the state (Risebrough et al. 1980). In 1979-80, transplanted mussels contained BHC, dacthal, all DDT breakdown products, dieldrin, endosulfan 1, and heptachlor (Stephenson et al. 1980). These high pesticide concentrations led to a special mussel watch study of Elkhorn Slough-Moss Landing Harbor in 1982-83 (Ladd et al. 1984), which documented the levels of endosulfan, toxaphene and DDT (Figure 3-2). Of the four stations sampled in the slough, the Sandholt Road bridge had the highest concentrations of DDT and Endosulfan 1 (total endosulfan was not sampled) and the Parson's Slough station had the highest levels of toxaphene in mussels. There were no obvious trends in concentrations among stations. Also in 1982-83, the Toxic Substances Monitoring Program of the Department of Fish and Game found detectable levels of DDT and breakdown products in water from Elkhorn Slough, the Old Salinas River and Blanco Drain; and endosulfan-1 in water from Moro Cojo Slough and Upper Tembladero Slough.

The State Mussel Watch found detectable levels of eight agricultural pesticides in mussels from Elkhorn Slough in 1984 and 1985 (Figure 3-2). The Sandholt Bridge had the highest concentrations of all pesticides (except endosulfan in 1984). Although the data allow no statistical inferences, concentrations of DDT and endosulfan were much higher in 1984 than in either 1983 or 1985. Endosulfan levels were the highest in the state in 1984, and DDT levels in mussels at Sandholt Road in 1985 were only exceeded by the Santa Fe Channel in Richmond-an EPA Superfund Cleanup Site.

The highest levels in the State in freshwater of 7 pesticides (see Figure 3-2) have been found in the Salinas River and Moro Cojo drainage. They include high levels in native fish (Watkins et al. 1984), in transplanted freshwater clams *Corbicula* (Watkins et al 1984), and in sediment (Agee 1986). We speculate that these two drainages probably are the major source of pesticides reaching Elkhorn Slough.

Recent pesticide monitoring has begun to concentrate on measuring pesticide concentrations in the soil. The Department of Food and Agriculture and the Water Resources Control Board have found high concentrations of DDT in agricultural soils from the Salinas Valley (see 3.2.4.2.1.). A study in the Elkhorn Slough watershed on toxaphene and endosulfan in agricultural soils and their drainages showed substantial concentrations of toxaphene (over 2000 ppb) and the 3 endosulfan isomers (over 3000 ppb) in the soils of both active and inactive fields, and equivalent concentrations in the drainages below those fields. Endosulfan sulfate concentrations were 20 times higher than endosulfan 1 concentrations, and both toxaphene and endosulfan were found to depths of over 45 cm in the soil (Oliver et al, 1988). A preliminary study on endosulfan by the Department of Food and Agriculture found endosulfan in water and sediment from the Sandholdt Road bridge and the Blanco Drain (Gonzalez et al, 1987). A larger-scale DFA soil survey for endosulfan in the Salinas Valley was conducted in late 1986, and the report is due out in early 1988.

3.2.4.1.2 Shellfish Pesticide Survey

The distribution of pesticides in the slough is poorly known, and pesticide concentrations in shellfish other than mussels have not been examined. Clams from the slough are consumed by people and otters, so high pesticide levels could pose a health threat. As part of the present study, mussels and clams were collected from the slough and analysed for pesticides (Appendix 2). Mussels (*Mytilus edulus*) were collected from 4 locations. Overall pesticide concentrations were similar to those found by the State Mussel Watch, but the trends in concentrations were reversed, with higher concentrations found farthest from the mouth of the slough. Three species of bottom-dwelling clams were also analyzed for pesticides: Washington clams (*Saxidomus nuttalli*), horse clams (*Tresus nuttallii*), and the piddock (*Zirfaea pilsbryi*). Pesticide concentrations were generally 2 to 4 times lower in the clams than in the mussels. DDT was the most prevalent pesticide, with concentrations ranging from 96 to 186 ppb. This is well below the FDA standard for human consumption of shellfish (5ppm wet weight), but above the NAS level for protecting predators (such as sea otters) from potential bioaccumulation effects.

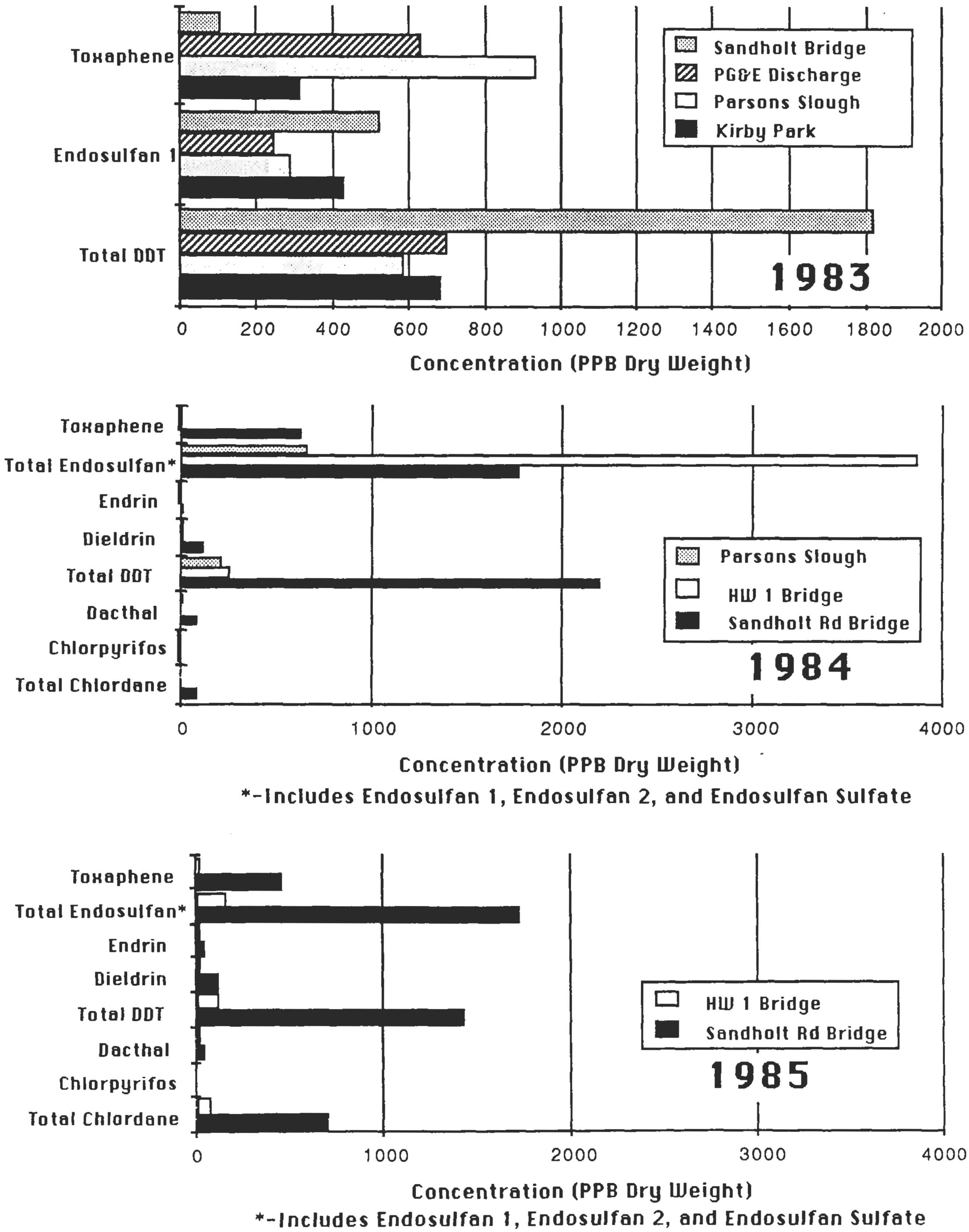


Figure 3.2: Concentrations of pesticides in mussels (Mytilus californianus) transplanted to stations in Elkhorn Slough and to the Sandholdt Road Bridge over the Old Salinas River Channel in 1983, 1984, and 1985.

3.2.4.2 Major Pesticide Patterns

3.2.4.2.1 DDT

The toxicity and bioaccumulation of DDT is well known because of its major effects on a variety of ecosystems, and locally because of detrimental effects on the production of egg shells in birds such as pelicans and raptors (Risebrough and Jarman 1985). The DDT applied to crops consists of an 80%:20% mixture of two isomers, p,p' DDT and o,p' DDT. Both isomers break down into DDD, which breaks down into DDE. DDD and DDE are also toxic, but they persist in the environment much longer. DDT was banned in California in 1972.

Recent observations indicate that the rates of breakdown of DDT can be much longer than previous estimates (Agee 1986). The o,p' isomer of DDT was thought to break down the fastest so that the ratios of the two DDT isomers in the environment indicated the time since application. However, in the Salinas Valley, 61 to 71% of the DDT in the soil and 13 to 69% of the DDT in aquatic sediment still has the isomeric ratios of fresh DDT, even though DDT's widespread use ended over a decade ago (Figure 3-3). Some unexplained process is causing the ratio of the two DDT isomers to remain relatively constant in the soil, while in aquatic sediment o,p'-DDT is sometimes concentrated. Although it was concluded that DDT is not being presently added to the soil, the concentration of total DDT in the soil was significantly higher than seen in earlier studies (Agee 1986), possibly as a result of more precise analytical techniques (B. Risebrough, pers. comm).

Several lines of evidence indicate that the persistent DDT probably originated before the early 1970's, and is not from recent illegal use (Mischke et al. 1985). Despite widespread monitoring of pesticide use on crops and occasional enforcement activity, no DDT use has been observed by regulatory agencies in the last 10 years. DDT residues only occur on crops that are in direct contact with the soil or whose leaves trap soil, implying that the detected DDT may consist of contaminated soil attached to the crops. If there were recent illegal use of DDT, other crops should contain residues. Finally, the distribution of DDT is widespread and fairly uniform in agricultural soils- not the pattern expected if patchy illegal applications were taking place (Mischke et al. 1985).

Although DDT was banned in 1972, high concentrations remain in fish and shellfish from the Salinas River and Old Salinas River (Watkins et al 1985), and in mussels from Elkhorn Slough (Figure 3-2). Local peregrine falcons still have only a 25% success rate in breeding, possibly due to DDT-induced eggshell thinning (Brian Walton, pers. comm.). Agricultural soils in the Salinas Valley contain a reservoir of DDT that is being released to the aquatic environment (Mischke et al 1985). The soil enters the waterways due to erosion during heavy rainfall, or due to poor agricultural practices. Soil is often plowed over the edges of fields directly into drainage ditches. In some fields, the access roads running along drainage channels are plowed, so when they are re-established at the beginning of the growing season, the excess soil ends up in the drainage channel. The soil containing DDT is then transported down the Salinas River into the Old Salinas River and through the Moss Landing Harbor, where it can be advected into the slough (See Chapter One on water movements). Considering its slow breakdown rate, the mixing of DDT into the soil column and normal soil erosion rates, it is probable that DDT release into the Salinas River will continue well into the 21st century (Agee 1986).

Little or no DDT was used on strawberries or artichokes. Since the major DDT crops (Figure 3-4) are minor crops in the Elkhorn Slough watershed, there was probably little DDT use here. Althoujgh no data are available on pesticide concentrations in slough sediment or in watershed soil, because of the known usage patterns of DDT, and the high DDT concentrations found in the Salinas Valley, the origin of DDT in Elkhorn Slough is probably the Old Salinas River.

3.2.4.2.2 Toxaphene

Toxaphene (also known as chlorinated camphene or Strobane-T) is a significant global contaminant and is more abundant than PCB in rainfall in the Eastern United States (Ali et al 1984). Introduced in 1948, it may be underreported in environmental surveys because of analytical problems. Almost 55,000 pounds were used in Monterey County in 1982, down from a high of 203,099 pounds in 1970. Between the years 1970 and 1982, average use in Monterey County was 96,985 pounds per year (Figure 3-3). Because of environmental persistence and toxicity, toxaphene usage was suspended in California by the California Department of Food and Agriculture in 1983 However, since it persists in soil and is transported through local waterways like DDT, toxaphene is likely to remain a local problem for many years.

Toxaphene has a half-life in soil from several months to 11 years, and a half-life in water from several months to 9 years (Cohen et al 1982). In sandy loam soil similar to the Aromas Sands, 45% of the applied toxaphene persisted after 14 years (Pollack and Kilgore 1978). It is extremely toxic to aquatic life, with chronic toxicity to fish in the ppt (parts per trillion) range (Eisler and Jacknow 1985). The EPA water criterion to protect human health from consumption of fish, shellfish and water is 0.71 ppt and the 24 hr average maximum concentration to protect wildlife is 13ppt (US EPA 1980b). The National Academy of Sciences recommends a total level of 100 ppb wet weight (approximately 800 ppb dry weight) of toxaphene and all other organochlorine pesticides in fish tissue. No level was set for shellfish, but fish and shellfish standards are often the same. The relatively high FDA action level of 5 ppm in commercial fish was established before knowledge of toxaphene toxicity and is under review (Cohen et al. 1982). The toxaphene levels in fish (880 ppb) and freshwater clams (23,000 ppb) from the Salinas River (Watkins et al 1984) and mussels (920 ppb) from Elkhorn Slough (Figure 3-2) exceed all safe levels established by government.

3.2.4.2.3 Endosulfan

Endosulfan is registered for use on over 60 crops, since first introduced in 1954 as "Thiodan". Although insect tolerance to endosulfan in some areas is high (U.N. FAO 1981), it is still used extensively in California. Endosulfan is highly toxic to aquatic organisms (U.N. WHO 1984), and causes the greatest number of pesticide-related fish kills in California (Ali et al 1984). Endosulfan is more water-soluble than other chlorinated hydrocarbons, so is more easily dissolved in runoff

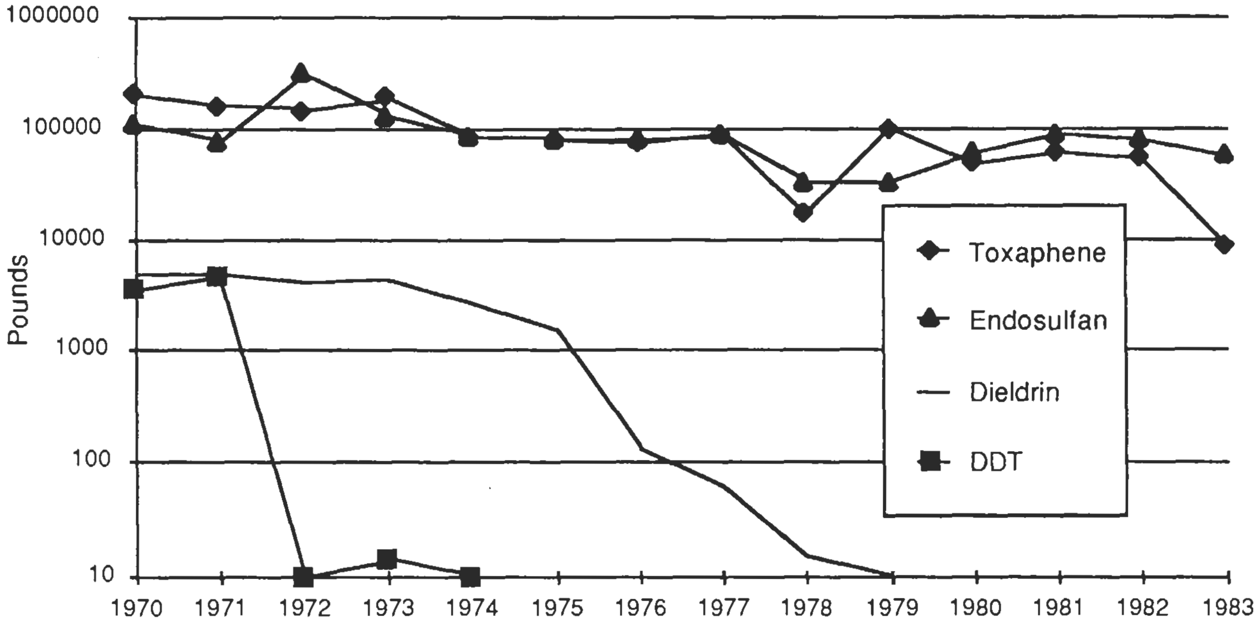


Figure 3-3: Total annual use of four pesticides in Monterey County. Amount used is in pounds, plotted on a logarithmic scale. Data from California Department of Food and Agriculture pesticide use reports.

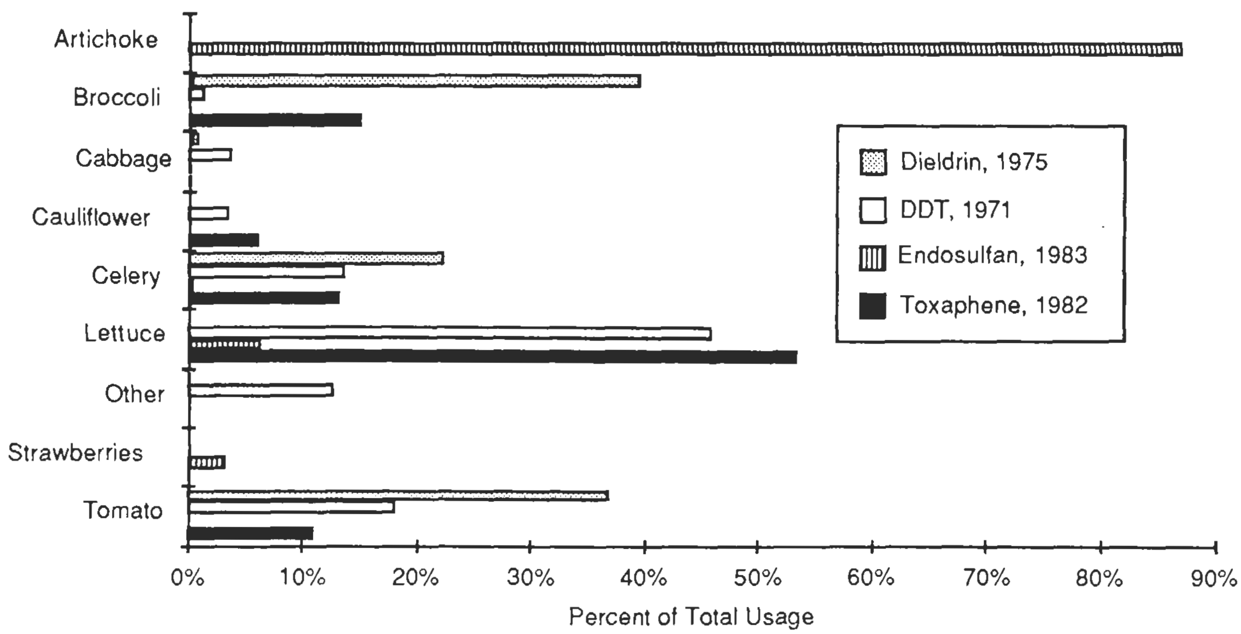


Figure 3-4: Usage of 4 pesticides by crop in Monterey County. Years of high pesticide use were chosen for the comparison. Data from California Department of Food and Agriculture pesticide use reports.

water. However, endosulfan is metabolized at a higher rate by living organisms than DDT and does not persist in animal tissue as long. The endosulfan applied to crops, is a 70%:30% mixture of two stereoisomers, endosulfan I and endosulfan 2. Endosulfan-1 breaks down into endosulfan-2 and endosulfan sulfate, which are both as toxic as endosulfan 1. The half-lives of the breakdown products are higher, persisting for 1-3 years in soil (Stewart and Cairns 1974). A source of confusion is that most environmental monitoring has only measured endosulfan-1, the least persistent isomer, and therefore significantly under-estimates the total concentration of this pesticide (Ali et al. 1984).

Endosulfan is highly toxic to aquatic organisms so the ambient water quality criteria are low. The protection levels are 0.056 ppb (24-hour average) and 0.22 ppb (instantaneous maximum) for freshwater life, and 0.0087 ppb and 0.034 ppb respectively for saltwater organisms (US EPA 1980a). EPA levels for endosulfan residues in agricultural commodities for human consumption range from 0.1 to 2.0 ppm, but no action levels are established for fish or shellfish. The National Academy of Sciences set guideline tissue levels of 100 ppb of only endosulfan or of endosulfan and other chlorinated hydrocarbons to protect predators against bioaccumulation. The EPA is re-evaluating the registration of endosulfan because information on its toxicology and environmental fate is "invalid and not useful for registration" (US EPA 1982), being based on fabricated laboratory results. The State Water Resources Control Board has issued a list of recommendations calling for endosulfan action levels to be established for tissue and water, and additional research to be performed on a variety of environmental effects of endosulfan (Cohen and Bowes 1984). The California Department of Food and Agriculture issued endosulfan use restrictions in late 1984 to reduce off-site environmental impacts, and is currently reviewing the registration of endosulfan. The CDFA review is dependent on the completion of some laboratory tests, but is expected to be finished in mid 1988.

Endosulfan is used extensively in Monterey County, where the average is almost 100,000 lbs/year between 1970 and 1983 (Figure 3-3). The majority is applied to artichokes (87% in 1983) (Figure 3-4). Approximately 60% of the endosulfan on artichokes is applied by aerial spraying, while all application to strawberries is from the ground (Ken Young, pers. comm.). Some artichoke fields drain directly into the slough, but the largest farms occur around Castroville and drain eventually into the Moss Landing Harbor, where their drainage water may be advected into the slough (see Chapter One for a discussion of water movement in the slough). Endosulfan is also used on strawberry fields, but this is probably a less important source than artichokes (Figure 3-4). The majority of endosulfan is applied in the early spring and early fall (Figure 3-5).

All mussels and freshwater clams collected from the Elkhorn Slough (Figure 3-2) and Salinas River (Watkins et al 1984) drainages in 1984-85 contained endosulfan concentrations over the NAS recommended guidelines. Endosulfan is the last of the persistent chlorinated hydrocarbons in use in California. It will probably remain a problem for many years.

3.2.4.2.4 Other Widespread Pesticides

Dieldrin, endrin, aldrin and chlordane are persistent chlorinated hydrocarbons, formerly

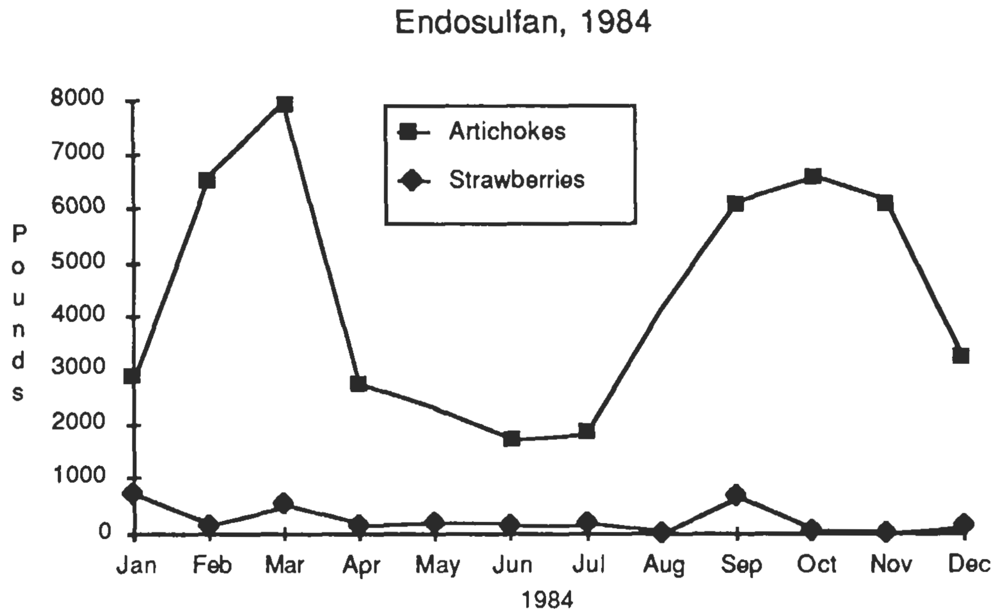


Figure 3-5: Monthly endosulfan use (in pounds) on strawberries and artichokes in Monterey County in 1984. Data from Monterey County Agriculture Department use reports.

used in agriculture as broad-spectrum insecticides, but now discontinued. Chlordane is still registered for use in structural pest (termite) control. All are detected in mussels from Elkhorn Slough (Figure 3-2), and in the freshwater clam *Corbicula* from the Salinas River (Watkins et al 1985). Dieldrin is the most persistent and was used in Monterey County on broccoli, celery and tomatoes until 1979 (Figures 3-3 and 3-4). In 1984, mussels from the Sandholdt Bridge contained about 100 ppb of dieldrin, and from Parson's Slough contained 30 ppb. Since dieldrin was not used on crops grown in the slough's watershed, it is probably imported from the Old Salinas River. Dieldrin, endrin, aldrin and chlordane persist and move through the environment like DDT, and will probably be detected for years.

Dacthal (also known as DCPA) is a persistent herbicide, used heavily on broccoli and brussel sprouts, and occasionally on many other crops including strawberries. Dacthal can only be applied at planting or 60 days before harvest.

Chlorpyrifos (trade name Lorsban) is a fairly persistent organo-phosphate insecticide, used for maggot control on row crops and fruit. Because of its persistence, it cannot be applied to strawberries when they are fruiting. Despite its persistence, chlorpyrifos continues to be used because no good chemical alternatives exist.

3.2.4.2.5 Strawberry Pesticides

Because strawberries are grown so extensively in the Elkhorn Slough watershed, special attention must be paid to the pesticides used in strawberry farming. The high rates of erosion from strawberry fields make these pesticides more likely to enter the slough. Over 940,000 pounds of pesticides were used on strawberries in Monterey County in 1984 (Table 3-4). With the exception of endosulfan, most of the pesti

Monterey County Pesticide Usage on Strawberries in 1984 (Pounds)

Chemical	J/F	M/A	M/J	July	Aug	Sept	Oct	N/D	Total	COMMENTS
Anilazine	195	1						1401	1597	
Bacillus thuringiensis			4	5	38	1	14		62	Bacterium used for worm control on many crops.
Benomyl	297	410	451	338	187	153	126	128	2090	Fungicids, must be used together because of
Captan	1216	1904	2885	1081	1216	831	460	729	10322	resistance. Not Persistant.
Carbofuran								4	4	
Cabaryl		146		62	64		34		306	Cutworm control.
Chloropicrin			34650	72379	78095	60253	59641	3122	308140	Soil fumigant, used w/ methyl bromide. Short-lived.
Copper Hydroxide	77	1						129	207	
Copper Sulfate	486	25					216	1706	2433	
Cyhexatin	244	304	221	311	225	117	73	78	1573	
Demeton							7		7	
Diazinon	130	199	6	30		40	62	81	548	
Dinoseb						187		456	643	
Dicofol	286	433	175	335		19		100	1348	
DNBP	179	1							180	
Endosulfan (=Thiodan)	841	627	320	153	2	659	42	126	2770	Persistent chlorinated hydrocarbon, 14 DtH, mites.
Fenbutatin Oxide	351	64	88	126	45				674	
Formetanate Hydrochloride		313	351	397	121	66	7		1255	
Malathion		11	79	262	62	117		25	556	
Metalaxyl	105	8							113	
Metaldehyde	240	37		16	6		9	24	332	
Methomyl		121	23	142	284	133	24		727	
Methyl Bromide			79006	131935	144476	109907	97327	6338	568989	Soil fumigant, dissapates overnight.
Mevinphos (=Phosdrin)	91	130	725	380	516	339	47	88	2316	Organo-phosphate insecticide,some resistant.
Naled (=Dibrome)	17	336	1924	1730	884	731	245	20	5887	Thripe control, 2-3 DtH.
Napropamide	1258	1			324	118	140	1098	2939	
Oxydemeton Methyl	113	49							162	
Parathion	2	2	2			1			7	
Propargite	102	63	11					102	278	
Strychnine			1						1	
Sulfur		260	2699	5865	249	66	38	463	9640	Fungicide
Thiophanate-Methyl	122	103	817	609	71	251	61	435	2469	
Thiram					307	138	153	16	614	
Vinclozolin		509	866	261	287	271	249	9	2452	
Xylene	2476	4316	1460	691	135	1399	210	536	11223	Solvent, carrier for water-insoluble chemicals.
Zinc Sulfate			18				4		22	
Total	8828	10374	126782	217108	227594	175797	159189	17214	942886	

TABLE 3-4. Pesticide usage on strawberries in Monterey County in 1984. Values are in pounds, by month, or for 2 months combined. DtH=Days to Harvest: Number of days after application before harvest can commence. Data from State Agriculture Department Pesticide Use Reports.

cides are thought to be not very persistent. However, very little is known about the environmental effects of most of these chemicals. One deserves special comment. Methyl bromide, a gas fumigant injected into the soil, accounts for 60% by weight of the pesticide use. Methyl bromide dissipates very rapidly (overnight), but is mutagenic and carcinogenic to animals in laboratory tests. Despite this, its use will continue because it is essential for strawberry production and no suitable alternatives exist.

