Moss Landing Marine Laboratories

ENVIRONMENTAL STUDIES OF MONTEREY BAY

AND THE CENTRAL CALIFORNIA COASTAL ZONE

Annual Report, July, 1971

A NATIONAL SEA GRANT PROJECT

supported by the
OFFICE OF SEA GRANT PROGRAMS
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
DEPARTMENT OF COMMERCE
Grant No. GH-94

edited by
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ENVIRONMENTAL STUDIES OF MONTEREY BAY
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I. INTRODUCTION

The present report is a supplement to our PROGRESS REPORT: FIRST HALF-YEAR OF OPERATION--JULY 1970-FEBRUARY 1971. The first four sections provide detailed information concerning major subdivisions of the Moss Landing Marine Laboratories data collection program: sea-air-land zone of contact, Monterey Bay, Elkhorn Slough, and the Pajaro River. These sections describe the physical characteristics of the study areas, indicate rationale for selection of stations and their locations, provide brief notes on historical background and on previous studies of each area, and furnish a selected list of references. These sections also outline procedures for organization of the Research Participation teams for the data collection program. They indicate scope of data collected during the first four months of full-scale operation and suggest certain first-vintage hypotheses which can be developed from these, as yet, entirely preliminary data.

Later sections outline procedures for data collection and analysis by discipline: fishes, benthic invertebrates, plankton, and sediment analysis. Final sections outline organizational and operational procedures of the SCUBA Marine Research team, which provides diver support for all phases of the program, as well as organization of information services in the library.

General institutional organization for the Sea Grant program has been discussed in some detail in the PROGRESS REPORT cited earlier. These procedures have been thoroughly tested during this first full semester of operation and have been found operationally sound and productive. In most instances, team efficiency has exceeded expectations both in quantity and quality of work.

A roster of personnel and their areas of responsibility indicates the scope of support provided for this program, which has become a total institutional effort at the Moss Landing Marine Laboratories.

Roster of Moss Landing Marine Laboratories Personnel and Their Sea Grant-Related Responsibilities

Ms. Genny Anderson	Receptionist -- student personnel
Mr. Patrick Albin	Diving master (faculty)
Dr. Robert Arnal	Marine geology -- sedimentology (faculty)
Ms. Doris Baron	Librarian
Mr. John Bell	Building and grounds maintenance
Mr. Ray Bernard	Superintendent, building and grounds
Dr. William Broenkow	Chemical-physical oceanography (faculty)
Mr. Scott Dailey	Pajaro River team leader
Mr. David Garrison	Invertebrates
Ms. Judy Hansen	Plankton-chlorophyll analysis
Dr. John Harville	Sea Grant project director (faculty)
Mr. Roger Hilaski	North Monterey Bay sector team leader
Mr. Gary Kukowski	Fishes
Mr. James Locke	Sedimentology
Mr. Arndt Lorenzen	Sea-air-land contact zone team leader
Mr. Gary McDonald	Monterey canyon sector team leader
Mr. Frank Monnich	Master, research vessel Amigo
Mr. Richard Parrish	Fishes (faculty)
Mr. Robert Read	Meteorology (faculty)
Mr. David Seielstad	Oceanographic technician
Dr. Mary Silver	Invertebrates, plankton (faculty)
Mr. Richard Smith	Elkhorn Slough team leader
Mr. Barry Turner	Salt marsh standing crop
Mr. Daniel Varoujean	Operator, work boat Orca
Mr. Russ Waidelich	Equipment technician
Ms. Patricia Wilson	MLML secretary

II. SEA-AIR-LAND ZONES OF CONTACT: METEOROLOGICAL ASPECTS

(Arndt Lorenzen, Graduate Teaching Assistant)

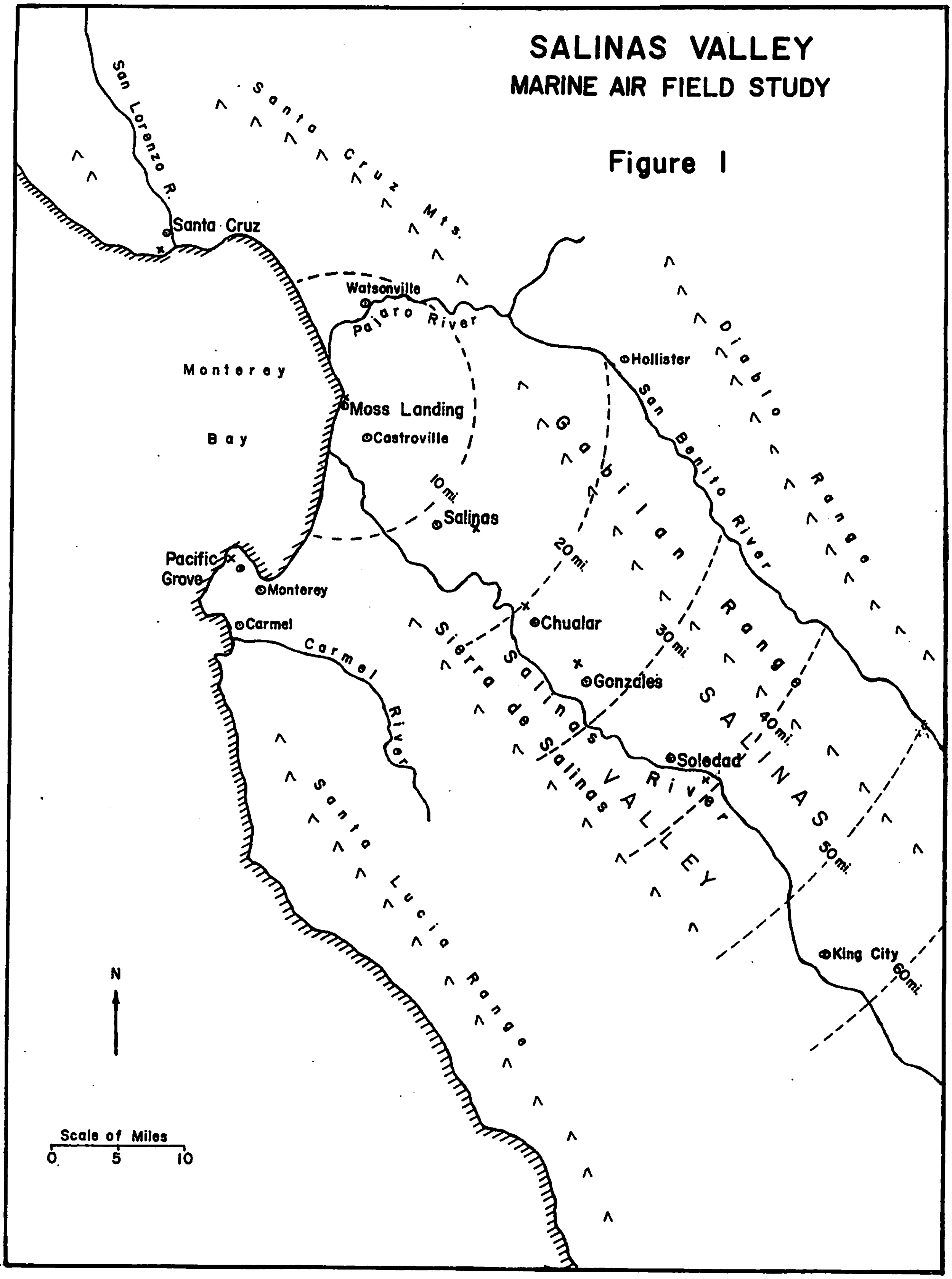
A. Sources of Meteorological and Climatological Data

To adequately study the meteorological aspects of the Monterey Bay area, all available meteorologic data between San Jose ($37^{0}20'$ N latitude) in the north, San Ardo ($36^{0}01'$N) in the south, the Diablo Range in the east, and twenty miles into the Pacific Ocean in the west will be used. Included in these approximately 7500 square miles are all of Santa Cruz and San Benito counties, most of Monterey County, the southern portions of San Mateo and Santa Clara counties, as well as all of Monterey Bay. Figure 1, while emphasizing the Salinas Valley, shows most of the Monterey Bay area. Figure 6 includes some of the depth and contour lines as well as the boundaries of the counties.

The study area is dominated by a series of parallel valleys which start in the southeast and then gradually deepen and widen as they open in the northwest onto various bays. The mountain ranges separating these valleys reach heights of 2000-4000 feet. They are quite effective in channeling marine air from the Pacific Ocean into the valleys and thereby greatly influence the valleys' climatic make-up.

The Santa Clara Valley (Santa Clara County) is bounded on the east by the Diablo Range and on the west by the Santa Cruz Mountains. Near Morgan Hill there is a low topographic divide that divides the drainage between San Francisco Bay and the Pajaro River. North of this divide the valley varies in width from about fourteen miles in the northwest portion near San Jose (where it opens onto San Francisco Bay) to less than one mile at the narrows near Coyote. South of the divide the valley varies in width from about three miles at Morgan Hill to about ten miles at Gilroy (near the Pajaro River). The Santa Clara Valley portion included in this study is about forty miles long from San Jose to the Pajaro River [California Department of Water Resources, 1959].

The San Benito River Valley (San Benito County) is the southeastward extension of the Santa Clara Valley. About fifteen miles southeast of the Pajaro River the valley is drastically narrowed to two miles near



SALINAS VALLEY
MARINE AIR FIELD STUDY
Figure I
San Lorenzo R.
Santa Cruz Mts.
Santa Cruz
Watsonville
Pajaro River
Monterey
Bay
Moss Landing
Castroville
Hollister
Diablo Range
San Benito River
Gabilan Range
10 mi.
Salinas
20 mi.
Pacific Grove
Monterey
Carmel
Carmel River
Chualar
Sierra de Salinas
Salinas River
Gonzales
30 mi.
SALINAS VALLEY
Soledad
40 mi.
50 mi.
Santa Lucia Range
King City
60 mi.
N
Scale of Miles
0 5 10

Tres Pinos as the San Benito River is squeezed between the Diablo Range on the east and the Gabilan Range (a continuation of the Santa Cruz Mountains) on the west [California Department of Water Resources, 1959].

The Pajaro Valley (Santa Cruz, Monterey, and San Benito counties) comprises about seventy-five square miles and extends from the Pajaro Gap, near Aromas, westward for twelve miles along the Pajaro River to Monterey Bay. The Santa Cruz Mountains form its northern boundary, and the drainage divide between the Pajaro River and Elkhorn Slough forms the valley's southern boundary. The floor of the Pajaro Valley slopes gently from an elevation of about 100 feet above sea level at the base of the Santa Cruz Mountains to sea level about five miles west of Watsonville [Haley, 1953; California Department of Water Resources, 1959].

