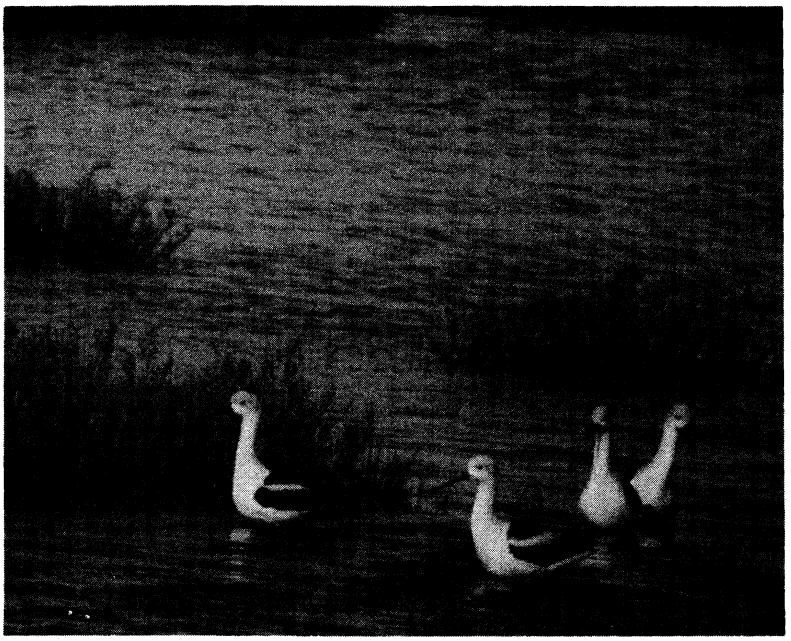
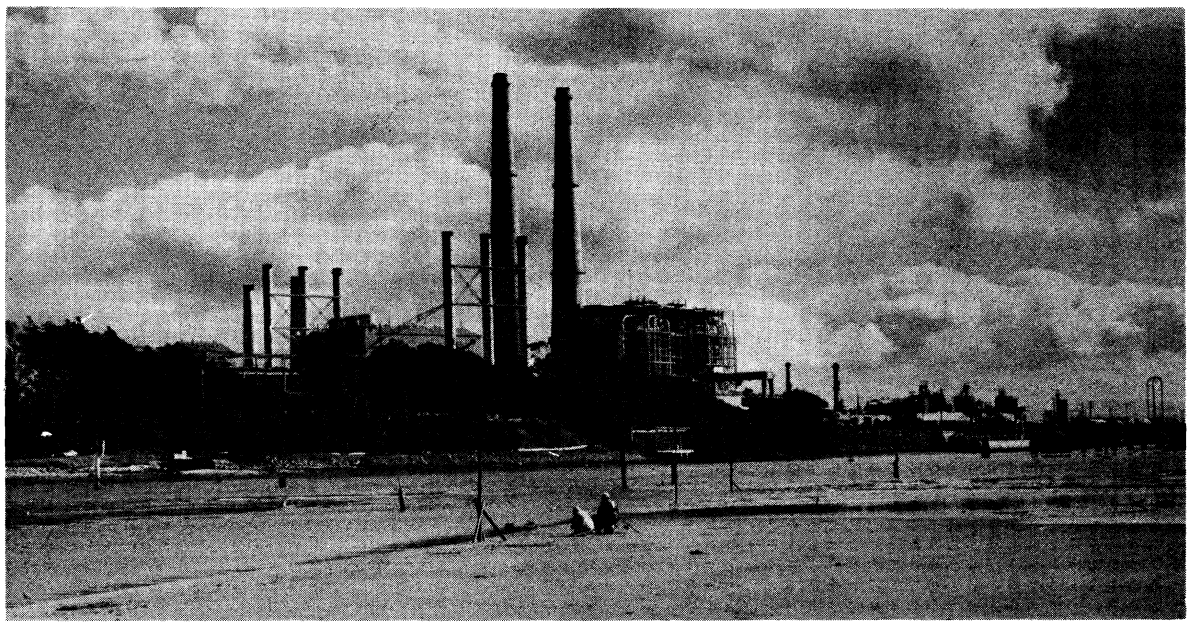
# THE NATURAL RESOURCES
# of
# ELKHORN SLOUGH



## THEIR
## PRESENT & FUTURE
## USE



STATE OF CALIFORNIA

## DEPARTMENT OF FISH AND GAME

JANUARY 1972

ERRATA

Page 43, bottom photo: for "Dowitchers" read Marbled Godwits.

Page 49, line 2: for "960" read 160.

Page 87, line 21: for "water" read tissue.

State of California

DEPARTMENT OF FISH AND GAME

# THE NATURAL RESOURCES OF ELKHORN SLOUGH THEIR PRESENT AND FUTURE USE

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January, 1972

COASTAL WETLAND SERIES - #4

Cover Photos by Frank Hubbard
Department of Fish and Game

Elkhorn Slough – Moss Landing ASCS photo June 1968

ACKNOWLEDGEMENTS

This report has been prepared by field personnel of the Monterey Office of the Fish and Game Department and staff members of the Wildlife Management Branch in Sacramento. Members of the Marine Resources Branch, Environmental Services Branch and Inland Fisheries Branch have also contributed essential information and data. John Speth, Paul Giguere and Carol Ferrel particularly gave helpful guidance and editorial assistance.

The authors are particularly grateful for the enthusiastic cooperation of the graduate students of Moss Landing Marine Laboratories and for the advice and editorial assistance of Dr. John Harville, former director.

Preparation of the report has been supported by Fish and Wildlife Preservation funds and by Pittman-Robertson Federal Aid to Wildlife programs. Representatives of the following organizations and agencies also contributed assistance, advice and data:

Moss Landing Marine Laboratories - John Harville

Hopkins Marine Station - Alan Baldridge

San Francisco State College - Leroy Gordon

Pacific Grove Museum of Natural History - Vernon Yadon

Monterey County Public Health Department - Walter Wong

Monterey County Planning Commission - Richard Arjo

Monterey County Park Department - Earl Smith

Monterey County Mosquito Abatement - Howard Greenfield

Moss Landing Harbor District - Elmer Horton

California Regional Water Quality Control Board - Bill Leonard

U. S. Army Corps of Engineers - George Kostal and Robert Edmisten

California Division of Highways - Dewey Bishop and Richard Crandall

Calif. Dept. of Public Health, Sanitary Engineering Bureau - Harry Witt

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# INTRODUCTION

"What good is a stinking, muddy swamp anyway? Nothing out there but worthless patches of pickleweed, an occasional shorebird or duck, and at low tide, yards of oozing, smelly mud." These are a few of the thoughts one might have after driving past the Kaiser refractory and the P. G. & E. power plant and crossing Highway 1 bridge over the mouth of Elkhorn Slough in Monterey County. To most Sunday drivers these might be typical thoughts. But, to an avid birdwatcher or waterfowl hunter, these thoughts would be a horror; to a marine laboratory director, an urgent concern; to a county planner or administrator, a perplexing problem; or to a biologist, a catastrophe. For it is a fact that Elkhorn Slough and its surrounding habitat represent only a remnant of the disappearing coastal wetlands of California.

Despite the encroachment of industry and pollution of its waters, Elkhorn Slough remains one of the most ecologically important estuarine systems on the coast, encompassing the second largest salt marsh in California. Its importance takes on a greater significance because more than two-thirds of California's original coastal wetlands already have been filled in, reclaimed or otherwise destroyed. Thus, it becomes critical that the people of California (and especially the residents and administrators of Monterey County, who ultimately will decide whether there will be an Elkhorn Slough) be informed of the value of the natural resources of the area. It is they who must demonstrate their concern for these dwindling resources and exercise the wisest possible use of such prime natural habitat.

Elkhorn Slough has a great potential as a deep-water harbor and site for scientific study, natural shellfish production, mariculture, recreation and industrial developments. Because of this, the slough and Moss Landing Harbor at its mouth probably has been the subject of more biological and physical investigations than any comparable estuarine area in California.

This report summarizes the history of the slough, ecological attractions, educational value, and problems facing its continued existence. Appended references provide the interested and concerned citizen with sources of more specific information.

As a result of the initial survey of estuarine areas of California (California Department of Fish and Game, 1969), the critical status of the coastal marshes became obvious. This report on Elkhorn Slough is part of the high priority inventory and assessment of coastal wetlands by the Department of Fish and Game, and it is intended as a guide for citizens, planners, administrators, and all others interested in the use and development of coastal lands and waters. As such, this report transcends local issues on pollution and development and, in fact, documents the status and future of natural resources that should be a part of the inheritance of following generations.

This publication is one of a scheduled series. It follows similar documents on Upper Newport Bay (Orange County), Goleta Slough (Santa Barbara County) and the Bolinas Lagoon (Marin County).

## SUMMARY

Elkhorn Slough is a large, relatively undisturbed estuarine area between San Francisco and Morro Bay. It consists of about 2,500 acres of submerged marine areas, tidal flats and salt marsh. Historically the slough was a freshwater lagoon before the Salinas River changed course in 1908. Thereafter, influenced by tidal waters it became an estuary. The construction of the present entrance channel in 1946 created Moss Landing Harbor.

The values of the natural resources of Elkhorn Slough and environs are many. The waters, mudflats and salt marshes of the estuary are important sources of food and shelter for wildlife. Primarily the slough serves as an important link in the coastal flyway for migratory shorebirds, waterfowl and other water-associated birds. Not only do migratory birds feed and rest here, but many species are permanent residents, including the endangered California clapper rail.

The tidal flats and waters in Elkhorn Slough are in public ownership under jurisdiction of the Moss Landing Harbor District. Virtually all of the bordering lands including most of the salt marsh are in private ownership. Nature Conservancy recently has acquired 140 acres of marsh at the upper end of the slough to retain it in a natural condition. The State Department of Parks and Recreation has allocated funds to buy the north spit, commonly called Jetty Beach, which would create $2\frac{1}{2}$ contiguous miles of public beach when linked to Zmudowski State Beach.

Some industrial development (as well as the Moss Landing Marine Laboratories) lies on either side of the slough's mouth and few commercial operations, generally marine-oriented, are found on the south spit. The harbor provides facilities for about 300 commercial fishing and pleasure craft. Uplands surrounding the estuary are used principally for truck crops, irrigated pasture and dairy operations.

Over 90 species of water-associated birds have been observed and identified in the area.

The slough and harbor waters are important nursery and feeding areas for many sport and commercial fishes. Elkhorn Slough also supports a rich fauna of bottom and mud-dwelling organisms, and the estuary has been a notable shellfish-producing area. Many clammers still work its mudflats even though deteriorating water quality has forced a recent public health closure. Despite the water quality problem research facilities have been established to explore the maricultural potential of the slough.

Educational and scientific use of the slough and harbor are of primary importance, despite poor access, industrial development and deteriorating water quality. Because of its proximity to Monterey Bay, the offshore submarine canyon and a variety of oceanic and estuarine environments the locale is a biological "paradise" for many schools. Ten local colleges and universities use the area for general and advanced studies in biology, ecology and marine sciences. The Moss Landing Marine Laboratories, sponsored by five state colleges, provide curriculum and research programs for as many as 300 individuals each school year. High school and elementary teachers annually lead thousands of students on field trips to study the natural resources of the area.

The Elkhorn Slough-Moss Landing waters support a popular sport fishery that accommodates about 26,000 angler days annually. But lack of public access limits opportunity for waterfowl and upland game hunting. Other important uses, with perhaps greater recreational potential include nature study, birdwatching or simply enjoying the sights, sounds and smells of an estuary.

At the present time, the most serious threats to the natural resources of Elkhorn Slough are the possibility of further expansion of Moss Landing Harbor, deteriorating water quality and further reclamation of the marshlands. Part of the master plan for Monterey County adopted in 1956 proposed industrial and harbor development of the seaward half of the slough. The plan is considered out of date because of water supply and sewage problems, and the County Planning Commission and Harbor District have requested new feasibility studies.

The spectre of "national need" hangs heavily over Elkhorn Slough. Factors such as demands for coastal development created by an expanding population, restrictions on San Francisco Bay development and anticipated needs for facilities to receive Alaskan oil may ultimately require the future expansion of Moss Landing Harbor. However, the Department feels that any dredging, filling or structural work associated with further development should be undertaken only after careful consideration of impact on the slough's ecological welfare. Such work should not be undertaken without complete demonstration of urgent national need.

Intensified use of the estuary and surrounding watershed have led to a gradual deterioration of the water quality in Elkhorn Slough. Major

sources of contamination responsible for the deterioration of Elkhorn Slough water quality are local dairy operations, agricultural run-off, sewage treatment effluents, and discharges from commercial enterprises, boats and homes. The two major industries of the area, a power plant and magnesia refractory, are making substantial efforts to comply with acceptable discharge standards.

Several state and local agencies have been carefully surveying water quality of the slough and harbor since 1954. In 1969 the slough and harbor were posted with signs warning of contaminated shellfish. Limitation and restriction placed on human use of shellfish resources due to contamination and pollution is of direct concern to the Department of Fish and Game. The Department feels the proposed water quality standards to allow for human use of the shellfish resource should be maintained until justifiable factors other than water quality requirements preclude their retention. The Department also maintains that standards enabling shellfish production and use will ensure ecological conditions required for research and educational use.

The Central Coastal Regional Water Quality Control Board and the Monterey County Public Health Department are now implementing the State Water Quality Control Board policy that stipulates that no domestic sewage--treated or untreated--may be discharged into public waters of the area. Studies by state and local agencies show that the area needs a new sewage treatment plant capable of meeting adopted standards; but taxpayer reaction to the high cost of providing the necessary system has been the primary obstacle to correction of water quality problems of the estuary.

Residues of DDT and certain other organochlorine insecticides have been found in oysters and mussels examined from Elkhorn Slough. These residues probably are a result of insecticide use in agricultural operations in the local drainage basin. The effects of these pesticide residues on the biota of Elkhorn Slough is not well understood, but no recognizable deleterious effects are apparent. Levels of pesticide use for local mosquito abatement apparently pose no threat to the water quality of Elkhorn Slough.

About half of the marshlands of Elkhorn Slough have been reclaimed or are in various stages of reclamation. Since the continued existence of these marshlands is basic to maintaining a viable extuarine system, a means of preserving these lands must be sought and implemented.

The State Division of Highways is planning the construction of a freeway crossing over the middle of the slough. Preliminary evaluation of design and construction plans indicates that direct effects upon the natural resources of the slough may be minimal. Indirect and long-term effects like post-construction developments (commercial and residential), traffic, noise and human activity cannot be predicted. But these effects could be of major proportions, if their impact is not fully considered in community planning and zoning.

The salt pond complex near the mouth of the slough is a valuable feeding and resting area for many shorebirds and other water-associated species. Because of the pond's location the area would be a "first choice" site for deposition of dredging spoils or filling for industrial or urban developments. Any alteration or loss of the salt pond

environment would have a serious effect on wildlife--both resident and nonresident species requiring this specialized habitat.

In the face of increasing demands for development of coastal resources, current and anticipated use of the estuary for scientific and educational purposes alone justify efforts to perpetuate its natural attractions and resources. But the slough's primary value lies in the important part it plays in maintaining fish and wildlife habitat for resident and migrant species dependent upon coastal wetlands for their continued existence.

## RECOMMENDATIONS

Because of the high value of the varied fish and wildlife resources of Elkhorn Slough, the potential opportunity to increase these rich resources through water quality improvement, the many advantages of the slough's location and value to educational institutions and because of the people's growing concern about the future of California's vital, but dwindling, coastal wetlands, the Department of Fish and Game recommends that:

A MASTER PLAN FOR THE DEVELOPMENT AND UTILIZATION OF THE ELKHORN SLOUGH MOSS LANDING HARBOR BE DEVELOPED TO PROVIDE FOR THE PRESERVATION AND MAINTENANCE OF THE AREA'S NATURAL RESOURCES DISCUSSED IN THIS REPORT FOR THEIR INTRINSIC, RECREATIONAL AND EDUCATIONAL VALUES, AND THAT THE PLAN RECOGNIZE EDUCATIONAL, SCIENTIFIC AND RECREATIONAL USE OF THESE NATURAL RESOURCES AS THE HIGHEST AND BEST USE OF THE AREA'S TOTAL ASSETS.

To point out specific areas of concern for consideration in planning for the development, utilization and preservation of Elkhorn Slough or in implementing any master or interim plan, the Department specifically recommends that:

1. The water quality of Elkhorn Slough and Moss Landing Harbor be upgraded to shellfish producing standards.
2. Indirect and long-range effects of the proposed Highway 1, mid-slough crossing be carefully considered and thoroughly investigated by local planning agencies prior to its construction.

3. Access to Elkhorn Slough be improved to provide recreational opportunity for an anticipated increase in demand for hunting, fishing, birdwatching, nature study and other forms of recreation.

4. The wetlands of the Department of Parks and Recreation's Jetty Beach project be used in a manner compatible with maintenance of their natural assets and that tidal flushing of that area be improved by construction of an additional culvert beneath Jetty Road.

5. The marshlands of the harbor area south of the County road crossing to the Sandholdt Spit should be maintained as fish and wildlife habitat.

6. The use of the privately owned salt pond area be restricted to uses compatible with the area's inherent capabilities to support fish, shellfish and wildlife.

7. Any dredging, filling or structural work associated with the further development or maintenance of the harbor or slough be carried out with minimum adverse impacts on the fish and wildlife resources.

8. Further reclamation of the salt marshes of the middle and upper slough for agriculture and other purposes be discouraged through local controls and tax incentives on an interim basis until a more permanent solution to the problem is agreed upon by all parties concerned.

9. Local gun clubs be encouraged to maintain and enhance their privately owned lands adjacent to the slough for hunting and other recreation.

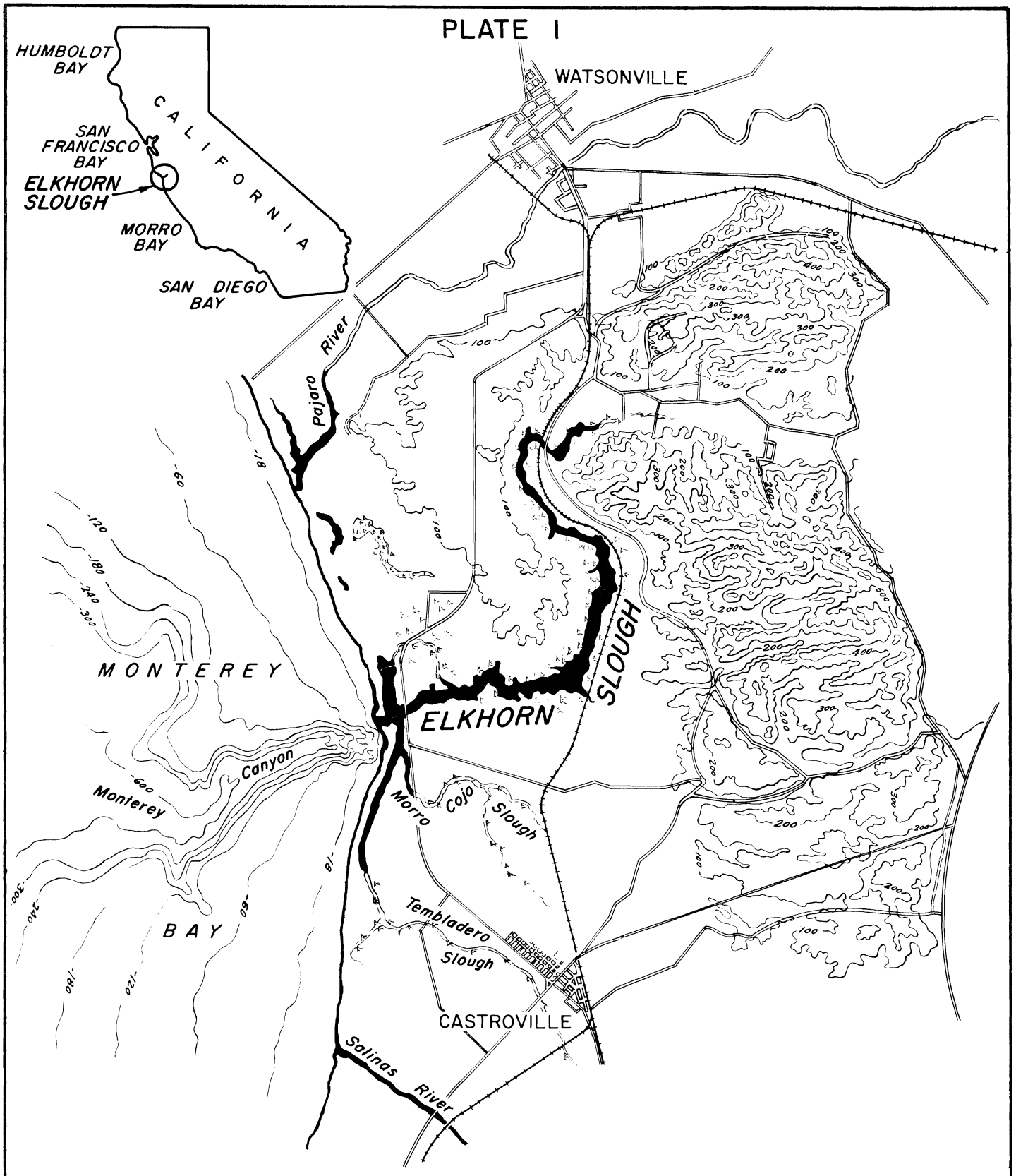
10. Conservation agencies and educational institutions be encouraged to continue to study and monitor all of the natural resources in Elkhorn Slough.

11. Tide and submerged lands granted to the Moss Landing Harbor District be surveyed and mapped.

12. The 1947 and 1967 tideland grants conveying title to tide and submerged lands to the Moss Landing Harbor District, be amended to protect and maintain the unaltered portions of Elkhorn Slough for fish, shellfish and wildlife purposes.

13. State, Federal and local governments cooperatively seek to acquire privately held marshlands in Elkhorn Slough to be managed for the maintenance, enhancement and utilization of the area's fish and wildlife resources.

Future uses of Elkhorn Slough and its environs, not related to the specific recommendations above, should be guided by criteria that require the use to be dependent upon, but not antagonistic to, the area's inherent resources and environmental attributes. Such uses should be of a nature that they could not occur at any location other than Elkhorn Slough.




ELKHORN SLOUGH
&
VICINITY

# ELKHORN SLOUGH AND ENVIRONS

## Description of Area

### Location

Elkhorn Slough is a shallow estuary located in northern Monterey County, about 100 miles south of San Francisco (Plate 1). The estuary joins the ocean at Moss Landing Harbor, a man-made small craft harbor, located on Monterey Bay half way between the communities of Monterey and Santa Cruz.