3.2.4.2.6 Non-chemical Pest Control

Bacillus thuringiensis , a bacterium used for worm control on many crops (including strawberries), is one of a group of non-chemical alternatives for pest management. Insect growth hormones are now used extensively in mosquito control in Monterey County. As insects develop resistances to chemicals, and the use of many chemicals is restricted, non-chemical controls have received more emphasis. Research interest is now centering on viruses, pheromones, and parasitic nematodes (M. Bari, pers. comm.). Because it is much more difficult for pests to develop resistances to biological controls, they represent a solution to present concerns over pesticides.

3.3 GROUNDWATER

3.3.1 Aquifers

There are four major groundwater units in the Elkhorn Slough area. The deepest unit consists of interbedded sand, silt and clay layers of the Purisima Formation. The Purisima has a maximum thickness of 800 ft. near the coast. The top of the formation in the Elkhorn Slough area is 800 ft deep. The Purisima extends to the northeast, tilting up at an angle of 5 to 7 degrees, and crops out in the Santa Cruz Mountains. It is a major aquifer in coastal Santa Cruz County. The Purisima and a younger formation, the Paso Robles, form the local 900 ft aquifer (Johnson 1983). Few wells are drilled into the Purisima around the slough, so yields are poorly known. Preliminary tests on a 1600 foot well drilled into the Purisima by PG&E near Moss Landing indicate yields of about 2000 gal/min. Water quality in the Purisima is generally good, although iron and manganese concentrations can be locally high (Gary Green, pers.. comm.).

The major water bearing formation in North Monterey County is Aromas Sand. It is as much as 800 ft. thick consisting of aeolian sand beds with lenses of silt and clay. Beds of impermeable silt and clay at the base of the Aromas Sand prevent vertical percolation of water downward into the Purisima. The two major water bearing units of the Aromas Sand, which are separated by clay layers, are the local 400 ft. and 180 ft. aquifers. The clay layers become thin to the east, allowing water to enter and recharge the aquifers in the Salinas Valley around Chular and Gonzales. The Aromas Sands also crops out in the hills around the slough. Local recharge occurs in the area roughly bounded by Elkhorn Slough on the west, Prunedale on the south, Highway 101 on the east, and Carneros Creek on the north. Wells into the Aromas Sand average about 450 gal/min, with upper yields of 750 gal/min. Water quality in unintruded areas of the Aromas Sand is suitable for most purposes, although manganese and iron are high in some wells and magnesium and calcium make others slightly hard for domestic or industrial use (Johnson 1983).

The surface water-bearing deposits consist of marine and continental unconsolidated gravel, sand, silt and clay units deposited as terraces and alluvium in late Pleistocene and Holocene times. Their thickness is highly variable, exceeding 100 feet in some places near the coast. Wells into the alluvial sands can yield as much as 500 gal/min. Fine grained, impermeable units predominate near the coastal estuaries and sloughs. These units are of variable length and thickness. One section, a clay-filled gorge which is an onshore extension of the Monterey Submarine Canyon, is at least 600 ft thick, and extends several miles up Elkhorn Slough. These alluvial clay deposits restrict horizontal ground-water movement from the Salinas Valley. The distribution of alluvial clay and sand deposits is complex and results in isolated local aquifers perched above the regional water table (Johnson 1983).

3.3.2 Source and Movement of Groundwater

Aquifers are recharged either by water percolating down from the surface through water-permeable rocks or by entering at the surface where the water-conducting formation crops out. Water moves downgradient until it encounters an impermeable layer (aquaclude). If the aquaclude dips, water moves downstream in the direction of the dip. The general downward movement can be reversed by pumping. If pumping withdrawal is higher than input from recharge areas, water levels decline and a trough develops where groundwater levels are depressed. Water moves into the trough from surrounding areas. If the aquifer crops out in the ocean, salt water moves into the aquifer.

Groundwater movement in the Elkhorn Slough area has historically been controlled by the dip trends of the two major formations, the Aromas Sand and the Purisima. The San Andreas Fault is an absolute barrier to groundwater movement. No water enters the Elkhorn Slough area from east of the fault. Clay lenses prevent Salinas Valley groundwater from moving northward, making the Aromas Sand aquifers in the Elkhorn Slough area essentially self contained (Johnson 1983).

The water movement in the Purisima (800 ft aquifer) parallels the San Andreas Fault, with water moving from the north towards the Pajaro River where it turns westward into the Monterey Bay (Figure 3-6). Water also moves down the Salinas Valley before going under the bay near Moss Landing. There are isolated outcrops of Purisima and older Tertiary formations near the San Andreas Fault. Water from those areas moves directly westward towards the bay.

The source of water in the Aromas Sand is rainfall within the drainage basin of Elkhorn and Moro Cojo Sloughs. Historically, water has entered the aquifer in the hills west of Moss Landing, and moved directly west to the bay. Water from the area to the east of the Granite Ridge (north and east of Prunedale) moves to the north around the ridge before turning west. Historical water movements are altered by overpumping. There is now a groundwater trough in the Upper Aromas Sand that extends from Castroville to the Pajaro River and roughly 4 miles inland at Elkhorn Slough (Figure 3-6). Water flow to the west of the trough axis has been reversed and now comes from Monterey Bay, where the Aromas Sand crops out 3 or 4 miles offshore in the Monterey Submarine Canyon. There is also a pumping trough in the Lower Aromas Sand between Moss Landing and the Pajaro River. It extends about 1.5 miles inland and is also intruded by saltwater from the bay (Figure 3-6).

3.3.3 Salinity in Groundwater

Salt water intrusion was first observed in the Salinas Valley in the early 1930's when several wells were abandoned near the coast because of high salinity. A freshwater artesian well in Moss Landing stopped flowing in the mid-thirties and many shallow wells (several feet deep) were contaminated by salt water soon after (Bill Lehman, pers. comm.). By the mid-1940's the rate of contamination prompted the first comprehensive study of groundwater by Monterey County and the California Department of Public Works (1946). The report found an overdraft of 27,000 acre-feet which would increase to 76,000 acre-feet per year at the time of 'ultimate development'. Today's overdraft in the Salinas Valley is 30,000 to 60,000 acre-feet. In 1984, there were 14,500 acres of land overlaying the intruded portion of the Upper Aromas Sands, plus a large area offshore that formerly contained freshwater. About 6,000 acres of land covered the intruded portion of the 400 ft aquifer. In recent years, seawater intrusion into the Upper Aromas Sands spread under an additional 450 acres per year; and at a rate of 275 acres per year in the Lower Aromas Sands (Leedshill-Herkenhoff Inc. 1985).

Groundwater recharge in the Elkhorn Slough area is also not adequate to meet pumping demand. The amount of the overdraft is not known, but the area of salt water intrusion is spreading. The dotted line on Figure 3-6 shows the approximate extent of intrusion in the 180 ft aquifer in 1986. The line will continue to advance until the water imbalance is corrected. Some wells do not follow the general trend because they are probably producing from perched aquifers which are isolated from surrounding areas.

The salt found in surface aquifers (Quaternary alluvium) probably comes from Elkhorn Slough and other inshore areas flooded with salt water. The majority of the salt water in the deeper aquifers comes from Monterey Bay where the aquifers crop out. If clay layers at the top of the Aromas Sand are discontinuous near the coast, some salt water may also percolate down from the surface. Water also moves down through improperly shielded wells passing through contaminated aquifers. Before 1972, Monterey County had no regulations governing well casings, so many older wells may act as direct conduits of salt water from contaminated surface aquifers into lower aquifers. Surface waters and abandoned wells would pose no threat if the water tables were not depressed by overpumping.

By the year 2000, between 9,000 and 11,000 additional acres of the Upper Aromas Sands, and 5,000-7,000 more acres of the Lower Aromas Sands will be contaminated with salt water. This problem will decrease crop production, increase groundwater production costs, decrease groundwater storage capacity, and decrease water supplies with many potential impacts (Leedshill-Herkenhoff 1985).

A variety of options are available to help balance the water budget. Expensive options include injection pumping of freshwater into the aquifers and a salt water extraction barrier. More realistic options, detailed below, are a reduction in pumping or developing supplemental water supplies.

Figure 3-6. Map showing saltwater intrusion and water movement around Elkhorn Slough. Large arrows show groundwater movement in the deep aquifer (Purisima), small dashed arrows show groundwater movement in the lower Aromas, small solid arrows show groundwater movement in the upper Aromas. Solid line shows the axis of the pumpiung trough in the upper Aromas, dashed line shows the approximate extent of saltwater intrusion in the upper Aromas, and stippled area shows outcrops of the Aromas Sands. Data from Johnson 1983, Leedshill-Herkenhoff 1985, Monterey County Health Department, Monterey County Flood Control District, and personal communications.

3.3.3.1 Reducing Pumping

A. Moratorium on well digging:
A well moratorium would require a county ordinance.

B. Pumping Fees:
Charging for water extracted from wells would probably reduce pumping. No county legislation is available for this option. In addition, institution of pumping fees requires expensive county-wide metering.

C. Water conservation practices:
Agriculture uses over 90% of the groundwater extracted in Monterey County. Most local strawberry farmers use highly efficient drip irrigation, so water conservation practices are unlikely to solve the local problem.

D. Changes in land use:
Land under cultivation requires significantly more water on a per acre basis than either grazing or non-urban housing. An acre of strawberries using drip irrigation requires about 3.25 acre-feet of water per year. Artichokes require about 2.5 acre-feet per acre per year, and lettuce 2.5 (2 crops) (Dept. Water Res. 1986). Monterey County has a per capita water use of 120-150 gal/person/day (Monterey County 1984). Based on these figures, an acre of high density housing (2 houses, 4 persons per house) requires about 1.1 acre-feet per year. Much of the land in the slough watershed is zoned for one house per 5 acres, requiring 0.11 acre feet/year, over ten times less than any agricultural usage. Grazing land requires the least water.

3.3.3.2 Supplemental Water Supplies

A. More extensive use of the deep aquifer:
The few wells that enter the deep aquifer or Purisima indicate that it is a source of usable water. The storage capacity of the Purisima is not known, but is thought to be large. One problem with using the deep aquifer is that it is expensive to drill a 1000+ foot well (in excess of $200,000). Despite the potential large capacity of the deep aquifer, the relative proximity of Monterey Bay (2-4 mi.) may allow salt water to rapidly invade the deep aquifer. The Purisima is already heavily utilized in the upper slopes of the Pajaro Valley in Santa Cruz County. Developing the deep aquifer is an experiment with unknown consequences for salt water intrusion.

B. Reclaimed wastewater:
Reclaimed wastewater must undergo tertiary treatment before use in agriculture or recharge to aquifers. A delivery system to the users must be built and the entire process is expensive. Monterey County has an ongoing feasibility study examining this option.

C. Increased surface water storage capacity:
The Monterey County Flood Control and Water Conservation District is considering the possibility of raising of the spillway on the Nacimiento Dam, increasing its storage capacity by 34,500 acre-feet (10%). A dam on the Arroyo Seco River has also been proposed.

A draft of the Salinas Valley Seawater Intrusion Program is currently under review (B.J. Miller, pers comm). Under this plan, water from the Salinas River would be delivered on an availability basis to farmland around Castroville and Moss Landing. Wells in the distribution area would be capped. The extent of the proposed system is not established, but is presently not planned to extend past Dolan Road. The importation of agricultural water could reduce overpumping, and perhaps stop the spread of the local intrusion. Inclusion of the Elkhorn Slough area in the primary or secondary distribution system is feasible, depending on financing and water availability (L. Schardt, pers comm), and we recommend that it should be considered.

Because the aquifers around Elkhorn Slough are isolated from the Salinas Valley by impermeable clay layers, the local salt water intrusion is not the result of overpumping in Salinas Valley. Barring an external solution, the most likely local and probably short-term remedy to the intrusion problem is to tap the 900 ft aquifer. Kaiser, P.G. & E. and the Moss Landing Harbor District have already done so. A shift to grazing and low-density housing will reduce pumping requirements. However, there are no documented examples of aquifers recovering from salt water intrusion (Gary Greene. pers. comm.).

3.3.4 Nitrogen in groundwater

The nutrient of most concern in groundwater in the Elkhorn Slough area is nitrogen, which is generally found as nitrate. The public health hazard related to drinking water with high nitrates is methemoglobinemia, which affects infants under six months of age. The build up of methemoglobin in the bloodstream interferes with the carrying capacity of oxygen in the blood, inducing cyanosis. Connections between cancer and high nitrate levels in drinking water are speculative. Based on the methemoglobinemia data, the Public Health Service set a standard of less than 45 ppm of nitrate in drinking water.

Groundwater is divided into two principal zones: the unsaturated zone from the root zone to the water table and the saturated zone from the top of the water table to the first aquaclude or impenetrable layer. Transport is generally vertical in the unsaturated zone and horizontal in the saturated zone. Nitrogen is the most common pollutant of groundwater and is introduced primarily from land use activities at the surface. Once below the root zone, nitrates may not be denitrifed or adsorbed on particles and thus move freely in groundwater. However, work in progress at the US Geological Survey in Menlo Park indicates that there may be some moderation of nitrogen in the deep groundwater by bacteria.

Agriculture is the principal source of percolating nitrogen. The concentration of nitrates that reaches the saturated zone is dependent upon the amount of nitrogen fertilizer applied at the surface and the type of crop. For example, while nitrate levels in an alfalfa field went from 36 mg/l at the surface to an average of 14 mg/l below 10 feet, the levels went from 74 mg/l at the surface to 47 mg/l below 10 feet in row crops (Esmaili and Associates 1978). Once nitrates get into the groundwater, they remain there. If they enter in a recharge area, they spread throughout the aquifer.

A significant percentage of the wells in the Elkhorn Slough area are contaminated with unacceptable levels of nitrates (Figure 3-7). Of the 63 domestic wells surveyed which penetrate the 180 ft aquifer, 7 (11%) had nitrate levels above the 45 mg/l limit considered safe for drinking. Another 19 (30%) had nitrate levels between 10 and 44 mg/l. Five of the 8 wells drawing from the surface waters (above 100 ft) were above 45 mg/l. There were no obvious patterns to the

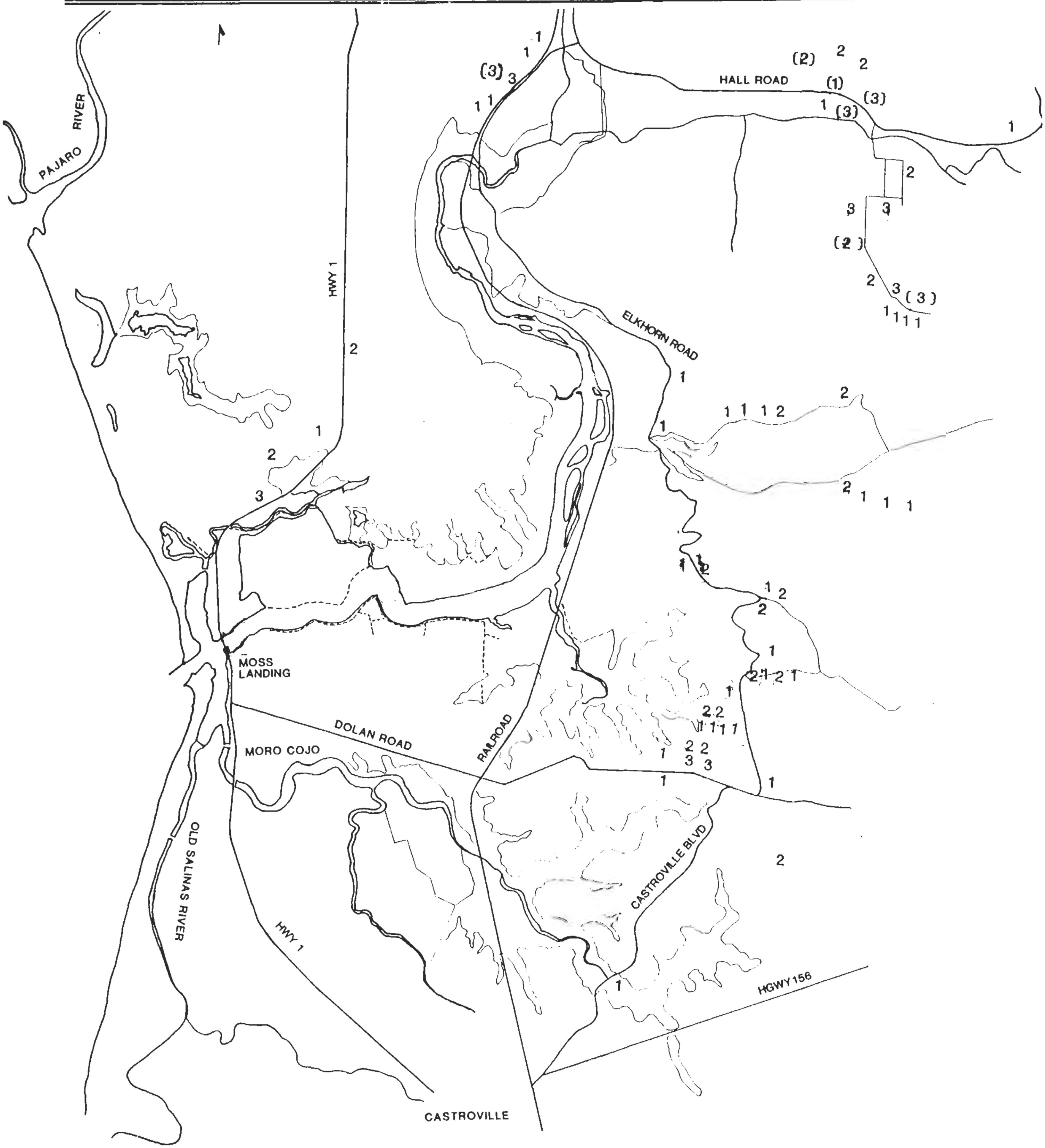


Figure 3-7: Nitrate (NO3) levels in water from domestic wells. 1=0-10 ppm, 2=11-44 ppm, 3=45-110 ppm. () indicates well drawing from above 180 ft aquifer (surface). Unpublished data from the Monterey County Health Department.

distribution of contaminated wells. Wells with elevated nitrate levels were sometimes located next to uncontaminated wells. (Data collated from the Monterey County Health Department)

High concentrations of well nitrates were reported from the Elkhorn Slough area from 1972 to 1977 (Esmaili and Associates 1978). Nitrate levels of 20 to 105 mg/l occurred at Hall Road. Eighty percent of the wells had nitrate levels over 45 mg/l, with one well having 480 mg/l, in the McClusky Slough area between the harbor and Pajaro River.

3.4 MANAGEMENT PROBLEMS

3.4.1 Surface Waters

The biggest environmental problem in the surface water of the slough and watershed is the high levels of persistent pesticides moving through the system and being exposed to aquatic organisms. The insecticides DDT, dieldrin, toxaphene, aldrin, chlordane endosulfan, and chlorpyrifos and the herbicide dacthal occur in water, sediment, fishes and/or shellfish from Elkhorn Slough. Because of the importance of agriculture to the local economy, a balance must be reached between a decrease in the amount of pesticides entering the waterways and the present dependence of the agricultural industry on chemicals. The major problems are listed in their order of importance to Elkhorn Slough.

1. High levels of persistent pesticides, especially DDT and toxaphene, in agricultural soils.
2. The probable transport of pesticides into slough waters from the Salinas River and Tembladero Slough via the Old Salinas River Channel.
3. Endosulfan presently being applied to local crops entering the slough.
4. High levels of coliform bacteria in slough waters.

3.4.2 Groundwater

The most significant groundwater problem around the slough is salt water intrusion of the surface, Upper and Lower Aromas Sand aquifers. The groundwater problems are listed in their order of importance:

1. Salt water intrusion of surface, Upper and Lower Aromas Sands aquifers.
2. High nitrate levels in well water.

CHAPTER 4. WETLAND ENHANCEMENT PLANS

4.1 INTRODUCTION

The goals of a specific wetland enhancement project must consider the regional natural history and existing wetland settings as well as local environmental constraints. In Elkhorn Slough, the major constraints are:

1. Strong tidal flows caused by the maintenance of the harbor mouth and the resulting erosion of the main slough.
2. The presence of essentially permanent dikes around wetlands such as the raised rail bed.
3. Low freshwater tables caused by pumping wells.
4. Occasional flooding caused by heavy rainfall and local land use.

Working within these constraints, the overall goal for each enhancement plan is to optimize habitat heterogeneity to harbor the greatest variety of wetland organisms. Although we have ranked birds highest in this process, habitat is also designed for wetland plants, aquatic invertebrates, insects and fishes (see Chapter 1: 1.3.4.1 Wetland Values). Non-disruptive public access (see Chapter 5) is also recommended to the five major enhancement sites in the slough (Figure 4-1).

4.2 BLOHM-PORTER MARSH

4.2.1 Environmental Constraints

The Blohm-Porter Marsh is separated from the main channel of Elkhorn Slough by Elkhorn Road. There are seven culverts (diameter= 3 ft) with flap valves allowing freshwater to drain into the slough while preventing salt water flow into the Blohm-Porter Marsh. However, since the flap valves are often held open by floating wood and other debris, salt water fills the main marsh channel and sometimes covers the marsh to depths of 1-3 ft. The valves can prevent tidal inflow if properly maintained. The gates are maintained by the County, through Public Works, and by local residents, especially Estelle Blohm. Public Works currently has no funds budgeted for this effort.

The surface of the marsh subsided 2-3 ft. when the wetland was drained and dried in past years (Chapter 1). Marsh elevations are 2-3 ft. below the surface of the salt marsh in the adjacent Elkhorn Slough. The subsidence extends well into the Porter reserve and east of Blohm Road into Hall Valley (Figure 4-2). Therefore, if tidal flow is returned to the marsh, the area will become a large, shallow salt water pond with very little vegetated marsh. If tidal flow were unconstrained through the culverts, salt water would kill most of the willow trees on the Porter reserve, cover Blohm Road and spread over farm land in Hall Valley. The resulting salt water pond would also reduce the the existing flood basin for Watsonville and Carneros Creeks (Federal Emergency Management Agency 1986).

The return of tidal flow to the Blohm-Porter Marsh would add a large volume of tidal water to the main channel of Elkhorn Slough. This additional volume would increase tidal currents and cause greater erosion in the slough. Erosion of wetland habitats by tidal currents is the most significant ecological problem in Elkhorn Slough. Therefore tidal inflows must be managed.

In summary, the major environmental constraints to wetland enhancement in the Blohm-Porter Marsh are:

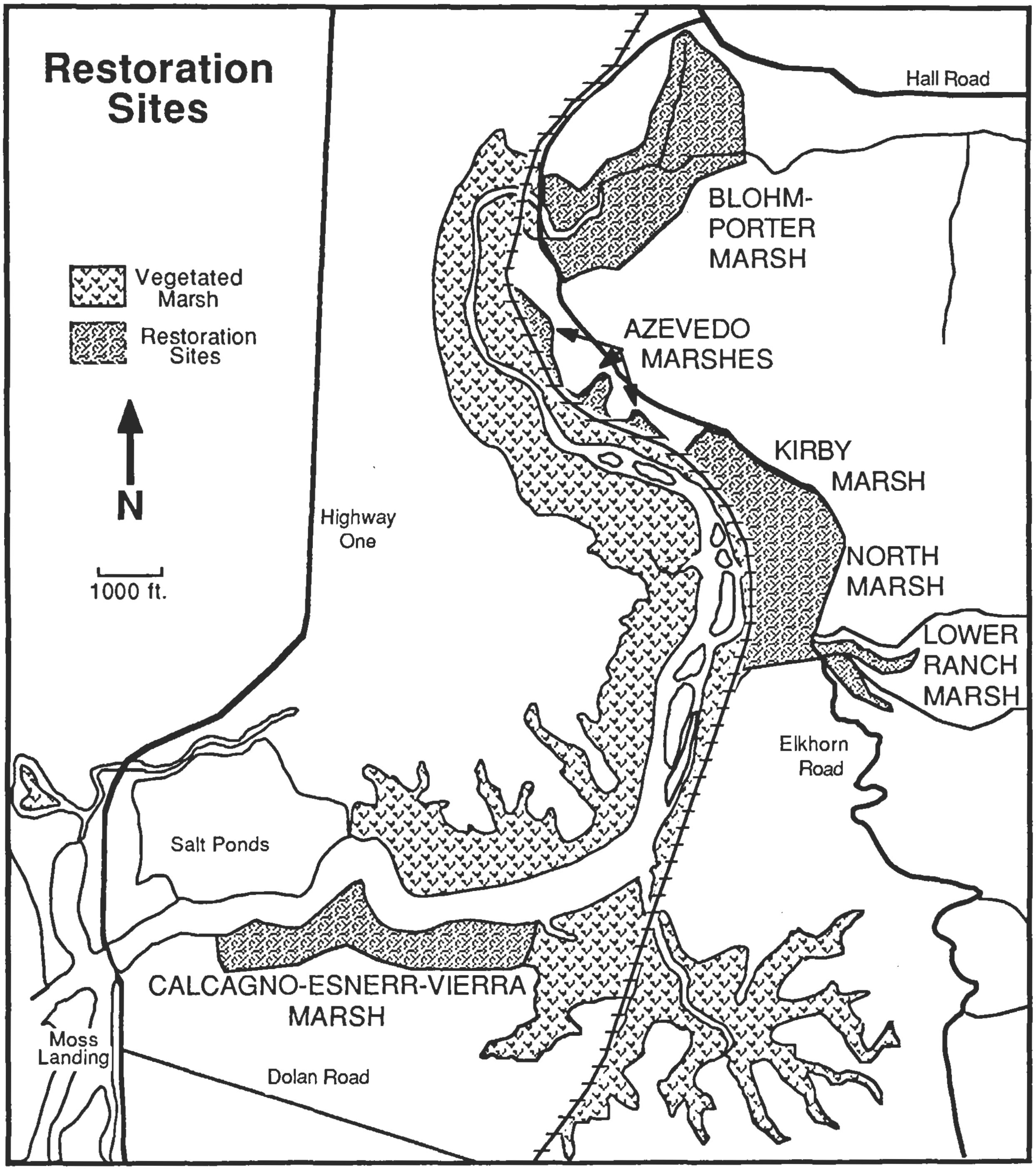


Figure 4-1. Recommended wetland enhancement sites in Elkhorn Slough.