The Salinas Valley (Monterey County) dominates the central portion of the Monterey Bay area. It is a narrow, elongated (southeast to northwest) valley about 100 miles long, an average of five-and-one-half miles wide; it includes about 660 square miles of irrigated and dry-farm lands. The valley is bounded by the Gabilan Range on the east and by the Sierra de Salinas on the west. The seventy-five miles from San Ardo in the southeast to Moss Landing in the northwest (near where the Salinas River flows into Monterey Bay) are included in this study. In that distance the valley floor drops about 440 feet [California Department of Water Resources, 1959].

The Carmel Valley's (Monterey County) floor occupies only five square miles. The valley, bounded by the Sierra de Salinas on the east and the Santa Lucia Range on the west, follows the Carmel River as it winds its way northwestward for about twenty-three miles to flow in the Carmel Bay just south of Carmel. Except for a small lagoon, practically all of the valley is utilized for truck crops [California Department of Water Resources, 1959]. Recently this area has undergone extensive residential development.

The San Lorenzo River Valley (Santa Cruz County) follows the San Lorenzo River as it flows southward from the Big Basin area to empty into Monterey Bay at Santa Cruz. The river passes between Ben Lomond Mountain on the west and the Santa Cruz Mountains on the east on its eighteen-mile journey to the sea.

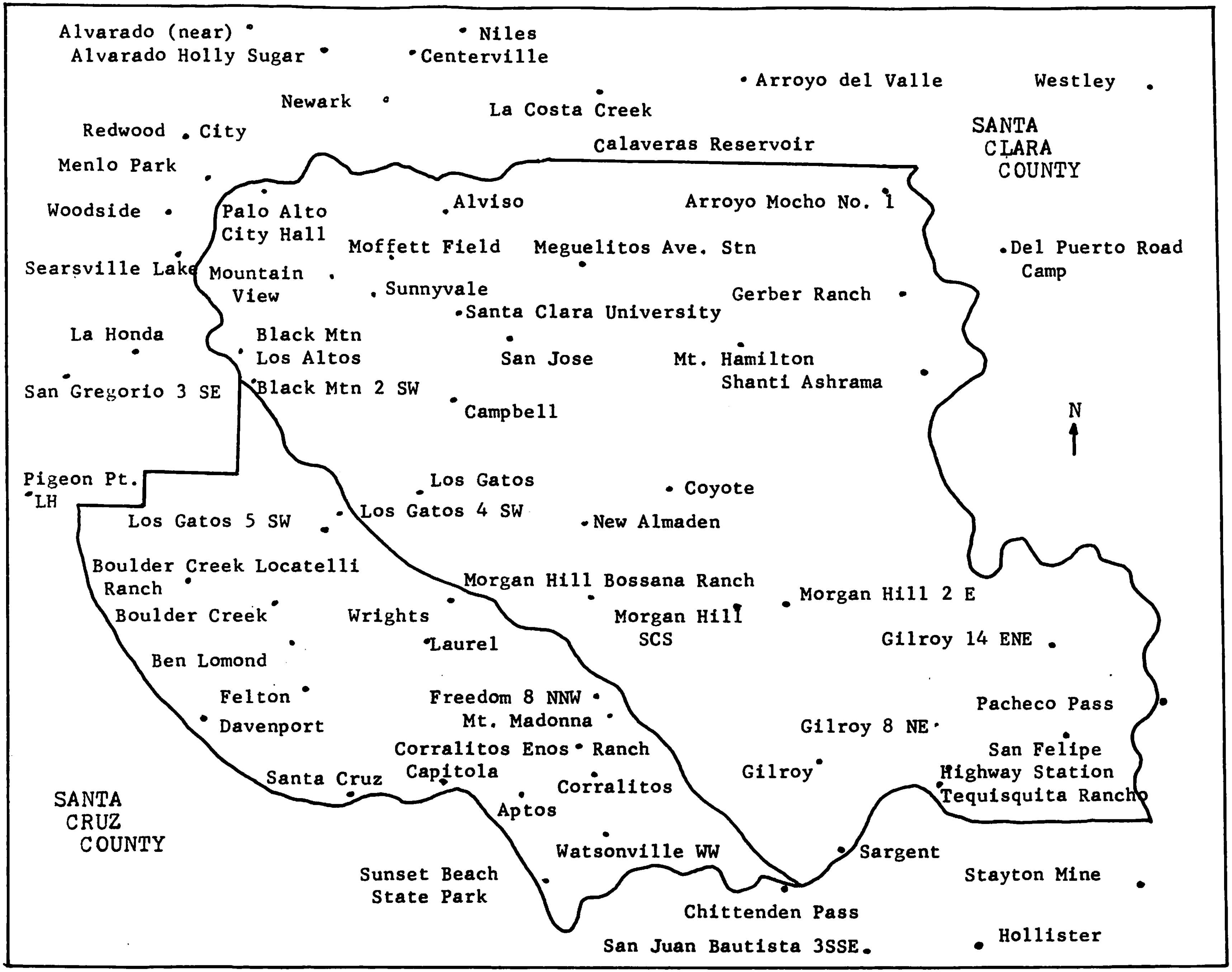


Figure 2 Weather reporting stations used in the Santa Clara - Santa Cruz counties summary. Stations are listed in Table 1, Appendix A. [Elford and Stilz, 1967]

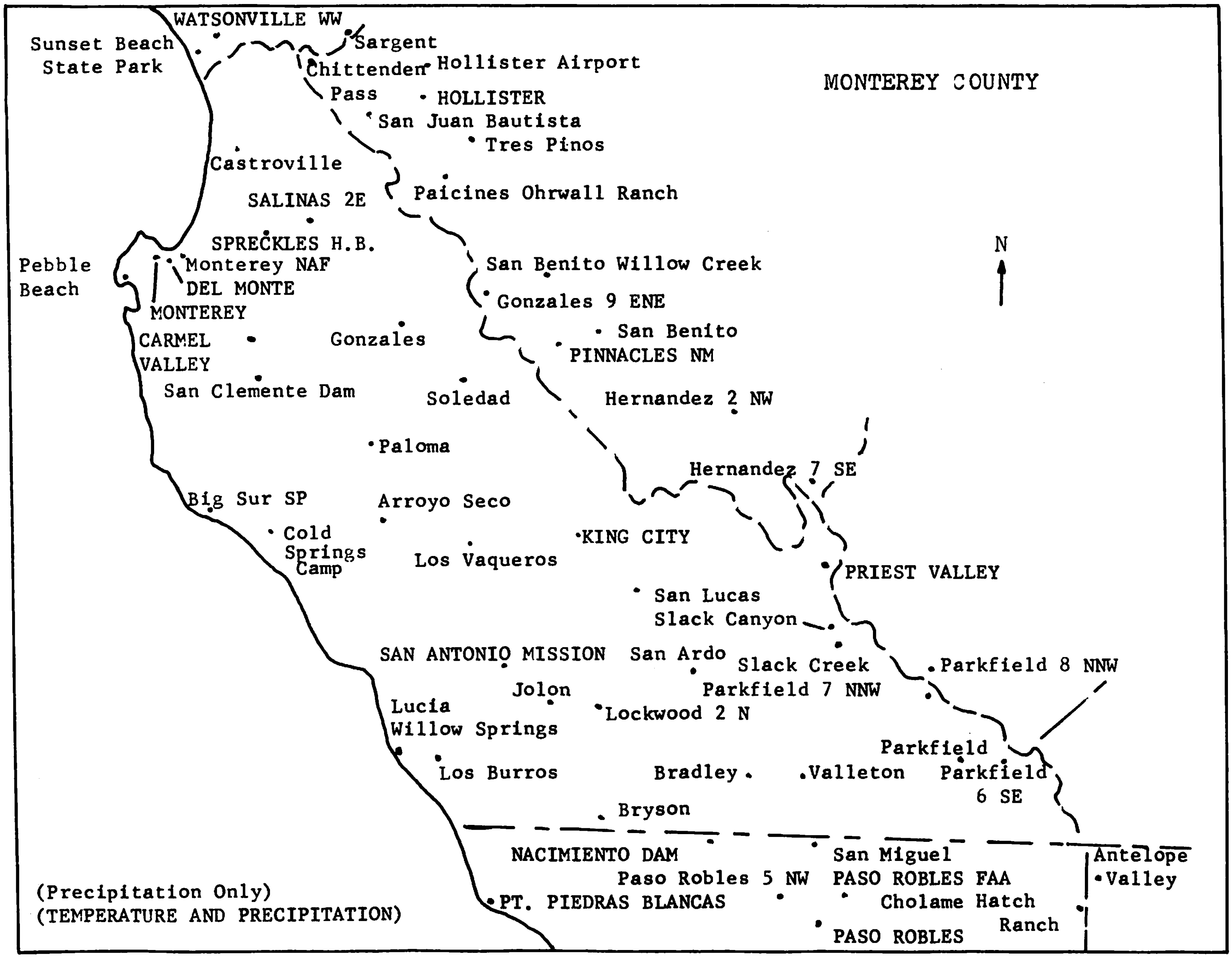


Figure 3 Weather reporting stations used in the Monterey County summary.
Stations are listed in Table 1, Appendix A.

[after Elford and Stilz, 1968]

Table I of Appendix A lists the weather reporting stations in the Monterey Bay area and includes their elevations, latitude and longitude, type of data, and length of record. All of the listed stations collect precipitation data, but none of them collect upper air data. In between these extremes are the stations which collect temperature, humidity, pressure, evaporation, and wind data. The closest upper air station is located at Oakland, Ca., some seventy miles to the north-northwest of Moss Landing. Figures 2 and 3 show the location of the stations used by Elford and Stilz in their 1967 and 1968 studies. Additional rain data are available from cooperating private citizens (as an example, in the Monterey Peninsula, forty to fifty have been taking observations since 1957 in cooperation with the US Naval Postgraduate School in Monterey) as well as from newly placed rain gages belonging to various governmental agencies. Air pollution is monitored in Santa Cruz, Monterey, Salinas, and in Gonzales by the Monterey-Santa Cruz Counties Unified Air Pollution Control District and in San Jose by the Bay Area Air Pollution Control District. Table II of Appendix A lists agencies which can be contacted for meteorological data indicated.

The general precipitation and temperature patterns have been depicted for Santa Cruz and Santa Clara counties as shown in Figures 4 and 5, and are tabulated for Monterey and most of San Benito counties. Table III of Appendix A is an example by Elford and Stilz [1967, 1968]. These general patterns demonstrate effects of terrain upon spatial distribution of meteorological parameters.

The National Weather Service does not maintain evaporation measurement stations in the Monterey Bay Area. The Monterey County Flood Control and Water Conservation District (in cooperation with the California Department of Water Resources) does: at Soledad Correctional Training Facility and at Salinas DeDampierre. Both of these stations use standard National Weather Service evaporation pans. The Moss Landing Marine Laboratories has recently started such measurements using Livingston porous porcelain atmometers. These data, in conjunction with surface wind, temperature, humidity, as well as pibal (upper air wind) data, will be useful for studying marine air penetration into the Salinas Valley with emphasis on seasonal variations. It should be noted that there are no meteorological stations permanently located in Monterey Bay nor in the twenty-mile-long coastal stretch of the Pacific Ocean which forms the western boundary of our study area.