The slough and harbor are shaped like a small "t". The north and south arms of the harbor cross the "t"; the slough extends inland about 4 miles and then curves in a northerly direction for another 3 (Plate 1). The slough is roughly 700 feet wide, gradually narrowing at its northern end. The harbor arms, about 500 feet wide, lie parallel to the ocean shoreline, behind sand spits that are about 1,000 yards long and 100 to 300 yards wide. The harbor entrance is a man-made channel about 500 feet wide.

### History

Elkhorn Slough and Moss Landing are rich in historical lore. Tule elk, whales, Indians, floods, earthquakes and World War II all have a part in the story and formation of the slough as we know it today.

The slough probably got its name from the fact that the native tule elk once roamed its banks (Gordon, 1971) - or possibly from its characteristic shape.

The Elkhorn Slough has not always been an estuary. A 1878 Coastal and Geodetic Survey map shows the slough as a lagoon opening into the old

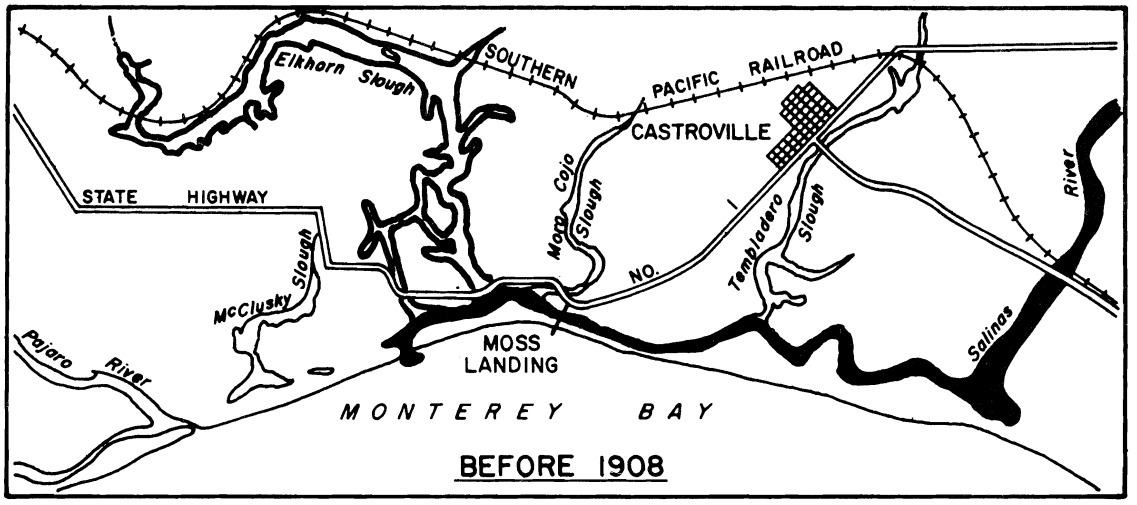
Salinas River channel. The mouth of the Salinas River was located at that time about 1-1/2 miles north of Moss Landing (Plate 2). Remnants of Indian shell mounds clustered around the vicinity of the old mouth of the Salinas River indicate that the river emptied there over long periods of pre-historic time (Gordon, 1971).

In the winter of 1908 the Salinas River suddenly began to empty into Monterey Bay about 5-1/2 miles southward (Plate 2). Some claim that the shift was caused by the 1906 earthquake, since the area lies on the San Andreas fault; but actually, the change of course occurred 2 years later (Gordon, 1971).

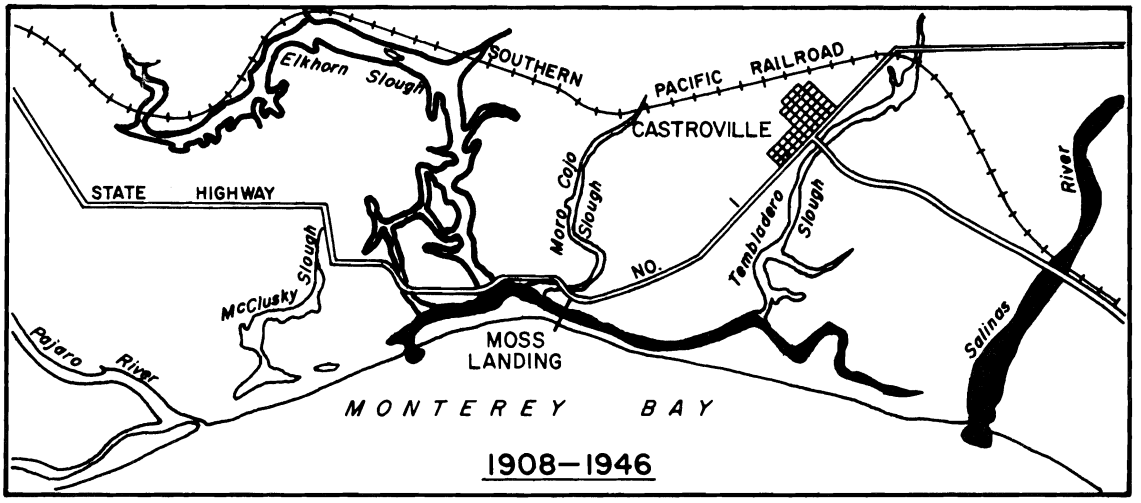
The Salinas River entrance to the sea, prior to flood control dam construction, occasionally shifted during violent winter storms. After the 1908 break-through the new river outlet was maintained by local farmers who reclaimed the former river channel for agriculture (Gordon, 1971). Hence, prior to 1908 the Elkhorn Slough was a freshwater lagoon with limited tidal influence and tributary to the Salinas River. After 1908 the slough was cut-off from the Salinas River and became an estuary. Until 1946 tidal action kept the old mouth of the Salinas River open, flushing the estuary with seawater.

Moss Landing was named after Charles Moss who built a wharf there in 1865. For a time a line of sailing schooners operated from Moss Landing (Scofield, 1954). Two periods of whaling activity occurred in those early days. From 1852 until 1888, Moss Landing was one of the most important whaling stations in the country. This was a period of small boats, beach flensing and open-air dry vats. From 1918 until the early

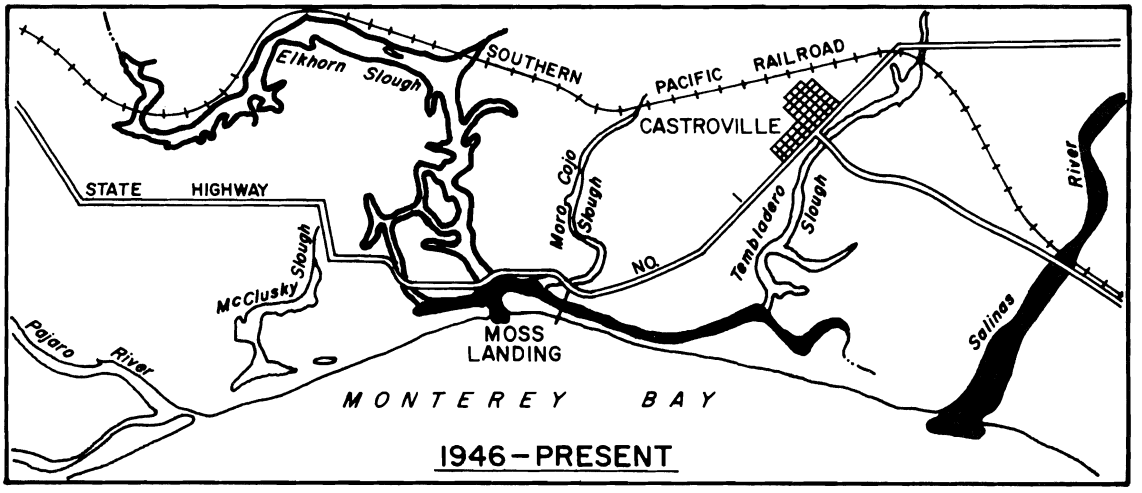
# PLATE 2




BEFORE 1908




1908–1946




1946–PRESENT

## HISTORICAL MAPS
## Changes in Salinas River & Mouth of Elkhorn Slough

1930's whaling was accomplished by killer tugs that towed their prey to a large shore station equipped with steam power, loading ramps and modern reduction equipment. Only the pier of this plant remains.

World War II brought about the next major changes at Moss Landing which influenced Elkhorn Slough significantly. In 1942 Kaiser Refractories constructed a magnesia plant added a refractory plant in 1946, and the industrialization of the Elkhorn environs began.

On October 21, 1943 the Secretary of War recommended the "early enactment of proposed legislation to provide for the improvement of Moss Landing Harbor, California at an estimated cost of $350,000 in the interest of the wartime need for increase in the production of fishery commodities." (Senate Doc. No. 50, 1945). In 1945 Congress passed the River and Harbor Act which provided for the construction of Moss Landing Harbor. Dredging operations began in the summer, 1946. By late October 1946, the entrance channel through the sandbar and the lagoon channels were complete. By October, 1947 the jetties to protect the entrance were constructed and the project was officially completed (Wong, 1970). Now Elkhorn Slough empties directly into the head of the submarine Monterey Canyon (Plate 2). The old mouth of the Salinas River gradually silted in and closed.

In the 1950's, Pacific Gas and Electric constructed its steam-electric generating plant and since then there have been two major expansions of that facility. The development of the Elkhorn Yacht Club and marina in the north wing of the harbor also took place in the 1950's.

Prior to 1935 commercial fishing occurred on a small scale at Moss Landing. The industry expanded that year and a cannery boom followed. The port activities peaked in 1944 and flourished after the war. By 1952 there were eight canneries and reduction plants and the harbor sheltered 30 or 40 fishing vessels; purse seiners, an occasional trawler and dozens of small trolling boats (Scofield, 1954). Due principally to the failure of the sardine supply, the Moss Landing fishery has declined the last 20 years. Although the Moss Landing boats still land over 15 million pounds of fish a year (Heimann and Carlisle, 1970), most of the fish is trucked out. At present there is only one operating cannery and it is due to shut down soon.

Despite industrial intrusion on the Elkhorn and its environs, urban sprawl has not been a serious problem in the Moss Landing area. There is some residential development in the foothills lying east of the slough, but most of the people employed in industrial activities commute from other communities. The population at Moss Landing in 1940 was 200; at present, about 500.

Drainage

The watershed emptying into the sea at Moss Landing Harbor is roughly rectangular with its major axis running from southeast to northwest (Plate 3). The basin drains about 226 square miles and empties into Elkhorn, Moro Cojo and Tembladero Sloughs. The low-lying, flat marshy areas of the sloughs are flanked on the east and northeast by rolling to moderately steep hills, several hundred feet in elevation. The southeast side of the basin slopes gently upward into the Salinas Valley. Adjacent drainage areas are the Pajaro Valley to the north and the lower Salinas River Valley to the south.

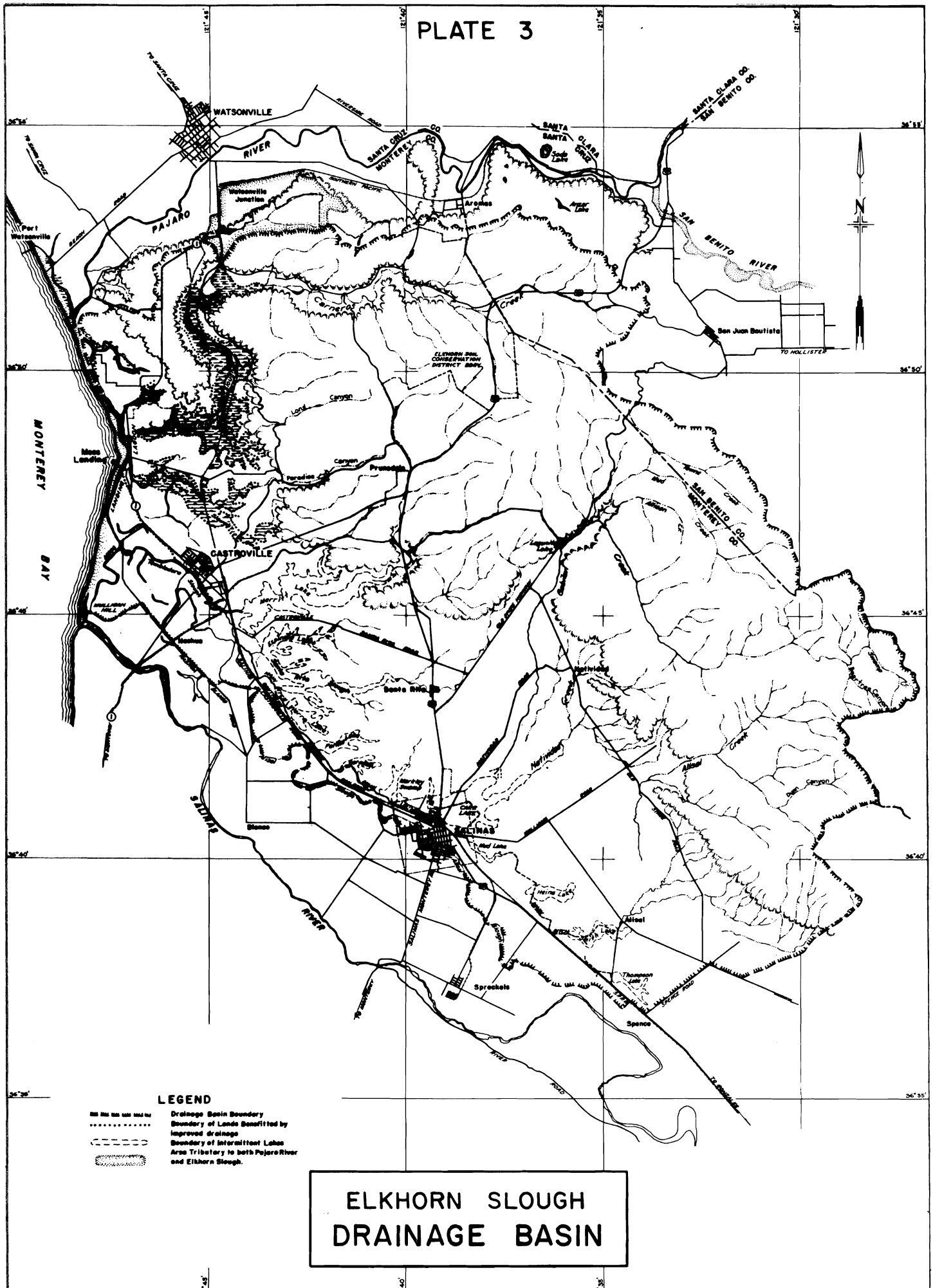


PLATE 3
WATSONVILLE
RIVER
PAJARO
SANTA CRUZ CO.
MONTEREY CO.
SANTA CLARA CO.
SAN BENITO CO.
Watsonville Junction
Aromas
Port Watsonville
SAN BENITO RIVER
San Juan Bautista
TO HOLLISTER
MONTEREY BAY
Moss Landing
CASTROVILLE
Prunedale
Elkhorn Slough
Salinas River
Natividad
Alisal
Sprecklels
Spence
LEGEND
Drainage Basin Boundary
Boundary of Lands Benefitted by Improved Drainage
Boundary of Intermittent Lakes Area Tributary to both Pajaro River and Elkhorn Slough.
ELKHORN SLOUGH
DRAINAGE BASIN

## Tides

Tidal action also affects the circulation and drainage of Elkhorn waters. Salinity of the slough varies with the tidal cycle and the amount of fresh water drainage off of the watershed.

The mean sea level in the Monterey Bay area is 2.8 feet above the lowest low tide level. The mean range between tide levels is 3.5 feet, but the average range between the highest and the lowest tide levels is 5.3 feet (Wong, 1970).

Tidal action in Elkhorn Slough was strong enough to keep the sandbar open at the original mouth and at the present time is vigorous enough to cause "scouring" at the lower end of the slough. At ebb tide a plume of suspended silt commonly spreads over several acres of the bay outside the harbor mouth - evidence of actual scouring (Gordon, 1971).

One result of the scouring is a deepening and widening of the channel in the lower part of the slough. In some places the banks in the lower part have been protected by riprap, but in others erosion has caused a decrease in the pickleweed association of plants, the dominant vegetation. Undercut and slumping banks can be seen all along the lower slough, a process probably being hastened by small crabs honeycombing the banks with burrows (Gordon, 1971). The mudflat area in the south arm of the harbor is being extended similarly, causing a decrease in the pickleweed marsh.

## Climate

The marine climate of the Monterey Bay area is one of the most moderate climates to be found in California, if not in the entire continent. The moderating influence of the sea limits (at Watsonville) the mean summer maximum temperature to 71°F and the mean winter minimum to 37°F (Smith, 1970). The average precipitation is 18 to 21 inches per year. November through March is the rainy season. The summers are virtually rainless, although a cooling, onshore flow of marine air and fog is a summer phenomenon.

## Land Ownership

The primary owner of lands in Elkhorn Slough is the Moss Landing Harbor District (M.L.H.D.). Under a California state grant, M.L.H.D. holds title to all the slough waters and lands, essentially to the "ordinary" high water or tide-line. Consequently, District ownership of lands important to fish and wildlife include channels and mudflats of the harbor and slough.

The Harbor District's title to the Elkhorn waters and lands came through Chapter 1190 of the 1947 California Statutes. Grant provisions conveyed to the District "all the right, title, and interest now held by the State of California by virtue of its sovereignty, in and to all lands, salt marsh, tidelands, submerged lands, and overflowed lands." The grant includes: the Old Salinas River Channel from its original (pre-1908) mouth to the county road bridging the channel at Moss Landing; the ocean opposite the said portion of the Old Salinas River; and Bennett, Elkhorn, and Moro Cojo sloughs between the Old Salinas River and the easterly extremities of the tidal action, therein (Plate 4). A 1967

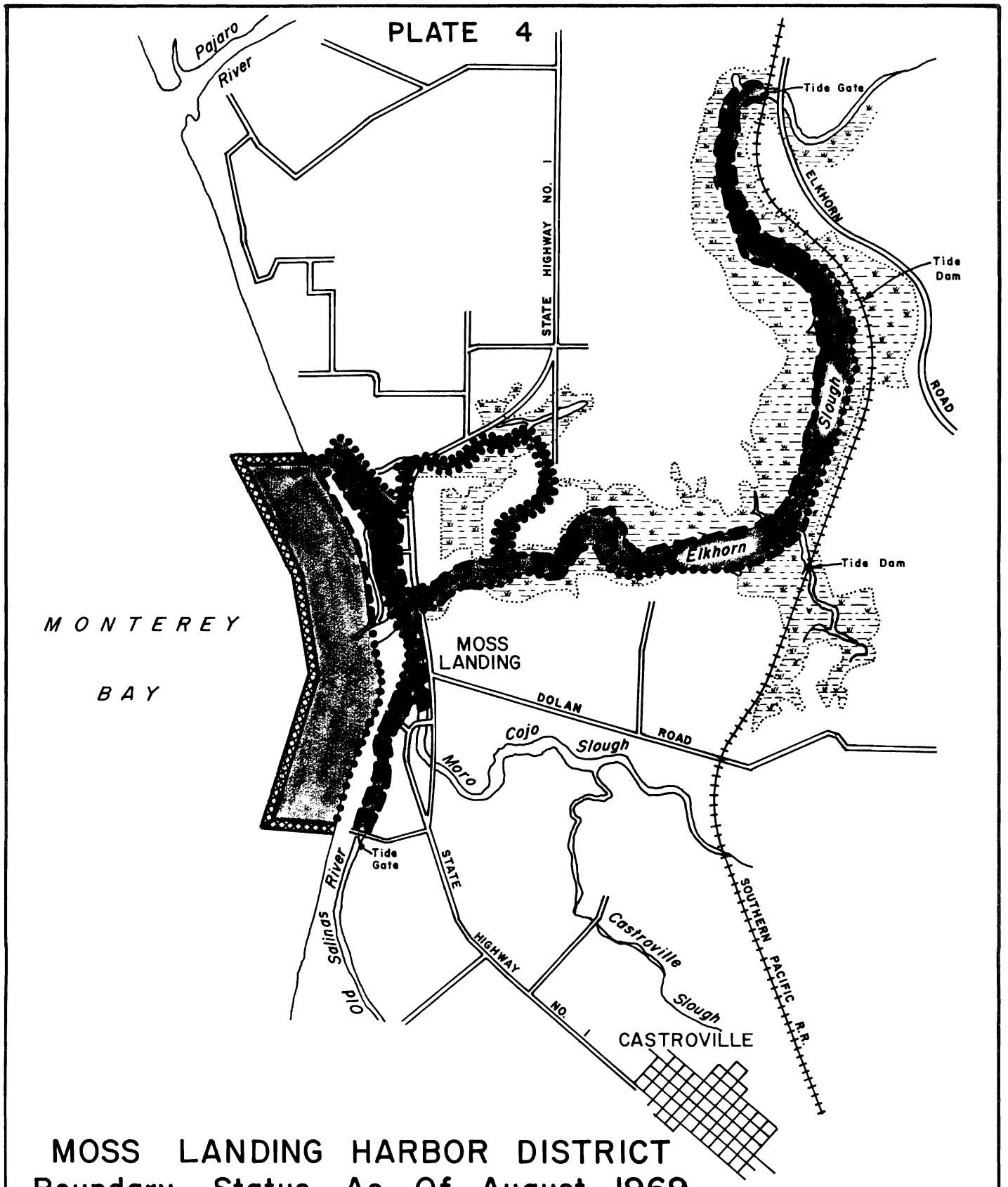


PLATE 4
Pajaro River
STATE HIGHWAY NO. 1
Tide Gate
ELKHORN
Tide Dam
ROAD
Slough
Elkhorn
Tide Dam
MONTEREY
BAY
MOSS LANDING
DOLAN
ROAD
Cojo
Slough
Moro
Tide Gate
Salinas River
Old
STATE
HIGHWAY
NO. 1
Castroville
Slough
SOUTHERN PACIFIC R.R.
CASTROVILLE
MOSS LANDING HARBOR DISTRICT
Boundary Status As Of August 1969
Unresolved Boundary
Fixed by Boundary Line Agreement
Grant Boundary in State Waters

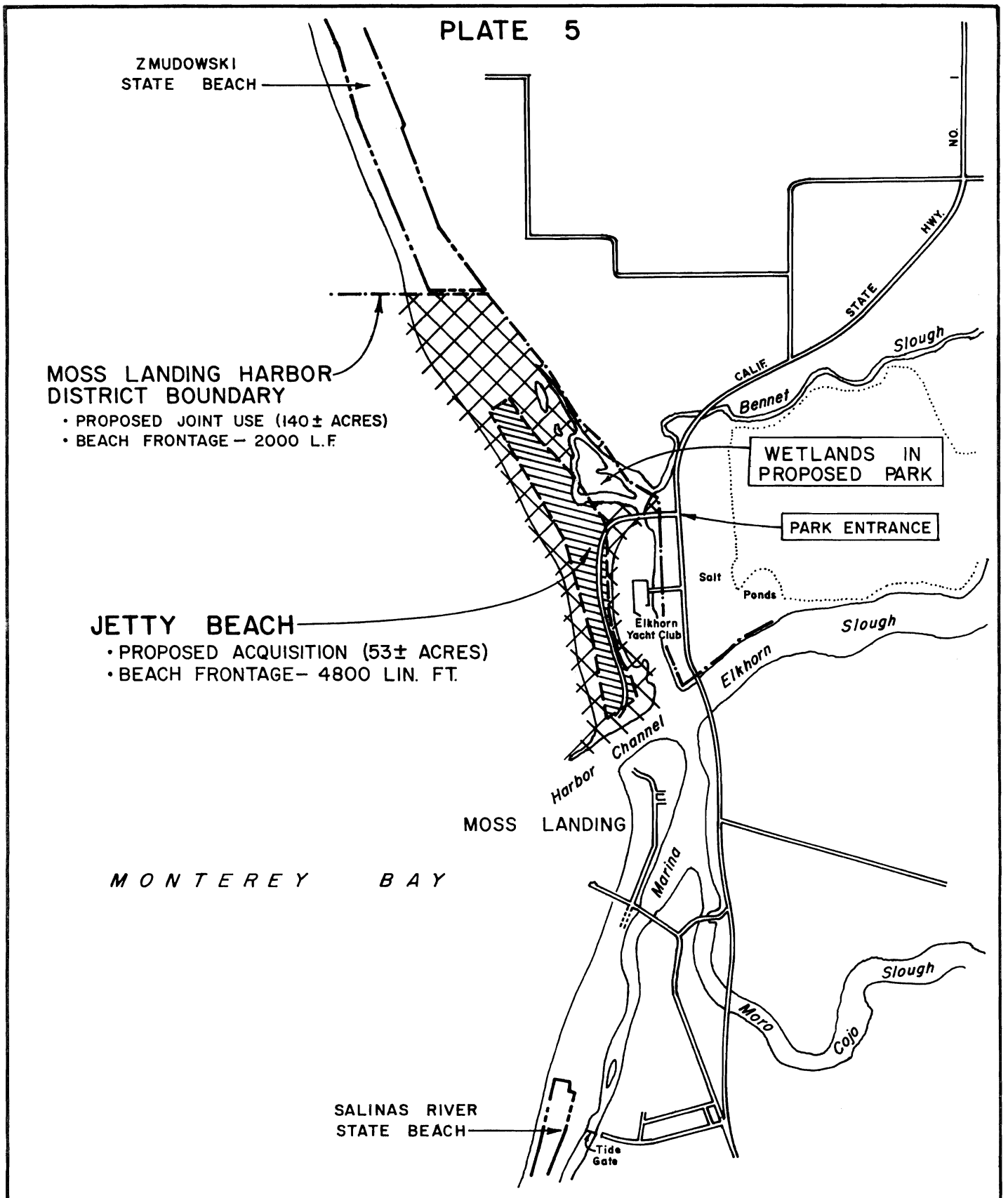

T he Wildlife Conservation Board and Kirby Park project provides needed access to the slough

Department of Fish and Game photo by John Speth
July 1971

amendment to the original grant clarified District ownership in the ocean as extending 2,000 feet seaward from the high water mark.