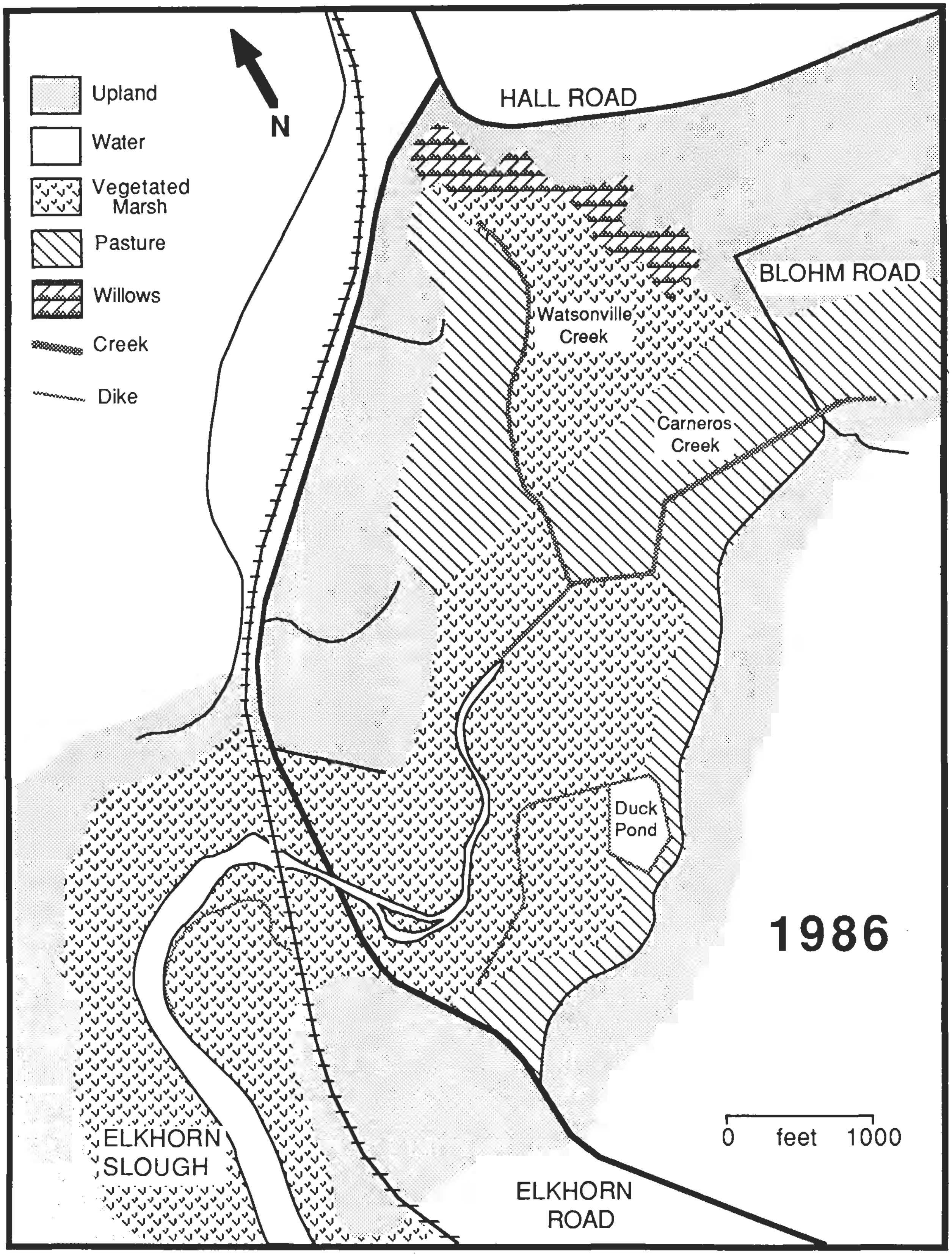


Figure 4-2. The existing environmental setting in the Blohm-Porter Marsh.

Site	BEFORE ENHANCEMNT Salt Marsh	Fresh Marsh	Pond	Pasture Upland	AFTER ENHANCEMENT Salt Marsh	Fresh Marsh	Pond Channel	Upland Habitat
Blohm-Porter Marsh	110	25	10	88	110	25	37	30
Azevedo Marsh	14	-	3	8	14	-	3	8
Kirby Marsh- Option 1	38	-	-	17	36	-	7	12
Kirby Marsh- Option 2	163	-	-	17	69	69	30	12
Lower Ranch Marsh	3	5	6	7	2	6	6	7
Calcagno-ESNERR-Vierra Site	36	2	22	-	48	-	12	-

Table 4-1. Acres of habitat type at each site before and after wetland enhancement.

1. Restricted flow under Elkhorn Road.
2. Subsidence of the old wetland surface by 2-3 ft.
3. Flood control problems in Hall Valley.
4. Severe erosion problems in Elkhorn Slough.

4.2.2 Existing Environment

The existing Blohm-Porter Marsh is a seasonal wetland and pasture. When the culvert system worked well, there was little salt water inflow into the marsh. However, over the last few years the inflow has been great enough to cover the area with as much as 3 feet of salt water. As a result, the pasture grasses have died in most of the central marsh which is now covered with salt grass and primarily pickleweed (Figure 4-2, Table 4-1). Neither of these plants is good cattle food. Freshwater usually flows from the area rapidly, although it is not uncommon to have as much as 3 feet of freshwater covering much of the marsh during heavy rainfall. At the same time, Blohm Road can be covered with 2-3 feet of water which extends into Hall Valley. Nevertheless, this cover of freshwater rarely lasts more than several days. It eventually drains into the Elkhorn Slough leaving standing water only in the narrow channel system (Figure 4-2).

The major wildlife use of the existing marsh is by waterfowl in the Blohm pond and seasonal wetlands and by songbirds in the willow trees on the Porter Ranch. The willow forest was reduced in size by salt water intrusion from 1947 to 1951 (Chapter 1: Figure 1-5) and to a lesser degree in recent years (Figure 4-2). The Blohm pond harbors many species of waterfowl and is used by duck hunters during some winters. They often pump extra water into the pond to keep it from drying out in late summer and fall. Although the feed is marginal, cattle still graze in the marsh throughout the year.

Since this area has been primarily a pasture for over 30 years, the only information on wildlife use of the site is the qualitative observations of local naturalists and residents. No endangered or threatened species have been recorded on the site. Area of existing habitats is shown in Table 4-1.

4.2.3 Enhancement Plan

The recommended enhancement plan will create a fresh water marsh consistent with the overall goal of optimizing habitat heterogeneity (Figure 4-3). In general, the plan will pond freshwater during the rainy season; widen and deepen the main channel; make two large ponds along the channels and create island habitats with the excavated debris; and pre-plant key habitats producing an optimal wildlife mosaic.

4.2.3.1 Hydrology

The plan will impound freshwater behind Elkhorn Road covering the flat pasture land with 1-2 feet of water throughout most of the rainy season (November to March) (Figure 4-3). Since the entire area has subsided 2-3 feet, the impounded water will cover all the old marsh habitat without flooding upland areas. A detailed topographic map was made of the study area and is stored with the Elkhorn Slough Foundation for use in engineering the marsh construction (see Appendix 1). The topographic map shows less than 1 foot of variation in elevation for most of the marsh which slopes gently into upland habitats at the borders. Most of the marsh is -1 to 0 feet above mean sea level.

Freshwater will be impounded behind Elkhorn Road by equipping the existing culverts with gate values operated from a metal framework on the east side of Elkhorn Road. The gate valves will be opened just enough to permit tidal flow along the main channel and pond system, but not above the elevation of the channel edges. This same valve design is currently used in the North Marsh. During heavy rain runoff, excess freshwater will flow through a trench in Elkhorn Road. A large flap valve will be maintained on the west side of the trench to prevent salt water from flowing into Blohm-Porter Marsh through the trench. The elevation of the trench bottom will determine the elevation of freshwater impounded behind or east of Elkhorn Road (1-2 feet above the present pasture elevation). The top of the trench will be a heavy metal grating and the trench will be cement lined. Depending on a flood level analysis, it may be necessary to have more than one overflow trench. Each trench will be 5 feet wide accommodating considerable freshwater overflow from the marsh. However, if flooding becomes a problem during abnormally high and persistent rainfall, the gate valves will be opened on the seven culverts allowing the entire marsh to drain through the culverts as well as the trench. When the culverts are open, the trench-culvert system will allow as much as 25% more water to exit the marsh compared with the present system of seven culverts.

The trench-culvert system will produce a large pond extending from Elkhorn Road to 400-500 feet east of Blohm Road. The pond can be maintained for a longer period into the spring by temporarily closely the gate valves at Elkhorn Road. The present elevation of Blohm Road is maintained at the same elevation as the pasture to prevent road washout during periods of flooding. The road is often covered with 2-3 feet of rainwater during most winters, when local residents use small boats to reach the two home sites on the south side of the road (Figure 4-2). The riparian marsh and seasonal agricultural lands east of Blohm Road are also commonly flooded during the winter months. The area just east of Blohm Road is the same elevation as the main Blohm- Porter Marsh (Federal Emergency Management Agency 1986, Appendix 1).

Blohm Road should be raised 1.5 feet, which is several inches above the elevation of standing water proposed for the new marsh. It will be covered with water about as much as it has been in the past, or probably a little less because of the greater flood control capacity of the proposed trench-culvert system. Freshwater will impound 400-500 feet up the Carneros Creek from Blohm Road by maintaining the

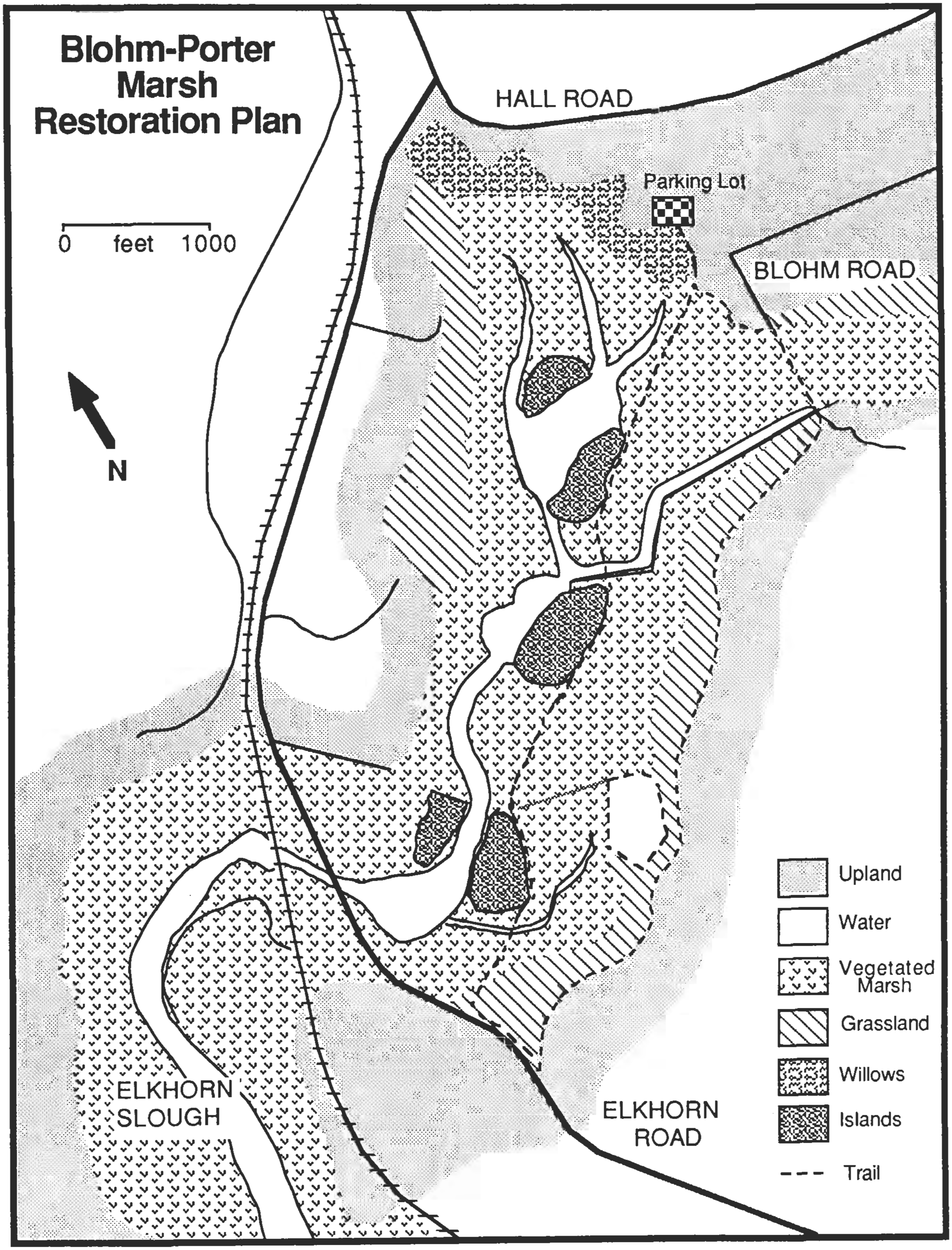


Figure 4-3. Recommended enhancement plan for the Blohm-Porter Marsh.

existing course of Carneros Creek through the road, where there is a small bridge over the creek.

The enhanced marsh will fill completely with rain water from Watsonville and Carneros Creeks during the late fall and especially early winter of most years. The water elevation will be about 1 foot above mean sea level during the rainy season. After the winter rains cease, the water level will gradually lower to the top of the channel and pond system (Figure 4-3).

Carneros and Watsonville Creeks are the two primary streams flowing into the Blohm-Porter Marsh. Watsonville Creek empties into Warner Lake and then flows through an earthen ditch into the marsh. Carneros Creek drains a much larger area including many strawberry farms. The high erosion rates on these farms produces high sediment loads into Carneros Creek. The sandy portion of this sediment appears to deposit out along the floodplain of Carneros Creek in agricultural fields and riparian thickets. No comprehensive survey of sediment transport along Carneros Creek has been completed; therefore, it is unknown how much sediment reaches the marsh or is transported out into Elkhorn Slough. It is likely that both fine and heavy sediments will deposit in the marsh during a large flood. A thorough examination of the sediment problems along this creek is needed. Sedimentation should be controlled through installation of erosion control measures in strawberry farms and possibly by installation of a sediment basin in Carneros Creek.

4.2.3.2 Wildlife

The general drainage patterns will produce a mixture of wetland habitats which will be submerged for different time periods. The islands will provide the same submergence gradient from upland to low marsh. Some islands will be isolated from the upland and some will be partially connected by service dikes and access walkways (Figure 4-3). The islands and dikes should be pre-planted with the most desirable vegetation to prevent less desirable volunteers from gaining control and to establish and maintain the best mix of wetland plants and animals. In other locations volunteer colonists will provide excellent wildlife settings. Selective weeding of less desirable plants during the early stages will also establish the dominance of the desired plants. Since all the dominant plants are perennials, once plant patches are established they will be difficult to invade and will therefore persist for long periods. The species of plants introduced into the various habitats, their patch size and mosaic and other specific habitat features will be determined by wetland scientists who are involved directly with this phase of the work through the Elkhorn Slough Foundation.

Part of the plant mosaic will be determined by the existing wetland plants. The wetland portion of the Porter Ranch is fringed with willow trees (Figure 4-3) that will persist and perhaps expand slightly into the upper marsh where salt water will not extend. The mouth of the marsh and some edges are covered with pickleweed and salt grass. These salt marsh plants will thrive at moderate levels of submergence in the marsh. They will persist for many decades or indefinitely with a mixture of other plants. This mix of salt, brackish and freshwater plants will harbor the greatest number of insects, many other invertebrates will be abundant, and the complex habitat structure will be used by many species of birds.

Waterfowl and shorebirds will use the marsh for resting, feeding and some breeding. Mallards, cinnamon teal and pintails may nest in the marsh and shorebirds such as blackneck stilts, avocets, plovers, killdeer, egrets and herons may nest here. In addition, a number of raptors will use the marsh including red-tailed hawks, red-shouldered hawks and black-shouldered kites. These raptors mainly feed on rodents and will not disturb other birds. Short (3-4 ft. tall) treated pilings should be driven into the sediment for these and other birds to perch on.

Since the islands and upper borders of the marsh will be submerged infrequently, many mammals will forage in the heavy wetland cover that will develop. These include California meadow mouse and other rodents, cottontail rabbit, opossum, raccoon, muskrat, and gray fox. The aquatic invertebrates will include the rich groups that inhabit the existing vernal ponds on the Porter property (ostracods, cladocera and many insect larvae) and species dependent on more stable ponds as well. Since salt water will remain in the central channels and ponds throughout the year, larger species of fish may colonize or can be introduced there. In addition to many species of estuarine fishes that presently live in the slough, stickleback may be seasonally abundant with one or several species of amphipod crustaceans and other benthic invertebrates. The fishes and invertebrates may be major prey for birds.

4.2.3.3 Interactions with Adjacent Habitats

The proximity of the marine waters of Elkhorn Slough will create a dramatic habitat shift at Elkhorn Road (Figure 4-3). Blohm-Porter Marsh will receive many transient visitors from a variety of faunal groups. This larger-scale or coarse-grained habitat heterogeneity should increase the total number of species using both the fresh and salt water marshes here. In addition, the adjacent uplands harbor many insects, birds and mammals that will use the marsh extensively. For example, several species of song birds will probably feed and even nest in the upper wetland areas. Conversely, some shorebirds will use the upland grasses, bushes and trees for perching and especially feeding. Herons and egrets may nest in adjacent upland habitats. The protected stands of willows on the Porter Ranch and the hillside habitats on the Porter Ranch and especially the Blohm Ranch have the greatest potential for allowing important ecological interactions between the recommended marsh and the adjacent upland.

Much of the upland habitat around the marsh is in low density rural housing, with some cattle pasture and greenhouses. Large areas of strawberry fields surround the marsh and are in Hall Valley where field erosion deposits considerable sand in Carneros Creek. Much of the surrounding upland habitat is or will be conserved in upland vegetation. A large oak-grassland was given to the county for a conservation easement by the Porter and Cooley families. The Porter family also gave much of the upland above their marsh to The Nature Conservancy.

4.2.3.4 Marsh Construction

The general plan for the channel, pond and island locations is shown in Figure 4-3. The channels and ponds will be excavated to a depth of 4 feet below mean sea level. The side slopes of channels, ponds and islands will be 1:5. The excavated soil is silt-clay mud and peat exactly like the deposits excavated in the

Estuarine Research Reserve. They do not compact and will not erode away because of the gentle side slopes (1:5) and the planned preplanting. Although the islands may sink slightly, the vegetation will hold the surface soil. The elevation of the island tops will be 3-4 feet above mean sea level.

The best results for the least cost can be realized by constructing the marsh under optimal conditions. The existing culvert system allows all or most of the water to be drained from the site and later pumped from the central channels. By summer, there will be little or no groundwater in the area except the water remaining in the existing channel system and this water will be pumped out. As a result, the enhancement area can be dried by late spring or early summer. The site will dry enough by late summer and early fall for tractors and trucks to excavate and move sediment. Excavation equipment can gain access to the marsh from several areas and will only be active around the channels, ponds and islands, where the maximum quantity of deposit must be moved. The deposit can be dried to at least 3 feet into the marsh. As a result, the channel, pond and island slopes and island shape can be closely controlled and created with minimum cost. In addition to the efficient construction of channels, ponds and islands, bird perches and access structures can be installed at substantially less cost compared to working on wet or submerged substrates.

This drying process may take more than one year and it may not permit the front area of the marsh to completely dry. However, at least the back half of the marsh is relatively dry today because of past drainage practices. If the front marsh cannot be dried, then more expensive traditional excavation techniques will be necessary, such as drag lines and mats. Nevertheless, the initial effort to dry the marsh will greatly decrease costs and permit better control of excavation for over half the area.

Existing wetland plants can be easily dug up and set aside on Foundation or The Nature Conservancy land, where they can be maintained by Foundation staff and volunteers. Excavation and replanting can be done with a small tractor and truck. Other preplanting efforts will be greatly facilitated by working from a pickup truck, which can transport new plants from outside the marsh directly to the planting sites that are dry until the first rains. Without the ability to save, stockpile and transport wetland plants over a relatively dry construction site, the preplanting of the marsh and establishment of the most desirable plant and other wildlife mosaics will be very difficult. Fortunately, the existing drainage conditions allow a highly effective construction operation where all aspects of the recommended enhancement plan can be realized. Foundation staff and scientific advisors will determine the best conditions for excavating, storing, and replanting marsh plants.

The material excavated from the channels and ponds will be deposited directly in the marsh to make the islands. This avoids the high costs of removing excavated soil and creates highly desirable wildlife habitats. The excavation quantities and additional habitat details are shown in Table 4-2.

4.2.3.5 Conservation & Acquisition

Presently most of the Blohm-Porter Marsh is in private ownership. The Nature Conservancy will eventually receive title to the Porter property through an agreement with the owners.

The remaining parcels– Hermansen, Kildolf, Blohm, Wang and Thomas– must be donated to or acquired by a public agency or a private non-profit group before the enhancement plan can proceed.

As currently proposed, long-term management of the Blohm-Porter Marsh will be done cooperatively by the Elkhorn Slough Foundation and The Nature Conservancy. Long-term management activities include maintenance of flap gates, culverts and trenches; repair and maintenance of fencing, birds perches, islands, and channels as needed; and oversight of public access and use of the area. This will be the second cooperative management agreement between these two organizations on the slough.

Site	Quantity of Excavation	Island Slope	Pond Slope	Max. Pond Depth*	Channel Width
Blohm-Porter Marsh	140,000 cu. yds.	1:5	1:5	-4 ft.	50 ft.
Azevedo Marsh	5000 cu. yds.	none	natural	-2 ft.	-
Kirby Marsh- Option 1	35,000 cu. yds.	1:5	1:5	-4 ft.	20 ft.
Kirby Marsh- Option 2	104,000 cu. yds.	1:5	1:5	-4 ft.	20 ft.
Lower Ranch Marsh	0	-	-	-	-
Calcagno/Vierra Site**	5,000 cu. yds.	none	1:5	-6 ft.	-

* From mean sea level; ** see text for pond depth and slope detail

Table 4-2. Construction information for wetland enhancement plans. Also see enhancement maps and text description for each site.

4.3 AZEVEDO MARSHES

4.3.1 Environmental Constraints

The Azevedo Marshes (Figure 4-4) were separated from the slough by the Southern Pacific railway dike in the late 1800's (Chapter 1). These pocket marshes are connected to Elkhorn Slough and the tide by culverts under the railway dike. The culverts are blocked by small dikes on the east side of the railway dike. These small dikes impede the flow of salt water into the marshes. The culverts were installed to drain freshwater from the pocket marshes into the slough. During freshwater discharge, the marshes are mixed and partially flushed. However, later in the year some salt water flows over the small dikes and into the pocket marshes and does not circulate well or drain out. The culverts are 5-6 ft. above MLLW. The main environmental constraints in the Azevedo Marshes are:

1. The railway dike and culvert system.
2. The limited seasonal input of freshwater to the pocket marshes.

4.3.2 Existing Environment

The existing pocket marshes have very little or no water exchange for much of the year. They harbor pickleweed, salt grass and some other salt tolerant plants near the railway dike and some freshwater plants such as rushes and sedges where freshwater springs outcrop during the winter and spring. There are no quantitative observations on the flora and fauna from the marshes. However, there is no evidence that they are used by any endangered or threatened species. Since the marshes are surrounded by private property, few local naturalists have spent much time observing wildlife here. Clearly the marshes are used by waterfowl and songbirds.

The marshes are surrounded by grazing or agricultural lands, which are presently growing strawberries. There are approximately 18 acres of degraded salt marsh and fringing freshwater marsh in the Azevedo Marshes.

4.3.3 Enhancement Plan

The enhancement plan for the Azevedo Marshes is to clean gravel, sediment and other debris from the existing culverts under the railway dike; remove small dikes that obstruct flow through the culverts; and excavate deeper ponds in the marshes (Figure 4-4). These actions will have major consequences for the hydrology and wildlife in the pocket marshes, increasing the value of the 18 acres of marsh (Table 4-1).

4.3.3.1 Hydrology

The existing culverts under the railway dike range in size from 2-foot pipes to 5-foot wide trenches. They are sufficient in size to flush the marshes by the tide. However, at present the culverts are severely obstructed with gravel from the railway dike, sediment and other debris. In some cases, small dikes also block the flow of water into the marshes. These small dikes are usually on the east side of the railway dike. Once the culverts are cleaned and the small dikes removed, the system will permit freshwater to drain into the slough and salt water to flush the marshes during the remainder of the year.

The pocket marshes have been filled by reducing tidal flow and probably by erosion from adjacent strawberry fields. Therefore the central ponds should be excavated to an elevation of 1-2 feet below the cleaned culvert bottoms. Tidal currents will be adequate to flush the small unvegetated basins in each pocket marsh. The resulting tidal amplitude will maintain the existing fringing salt marshes. Therefore, the major changes in hydrology will be increases in tidal flushing and amplitude within the Azevedo Marshes.

4.3.3.2 Wildlife

These simple changes in hydrology will have a dramatic effect on the wetland wildlife. Increased tidal flushing and amplitude will create an intertidal zone around the old stagnant basins and make the shallow subtidal habitats suitable to marine and brackish water invertebrates and fishes. These should be the same faunal groups that inhabit the upper tidal creeks in Elkhorn Slough (Chapter 1). The vegetated marsh will also be suitable for many invertebrates, particularly amphipods and crabs which will probably be abundant throughout the pocket marshes. The invertebrates and fish and the intertidal habitat will attract foraging shorebirds; and the vegetated marsh will be used by shorebirds, waterfowl and birds from adjacent upland habitats. Tidal flushing will eliminate long periods of partial emersion in stagnant salt water and produce a lush, healthy cover of salt marsh plants. The insect fauna will also increase in the vegetated salt marsh.

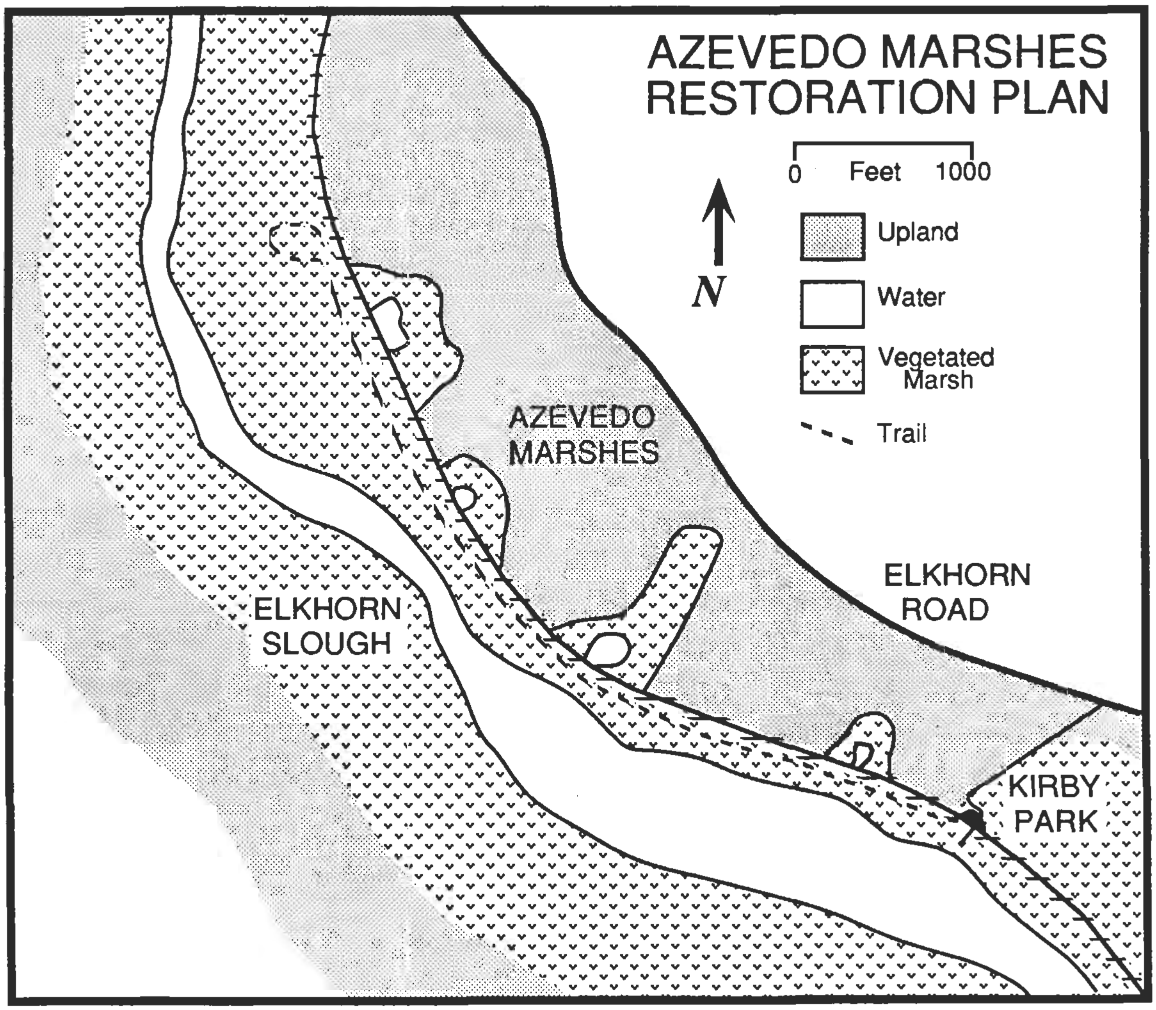


Figure 4-4. Recommended enhancement plan for the Azevado Marshes.