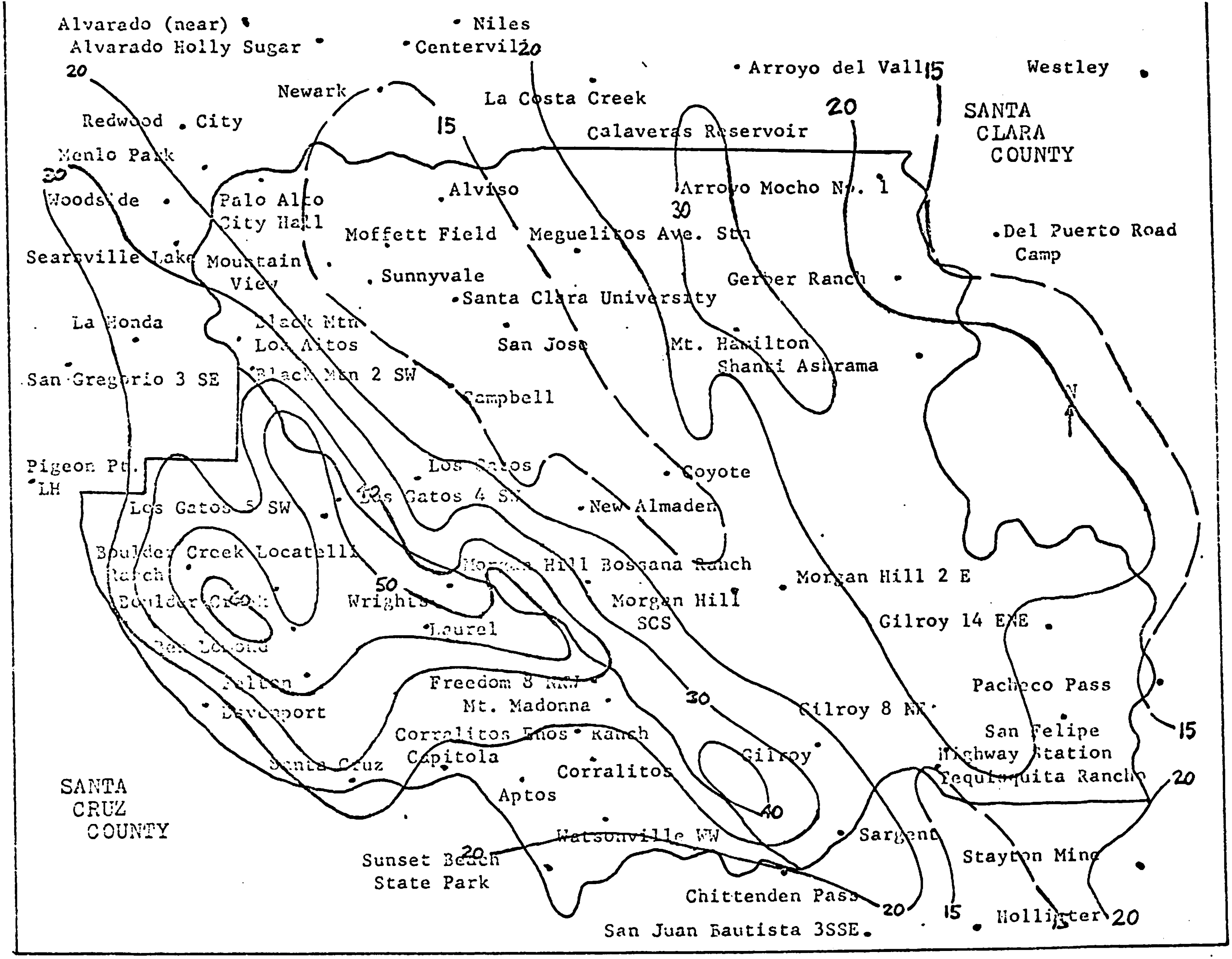


Figure 4 Average seasonal precipitation (inches) for the Santa Clara - Santa Cruz counties area.
[after Elford and Stilz, 1967]

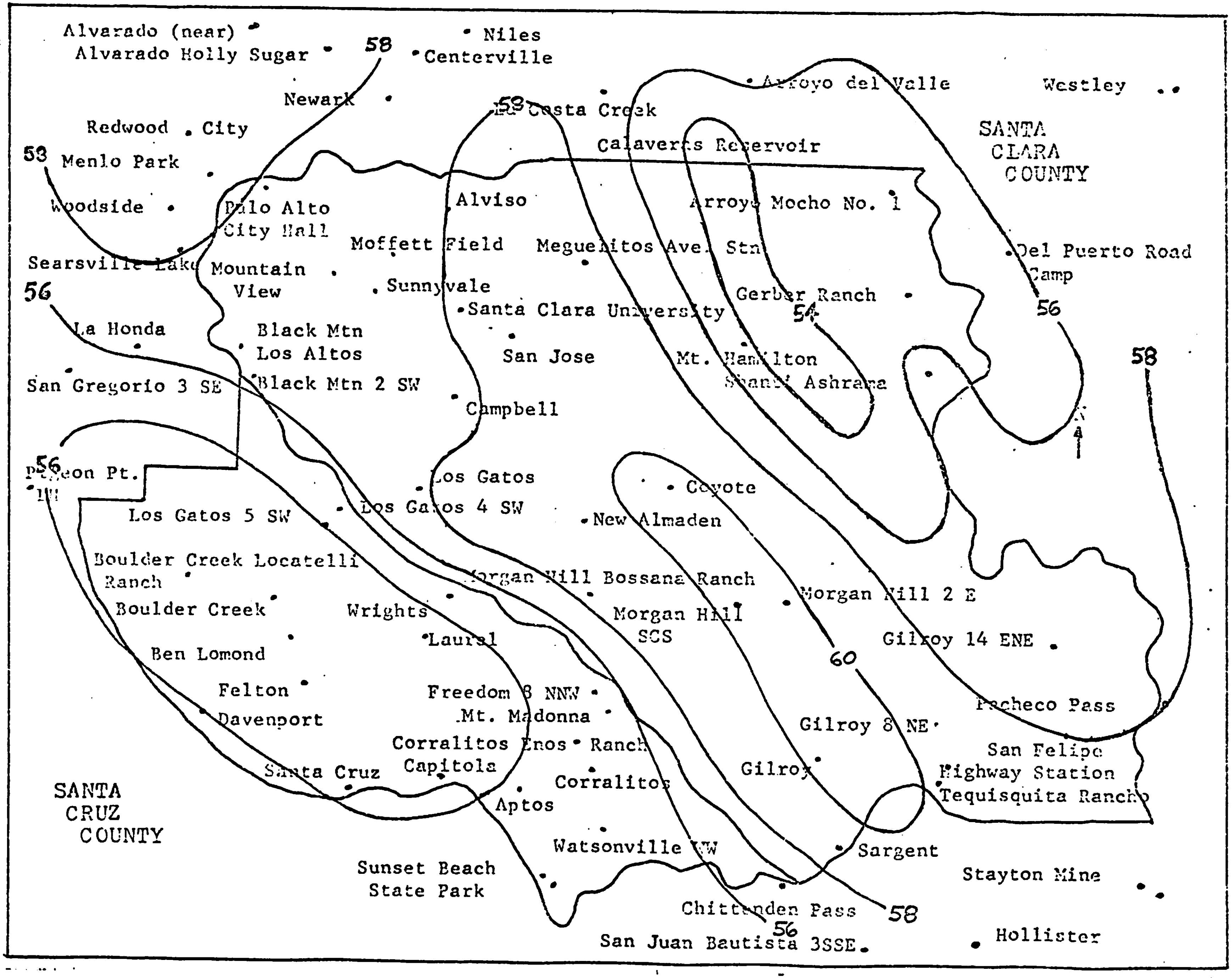


Figure 5 Average annual temperature (degrees Fahrenheit) for the Santa Clara - Santa Cruz counties area. [after Elford and Stilz, 1967]

B. Review of Monterey Bay Area Climatology

The following discussion of the climate of the Monterey Bay area follows the description given by Gilliam [1962] unless otherwise noted.

1. Spring climate

In the spring months, March, April, and May, the westerlies 1/* are greatly intensified as the days become longer and the temperature contrast between land and sea masses increases. In the San Joaquin Valley (also known as the great Central Valley) of California, a 500-mile-long basin surrounded by mountains, the sun-heated air rises strongly resulting in a lower pressure area. At the same time, over the Pacific Ocean the air in contact with the water is still cool, and therefore denser, resulting in a higher pressure area. The result of this differing pressure, i.e. of this onshore 2/ pressure gradient, is that the air from the high pressure area (cool maritime air) rushes to the low pressure area (warm inner valley air). March and April weather is highly variable as gusty winter days are followed by warm, hazy days. Along the coastline the battering of the winter storm waves is replaced by the quiet of gentle swells. The start of a sea breeze can be noted in early April. As the sun sufficiently heats the land to cause the surface air to warm and rise (creating an area of slightly lower pressure), the cooler air from the higher pressure area offshore moves in and clears the haze away during the afternoon.

The onshore winds are also intensified by the Pacific High 3/ as it migrates northward in spring to take a position a thousand miles or so west of the Monterey Bay area. Pushed from the rear by the Pacific High and pulled from the front by the heating of the Central Valley (and other warming inland regions), masses of air begin moving toward the continent with increasing speed. Since the Coriolis force 4/ causes winds to curve to the right, the winds are coming from the northwest by the time they reach the coast. The coastal mountain

* Numerals refer to Glossary, Appendix A.

ranges prevent their inland movement causing the winds to blow down the coast breaching the mountain barrier only where gaps, passes or open valleys (such as the Salinas Valley) permit tongues of ocean air to penetrate inland.

The great fog bank that hangs along most of the California coast intermittently during the late spring and the entire summer is formed when the westerlies (moist maritime air) come into contact with the streak of cold upwelled [5] waters along the coast. This fog bank ranges in height from a hundred feet to one-half mile and in width from a hundred yards to more than a hundred miles. The spring and summer fogs of this area are known as advection fogs since they are formed by the horizontal movement of air.