Virtually all of the lands bordering Elkhorn Slough and abutting the District lands are privately owned; mostly by long-time residents, farmers and dairymen. Private ownerships extend into the slough to include most of the 770 acres of natural salt marsh and about 670 acres of marsh in various stages of reclamation. The only public land adjacent to the slough is county-owned Kirby Park, a narrow, 10 acre strip between the slough and Elkhorn Road, at the upper end of the slough. The Wildlife Conservation Board of the Department of Fish and Game leased a piece of Harbor District land abutting the county-owned strip. In June, 1961 the Board, in cooperation with the County, completed a parking and boat launching facility on the leased land. Kirby Park is the only public access into Elkhorn slough, other than by small boat or via the mudflats (at low tide) from Moss Landing Harbor.

Except for a few parcels that the M.L.H.D. has purchased in order to improve and expand their harbor facilities, all of the lands surrounding the harbor are in private ownership. The north spit called Jetty Beach, some 54 acres and 4,800 lineal feet of ocean frontage, is privately owned. However, the California Department of Parks and Recreation proposes to buy this property with 1964 bond monies allocated in the 1971-72 budget. Zmudowski State Beach lies immediately north of Jetty Beach. With the Jetty Beach acquisition and by cooperative agreement to use or lease the District-owned beach at the mouth of the Old Salinas River Channel, the State will control 2-1/2 miles of contiguous public beach (Plate 5).




# PROPOSED JETTY BEACH ACQUISITION

DEPT OF PARKS & RECREATION 1971–1972

The south spit could be called the "Sandholdt Spit" after a family that originally developed most of it. The south spit or "island" as it is known locally, contains commercial plots owned or leased by boat maintenance, fuel, and supply facilities, a real estate brokerage and the one remaining fish cannery. The Moss Landing Marine Laboratories, sponsored by five state colleges, is located at the center of the south spit.

The town of Moss Landing lies on the east shore of the south arm of the harbor and the Moss Landing Yacht Club and several cafes on the east shore of the north arm.

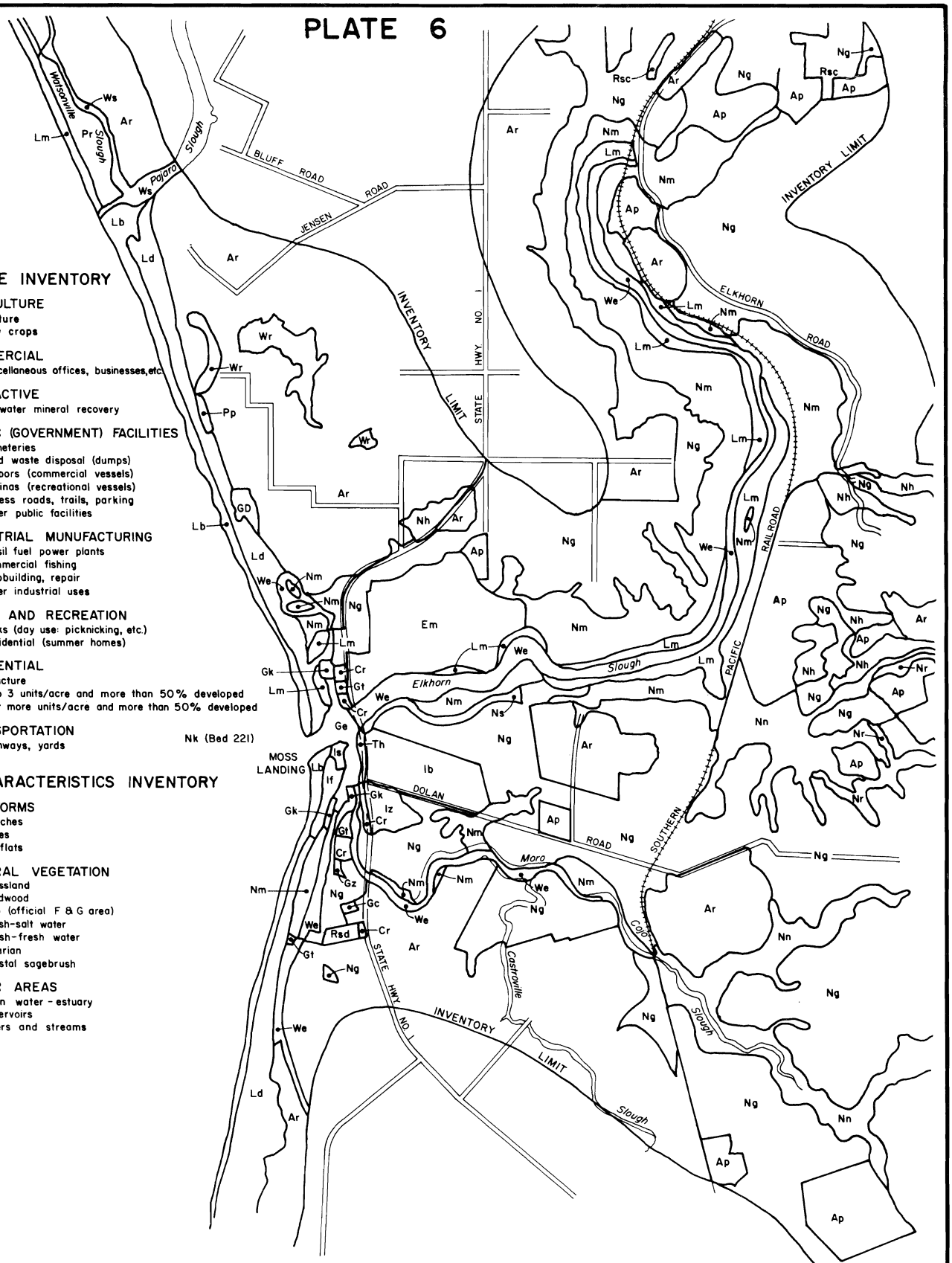
## Land Use
(Plate 6)

Much of the salt marsh bordering the slough channels and mudflats provides fish and wildlife oriented, recreational and educational (scientific) use. The salt marsh, with its maze of channels and potholes, is where many of the shorebirds and waterfowl are observed. Several private duck hunting clubs lie adjacent to the slough. Recreational and educational use will be outlined more fully in following sections of the report.

Nearly half of the Elkhorn marshlands are in various stages of reclamation, primarily for livestock grazing. Irrigated pastures, both alfalfa and mixed pasture, lie on the broad flats above the slough. This pasturage is owned and used by the principal dairies in the vicinity.

Other irrigated pasture is found east of the slough at the base of the rolling foothills, which are vegetated with oak-grassland and chaparral. Most of the oak-grassland is used for livestock grazing and occasional clearings support strawberry crops. Some residential use of the foothill

# PLATE 6




## LAND USE INVENTORY

**A – AGRICULTURE**
- p – Pasture
- r – Row crops

**C – COMMERCIAL**
- r – Miscellaneous offices, businesses, etc.

**E – EXTRACTIVE**
- m – Seawater mineral recovery

**G – PUBLIC (GOVERNMENT) FACILITIES**
- c – Cemeteries
- d – Solid waste disposal (dumps)
- e – Harbors (commercial vessels)
- k – Marinas (recreational vessels)
- t – Access roads, trails, parking
- z – Other public facilities

**I – INDUSTRIAL MUNUFACTURING**
- b – Fossil fuel power plants
- f – Commercial fishing
- s – Shipbuilding, repair
- z – Other industrial uses

**P – PARKS AND RECREATION**
- p – Parks (day use: picknicking, etc.)
- r – Residential (summer homes)

**R – RESIDENTIAL**
- s – Structure
  - c. 0 to 3 units/acre and more than 50% developed
  - d. 4 or more units/acre and more than 50% developed

**T – TRANSPORTATION**
- h – Highways, yards

## SITE CHARACTERISTICS INVENTORY

**L – LANDFORMS**
- b – Beaches
- d – Dunes
- m – Mudflats

**N – NATURAL VEGETATION**
- g – Grassland
- h – Hardwood
- k – Kelp (official F & G area)
- m – Marsh-salt water
- n – Marsh-fresh water
- r – Riparian
- s – Coastal sagebrush

**W – WATER AREAS**
- e – Open water - estuary
- r – Reservoirs
- s – Rivers and streams

# LAND USE AND SITE CHACTERISTICS

FROM DEPT. OF NAVIGATION AND OCEAN DEVELOPMENT
COMPREHENSIVE OCEAN AREA PLAN — 1970

area occurs along Elkhorn Road, a county road that traverses the base of the foothills just east of the slough. Suburban development is occurring in the vicinity of Carneros Creek and Hall Road at the northern end of the slough.

Irrigated truck and field crops are grown on the rich alluvial soils found to the north and south of the slough. Artichokes, cole crops (brussel sprouts, cabbage), beans (green and dry), lettuce, melons and sugar beets are commonly produced.

Moss Landing Harbor is the focus for the major urban residential, commercial, and industrial development and use in the environs of Elkhorn Slough. In addition to marine-oriented commercial development, there are the docking facilities and office of the Harbor District, the yacht club, the power and refractory plants, the Moss Landing Marine Laboratories, the Monterey Salt Works Company salt-producing operation, as well as the community of Moss Landing.

The ocean side of the harbor is mostly beach and sparsely vegetated sand dunes. The beach areas, of course, offer a great potential for recreational use, such as fishing, camping, picnicking, sight-seeing, clamming, swimming, nature study and photography. The proposed development of the Jetty Beach property by the Department of Parks and Recreation will greatly enhance the opportunity for recreational use.

Commercial and pleasure craft moor at Moss Landing Harbor District facilities

Department of Fish and Game photo by Frank Hubbard
March 1970

## RESOURCES

### Habitat and Ecology

Pritchard (1967) has defined an estuary as "a semi-enclosed body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage." At least part of the year, in response to run-off from fall and winter rains, Elkhorn Slough fits the description of a true estuary. During the summer months, however, the creeks dry up, local drainage becomes minimal and salinities rise as high as 33 to 37 parts salt per thousand of water, slightly above that of sea water (Smith, 1970). The upper end of the slough virtually stagnates during the summer period. The slough then exhibits most of the characteristics of a lagoon.

Whether a true estuary or a part-time lagoon, Elkhorn Slough shares the fate of all coastal estuaries and lagoons--that of a slow evolutionary death from gradual conversion of water and mudflats to marshlands and, finally, to upland habitat. Signs of this normal evolutionary process, caused by deposition of silt and debris by runoff from the surrounding watershed, are observable in the upper end of the slough in the vicinity of the Elkhorn Road crossing. The surrounding watershed, however, has gentle slopes and is relatively free of man's usual misuse. Hence, erosion is slow; the life expectancy of Elkhorn Slough should be considerably greater than, for instance, that predicted for Bolinas Lagoon in Marin County (Giguere, 1970) and Goleta Slough in Santa Barbara County (Speth, 1970). Man's activities have accelerated the decline of those two coastal wetlands.

Estuarine circulation and tidal movement of water produces a gradient of submersion and exposure. Examination of the shores of the

slough reveals a zonation, or stratification, of habitat and vegetation. Ecologists recognize three estuarine zones: the marine zone, that area continually under water; the littoral zone, that area subject to tidal submergence; and the maritime zone, that area between the upper edge of the littoral zone and the surrounding upland vegetation.

The estimated acreages of habitats within each zone are shown below. Habitat distribution is depicted in Plate 7.

| | |
|---|---|
| Marine | |
| Harbor and natural channels | 350 acres |
| Saltponds | 190 acres |
| Littoral | |
| Mudflats | 420 acres |
| Salt marsh | 1,440 acres* |
| Maritime | |
| Dunes and beach | 100 acres |
| Total Elkhorn and Moss Landing Habitats | 2,500 acres |

*Includes 670 acres of salt marsh in various stages of reclamation partially or totally isolated from tidal influence by tide gates, dams and levees.

In the marine zone, most of the vegetation is algae. Blue and green algaes are well distributed throughout the slough. Enteromorpha, a green algae, is the most common and abundant. In addition to being a food source, this algae serves as a place of attachment for the eggs of many estuarine animals. A variety of single-celled plants (diatoms) are

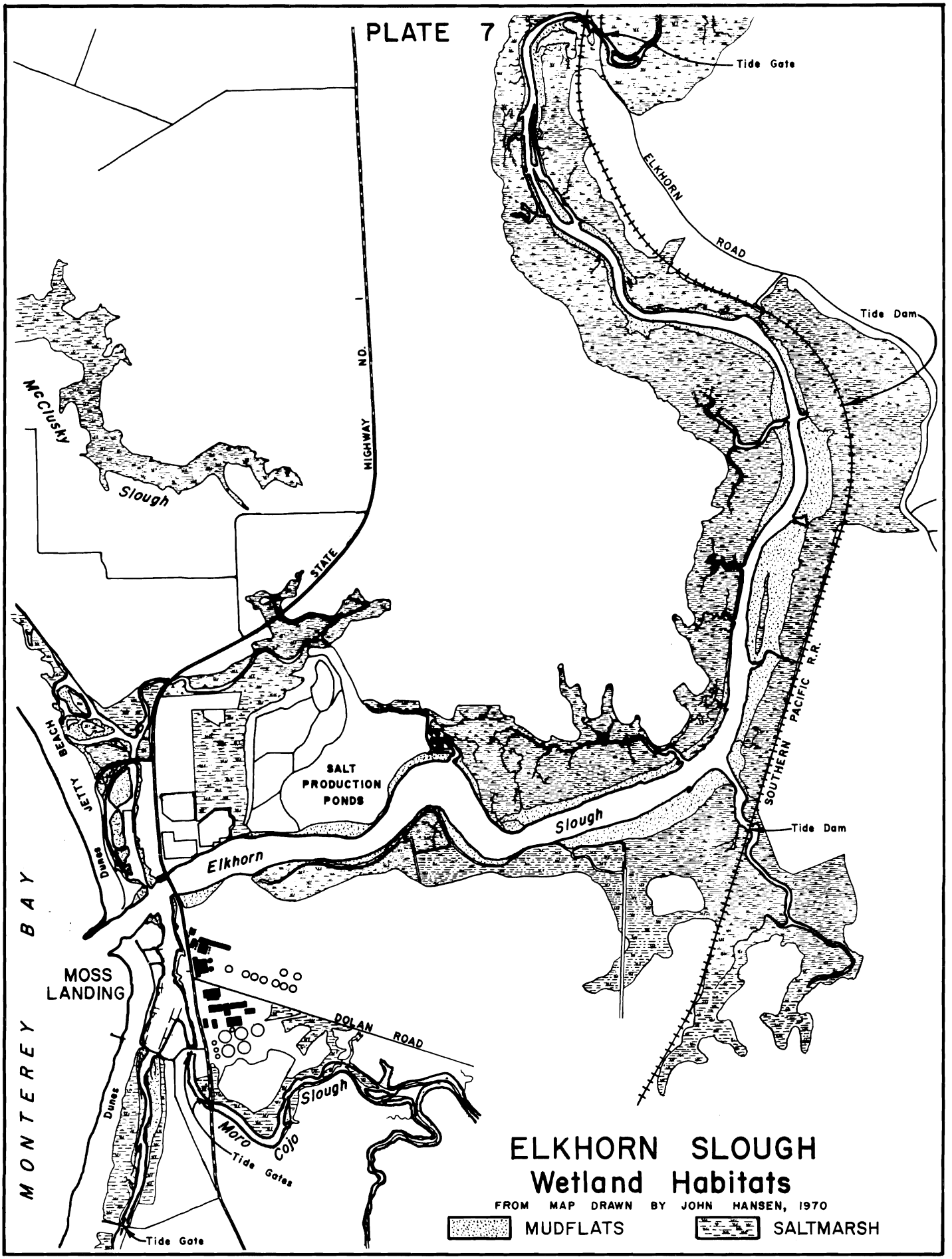


PLATE 7
Tide Gate
ELKHORN ROAD
Tide Dam
HIGHWAY NO. 1
McClusky Slough
STATE
BEACH
JETTY
Dunes
SALT PRODUCTION PONDS
Elkhorn Slough
SOUTHERN PACIFIC R.R.
Tide Dam
MONTEREY BAY
MOSS LANDING
DOLAN ROAD
Moro Cojo Slough
Dunes
Tide Gates
Tide Gate
ELKHORN SLOUGH
Wetland Habitats
FROM MAP DRAWN BY JOHN HANSEN, 1970
MUDFLATS
SALTMARSH

found anchored to the algal forms. Diatoms are a source of food for some of the lower forms of living organisms.

Before the dredging of the entrance and development of the harbor, extensive beds of eelgrass, a narrow-leaved, grass-like, submerged aquatic plant existed in the lower reaches of the slough. This plant, which is the coastal migratory black brant's main food, now is found only in a few patches in the old Salinas River channel, the south arm of the harbor and about the mouth of the slough. The exact cause of the disappearance of this important marine plant is unknown; however, it probably is due to man's influence on the fragile estuarine ecoystem through some form of pollution.

Bare mudflats occur in the lower part of the littoral zone. About one-fourth of the littoral zone is devoid of vegetation. These mudflats, which range from true mud and clay to medium or fine sands, are rich in organic matter and host large quantities and varieties of invertebrate organisms such as crabs, clams, snails and worms. It is the mudflats that are so attractive to the shorebirds and furnish much of their food.

Mudflat habitat at low tide may be found the length of the slough (Plate 7). Key mudflat areas especially attractive to shorebirds, shellfishermen and birdwatchers alike are found in the south harbor arm (along the old Salinas River channel), at the mouth of the slough (good clamming beds in the vicinity of the bridge), and in the extension of the north harbor arm just above the Jetty Beach Road (part of which will be incorporated as a nature study area in the proposed Parks and Recreation Jetty Beach development).

Mudflats attract shorebirds and furnish much of their food

Department of Fish and Game photo by Frank Hubbard
October 1970

Shorebirds can be found distributed about tidal flat habitat according to their feeding habits as determined by their body characteristics (length of legs, type of beak, etc.) and the stage of the tide. They may be found wading in the shallow water or scurrying about the surface of the mudflats or resting and awaiting the contributions of the next turn of the tide.

The principal vegetation of the slough, found in the higher part of the littoral zone, is classified as a "typical" salt marsh (Greene, 1968). The dominant species of this plant community is perennial pickleweed (Salicornia), which comprises over 90 percent of the vegetative cover of the Elkhorn marsh. Factors affecting distribution and zonation of littoral plants are soil moisture and salt content, organic content of the substrate, percent gradient, particle size of the silt components and the length of time of tidal exposure. Elkhorn Slough appears to have an optimum of these conditions to support perennial pickleweed; and, just as the mudflats have their specialized inhabitants, so does the salt marsh habitat. Some of the longer legged shorebirds can be observed searching for food in the pockets and pools located among the pickleweed plants.

The maritime zone is located at the higher and outer edge of the marsh. This area, where exposure to tidal waters is rare or lacking, is vegetated with salt-loving plants such as saltgrass, frankenia and the adventive iceplant. The maritime vegetation furnishes important escape, resting and loafing cover for many estuarine birds. Elkhorn's maritime zone includes sand dunes and beach between the harbor and ocean.

Perennial pickleweed comprises over 90 percent of the marsh vegetation

Department of Fish and Game photo by John Speth
July 1970

The salt ponds on the north side of the harbor end of the slough are another, although specialized, type of Elkhorn habitat. These ponds are used as loafing (resting) and feeding areas by several species of migrating birds. October censuses in 1967 recorded over 9,000 birds including the Forster's tern, caspian tern, avocet, black-necked stilt, phalaropes and California brown pelican utilizing the ponds. Department studies of similar salt ponds in the San Francisco Bay area (Anderson, 1970) document the high value of this type of habitat to wildlife.