4.3.3.3 Interactions with Adjacent Habitats

Freshwater drains into the pocket marshes from the watershed during the rainy season and also from springs along the adjacent hillsides. Freshwater plants surround the springs and spread into the upper edges of the pocket marshes (Figure 4-4). Songbirds use these spring habitats and will use the enhancement site much more frequently when the salt marsh habitat is better flushed. Short pilings will also be placed around the marshes for bird perches. Small mammals will forage on the healthy vegetation and abundant wetland fauna.

Strawberry fields surround most of the marshes. All the marshes may be threatened by sedimentation from these fields. The smallest and most southerly marsh is clearly being filled by erosion from adjacent strawberry fields. The sedimentation comes from plowing the fields into the marsh. Sedimentation here and potential problems in the other marshes could be reduced significantly by establishing a 100 foot buffer zone around the existing marshes where no plowing is done and vegetating this zone with a dense cover of salt grass or other native vegetation. Erosion from runoff can be reduced by contouring the adjacent slope with furrows with no slope and preventing gully formation by planting roadways with grass (also see Chapter 7, section 7.3). The landowner would have to agree to these changes in agricultural practices.

4.3.3.4 Construction

There are no special construction conditions for cleaning the culverts and removing the small dikes. After the culverts are cleaned, it may be desirable to prevent future clogging by building structures to stop the railway dike gravel from falling into the culverts. The excavation of the central ponds can be done with a drag line and the resulting sediment can be deposited above the marsh and revegetated with native plants.

4.3.3.5 Conservation & Acquisition

The pocket marshes are owned by the Azevedo family. They have kept the three largest marshes in good condition from the upland side and have no plans to modify land use around the marshes. However, erosion from strawberry fields has filled small freshwater marshes in the watershed (Chapter 2), has filled the most southern Azevedo Marsh, and may threaten the three larger Azevedo Marshes in the future. The Azevedo Marshes must be donated or acquired by a public agency or non-profit group before the enhancement plan can proceed.

If the Azevedo family decides to donate or sell the marshes in the future, the Natural Conservancy and Elkhorn Slough Foundation are the likely management organizations since the adjacent marsh on the west side of the railroad dike belongs to the Nature Conservancy. The Foundation and Conservancy are presently developing cooperative plans to maintain public access to this marsh.

The Southern Pacific Company would have to agree to allow debris removal from their culverts. This action would be beneficial to the railway by reducing flood risks created by clogged culverts.

4.4 KIRBY MARSH

4.4.1 Environmental Constraints

Tidal flow was reduced to the Kirby Marsh by the construction of the Southern Pacific railway in the late 1800's. The marsh was later diked and drained for grazing by the 1940's. As the marsh dried it subsided 2-3 ft. from its original elevation. It is 2-3 ft. too low to support salt marsh vegetation under full tidal exposure. A detailed topographic map was made of the Kirby Marsh to aid in engineering the marsh construction (see Appendix 1). The survey documents the relatively flat topography in the central marsh at an elevation of 0 to 1 foot above mean sea level and a gentle slope into the surrounding uplands.

The only potential input of salt water comes from the opening under the railroad trestle that brings salt water into the North Marsh of the Elkhorn Slough National Estuarine Research Reserve (Figure 4-5). Present tidal flow into the North Marsh is highly constrained due to two low regions along Elkhorn Road. If full tidal action were restored to the North Marsh, these two road segments would be under tidal waters much of the time (e.g., Federal Emergency Management Agency 1986). Since there is a major erosion problem in Elkhorn Slough caused by strong tidal currents (Chapter 2), returning complete tidal flow to the North Marsh and Kirby Marsh may not be desirable even if the road were raised (see Chapter 2). Therefore, if tidal action is restored to Kirby Marsh in the near future, tidal flushing and amplitude will be similar to the North Marsh.

In summary, the main environmental constraints for the enhancement of Kirby Marsh are:

1. The elevation of Elkhorn Road is low at two locations near the North Marsh.
2. Salt water must enter through the North Marsh where gate valves limit tidal inflows from the slough to avoid flooding the road.
3. There are severe tidal erosion problems in Elkhorn Slough.

4.4.2 Existing Environment

The existing environment in the Kirby Marsh is a diked pasture which no longer drains as well since the North Marsh (Figure 4-5) was returned to tidal flow. The standing salt water has killed all the winter grasses in the central marsh where pickleweed and salt grass now account for almost all the plant cover. A freshwater spring maintains a small patch of reeds near the center and a small riparian habitat has developed near the large sediment fan produced by upland erosion of strawberry fields (Chapter 2). There is some ponded water during the winter months when waterfowl are present, but in general the area is poorly used by wetland wildlife.

There are 38 acres of marsh and 17 acres of upland pasture on the site (Table 4-1). Since this area was used for cattle pasture until 1986, there are no quantitative observations on the flora or fauna from the site, although there is no evidence that any endangered or threatened species use the Kirby Marsh.

The second enhancement option also considers the North Marsh. The existing environmental setting here is limited by the restricted inflow and outflow of tidal waters through the culverts and gate valves at the railway trestle. The only abundant plant in the marsh is pickleweed. Its cover and productivity are low because of long submergence times and poor tidal flushing. Common and snowy egrets are common in the marsh, which is also periodically used by other shorebirds and waterfowl. There are no quantitative information on the flora and fauna from the North Marsh and no evidence of use by endangered or threatened species.

4.4.3 Enhancement Plan- Option 1

This option returns limited tidal flow to Kirby Marsh without raising the two low areas in Elkhorn Road. The low spots are approximately 2 feet above mean sea level. Tidal flow is limited by the existing culvert system letting just enough water into the North Marsh to prevent salt water from covering the two low areas. The only source of tidal water to Kirby Marsh is through the culverts feeding the North Marsh.

The general plan is to excavate a central channel that bisects two central ponds. The excavated material will make island habitats. This plan will also prepare the Kirby Marsh for incorporation into the second option discussed in section 4.4.4 Enhancement Plan: Option 2.

The first option will increase the habitat value of 38 acres of salt marsh (Table 4-1).

4.4.3.1 Hydrology

The central channel, ponds and islands (Figure 4-5) are similar to the system designed for the larger Blohm- Porter Marsh (Table 4-2). The system of channels and ponds provide maximum tidal flushing to the Kirby Marsh, given the source of water from the North Marsh. The slope of the bordering habitat will provide better tidal drainage and will harbor healthier salt marsh vegetation than the existing North Marsh. The islands will provide additional habitat above the elevation of restricted tidal exchange. The hydrology of this option is limited by existing tidal exchange into the North Marsh where tide gates permit only restricted tidal flow to prevent flooding the Elkhorn Road. The tidal range in the North Marsh is approximately 0-2 feet above mean sea level.

4.4.3.2 Wildlife

The plant and animals using the Kirby Marsh will be generally similar to those in the adjacent North Marsh. Common and snowy egrets are the most conspicuous shorebirds using the North Marsh. However, the plant and animal life should be richer in the Kirby Marsh because of the better drainage conditions along the slopes established for the islands and bordering upland habitats. The tidal amplitude in the North Marsh is less than 2 feet in order to keep water off Elkhorn Road, so that will be the amplitude in Kirby Marsh. Many waterfowl will use the large ponds. The islands and fringing upland habitats will harbor songbirds, small mammals, insects, mud crabs, amphipods and other wetland species.

4.4.3.3 Interactions with Adjacent Habitats

The most important interaction is between Kirby Marsh and North Marsh. These marshes are essentially part of one larger system and are obviously dependent on each other. In general, the interactions with adjacent habitats will be similar to those described for the Blohm-Porter and Azevedo Marshes.

Since the Kirby Marsh is surrounded by roads and railroads, there is little impact from upland land use. The one exception is drainage of water from strawberry fields across the Elkhorn Road. This water has eroded deep gullies at the north end of the marsh.

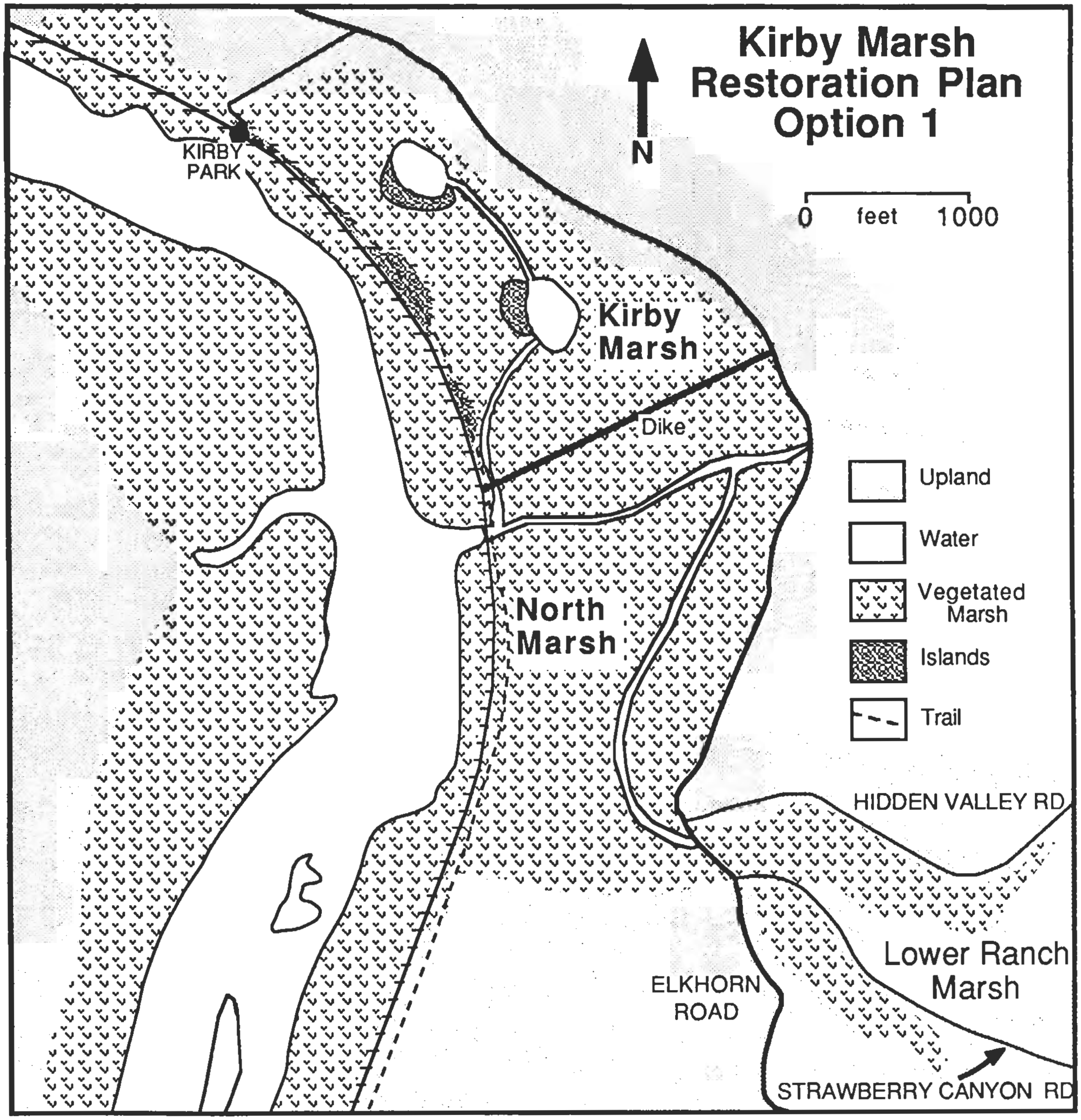


Figure 4-5. The existing environmental setting in the North Marsh and Lower Ranch Marsh, and option 1 enhancement plan for the Kirby Marsh.

4.4.3.4 Construction

The Kirby Marsh is relatively isolated from the North Marsh by a dike. However, there are some breaks in the dike allowing limited salt water invasion of Kirby Marsh. The dike can be easily fixed during the dry season and the remaining water pumped from the area as recommended for the Blohm-Porter Marsh. This may not remove all the water from the marsh, but will at least permit much better access around the perimeter and for some distance into the marsh. This improved access for equipment will reduce excavation costs significantly. Since the area is now much wetter than in the past, the drying process may take more than one year. The island, channel and pond slopes are the same as those recommended for Blohm-Porter Marsh (Table 4-2). All excavated material will be used to construct islands (Figure 4-5), and does not need to be removed from the site.

It is important here to emphasize the potential usefulness of drying the marsh as much as possible. One year before the restoration of the South Marsh, the water table in the pasture was four feet below the soil surface, which was at approximately the elevation of mean sea level (2-3 feet above MLLW). Sea water does not easily percolate through the silt-clay deposit of the marsh, despite the proximity of Elkhorn Slough. The area was dried by draining water into the perimeter channels and pumping these dry.

Since it mat not be possible to dry Kirby Marsh as well as South Marsh had been dried over many years, the central excavation may require drag lines and mats for moving equipment. Nevertheless, the little cost and planning required to drain and dry the area may greatly lower total cost and improve the restoration product. The past aesthetic failures at marsh restoration in the slough were the result of poor planning and excavation in very wet settings that could have been dried considerably. Fortunately, many of the wetlands that can be enhanced in Elkhorn Slough can be at least partially dried before construction operations commence.

4.4.3.5 Conservation & Acquisition

Kirby Marsh is presently in private ownership by the Estrada family. The property must be acquired or donated to a public agency or nonprofit organization prior to commencing any enhancement activities.

4.4.4 Enhancement Plan- Option 2

The second option for Kirby Marsh involves the North Marsh and is only recommended if the low areas in Elkhorn Road are raised. This option constructs the same habitats described in option 1 for Kirby Marsh but also creates four similar pond and island systems in the North Marsh (Figure 4-6). Therefore, if option 1 is followed and later the road is raised, option 2 can be completed by doing only the work in the North Marsh.

Option 2 creates a brackish wetland in the Kirby and North Marshes. Here the level of fresh and salt water can be manipulated to investigate the effects of salinity, submergence, flushing and other processes on wetland ecosystems. Since the North Marsh is part of the Elkhorn Slough National Estuarine Research Reserve and the Kirby Marsh will undoubtedly join the Reserve, this is an excellent location for doing long-term wetland research.

Transitional wetlands are areas that are usually influenced by freshwater, but are periodically invaded by tidal waters. Since many plants and animals do not tolerate exposure to salt water, episodic tidal disturbances can have a major impact on the structure and function of wetland communities. While these areas can also be called brackish wetlands, they are brackish for a relatively short and often unpredictable period. They are transitional wetlands between many salt marshes and freshwater wetlands. Before the Reclamation Period (1850's) there were probably hundreds or even thousands of acres of transitional wetlands in the Monterey Bay area (Chapter 1). Now there are few. As a result, the recreation and study of brackish or transitional wetlands is a major research priority developed for the Research Reserve.

4.4.4.1 Hydrology

Tidal input to the North Marsh is restricted by culverts equipped with gate valves. The valves are opened partially allowing the tide to rise just below the low areas in Elkhorn Road (about 2 feet above mean sea level). The tidal amplitude (0-2 feet) is limited and wetland plants are submerged much of the time. As a result, the only abundant plant, pickleweed, does not develop a dense canopy and has low productivity.

The hydrology of this option will be similar to that described for the Blohm-Porter Marsh. The major difference is that less freshwater flows into the smaller Kirby and North Marshes. In addition, the salinity and water levels in the Kirby Marsh can be experimentally manipulated in a long-term research project as part of the Estuarine Research Reserve's scientific program.

The existing gate valves or a system of flaps and weirs will be adjusted to pond freshwater in the North and Kirby Marshes. The gates will be opened if the level of freshwater rises too high during abnormally heavy rainfall and will be closed to prevent salt water inflow most of the time. The marsh will fill with freshwater runoff primarily from the Strawberry Canyon and Hidden Valley drainages. Later in the year the water will evaporate and drain into the channel and pond systems. During most years there is adequate runoff to fill the marshes completely.

Marsh hydrology will be modified during experimental manipulations of salinity and water levels, including experimental flooding of the marsh with salt water. The disturbance, colonization and re-disturbance processes can be studied through the Research Reserve programs. The marsh can be redisturbed with salt water in a controlled manner to restart the colonization process under a wide variety of experimental conditions. The pond-channel-island system provides replicate settings for holding water at a high elevation in some replicates and at a low elevation or for a longer time in others. The number of potential manipulations are large. The experiments can be much more sophisticated and well controlled by adding other structures to manipulate the hydrology and wildlife in each pond-channel-island system separately. However, these construction details and the many questions or hypotheses that can be tested are not considered here. They should be developed by wetland scientists in close cooperation with the Department of Fish and Game and the Elkhorn Slough Foundation. This option establishes the basic structure for the pond-channel-island system that can be expanded in many ways for wetland research.

One practical set of experiments involves the control of mosquitoes under a variety of exposures to salt water. For example, it may be possible to kill the larvae of freshwater mosquitoes without harming plants and many other species. These and similar research results will be useful in determining the optimal tidal exposure in the Blohm-Porter Marsh and in other marshes such as those in the Moro Cojo Slough.

4.4.4.2 Wildlife

This option will produce much greater habitat heterogeneity, species richness and scientific research potential for the National Estuarine Research Reserve than option 1. It will be colonized by the same basic flora and fauna that will inhabit the Blohm- Porter Marsh. The marsh will contain a mosaic of salt marsh plants that will persist in dense patches as the marsh is colonized by freshwater species. The number of species of plant and animal life, especially the waterfowl and shorebirds, will be much greater than they are today. Table 4-1 shows the changes in habitat areas after each enhancement option.

4.4.4.3 Interactions with Adjacent Habitats

These interactions will be the same as those described for the Blohm-Porter Marsh and for option 1 for the Kirby Marsh.

4.4.4.4 Construction

The general construction techniques described for the Blohm-Porter Marsh and the Kirby Marsh also apply for this option. The marsh can be at least partially dried over one to several years with a significant decrease in excavation cost and control of construction as discussed for the Blohm-Porter Marsh and the Kirby Marsh.

Sediment excavated from channels and ponds can be placed on islands while the size, shape and slope of features are easily controlled. At the same time, other structures can be added such as dam or weir systems allowing water to be manipulated separately in each pond-channel-island system (Figure 4-6). Again, these design details should be developed by wetland scientists for research use. These improvements could be funded with research funds. This option provides the basic plan concept.

4.4.4.5 Conservation & Acquisition

The North Marsh is part of the Elkhorn Slough National Estuarine Research Reserve. Kirby Marsh is presently in private ownership and would have to be acquired or donated to a public agency or non-profit organization prior to commencing any enhancement activities.

The North and Kirby Marshes will be maintained by the Department of Fish and Game as part of the Research Reserve. The experimental structures will be paid for and maintained through grant money and donations to the Elkhorn Slough Foundation, which organizes and operates the education and research programs on the Reserve.

4.5 LOWER RANCH MARSH

4.5.1 Environmental Constraints

The Lower Ranch Marsh is divided into two branches. The Hidden Valley Marsh branch covers a larger area including both Hidden Valley and Strawberry Canyon (Figure 4-6). The

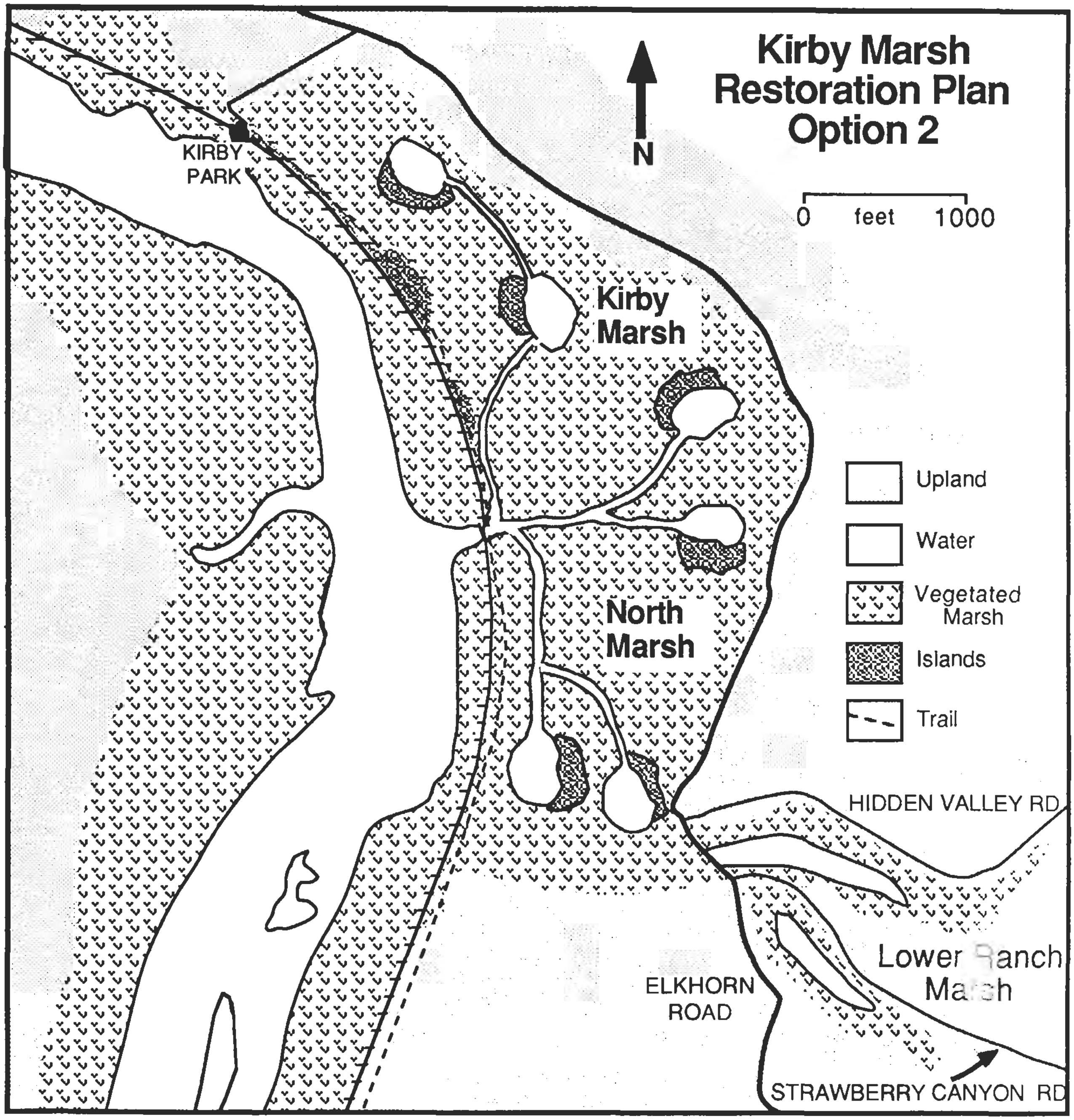


Figure 4-6. Option 2 enhancement plan for the Kirby Marsh and North Marsh and related enhancement plan for the Lower Ranch Marsh.

two branches connect by a culvert under Strawberry Canyon Road. Both drain into the North Marsh through several culverts under Elkhorn Road. Today much of the marsh is only 1-2 ft. below the elevation of Elkhorn Road. Salt water flows into the Hidden Valley branch since limited tidal flow was restored to the North Marsh.

The major environmental constraints to wetland enhancement in the Lower Ranch Marsh are:

1. The low elevations of Elkhorn and Strawberry Canyon Roads.
2. Limited tidal flow into the North Marsh.

4.5.2 Existing Environment

A dense growth of freshwater plants, primarily rushes and sedges, covers much of the Strawberry Canyon branch. The growth limits the amount of open water in the pond, but the wetland is used by waterfowl especially during the winter. Since salt water enters the Hidden Valley branch from the recently restored North Marsh (Figure 4-6), the area is primarily covered with pickleweed and the introduced plant, brass buttons. There are patches of riparian vegetation along some of the border and at the head of this branch. The marsh is used by waterfowl and by shorebirds. Egrets and herons also forage in the Hidden Valley branch.

There is no quantitative information on the flora and fauna from these marshes and no evidence that the sites are used by endangered or threatened species.

4.5.3 Enhancement Plan

The general enhancement plan for the Lower Ranch Marsh is to raise the elevations of Elkhorn and Strawberry Canyon Roads and to pond freshwater behind the raised Elkhorn Road. If the roads are not raised, no enhancement plan is recommended for this marsh.

4.5.3.1 Hydrology

The hydrology of the Lower Ranch Marsh will be similar to the Blohm- Porter Marsh. A culvert system installed under Elkhorn Road at an elevation of 2 feet above mean sea level allowing excess freshwater to drain into the North Marsh. As the level of freshwater drops in the marsh by evaporation, water will pond in into the central marsh keeping the surrounding wetland well drained. If the roads are not raised, no enhancement is proposed and the marsh would remain in its present condition.

4.5.3.2 Wildlife

The enhancement of the Lower Ranch Marsh will create a freshwater marsh with many patches of salt marsh plants dispersed among the colonizing freshwater plants. On a smaller scale, the wildlife changes will be similar to those described for the Blohm-Porter Marsh. In general, the plan will produce a heterogeneous habitat that will harbor a number of waterfowl and shorebirds. Some waterfowl may nest here. As in the Blohm- Porter Marsh, this plan will increase large-scale habitat heterogeneity as a new freshwater marsh will interact with the larger salt marsh fauna from the Elkhorn Slough.

4.5.3.3 Interactions with Adjacent Habitats

The interactions with adjacent habitats will be similar to those described for the Blohm-Porter Marsh except on a smaller scale. The marsh will be used by raptors and songbirds along its edges and should be an outstanding area for bird watching.

The Hidden Valley branch is presently threatened with sedimentation from eroding raspberry fields next to the marsh and strawberry fields further up the watershed. Erosion control systems should be installed in the immediate watershed. The upper reach of the marsh should be studied for the feasibility of installing a sediment catchment basin.

4.5.3.4 Construction

The raised Elkhorn Road will be the dike to hold freshwater in the system. The road fill would require special design and engineering to prevent saturation and seepage. The road should be raised to an elevation of 8 feet above mean sea level. The culvert system will be placed at 2 feet above mean sea level to pond water without flooding other roads.

4.5.3.5 Conservation & Acquisition

The Lower Ranch Marsh is part of the Elkhorn Slough National Estuarine Research Reserve and is therefore preserved for education, research and wildlife conservation.