2. Summer climate

The forces that produce the fog and stratus (low clouds that can be thought of as fog not touching the ground) increase in intensity as summer approaches. The Pacific High moves farther north, closer to the latitude of Monterey Bay, sending out stronger winds. Offshore the upwelling increases and thereby the wind's moisture condenses into thicker masses of fog. In the Central Valley the northward moving sun sends temperatures to the 100°F mark and beyond. The hot air rises drawing cool masses of ocean air into the valleys. With the ocean air comes the fog, which evaporates gradually in the hot dry air of the interior valleys. When the valleys cool sufficiently, the entire fog-producing system breaks down and the coastline becomes fog free. The entire process then starts over again. With the wind and fog gone, the sun gradually reheats the valleys and the rising air brings in the marine air and the stratus is produced once again. This cycle takes place over about a week. There is also a daily cycle which takes place during the early stages of the weekly cycle when there is an equilibrium of the fog-producing forces. In the afternoons the stratus moves into the Salinas Valley (and other coastal valleys), spreads over a large area during the night, and is then burned off by the morning sun. The third type of fog cycle is seasonal; it begins in early spring. As the Pacific High grows stronger and the valley heat increases, the stratus penetrates farther inland and remains longer with each weekly cycle, reaching a maximum in August, then decreasing through September [Gilliam, 1962].

Because the Pacific High (or semipermanent Pacific Anticyclone), whose center reaches its northernmost point in July and August, is quite persistent in summer, cyclones (low pressure systems) rarely affect the California coast during this season. In addition to the dominant Pacific High, the west coast summertime circulation pattern is characterized by a thermal low pressure system extending from the Sonoran-Mojave Desert into the Central Valley. In July the typical onshore sea-level pressure gradient is of the order of three millibars per one hundred miles in the vicinity of San Francisco. During this same month the surface waters off San Francisco have a temperature of about 54°F compared to 57°F off Vancouver (more than 700 miles farther north) showing that the coastal upwelling is quite important in regulating the water temperatures in this area [Williams and DeMandel, 1966].

The sea breeze between the coast and Central Valley starts near the surface along the coast. Onshore breezes appear locally in late morning or early afternoon. As the afternoon progresses, the sea breeze layer intensifies and deepens while spreading inland and flowing over the lower coastal hills. (The sea breeze usually does not flow over terrain exceeding about 1500 feet due to the low elevation of the inversion [6/]. [Williams and DeMandel, 1966]

Because of the inversion lid of warm air above it, the foggy layer usually cannot rise and cool sufficiently to turn into rain, but occasionally a wet fog will be so thick as to deposit a measureable amount of moisture in rain gages. It is the steady drip from this moisture deposited on the leaves that provides water to nurture the redwood groves in the coastal canyons. The fog drip is normally the only kind of precipitation that reaches the California coast in the summertime. The rare summer shower that strikes the coast usually comes in from the south as an errant mass of warm, moist air moving northwest two thousand miles from the Gulf of Mexico, and perhaps accompanied by thunder and lightning. The summer fogs along the coast make the valleys opening on the ocean ideal for growing such cool-weather crops as artichokes and Brussels sprouts. The coastside areas of Santa Cruz and Monterey counties grow most of the artichokes raised in the United States. When the Pacific High and the prevailing westerlies fail to produce the normal fog, the sun beats down on the coastal valleys and the artichokes tend to dry out, with serious results for growers. [Gilliam, 1962]

3. Autumn climate

As autumn approaches, temperatures in the Central Valley steadily drop from around 100^{o}F into the 80's, and then the 70's as the days shorten. The Pacific Ocean reaches its annual maximum temperatures in early fall; however it absorbs the sun's heat far more slowly than does the land. As the Pacific High begins to move southward with the sun and ceases to send strong winds racing toward the coast, the Central Valley is no longer hot enough to bring air in through the coastal gaps (such as the Golden Gate and the Salinas Valley) as it did in midsummer. As the onshore winds die down, upwelling slows to a halt and the coastal fog bank dissipates resulting in sunny weather along the Monterey Bay coastline. The inversion layer of warm air that hung over the coastal regions during the summer now presses down lower as the winds die down. Below it the hazy surface layer of moisture-laden ocean air thins out to a depth of only a few hundred feet and the industrial and automobile air effluents mix with it to form smog. The first storms to strike the Monterey Bay area may come as early as September or October from the offshore areas of Mexico to the south or from the weakening Pacific High to the west. [Gilliam, 1962]

4. Winter climate

In the winter the Pacific High moves far enough to the south to permit transoceanic storms free access to the California coast. Often a series of storms will hit the coast in such close succession that the weather fails to clear between them. The principal herald of a storm is a change in wind direction accompanied by low cloudiness. The reason for the wind shift is the counterclockwise circulation of air around the low-pressure center of an approaching storm. As a low approaches from the ocean, the winds circling the low will come from a southerly direction (from the southwest if the storm center is approaching northern California, from the southeast when it is coming from the west or southwest). Winds from a southerly direction indicate that the storm has yet to reach its peak, while winds from a northerly or westerly direction indicate that the storm is on its way out. [Gilliam, 1962]

The rainfall pattern is more complicated than the summer fog pattern (which comes from the ocean and dissipates to the east) since the rain comes from several directions during the course of a single storm. Dry San Jose (13 inches average annual precipitation), in the center of the Santa Clara Valley and bounded by mountains on the south, east, and west, is in the "rain shadow" of these mountains, i.e. it is protected from the rain-bearing winds. In general then, the southern and western slopes of mountains receive more rain than the northerly or easterly slopes. Thus a valley open to the south (such as the San Lorenzo River Valley in Santa Cruz County) will be deluged, while a valley opening to the north (such as the Salinas Valley) will be relatively arid. [Gilliam, 1962] Indications are that there are more than 50 days per year, on the average, in parts of the Santa Cruz Mountains with 0.10 inches or more of precipitation. Thunderstorms are experienced about three times per year in the mountainous areas but only one or two days per year in the Santa Clara Valley. Precipitation intensities are greatest in the coastal mountains and generally decrease with distance from the ocean. [Elford and Stilz, 1967]

Winter temperatures are strongly influenced by a locality's position in relation to the ocean and nearby mountains. The ocean is a great moderator of temperatures since it varies in temperature only a few degrees from winter to summer. Consequently, it is significantly warmer than the land in winter (and cooler than the land in summer). As a result, winter west winds bring warmth from the ocean to the land. This coastal warmth is prevented from moving inland by successive ranges of hills, and each valley farther inland is colder.

As the nights lengthen, the earth and the air quickly lose their heat after sundown, radiating it outward. The coldest air accumulates in the lower areas farthest from the ocean. After the first winter rains, the cold air in these places absorbs moisture from the damp earth. In the cold hours before dawn the temperature sometimes drops so low that the moisture condenses into vapor forming radiation fogs. Usually these radiation fogs last only a few days and are then driven away by the resumption of the normal ocean breeze. Usually two or three times a winter the area comes under the influence of a polar air invasion from the Sierra (lasting for a few days) bringing clear and cold weather. [Gilliam, 1962]

C. Meteorological Data Collection Program, 1970-71

To increase and diversify weather data available for the Monterey Bay - Salinas Valley area, four sampling programs were begun by the Moss Landing Marine Laboratories during the past academic year. They consist of daily weather observations and pibal releases at the lab itself; weather observations taken on Monterey Bay in conjunction with the Sea Grant cruises; maintenance of permanent stations(at Moss Landing, Santa Cruz, and King City) established to obtain continuous traces of various meteorological parameters; and special studies in the Salinas Valley, of one to two days duration, to investigate the distribution of various parameters up the valley.

To obtain all of these data, many students, teaching assistants, and teachers participated in various aspects of the sampling programs. Daily weather observations at the Moss Landing Marine Laboratories involved members of the marine meteorology class and of the Monterey Bay section of the saturday research participation class, as well as Teaching Assistants Roger Hilaski and Arndt Lorenzen. The pibal release program had additional help from Teaching Assistants Gary McDonald, Richard Smith, and other interested observers.

Weather observations on Monterey Bay were conducted by Roger Hilaski and his Monterey Bay research participation team on saturday cruises and by Gary McDonald and Arndt Lorenzen on the tuesday cruises.

Establishment of permanent weather recording stations involved construction of the instrument shelters, placing them in the field, and changing the charts as needed. External cooperators who assisted the Moss Landing Marine Laboratories team with this program included John Hansen at Marello High School in Santa Cruz and Don Francis at Basic Vegetable Products, Inc. in King City.

Special short-term intensive studies in the Salinas Valley involved the marine meteorology class from Moss Landing Marine Laboratories and several San Jose College meteorology classes and their instructors. The US Naval Postgraduate School supplied a helicopter and crew, also a radiosonde team; and the Monterey-Santa Cruz Counties Unified Air Pollution Control District took some oxidant readings along the Salinas Valley on one of the field trips. All of these special Salinas Valley studies were under the general direction of Associate Professor Robert Read. Data gathered and instruments used were as follows:

1) The daily weather observations at Moss Landing Marine Laboratories were begun in October 1970 and included:

   a) cloud types, amounts, heights (comparison with charts)
   b) visibility and obstructions (comparison with charts)
   c) pressure (microbarograph)
   d) wet and dry bulb temperatures (sling psychrometer)
   e) surface wind direction and speed (aerovane)
   f) evaporation (black and white Livingston atmometers)
   g) precipitation (standard rain gage)

   The upper air winds (beginning in February 1971) were determined by means of a theodolite used to track a helium-filled 30-gram pilot balloon. These pibals were inflated to a buoyancy of 139 grams, released, and tracked by the theodolite. Elevation and azimuth angles were read and recorded every 30 seconds, and the data plotted to estimate wind velocities and direction at successive height intervals.

2) Generally, one weather observation was taken at each station during Sea Grant cruises on Monterey Bay. These observations included:

   a) cloud types, amounts, heights (comparison with charts)
   b) visibility and obstructions (charts, radar)
   c) pressure (aneroid barometer)
   d) wet and dry bulb temperatures (sling psychrometer)
   e) wind speed and direction (airmeter, compass, stopwatch)
   f) swell direction, height, period (compass, stopwatch)

3) Permanent recording stations were set up at:

a) Moss Landing Marine Laboratories, Moss Landing, Ca.
(Several years of incomplete data already were available.)

i) temperature, humidity, pressure (meteorograph)
ii) pressure (microbarograph)
iii) temperature, humidity (hygrothermograph)
iv) wind speed and direction (aerovane recorder)

b) Marello High School, Santa Cruz, Ca.
(started March 1971)

temperature, humidity, pressure (meteorograph)

c) Basic Vegetable Products, Inc., King City, Ca.
(started March 1971)

temperature, humidity, pressure (meteorograph)

The wind recorder at Moss Landing Marine Laboratories operates continuously for about one month; all of the other recording instruments mentioned above are on a weekly cycle. In addition to the above data, Gonzales Union High School, Gonzales, Ca., furnishes us with copies of their pressure, temperature, and humidity traces, and Pacific Gas and Electric Company provides copies of their Moss Landing power plant wind data.