The entry of a tributary into the vegetation of the maritime zone provides another specialized habitat. This habitat, classified as fresh-water marsh, is vegetated with dense stands of cattails, rushes and bulrushes, which make ideal nesting and escape cover.

So it is, then, that each estuarine zone, plant association, or type of marsh habitat contributes to the whole ecosystem that is Elkhorn Slough. It is this biological system that provides the feeding, resting and nursery areas for the many species of fish and wildlife that either reside in the area the year-round or migrate through occasionally or annually.

Many of the shorebirds, waterfowl and marsh birds use the slough for periods of 6 to 9 months each year, as they migrate along the coast or upon selecting the area as their particular wintering grounds. Others, including the snowy plover, avocet, mallard duck and the California clapper rail, are considered residents and nest and raise their young in the marshy edges of the slough. Some resident birds require relatively large unbroken expanses of the highly specialized habitat that the slough

provides, in order to survive. One such resident is the secretive clapper rail, now on the Department's list of endangered species (Department of Fish and Game, 1971).

Coastal birds use the slough and harbor waters for resting or loafing between migration or feeding flights. Large flocks of brown pelicans and phalaropes have been observed loafing in, or on the banks of, the salt ponds. Other ocean-dwelling or inshore species, the murres, guillemots, murrelets, grebes, loons, cormorants and some species of diving ducks use the waters of the sheltered harbor for resting and feeding.

Despite a scarcity of good spawning substrate the slough is a nursery area for some of the fish that inhabit the inshore areas of Monterey Bay. Pacific herring, starry flounders, staghorn sculpin, shiner perch, jacksmelt, topsmelt, pile perch and several species of sharks and rays either spawn or give birth to their young in the waters of the slough.

The water, mudflat and salt marsh literally teem with vast quantities and varieties of food organisms. Plants, by means of photosynthetic activity and storing nutrients, are the primary source of all food. Some herbivores, such as the geese, feed directly on the salt marsh plants. However, a considerable proportion of estuarine vegetation is converted to detritus which forms a substrate for bacteria. It is both the bacteria and the detritus that begin the complex food chain, web, or pyramid, that holds or weaves the cycle of life together.

Clams and other mollusks filter the bacteria and detritus directly from the water. Marine worms and other mud-dwellers actually ingest the mud to extract nutrients. These lower animal forms are eaten in turn by bottom feeders and scavengers like crabs, stingrays and small fish. The larger fish--an occasional striped bass or halibut--lured into the slough by the rich source of nutrients at the slough's mouth; or the sharks or marine animals, such as the seals and sea lions; and man himself, complete this one example of the many and complex food chains that exist in the slough.

The rich food sources of Elkhorn Slough support many fish which spawn elsewhere but come to the slough to mature. The continued existence of many of the resident and migratory wildlife of Elkhorn Slough is almost entirely dependent on the food resources and habitat of this and other coastal wetlands.

## Wildlife

During the height of the migration period from early fall to early spring the slough and its environs abound with hundreds of shorebirds, wading birds, marsh birds, waterfowl, inshore and pelagic (ocean-dwelling) birds. Department personnel, ably and enthusiastically assisted by members of local bird societies, have observed and identified over 90 species of water-associated birds in the Elkhorn and Moss Landing Area (Appendix A).

There are more species of shorebirds than any other type of visitant or resident. This group includes the sandpipers, plovers, dowitchers, willets, curlews, godwits, avocets and phalaropes. Wading birds, such as the herons and egrets, frequent the salt marsh habitat and several species of birds that dive for their food, such as the grebes, loons and an occasional cormorant, can be seen in the open water. Nine species of gulls

Top Photo: Long-billed curlew Bottom Photo: Dowitchers

Department of Fish and Game photos by Frank Hubbard
October 1970

and seven kinds of terns rest or feed year-round in the slough. Of special interest are reports that brown pelicans, in numbers in excess of 2,000 have been observed loafing in the concentration ponds of the salt works at the mouth of the slough and feeding in the slough itself.

The California clapper rail, an endangered species, is reported as a resident. This bird is dependent on pickleweed marsh. Any significant loss of this type of habitat along the coast could add the clapper rail to the list of extinct species.

Waterfowl, including the mallard, pintail, green-winged and cinnamon teal, shoveler, greater and lesser scaup, the white-winged and surf scoters, ruddy duck, and American coot use the slough as a resting and feeding area during their annual migrations. A few mallards, cinnamon teal and coots nest in the marshy edges of the slough. An occasional flock of geese (white-fronted, lesser Canada, snow, Ross and black brant) wings into the slough on its way up or down the coastal flyway. As many as 19 whistling swans have been observed during a census.

Resident birds (Appendix A) nest and raise their young in the marsh. Most birds observed are migrants; however, as one might expect, the numbers of migrants vary with the season.

The Department, which is responsible for all of California's non-game, as well as its rare and endangered species, censused the area from July, 1967 through June, 1968. Presently another census, begun in August, 1970, is being conducted by William Anderson, a retired Department biologist and Mrs. Viola Anderson of the Santa Cruz Bird Society. The latter census is part of an ongoing study by the Special Wildlife Investigations Project of the Department.

These censuses (Appendix B) show that population numbers tend to peak twice, once in late summer or fall (as late as the first week in December) and again in the spring (return flights towards ancestral breeding grounds). Numbers of water-associated birds ranged over 20,000 in October, 1967, for instance. Duck counts were as high as 2,400 in 1968. These census figures are impressive and rank the Elkhorn Slough among the most important of the coastal marshes. There is no doubt about the ecological importance of these coastal wetlands to migratory water-associated birds like shorebirds and waterfowl.

Several raptors, including the white-tailed kite, marsh hawk, red-tailed hawk, sparrow hawk and an occasional golden eagle may be seen perched at their observation posts about the slough or wheeling overhead. The California quail and the mourning dove are found in the adjacent uplands and an occasional band-tailed pigeon and ring-necked pheasant have been observed.

Moderate populations of black-tailed deer inhabit the chaparral and oak-grasslands of the surrounding watershed. This habitat also supports jackrabbits, brush rabbits, bobcats, coyotes, gray fox and raccoons. Jackrabbits and brush rabbits are found in the upper edges of the marsh habitat and raccoons and muskrats sometimes are seen searching the littoral area for food.

## Fish

Fish are an important resource in Elkhorn Slough and Moss Landing Harbor. A composite list (Appendix C), compiled from several Department and Moss Landing Marine Laboratories sources (Tarp, 1952; Herald, et al., 1960; Kukowski, 1966; Forsyth, 1968; Ackerman, 1969), identifies over

70 species of fish; 48 collected from the slough proper, 56 from the harbor and 23 from the jetties and Sandholdt pier on the ocean side of the harbor.

The slough serves as a nursery area for many of the fishes listed. Bat rays give birth to their young in the slough and there is an indication that the shovelnose guitarfish, leopard shark, round stingray, gray and brown smoothhounds and thornback, all closely related species, come into the slough in the late spring or early summer to have their young (Herald, et al., 1960).

The starry founder seeks out shallow waters near rivermouths and sloughs and is a probable spawner in the Elkhorn (Orcutt, 1950).

The Pacific herring, a commercially important fish, spawn sporadically in Elkhorn Slough, although the area has limited amounts of proper spawning substrate and cannot accommodate the large numbers of herring that are found in the Monterey Bay. "Heavy" spawning activity has been recorded in past years (1952, 1955) (Miller and Schmidtke, 1956).

Most of the fish collected from the slough, including the staghorn sculpin, shiner perch, topsmelt and jacksmelt, spawn or give birth to their young in the slough. The smelt are important forage fish for larger and commercially significant fish and are preyed upon by pelicans and cormorants and other inshore and pelagic birds.

The slough also serves as a feeding area for many of the fish attracted to or inhabiting its waters. Sharks and rays feed on crabs, shrimp, clams, worms and small fish such as the midshipman and arrow goby. Other bottom feeders, like the starry flounder, have similar diets

and occasionally forage along the bottom clipping the siphons off of clams (Herald, et al., 1960). Striped bass and other large predacious fish often follow schools of smelt or herring into the harbor or slough's mouth.

## Shellfish

Elkhorn Slough supports a rich fauna of bottom and mud-dwelling invertebrates. Shellfish are well represented in this marine and littoral fauna (Appendix E). MacGinitie's (1935) classical ecologic study of the Elkhorn Slough from 1926 to 1935 lists 28 species of clams, 5 oysters (1 native, 4 exotic), 8 kinds of shrimp, 12 crabs and 11 shore-crabs, 8 amphipods (fairy shrimp) and 5 barnacles. MacGinitie also identified two species of mud shrimp and 1 echiurid worm as being the most abundant animals in the marsh and extremely important in the food chains of the slough. Smith and Gordon (1948) list 35 species of mollusks most of them pelecypods (clams). Addicott (1952), studying the clams in the area, reported the following shellfish (in decreasing order of abundance): bentnose clam, irus macoma, white sand clam, gaper or horse-neck clam, littleneck, basket cockle, Washington clam, 2 species of soft-shell clams, and the baymussel.

Eissinger (1970), conducting a study for the Department to determine the density and distribution of the gaper, littleneck and Washington clams, reports as many as 312 gaper siphons in a 100 square foot area of mudflat. Based on Eissinger's (1969) final report, W. A. Dahlstrom, a Department marine biologist, estimates nearly 90,000 gaper clams alone are located in the vicinity of the mouth of the slough.

Historically, shellfish were found at the mouth of the slough, along the mudflats of the old Salinas River channel and its outlet to the sea. California Indian kitchenmiddens at the pre-1908 mouth of the Salinas River contained many shellfish remains. Prior to the opening of the harbor entrance in 1946, only small tidal flats existed east of the mouth of the slough. These flats are inhabited by the rich diversity of tidal flat fauna that exist today.

The native oyster was once plentiful in the Elkhorn, but in 1926 several oystermen worked the beds and greatly depleted them (Gordon, 1971). Since that time there has been a long history of experimental plantings of native and nonnative oysters. The eastern, Mexican, European flat, Portuguese, and giant Pacific oysters have been tried. Only scattered remnants of the giant Pacific oyster beds still exist in the slough, approximately where it turns north. Other mollusks, such as the soft-shelled clams, the Japanese littleneck and Japanese mussel are found in the Elkhorn today, probably introduced during the exotic oyster transplants (Gordon, 1971).

MacGinitie (1935) claimed that pollution was not a menace at the time of his study because "the population was sparce and there was little sewage." In relatively recent times, however, deterioration of water quality due to contamination and pollution has made shellfish a potential public health hazard although good populations of shellfish still exist.

## RESOURCE USES

### Hunting

Within a 20 mile radius of Elkhorn Slough there are an estimated 1,200 waterfowl hunters; however, only about 960 use the slough. Twelve duck clubs are adjacent and adjoining the Elkhorn, utilizing an estimated 70 acres of marsh habitat. Limited membership in the gun clubs (about 90 persons) is one reason so few hunt the slough. Approximately another 70 persons use the public waters for hunting. Initial high costs (boat, etc.) and a low return in quantity and quality of birds, compared to the availability of less expensive and better quality hunting on private as well as public waterfowl management areas in the San Joaquin Valley, probably curtails public use of the slough.

### Fishing

Department surveys show over 26,000 angling days annually in Elkhorn Slough, in Moss Landing Harbor and off of the piers and jetties on the ocean side of the harbor:

| | |
|---|---|
| Shore | 2,000 man-days |
| Skiff | 2,400 man-days |
| Pier | 4,000 man-days |
| Jetties | 18,000 man-days |

Water courses are deep enough for small outboard boats even at the lowest tides and there is a Wildlife Conservation Board launching ramp at Kirby Park in the upper end of the slough. Launching facilities and boat rentals are available at the harbor. Access is good to the shoreline around the harbor and mouth of the slough, but there is practically

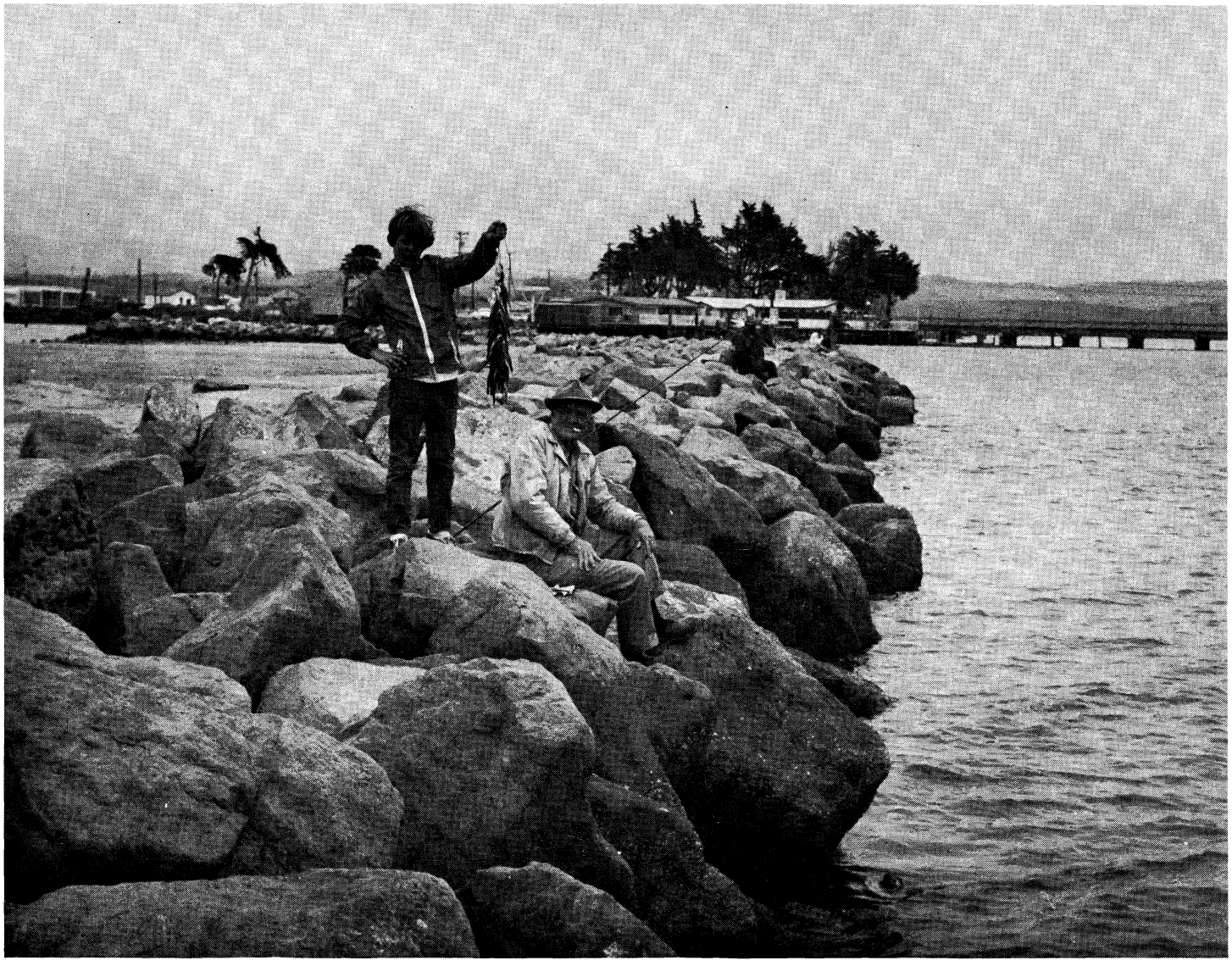
no access to the upper slough except at Kirby Park. Boats may be launched there but people commonly fish from the banks.

Fish species in the local sport catch are: rubberlip sea perch, pile perch, black perch, jacksmelt, sand sole, staghorn sculpin, starry flounder, walleye perch and cabezon. Striped bass and California halibut are highly prized locally and much fishing effort is expended to lure them to the hook; however, they are not common in the catch.

The annual shark derbies, sponsored by local rod and gun clubs are of special interest. These derbies usually are held in June, and occasionally in May or July. Entrants are charged a nominal fee and prizes are based on their catch between 7 a.m. and 1 p.m. on derby day. Prizes of fishing and hunting equipment are given and the proceeds have been used to support youth programs run by the sponsoring clubs.

Derby records kept in the 1950's show that the fish commonly caught are bat rays, shovelnose guitarfish, leopard sharks, round stingrays, gray and brown smoothhounds and thornbacks (Herald, et al., 1960). The few bony fishes caught at the same time were the common jacksmelt, the omnipresent staghorn sculpin and an occasional striped bass. Rarely taken species include the California halibut, starry flounder, sarcastic fringehead and spotted snake eel (Herald, et al., 1960).

From the old whaling days, through the sardine hey-day, to the present limited operations, the offshore commercial fisheries of Moss Landing Harbor are well documented. The last cannery is now for sale. Except for a little squid and anchovy most of the fish brought in by the more than 200 commercial fishing boats sailing from the harbor are



Sculpin fishing off of the North Jetty is popular at Moss Landing Harbor
Department of Fish and Game photo by John Speth
July 1971

trucked to processing plants out of the area. However, annual commercial landings at Moss Landing are impressive. In 1968, for instance, slightly over 15 million pounds of fish and squid, valued at $750,000, were landed. Salmon, albacore, anchovys, rockfish, jack mackerel, Pacific herring, Petrale sole, English sole, sanddabs, sablefish, rex sole and squid are the principal species comprising the local commercial catch (Heimann and Carlisle, 1970) (Table 1).

About 150 noncommercial boats also use the harbor. Half of the boats are moored at the Harbor District's facilities in the south harbor. The rest are moored in the north end of the harbor at the yacht club facilities. Activities of these pleasure craft are divided between fishing and running-about, and some of the boats, according to the harbor master, Elmer L. Horton, "just plain sit there."

## Shellfishing

Historically, shellfish have been one of the richest resources of the slough. Shellfish are taken both commercially and in pursuit of recreation.

At virtually every clam tide, numerous diggers can be seen working the exposed mudflats around the mouth of the slough and harbor, despite the fact that the Elkhorn has been posted since 1969 with signs warning of contaminated shellfish.

The most abundant and highly-prized clams are the gapers, or horse-neck clams. Others taken are Washington clams, littleneck and soft-shelled clams, native oysters and piddocks. Up to 40 or 50 clam diggers have been seen during favorable low tides. Pismo clams are obtained on

Table 1

MARINE FISH CATCH FOR 1968
(Heimann and Carlisle, 1970)

Moss Landing

| | Value | Pounds |
|---|---|---|
| Salmon | $224,425 | 338,210 |
| Albacore | 210,929 | 1,124,822 |
| Anchovy | 82,187 | 8,336,379 |
| Squid | 69,147 | 2,529,250 |
| Rockfish | 39,647 | 613,840 |
| Jack mackerel | 35,239 | 831,500 |
| Pacific herring | 28,442 | 301,094 |
| Petrale sole | 16,412 | 111,496 |
| English sole | 15,531 | 187,140 |
| Sanddab | 8,695 | 119,641 |
| Sablefish | 7,172 | 130,203 |
| Rex sole | 5,892 | 79,175 |
| All other species | 25,439 | 298,295 |
| Port totals | $769,157 | 15,001,045 |

Clam digging on the mudflats between the mouth of the slough and the yacht club often is rewarding

Department of Fish and Game photo by Frank Hubbard
October 1970

the ocean side of the harbor and it is not unusual for a dedicated shellfisherman to get a limit of Pismos from the beach, then cross the dunes to dig in the banks of the slough for gapers or Washingtons. Department observers, during a good low tide, have counted 500 Pismo clammers between the mouth of the Salinas River and Moss Landing. The Department estimates up to 2,500 man-days annually are expended clamming in the vicinity.

Elkhorn Slough apparently has tremendous potential for shellfish production. Commercial shellfishing dates back to the early 1920's. The two best years were 1931 and 1932, when 45 percent and 31 percent, respectively, of the state's total shellfish harvest came from the Elkhorn-Moss Landing Area (Bureau of Sanitary Engineering, 1967). An early Department survey of coastal waters for suitable oyster culture areas classified the Elkhorn as one of three (Drakes Estero in Marin County and Humboldt Bay were the other two) believed to have "good" potential (Bonnot, 1935).

After the early demise of the native oyster, several attempts were made to introduce other species of oysters with commercial potential. An unsuccessful venture was made with Mexican oysters in 1929 (Bonnot, 1935) and Japanese oysters, now called giant Pacific, were tried in the 1930's on the tidal flats and narrow parts of the slough (Barrett, 1963).

In 1931, the Japanese method of hanging culture (imported seed set on tarred ropes, hung from floats in deeper water) was used very successfully. The oysters reached marketable size in only one year in Elkhorn's relatively warm waters. Racial problems hampered marketing and the venture failed again. Another company took over the operation in 1936 and made still another seed plant, the last until after World War II (Barrett, 1963).

A few oyster allotments were granted by the Department after the war, but each was declared "abondoned" after a few years. Remnants of these exotic plantings are still found in the slough, but are not used commercially. Water quality has continued to deteriorate during the last 20 years and in 1966 public health closures were put in effect and the area posted.

Increasing demands for the use of this highly valued and potential resource, together with an accompanying awareness of the contamination problem and the possibilities for improved water quality, have created a new interest in local shellfish production or mariculture. Several new, experimental plantings have been approved by the Department recently. These experiments are designed to test the feasibility of a new shellfish industry. Research directed at the nurture and growth of juvenile specimens of scallops, abalone and clams, as well as several species of oysters, have produced dramatic results; spawning experiments also have met with some success. One newly formed corporation is negotiating to lease or purchase property at the mouth of the Elkhorn Slough in order to construct deep ponds needed to create a controlled environment for raising several species of shellfish. This research and land acquisition amounts to a considerable investment in the future. It appears that water quality is the only obstacle to realizing the full potential for production and use of the shellfish resources of Elkhorn Slough.

## Nature Study, Birdwatching and Photography

The general public is becoming aware of the ecological importance of our coastal wetlands. As this appreciation increases, more and more people are taking advantage of the few and relatively undisturbed tidal areas, such as Elkhorn Slough, to watch and study estuarine wildlife. This awareness and appreciation is nowhere more apparent than in the central California coast regions and especially in Monterey County.

Several conservation and sportsmen clubs in and about the County use the slough for recreation. The Monterey, Santa Clara and Golden Gate Audubon societies, as well as Santa Cruz Bird Club, have a keen interest in Elkhorn Slough. Some enthusiastic birdwatchers come from as far away as the San Francisco Bay area. The Izaak Walton Club, Ventana Chapter of the Sierra Club, Monterey County Sportsman Club, Federation of Western Outdoor Clubs, and the Scientific Institute for Public Information, all use the slough for outings or have an active interest in its preservation (Alan Baldridge, pers. comm.).