4.6 CALCAGNO-ESNERR-VIERRA MARSH

4.6.1 Environmental Constraints

This wetland complex includes several diked wetlands areas and ponds. The Minhoto Pond is the furthest east (Figure 4-7) and collects rainwater and limited local runoff. This pond is rarely full. The Calcagno Pond receives wash water and runoff from the dairy. It is designed to impound the wash water and prevent high bacteria water from entering the main slough and is usually full. The adjacent Sanctuary Pond, Seal Bend Marsh, and Vierra Marsh are separated from the slough by an outer dike (Figure 4-7). If the dike were removed, there would be severe tidal erosion of these wetland habitats. Therefore, the major environmental constraints to wetland enhancement in these ponds and marshes are:

1. Containment of dairy waste in Calcagno pond.
2. Dike maintenance to prevent wetland erosion.

4.6.2 Existing Environment

The Minhoto and Calcagno Ponds harbor a large number of waterfowl throughout the year. The Minhoto Pond harbors more vegetation because it is not as full as the Calcagno Pond and often dries up. The ESNERR Pond drys up by early summer. It harbors a mix of freshwater (rushes, cattails, sedges) and salt water plants (primarily pickleweed) and is used by waterfowl during the rainy season. However, since the pond was acquired by the Department of Fish and Game, no freshwater has been pumped into the pond and the unvegetated areas have been covered by pickleweed and fat hen. The Vierra Marsh harbors a lush mix of freshwater (rushes, sedges, cattails, willows) and primarily salt water plants (pickleweed, salt grass, alkali heath, *Jaumea* , fat hen, gum bush, Pacific silver weed). Several species of waterfowl (Mallards and Teal) nest along the upland edge of this marsh. The Seal Bend Marsh is covered with pickleweed. However, because rainwater is trapped here and there is no circulation of salt water, this site has one of the densest mosquito populations in the slough. The mosquitoes will not live in the marsh when tidal circulation is restored. The enhancement plan will not destroy any of the desirable wildlife in the Calcagno-ESNERR-Vierra area. It will lead to more bird use and better plant

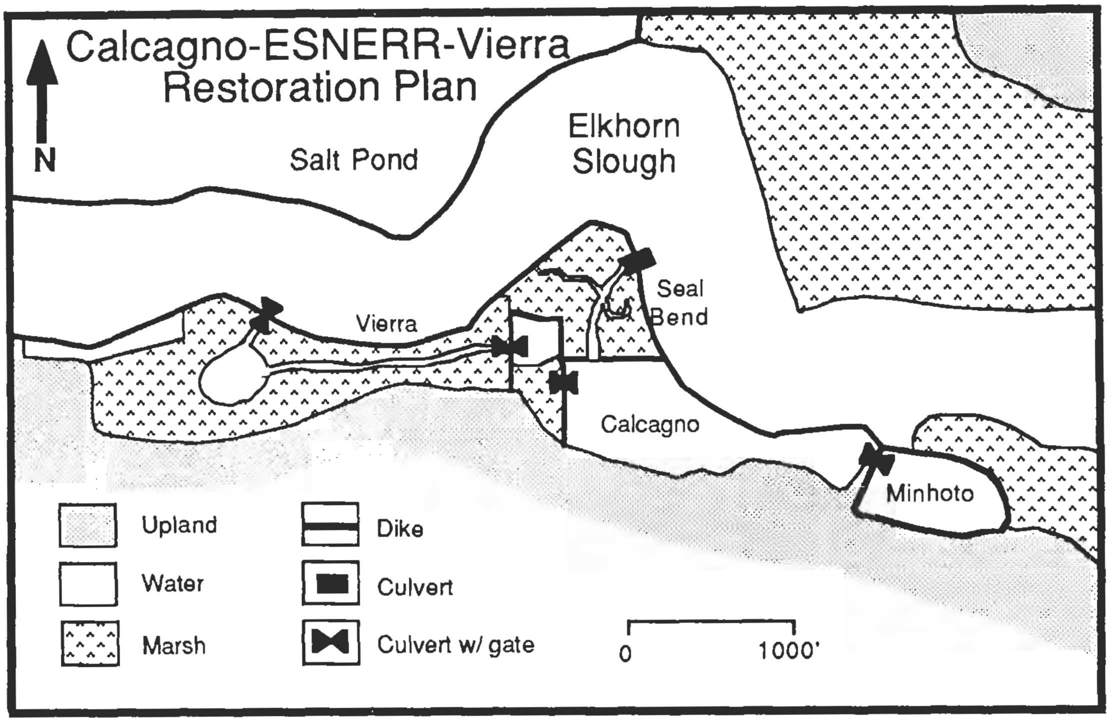


Figure 4-7. Recommended enhancement plan for the Calcagno-ESNERR-Vierra site.

cover. Table 4-2 shows the change in habitat areas made by the enhancement.

There are no quantitative data on the flora and fauna from these habitats and no evidence of use by endangered or threatened species.

4.6.3 Enhancement Plan

The general enhancement plan is to maintain the outer dike system preventing ercsion of the protected wetlands and to restore controlled tidal flow through a culvert to Seal Bend Marsh, through another culvert to ESNERR Pond and another culvert to Vierra Marsh. Because the Calcagno Pond presently functions as a dairy waste pond, no enhancement activities are proposed here (Figure 4-7).

4.6.3.1 Hydrology

Several culverts will be placed in the outer dike to allow limited tidal flows into the Seal Bend Marsh and the Vierra Marsh/ESNERR Pond. The Minhoto Pond could also be connected to the slough through a culvert. The tidal range created in these areas should be restricted, however, to avoid tidal erosion of the habitats. The culvert system could create a limited tidal range in each marsh to enhance the salt marsh habitat. A central channel would be excavated in the Vierra Marsh to allow for tidal water circulation. A more detailed engineering design of the culvert and circulation system will be needed and should include mapping of elevations in the marshes and ponds and simulation of several limited tidal regimes to determine the level of tidal flooding and habitat enhancement possible in each area.

4.6.3.2 Wildlife

This system will maintain healthy salt marsh habitats adjacent to Calcagno Pond. The fringing vegetation in Vierra Marsh is a favorite nestling area for waterfowl. The enhanced mix of vegetation will harbor many species of shorebirds, waterfowl and terrestrial birds from the adjacent forest. In general, the wildlife will be similar to that described for the Blohm-Porter Marsh.

4.6.3.3 Interactions with Adjacent Habitats

The primary adjacent habitats are the main channel of Elkhorn Slough and the *Eucalyptus* forest on the landward side. The forest is now part of the Elkhorn Slough National Estuarine Research Reserve. It supports a few deer, other mammals and many birds. Across the slough the salt ponds are a resting, feeding and breeding habitat for the largest variety of birds in the slough. Many of these birds will also use the Calcagno-ESNERR-Vierra habitats.

4.6.3.4 Construction

The dikes around Seal Bend and Vierra Marsh should be repaired if the erosion in Elkhorn Slough continues. The dikes at the Calcagno Pond are exposed to less erosion and are maintained very well by the dairy. The dikes around the Minhoto Pond are protected by a wide fringing salt marsh and have no erosion problems. The sizes and elevations of proposed culverts will be determined through an engineering design study.

The excavation of a small channel and central pond in the ESNERR Pond and Vierra Marsh can be done with a drag line and if feasible the material deposited on the dike. The volume of deposit will be small (Table 4-2).

Finally, the details for repairing the dikes depend on the future plans for the mouth of the slough. Temporary protection is only needed for the dikes around the Vierra Marsh, and this is being done by the Vierra family. If a permanent erosion control structure such as a rock sill is recommended by the Corps of Engineers model and accepted for the slough, the dikes will not need protection. The Corps model addresses the slough-wide erosion from the tide, which is the number one environmental problem in the slough (Chapter 2). If no system-wide control is initiated, the dikes will need more expensive long-term repairs.

4.6.3.5 Conservation & Acquisition

The Calcagno Pond and Vierra Marsh are presently in private ownership. The ESNERR Pond and Seal Bend Marsh are part of Elkhorn Slough National Estuarine Research Reserve and are thus preserved for education, research and wildlife conservation. The Minhoto Pond is owned by the Mearle Corporation which farms the adjacent agricultural lands.

A conservation easement or title to the Vierra and Minhoto property acquired by or donated to a public agency or non-profit organization will be required prior to any enhancement activities.

4.7 Compatible Wetland Uses

There are a number of uses that are compatible with the recommended wetland enhancement plans. Public access for aesthetic enjoyment, education and research are the most common and important uses. However, there are other potential uses of the wetlands. For example, organizations such as Ducks Unlimited restore habitat for waterfowl throughout this and other countries. They could develop local habitats to enhance the breeding or resting sites of certain waterfowl. The recommended enhancement plans could improve by this type of compatible interaction and use of local wetlands. Native plants could also be harvested for seeds and cut or cored for shoots or root material to develop a local source of native wetland and associated plants. Enhancement sites may be gifted with the conditions that a local native plant nursery could use the site. The Elkhorn Slough Foundation could manage these activities and insure no detrimental effects to the marsh. The positive implications of this compatible use are many. At present, local sources of native wetland and adjacent upland plants are very limited. A local source will help in future preplanting within and around the slough. It may play a central role in returning native vegetation to many local habitats. This and other potentially compatible uses of wetlands and their buffer zones should not be excluded from future planning.

4.8 Monitoring Enhancement Projects

Each wetland enhancement project is a large-scale experiment that can teach managers, planners and wetland scientists much about how wetlands work and how to best improve them after degradation. There are several excellent general accounts of the environmental problems that should be considered in monitoring an enhancement project (e.g., Zedler 1984). There are good management and scientific reasons for monitoring the hydrology and wildlife of certain enhanced wetlands, especially the Blohm-Porter Marsh, Kirby/North Marshes, and the Vierra Marsh because manipulations of fresh and salt water are possible and highly desirable. These manipulations will teach us much about how salinity and emergence influence wetland ecosystems. This information will determine future management practices in these and other regional marshes. However, the details of each monitoring program should be site specific and developed by local naturalists and scientists with direct input from managers and planners. Wetland monitoring programs should be developed by the Elkhorn Slough Foundation with input from the Research Reserve Advisory Committee. The monitoring program should not be designated until interested scientists are involved and determine the best questions and the best manipulations for each enhancement, including monitoring habitat conditions and wildlife both before and after the enhancement.

CHAPTER 5.
PUBLIC ACCESS

5.1 INTRODUCTION

Monterey County Planning Department has drafted a North County Trails Plan which covers the existing roads and trails around Elkhorn Slough. Trails were considered for the following uses: hiking; hiking and horse back riding; hiking and bicycling; hiking, riding and bicycling; and only bicycling. The draft plan provides an excellent overview of the 1984 Regional Transportation Plan, North County Area Plan policies, North County Land Use Plan policies, and Monterey County General Plan policies as they relate to public access trails.

The draft plan does not consider public access trails to any of the wetland enhancement sites recommended in the present plan and does not discuss specific public access problems for Elkhorn Slough. Therefore, this chapter presents the public access plan for each enhancement site recommended in Chapter 4, presents public access plans for major slough wetlands where no enhancement plan is recommended, and relates all wetland access plans to the existing road and highway system (Figure 5-1).

5.2 Public Access to Wetland Enhancement Sites

5.2.1 Blohm-Porter Marsh

There is excellent potential public access to the Blohm-Porter Marsh. The hiking trail is shown in Figure 4-3. There will be no automobile entrance from Elkhorn Road. We recommend that the main entrance be on the Porter Reserve where a parking lot will accommodate automobiles from Hall Road. There will be direct access to four loop trails of varying lengths from the parking area. The first loop will go from the parking lot to the second island and return along the existing dirt road above the marsh. The second loop trail will go through the central marsh, across the islands and existing dikes and return by the dirt road. This trail gives access to two smaller loop trails at the south end of the marsh. The shortest trail will circle the existing duck pond. The trails will go along wooden causeways, existing dikes reinforced with excavated sediment, islands and the existing dirt road along the east side of the marsh. There is an excellent opportunity to develop one of the buildings on the Porter Ranch into a visitor center next to the parking area with access to overlooks of the wooded habitats at the marsh edge (Figure 4-3). The cost of developing this trail and parking system is considered in implementing the enhancement plan.

5.2.2 Azevedo Marshes

The Azevedo Marshes are bounded on the east by private land, the Azevedo Ranch, and on the west by the railway trestle. However, the salt marsh and adjacent upland just west of the railway trestle belongs to The Nature Conservancy. They are developing a public access trail along the marsh and their hilltop property that overlooks the Azevedo Marshes at several locations (Figure 4-4). This trail provides excellent, non-disruptive public access to the pocket marshes while visitors also enjoy the habitats preserved by The Nature Conservancy and several outstanding overviews of upper Elkhorn Slough. This trail could also connect with sanctuary trails at Kirby Park as shown in Figure 4-5 and 4-6.

The Nature Conservancy trail is being developed in cooperation with the Elkhorn Slough Foundation, Moss Landing Harbor District and the State Coastal Conservancy.

5.2.3 Kirby and North Marsh

The main public access to the Kirby and North Marshes will be along the inside of the railway trestle on an existing dike system (Figures 4-5 and 4-6). The dike must be raised in several areas to make a continuous hiking trail through the North and Kirby Marshes. The trail will join The Nature Conservancy trail at Kirby Park (Figure 4-4) and create outstanding public access to the east side of Elkhorn Slough. This trail will be developed by the Department of Fish and Game as a part of the Elkhorn Slough National Estuarine Research Reserve and is part of their trail plan. The cost of developing the trail is considered in implementing the enhancement plan.

5.2.4 Lower Ranch Marsh

The only available public access to the Lower Ranch Marsh is from Elkhorn, Hidden Valley and Strawberry Canyon Roads (Figures 4-5 and 4-6). A few automobiles can park on the existing roadside shoulders, but in general much better access is available to the other marshes. Visitors will be able to see much of the Lower Ranch Marsh from the roads. There is no area for developing parking and providing safe access.

5.2.5 Calcagno-ESNERR-Vierra Site

Eventually excellent public access can be developed to this series of ponds and marshes with a long walk along the outer dike system. However, at present there is no simple access to the ponds and marshes from the main road, and the condition of some dikes are inadequate for regular hiking; they are seriously eroding. Access to the ESNERR site, which is directly across Elkhorn Slough and south of the Wildlife Area and Packard Ranch, may be developed along an existing easement from Dolan Road. The ESNERR property can provide parking, trails, and observation areas to and along Elkhorn Slough and the wetlands to the north.Access plans to the diked area will require accompanying structural improvements to assure stability. No access to the Vierra .and Calcagno properties is proposed.

5.3 Additional Wetland Access

There are four other large wetland habitats in Elkhorn Slough where no wetland enhancement is recommended, but where public access is present or possible.

1. The central part of Elkhorn Slough National Estuarine Research Reserve.
2. Moss Landing Wildlife Area (Salt Ponds)
3. Packard Ranch wetlands.
4. The Nature Conservancy wetlands along the western slough.

Public access plans have been made and many of the trails already exist for the two slough wetland areas under the management control of the Department of Fish and Game: the Research Reserve and Wildlife Area (Figure 5-2). The Moss Landing Wildlife Area includes a large area of salt marsh bordering the Packard Ranch (Figure 5-1). The existing trail borders the marsh and is on the Packard Ranch. This trail will eventually extend to the north end of the Wildlife Area salt marshes and to the northern end of the Packard Ranch. Here there is an outstanding site for a small vistors center and direct access to Highway One through the Packard Ranch. Although the ranch is not open to the public, it may become a major education area for the Monterey Bay Aquarium.

The last large wetland area where public access is possible is The Nature Conservancy Land along the west side of Elkhorn Slough. No public access is recommended for this marsh. First, The Nature Conservancy already brings many groups to the marsh through their excellent field programs, which are open to the public. Second, the only access from the road is across private agricultural land. Local owners have given The Nature Conservancy permission to pass. Finally, this area of the slough is generally difficult to enter, and so receives relatively few visitors, thereby providing a large region with minimum human intervention and disturbance. Since public access is easy and well developed in other areas, this region should be maintained with minimal public access.

5.4 General Access to the Slough

The final important component of public access to Elkhorn Slough concerns the surface roads and highways that feed the region. Highway One provides unlimited access to the area. It is now often crowded but will not be the limiting factor in wetland access. Rather, the number of visitors to the Moss Landing Wildlife Area and perhaps someday to the Packard Ranch is not limited by the access roads, but by the maximum optimal number of visitors at the site.

Access to the Blohm-Porter Marsh is via Hall Road, a major road connecting Watsonville, Prunedale, Aromas and Elkhorn. It does not limit the number of visitors to the Blohm-Porter Marsh. Access to Hall Road is adequate from Highway One via Salinas Road and excellent from Watsonville via Riverside Road. From the north, access to Hall Road from Highway 101 is excellent. Few visitors would probably come from the south via Highway 101 (Figure 5-1).

In contrast, access to the Research Reserve is from a smaller rural road and a scenic highway, Elkhorn Road. Additional traffic here would have a negative impact on traffic safety and on the aesthetic or scenic aspects of the drive, which includes many overviews of wetland habitats. The Elkhorn Slough Foundation is currently seeking funds to evaluate the optimal number of visitors to the various wildlife recreation areas around the slough. This study will consider the limits to public access imposed by Elkhorn Road. Since no public access is presently recommended for the Calcagno-ESNERR-Vierra site, a similar problem is not likely along Dolan Road.

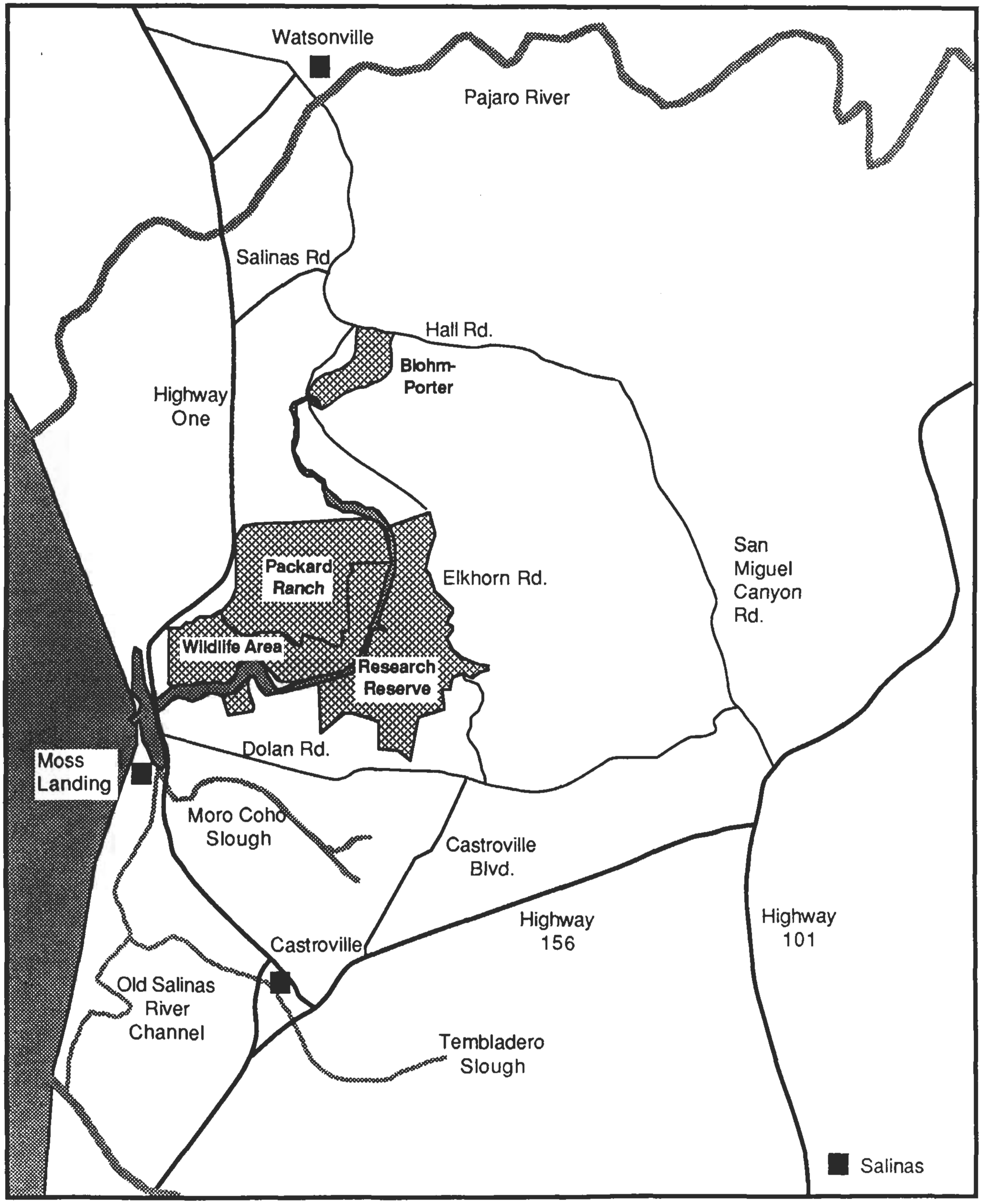
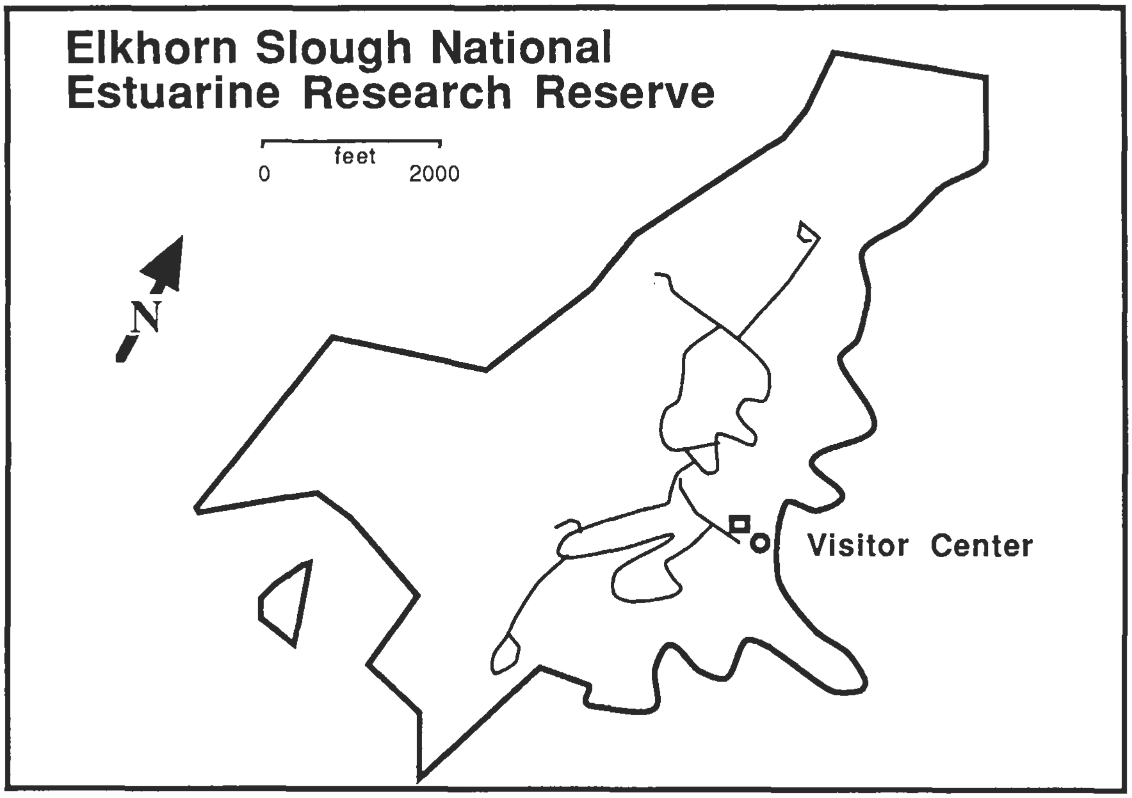


Figure 5-1. Overview of public access to Elkhorn Slough.



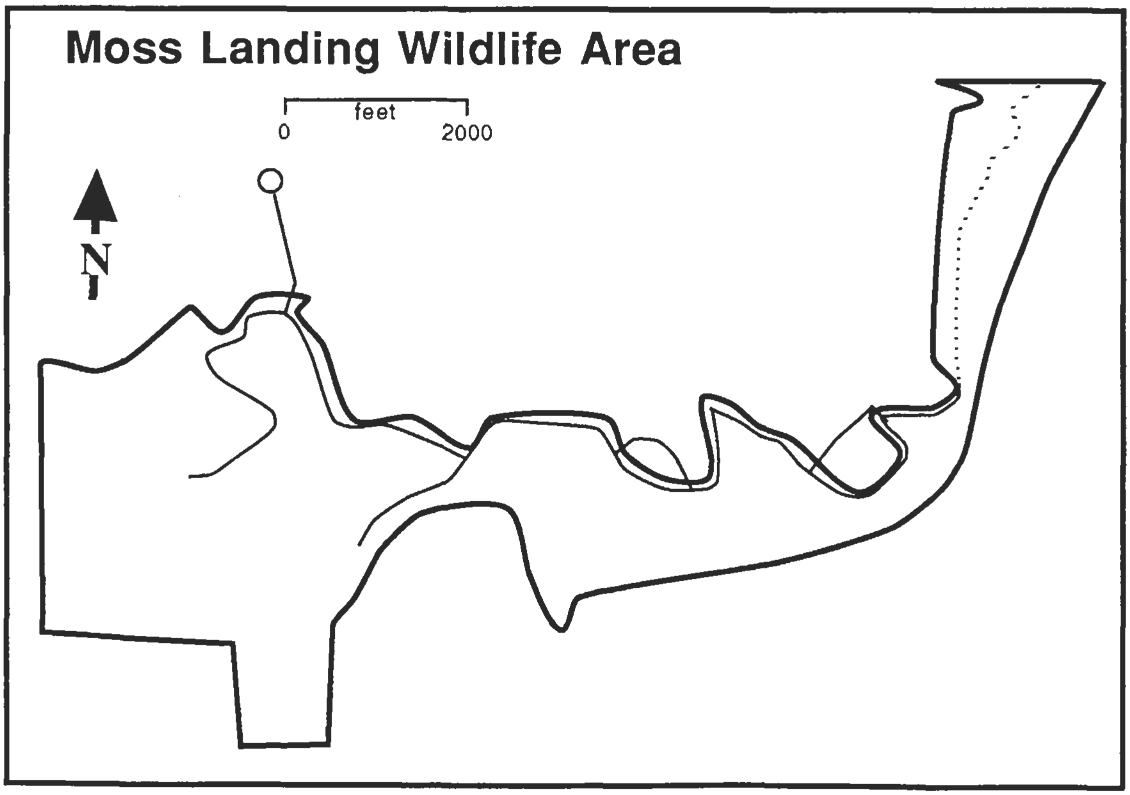


Figure 5-2. Public access trails to Moss Landing Wildlife Area and Elkhorn Slough Estuarine Research Reserve.

CHAPTER 6
PLAN IMPLEMENTATION

6.1 Introduction

The preceding chapters summarize the important natural history of the slough system, consider existing problems with erosion and sedimentation and water quality, present enhancement plans for slough wetlands and propose public access to several wetland areas. This chapter describes the basic steps to implement the recommendations of the plan. The responsible agencies and potential funding sources are identified for each part of the plan and costs are estimated for most elements.

The plan found the following management problems in the slough:

6.2 Erosion and Sedimentation

The major erosion problems in Elkhorn Slough and its watershed are (Table 6-1):

1. Erosion of wetland habitats within Elkhorn Slough from tidal currents.

2. Erosion of soil from strawberry fields on steep slopes.

3. Erosion of large gullies along the steep, vegetated slopes above the west slough.

4. Visual impacts of erosion scars and unvegetated fans.

The major sedimentation problems in the slough and its watershed are (Table 6-1):

1. Deposition of sediment into small freshwater ponds and wetlands along the slough.

2. Deposition and build-up of sediment in Carneros Creek.

3. Deposition of sediment on the upper edge of the pickleweed marsh along the west slough.

4. Deposition of sediment along Elkhorn Road and other public and private roads.

6.2.1 Slough Erosion

The most serious problem within Elkhorn Slough is the continuing erosion of tidal habitats caused by the construction of the harbor entrance at the mouth of the slough. Erosion is most conspicuous in the vegetated marsh which is being transformed to subtidal channel or mudflat habitat. Mudflat habitat is also threatened because much of the slough may eventually revert to subtidal channel habitat. This erosion dominates the past 40 years of slough history and will probably dominate future changes in the major habitats of the slough. This erosion directly affects one of the wetland enhancement areas by threatening dikes that protect wetland habitat.

A numerical model of slough currents should be developed to evaluate the best erosion control structure. One possibility is construction of a rock sill at the Highway One bridge. Such a feature would be expensive and have complex biological and well as hydraulic effects. Therefore, this concept must be studied in detail.

The Monterey County Board of Supervisors should request the Army Corps of Engineers to develop the model and the optimal sill structure for control of erosion caused by harbor construction and maintenance. The Board should request support for this project from California representatives to the U. S. Congress.

Once the model is completed and the best structure developed on paper, a plan for implementing the recommendations should be developed by Monterey County in conjunction with the Corps, the Fish and Wildlife Service, the Department of Fish and Game, the Elkhorn Slough Research Reserve Advisory Committee, and the Coastal Commission.

A second possible step to controlling erosion of the wetland is to introduce cordgrass (*Spartina foliosa*), which is presently absent from Elkhorn Slough. Cordgrass is a low marsh plant species and in many estuaries plays an important role in stabilizing upper intertidal mudflats. Its introduction into several experimental areas could retard erosion of the marsh fringe as well as increase habitat diversity. Cordgrass will not help the erosion problems in the intertidal mudflats below the elevation of cordgrass, in the main channel, in tidal creeks with vertical walls, and at upland edges including most dikes. Fragments of cordgrass have been found in sediment cores in the slough, but the timing and reasons for its disappearance are unknown.