4) Four special Salinas Valley field trips were organized to obtain the various meteorological data necessary to study the marine air intrusion up the valley. The data were collected hourly for ten to twelve hours on each study day - 7-8 November 1970, 27 March 1971, 6 April 1971, and 1-2 May 1971. These data included:

a) cloud types, amounts, heights (charts)
b) visibility and obstructions (charts)
c) pressure (aneroid barometer)
d) wet and dry bulb temperatures (sling psychrometer)
e) surface wind speed and direction (airmeter, compass, stopwatch)
f) evaporation (black and white Livingston atmometers)

At selected stations these additional data were collected:

g) upper air wind speed and direction (pibals, theodolite)
h) temperature and humidity soundings (helicopter, radiosondes)
i) condensation nuclei (nuclei counter)
j) oxidant concentration (oxidant meter)

In addition, a roving station was used to take the wet and dry bulb temperatures every two miles from Moss Landing to Soledad and back.

D. Data Reduction

The data collected during the four programs' duration were either used "as is" or were summarized or reduced to useable form as follows:

Temperature: The daily maximum and minimum temperatures were extracted from the meteorograph/hygrothermograph charts and plotted for a month at a time for each station.

Evaporation: The burette readings were multiplied by the appropriate coefficient (0.79 for all of our Livingston porous porcelain atmometers) so that the actual evaporation could be determined for comparison purposes.

Surface wind: A proper time interval was chosen to obtain the average wind speed direction from the continuous strip charts for every hour. These values were then tabulated for later analysis.

Upper air wind: A plotting board was used in the beginning to obtain the resultant wind field. This was found to be too time-consuming and not sufficiently accurate enough; therefore the process was computerized. The azimuth and elevation angles, recorded every thirty seconds during pibal runs, were punched on machine manageable cards, and then programmed to calculate wind speed and direction for each vertical point desired. San Jose State College's CDC 3300 was used to accomplish this.

E. Tentative Conclusions

Data from limited duration observations such as ours become most meaningful when combined with those collected by others over a longer time scale and wider area. An example of this is presented in Figure 6 which diagrams the current season's rainfall based on the data from many sources. Note that rainfall decreases with distance from Monterey Bay up the Salinas Valley.

Temperature data clearly demonstrate the moderating influence of the bay. Daily maximum temperatures generally increase with distance from the bay. (For example, Figure 7 charts the time period from 6-17 April 1971 for three locations: Moss Landing, on the bay; Salinas, 10 miles up-valley; and King City, 50 miles away.) Similarly, daily minimum temperature decreases with distance from the bay.

Our first six months of data suggest related seasonal evaporation trends. The average daily evaporation at Moss Landing Marine Laboratories (Figure 3) indicates that maximum evaporation occurs from February to April and then falls off as stratus overcast becomes a more common daily phenomenon with the advent of upwelling just off shore. Data taken on Sea Grant cruises have been compared with hydrographic data taken concurrently, but there are insufficient data at present for development of meteorological conclusions.

The Salinas Valley intensive studies have been reported separately by Professor Robert Read. His paper includes a discussion of the distribution of the upper air winds and the surface evaporation along the Salinas Valley gradient. Daily pibal data taken at Moss Landing are still in the process of analysis.

Collection and analysis of these meteorological data will continue throughout the coming year in order to support development of a climatological data base for the Monterey Bay region.

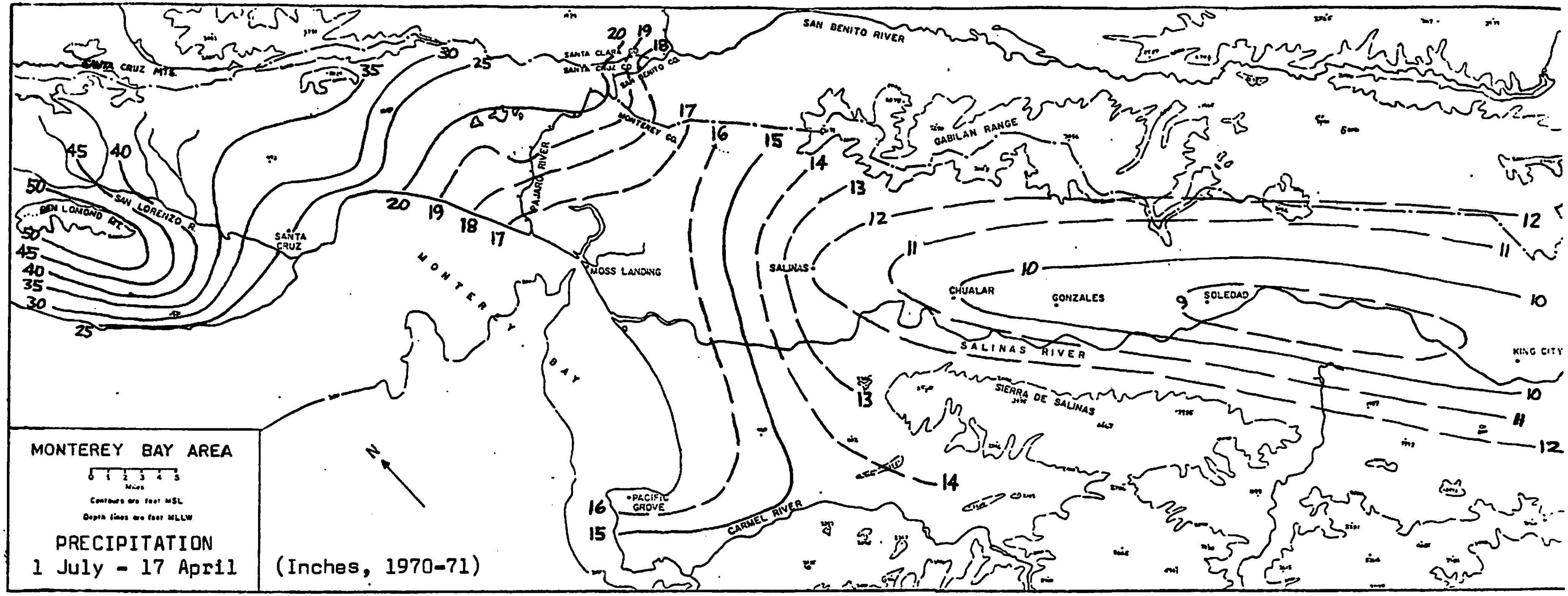


Figure 6 Precipitation (in inches) from 1 July 1970 to 17 April 1971 in the Monterey Bay area. Preliminary analysis based on data listed below.

Santa Cruz	26.45	Rio del Mar	23.33	Carmel	14.54
Bonny Doon	45.19	Day Valley	27.86	Carmel Valley	14.78
Davenport	25.07	Beach Road	17.35	Castroville	18.08
Soquel	22.49	Corralitos	23.85	Gonzales	9.44
Ben Lomond	39.00	Eureka Canyon	34.80	Greenfield	8.71
Capitola	22.15	Freedom	19.07	Harper Canyon	13.61
Aptos	30.29*	Watsonville	19.22	King City	9.18
Scotts Valley	34.39	Aromas	21.63	Monterey	16.61
Boulder Creek	47.42*	Chittenden	17.66	Salinas	12.07
Felton	40.12			Soledad	8.90
Swanton	32.00				
Mt. Hermon	37.86				
Cave Gulch	51.92				
courtesy <u>Santa Cruz Sentinel</u>		courtesy <u>Watsonville Pajaronian</u>		courtesy <u>Salinas Californian</u>	

Moss Landing 15.72#

* to 14 April

\# from 1 October
MLML

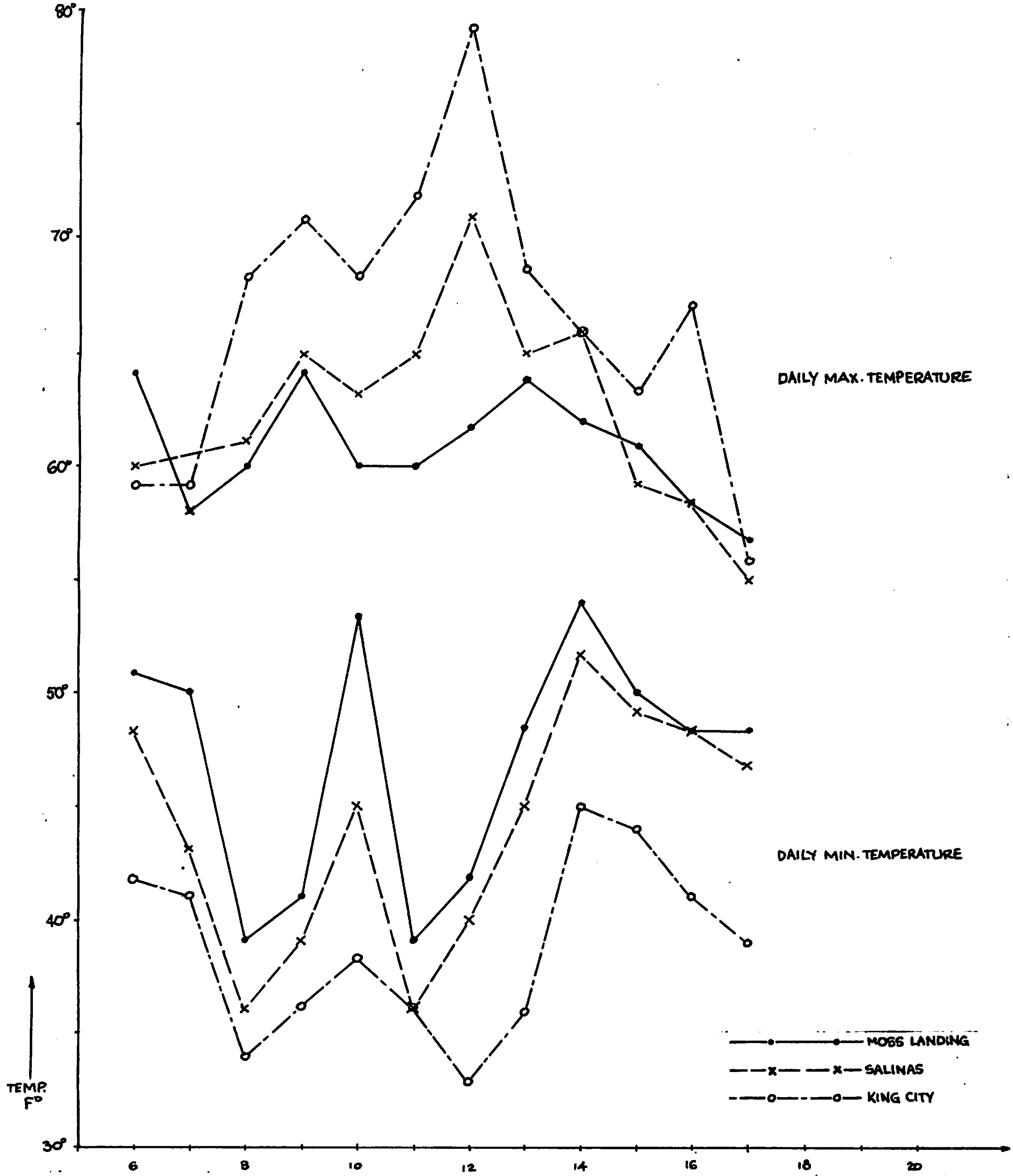


Figure 7 Comparisons of temperatures up the Salinas Valley from Moss Landing to King City during the period 6-17 April 1971.