In 1967, the Department estimated that 1,600 man-days were expended in nonappropriative, or nonconsumptive use, i. e. birdwatching, photography, etc., about six times that expended in consumptive use, i.e. hunting, collecting, etc. But what is more significant, it is estimated that this type of nonappropriative use could be increased to 70,000 man-days without disturbing the slough's ecology. The Department of Parks and Recreation estimates a day-use potential of over one-quarter of a million annually for the proposed Jetty Beach facility. These impressive estimates bring sharply into focus the recreational potential of the Elkhorn environs.

The marsh area north of Jetty Beach Road will make a good nature study area for the proposed Jetty Beach State Park

Department of Fish and Game photo by John Speth
July 1971

This potential also has economic possibilities, since the peak of the birdwatching season occurs in the winter months when tourism is normally at its lowest ebb. Local communities may reap the economic benefits during the so-called "off-season."

Access is the principal drawback to the development of the full, nonconsumptive use potential of Elkhorn Slough. Access is restricted to the harbor, the mouth of the slough, and to the Kirby Park boat launching area; and no picnic, camping, or sanitary facilities are available at the latter area. Acquisition and development of the Jetty Beach property by the Department of Parks and Recreation will provide additional facilities as well as access to the mudflats and marshland around the north arm of the harbor and to the beach on the ocean side (Plate 6). However, other access or observation points should be developed to ensure fulfillment of nonconsumptive use potential.

### Scientific and Educational

The educational and scientific use of the Elkhorn Slough is probably the most important use of its resources. Elkhorn Slough truly is a "living laboratory", a "biological treasure" uniquely suited and situated for scientific research and study.

Virtually every remaining coastal wetland is unique for some combination of its wildlife resources and natural attractions and Elkhorn Slough is no exception. One key to its uniqueness is the noted Monterey Canyon which heads at the slough's mouth. A submarine canyon, it bisects the bottom of the Monterey Bay as a deep east-west cleft and reaches depths in excess of one mile just offshore. Nutrients upwelling from the depths of

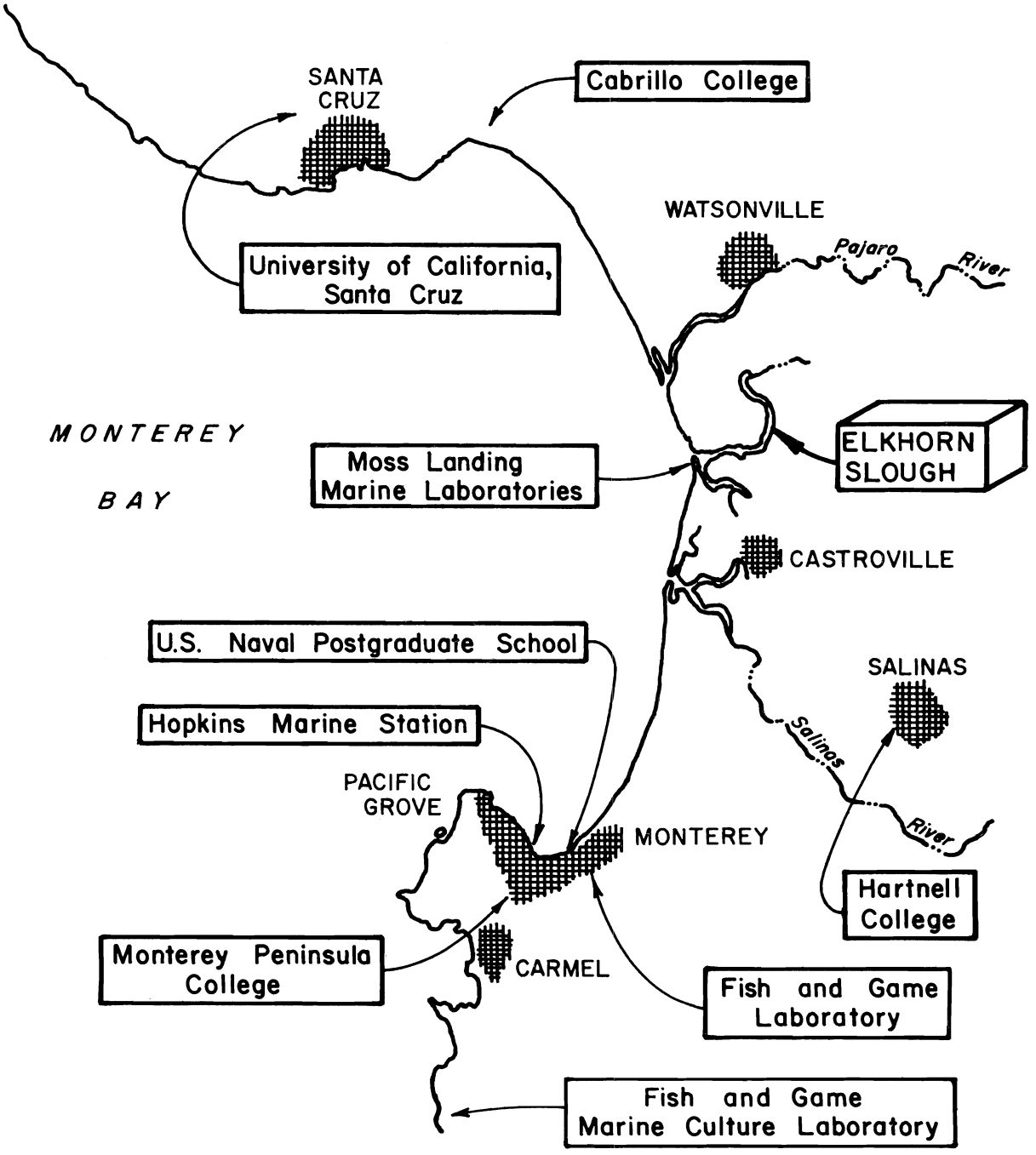
the canyon are in a constant interchange with waters and organisms of the slough, due to drainage and tidal action. Thus the slough and harbor, while constituting a limited ecosystem comprised of certain biological communities, are part of a still greater ecosystem -- that of the Monterey Bay, Monterey Canyon, adjacent shore and open sea. The remarkable diverse characteristics of this total ecosystem make it particularly valuable for study and research.

Because of these unique and accessible natural assets, the staff and students of many schools, colleges, and universities utilize the slough and the harbor and their surroundings for general and advanced studies in natural history, general biology, ecology and the marine sciences.

Seven college level institutions are located on Monterey Bay (Plate 8), all making considerable use of the area. Doctor John Harville, past director of the Moss Landing Marine Laboratories, in a prepared statement to the U. S. Army Corps of Engineers in relation to Moss Landing Harbor development (Harville, 1968), stated that four of these institutes have major research committments for the education of marine scientists and engineers.

Three junior colleges, Cabrillo in Santa Cruz County, Hartnell in the City of Salinas, and Monterey Peninsula College in the City of Monterey are in the process of creating a marine technician training program. Dr. Winona Trason, division chairman of the Monterey Peninsula College Life Science

PLATE 8




LOCATION OF ELKHORN SLOUGH IN RELATION TO NEARBY EDUCATIONAL INSTITUTIONS AND RESEARCH FACILITIES

Division, states that students from her division take several field trips each year to study estuarine life--both birds and invertebrates--and that, as a biological study area, Elkhorn Slough is "invaluable" to the college.

Four senior colleges and universities, representing four entirely different segments of the higher education resources of the state and nation, are among those located on the Bay. The United States Navy maintains the Naval Postgraduate School at Monterey, the only institution of its kind. For over 25 years, Dr. E. C. Haderlie, professor of oceanography, has been taking students on field trips to the Elkhorn area, and for 5 years has directed the programs of graduate students in marine ecology.

The University of California has established a campus at Santa Cruz. Staff members and students of this relatively new institution use the unique resources of the Moss Landing-Elkhorn area for ecological studies in support of Ph.D. programs.

The Hopkins Marine Station of Stanford University is the oldest biological laboratory on the Pacific Coast, founded at Pacific Grove in 1891. In a recent statement on scientific study as a beneficial use for coastal waters to the Central California Regional Water Quality Control Board, Dr. John Phillips, Director of the Hopkins Station, listed 56 higher degrees, most of them at the doctoral level, which had been awarded since 1950 by Stanford University for studies conducted at least in part at the Hopkins Marine Station. Many of these studies were done entirely or in part in the Moss Landing-Elkhorn Slough area (Harville, 1968).

Finally, the Moss Landing Marine Laboratories (M.L.M.L.), representing the State College system of California in the area has a 14,000 square

foot marine sciences research facility at Moss Landing. The facility was established in 1965 by five central California State Colleges (at Fresno, Hayward, Sacramento, San Francisco, and San Jose). These laboratories operate year-round and maintain an interdisciplinary staff of 6 to 10 scientists. Course work and research programs are provided for about 60 upper division and graduate students during the regular school year and three times that number through the summer months--a total of more than 300 individuals from the 1967-68 school year, for instance (Harville, 1968). Field studies by these advanced students are made in Moss Landing Harbor, Elkhorn Slough and adjacent waters of Monterey Bay.

Many of these studies are funded in part by local government and private industry, demonstrating that educational processes have significant practical values, as well as basic educational values. Several recent congressional enactments such as the 1966 Marine Resources and Development Act and the 1966 National Sea Grant College and Program Act have given impetus to and created funds for such research being done at the laboratories. Most of the seven institutions of higher education in the Monterey Bay area have indicated intent to participate in this national effort under the provisions of the Sea Grant College Act (Harville, 1968).

Elkhorn Slough also attracts other school groups each year. The M.L.M.L. provides laboratory space for many field trip studies conducted by professors from inland colleges. High school and elementary school students by the hundreds flock to the seashore with their teachers on organized field trips. Elkhorn Slough and Moss Landing Harbor are favored destinations for such excursions. Dr. Harville estimates 5,000 to 6,100 man-days are used in educational scientific pursuits in the Elkhorn-Moss Landing Area involving over 2,700 students.

| | Man-days/year | Number of students |
|---|---|---|
| Moss Landing Marine Laboratories | 2,500 - 3,000 | 400 |
| Other Senior Colleges (Monterey Bay) | 100 | 20 |
| Junior Colleges | 500 | 300 |
| Other colleges (out of area) | 1,000 | 500 |
| High schools | 1,000 | 1,000 |
| Elementary schools | 500 | 500 |
| TOTALS | 5,600 - 6,100 | 2,720 |

To paraphrase a popular advertising cliche, "Is there any other reason for preserving the Elkhorn Slough and its environs?"

## PROBLEMS AND USE CONFLICTS

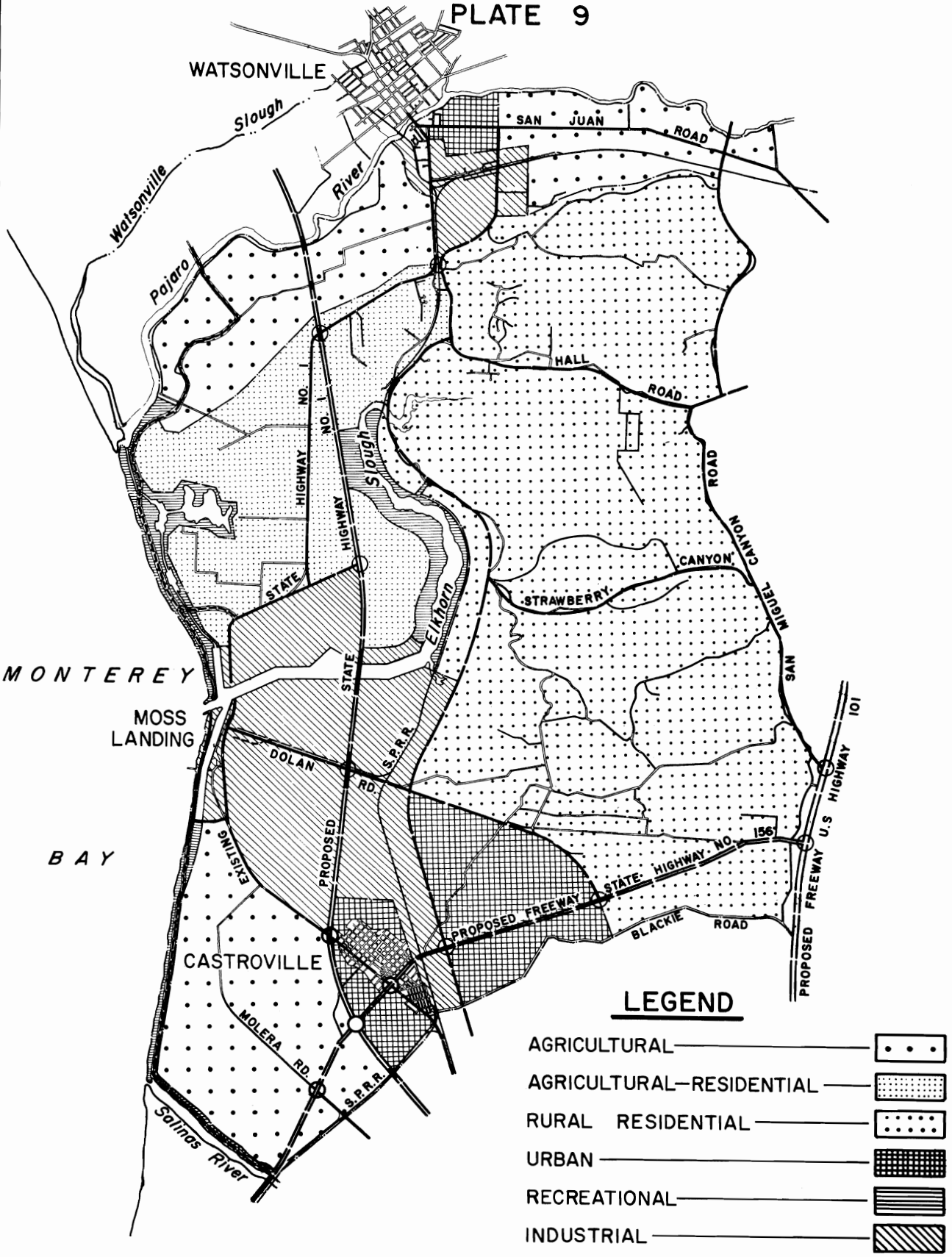
### Harbor Expansion and Development

Elkhorn Slough has tremendous potential as a deep water harbor and for industrial development. It is located at the head of a deep submarine canyon, railhead and transportation hook-ups are feasible, and there is virtually unlimited local power.

The Moss Landing Harbor District is responsible for developments needed to promote commerce and navigation and for maintaining the harbor and docking facilities. Having fulfilled the conditions of the original State grant to the Elkhorn waters, the Harbor District became legal trustee to the granted lands. Consequently, the District requested the Monterey County Planning Commission to draw up a plan for the development of the area. The Planning Commission studied the possibilities and recommended the "Moss Landing Area Development Plan" (Plate 9), which was adopted as part of the Monterey County Master Plan by the Board of Supervisors in September, 1956. A simplified version of the Planning Commission findings is as follows:

1. That the development of a deep-water harbor at Moss Landing is highly desirable.
2. That Moss Landing be developed to provide the industrial hub of Monterey County.
3. That Pajaro be developed as an industrial community.
4. That the study area provides sufficient land of a type to accommodate industrial development.
5. That the development of the study area as proposed integrates and harmonizes with the surrounding area and all of Monterey County.

PLATE 9




# MOSS LANDING AREA DEVELOPMENT PLAN

MONTEREY COUNTY PLANNING COMMISSION, 1956

6. That sufficient urban and residential acreage be set aside to serve the proposed industrial development.

7. That sufficient harbor facilities for commercial fishing and commercial recreational facilities be provided for.

8. That as much of the Pajaro and Salinas Valleys as is practical be protected and perpetuated agriculturally.

9. That natural recreational areas should be set aside for future public use.

10. That Highways No. 1 and No. 156 be developed as freeways.

11. That Highway No. 1 should be relocated, but to best serve through traffic needs as well as local development, should remain on the west side of Elkhorn Slough.

12. That the existing Highway No. 1 bridge across the Elkhorn Slough be removed immediately upon completion of the high level bridge.

13. That a network of major and secondary county roads should be established.

14. That appropriate steps should be taken to prevent air pollution.

Although the area development plan recommends the development of only a third of the slough into a harbor, it also calls for industrialization of virtually all lands on either side of the western half of the slough. The upper half would be zoned for recreation, but would be surrounded by agricultural and rural-residential zones. Development undoubtedly would stimulate further encroachment into the upper slough, if not the eventual destruction of the recreational values of the whole ecosystem.

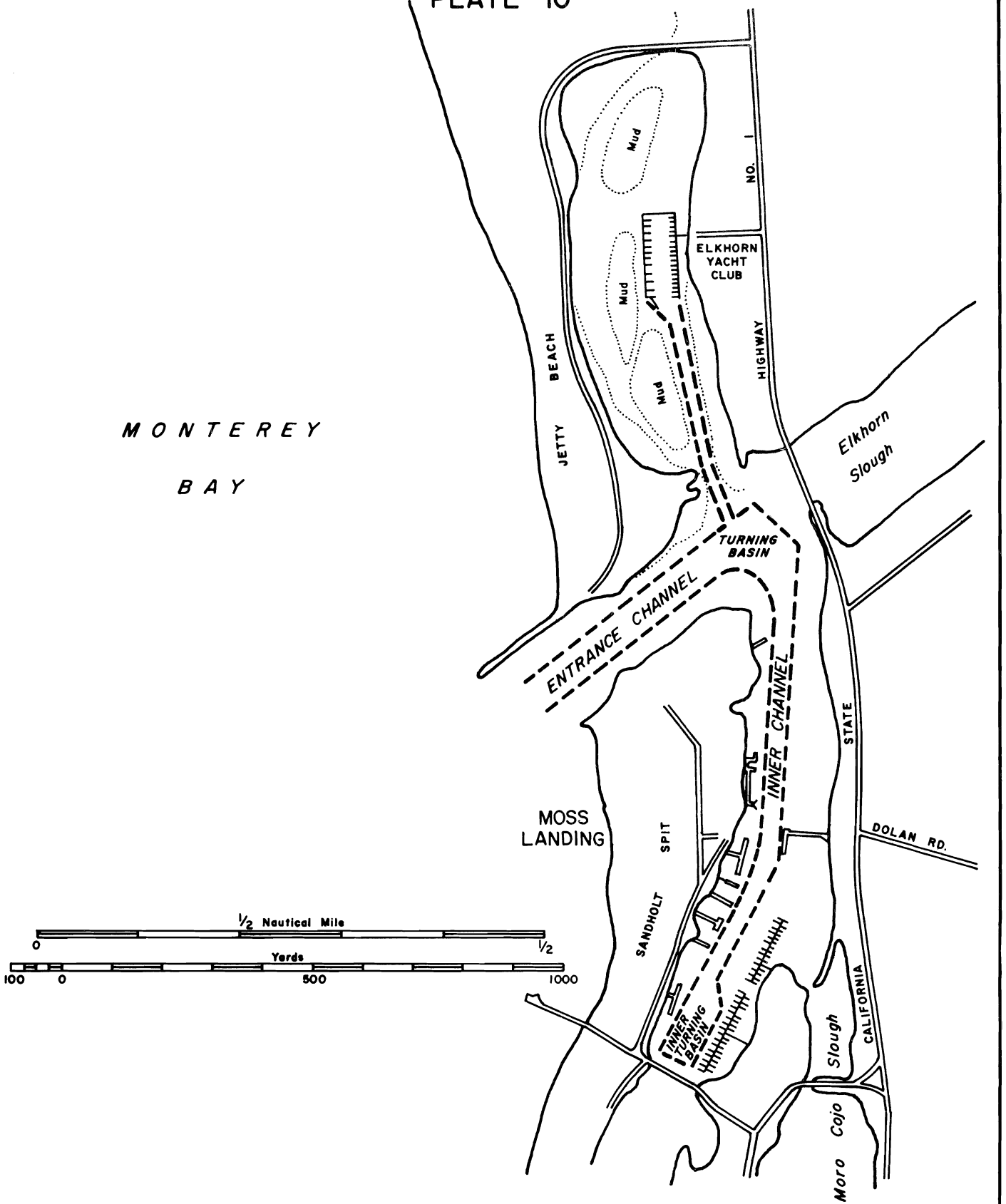
Because of new priorities, water and sewage problems and local public resistance to industrial development, however, the 1956 plan is now considered out-of-date and subject to revision and new feasibility studies (Monterey County Planning Commission, pers. comm.). Federal funds are being requested to fund new studies. Housing and Urban Development (HUD) 701 funds were denied recently and the County and Harbor District have

turned to the Economic Development Agency (EDA) for funding. The County Planning Commission, on the other hand, has shifted its priorities and energies to the Association of Monterey Bay Area Governments (AMBAG) master plan for the development and use of the entire Bay area, but feels, however, that this plan will cover surrounding land and water resources including those of the Elkhorn. In accordance with 1970 legislation, Chapters 717 and 1590, Monterey County is required to prepare an open space-conservation plan for submission to the Legislature by July 1972.

The U. S. Army Corps of Engineers also has an interest in plans for the development of the Elkhorn-Moss Landing area. The responsibility of the Corps lies with small craft harbor development and maintenance. The Moss Landing Harbor, as it exists today (Plate 10) was created by the Corps with improvements authorized by the 1945 River and Harbor Act, at an initial cost of $338,215. Maintenance and additional improvements through 1968 have cost the Corps an additional $1,344,366 (U.S. Army Corps of Engineers, 1969).

Directed by the House of Representatives Committee on Public Works to review survey reports on Monterey Bay (including Moss Landing), the Corps held a public hearing in June, 1968, at Salinas to determine if any modification of the project is advisable. All concerned parties including representatives of federal, state, county, and municipal agencies, as well as commercial, industrial, civic, highway, railroad, other transportation interests and property owners were afforded full opportunity to express their views of the character and extent of improvements desired. At that hearing the Department urged that all Corps studies give "full and equal consideration to all values of the area as a place to enjoy and study fish and wildlife resources."

PLATE 10




# MOSS LANDING HARBOR

The Corps is ready to offer assistance with additional harbor development should the local planning agencies decide there is a need. In the meantime the Corps is preparing a feasibility report on small-scale expansion of small craft facilities in both arms of the harbor. Proposed development in the south arm would include the removal of the existing county bridge between Moss Landing and the Sandholdt Spit and expansion into the mudflats that lie south of the bridge (Robert Edmisten, U. S. Army Corps of Engineers, pers. comm.).

Based on current levels of commercial and sports fish activities and landings, the Department believes that there is no present need for expansion of small craft facilities at Moss Landing. Any extension of the harbor into the mudflats of the old Salinas River channel south of the county road crossing or north of the yacht club marina would adversely affect the many shorebirds, pelagic and inshore birds and waterfowl that use this vitally important habitat.