Several experimental planting areas in different parts of the slough could be initiated and their success at lowering erosion rates monitored. These experimental plantings could be accomplished most appropriately through the Research Reserve.

6.2.2 Watershed Erosion and Sedimentation

The remaining problems identified in the plan are directly related to erosion of sediment from strawberry fields and the erosional effects of increased runoff from agricultural fields. The Soil Conservation Service's report on the Strawberry Hills Target Area (which includes most of the slough's watershed) makes recommendations to prevent this erosion. It also gives a detailed outline of the best erosion control systems for strawberry fields on steep slopes. These systems are well described in various publications (Edwards 1984, Eisenman 1984, Soil Conservation Service 1984, 1985), and reduce erosion to acceptable levels of below 5 tons/acre/year. They include contour planting with no furrow slope, installing collection pipes for water between every three or four furrows, and a buried pipe system transporting water from each collection pipe to the base of the hill. The water is then captured in catchment basins or released along paved surfaces into natural drainages.

Installation of these systems is done on a voluntary basis by landowners. The Soil Conservation Service will lend design assistance to landowners. Federal cost-sharing is available on a very limited basis of a maximum of $3,500 per farm per year. The cost to install these improvements may run as high as $3,000 per acre, and the life of these improvements is 10-20 years. The high capital costs and limited public financing have induced few farmers to participate. In addition, where farms are leased out, neither the landowner nor the leasee is motivated to make large improvements to the land. There are several possible solutions to this problem.

6.2.2.1 Increased Public Financing for Erosion Control Improvements

Many growers are spending up to $1,000 per acre per year to install temporary erosion control devices such as plastic linings and silt fences.

These devices are rarely effective in controlling soil movements. If growers could be assisted with public financing of a portion of the cost of erosion control systems, they could use their funds now applied to temporary systems for permanent systems. The existing federal cost-sharing program is inadequate to encourage farmers to install these permanent systems.

The Coastal Conservancy has explored a program with the Monterey Coast Resource Conservation District to provide additional funds to cost-share for installation of these systems. The Monterey Coast Resource Conservation District (MCRCD) is the most appropriate local agency to implement such a program. The MCRCD had some reservations about participating in such a program, and currently no proposal for such a program is under discussion.

The Board of Supervisors should discuss program options with the Monterey Coast Resource Conservation District and the Coastal Conservancy.

6.2.2.2 Implementation of County Erosion Control Ordinance

The Monterey County Erosion Control Ordinance (No. 2806) allows the County to penalize landowners whose land causes an erosion problem which creates a hazardous condition. Practically speaking, the ordinance has been enforced when sediment from farms covers roads or someone's property and must be cleaned up.

The County should fully implement this ordinance to include violations where sediment is deposited in wetlands or stream channels as well as the obvious problems on public roads. It may be necessary to revise the Erosion Control Ordinance to include the resource areas as designated in the LCP. The Board of Supervisors should direct the Planning and Building Inspector's Department to explore methods to fully implement this ordinance. Full implementation would greatly increase the interest of farmers in installing permanent erosion control systems and controlling their erosion on-site, and would help protect a number of threatened fresh and salt water wetlands in the slough's watershed.

6.2.2.3 Changes in Land Use in Slough Watershed

The North Monterey County Local Coastal Plan recommends converting steep strawberry lands to low-density rural housing by designating these areas for this land use. This long-term change in land use is also recommended by this plan. The LCP (section 2.5.3) also requires that watershed restoration be accomplished in designated subwatersheds by reducing the amount of bare ground in impacted subwatersheds. Reduction of bare ground is a means of controlling the cumulative erosion impacts of development. Development in Elkhorn Slough should adhere to the Watershed Restoration Program outlined in the LCP.

Further, all new development shall require erosion control plans and mitigation devices as conditions of approval. Also, where appropriate, clustering to reduce impervious forms of development shall be required to minimize runoff. Lastly, as previously indicated, flood control projects maintaining natural stream bed maintenance are the required alternative to flood control structures for new development. Natural streambed maintenance, including broad, low-angle contouring, is the environmentally preferred method of stream maintenance over channelization.

6.2.2.4 New Strawberry Lands

Under the Local Coastal Plan, the County requires that agricultural management plans be submitted for development of any new strawberry or other agricultural lands in the slough watershed. At the time of permit review for these new agricultural lands, the County should require the installation of permanent erosion control systems as designed by the Soil Conservation Service.

6.2.2.5 West Slough Gullies (Springfield Terrace)

Whereas the problem with strawberry lands is the transport and deposition of large amounts of soil from farmlands, the formation of gullies along the west side of the slough is a result of concentrated runoff from agricultural fields above the slough. The sediment from these gullies is covering over salt marsh.

The major crops here are artichokes and brussels sprouts. The land is relatively flat. However, furrows are not contoured, allowing rapid runoff of rain and irrigation water to the steep slope and into the eroding gullies. The velocity of this flow should be reduced by contouring furrows near the steep slopes. If hilltop contouring and drainage practices do not stop gully erosion, runoff water should be collected behind low dikes where water flows off the hilltop. Here water should be diverted into pipes and conveyed to the bottom of the steep slope into small ponds with rock or other structures to reduce water velocity and potential erosion below the slope. The most serious erosion is caused by rapid water flow down these steep slopes. Once the drainage is diverted from the gully and it is no longer actively eroding, natural revegetation can begin. Some planting of grasses or willows in these gullies could speed the stabilization process.

These drainage improvements must be accomplished on private lands with the full cooperation of the landowners. Depending upon the costs for installation of drainage pipe, some cost-sharing may be required to encourage landowners to participate. It is possible for the Coastal Conservancy to supply some funds for these activities through a grant to the Elkhorn Slough Foundation or another non-profit organization or a public entity such as the Monterey Coast Resource Conservation District or Monterey County.

The Board of Supervisors should direct the County Planning and Building Inspection Department to investigate methods to establish a special study area comprised of the West Slough Gully area for the purposes of controlling erosion and reducing sedimentation onto the salt marsh.

6.3 Water Quality

The plan identifies the following management problems in the slough (Table 6-2):

Surface Waters

The biggest environmental problem in the surface water of the slough and watershed is the high levels of persistent pesticides moving through the system and being exposed to aquatic organisms. The insecticides DDT, dieldrin, toxaphene, aldrin, chlordane, endosulfan, and chlorpyrifos and the herbicide dacthal occur in water, sediment, fishes and/or shellfish from Elkhorn Slough. Because of the importance of agriculture to the local economy, a balance must be reached between the elimination of pesticides from the waterways and the present dependence of the agricultural industry on chemicals. The major problems are listed in their order of importance to Elkhorn Slough (Table 6-2).

1. High levels of persistent pesticides, especially DDT, endosulfan, and toxaphene, in agricultural soils.

2. The probable transport of pesticides into slough water from the overflow of Salinas River water into the Old Salinas River channel and into the slough.

3. Endosulfan presently being applied to local crops, with runoff entering the slough.

4. High levels of coliform bacteria in slough waters.

Groundwater

The most significant groundwater problem around the slough is salt water intrusion of the surface, Upper and Lower Aromas Sand aquifers. The groundwater problems are listed in their order of importance:

1. Salt water intrusion of surface, Upper and Lower Aromas Sands aquifers.

2. High nitrate levels in well water.

6.3.1 Surface Waters

6.3.1.1 Pesticide Transport

The limited level of current monitoring data indicates that the high levels of pesticides found in Elkhorn Slough did not come from the immediate slough watershed. Instead, it is probable that the source is the Salinas River, a much larger drainage area carrying runoff from the major agricultural center of Monterey County. Since the agricultural industry of the County relies heavily on pesticide use, this plan does not recommend banning or limiting the application of all pesticides. Such a change in farming practices may occur in the long term but does not represent a viable solution to the present water quality problems in Elkhorn Slough.

Instead, this plan recommends management of the runoff from the Salinas River to avoid continued transport of pesticides into the slough. During many months a sand bar blocks the mouth of the Salinas River. During this period Salinas River flows are directed through a culvert into the Old Salinas River channel and Moss Landing Harbor. This water may be transported up the slough by tidal currents or due to advection from the PG&E intake structures. In times of high rainfall, the Monterey County Flood Control District opens the mouth of the Salinas River with a bulldozer, allowing the river to flow directly into Monterey Bay.

This system of water drainage facilities could be better managed to reduce transport of Salinas River water through the harbor and into the slough. During summer and fall months when rainfall is slight, river water is primarily composed of agricultural return water. Reducing the volume of this water reaching the slough is an important first step in reducing the build-up of persistent pesticides in the slough.

The Monterey County Board of Supervisors should direct the County Flood Control District to complete an alternative drainage plan which has as its primary goal the maximum reduction of drainage of Salinas River water into the Old Salinas River Channel and Moss Landing Harbor and movement of this water into the slough.

While this alternative drainage plan is being formulated, the Board of Supervisors should request the Regional Water Quality Control Board to complete a study of water exchange between the Salinas River and the slough under the present system and its effects on pesticide transport. The Board of Supervisors should also request the Regional Water Quality Control Board to begin a long-term monitoring study of pesticide levels in the slough following implementation of an alternative drainage system.

6.3.1.2 Chemical Replacement

The amount of endosulfan (the last persistent chlorinated hydrocarbon pesticide used in the watershed), dacthal and chlorpyrifos reaching the slough and concentrating in animal tissue should be reduced. Chemical or biological replacements for pesticides should be developed by the State Department of Food and Agriculture. The County Board of Supervisors should request the Department of Food and Agriculture to consider levels of environmental contamination in its review of the registration of endosulfan, and greatly restrict or eliminate its use in California.

6.3.1.3 Bacteria

The sources of high coliform bacteria levels in the slough, and the relative contributions of humans, domestic and wild animals, need to be determined. The County Health Department should request the State Department of Health and/or the Federal Food and Drug Administration (FDA) to determine the source of bacteria in the slough. The Board of Supervisors should then work with State Health, the FDA, California Department of Fish and Game, and the Regional Water Quality Control Board to reduce coliform counts to safe levels. The Board of Supervisors should also request the completion of the FDA report on slough bacteria begun in March 1985.

6.3.1.4 Shellfish Contamination

The potential human health risk from eating shellfish from the slough should be established. The Board of Supervisors should direct the California Department of Health, the Federal Food and Drug Administration (FDA) and the California Department of Fish and Game to determine the possible human health risk from high coliform levels and pesticides in shellfish in the slough. This study should include an assessment of the amount of clamming in the slough. Should a significant health risk be determined, the Board of Supervisors should request the Department of Health to adequately post the area.

6.3.1.5 Plowing and Pesticides

In order to reduce the amount of pesticides reaching waterways, the plowing of agricultural soil into waterways and erosion from rainfall should be reduced. It is common agricultural practice to create peripheral roads around fields by grading, and to plow all the way to the edge of the field. When a field borders a waterway or drainage ditch, this practice causes soil from the field to be deposited into the waterway. Any pesticides in the soil then enter directly into the aquatic system.

Buffer zones in which no plowing or grading is permitted should be established along waterways. The County Department of Agriculture and the State Department of Food and Agriculture should educate farmers to minimize erosion and plowing of soil into waterways. This effort should be done in conjunction with the Central Coast Agricultural Task Force, the University of California Agricultural Extension, the Farm Bureau, the Monterey Coast Resource Conservation District, and the Soil Conservation Service.

The Board of Supervisors should direct the County Building Inspector's office to strictly implement completely the existing Monterey County Erosion Control Ordinance to further control soil erosion (Table 6-2).

6.3.2 Groundwater

There are no simple solutions to the groundwater problems in the watershed. They are part of a region-wide groundwater problem. Pumping water and the application of nitrogen fertilizers are essential to agriculture. The salt water intrusion problem will be temporarily postponed by using the 900 ft. aquifer. The long-term recommendations for groundwater management are discussed in Chapter 7.

6.4 Enhancement Plans

6.4.1 Design of Plans

The enhancement plans contained in Chapter 4 are conceptual in nature and will require greater refinement and engineering design before being implemented. For the most part, the plans outline actions for private lands in the slough; these lands must be donated or acquired by a public agency or a non-profit organization before any further design work should occur. Once the properties in a plan area are secured, the following design steps should be completed and final engineering designs prepared:

1. Determine tidal elevations in the middle and upper slough area.
2. Complete a study of flood and tidal routing and sedimentation in the Blohm-Porter Marsh and determine weir and culvert dimensions and elevations. Determine water balance for the freshwater area of Blohm-Porter marsh to identify duration of ponding in wet, median and dry years.
3. Complete a study of tidal routing for the Azevedo, Kirby, North and Calcagno-ESNERR-Vierra marsh areas to determine culvert dimensions, designs and elevations.
4. Develop more detailed cost estimates, construction methods and schedules and design drawings, specifications and contract documents for each plan area.
5. Obtain all needed permits for each enhancement project, including Monterey County/Coastal Commission, Army Corps of Engineers and Department of Fish and Game. Fulfillment of all requirements of the California Environmental Quality Act and National Environmental Policy Act would be made during the permit process.
6. The design of all public access facilities would be included as part of the implementation of each enhancement plan.

6.4.2 Blohm-Porter Marsh

The Blohm-Porter marsh is the largest of the enhancement areas with the greatest potential for habitat diversity and public access. Besides the Porter land held by The Nature Conservancy, all the other property in the marsh is privately owned. These parcels include: the Blohm, Thomas, Hermansen, Kilduff and Wang properties. The wetland area and an upland buffer strip (minimum of 100 ft. in width) must be donated or acquired in fee title or through a conservation easement for each of these parcels. Potential public sources of funds for these properties include the State Coastal Conservancy and the Wildlife Conservation Board; and potential private sources include The Nature Conservancy, Elkhorn Slough Foundation and other non-profit organizations. Monterey County, through their permit authority, can require dedication of the wetland and buffer area as part of any larger development or subdivision proposal on these parcels.

Once the land acquisitions or donations are completed, the landholder or Monterey County should seek funds to complete the enhancement activities from either the State Coastal Conservancy, Wildlife Conservation Board or private non-profit organizations. The landholder must determine a source of funding for long-term management of the marsh area. These implementation steps are outlined in Table 6-3.

6.4.3 Kirby Marsh

Kirby Marsh is the second-largest marsh enhancement site and would be connected with the Elkhorn Slough National Estuarine Research Reserve. Because of its proximity to the Reserve, the property would be most appropriately managed by the Department of Fish and Game as part of the Reserve. The Kirby marsh is presently owned by the Estradas and could be acquired by or donated to the Wildlife Conservation Board, State Coastal Conservancy or a private entity–The Nature Conservancy or Elkhorn Slough Foundation.

Two options are outlined for the enhancement of this site; the second option requires improvements to Elkhorn Road, a County-owned roadway. Monterey County should review its ability to complete these road improvements. The County could seek additional funds from the State Coastal Conservancy, Wildlife Conservation Board or a private group to complete these road improvements as a first step towards marsh enhancement (see Table 6-4).

6.4.4 Calcagno-ESNERR-Vierra Marsh

This wetland enhancement plan is of a lower priority than the preceding two because most of the marsh presently belongs to the Research Reserve or is held by private owners with a long history of habitat conservation. However, there is one immediate problem: the dikes along the Calcagno-ESNERR-Vierra Marsh should be repaired at least temporarily. If a slough-wide erosion control mechanism, such as a sill as proposed in section 6.2.1, is not developed within the next 5-10 years, permanent site-specific protection should be developed. Temporary repair is adequate until the slough-wide erosion problem is resolved. The Calcagno-ESNERR-Vierra site will be exposed to severe tidal erosion if the existing dikes fail. Other dikes in this area are less threatened.

A conservation easement or fee title over the Vierra Marsh and Minohto Pond must be donated or acquired before any enhancement work can begin on these two sites. Either a public funding source (SCC or WCB) or a private group (The Nature Conservancy or

Elkhorn Slough Foundation) could complete this land transfer. The ESNERR Pond and Seal Bend areas belong to the Reserve already. Funding sources for enhancement work are the same as for the land transfer (see Table 6-5).

6.4.5 Lower Ranch Marsh

No enhancement is recommended here unless Elkhorn Road is raised. If so, a short section of Strawberry Canyon Road between the two branches of the marsh must be raised as well. Table 6-6 lists the responsible public agencies, potential funding sources and estimated cost for each element of the enhancement plan.

6.4.6 Azevedo Marsh

This site is ranked lowest because the Azevedo family is not likely to sell or place an easement over the marshes. Although the marshes have persisted in their present form for many years, there is a threat of filling from erosion of adjacent strawberry fields. If the land were acquired, Table 6-7 lists the responsible public agencies, potential funding sources and estimated costs for each element of the enhancement plan.

6.5 Public and Private Cooperation

Several organizations will have major impacts on the implementation of various parts of this plan. The Department of Fish and Game, the Elkhorn Slough Foundation and The Nature Conservancy all own and manage slough wetlands, presently operate programs for public access and research, and will be deeply involved in future wetland acquisition and management in the slough. These groups, the Harbor District, County Planning Department, California Coastal Commission, Fish and Wildlife Service, other public agencies and local residents and landowners presently cooperate through membership in the Advisory Committee to the Research Reserve or membership in the Elkhorn Slough Foundation. The Foundation produces a newsletter several times each year to keep its larger membership informed of problems, plans and possibilities. The State Coastal Conservancy and Wildlife Conservation Board will probably be major funding sources for parts of the plan, working in cooperation with the Foundation, The Nature Conservancy and Department of Fish and Game on wetlands. The Elkhorn Slough Foundation was established as a clearing house for information and activities involving the Elkhorn Slough system and other wetlands in Monterey Bay. The Foundation operates the education and research programs on the Research Reserve with the Department of Fish and Game and cooperates with The Nature Conservancy and the State Coastal Conservancy on joint programs in education, public access, and wetland management. The Foundation will play a central role in bringing concerned interests together and implementing the wetland management plan for the slough.

6.6 Revisions to Plan

To assure that a consistent and contemporary Wetland Management Plan is maintained, the Planning and Building Inspection Department, in cooperation with the Elkhorn Slough Foundation, should review the Plan every five years. If there is a clear need to change the Plan, the County should propose amendments to the Plan and/or the North County Land Use Plan consistent with the amendment process provided for in the Coastal Act.

PROBLEM	RESPONSIBLE AGENCIES	POTENTIAL FUNDING SOURCES
Slough Erosion	Corps, Harbor District	Corps
Erosion Control Improvements	RCD,SCS, Monterey County	SCC, Private, ASCS
Erosion Control Ordinance	Monterey County	Private
Land Use Changes	Monterey County	N/A
New Lands	Monterey County	N/A
West Slough Gullies	Monterey County, RCD, SCS	Private, SCC, ASCS

RCD = Monterey Coast Resource Conservation District
SCS = Soil Conservation Service
Corps = U.S. Army Corps of Engineers
SCC = State Coastal Conservancy
ASCS = Agricultural Stabilization and Conservation Service
Private = Private Landowners
Mont. County = Monterey County
Harbor District = Moss Landing Harbor District

Table 6-1. Implementation of management recommendations for sedimentation and erosion in Elkhorn Slough and its watershed.

PROBLEMS	RESPONSIBLE AGENCIES	POTENTIAL FUNDING SOURCES
SURFACE WATER		
Pesticide Transport	Mont. Co. Flood Control District, SWRCB, Mont. County	Mont. Co. Flood Control District, SWRCB
Chemical Replacement	DFA	DFA, SWRCB
Coliform Bacteria	County Health Dept.	County Health Dept., FDA, State Health Dept.
Plowing & Pesticides	DFA, County Dept. Ag.	DFA, County Dept. Ag.

Mont. Co. Flood Control District = Monterey County Flood Control District
SWRCB = State Water Resources Control Board
Mont. County = Monterey County
DFA = Federal Department Food & Agriculture
FDA = Federal Food & Drug Administration
County Health Dept. = Monterey County Department of Public Health
CDF&G = California State Department of Fish & Game
County Dept. Ag. = Monterey County Department of Agriculture

Table 6-2. Implementation of the water quality recommendations for the Elkhorn Slough watershed.

PLAN ELEMENTS	RESPONSIBLE AGENCIES	POTENTIAL FUNDING SOURCES	PRELIMINARY COST ESTIMATES
LAND ACQUISITION	Mont. County, CCC	TNC, WCB, SCC, ESF	not available
Blohm, Thomas, Hermansen, Kilduff and Wang wetland properties			
DESIGN, ENGINEERING DRAWINGS & SPECIFICATIONS, PERMIT APPROVALS	Mont. County, CCC, CDF&G, Corps	WCB, SCC, TNC, ESF	$100,000
CONSTRUCTION	Mont. County, CCC, CDF&G, Corps, USFWS	SCC, WCB, TNC, ESF	
Dryland land			2,400
Excavation			252,000
Trench			18,000
Culverts			24,000
Perches/habitat			2,400
Preplanting			9,600
PUBLIC ACCESS	Mont. County, CCC, Corps	SCC, WCB, TNC, ESF	
Parking & Roads			18,000
Trails			18,000
Causeways/overlooks			12,000
MONITORING	Mont. County, CCC, CDF&G, USFWS	ESF	
Hydrologic Monitoring			5,000/year
Wildlife Monitoring			15,000/year
MANAGEMENT & MAINTENANCE	Mont. County	EST, TNC, CDF&G	unknown

USFWS - U.S. Fish and Wildlife Service; CCC - California Coastal Commission
CDF&G = California Department of Fish ang Game; SCC - State Coastal Conservancy
WCB = Wildlife Conservation Board; TNC = The Nature Conservancy
Mont. County = Monterey County; Prv = Private Landowners
ESF = Elkhorn Slough Foundation; Corps = Army Corps of Engineers

Table 6-3. Implementation of Blohm Porter Marsh Enhancement Plan

PLAN ELEMENTS	RESPONSIBLE AGENCIES	POTENTIAL FUNDING SOURCES	PRELIMINARY COST ESTIMATES ($)
LAND ACQUISITION			
Estrada Parcel	Mont. County, CCC	WCB, SCC, TNC, ESF	not available
DESIGN, ENGINEERING DRAWINGS 7 SPECIFICATIONS, PERMIT APPROVALS	Mont. County, CCC, Corps, CDF&G	WCB, SCC, Mont. County, TNC, ESF	
Option 1			$ 40,000
Option 2			70,000
CONSTRUCTION			
Option 1	Mont. County, CCC, CDF&G, USFWS	WCB, SCC, TNC, ESF	
Drying Land			2,000
Excavation			60,000
Perches/Habitats			1,200
Preplanting			4,800
Option 2	Mont. County, CCC, CDF&G, USFWS	Mont. County, WCB, SCC, TNC, ESF	
Raising Elkhorn Rd.			600,000
Drying Land			2,000
Excavation			180,000
Perches/Habitat			1,200
Preplanting			9,600
Options 1 & 2 PUBLIC ACCESS Sanctuary Trail	CDF&G	WCB	12,000
MONITORING	Mont. County, CCC, CDF&G, USFWS		
Hydrologic Monitoring		CDF&G	5,000/year
Wildlife Monitoring		CDF&G	15,000/year
MANAGEMENT & MAINTENANCE	Mont. County, CDF&G	CDF&G	unknown

Mont. County = Monterey County; CCC = California Coastal Commission
WCB = Wildlife Conservation Board; SCC = State Coastal Conservancy
TNC = The Nature Conservancy; ESF = Eskhorn Slough Foundation
Corps = Army Corps of Engineers; USFWS = U.S. Fish & Wildlife Service
CDF&G = California Department of Fish & Game

Table 6-4. Implementation of the Kirby Marsh Enhancement Plan – Options 1 & 2

PLAN ELEMENTS	RESPONSIBLE AGENCIES	POTENTIAL FUNDING SOURCE	PRELIMINARY COST ESTIMATE ($)
LAND ACQUISITION			
ESNERR Land	CDF&G	unnecessary	none available
Vierra Marsh	Mont. County, CCC	WCB, SCC, TNC, ESF	
Mearle Pond			
DESIGN, ENGINEERING DRAWINGS & SPECIFICATIONS, PERMIT APPROVALS	Mont. County, CCC, CDF&G, Corps	WCB, SCC, TNC, ESF	$20,000
CONSTRUCTION/ PHYSICAL	Mont. County, CCC, CDF&G, Corps, USFWS	WCB, SCC, TNC, ESF Priv.	
Dike Repair			60,000*
Drying Ponds			2,000
Excavation			18,000
Culverts			30,000
Perches/Habitats			1,200
Preplanting			4,800
MANAGEMENT & MAINTENANCE	Mont. County, CDF&G	ESF, TNC, CDF&G	unknown

* Temporary repair until slough-wide erosion control system is installed.

Mont. County = Monterey County; CDF&G = California Department of Fish & Game
CCC = California Coastal Commission; WCB = Wildlife Conservation Board
ESF = Elkhorn Slough Foundation; Priv. = Private Landowners
TNC = The Nature Conservancy; SCC = State Coastal Conservancy
Corps = Army Corps of Engineers; USFWS = U.S. Fish & Wildlife Service

Table 6-5. Implementation of the Calcagno-ESNERR-Vierra Marsh Enhancement Plan.

PLAN ELEMENTS	RESPONSIBLE AGENCIES	POTENTIAL FUNDING SOURCES	PRELIMINARY COST ESTIMATES ($)
LAND ACQUISITION			
Research Reserve Land	CDF&G	unnecessary	
DESIGN, ENGINEERING DRAWINGS & SPECIFICATIONS, PERMIT APPROVALS	Mont. County, CCC, CDF&G, Corps	WCB, CDF&G	$ 30,000
CONSTRUCTION	Mont. County, CCC, CDF&G, USFWS	Mont. County, WCB, SCC, TNC, ESF	
Raising Elkhorn Rd.			600,000
Raising Strawberry Canyon Road			180,000
Culverts			2,400
Perches/Habitats			1,200
Preplanting			2,400
PUBLIC ACCESS Existing Roads		unnecessary	
MANAGEMENT & MAINTENANCE	CDF&G	CDF&G	unknown

Mont. County = Monterey County; CDF&G = California Department of Fish & Game
CCC = California Coastal Commission; WCB = Wildlife Conservation Board
ESF = Elkhorn Slough Foundation; TNC = The Nature Conservancy
SCC = State Coastal Conservancy; Corps = Army Corps of Engineers
USFWS = U.S. Fish & Wildlife Service

Table 6-6. Implementation of the Lower Ranch Marsh Enhancement Plan.

PLAN ELEMENTS	RESPONSIBLE AGENCIES	POTENTIAL FUNDING SOURCES	PRELIMINARY COST ESTIMATES ($)
LAND ACQUISITION Azevedo Wetland Property	Mont. County, CCC	TNC, WCB, SCC, ESF	not available
DESIGN, ENGINEERING DRAWINGS & SPECIFICATIONS, PERMIT APPROVALS	Mont. County, CCC, CDF&G, Corps, So. Pac. RR	WCB, SCC, TNC, ESF	$ 15,000
CONSTRUCTION	So. Pac. RR, Mont. County, CCC, CDF&G, USFWS	WCB, SCC, TNC, ESF	
Culverts			120,000
Perches/Habitats			1,200
Preplanting			4,800
PUBLIC ACCESS Nat. Cons. Trail	Mont. County, CCC, So. Pac. RR, TNC	TNC, ESF, SCC	unknown
MANAGEMENT & MAINTENANCE	Mont. County	ESF, TNC, So. Pac. RR	unknown

Mont. County = Monterey County; CDF&G = California Department of Fish & Game
CCC = California Coastal Commission; WCB = Wildlife Conservation Board
ESF = Elkhorn Slough Foundation; TNC = The Nature Conservancy
SCC = State Coastal Conservancy; Corps = Army Corps of Engineers
USFWS = U.S. Fish & Wildlife Service
So. Pac. RR = Southern Pacific Railroad Company

Table 6-7. Implementation of the Azevedo Marsh Enhancement Plan.

CHAPTER 7. LONG-TERM MANAGEMENT PROBLEMS

This chapter addresses longer-term problems that should be considered for future conservation and management of slough habitats. These other problems are presented in their general order of importance to wetland enhancement and management in Elkhorn Slough. They require additional field research. The proposed implementation plan for these studies is outlined in Table 7-1.