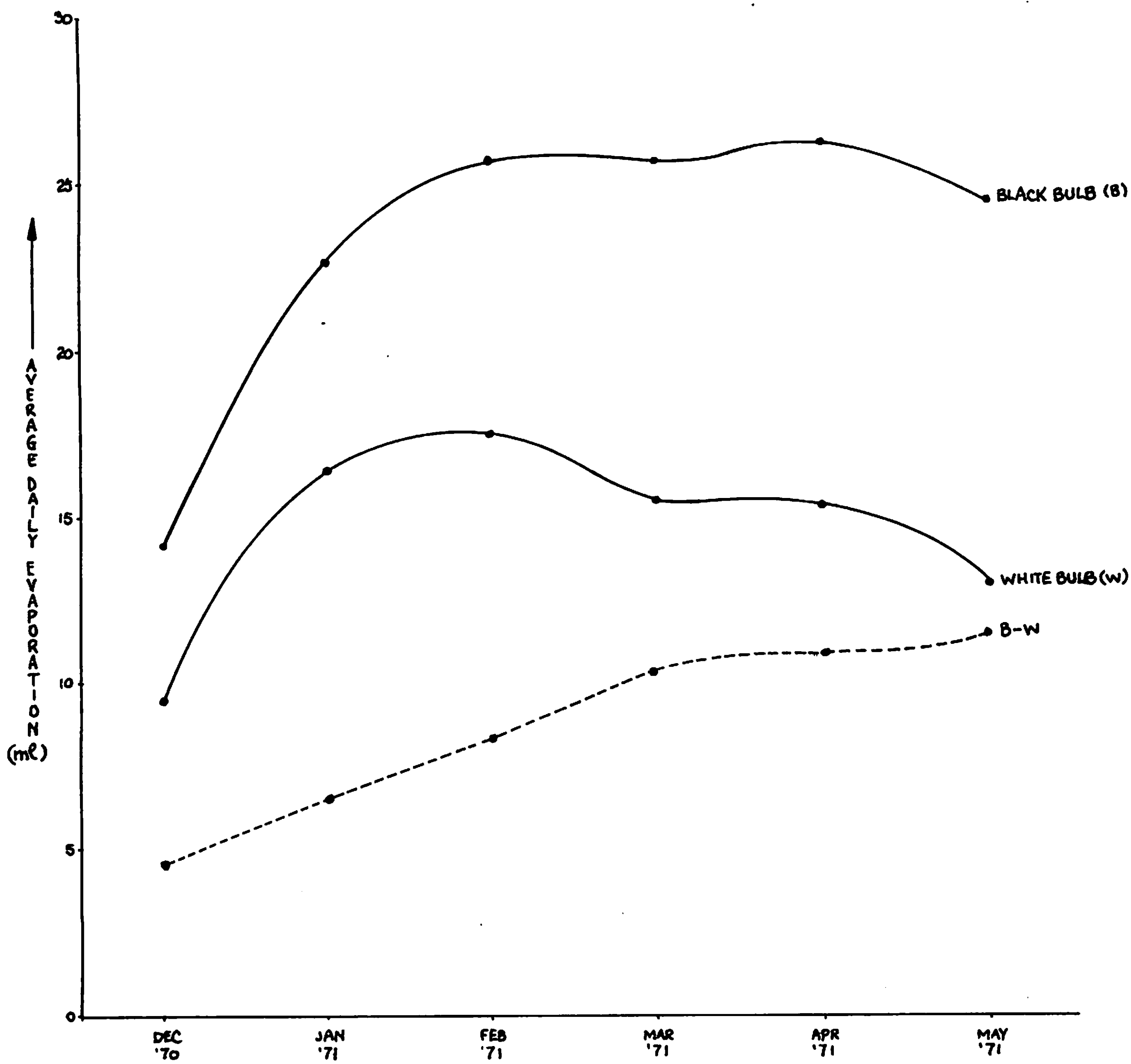


Figure 8 Average daily evaporation (in milliliters) from Livingston atmometers at Moss Landing Marine Laboratories, Moss Landing, Ca. from December 1970 to May 1971.

Notes

1) Daily data supporting these curves are maintained in the Moss Landing Marine Laboratories Sea Grant archives.

2) Atmometers are instruments designed to measure the capacity of the atmosphere to remove water from plants or other objects. When black and white bulbs are put outdoors side by side, a good reading of the radiant energy (especially sunlight) is obtained by subtracting the white reading from the black. Porous porcelain atmometers are discussed by Livingston [1935].

F. <u>References</u> (with some annotations)

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III. MONTEREY BAY

A. General Description

(Monterey Canyon and North Bay sectors are combined for this background review.)

Monterey Bay is California's second largest bay and is located about 70 miles south of San Francisco. (Center of the bay is approximately $36^{0}47'$ north latitude; $121^{0}54'$ west longitude.) Monterey Bay is shaped like a reversed C approximately 24 miles long, north to south, and 12 miles wide (Figure 9). Its seaward limit may be considered a line connecting the headlands from Table Rock, near Point Santa Cruz, to Cypress Point, on the Monterey Peninsula. Its maximum surface area is about 200 square miles [Yancey, 1968].

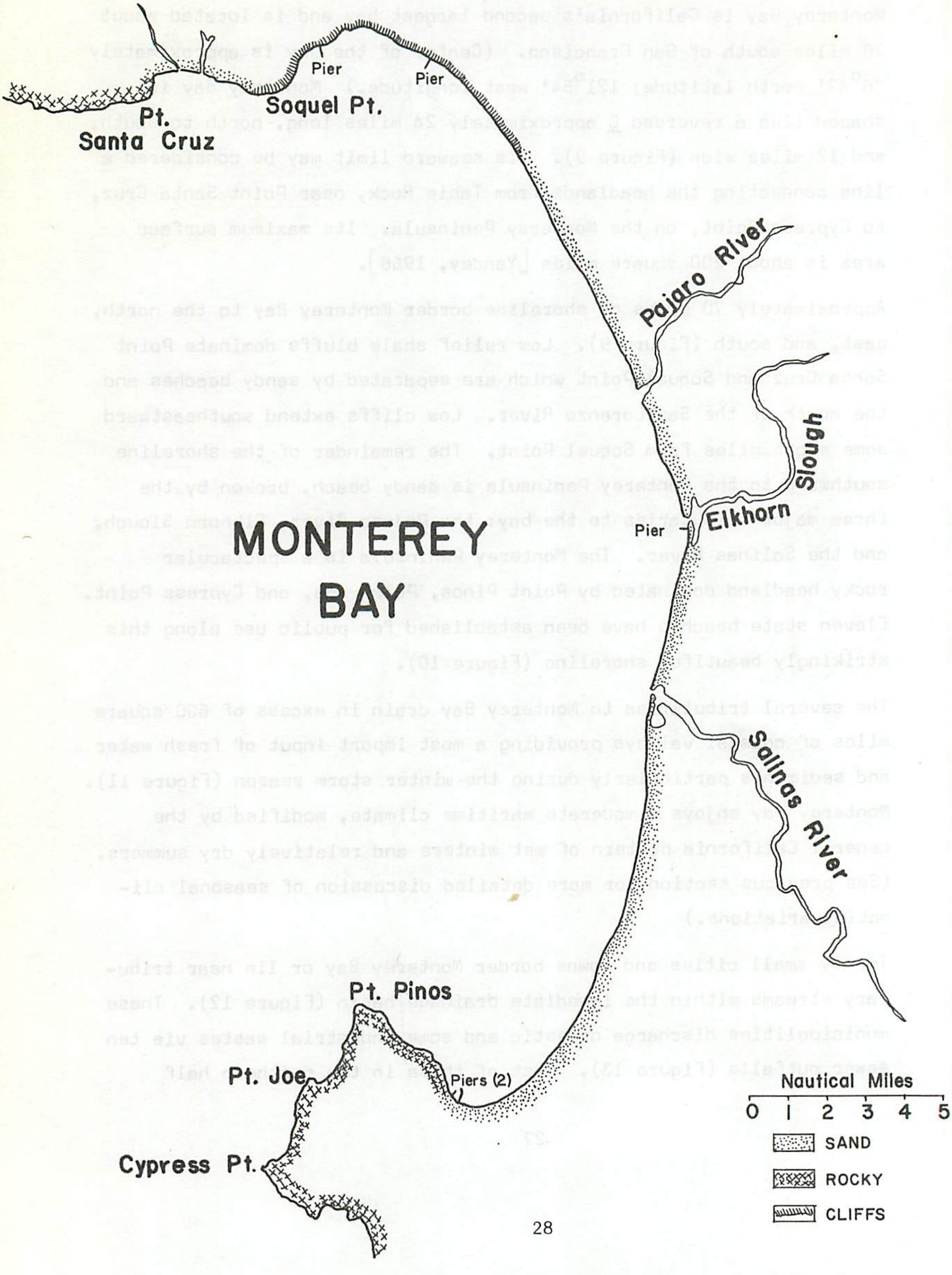
Approximately 70 miles of shoreline border Monterey Bay to the north, east, and south (Figure 9). Low relief shale bluffs dominate Point Santa Cruz and Soquel Point which are separated by sandy beaches and the mouth of the San Lorenzo River. Low cliffs extend southeastward some eight miles from Soquel Point. The remainder of the shoreline southward to the Monterey Peninsula is sandy beach, broken by the three major tributaries to the bay: the Pajaro River, Elkhorn Slough, and the Salinas River. The Monterey Peninsula is a spectacular rocky headland dominated by Point Pinos, Point Joe, and Cypress Point. Eleven state beaches have been established for public use along this strikingly beautiful shoreline (Figure 10).

The several tributaries to Monterey Bay drain in excess of 600 square miles of coastal valleys providing a most import input of fresh water and sediments particularly during the winter storm season (Figure 11). Monterey Bay enjoys a moderate maritime climate, modified by the general California pattern of wet winters and relatively dry summers. (See previous section for more detailed discussion of seasonal climatic variations.)