## Harbor Maintenance

Since the initial dredging in 1946, shoaling (filling in with sand and sediment) has occurred in the entrance and harbor channels, as well as in the north and south harbors. Periodic condition surveys showed that the entrance channel shoaled to a depth of between 10 and 12 feet below the low water tide level before maintenance by the U. S. Corps of Engineers began. The Corps has undertaken several remedial dredging operations; 124,381 cubic yards in 1947; 170,802 in 1948; 146,064 in 1953; 113,000 in 1957; 155,156 in 1961; 85,160 in 1964; and 48,469 in 1968 (Wong, 1970).

The old Salinas River channel between Sandholt Road and Potrero Road provides vital tidal habitat for shorebirds and waterfowl

Department of Fish and Game photo by John Speth
July 1971

Disposing of the dredging spoils from the maintenance operations has been a problem. Where does one get rid of the spoils? Because of the complex and interdependent nature of the slough and harbor ecosystem, indiscriminate dumping is out of the question. The 1958 Fish and Wildlife Coordination Act (PL 85-624, Section 2) and the 1969 National Environmental Policy Act (PL 91-190), essentially require that every project having an impact on the environment must be reviewed by the state and federal agencies responsible for the natural resources. Under the impetus of the 1958 Act, the Corps, in recent years, has selected and used spoil sites having minimal effects on the resources. The growth of cooperation and agreement between the agencies involved has been very satisfying to all concerned. The Corps, Harbor District, Moss Landing Marine Labs and Department of Fish and Game all contributed to this splendid cooperative effort on behalf of the area's natural resources.

## Reclamation of Wetlands

Parts of the natural salt marsh and mudflats bordering Elkhorn Slough are being reclaimed for agricultural use. About 350 acres, mostly along the southern and eastern edges of the slough, are in various stages of reclamation behind tide gates and dams.

Tidal action also is blocked from the old Salinas River channel by a tide gate under Potrero Road. Moro Cojo Slough is virtually dried up behind gates installed at its outlet at Moss Landing Road and State Highway 1 (Plate 7). This type of reclamation is decreasing the fish and wildlife production of the estuary. Further encroachments should be discouraged.

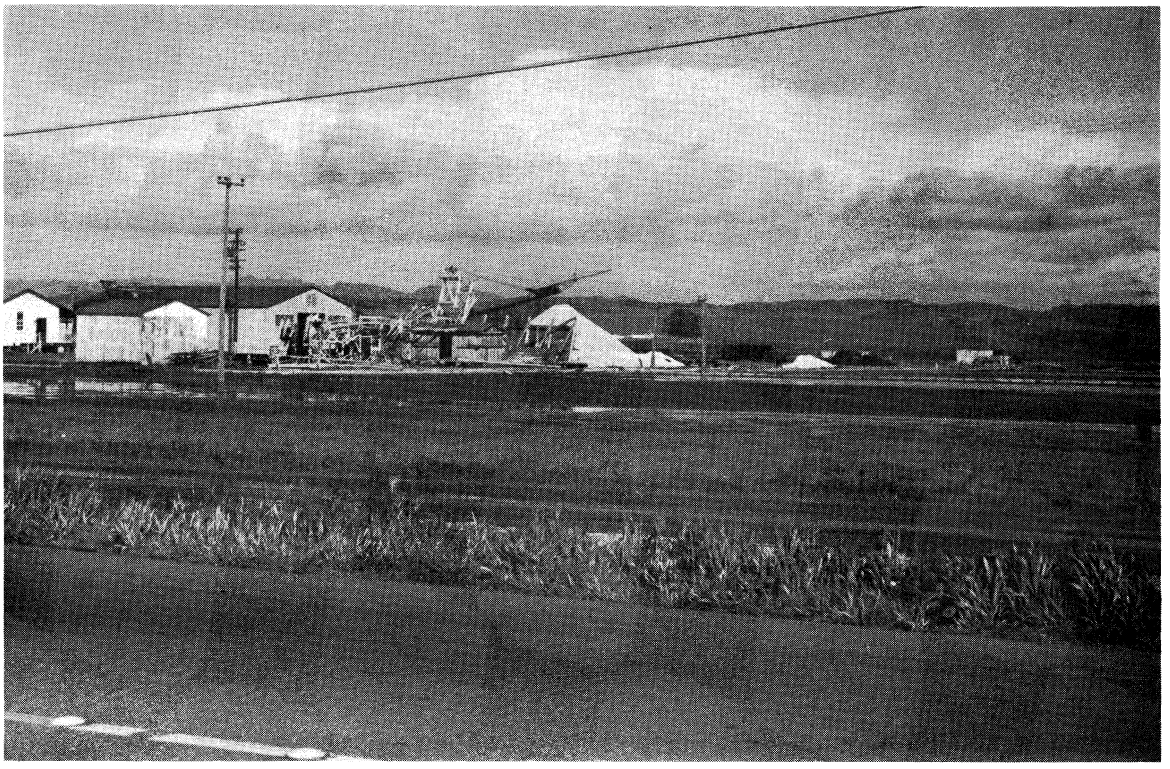
## Salt Ponds

The salt pond area, located on the north side of the slough where it joins the harbor, was reclaimed for salt production over 50 years ago. Approximately 800 acres of crystalizing and concentration (evaporating) ponds and salt marsh are owned by the Monterey County Salt Works. A discussion of use conflicts in the Elkhorn area should include these ponds which are extremely important loafing (resting) and feeding areas for several species of migrating birds, including the California brown pelican, Forsters' tern, Caspian tern, avocet, black-necked stilt and the phalaropes.

The Monterey County Salt Works were established in 1916 and at one time supplied salt to the Moss Landing canneries (Hart, 1966). Since 1960 only 300 acres have been in production. Because of their location the lands belonging to the salt works would be key property in any future development of Moss Landing Harbor.

Careful dredging accompanying the expansion and development of the harbor may not have a serious, direct effect on this vital habitat. However, shallow water areas like the ponds and the surrounding low-lying marsh would make ideal dredging spoil sites or reclamation sites, suitable for urban and industrial development. Any use of the ponds for such purposes would eliminate an extremely valuable habitat.

Another potential use of the salt pond areas is mariculture, or shellfish production. Such use would cause less conflict and may be beneficial to some fish and wildlife species. Whoever makes land use plans and decisions should give mariculture close consideration. However, should the salt ponds be dredged out for <u>any</u> purpose, the Department recommends careful selection of spoil sites.



Top Photo: The salt ponds at Elkhorn Slough provide good loafing and feeding areas for coastal migratory birds.
Agricultural Stabilization & Conservation Service photo – June 1968

Bottom Photo: Monterey County Salt Works
D.F.G. photo by Frank Hubbard – March 1970

## Water Quality

The direct quantitative loss of habitat due to development or land use change is, of course, an obvious threat to the natural resources of any area. Qualitative loss of estuarine habitat due to degradation of its waters is a more insidious kind of threat, but equally serious. Intensified use of the estuary and surrounding watershed have led to a gradual deterioration of the water quality in Elkhorn slough.

### History

MacGinitie, (1935) reported virtually no pollution during the 9 years prior to 1935 that he studied the ecology of the slough--"population was sparse and produced little sewage." Reports of "marginal" water quality began to show up (Table 2) after 1954, when the Bureau of Sanitary Engineering (B.S.E.) of the Department of Public Health initiated a series of investigations at the request of local shellfish growers. By 1965 tests showed that water samples no longer met standards set by the Public Health Service for approved shellfish growing areas. Only two out of 14 shellfish meat samples met bacteriological criteria for shucked oysters at the wholesale market level. Neither did the waters consistently meet the State Department of Public Health water contact sports standards (B.S.E., 1967). Because of excessive bacterial concentrations found during 1966 the one remaining commercial oyster bed was closed early in 1967 by the Public Health Department.

Since 1966 the Monterey County Department of Public Health, in cooperation with the Moss Landing Harbor District staff, has routinely sampled the Elkhorn waters twice a month. Finally, in 1969 the slough and harbor was posted with signs warning of contaminated shellfish. The law requiring

Table 2

Bacteriological sampling of Elkhorn Slough Waters [1]/

(Bureau of Sanitary Engineering, 1967)

| Year | Total No. of samples | Results |
|---|---|---|
| 1954 | 15 | Met standards |
| 1960 | 10 | Marginal |
| 1962 | 51 | Failed to meet standards |
| 1963 | 9 | Met standards |
| 1964 | 6 | Met standards |
| 1965 | 45 | Failed to meet standards |
| 1966 | 192 | Failed to meet standards |
| 1967 | 357 | Failed to meet standards |

1/ Interpreted by comparison with Public Health Service Shellfish criteria for approved growing areas.

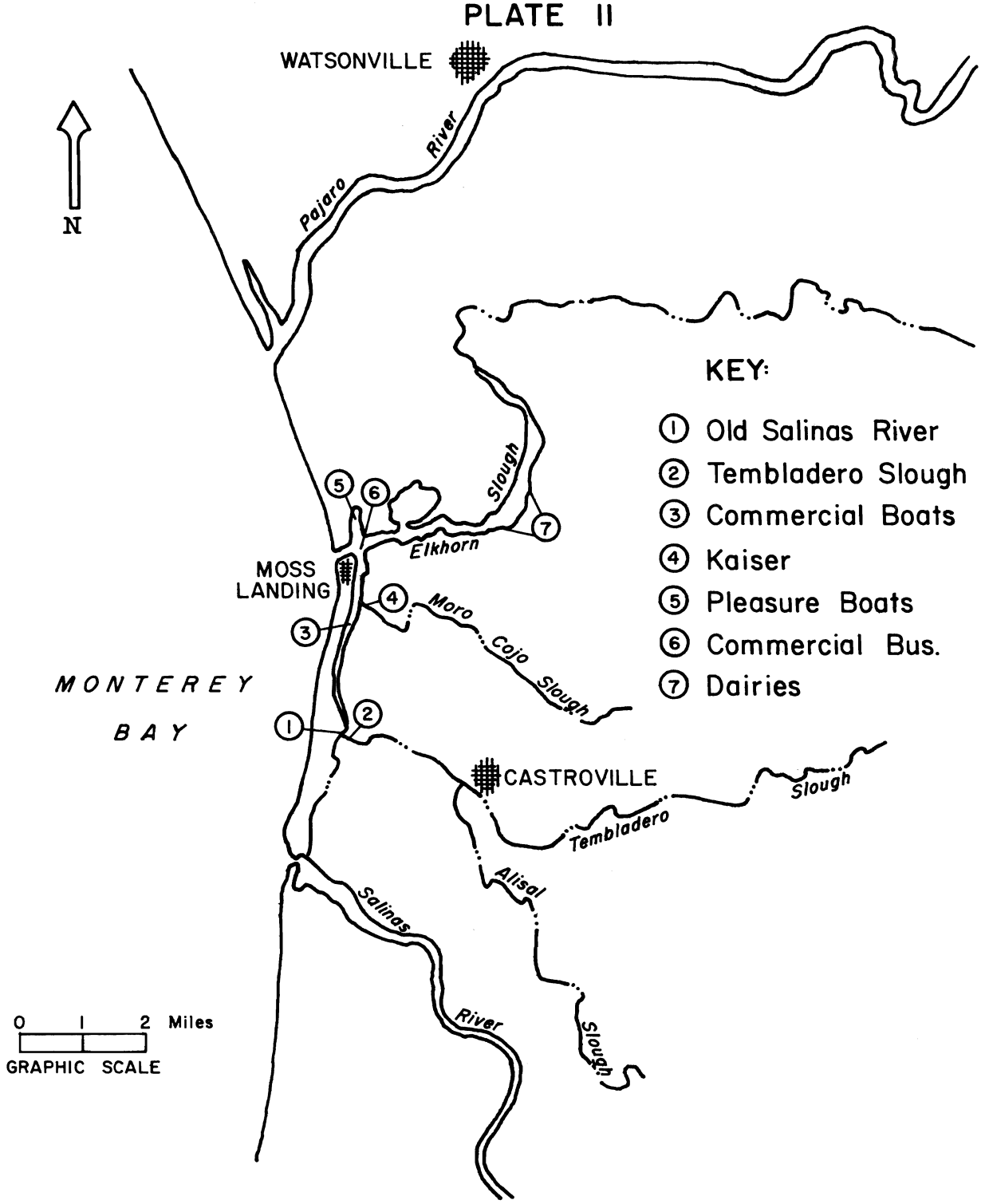
posting is in the California Administrative Code which states that counts of coliform organisms (bacteria characteristically associated with fecal matter) shall not exceed 230 MPN (most probable number) coliform per 100 grams of meat and the waters shall not have counts exceeding 70 MPN per 100 milliliters of water. The Monterey County Department of Public Health 1970 counts revealed that gaper clams contain as high as 2,200 MPN and that the water samples still run over 24,000 MPN/100 ml. For the past two years the area has been posted as potentially hazardous to public health and presently is still posted.

Sources of Pollution

While the word pollution is commonly used to describe impairment of water quality, it should be pointed out that the problem in Elkhorn Slough, and especially in Moss Landing Harbor, is one of contamination, as well as pollution. The State Water Code (13005) defines contamination as an impairment in water quality "to the degree which creates an actual hazard to public health through poisoning or through the spread of disease." Pollution is defined as impairment which does not create an actual hazard to public health, but which does "adversely and unreasonably" affect beneficial uses of State waters. If present levels of contamination are deemed an unreasonable interference with the water contact and harvesting of shellfish uses, then a state of pollution exists.

The two major sources of contamination of the Elkhorn environs are the watershed drainage and runoff and direct discharge of sewage into the harbor. Principal watershed sources apparently are the old Salinas River channel and the Tembladero Slough, both of which receive agricultural (irrigation) runoff and sewage treatment plant effluent; and the dairies that are located on the south and east side of the slough (Water Resources Engineers, Inc., 1969) (Plate 11).

PLATE II




# SOURCES OF COLIFORM ORGANISMS TO WATERS

## Moss Landing—Castroville Vicinity

WATER RESOURCES ENGINEERS, INC. 1969

Direct discharges of untreated sewage enter the lower slough and the harbor from industrial, commercial and residential sources as well as from the commercial and pleasure boats moored in the harbor.

Within each of the three major arms of the harbor-slough complex, highest concentrations of the indicative coliform organisms were found in the southern portion of the harbor (B.S.E., 1967). The slough has the next highest concentration, the degree of contamination at any one time depending on the stage of the tide. There is evidence, for instance, that during flood tide conditions, contaminants are actually carried into the slough from the harbor (Merry, 1966).

Old Salinas River Channel

In 1967 the Bureau of Sanitary Engineering indicated that the total coliform density of the old channel was 24,000 MPN per 100 milliliters of water sample. The Bureau reported that causes for these rather high counts could not be accurately pinpointed, but speculated that they probably came from (1) regrowth of coliforms, (2) irrigation runoff (artichokes, strawberries, etc.), (3) the sea gull colony living at the mouth of the river, and/or (4) another local source. The relatively low ratio of fecal coliform to other coliform organisms indicates that high counts probably are due to agricultural drainage rather than sewage (Merry, 1966).

Tembladero Slough

The Castroville sewage treatment plant is Moss Landing Harbor's major source of contaminants which are discharged through this slough. Tembladero Slough also drains a considerable amount of irrigated land. The Sanitary Engineering Bureau reports a high density of coliform organisms (24,000 MPN/100 ml.) at its confluence with the old Salinas River channel. Surface nutrient (phosphate, nitrate, nitrite, silicate and ammonia) levels in

the channel consistently have been observed to be 20 to 50 times greater than in any other area of the slough or harbor (Richard E. Smith, pers. comm.).

Dairies

There are three dairies located on the Elkhorn watershed. They all are rated Grade A Market Milk Dairies and have been operating for many years. Together they run over 1,000 head of dairy cows and about half are milked daily.

In general, liquid and solid wastes originate in the dairy barns, from washing, rinsing, and sanitary operations. The wastes are then transmitted untreated by a system of ditches to Elkhorn Slough. At the point of discharge into the slough, these wastes have varied from an MPN of 2,000 to 2,000,000 per 100 ml. in coliform bacteria content (B.S.E., 1967). Two septic tanks from each of two of the dairies also contribute to the contamination of Elkhorn Slough.

P. G. and E.

By far the largest discharger in the area is the Pacific, Gas and Electric Company power plant that expels waste waters from electric generator cooling condensers. The P. G. & E. outfall discharges just above the mouth of Elkhorn Slough and directly into ocean through two 12 foot pipes, 600 feet offshore.

According to a Department evaluation (Pelgen, 1951) and other reports (B.S.E., 1967; Water Resources Engineers, Inc., 1969) the discharge is of little public health significance. The waste waters are essentially unchanged sea water, but for a rise in temperature (6.1°F average and 18°F at peak) and foam from a screen cleaning operation. However, P. G. & E. will soon have to comply with new standards concerning thermal discharges.

Recent California legislation calls for new environmental impact statements by 1973 and more rigid restrictions on thermal discharges both on new and existing facilities.

Kaiser Refractories

The Kaiser Aluminum and Chemical Corporation discharges processing and cooling waters, as well as their sanitary wastes, into the harbor via Moro Cojo Slough. These wastes are passed first through an Imhoff or septic tank. Although coliform counts have been measured at 160 MPN/100 ml. (Water Resources Engineers, Inc., 1969), this degree of contamination is considered insignificant since the wastes are diluted about 1,000 times with waste sea water from the processing operation (B.S.E., 1967).

During World War II, Kaiser Industries removed magnesium, needed for the war effort, from sea water. Today, magnesium oxide, used to make refractory bricks, is the resultant product. A process which mixes sea water with reduced dolomite yields calcium ions and magnesium hydroxide (Hart, 1966). The effluent is calcium-rich water and contains the remaining magnesium compound which escapes Kaiser's settling ponds. These chemicals, that mix with the sea water to cause grey-white deposits, which coat about 1,000 feet of slough shoreline, may have an adverse effect on bottom-dwelling organisms. Although a steady and continuing rate of discharge over the past years has yielded few apparent long-range effects on the environment, no definitive study has been made to date.

Boats

About 250 boats (mostly commercial) dock in the south part of the harbor and another 50 (mostly pleasure craft) moor at the Elkhorn Yacht Club in the north harbor. Although there is no permanent resident population aboard the vessels in the harbor, occasionally the boats are used

for temporary residence during maintenance operations. Water Resources Engineers, Inc., (1969), a private engineering firm estimates that there are enough people, boats and commercial activity to cause 2,000 gallons of waste per day with an extremely high coliform count (estimated at $5.42 \times 10^7$ MPN count per 100 ml.).

Other Commercial and Residential Sources

During the Bureau of Sanitary Engineering 1967 survey of the area, several private sewage systems with deficiencies were found contaminating the harbor. A cafe, restaurant bar and boathouse, all located just inside the north harbor, and the yacht club as well, were responsible for considerable discharge with very high coliform count. A few local residents and house trailers about the harbor and at Moss Landing also were found contributing to the generally contaminated state of the harbor waters.

Control

Contamination and pollution of the waters of Elkhorn Slough and Moss Landing Harbor are of direct concern to the Department of Fish and Game because of the limitation and restriction placed on the human use of the shellfish resources due to high coliform bacteria levels and because of the presence of materials harmful to other fish and wildlife resources. Pollutants commonly appearing in raw sewage, for instance, often include grease, sludge, oils, solvents, detergents, bleaches, corrosives, and a wide variety of other harmful materials. These can affect aquatic organisms several different ways, including abrasion and corrosion of body tissues, poisoning through ingestion, suffocation by coating the gill surfaces, depression of dissolved oxygen, and alteration of habitat by the deposition of slimes and sludges (Giguere, 1970). Consequently, the Department for many years has worked closely with the State and County

agencies responsible for control of public health and pollution problems of the Elkhorn and its environs. A brief chronology of measures taken to control the quality of the Elkhorn waters and policies adopted by the State and local agencies involved should be helpful.

In November, 1955, the Central Coastal Regional Water Quality Control Board adopted a policy statement for tidal waters in the Moss Landing area that declared its intention to protect the following beneficial uses of State waters against impairment from waste discharges: (1) sport fishing, (2) industrial supply, (3) clamming, (4) fish propagation, and (5) general beach recreation. At that time (1954) the Board also recognized that the upper waters of Elkhorn Slough were used for commercial oyster operations and the waters of the harbor for processing fish at local canneries (B.S.E., 1966).

Then, in compliance with the Federal Interstate Water Quality Plan of 1965, the Regional Board developed a new policy for the only interstate waters in its jurisdiction, the coastal waters of the Pacific Ocean from Point Piedras Blancas to Pescadero Point, including the tidal waters of the Elkhorn Slough. This policy, however, precluded standards high enough to protect shellfishing in the slough, since the Board at that time felt that the extent and use of the shellfish resource was insignificant. At a 1967 public hearing held by the State Water Quality Control Board to review this policy prior to its adoption, the Department offered strong support for "designation of shellfishing as a beneficial use to be protected in Elkhorn Slough" until which time "some future factor other than water quality precludes the propagation of shellfish in this area" (Department of Fish and Game, 1967). The State Board ultimately amended the new regional policy to include protection of harvesting shellfish for human consumption. That policy is still in effect.

In May, 1969, the State Board, at the request of the Regional Board, authorized Water Resources Engineers, Inc. (WRE), a private civil engineering firm, to make an evaluation of alternate water quality control plans for the slough and harbor. Some of the conclusions presented by this firm are as follows (WRE, 1969):

1) The major contributors of contamination apparently are the sewage treatment plants whose effluents reach the south harbor via the Old Salinas River (channel) and the dairies who discharge barn wastes to Elkhorn Slough.

2) The effect of increased cooling water pumpage from the south harbor by P.G. & E. has been to improve the water quality of the entire system, especially in the south harbor and lower slough.

3) That even with all users (navigation, hunting, fishing, shellfish harvesting, industrial water supply, water contact sports, scientific study, pleasure boating and preservation and enjoyment) growing to 10 times their present levels in 50 years, the dollars and cents of benefits and costs do not justify attaining an environmental coliform count of only 70 MPN/100 ml. (Note: 90 to 99 percent of the sources would have to be eliminated to attain this standard).

4) The present coliform concentration of approximately 400 MPN/100 ml. is apparently quite adequate to protect and support the large majority of users of the Elkhorn and Moss Landing environment (Table 3).