7.1 Persistence and Movement of Pesticides

Several major pesticides persist in local soils and in aquatic habitats affected by agricultural drainage. These include DDT, endosulfan and toxaphene. Although endosulfan is the only one of these in widespread use today, all are present in the environment. There is little information on the location and quantity of the chemicals in the environment and little is known about their persistence as toxic breakdown products. In addition, the movement of the chemicals in the soil, through the watershed drainages and into sloughs and other wetlands is unknown, including potential interactions with shallow and deeper groundwater resources. Soil composition, soil turnover, erosion, and rain probably have important effects on chemical persistence and transport through the local environment. Investigating these problems is central to understanding the pesticide problem in the Monterey Bay area and around the slough. The persistence and movement of pesticides should be investigated by the State and Regional Water Quality Control Boards.

7.2 Incremental Wetland Loss

The recent drought years have accelerated a long-standing problem of wetland loss. Historical wetland habitats have become abnormally dry, permitting greater and greater encroachment from surrounding land use, especially agriculture. Cultivated fields are often expanded into wetland habitats, particularly in dry seasons and years. The result is replacement of wetlands with fields, roads, ditches, or other non-wetland habitats. This incremental loss of habitat has not been documented, and is generally unrecognized and unregulated. One solution is to map the cover of wetlands throughout the slough's watershed to establish a baseline for wetland boundaries to prevent further encroachment and mitigate recent losses. The best baseline can be developed from aerial photographs of the watershed taken in 1980 by the State Coastal Commission. Once wetland areas and boundaries are established, incremental wetland loss can be identified, land owners can be educated, and protection and mitigation activities can proceed. Funding for the baseline determination could come from the State Coastal Conservancy, while education and enforcement would be the responsibility of the Monterey County Planning Department.

7.3 Agricultural Practices and Pesticides

Different agricultural practices probably have different effects on moving pesticides from fields into the watershed. Some fields are drained by tiles- perforated pipes surrounded by gravel. Other fields are drained by surface ditches. Some fields on sloping ground drain into catchment basins and others drain directly into natural watersheds. In addition to drainages practices, methods of plowing, other land preparation and irrigation vary on different fields. There is no information on how any of these agricultural practices influence pesticide persistence and transport. The effects of agricultural practices on the mobilization of pesticides from fields in the Monterey Bay area should be investigated by the Regional Water Quality Control Board.

7.4 Effects of Pesticides on Natural Communities

High levels of several pesticides have been recorded in the tributaries to the slough. In some cases, concentrations have been measured in animal tissues as well as in the environment. However, no one knows what these levels actually do to individuals or communities of organisms in nature. The ecological effects of the pesticides can be documented by looking for community and population changes near field hot spots; and by looking for changes in the survival, reproductive patterns and important ecological behavior (e.g., ability to feed or locate mates) of native animals under realistic experimental settings. It is still unknown whether these pesticides cause undesirable changes in the structure of local natural communities, or if animals behaviorally avoid hot spots, or if they die there. Despite the high levels, are there any detrimental effects on local aquatic communities?

This study should be done by the State and Regional Water Quality Control Boards or be incorporated into regional studies of toxic substances that may be funded by federal or state agencies in the future.

7.5 Water Quality Task Force

The Monterey County Board of Supervisors should set up a Task Force or County Committee to review the water quality problems in the Elkhorn Slough system and their relationship to regional agriculture and environmental problems.

7.6 Long-Term Ecological History of Wetland Habitats as a Model for Wetland Enhancement

Historical information on the wetland habitats and wildlife that once lived in our coastal region and in the Elkhorn Slough is very poor. Human activities since the Reclamation Period (1880) are much better known and have caused major changes in salt and freshwater wetlands. The historical wildlife setting can be recreated from sediment cores taken from existing and former wetlands and examined for microfossils, pollen, root material, sediment composition, and organic matter. Cores can be dated with lead 210 and carbon 14 and the rates of change in wetland habitats can be established and used to assess the optimal habitat types for restoration and their likely persistence. This historical perspective has a critical local and regional component. The determination of key habitat and wildlife values for wetland restoration and enhancement must be based on a sound understanding of the historical development of natural wetlands.

7.7 Wildlife Value of Transitional Wetlands

There are few transitional or brackish wetlands in the Monterey Bay area, although they were probably much more extensive than marshes with regular tidal inundation in the past. These brackish marshes were primarily freshwater wetlands which were periodically covered with salt water producing distinct habitats between the freshwater and salt water marshes. Today salt water is confined to the ocean end of well defined drainages. Transitional wetlands can be restored in the slough and throughout the bay area. At present, we have no way of evaluating the wildlife value of these habitats. This value can be assessed experimentally within the marsh habitats of Elkhorn Slough National Estuarine Research Reserve, particularly the North Marsh if the Elkhorn Road is raised in the future.

7.8 Long-Term Patterns of Wetland Erosion and Sedimentation

Long-term patterns of slough erosion and sedimentation should be monitored with permanent reference stations and high resolution color infra red aerial photography, which was first done in the slough in 1980. The older black and white aerial photographs do not have enough resolution to measure recent rates (within the last 10 years). When recent rates are known, future trends can be projected with much greater accuracy. If predicted erosion rates continue to be high, a sound quantitative basis for implementing erosion control will be established and long-term monitoring will document the success or failure of erosion control options. The Elkhorn Slough Foundation was established to facilitate this type of long-term monitoring program with support from the federal National Estuarine Research Reserve System Office at NOAA and other government and private sources.

7.9 Develop Future Groundwater Plans

Water tables are much lower than they were in the past when year round springs were a common component of the landscape. Salt water intrusion is extremely serious around Moss Landing and the mouth of Salinas River and the problem is getting worse. With the growth of human populations, this is one of the most important planning and management problems in the county. However, given the strong influence of salt water in Elkhorn Slough, ground water is not one of the most important problems in the slough itself. Nevertheless, if freshwater springs and ponds were as abundant as they were before the wetland reclamation and well-drilling periods, the wetlands around Elkhorn Slough would be much richer and more widespread (Chapter 1). In addition, the origin of locally high levels of nitrates in well water is still unknown. More important, there is very little information on potentially high levels of various pesticides in local well waters. The Regional and State Water Resources Control Boards should investigate the exchange of surface water with shallow and deeper aquifers in the bay area.

Where will we get water in the future? Can it be developed from our own watershed without destroying outstanding natural environments such as the Arroyo Seco? The watershed is the most important ecological unit in the landscape. This is a major planning problem which should be addressed by the Monterey County Planning Department.

7.10 Ecological Effects of New Chemicals

The herbicide, Dacthal, and the pesticide, Chlorpyrifos, are widely used throughout the region. Although they have been detected in mussel tissue, they apparently do not persist and concentrate in the environment to the extent of chemicals such as DDT. However, there is no information on the quantity of these chemicals and their toxic breakdown products in local soils or drainages. There is also no information on their potential effects on native animals and plants. The State and Regional Water Quality Control Boards should study the levels of these and recently introduced chemicals in the local environment and determine their effects on native organisms in realistic field and laboratory experiments or bioassays. While pesticides may be presently necessary for the maintenance of agriculture in the region, research should continue on more integrated methods of pest control.

7.11 Ecological Effects of Organo-Tin

Organo-tin is a toxic chemical used to protect boat surfaces from fouling. Its effect on coastal animals has become a nation-wide problem. Its environmental persistence is not known, but it is highly toxic, especially to settling larvae and to shellfish. High levels have been measured in systems similar to Elkhorn Slough, and moderate concentrations have been found in Moss Landing Harbor sediment. The State and Regional Water Quality Control Boards should determine the levels in Moss Landing Harbor water and sediments and their effects on native shellfish and their larvae.

7.12 Management of the Salt Ponds and Other Pond Habitats

The salt ponds harbor a large number and variety of shorebirds and waterfowl. Future management can optimize the use of the area for resting, feeding and breeding. Our present knowledge of the existing patterns of use and the potential for manipulating the habitat to attract more or particular birds is poor. This information can be obtained by surveys of bird use patterns and well-directed study of prey species and their use in different ponds under different hydrographic conditions. Since different prey communities can be developed in different ponds by simple manipulations of pond hydrology, the ponds can be managed to feed many birds. It is essential to have direct input from local scientists, other naturalists, concerned neighbors and other government agencies into the management of the salt ponds. This could be done very easily by making the Advisory Committee to the Elkhorn Slough National Estuarine Research Reserve also the Advisory Committee to the Department of Fish and Game for the salt ponds.

In addition to the salt ponds, there are many other ponded habitats around the Elkhorn Slough system. Little is known about their interaction with salt marsh habitats and about the best future management and enhancement options for these ponds. The Elkhorn Slough Foundation is an excellent organization to cooperate with private landowners who own many ponds, design ecological surveys, and acquire support for field work.

7.13 Human Health Effects of Contaminated Shellfish.

Several species of shellfish are routinely collected and consumed by sport fisherman in the slough. The most common are clams that filter food from the slough water and are well known for concentrating anthropogenic chemicals in their tissues. Although there is no evidence of serious contamination, past sampling has been quite limited. Periodic monitoring of various chemicals in shellfish tissues will locate hot spots that are unknown and identify future problems if they arise. This monitoring should be conducted by the Regional Water Quality Control Board in cooperation with the State

Mussel Watch Program.

7.14 Effects of Boat Traffic on Marine Mammals

Harbor seals and sea otters are both relatively abundant in the slough. Otters congregate in floating "rafts" and seals haul out on several mudflats. Although some sites are apparently preferred, the reason for movement from one area to another is unknown. Sea otters and especially seals are disturbed by boat traffic. Their movements may be strongly influenced by human disturbance.

This problem can be defined with a simple, systematic survey of the movements and other activities of sea otters and seals in the slough with special attention to changes in these patterns when boats are present under a variety of conditions. This study should be done by the Elkhorn Slough Foundation with support from CalTrans, which constructed the new Highway One bridge much higher above the water than the previous bridge, thereby allowing more boat traffic into the slough.

7.15 Habitat Value of Introduced Species

Many exotic plant and animal species have been introduced to the slough and its watershed. Introduced species are a major world-wide problem. In many cases the introductions were made so long ago and were so successful that most people mistake introduced species as the natural or native condition. One of the most conspicuous and controversial introduced species around the slough is the *Eucalyptus* tree. Should we remove it or manage it as a habitat for other creatures?

It may not be wise or realistic to assume that all introductions are bad, since the majority of annual plants in California grasslands are introduced. Many ecologists refer to this group as the "new native annuals". In the case of the *Eucalyptus* , birds and other animals that use these forests should be surveyed before a general policy of removal is accepted. Since large forests occur on lands managed by the Department of Parks and Recreation and the Department of Fish and Game, this study should be performed by them.

7.16 Regional Archaeological Resources

There are numerous Indian middens around the Elkhorn Slough. Their relative importance is not established. Which are likely to be the best and what does the best mean? How should they be preserved to maximize their value? Local sites need to be resurveyed and ranked by their relative importance. This importance will probably depend on the potential contribution that each site has to a general understanding of coastal archaeology. This study should be accomplished by the Elkhorn Slough Foundation with support from government or private sources.

7.17 Recreational Traffic Impacts

Expansion of recreational opportunities around the slough is likely to increase automobile traffic, especially on Elkhorn Road. Although recent growth in slough recreation may have already impacted local traffic, there is no information on local or regional changes in auto traffic. This traffic may directly impact wildlife by disturbing birds and other animals near roads, and indirectly by contributing to regional degradation of air quality. There may also be an increase in road debris and a decrease in the quality of the slough's viewshed. The increase in traffic and potential impacts can be periodically monitored and related to recreation. The Elkhorn Slough Research Reserve is an excellent center for this monitoring.

PROBLEMS	RESPONSIBLE AGENCIES	POTENTIAL FUNDING SOURCES
Pesticides in Watershed	Mont. County HD, SWRCB, Food & Ag.	SWRCB, EPA
Incremental Wetland Loss	Mont. County Planning Dept.	Coastal Conservancy
Agricultural Practices	Mont. County HD, SWRCB, Food & Ag.	SWRCB, EPA
Pesticides and Communities	Mont. County HD, SWRCB, Food & Ag.	SWRCB, EPA
Water Quality Task Force	Monterey County Supervisors	none needed
Wetlands Historical Patterns	CDF&G, USFWS	ESF
Transition Wetlands	CDF&G, USFWS	ESF
Monitor Erosion	Corps, Harbor District, USFWS, CDF&G	ESF
Groundwater	USGS, Mont. County	Mont. County
New Chemicals	Mont. County HD, SWRCB, Food & Ag.	SWRCB, EPA
Organo-Tin	SWRCB, EPA	SWRCB, EPA, NOAA
Salt Ponds	CDF&G, USFWS	CDF&G
Contaminated Shellfish	Mont. County HD Food & Ag.	Food & Ag. US FDA
Boats & Marine Mammals	CDF&G, USFWS	ESF
Introduced Species	CDF&G, USFWS	CDF&G
Archaeological Resources	State Historical Preservation Office	CDF&G, ESF
Recreational Traffic	Monterey County	CDF&G, Monterey County

USFWS = U.S. Fish and Wildlife Service
USFDA = U.S. Food and Drug Administration
Corps - U.S. Army Corps of Engineers
SCS = Soil Conservation Service
EPA = Environmental Protection Agency
USGS = U.S. Geological Survey
NOAA = National Oceanic and Atmospheric Administration
Food & Ag. = Federal Department of Food and Agriculture
CDF&G = CA Department of Fish and Game
SWRCB = State Water Resources Control Board
FC = Flood Control
ESF = Elkhorn Slough Foundation
Monterey County HD = Health Department
Harbor District = Moss Landing Harbor District

Table 7.1. Implementation of long-term management research recommendations for Elkhorn Slough.

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GLOSSARY

aquifer - underground layer of sand, rock, or gravel-saturated with water

benthic - bottom; mud, sand, or rock bottom of ocean or freshwater body.

bioaccumulation - buildup in living tissue (plants or animals) of a particular substance; the substance may be concentrated by biochemical processes of the organism, e.g. build-up of DDT in fish, and, in turn, pelicans.

biomass - total weight of plants or animals of an area; a useful measure of the richness or productivity of an area.

coastal shelf - undersea edge of the continental land mass, usually extends several miles out from the shoreline before falling steeply to the floor of the ocean basin.

coastal wetlands - general term for the low lying lands adjacent to the coast, or bays or estuaries, which harbor marshy habitats.

coliform bacteria - bacteria which live in and come from the intestine of animals, including people; often indicative of fecal contamination in water. (scientific name *Escherichia coli*, often *E. coli*).

Costanoan - Spanish name (costaños = coast people) of the Indian tribe which lived along the coast from Big Sur to San Francisco.

deposition - laying down, or depositing, of particles; when currents carrying the particles slow down sufficiently the particles come to rest.

Elkhorn River - prehistoric (over 10,000 years before present) river which scoured out the valley (now filled in with mud forming Elkhorn Slough) when sea level was as much as 300 feet lower than today.

Elkhorn Valley - site of Elkhorn Slough; filled in with mud deposited by a rising sea which flooded the vally.

Elkhorn Slough watershed - the area surronding Elkhorn Slough in which all water drains into the Slough.

erosion - carrying off of soil, usually by water.

estuary - aquatic habitat transitional between marine and fresh; where freshwater meets tidal flow.

gravid - pregnant or carrying eggs or embryos.

ground water - water which occurs in the underground layers of sand, gravel, or rock.

habitat - environment, including biological and physical features, in which plants and animals live.

habitat heterogeneity - mixture or divesity of habitat types.

heavy metal - dense or high specific density metal which may be toxic in minute or moderately small quantities, e.g. lead, zinc, cadmium, silver.

hydrology - study of water, its properties, movements, and effects.

hypersaline - water saltier than normal sea water, i.e. >35 parts per thousand

infauna - invertebrate animals, usually small excepting clams, that live within sand or mud.

intertidal - the part of the shore which is covered and uncovered by water sometime during the tidal cycle.

invertebrates - animals without backbones; everything except mammals, birds, reptiles and fish.

isomer - chemical compounds with the same composition but different internal structures.

lagoon - shallow coastal lake, usually of salt water, connected to the ocean permanently or seasonally.

macroalgae - seaweed; large marine or estuarine algae; e.g. kelp in Monterey Bay and *Enteromorpha* which forms green mats on mud flats of the Slough.

marsh - wet or seasonally flooded ground and/or its community of plants and animals.

Monterey Submarine Canyon - the huge undersea canyon which begins at the entrance of Moss Landing Harbor and cuts through the coastal shelf to meet the Pacific Ocean floor at a depth of 10,000 feet.

mosaic - mixture or multifaceted pattern of, for example, habitats.

most probable number (MPN) - the approximate number of bacteria in a sample, used for comparison purposes.

mudflat - broad, flat intertidal mud area in the Slough between the vegetated marsh and the channels; presently expanding as the higher marsh is eroded down and converted to mud flat.

natural history - activities of plants and animals, particularly their reproductive biology, feeding, movement, and habitat preference.

pelagic - open ocean.

planktonic - weakly swimming or passively carried by in the water.

pocket marsh - small coves of marsh isolated from the main marsh by man-made structures such as road or railroad beds.

ppb - a measure of concentration, parts per billion or nanograms per gram (1ppb=0.000000001g/g)

ppm - a measure of concentration, parts per million or micrograms per gram (1ppm=0.000001g/g)

ppt - a measure of concentration, parts per trillion or picograms per gram (1ppt=0.000000000001g/g)

raptor - predaceous birds: hawks, falcons, and owls.

reclamation - conversion of natural habitat to agricultural land.

riparian - on the banks of a river or stream.

salinity - amount of salt in water; variable from none in esturaries to 35 parts of salt per 1000 parts of water, fully marine.

saltwater intrusion - the replacement of freshwater in subterranean water tables (aquifers) by salt water; occurs along the coast where ocean pressure forces marine water into the space left when large amounts of freshwater are pumped out the aquifers.

sediment fans - the outwash of sand eroded from hills and depostied on flatter areas such as Slough marsh.

sedimentation - laying down or depositing of soil particles (sand or mud); occurs when current velocity carrying the particles slows enough for the particles to sink from the water or come to rest if carried by air.

shorebirds - small and medium sized birds that live near water: plover, sandpiper, and avocet families; also may include heron family.

surface water- free-flowing or standing water, rivers, lakes, etc. as opposed to ground water.

tidal creek - meandering inlets off the main Slough channel in which water currents flow back and forth due to tidal action.

tidal prism - wedge of marine water pushed shoreward on a rising tide; it flows along the bottom pushing beneath freshwater in estuaries.

waterfowl - ducks, geese, and swans (duck family), grebe family, loon family and rail family (includes mudhens).

watershed - land area, or basin, in which all water drains to a particular stream, river, or lake.

wetlands - wet or seasonally flooded lands and/or the plant and animal community living there.

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Jack Dolan
Land owner

Harry Hermansen
Land owner

Ed Kilduff
Landowner

Jack Kirby
Land owner

Roberta Thomas
Landowner

Bill Lehman
Land owner

David Packard
Land owner

Mrs Porter
Land owner

Robert Rubis
Land owner

Charlie Vierra
Land owner

SPECIES LISTS

List of species found along Elkhorn Slough and its immediate environs, including adjacent beach and upland habitat.

VASCULAR PLANTS[1]

Abronia latifolia
Yellow Sand Verbena
Achillea borealis
Common Yarrow
Adenostoma fasciculatum
Chamise
Alisma plantago-aquatica
Water-Plantain
Allocarya chorisiana hickmanii
Hickman's Allocarya
Amsinckia spectabilis
Seaside Amsinckia
Amsinckia sp.
Fiddleneck
Anagallis arvensis
Scarlet Pimpernel
Anthemis sp.
Dog Fennel
Arabis sp.
Rock Cress
Arbutus menziesii
Madrone
Arctostaphylos hookeri
Hooker's Manzanita
Arctostaphylos pajaroensis
Pajaro Manzanita
Arctostaphylos tomentosa
Brittleleaf Manzanita
Artemisia californica
California Sage
Artemisia douglasiana
Douglas' Mugwort
Asclepias eriocarpa
Indian Milkweed
Aster chilensis
Common California Aster
Astragalus nuttallii
Coastal Dunes Nettleweed
Atriplex patula hastata
Fat Hen
Atriplex semibaccata
Australian Saltbush
Avena barbata
Slender Wild Oat
Avena fatua
Wild Oat
Baccharis pilularis
Coyote Brush
Baccharis douglasii
Salt Marsh Baccharis
Baccharis viminea
Mule Fat
Beta vulgaris
Wild Beet
Brassica campestris
Common Field Mustard
Brassica nigra
Black Mustard
Briza minor
Little Quaking Grass
Brodiaea pulchella
Blue Dicks
Bromus mollis
Soft Chess
Bromus rigidus
Ripgut Grass
Cakile maritima
Sea Rocket
Carex brevicaulis
Short-stemmed Sedge
Carex sp.
Sedge
Cardamine oligosperma
Few-seeded Bitter Cress
Castilleja foliolosa
Wholly Painted Cap
Castilleja latifolia
Monterey Paintbrush
Castilleja sp.
Indian Paintbrush
Ceanothus dentatus
Dwarf Ceanothus
Ceanothus griseus
Carmel Ceanothus
Ceanothus rigidus albus
White Ceanothus
Ceanothus thyrsiflorus
Blue-blossom
Chenopodium ambrosioidea
Mexican Tea
Chenopodium macrospermum
Coast Goosefoot
Chenopodium rubrum
Red Goosefoot
Chlorogalum pomeridianum
Soap Root
Cichorium intybus
Chickory
Cirsium californicum
California Thistle
Cirsium occidentale
Cobweb Thistle
Cirsium vulgare
Bull Thistle
Conium maculatum
Poison Hemlock
Convolvulus occidentalis
Beach Morning-glory
Conyza canadensis
Horseweed
Corethrogyne sp
Corethrogyne
Cortaderia jubata
Pampas Grass
Corylus californica
Hazelnut
Cotula coronopifolia
Brass Buttons
Cressa truxillensis vallicola
Alkali Weed
Cupressus macrocarpa
Monterey Cypress
Cuscuta salina
Salt Marsh Dodder
Cynodon sp.
Bermuda Grass
Cyperus egarostis
Tall Cyperus
Cyperus sp.
Umbrella Sedge
Danthonia californica
California Oat Grass
Dendromecon rigida
Tree Poppy
Distichlis spicata
Salt Grass
Dryopteris arguta
Coastal Wood Fern
Dudleya farinosa
Live-forever
Eleocharis sp.
Spike-rush
Elymus mollis
American Dune Grass
Elymus triticoides
Alkali Rye Grass
Epilobium sp.
Fireweed
Erechtites arguta
Cut-leaved Coast Fireweed
Ericameria ericoides
Mock Heather
Ericameria fasiculata
Mock Heather
Eriogonum latifolium nudum
Wild Buckwheat
Eriogonum nudum
Naked-stemmed Eriogonum
Eriophyllum confertiflorum
Golden Yarrow
Erodium botrys
Long-beaked Filaree
Erodium moschatum
White-stemmed Filaree
Eryngium sp.
Coyote Thistle

Eschscholzia californica
California Poppy
Eucalyptus globosus
Blue Gum
Festuca myuros
Rattail Fescue
Festuca sp.
Fescue
Foeniculum vulgare
Sweet Fennel
Fragaria californica
California Strawberry
Frankenia grandifolia
Alkali Heath
Franseria chamissonis
Beach-bur
Galium aparine
Goose Grass
Galium californicum
California Bedstraw
Galium nuttallii
Climbing Bedstraw
Garrya elliptica
Coast Silk-tassel
Geranium dissectum
Cut-leaved Geranium
Geranium molle
Cranesbill
Gnaphalium californicum
California Everlasting
Gnaphalium purpureum
Cudweed
Grindelia humilis
Marsh Grindelia
Grindelia latifolia
Gum Plant
Helenium puberulum
Sneezeweed
Heleocharis sp.
Spike-rush
Helianthella sp.
Helianthella
Helianthemum scoparium
Rock-rose
Heliotropium curassavicum
Seaside Heliotrope
Heterotheca grandiflora
Telegraph Weed
Holocarpha macradenia
Santa Cruz Tarplant
Holodiscus discolor
Cream Bush
Hordeum geniculatum
Mediterranean Barley
Horkelia cuneata
Wedge-leaved Horkelia
Hordeum leporinum
Farmer's Foxtail
Hydrocotyle sp.
Marsh Pennywort
Hypochaeris radicata
Hairy Cat's Ear
Iris douglasiana
Douglas' Iris
Iris longipetala
Long-petaled Iris
Iris pseudocorus
Yellow Iris
Jaumea carnosa
Fleshy Jaumea
Juglans sp.
Walnut
Juncus bufonius
Toad Rush
Juncus effusus pacificus
Pacific Bog Rush
Juncus lesuerii
Salt Rush
Juncus patens
Common Rush
Juncus phaeocephalus
Brown-headed Rush
Juncus xiphioides
Iris-leaved Rush
Lasthenia glabrata
Yellow-rayed Lasthenia
Lathyrus jepsonii californicus
Wild Pea
Lavatera cretica
Tree Mallow
Lemna sp.
Duckweed
Leptospermum sp.
Australian Tea Tree
Lilaea scilloides
Flowering Quillwort
Limonium californicum
Sea Lavender
Linaria canadensis
Toad Flax
Lobularia maritima
Sweet Alyssum
Lolium multiflorum
Italian Ryegrass
Lolium perenne
Perennial Ryegrass
Lomatium dasycarpum
Lace Parsnip
Lonicera involucrata
Twinberry
Lotus corniculatus
Bird's Foot Trefoil
Lotus formosissimus
Coast Trefoil
Lotus scoparius
Deerweed
Lotus subpinnatus
Chile Trefoil
Lupinus albifrons
Silver Lupine
Lupinus aboreus
Yellow Beach Lupine
Lupinus bicolor
Lindley's Annual Lupine
Lupinus chamissonis
Blue Beach Lupine
Lupinus nanus
Sky Lupine
Lupinus ?succulentus
Succulent Annual Lupine
Lupinus sp.
Lupine
Lythrum hyssopifolia
Hyssop Loosestrife
Madia sp.
Tarweed
Malva parvifolia
Cheeseweed
Malva sp.
Mallow
Marah fabaceus
Common Manroot
Marah sp.
Wild Cucumber
Marrubium vulgare
Horehound
Medicago hispida
Bur Clover
Medicago polymorpha vulgaris
Yellow Bur-clover
Melilotus albus
White Sweet Clover
Melilotus indicus
Yellow Sweet Clover
Mentha pulegium
Pennyroyal
Mesembryanthemum chilense
Sea Fig
Mesembryanthemum edule
Hottentot Fig
Mesembryanthemum nodiflorum
Slender-leaved Iceplant
Mimulus guttatus
Large Monkeyflower
Mimulus aurantiacus
Sticky Monkeyflower
Monardella villosa
Coyote Mint
Montia perfoliata
Miner's Lettuce
Myrica californica
California Wax Myrtle
Nasturtium officinale
Water Cress
Navarretia intertexta
Navarretia
Navarretia squarrosa
Skunkweed
Oenanthe sarmentosa
Pacific Oenanthe