Twenty small cities and towns border Monterey Bay or lie near tributary streams within the immediate drainage basin (Figure 12). These municipalities discharge domestic and some industrial wastes via ten sewer outfalls (Figure 13). Most of these in the northern half

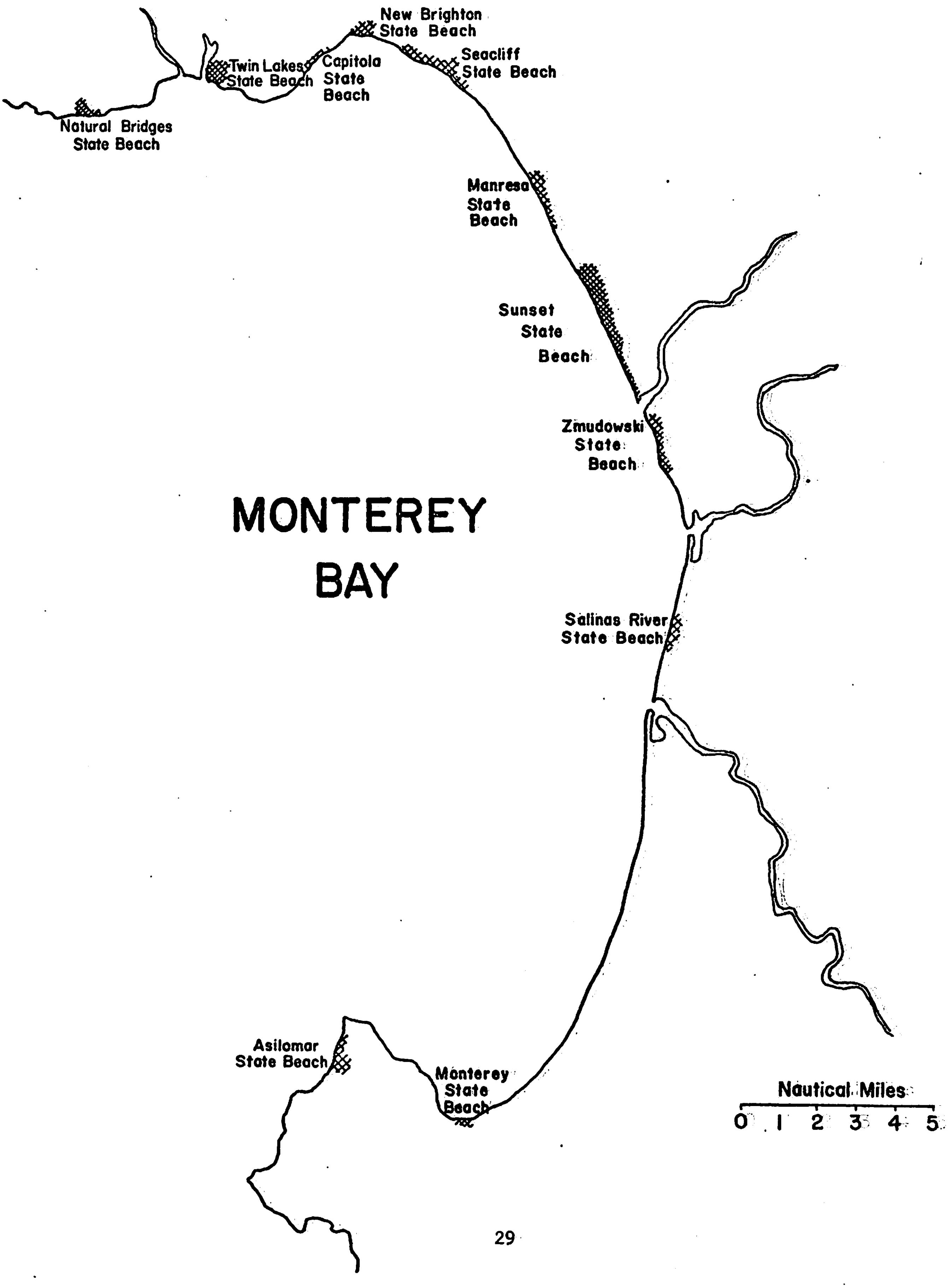
SHORELINE FEATURES

Figure 9



STATE BEACHES AND PARKS

Figure 10



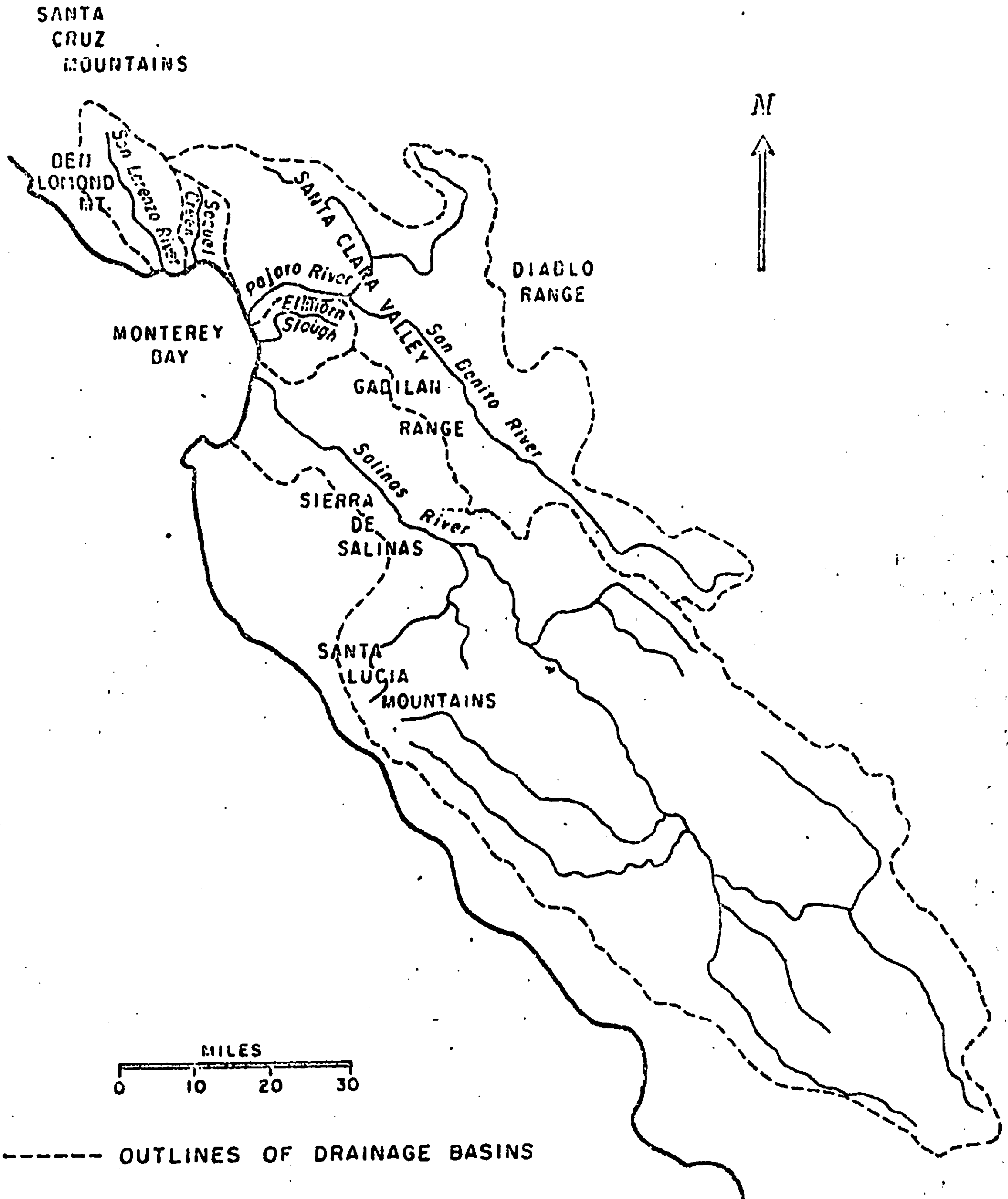
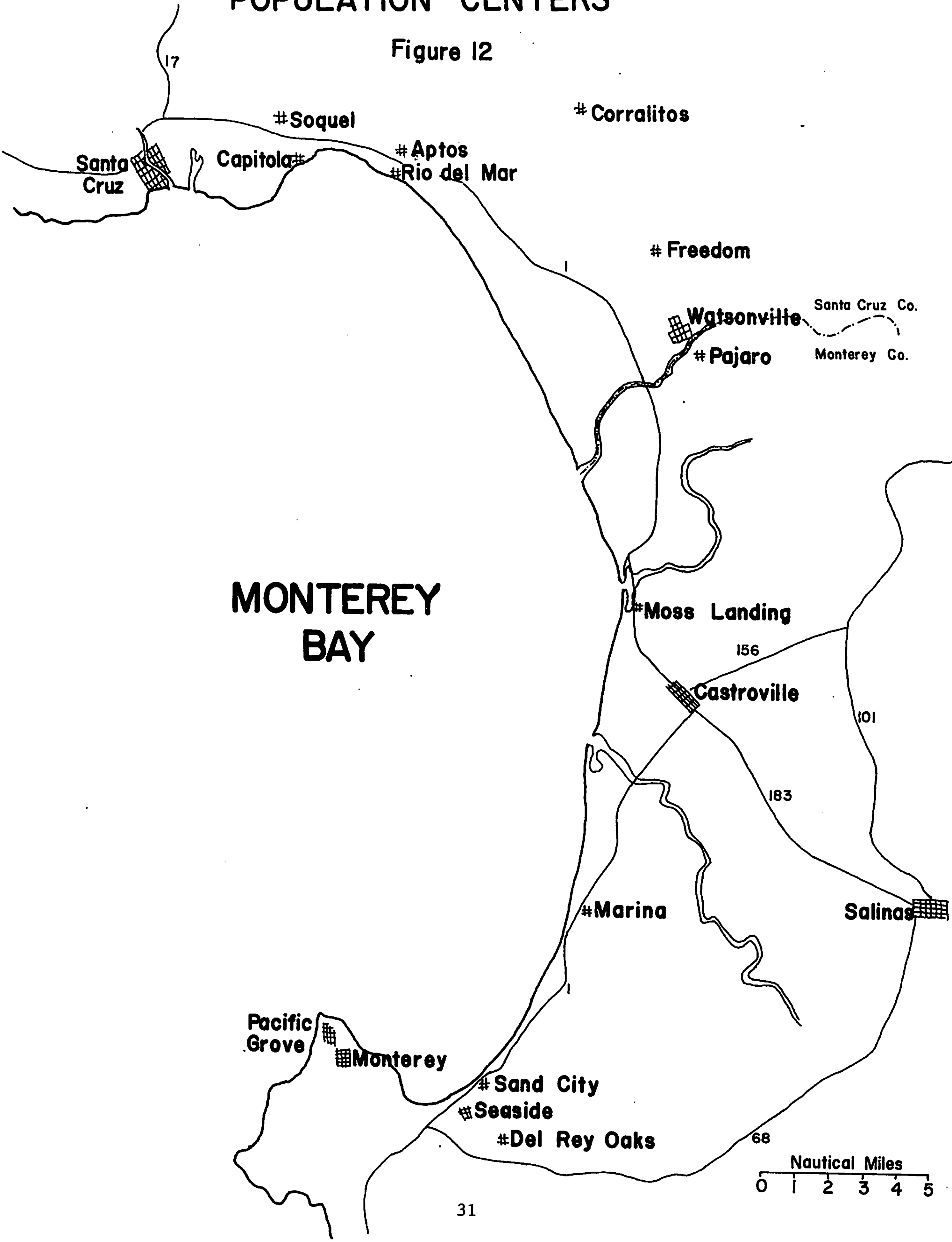