The WRE report summary states that while there is no apparent economic justification for attaining shellfish growing standards, "neither is there any social or moral justification for permitting the quality of Elkhorn Slough to decay (any further)." The key phrase is "economic justification." The Department, of course, recognizes the economics that are involved. However, in the face of the total threat now confronting the disappearing wetlands of California, as well as to the many other critically threatened "open spaces," the Department feels that there can be no moral or social justification to allow <u>any</u> decay of the water quality of <u>any</u> remaining

TABLE 3

ENVIRONMENTAL WATER USE LEVELS AND QUALITY CRITERIA

IN ELKHORN SLOUGH AND MOSS LANDING HARBOR

(Water Resources Engineers, Inc., 1969)

| USE | COLIFORM CRITERIA, MPN/100 ml | |
|---|---|---|
| | TOTAL | FECAL |
| 1. Navigation | 10,000 | 2,000 |
| 2. Hunting | 10,000 | 2,000 |
| 3. Fishing | 10,000 | 2,000 |
| 4. Shellfish Harvesting | 70 | 7 |
| 5. Industrial Water Supply | 10,000 | 2,000 |
| 6. Water Contact Sports | 1,000 | 200 |
| 7. Scientific Study | 5,000 | 1,000 |
| 8. Wildlife Preservation & Enjoyment | 5,000 | 1,000 |
| 9. Pleasure Boating | 10,000 | 2,000 |

coastal wetland. Hence, until the time a factor other than water quality precludes the propagation of shellfish in the area, the Department must urge that shellfishing as a beneficial use of the State waters be protected in Elkhorn Slough.

No subsequent action has been taken since the Regional Board accepted the WRE report. However, new plans for the central coastal region are being prepared now under guidelines of the Federal Environmental Protection Agency and the State Board. These new plans, called Interim Water Quality Management Plans were reviewed publically on May 5, 1971, at San Luis Obispo by all concerned interests and were to be completed by July, 1971, in order to qualify for federal funding. The plan for the Monterey Bay Area, including the Elkhorn Slough-Moss Landing region, provides that no domestic sewage, treated or untreated, may be discharged directly into the waters of the area. The State Board, fortified by the Porter-Cologne Clean Water Act of 1969, which provides for stringent measures regarding violations of waste discharge requirements in State waters, has adopted a policy for coastal and tidal waters that "prohibits domestic discharge in waters within 1,000 feet from shore or above the 100 foot contour level on the ocean floor, whichever is the most restrictive."

In the meantime, under the policy still in existence, the Regional Board, working with the Monterey Department of Public Health, has placed restrictions on direct discharge by local dairies and is encouraging the town of Castroville to improve treatment and land deposition of its domestic wastes.

The Monterey County Public Health Department also has been active in the problem of water quality in the Elkhorn Slough area. The County Department was instrumental in forming a citizens committee to evaluate

corrective needs. Composed of representatives for industry, recreation, private citizens, fishermen, and government, the committee recommended to the County Board of Supervisors that a study of sewage facility needs in the Moss Landing area be made. Consulting engineering firms recommended that the Castroville sewage treatment plant be abandoned and that a new joint Castroville-Moss Landing plant be constructed near Moss Landing which would discharge its effluent through an ocean outfall. However, by means of a public referendum, the people of the area rejected the new facility as not economically feasible at the local level.

Pesticides

Agricultural insecticides are another source of pollution. Levels of pesticide residues tend to reach relatively high levels in the Elkhorn vicinity due to the broad, shallow watershed basin that drains many truck crops, irrigated pasture and dairy operations.

As a part of a nationwide program to monitor organochlorine pesticide residues in the nation's estuaries, the Department--under contract with the U. S. Bureau of Commercial Fisheries--has been sampling shellfish at 10 to 20 stations distributed along the California coast. Residues of DDT and certain other organochlorine insecticides have been found in oysters and mussels sampled from the Elkhorn area. Highest levels found in these shellfish total almost two parts of residue per million parts of water (California Department of Fish and Game, 1967, et. seq.). But, in most instances, samples contained less than one ppm. Although these levels are among the highest found at the coastal stations sampled, they are well below concentrations allowable by the Food and Drug Administration in processed foods.

It is the insidious nature of the chlorinated hydrocarbons, like DDT, to accumulate in the flesh and fat of mollusks, fish, fish-eating birds, and many other adult and larval forms of water-associated animals. Recently, however, the use of these organochlorine pesticides has been curtailed by legislative action. Hopefully the pollution of the biota of the Elkhorn area from this source will steadily decline.

The most recent and graphic illustration of the subtle and far-reaching effects of persistent pesticides is the plight of the California brown pelican that finds the Elkhorn such a good resting area. Nesting failure of the pelican colony on Anacapa Island in the Santa Barbara Channel has been attributed to eggshell weakness linked with accumulation of DDT (report in progress, Department of Fish and Game). Based on present knowledge, it is strictly conjectural as to how long it will take the coastal estuaries like Elkhorn Slough to purge themselves of persistent pesticides. It is important that input of these materials into the slough be at an absolute minimum.

Mosquito Abatement

According to the Monterey County Mosquito Abatement District, key problem areas are in the low marshy areas between Elkhorn Road and the railroad right-of-way, the drainage systems of the dairies, and in the vicinity of the old duck ponds on the north side of the slough. Residential development in the foothill area has changed the watershed, increased run-off and caused some mosquito problems. However, strong tidal flushing minimizes problems in the slough itself.

The District controls mosquitos through proper drainage maintenance and aerial application of pesticides. "Baytex" is used in estuarine situations; "Dursban" in organically polluted areas; and "Abate" in host

specific situations (there are 18 species of mosquitos and midges in Monterey County) (Howard Greenfield, 1971, pers. comm.). All of these compounds are organic phosphates and if properly applied have a less destructive effect on the environment than some of the chlorinated hydrocarbons (DDT and the like). However, "Baytex" can be highly toxic to shorebirds (Keith, 1969) and should not be used in areas attractive to them.

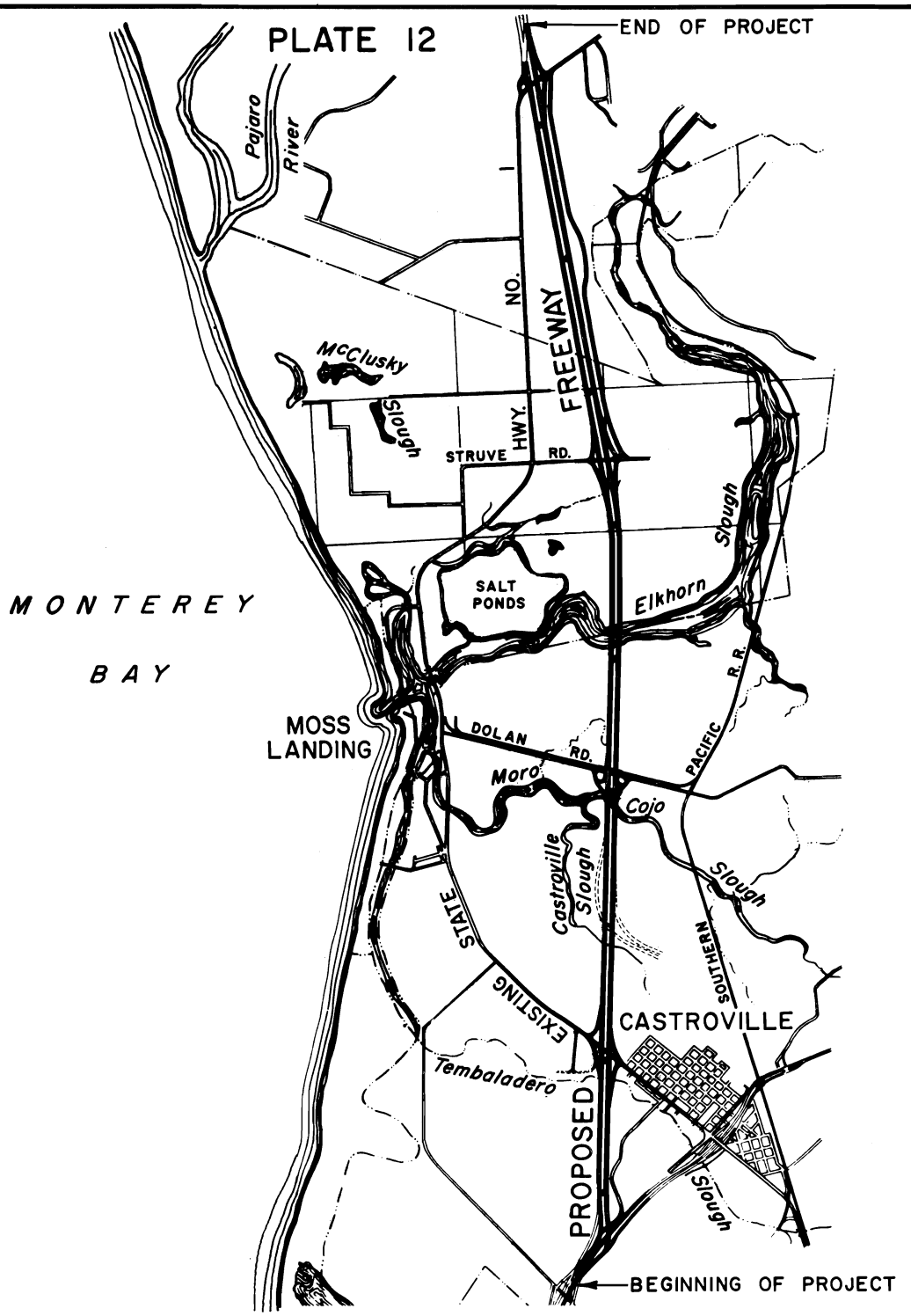
The local mosquito abatement district is aware of wildlife needs and the levels of pesticides used apparently pose no serious threat to the water quality of the estuary, nor to its fish and wildlife.

## Highway Relocation

The State Division of Highways plans to relocate the State Highway 1 crossing $1\frac{1}{2}$ miles up the slough from the present bridge location. The relocation is part of a Division project to build a segment of freeway from Merritt Street in Castroville to 0.6 miles south of the Pajaro River (Plate 12). This project is part of a proposed freeway system that ultimately will link the cities of Santa Cruz and Monterey. The initial phase of construction is scheduled for late 1974.

Early in 1970, the Division of Highways requested the Department's comments on the possible effects of the project on the slough. At that time the Department, concerned with direct effects, suggested that: (1) no siltation be allowed to enter the Elkhorn Slough either during or after construction; (2) no devices should be placed in the slough which would obstruct in any way the free flow of tidal exchange or other waters; (3) no fill material should be placed upon the surrounding marshland, or in the water. In addition to welcoming these suggestions, the Division indicates that every precaution will be used to cross the slough with as little disturbance as possible.

The State Environmental Quality Act of 1970 requires that an environmental impact report on this and every highway project be prepared by the Division. The Act provides for review by the Department and other concerned agencies prior to the report's submission to the State Highways Commission for project funding. The project also will be reviewed according to Public Law 90-495 by the U. S. Department of Transportation which now requires an environmental impact review of all crossings over navigable waters. According to Public Law 90-495, the ever-increasing numbers of environmental safeguards which are coming to the rescue of our




# PROPOSED FREEWAY ROUTE ACROSS ELKHORN SLOUGH

threatened coastal wetlands, as well as other of our open spaces, is encouraging; and the cooperative way that public agencies such as the Division of Highways are responding to them is equally encouraging and commendable.

The proposed mid-slough crossing actually will provide two very good opportunities to enhance the use of the natural resources of the Elkhorn area. A turnout or parking area at the immediate north end of the proposed crossing would make a splendid observation point for wildlife watching and general viewing of the marsh. Should the center span of the present bridge be removed for some future harbor development, the approaches, with minor modifications, could be left as fishing and observation piers.

The natural resources of Elkhorn Slough apparently would be able to survive the direct effects of a carefully conceived and constructed highway crossing at mid-slough. But what about the indirect effects of such a freeway system through the area?

Until the County's long-range plans for the Elkhorn-Moss Landing area are finalized, the Department will not be able to satisfactorily evaluate the long-range, indirect effects of the freeway on the slough's resources and habitat. However, such an evaluation should be made prior to the project's construction because the desirability and suitability of the Elkhorn environs as urban-residential and urban-industrial land surely will increase as traffic through and access to the area are increased. Further residential and/or industrial development obviously will have direct effects on the slough's habitats and, hence, upon its fish and wildlife.

## DISCUSSION AND OVERVIEW

In this report the Department has made the offer to interpret the unique natural and aesthetic values of the Elkhorn Slough area for all concerned about future development plans. But, in the routine, orderly documentation of the resources of any natural area, even one as important and vital as Elkhorn Slough is to the total ecology of the California coastal wetlands, certain biopolitical factors such as State concern, national need and changing public attitudes and needs, are often left out or overlooked. A brief overview should clarify the significance of some of these factors as they affect the future of Elkhorn Slough.

Since World War II, California has doubled in population. Most of this growth has been concentrated on the coast; some 13 million Californians now live within an hour's drive of the Pacific. The coastal resident population is estimated to approach 20 million by 1980. Is it any wonder then that citizens and their leaders are showing increased concern about protecting what is left of our priceless and irreplaceable coastal assets?

California's mounting concern for nearshore waters, the coastal zone, bays and estuaries, has been reflected in several State actions; first, to study the problems involved and second, to mobilize the resources to meet these problems. In its 1965 "Study of Resource Policy Directions for California" the State Resources Agency recognized the competition for our resources, as well as the deterioration of our environment, and stated that environmental quality must be included as an integral part of all planning and developmental programs. The Resources Agency policy statement calls for "enhancement of the quality of life," "freedom of choice in the enjoyment of the State's natural resources" and intergovernmental collaboration for the "coordination of resources management."

Stimulated by a clear policy from the Resources Agency, executive action and later, legislative mandate, created top-level advisory commissions on marine and coastal resources, charged to make policy recommendations to the Governor and the Legislature (Governor's Advisory Commission on Ocean Resources, 1965-68; superseded by the California Advisory Commission on Marine and Coastal Resources, 1968; and most recently, an executive Interagency Council on Ocean Resources, composed of the heads of concerned State agencies and chaired by the Lieutenant Governor). These commissions have made firm recommendations for: the establishment of bay and estuary preserves, low-density use for key marine environments, waste management pollution control, and augmentation of higher education, to name a few.

In addition to the Resources Agency policies and the Governor's Advisory Commission's recommendations for ocean and coastal resources, there are further recommendations contained in the Department's three-volume California Fish and Wildlife Plan of 1966, certainly the most comprehensive fish and wildlife resources planning program of its kind developed by any state.

There is, then, a continuing and increasing concern by the State for our coastal natural resources. Policies, recommendations and plans for resources protection, maintenance and wise use <u>are</u> available. It is important to implement this concern with proper decisions and action. Many of these decisions will have to be made at the local level.

Another factor which ultimately could decide the fate and future of Elkhorn Slough is "national need." The continued population crush, further restrictions on the development of the San Francisco Bay area, need for new coastal inlets for Alaskan oil, together with the Elkhorn's

unique potential as a deep water harbor all make the Elkhorn-Moss Landing area seem like a "natural" for harbor development. However, there are other areas with similar potential elsewhere along the coast.

But "national need" does not include only harbors and railheads. A recent Westinghouse Ocean Research Laboratory publication estimates the total annual economic value of California's nearshore waters at nearly 1.3 billion dollars, of which approximately 887 million dollars derive from recreational uses, 390 million from commercial use and 9.4 million from sewage disposal (Clarke, 1967). As more and more people obtain more and more leisure time, the need for recreation will increase manyfold.

Still another "national need" looms large in the assessment of the total values and assets of Elkhorn Slough. More and more the scientists and leaders of the nation are turning their interests and energies to the development of the ocean's seemingly boundless resources. Again the uniqueness of the Elkhorn-Moss Landing environs makes it highly suitable for providing "the specialized research experiences required for the education of scientists and engineers who will lead this nation toward the mastery of the oceans and resources" (Harville, 1968). There is no other area along the coast with similar potential.

Finally, one last factor cannot be overlooked as a significant influence in the struggle to save our coastal wetlands, and that is public opinion. At this point in time, there is no doubt that the banner of "environmental concern" waves high over the land. Increased leisure time and need for recreation, increased awareness of environmental deterioration, the increasing popularity of hiking, photography, nature study and other nonappropriative use and an increasing ecological sensitivity to the principle that each living organism has a right to its "place in the sun,"

all have contributed to the growing momentum of public concern for our environment. Nowhere is this more apparent than along the California coast and in Monterey County in particular. Herculean efforts are now being made to save the remaining salt marshes of the San Francisco Bay area. The county officials and local citizenry and conservation agencies, such as the Audubon Society and Nature Conservancy have taken great strides towards maintaining the ecological integrity of Bolinas Lagoon in Marin County (Giguere, 1970). The "Friends of Newport Bay" and others have delayed implementation of a plan for complete development of Upper Newport Bay. Goleta Slough in Santa Barbara County has received the same sort of support from the people of that area.

The people of Monterey County have made their feelings known with regard to the development and pollution of Elkhorn Slough and Moss Landing Harbor. In 1966, a "Citizens for Clean Air" committee gathered over 12,500 signatures against the construction of an oil refinery in the Elkhorn area; the proposed site is now up for sale (Monterey Peninsula Herald, February 4, 1971). The Six Cities Fund, a group also opposed to such development at Moss Landing, in 1965 endorsed a complaint of air and water pollution against the Kaiser plant by local fishermen (Monterey Peninsula Herald, December 10, 1965). The Anti-Pollution Association of Monterey County has expressed their concern about the water quality in Elkhorn Slough. Sportsmen, birdwatchers, fishermen, local citizens, all are joining forces for the preservation and wise use of the County's natural resources.

The Department of Fish and Game welcomes this kind of concern and support in its effort to preserve, maintain or improve the natural resources of Elkhorn Slough.

One of the principal goals of the North Monterey County General Plan (Hahn, Wise and Associates, Inc., 1968) is "to maintain the character and natural amenities of Monterey County while providing for its inevitable growth." Resolving "natural amenities" with "inevitable growth" will be an important decision that the people of Monterey County will have to make; and soon; for "not to decide, is to decide."

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Note: These few papers represent only a small cross-section of the broad interests and efforts by students in their biological pursuits in Elkhorn Slough.

APPENDIX A

Bird Life of Elkhorn Slough and Moss Landing Harbor

| Common Name | Scientific Name 1/ | Population Peak, Number and Month (1967-68) | | |
|---|---|---|---|---|
| **Shorebirds** | | | | |
| Avocet, American | Recurvirostra americana | R 2/ | 606 | Dec. |
| Curlew long-billed | Numenius americanus | M | 147 | Aug. |
| Dowitcher, long-billed | Limnodromus scolopaceus | M | 45 | Jan. |
| Dowitcher, short-billed | Limnodromus griseus | M | 40 | Jan. |
| Dunlin | Erolia alpina | M | 524 | Nov. |
| Godwit, marbled | Limosa fedoa | M | 1454 | Dec. |
| Killdeer | Charadrius vociferus | R | 210 | Dec. |
| Knot | Calidris canutus | M | 1 | Apr. |
| Phalarope, northern | Lobipes lobatus | M | 8175 | Oct. |
| Phalarope, red | Phalaropus fulicarius | M | 4 | Feb. |
| Phalarope, Wilson's | Steganopus tricolor | M | 34 | Aug. |
| Plover, American golden | Pluvialis dominica | M | 3/ | -- |
| Plover, black-bellied | Squatarola squatarola | M | 105 | Jan. |
| Plover, semipalmated | Charadrius semipalmatus | M | 32 | Apr. |
| Plover, snowy | Charadrius alexandrinus | R | -- | -- |
| Sanderling | Crocethia alba | M | 227 | Nov. |
| Sandpiper, Baird's | Erolia bairdii | M | 5 | Apr. |
| Sandpiper, least | Erolia minutilla | M | 530 | Dec. |