Oenothera micrantha
Primrose
Oenothera ovata
Sun Cups
Orthocarpus densiflorus
Owl's Clover
Orthocarpus erianthus
Butter and Eggs
Orthocarpus pusillus
Dwarf Orthocarpus
Oxalis pes-caprae
Bermuda Buttercup
Oxalis sp.
Wood Sorrel
Parapholis incurva
Sickle Grass
Paspalum dilatatun
Dallis Grass
Pedicularis densiflora
Indian Warrior
Pellaea mucronata
Bird's Foot Fern
Phalaria tuberosa stenoptera
Harding Grass
Photinia arbutifolia
Toyon
Picris echioides
Bristly Ox Tongue
Pinus radiata
Monterey Pine
Pityogramma triangularis
Goldenback Fern
Plantago bigelowii
Annual Plantain
Plantago coronopus
Cut-leaved Plantain
Plantago erecta
California Plantain
Plantago heterophylla
Plantain
Plantago hirtella galeottiana
Mexican Plantain
Plantago lanceolata
Ribwort
Plantago major
White Man's Foot
Plantanus racemosa
Sycamore
Poa annua
Annual Bluegrass
Polygala californica
California Milkwort
Polygonum aviculare
Dooryard Knotweed
Polygonum coccineum
Swamp Knotweed
Polygonum persicaria
Lady's Thumb
Polygonum punctatum
Water Smartweed
Polypodium californicum
Resurrection Fern
Polypogon monspeliensis
Rabbit's Foot Grass
Potentilla egedii grandis
Pacific Silverweed
Pteridium aquilinum
Bracken Fern
Quercus agrifolia
California Live Oak
Ranunculus sp.
Buttercup
Raphanus sativus
Wild Radish
Rhamnus californica
Coffeeberry
Rhus diversiloba
Poison Oak
Ribes divaricatum
Straggly Gooseberry
Rosa californica
California Rose
Rubus ursinus
California Blackberry
Rumex acetosella
Sheep Sorrel
Rumex conglomeratus
Green Dock
Rumex crispus
Curley Dock
Rumex sp.
Dock
Ruppia maritima
Ditch Grass
Salicornia virginica
Pickleweed
Salix lasiolepis
Arroyo Willow
Salix sp.
Willow
Salsola kali tenuifolia
Russian Thistle
Salvia mellifera
Black Sage
Sambucus mexicana
Blue Elderberry
Sanicula crassicaulis
Gambleweed
Satureja douglasii
Yerba Buena
Scirpus acutus
Giant Bulrush
Scirpus californicus
California Bulrush
Scirpus microcarpus
Panicled Bulrush
Scirpus olneyi
Olney's Bulrush
Scirpus robustus
Prarie Bulrush
Scrophularia california
California Figwort
Scutellaria tuberosa
Danie's Skull Cap
Scrophularia californica
California Bee Plant
Selaginella bigelovi
Bigelow's Club Moss
Senecio vulgaris
Common Groundsel
Senecio mikanioides
German Ivy
Sidalcea ?malvaeflora
Checkera
Silybum marianum
Milk Thistle
Sisyrinchium bellum
Blue-eyed Grass
Solanum nodiflorum
Black Nightshade
Solanum umbelliferum
Blue Witch
Solanum sp.
Nightshade
Solidago sp.
Goldenrod
Sonchus oleraceus
Common Sow Thistle
Sonchus sp.
Sow Thistle
Sparganium eurycarpum
Broad-fruited Burreed
Spergularia marina
Salt-marsh Sand Spurry
Stachys bullata
Hedge Nettle
Stellaria media
Common Chickweed
Stipa cernua
Needlegrass
Stipa pulchra
Nodding Stipa
Suaeda californica
California Sea-Blite
Symphoricarpos sp.
Snowberry
Taraxacum oficinale
Common Dandelion
Tillaea erecta
Pigmyweed
Trifolium angustifolium
Narrow-leaved Clover
Triflolium incarnatus
Crimson Clover
Trifolium sp.
Clover
Triglochin concinna
Slender Arrow Grass
Triglochin maritima
Seaside Arrow Grass

Trillium ovatum
Wake Robin
Typha angustifolia
Narrow-leaved Cat-tail
Typha latifolia
Broad-leaved Cat-tail
Typha sp.
Cattail
Urtica holosericea
Stinging Nettle
Urtica urens
Dwarf Nettle
Vaccinium ovatum
California Huckleberry
Verbena lasiostachys
Western Verbena
Vinca major
Periwinkle
Viola pedunculata
Johnny Jump-up
Xanthium spinosum
Spiny Clotbur
Xanthium strumarium
Cocklebur
Zantedeschia aethiopica
Calla Lily
Zauschneria californica
California Fuchsia
Zigadenus fremontii
Star Lily
Zostera marina
Eelgrass

AMPHIBIANS[2]

SALAMANDERS

Aneides lugubris
Arboreal Salamander
Ambystoma macrodactylum croceum
Santa Cruz Long-toed Salamander
Ambystoma tigrinum californiense
California Tiger Salamander
Batrachoseps pacificus
Pacific Slender Salamander
Ensatina eschscholtzii
Monterey Salamander
Taricha torosa torosa
Coast Range Newt

FROGS and TOADS

Bufo boreas halophilus
California Toad

Hyla regilla
Pacific Treefrog
Rana aurora draytonii
California Red-legged Frog
Rana boylii
Foothill Yellow-legged Frog
Rana catesbeiana
Bullfrog

REPTILES[2]

TURTLES

Clemmys marmorata marmorata
Southwestern Pond Turtle

LIZARDS

Anniella pulchra nigra
Black Legless Lizard
Eumeces skiltonianus skiltonianus
Northwestern Fence Lizard
Gerrhonotus coeruleus coeruleus
San Francisco Alligator Lizard
Gerhonotus multicarinatus multicarinatus
California Alligator Lizard
Phrynosoma coronatum
Coast Horned Lizard
Sceloporus occidentalis occidentalis
Northwestern Fence Lizard

SNAKES

Charina bottae bottae
Pacific Rubber Boa
Coluber constrictor mormon
Western Yellow-bellied Racer
Contia tenuis
Sharp-tailed Snake
Crotalus viridis oreganus
Northern Pacific Rattlesnake
Diadophus punctatus vandenburghi
Monterey Ringneck Snake
Lampropeltis getulus californiae
California Kingsnake
Masticophis lateralis lateralis
Alameda Whipsnake
Pituophis melanoleucus catenifer
Pacific Gopher Snake
Thamnophis couchi atratus
Santa Cruz Garter Snake
Thamnophis elegans terrestris
Coast Garter Snake
Thamnophis sirtalis parietalis
Red-sided Garter Snake

BIRDS[3]

LOONS
Arctic Loon
Common Loon
Red-throated Loon
Yellow-billed Loon

GREBES
Eared Grebe
Horned Grebe
Pied-billed Grebe
Red-necked Grebe
Western Grebe

TUBENOSES
Black-footed Albatross
Laysan Albatross
Northern Fulmar
Ashy Storm Petrel
Black Storm Petrel
Fork-tailed Storm Petrel
Galapagos Storm Petrel
Leach's Storm Petrel
Least Storm Petrel
Wilson's Storm Petrel
Buller's Shearwater
Flesh-footed Shearwater
Manx Shearwater
Pink-footed Shearwater
Short-tailed Shearwater
Sooty Shearwater
Streaked Shearwater

PELICANS, CORMORANTS
Brandt's Cormorant
Double-crested Cormorant
Pelagic Cormorant
Magnificent Frigatebird
American White Pelican
Brown Pelican
Red-billed Tropicbird

HERONS
American Bittern
Black-crowned Night Heron
Cattle Egret
Great Blue Heron
Great Egret
Green Heron
Least Bittern
Reddish Egret
Snowy Egret

IBISES, SPOONBILLS
American Flamingo
Roseate Spoonbill
White-faced Ibis

WATERFOWL
- Whistling Swan
- Canada Goose
- Brant
- Emperor Goose
- Greater White-fronted Goose
- Snow Goose
- Ross' Goose
- Mallard
- Gadwall
- Common Pintail
- Green-winged Teal
- Blue-winged Teal
- Cinnamon Teal
- American Wigeon
- Northern Shoveler
- Wood Duck
- Redhead
- Ring-necked Duck
- Canvasback
- Greater Scaup
- Lesser Scaup
- Common Goldeneye
- Barrow's Goldeneye
- Bufflehead
- Oldsquaw
- Harlequin Duck
- King Eider
- White-winged Scoter
- Surf Scoter
- Black Scoter
- Ruddy Duck
- Fulvous Tree Duck
- Hooded Merganser
- Common Merganser
- Red-breasted Merganser

HAWKS
- Turley Vulture
- Black-shouldered Kite
- Sharp-shinned Hawk
- Cooper's Hawk
- Red-tailed Hawk
- Harlan's Hawk
- Red-shouldered Hawk
- Swainson's Hawk
- Rough-legged Hawk
- Ferruginous Hawk
- Golden Eagle
- Bald Eagle
- Northern Harrier
- Osprey
- Prarie Falcon
- Peregrine Falcon
- Merlin
- American Kestrel

QUAIL, PHEASANT
- California Quail
- Ring-necked Pheasant

RAILS, COOTS
- Clapper Rail
- Virginia Rail
- Sora
- Common Gallinule
- American Coot

SHOREBIRDS
- Black Oystercatcher
- Black-necked Stilt
- American Avocet
- Semipalmated Plover
- Killdeer
- Snowy Plover
- Lesser Golden Plover
- Black-bellied Plover
- Mountain Plover
- Marbled Godwit
- Whimbrel
- Long-billed Curlew
- Greater Yellowlegs
- Lesser Yellowlegs
- Willit
- Wandering Tattler
- Ruddy Turnstone
- Black Turnstone
- Wilson's Phalarope
- Northern Phalarope
- Red Phalarope
- Common Snipe
- Short-billed Dowitcher
- Long-billed Dowitcher
- Surfbird
- Red Knot
- Sanderling
- Western Sandpiper
- Least Sandpiper
- Baird's Sandpiper
- Pectoral Sandpiper
- Solitary Sandpiper
- Semipalmated Sandpiper
- Sharp-tailed Sandpiper
- Rock Sandpiper
- Buff-breasted Sandpiper
- Spotted Sandpiper
- Dunlin
- Stilt Sandpiper
- Ruff

GULLS
- Pomarine Jaeger
- Parasitic Jaeger
- Long-tailed Jaeger
- South Polar Skua
- Glaucous Gull
- Glaucous-winged Gull
- Western Gull
- Herring Gull
- Thayer's Gull
- California Gull
- Ring-billed Gull
- Mew Gull
- Franklin's Gull
- Bonaparte's Gull
- Heermann's Gull
- Laughing Gull
- Little Gull
- Sabine's Gull
- Black-legged Kittiwake
- Forster's Tern
- Common Tern
- Artic Tern
- Least Tern
- Royal Tern
- Elegant Tern
- Caspian Tern
- Black Tern
- Black Skimmer

AUKS, MURRES
- Common Murre
- Pigeon Guillemot
- Marbled Murrelet
- Ancient Murrelet
- Craveri's Murrelet
- Xantu's Murrelet
- Cassin's Auklet
- Rhinoceros Auklet

PIGEONS, DOVES
- Band-tailed Pigeon
- Rock Dove
- Mourning Dove

CUCKOOS
- Roadrunner
- Yellow-billed Cuckoo

OWLS
- Barn Owl
- Great Horned Owl
- Burrowing Owl
- Short-eared Owl
- Snowy Owl

NIGHTHAWKS
- Lesser Nighthaw

SWIFTS, HUMMINGBIRDS
- Vaux's Swift
- White-throated Swift
- Anna's Hummingbird
- Rufous Hummingbird
- Allen's Hummingbird
- Calliope Hummingbird
- Black-chinned Hummingbird

KINGFISHERS
- Belted Kingfishers

WOODPECKERS
- Common Flicker
- Acorn Woodpecker
- Yellow-bellied Sapsucker
- Hairy Woodpecker
- Downy Woodpecker
- Nuttall's Woodpecker

FLYCATCHERS
- Tropical Kingbird
- Western Kingbird
- Cassin's Kingbird
- Ash-Throated Flycatcher
- Black Phoebe
- Say's Phoebe
- Western Flycatcher
- Western Peewee
- Willow Flycatcher
- Gray Flycatcher
- Olive-sided Flycatcher

LARKS
- Horned Lark

SWALLOWS
- Violet-Green Swallow
- Tree Swallow
- Rough-winged Swallow
- Bank Swallow
- Barn Swallow
- Cliff Swallow
- Purple Martin

JAYS, CROWS
- California Jay
- Yellow-billed Magpie
- American Crow

CHICKADEES, BUSHTITS
- Chestnut-backed Chickadee
- Plain Titmouse
- Bushtit

WRENTIT

NUTHATCHES, CREEPERS
- White-breasted Nuthatch
- Red-breasted Nuthatch
- Pygmy Nuthatch
- Brown Creeper

WRENS
- House Wren
- Winter Wren
- Bewick's Wren
- Long-billed Marsh Wren

MOCKINGBIRDS, THRASHERS
- Northern Mockingbird
- California Thrasher

THRUSHES
- American Robin
- Varied Thrush
- Hermit Thrush
- Swainson's Thrush
- Western Bluebird
- Townshend's Solitaire

KINGLETS, GNATCATCHERS
- Ruby-crowned Kinglet
- Golden-crowned Kinglet
- Blue-gray Gnatcatcher

WATER PIPIT

CEDAR WAXWING

LOGGERHEAD SHRIKE

EUROPEAN STARLING

VIREOS
- Hutton's Vireo
- Red-eyed Vireo
- Warbling Vireo

WARBLERS
- Orange-crowned Warbler
- Nashville Warbler
- Yellow Warbler
- Yellow-rumped Warbler
- Black-throated Gray Warbler
- Townshend's Warbler
- Northern Waterthrush
- Common Yellowthroat
- Wilson's Warbler
- Magnolia Warbler
- Hermit Warbler
- Blackpoll Warbler
- Palm Warbler
- MacGillivray's Warbler
- Yellow-breasted Chat
- American Redstart

HOUSE SPARROW

BLACKBIRDS, ORIOLES
- Western Meadowlark
- Yellow-headed Blackbird
- Red-winged Blackbird
- Tricolored Blackbird
- Brewer's Blackbird
- Brown-headed Cowbird
- Northern Oriole

WESTERN TANAGER

FINCHES, SPARROWS
- Black-headed Grosbeak
- Evening Grosbeak
- Purple Finch
- House Finch
- Pine Siskin
- American Goldfinch
- Lesser Goldfinch
- Lawrence's Goldfinch
- Rufous-sided Towhee
- Brown Towhee
- Oregon Junco
- Savannah Sparrow
- Brewer's Sparrow
- White-crowned Sparrow
- Fox Sparrow
- Lincoln's Sparrow
- Swamp Sparrow
- Song Sparrow
- Lark Sparrow
- Chipping Sparrow
- Lazuli Bunting
- Lapland Longspur
- Chestnut-collared Longspur

MAMMALS[2]

MARSUPIALS

Didelphis marsupialis
- Opossum

INSECTIVORES

Neurotrichus gibbsi
- Shrew Mole

Scapanus latimanus
- California Mole

Sorex ornatus
- Ornate Shrew

Sorex trowbridgei
- Trowbridge Shrew

Sorex vagrans
- Vagrant Shrew

BATS

Antrozous pallidus
- Pallid Bat

Eptesicus fuscus
- Big Brown Bat

Lasiurus borealis
- Red Bat

Lasiurus cinereus
- Hoary Bat

Myotis californica
- California Myotis

Myotis evotis
- Long-eared Myotis

Myotis leibii
- Small-footed Myotis

Myotis lucifugus
Little Brown Myotis
Myotis thysanodes
Fringed Myotis
Myotis volans
Long-legged Myotis
Myotis yumanensis
Yuma Myotis
Pipustrellus hesperus
Western Pipistrel
Plecotus townsendi
Western Big-eared Bat
Tadarida brasiliensis
Brazilian Free-tailed Bat

CARNIVORES

Bassariscus astutus
Ringtail
Canis latrans
Coyote
Enhydra lutris
Sea Otter
Felis concolor
Mountain Lion
Lynx rufus
Bobcat
Mephitis mephitis
Striped Skunk
Mustela frenata
Longtail Weasel
Procyon lotor
Raccoon
Spilogale putorius
Spotted Skunk
Taxidea taxus
Badger
Urocyon cinereoargenteus
Gray Fox
Vulpes Fulva
Red Fox

PINNIPEDS

Phoca vitulina
Harbor Seal
Zalophus californianus
California Sea Lion

RODENTS

Castor canadensis
Beaver
Dipodomys heermanni
Heermann Kangaroo Rat
Dipodomys venustus
Santa Cruz Kangaroo Rat
Microtus californicus
California Vole
Mus musculus
House Mouse
Neotoma fuscipes
Dusky-footed Wood Rat
Ondatra zibethica
Muskrat
Perognathus californicus
California Pocket Mouse
Peromyscus californicus
California Mouse
Peromyscus maniculata
Deer Mouse
Peromyscus truei
Piñon Mouse
Rattus norvegicus
Norway Rat
Rattus rattus
Black Rat
Reithrodontomys megalotis
Western Harvest Mouse
Sciurus carolinensis
Eastern Gray Squirrel
Sciurus griseus
Western Gray Squirrel
Scirus niger
Fox Squirrel
Spermophilus beecheyi
California Ground Squirrel
Thomomys bottae
Valley Pocket Gopher

HARES and RABBITS

Lepus californicus
Blacktail Jackrabbit
Sylvilagus audubonii
Audubon Cottontail
Sylvilagus bachmani
Brush Rabbit

UNGULATES

Odocoileus hemionus
Blacktail Deer

CETACEANS

Eschrichtius robustus
Gray Whale
Phocoena phocoena
Harbor Porpoise

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[1]Compiled from: Harvey and Stanley Associates (1985), King and Griffin (1983), Schettler (1985).
[2]From Schafer (1986).
[3] From Ramer, Ramer, and Warriner (1978)

Appendix : Reduction of topographic map of Kirby Marsh. The large original will be used for construction engineering. Contor interval=1 foot.
1 inch=315 feet.

ABA Consultants

Appendix : Reduction of topographic map of Blohm-Porter Marsh. The large original will be used for construction engineering. Contor interval=1 ft. 1 inch=315 feet.

ABA Consultants

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Jim Oakden

OR

John Oliver

AII

Distrct

Moss Landing and Moro Cojo Slough areas. The list indicated most of the species likely to occur on the site, and we noted species demonstratably present at the time of our survey. In this report we again present a comprehensive list, and show which species were present and identifiable at the time of the survey.

We carried out the survey by walking transects through all of the vegetation types. Transects included the entire perimeter of the parcel, the length of the ditch, across the open field along several lines, and along several routes on the upper, south, end. The entire parcel was visually surveyed from not farther than 20 - 30 feet. Most plants were readily identified visually in the field. Plant names and an index of abundance were recorded on a clipboard throughout the walk. We also paced distances in order to place the location of plant community boundaries. Because the parcel is small and the communities few and uncomplicated, sophisticated ecological survey methods were unnecessary. Any plant not recognized in the field was given a temporary descriptive name, collected as a voucher specimen and returned to the laboratory where a microscope and literature was used to identify it. After its identification, the proper name was substituted for its temporary field name. Literature used to identify or confirm identifications included: Munz and David Keck 1959; Thomas 1961; Mason 1957; Niehaus & Ripper 1976; Abrams 1923-; Hitchock 1958. In addition we used Reed 1988 to designate the wetland value of the plants.

We surveyed plant communities in the mitigation site across Highway one in a similar manner.

2.1.2 Results

Four vegetative communities or plant associations were evident on the small parcel: roadside, field (Rye grass), ditch, and Distichlis (Salt Grass). The roadside community was comprised of weedy exotics, species mainly from Europe which invade disturbed habitats. The most evident of these species was Poison Hemlock which occured in dense stands often over six feet tall. Mustard and Radish plants also formed similar tall dense stands. Numerous other species occured in varying densities and graded from the very edge of the road pavement, e.g. Cut-leaved Plantain, to habitats intergrading with the wetland, e.g. Bristly Ox-tongue. This community extended along both roads and onto the south high elevation ground surrounding the Cypress trees. Perhaps here more than in the

~ms / new planning person
~ings For Blohm Rd

WETLAND HABITATS ON PARCEL (give #) IN MONTEREY COUNTY

THE CHEESE FACTORY DEVELOPMENT:

Delineation and Preliminary Mitigation Plan

1. INTRODUCTION

This report is primarily a follow-up to a previous wetland assessment done by ABA Consultants (1985). The previous report was required for a minor subdivision, which created the present parcel (# 133-221-2) the proposed site of the Cheese Factory Development (Figure 1). Since the application for a Coastal Development Permit involves excavation and filling of historical and existing wetlands, the US Army Corps of Engineers must review the permit. They recommended a more complete mapping and delineation of wetland plants and habitats, using the recently adopted Federal criteria for wetland delineation. This delineation was not required in the previous wetland assessment, because the Corps was not involved in permitting the subdivision as no wetlands were filled.

Throughout the present report, we refer to the parcel as the site of the proposed Cheese Factory Development. The parcel is a pie shaped area of 2.5 acres on the west side of Highway One (Figure 2). The mitigation site is a much larger area (16 acres) on the east side of Highway One (Figure 4). This area was given to the Elkhorn Slough Foundation for wetland conservation and enhancement when the minor subdivision was formed.

2. WETLAND VEGETATION MAPPING AND DESIGNATION

2.1 Plant Survey

2.1.1 Methods

The plant survey was performed in July with follow-up visits in early August. At this time of year many species have completed their annual cycle. Consequently small and/or herbaceous annual forms specific to other seasons are not present and therefore cannot be recognized. Our previous survey of the parcel was in November of 1985, again not as ideal a time as spring would have been. For that report we presented a general species list from

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APPENDIX 2.

MATERIALS & METHODS FOR SHELLFISH ANALYSES

Samples were collected from eight stations in Elkhorn Slough (see site map in text) and depurated in flowing seawater for 24 hours. The shellfish were then wrapped in aluminum foil, placed in polyethylene bags and frozen until analysis. When analyzed, the entire contents of the thawed samples (less byssal threads in mussel samples) were shucked into kilned-fired glass jars and were homogenized with a Brinkmann Polytron homogenizer. 60-80 grams of homogenate were placed in Teflon flasks and freeze-dried to remove moisture. The dried samples were ground with anhydrous sodium sulfate with a mortar and pestle and extracted for twelve hours in a sohlet extraction apparatus using dichloromethane. The dichloromethane was removed from the lipid extract by rotary evaporator and the lipid was redissoved in 1-2 ml of hexane. Lipids were fractionated by florisil column chromatography (0.5% deactivation) and three fractions were collected; hexane, 30% dichloromethane in hexane, and 15% diethyl ether in hexane. The second and third fractions were reduced to near driness by rotary evaporator and diluted with hexane prior to GC analysis.

High resolution electron capture gas chromatography was performed using a Carlo Erba 4160 gas chromatograph equipped with a 30 M x 0.32 mm I.D. DB-1 fused silica capillary column (J & W Scientific). The compounds reported were quantified initially on the basis of the electron capture response of decachlorobiphenyl (DCB), which was co-injected as an internal standard. Quantitations were then adjusted by the appropriate response factor of the authentic standard. Polychlorinated biphenyls (PCB's) were quantified on the basis of six peaks in the Aroclor 1254 mixture. Endosulfan II and endosulfan cyclic sulfate were not detected by this methodology as they require a 50% ethyl ether in hexane for column chromatography elution. This polar fraction frequently contains a high concentration of lipids and can cause a rapid deterioration of chromatographic instrumentation.

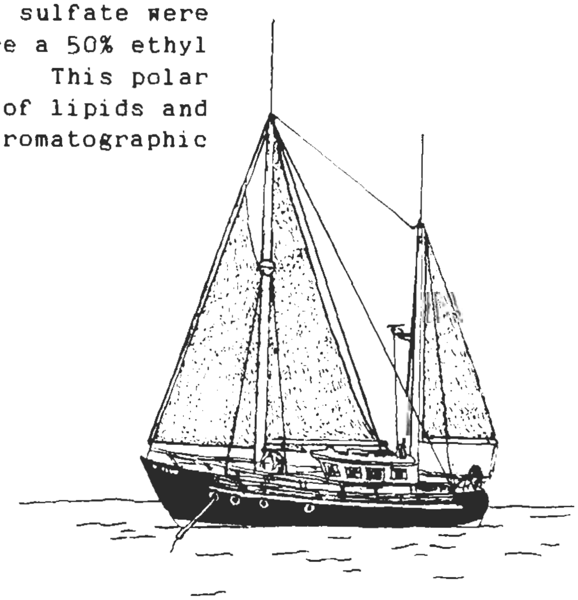

Table 1. Shellfish obtained from Elkorn Slough in May-June 1986 for organochlorine analysis.

Species, locality	No.	Date	Mean length (cm; s.d.)	Mean weight (g)	% water	% lipid
Mytilus edulis						
Highway 1 Bridge	25	08-06-86	6.68 ± 0.66	11.6	83.6	1.55
Dairy	25	31-05-86	7.49 ± 0.79	11.4	87.4	2.03
Kirby Park	25	31-05-86	7.90 ± 0.42	13.7	86.2	1.27
Hudson's Landing	13	31-05-86	8.03 ± 1.89	15.4	86.3	1.44
Saxidomus nuttallii						
Vierra	2	24-04-86	12.35 ± 0.07	114.1	87.3	0.44
Zirfaea pilsbryi						
Skippers	3	24-04-86	6.53 ± 1.54	23.2	88.8	0.64
Tresus nuttallii						
Dairy	4	07-05-86	10.3 ± 1.11	nm	85.7	0.88
Slough Sanctuary	15		nm	29.1	82.5	0.91

Table 2. Organochlorines in shellfish from Elkorn Slough, May-June 1986. Parts per billion of the dry weight, except where noted.

Species, locality	p,p'-DDE (lipid wt.)	p,p'-DDE	o,p'-DDE	p,p'-DDT	o,p'-DDT	p,p'-DDD	o,p'-DDD	p,p'-DDMU
Mytilus edulis								
Highway 1 Bridge	1,400	130	3.3	38	14	33	9.6	8.0
Dairy	1,400	230	6.0	46	21	68	28	26
Kirby Park	3,400	320	8.3	32	22	66	37	38
Hudson's Landing	3,600	380	12	13	6.2	10	3.2	16
Saxidomus nuttallii								
Vierra	1,800	64	1.2	22	2.6	14	2.5	2.7
Zirfaea pilsbryi								
Skippers	1,700	100	1.6	46	4.7	24	6.1	3.0
Tresus nuttallii								
Dairy	1,600	96	5.6	33	18	55	26	32
Slough Sanctuary	1,200	60	≤ 1.0	6.5	2.5	16	4.4	6

Species, locality	HCB	PCBs	Mirex	alpha-HCH	beta HCH	gamma-HCH
Mytilus edulis						
Highway 1 Bridge	≤ 0.32	80	< 0.05	0.72	0.2	0.1
Dairy	≤ 0.54	110	≤ 0.12	0.26	≤ 0.5	< 0.1
Kirby Park	≤ 0.34	110	≤ 0.25	nm	nm	nm
Hudson's Landing	≤ 0.25	150	≤ 0.6	0.34	< 0.2	< 0.1
Saxidomus nuttallii						
Vierra	≤ 0.2	40	≤ 0.05	< 0.05	< 0.03	< 0.05
Zirfaea pilsbryi						
Skippers	≤ 0.2	35	≤ 0.07	0.20	< 0.1	< 0.05
Tresus nuttallii						
Dairy	≤ 0.20	37	< 0.06	0.13	< 0.05	< 0.1
Slough Sanctuary	≤ 0.12	37	< 0.05	0.46	≤ 0.2	0.29

Species, locality	trans-nonachlor	cis-nonachlor	gamma chlordane	alpha chlordane	oxychlordane	heptachlor epoxide
Mytilus edulis						
Highway 1 Bridge	5.6	2.5	3.8	3.8	0.59	< 10
Dairy	7.2	4.9	9.1	8.4	0.95	< 10
Kirby Park	13	11	18	17	3.7	< 10
Hudson's Landing	10	< 1.4	1.6	2.3	0.3	< 10
Saxidomus nuttallii						
Vierra	0.84	0.64	0.7	0.86	< 0.03	< 10
Zirfaea pilsbryi						
Skippers	0.7	1.2	0.5	0.5	0.3	< 10
Tresus nuttallii						
Dairy	11	10	15	16	2.3	< 20
Slough Sanctuary	1.6	1.2	1.8	1.7	< 0.05	< 27

Species, locality	dieldrin	endrin	endosulfan I	dacthal	chlorpyrifos	toxaphene
Mytilus edulis						
Highway 1 Bridge	< 24	< 2	50	5	< 2	≤ 30
Dairy	< 26	< 2	80	2	< 2	≤ 90
Kirby Park	< 20	< 2	64	< 2	< 2	≤ 130
Hudson's Landing	< 20	≤ 4	110-200	4	8	≤ 20
Saxidomus nuttallii						
Vierra	< 13	< 3	43	< 2	< 2	≤ 10
Zirfaea pilsbryi						
Skippers	< 18	< 2	80	3	< 2	≤ 10
Tresus nuttallii						
Dairy	< 40	< 3	120	< 3	< 3	≤ 60
Slough Sanctuary	< 10	< 0.9	80	< 1	< 1	≤ 10