1/ Scientific names from Peterson s A Field Guide to Western Birds

2/ R=resident
M=migrant

3/ Not recorded on Department censuses

4/ Escaped exotic

5/ Rarely

| Common Name | Scientific Name | | Population Peak, Number, and Month (1967-1968) | |
|---|---|---|---|---|
| Sandpiper, pectoral | Erolia melanotos | M | 12 | Sept. |
| Sandpiper, spotted | Actitis macularia | M | 1 | Feb. |
| Sandpiper, western | Ereunetes mauri | M | 1460 | July |
| Snipe, common | Capella gallinayo | M | 1 | Feb., April |
| Stilt, black-necked | Himantopus mexicanus | R | 30 | Feb. |
| Surfbird | Aphriza virgata | M | -- | -- |
| Turnstone, black | Arenaria melanocephala | M | 6 | Aug. |
| Turnstone, ruddy | Arenaria interpres | M | 5 | June |
| Yellowlegs, greater | Totanus melanoleucus | M | 6 | Nov. |
| Yellowlegs, lesser | Totanus flavipes | M | 1 | Jan., Apr., May |
| Willet | Catoptrophorus semipalmatus | M | 1874 | Aug. |
| Whimbrel | Numenius phaeopus | M | 40 | Apr. |
| **Wading Birds** | | | | |
| Bittern, American | Botaurus lentiginosus | M | -- | -- |
| Egret, common | Casmerodius albus | M | 15 | Jan. |
| Egret, reddish | Dichromanassa rufescens | M | 1 | Aug., Nov. |
| Egret, snowy | Leucophoyx thula | M | 26 | Mar. |
| Flamingo, American | Phoenicopterus ruber | 4/ | 1 | -- |
| Heron, great blue | Ardea herodias | M | 45 | Jan., Dec. |
| Heron, black-crowned night | Nycticorax nycticorax | R | 1 | Aug., Nov. |
| **Gulls and Terns** | | | | |
| Gull, Bonaparte's | Larus philadelphia | M | 207 | Mar. |
| Gull, California | Larus californicus | M | 1202 | Nov. |
| Gull, glaucous-winged | Larus glaucescens | M | 15 | Mar., Apr. |
| Gull, herring | Larus argentatus | M | 40 | Mar. |
| Gull, Heerman's | Larus heermanni | M | 705 | Dec. |
| Gull, mew | Larus canus | M | 320 | Jan. |

| Common Name | Scientific Name | Population Peak, Number, and Month (1967-68) | | |
|---|---|---|---|---|
| Gull, ring-billed | Larus delawarensis | M | 44 | Mar. |
| Gull, western | Larus occidentalis | M | 396 | Oct. |
| Kittiwake, black-legged | Rissa tridactyla | M | -- | -- |
| Tern, black | Chlidonias niger | M | 1 | Aug. |
| Tern, Caspian | Hydroprogne caspia | M | 37 | June |
| Tern, common | Sterna hirundo | M | 11 | Sept. |
| Tern, elegant | Thalasseus elegans | M | 9 | Oct. |
| Tern, Forster's | Sterna forsteri | R | 208 | April |
| Tern, least | Sterna albifrons | M | 1 | Mar., April |
| Tern, royal | Thalasseus maximus | M | -- | -- |
| Waterfowl | | | | |
| Brant, black | Branta nigricans | M | 9 | April |
| Bufflehead | Bucephala albeola | M | 62 | Feb. |
| Canvasback | Aythya valisineria | M | 14 | Dec. |
| Gadwall | Anas strepera | M | 12 | April |
| Golden-eye, common | Bucephala clangula | M | 27 | Jan. |
| Goose, lesser Canada | Branta canadensis parvipes | M | -- | -- |
| Goose, Ross | Chen rossii | M | 1 | Feb. |
| Goose, snow | Chen hyperborea | M | 1 | Dec., Jan. |
| Goose, white-fronted | Anser albifrons | M | 19 | Jan. |
| Mallard | Anas platyrhinchos | R | 50 | Aug. |
| Merganser, red-breasted | Mergus serrator | M | 13 | Jan. |
| Oldsquaw | Clangula hyemalis | M | 3 | Jan., Feb. |
| Pintail | Anas acuta | M | 147 | Dec. |
| Redhead | Aytha americana | M | 2 | Dec. |
| Ring-necked duck | Aythya collaris | M | 11 | Dec. |
| Ruddy duck | Oxyura jamaicensis | M | 932 | Jan. |
| Scaup, greater | Aythya marila | M | 395 | Dec. |

| Common Name | Scientific Name | Population Peak, Number, and Month (1967-68) | | |
|---|---|---|---|---|
| Scaup, lesser | Aythya affinis | M | | |
| Shoveler | Spatula clypeata | M | 248 | Feb. |
| Scoter, common | Oidemia nigra | M | 2 | April, May |
| Scoter, surf | Melanitta perspicillata | M | 397 | Feb. |
| Scoter, white-winged | Melanitta deglandi | M | 187 | Dec., Mar. |
| Swan, whistling | Olor columbianus | M | 16 | Jan. |
| Teal, cinnamon | Anas cyanoptera | M | 300 | Aug. |
| Teal, green-winged | Anas carolininsis | M | 119 | Mar. |
| Widgeon, American | Mareca americana | M | 25 | April |
| **Miscellaneous Marsh and Water-Associated Birds** | | | | |
| Coot, American | Pulica americana | R | 1004 | Oct. |
| Grebe, eared | Podiceps caspicus | M | 38 | Feb. |
| Grebe, horned | Podiceps auritus | M | 50 | April |
| Grebe, pied-billed | Podilymbus podiceps | R | 14 | Nov. |
| Grebe, western | Aechmophorus occidentalis | R | 5/113 | Jan |
| Kingfisher, belted | Megaceryle alcyon | | -- | -- |
| Rail, clapper | Rallus longirostris | R | 4 | June |
| Rail, Virginia | Rallus limicola | R | -- | -- |
| **Miscellaneous Coastal and Pelagic Birds** | | | | |
| Cormorant, Brandt's | Phalacrocorax penicillatus | M | 3 | Sept. |
| Cormorant, double-crested | Phalacrocorax auritus | M | 4 | Feb. |
| Cormorant, pelagic | Phalacrocorax pelagicus | M | 1 | Mar. |
| Guillemot, pigeon | Cepphus columba | M | 4 | Aug., Feb. |
| Loon, artic | Gavia artica | M | 4 | May |
| Loon, common | Gavia immer | M | 3 | May |
| Loon, red-throated | Gavia stellata | M | 4 | Jan. |

| Common Name | Scientific Name | Population Peak, Number, and Month (1967-68) | | |
|---|---|---|---|---|
| Murre, common | Uria aalge | M | 1 | Sept., May |
| Murrelet, ancient | Synthliboramphus antiquum | M | 2 | Sept. |
| Pelican, brown | Pelecanus occidentalis | M | 2243 | Aug. |
| Pelican, white | Pelecanus erythrorhynchos | M | 17 | Dec. |
| **Land-associated Birds** | | | | |
| Blackbird, Brewer's | Euphagus cyanocephalus | R | -- | -- |
| Blackbird, red-winged | Agelaius phoenicus | R | -- | -- |
| Blackbird, tricolor | Agelaius tricolor | M | -- | -- |
| Bushtit, common | Psaltriparus minimus | M | -- | -- |
| Crow, common | Corvus brachyrhynchos | R | -- | -- |
| Dove, mourning | Zenaidura macroura | M | -- | -- |
| Eagle, golden | Aquila chrysaetos | M | -- | -- |
| Finch, house | Carpodacus mexicanus | M | -- | -- |
| Flicker, red-shafted | Colaptes cafer | M | -- | -- |
| Flycatcher, western | Empidonax difficilis | M | -- | -- |
| Goldfinch, American | Spinus tristis | R | -- | -- |
| Hawk, marsh | Circus cyaneus | M | -- | -- |
| Hawk, red-tailed | Buteo jamaicensis | M | -- | -- |
| Hawk, sparrow | Falco sparverius | R | -- | -- |
| Jay, scrub | Aphelocoma coerulescens | M | -- | -- |
| Kinglet, ruby-crowned | Regulus calendula | M | -- | -- |
| Kite, white-tailed | Elanus leucurus | R | -- | -- |
| Lark, horned | Eremophila alpestris | M | -- | -- |
| Magpie, yellow-billed | Pica nuttali | M | -- | -- |
| Meadowlark, western | Sturnella neglecta | R | -- | -- |
| Owl, short-eared | Asio flammeus | M | -- | -- |
| Pheasant, ring-necked | Phasianus colchicus | R | -- | -- |

| Common Name | Scientific Name | Population Peak, Number, and Month (1967-68) |
|---|---|---|
| Phoebe, black | Sayornis nigricans | R -- -- |
| Phoebe, Say's | Sayornis saya | M -- -- |
| Pigeon, band-tailed | Columba fasciata | M -- -- |
| Pipit, water | Anthus spinoletta | M -- -- |
| Quail, California | Lophortyx californicus | R -- -- |
| Shrike, loggerhead | Lanius ludovicianus | R -- -- |
| Sparrow, golden-crowned | Zonotrichia atricapilla | R -- -- |
| Sparrow, house | Passer domesticus | R -- -- |
| Sparrow, savannah | Passerculus sandwichensis | R -- -- |
| Sparrow, song | Melospiza melodia | R -- -- |
| Sparrow, swamp | Melospiza georgiana | M -- -- |
| Sparrow, white-crowned | Zonotrichia leucophrys | R -- -- |
| Starling | Sturnus vulgaris | M -- -- |
| Swallow, violet-green | Tachycineta thalassina | M -- -- |
| Towhee, brown | Pipilo fuscus | R -- -- |
| Thrasher, California | Toxostoma redivivum | R -- -- |
| Warbler, Audubon's | Dendroica auduboni | M -- -- |
| Wren, Bewick's | Thryomanes bewickii | R -- -- |
| Wren, long-billed marsh | Telmatodytes palustris | R -- -- |

APPENDIX B

COMPARATIVE MONTHLY COUNTS (HIGHEST NUMBER) OF SHOREBIRDS CENSUSED FROM COASTAL WETLANDS

| | | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bolinas Lagoon-Tomales Bay[1/] | 1968 | - | - | - | - | - | - | - | 4,505 | 5,575 | 12,850 | 10,899 | - |
| | 1969 | 9,298 | - | 8,488 | - | 2,484 | - | - | - | 2,467 | 4,859 | 12,220 | - |
| | 1970 | 6,911 | 5,736 | 14,051 | 24,165 | - | - | - | - | - | - | - | - |
| South San Diego Bay[2/] | 1970 | 5,766 | 8,618 | 7,614 | 13,678 | 466 | 889 | 3,699 | 8,653 | 8,608 | 9,750 | - | - |
| Humboldt Bay[1/] | 1968 | - | - | - | - | - | - | - | 23,477 | 59,365 | 14,995 | 52,811 | - |
| | 1969 | 18,479 | - | 27,721 | 34,643 | 1,044 | 782 | - | 14,850 | 22,610 | 42,823 | 58,644 | 40,317 |
| | 1970 | - | 29,127 | 9,105 | 40,521 | 1,694 | 788 | 6,555 | 7,384 | 20,922 | - | - | - |
| Elkhorn Slough[2/] | 1967 | 6,244 | 4,228 | 7,718 | 17,067 | 341 | 300 | 3,915 | 6,127 | 3,753 | 17,457 | 16,826 | 8,821 |
| | 1968 | 10,869 | 11,191 | 9,010 | 9,018 | 504 | 836 | - | - | - | - | - | - |

1/ - aerial census

2/ - on foot

APPENDIX C

LIST OF FISHES COLLECTED IN
ELKHORN SLOUGH AND ITS ENVIRONS 1/

| Common Name | Scientific Name | Slough | Harbor | Pier & Jetty |
|---|---|---|---|---|
| Anchovy, northern | Engraulis mordax | x | x | |
| Bass, striped | Marone saxatilis | x | x | |
| Boccacio | Sebastes paucispinis | x | x | |
| Cabezon | Scorpaenichthys marmoratus | x | x | x |
| Croaker, white | Genyonemus lineatus | | x | x |
| Flounder, starry | Platichthys stellatus | x | x | x |
| Fringehead, onespot | Neoclinus uninotatus | x | | |
| Fringehead, sarcastic | Neoclinus blanchardi | | | |
| Goby, arrow | Clevelandia ios | x | x | |
| Goby, bay | Lepidogobius lepidus | x | | |
| Greenling, kelp | Hexagrammos sp. | | x | |
| Guitarfish, shovelnose | Rhinobatos productus | x | x | |
| Hake, Pacific | Merluccius productus | | x | |
| Halibut, California | Paralichthys californicus | x | x | |
| Herring, Pacific | Clupea harengus pallasi | x | x | |
| Jacksmelt | Atherinopsis californiensis | x | x | x |
| Lingcod | Ophiodon elongatus | | x | x 2/ |
| Lizardfish, California | Synodus lucioceps | | x | |
| Lusk-eel | Otophidum taylori | x | x | |
| Mackerel, jack | Trachurus symmetricus | x | x | |
| Midshipman, plainfin | Porichthys notatus | | x | |
| Mudsucker, longjaw | Gillichthys mirabilis | x | x | |
| Perch, black | Embiotoca jacksoni | x | x | x 2/ |

1/ Nomenclature from American Fisheries Society Special Publication #6, Common and Scientific Names of Fishes from the United States and Canada.

2/ Species observed under the pier on scuba portion of study.

3/ Juveniles

| Common Name | Scientific Name | Slough | Harbor | Pier & Jetty |
|---|---|---|---|---|
| Perch, dwarf | Micrometrus minimus | x | x | |
| Perch, pile | Rhacochilus vacca | x | x | x |
| Perch, reef | Micrometrus aurora | x | | |
| Perch, shiner | Cymatogaster aggregata | x | x | x 2/ |
| Pipefish, bay | Syngnathus griseolineatus | | x | |
| Pipefish, kelp | Syngnathus californiensis | | x | |
| Pompano, Pacific | Peprilus simillimus | x | x | |
| Queenfish | Seriphus politus | x | x | |
| Ray, bat | Myliobatis californica | x | x | |
| Rockfish | Sebastes sp. | | x | |
| Rockfish, blue | Sebastes mystinus | x 3/ | | |
| Rockfish, brown | Sebastes auriculatus | x | x | |
| Rockfish, kelp | Sebastes atrovirens | | x | |
| Rockfish, grass | Sebastes rostrelliger | x 3/ | | |
| Sanddab, Pacific | Citharichthys sordidus | x | x | |
| Sanddab, speckled | Citharichthys stigmaeus | x | x | x 2/ |
| Sardine, Pacific | Sardinops sagax | x | x | |
| Sculpin, Pacific staghorn | Leptocottus armatus | x | x | x |
| Seaperch, rainbow | Hypsurus caryi | x | x | x |
| Seaperch, rubberlip | Rhacochilus toxotes | x | x | |
| Seaperch, sharpnose | Rhanerodon atripes | | | x |
| Seaperch, striped | Embiotoca lateralis | x | | x 2/ |
| Seaperch, white | Phanerodon furcatus | x | x | x |
| Shad | Alosa sp. | | x | |
| Shad, American | Alosa sapidissima | | x | |
| Shad, threadfin | Dorosoma petenense | | x | |
| Shark, brown smoothhound | Mustelus henlei | x | | |
| Shark, gray smoothhound | Mustelus californicus | x | | |
| Shark, leopard | Triakis semifasciata | x | x | x |

| Common Name | Scientific Name | Slough | Harbor | Pier & Jetty |
|---|---|---|---|---|
| Skate | Raja sp. | | x | |
| Skate, California | Raja inorata | | | x |
| Smelt, surf | Hypomesus pretiosus | x | x | |
| Snake eel, Pacific | Ophichthus triseralis | x | x | |
| Snake eel, spotted | Ophichthus ophis | x | | |
| Smelt, whitebait | Allosmerus elongatus | | x | |
| Sole, curlfin | Pleuronichthys decurrens | x | | |
| Sole, English | Parophrys vetulus | x | x | x |
| Sole, sand | Psettichthys melanostictus | | x | |
| Stickleback, threespine | Gasterosteus aculeatus | | x | |
| Stingray, round | Urolophus halleri | x | x | |
| Surfperch, barred | Amphistichus argenteus | | x | x |
| Surfperch, calico | Amphistichus koelzi | x | | x |
| Surfperch, red-tailed | Amphistichus rhodoterus | | | x |
| Surfperch, silver | Hyperprosopon ellipticum | | | x 2/ |
| Surfperch, spotfin | Hyperprosopen anale | | x | |
| Surfperch, walleye | Hyperprosopon argenteum | x | x | x |
| Thornback | Platyrhinoides triseriata | x | | |
| Tomcod, Pacific | Microgadus proximus | | x | |
| Tonguefish, California | Symphurus atricauda | x | | |
| Topsmelt | Atherinopsis affinis | x | x | |
| Turbot, diamond | Hypsopsetta guttulata | x | x | |
| Wolf-eel | Anarrhichthys ocellatus | | | x |

# APPENDIX D

## MISCELLANEOUS PLANTS AND ANIMALS*

| | Common Name | Scientific Name |
|---|---|---|
| **Plants:** | | |
| 1. | Bulrushes | Scirpus spp. |
| 2. | Cattail | Typha spp. |
| 3. | Eelgrass | Zostera marina |
| 4. | Frankenia | Frankenia grandifolia |
| 5. | Ice-plant | Mesembryanthemum sp. |
| 6. | Pickleweed | Salicornia spp. |
| 7. | Rushes | Juncus spp. |
| 8. | Saltgrass | Distichlis spicata |
| **Mammals:** | | |
| 1. | Black-tailed deer | Odocoileus hemionus columbianns |
| 2. | Brush rabbit | Sylvilagus bachmani |
| 3. | Bobcat | Lynx rufus |
| 4. | Coyote | Canis latrans |
| 5. | Gray fox | Urocyon cinereoargenteus |
| 6. | Jackrabbit | Lepus californicus |
| 7. | Muskrat | Odonatra zibethica |
| 8. | Raccoon | Procyon lotor |
| 9. | Seal | Phocidae |
| 10. | Sea lion | Otariidae |
| **Fish and Squid:** | | |
| 1. | Albacore | Thunnus alalunga |
| 2. | Jack mackerel | Trachurus lathami |
| 3. | Petrale sole | Eopsetta jordani |
| 4. | Rex sole | Glyptocephalus zachirus |
| 5. | Rockfish | Sebastes spp. |
| 6. | Sablefish | Anoplopoma fimbria |
| 7. | Salmon | Oncorhynchus spp. |
| 8. | Squid | Loligo opalescens |
| **Shellfish:** | | |
| 1. | European flat oyster | Ostrea edulis |
| 2. | Japanese mussel | Modiolus sanhausi |
| 3. | Japanese littleneck clam | Tapes semidecussata |
| 4. | Mexican oyster | Crassostrea sp. |
| 5. | Portuguese oyster | Crassostrea angulata |

* Not listed in check lists of birds, fish, and shellfish.

APPENDIX E

SHELLFISH OF ELKHORN SLOUGH[1/]

Crustaceans

| Common Name | Scientific Name |
|---|---|
| Crabs and shrimp: | |
| Rock crab | Cancer antennarius |
| Yellow crab | Cancer anthonyi |
| Cancer crab | Cancer gibbosulus |
| Slender crab | Cancer gracilis |
| Cancer crab | Cancer jordani |
| Dungeness or market crab | Cancer magister |
| Red crab | Cancer productus |
| Purple shore crab | Hemigrapsus nudus |
| Shore crab or Oregon mud crab | Hemigrapsus oregonensis |
| Mottled pea crab | Opisthopus transversus |
| Porcelain crab | Pachycheles rudis |
| Lined shore crab | Pachygrapsus crassipes |
| Hermit crab | Pagurus hirsutiusculus |
| Hermit crab | Pagurus samuelis |
| Flat or Porcelain crab | Petrolisthes cinctipes |
| Commensal pea crab | Pinnixa faba |
| Commensal pea crab | Pinnixa franciscana |
| Commensal pea crab | Pinnixa longipes |
| Commensal pea crab | Pinnixa schmitti |
| Commensal pea crab | Pinnixa tommentosa |
| Commensal pea crab | Pinnixa tubicola |

1/ Compiled from Addicott, 1952; Eissinger, 1970; Macginitie, 1935; Smith and Gordon, Jr., 1948. Some common names from Ricketts and Calvin, 1952; Fitch, 1953; Hedgpeth, 1967; and MacGinitie and MacGinitie, 1968.

| Common Name | Scientific Name |
|---|---|
| Kelp crab | Pugettia producta |
| Commensal pea crab | Scleroplax granulata |
| | Betaeus longidactylus |
| Ghost shrimp | Callianassa californiensis |
| Long-handed ghost shrimp | Callianassa gigas |
| Bay shrimp | Crago nigricauda |
| Gross shrimp | Hippolyte californiensis |
| Broken back shrimp | Spirontocaris paludicola |
| Broken back shrimp | Spirontocaris picta |
| Blue mud shrimp | Upogebia pugettensis |
| Amphipods: | |
| | Ampithoe lacertosa |
| Water flea | Aoroides columbiae |
| Skeleton shrimp | Caprella acutifrons |
| Skeleton shrimp | Caprella equilibra |
| Skeleton shrimp | Caprella scaura |
| Water flea | Corophium salmonis |
| Water flea | Corophium spinicorne |
| Sand hopper | Gammarus confervicolus |
| Barnacles: | |
| Acorn barnacle | Balanus nubilis |
| Acorn barnacle | Balanus tintinnabulum |
| Gooseneck barnacle | Lepas hilli |
| Parasitic barnacle | Sacculina sp. |
| Copepods: | |
| Parasitic copepod | Argulus melanostictus |
| Parasitic copepod | Hemicyclops callianassae |
| Parasitic copepod | Hemicyclops thysanotus |
| Parasitic copepod | Modiolicola gracilis |

| Common Name | Scientific Name |
|---|---|
| **Isopods:** | |
| Boring isopod (Gribble) | *Limnoria lignorum* |
| Pill bug | *Livoneca vulgaris* |
| Isopod | *Pentidotea resecata* |
| Commensal isopod | *Phyllodurus abdominalis* |
| **Mollusks** | |
| **Snails and Nudibranchs:** | |
| Nudibranch | *Aeolida papillosa* |
| Sea slug | *Aplysia californicus* |
| Nudibranch | *Coryphella* sp. |
| Nudibranch | *Dendronotus* sp. |
| Nudibranch | *Doto* sp. |
| Nudibranch | *Galvina* sp. |
| Bubble shell | *Haminoea vesicula* |
| Nudibranch | *Hermissenda crassicornis* |
| Sea slug | *Navanax inermis* |
| Sea slug | *Philine* sp. |
| **Oysters, clams and mussels:** | |
| Giant Pacific oyster | *Crassostrea gigas* |
| Eastern oyster | *Crassostrea virginica* |
| Rockboring mussel | *Lithophaga plumula* |
| Bay mussel | *Mytilus edulis* |
| Fat horsemussel | *Volsella capax* |
| Horsemussel | *Volsella diegensis* |
| Straight horsemussel | *Volsella recta* |
| California soft-shelled clam | *Cryptomya californica* |
| Nestler clam | *Kellia laperousii* |
| Inconspicuous macoma | *Macoma inconspicua* |

| Common Name | Scientific Name |
|---|---|
| Sand clam | Macoma inquinta |
| Irus macoma | Macoma irus |
| Bent-nosed clam | Macoma nasuta |
| White sand clam | Macoma secta |
| California mactra | Mactra californica |
| Mactra | Mactra dolabiformis |
| Geoduck | Panope generosa |
| Wart-necked piddock | Pholadidea ovoidea |
| Boring clam | Pholadidea penita |
| Petricola clam | Petricola carditoides |
| Common littleneck | Protothaca staminea |
| Thin shelled littleneck | Protothaca tenerrima |
| California reversed clam | Pseudochama exogyra |
| Commensal clam | Pseudophthina rugifera |
| Purple clam | Sanguinolaria nuttalli |
| Saxicava clam | Saxicava arctica |
| Common Washington clam | Sacidomus nuttallii |
| Razor clam | Siliqua lucida |
| Northern razor clam | Siliqua patula |
| Sickle razor clam | Solen sicarius |
| Dish clam | Spisula planulata |
| California jackknife clam | Tagelus californianus |
| Bodega tellen | Tellina bodegensis |
| Tellen | Tellina buttoni |
| Pismo clam | Tivela stultorum |
| Gaper clam | Tresus nuttallii |
| Boring clam | Zirfaea gabbi |
| Rough piddock | Zirfaea pilsbryi |

| Common Name | Scientific Name |
|---|---|
| Miscellaneous mollusks: | |
| Angular unicorn snail | Acanthina spirata |
| File limpet | Acmaea limatula |
| Butterfly limpet | Acmaea persona |
| Ribbed limpet | Acmaea scabra |
| Shipworm | Bankia setacea |
| Basket cockle | Clinocardium nuttallii |
| Slipper shell | Crepidula nivea |
| Keyhole limpet | Diodora aspera |
| Rock scallop | Hinnites multirugosus |
| Cooper's chiton | Ischonchiton cooperi |
| Waddling snail | Lacuna porrecta |
| Chink shell | Lacuna unifasciata |
| Chiton | Lepidochitona raymondi |
| Checkered littorina (Perwinkle) | Littorina scutulata |
| Hairy-girdled chiton | Mopalia ciliata |
| Mossy chiton | Mopalia muscosa hindsii |
| Mossy chiton | Mopalia muscosa |
| Channeled basket shell | Nassarius fossatus |
| Purple olive | Olivella biplicata |
| Checked borer | Platyodon cancellatus |
| Abalone jingle | Pododesmus cepio |
| Moon shell | Polinices draconis |
| Moon shell | Polinices lewisii |
| Black turban | Tegula funebralis |
| Toredo | Teredo diegensis |