Figure 11. DRAINAGE BASINS AND MOUNTAIN RANGES ADJACENT TO MONTEREY BAY

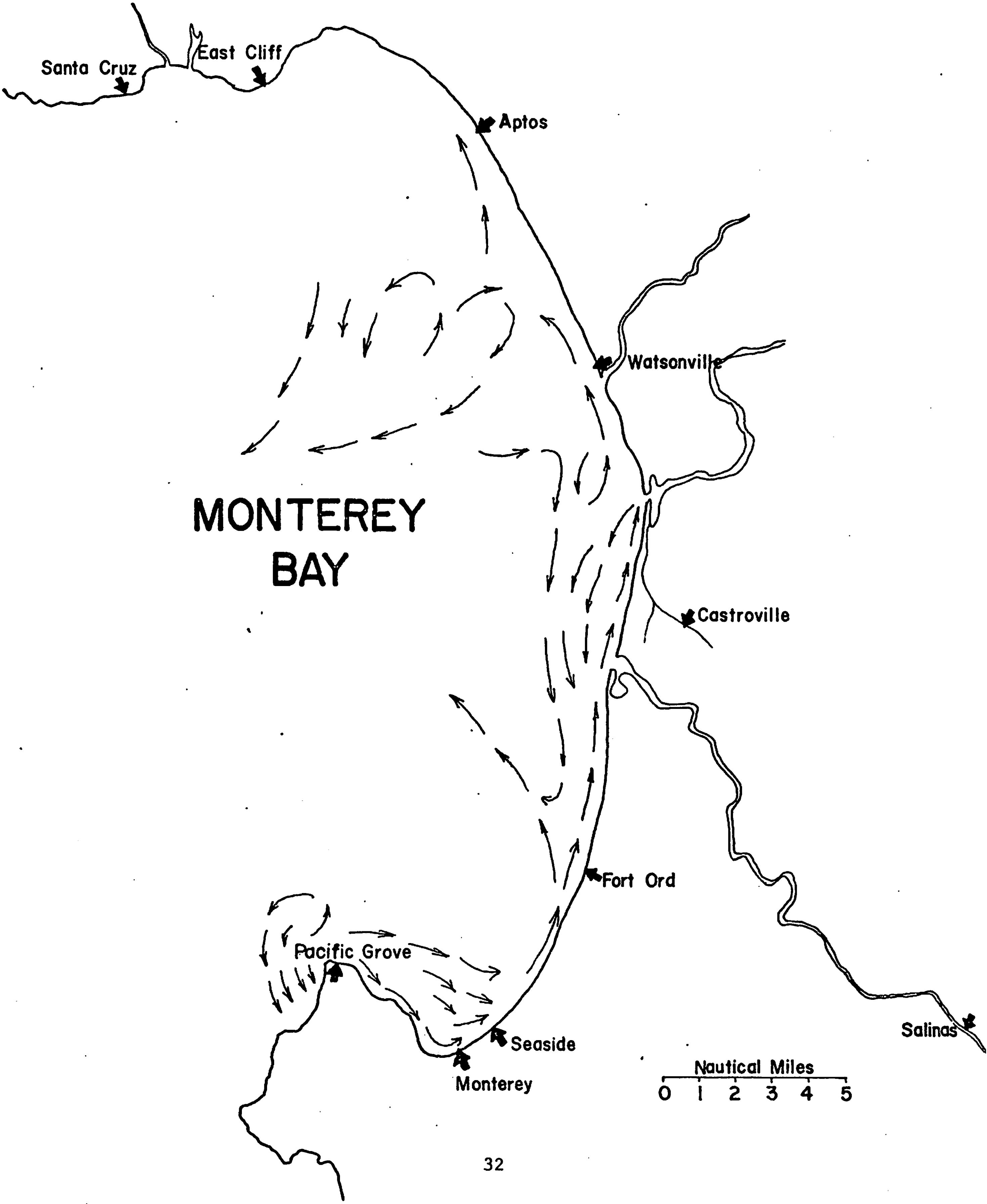
POPULATION CENTERS

Figure 12



SEWAGE TREATMENT PLANT OUTFALLS AND NEARSHORE CURRENTS

Figure 13



of the bay undergo primary treatment only; those in the southern bay are subjected to secondary treatment. All systems have bypasses used during flood periods or in event of mechanical failures in the treatment plants. These ten outfalls release a total of about 31 million gallons a day, of which 23 million gallons are discharged directly into Monterey Bay [Wong, 1970].

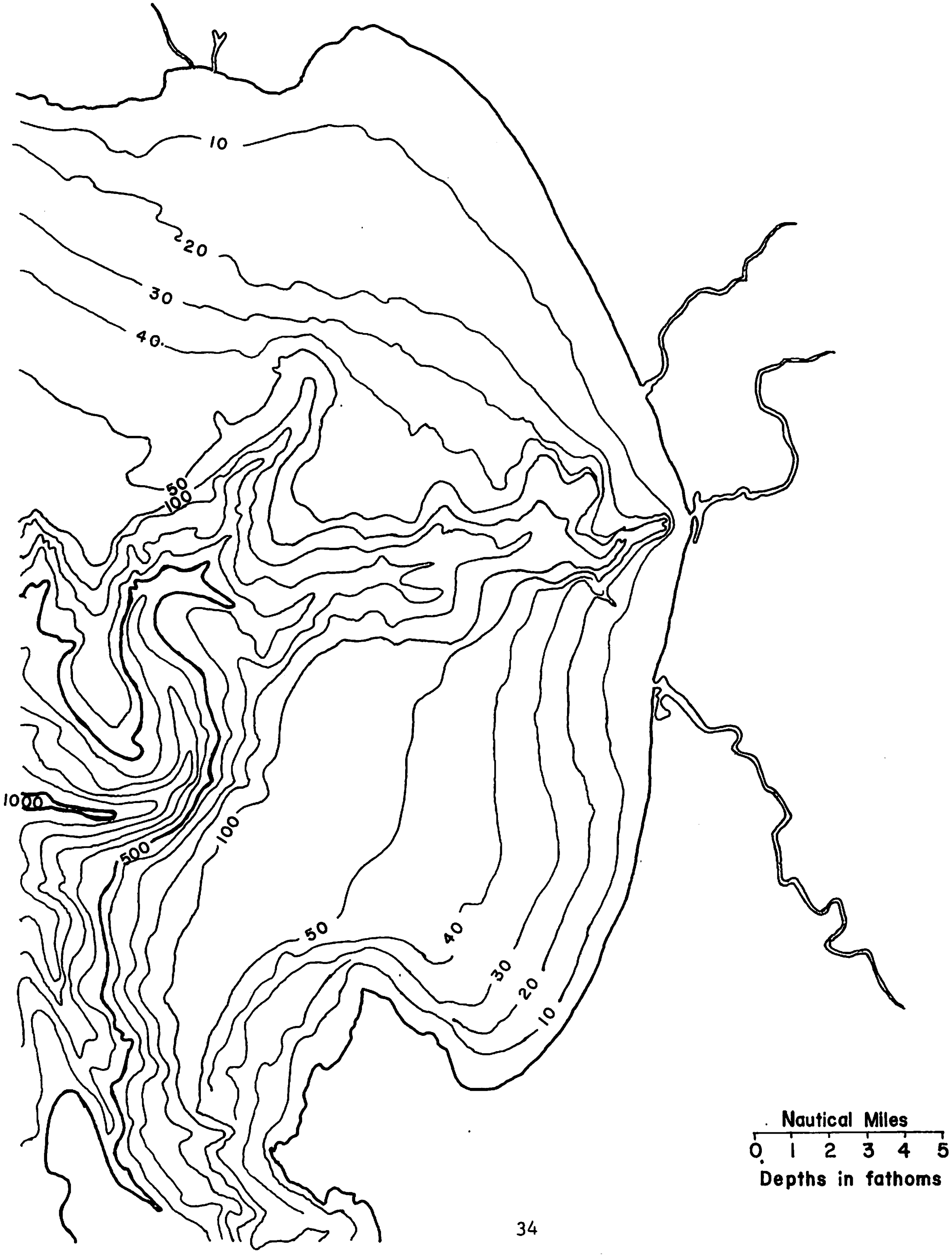
Monterey Bay is relatively shallow nearshore sloping off gradually toward the west with a great canyon bisecting its center from east to west (Figure 14). The mainland shelf is widest along the Santa Cruz and Monterey sides of Monterey Bay; the 100-fathom contour is 10 miles offshore from Santa Cruz. Submerged shale reefs are found from Capitola northward, and granite reefs are found offshore from Pacific Grove southward [Odemar, et al, 1968].

Certainly the most prominent geological feature of Monterey Bay is the Monterey Submarine Canyon. It is the deepest and largest canyon along the west coast of North America, and one of the largest in the world. Deep, steep, V-shaped walls mark the Monterey canyon and its two primary sub-canyons. The main canyon originates just outside the breaker zone at Moss Landing; a highly unusual feature as most submarine canyons start well offshore. The Soquel Canyon is a northern branch originating about five nautical miles offshore just outside the 40-fathom curve (Figure 14). The Carmel Canyon joins the Monterey canyon from the south outside of Monterey Bay proper.

Monterey Submarine Canyon begins at a depth of approximately 18 meters and continues at a very steep gradient (125 m/km). At a depth of 910 meters the gradient is reduced to 20 m/km. At an axial depth of 1920 meters the canyon floor becomes much broader, ultimately having a flattened floor with a width of approximately one mile. Despite the flattened floor of the lower canyon, the steep walls continue to an axial depth of 2925 meters. At this point the true canyon ends, 51 miles from the head of the canyon [Shepard and Dill, 1966].

Bathymetry of Monterey Bay

Figure 14



Surface sediments within Monterey Bay occur in three widespread bands aligned with the submarine contours. The outermost band lies on the outer edge of the continental shelf and varies from 1 to 3 miles in width. It is predominantly of coarse grained silts, including some cobbles, and is a relict deposit of the Pleistocene age. The middle band is 3 to 4 miles wide on the middle continental shelf and grades abruptly into the outer band. This middle band is of very fine grained sands and occurs in water depths between 150 and 300 feet. The inner band is of coarse and medium grained sands [Wolf, 1968; Yancey, 1968]. (See Figure 15 [after Galliher, 1932].)

The sediments in the Monterey canyon may be characterized as sand, mostly fine sand, with an abundance of silt and some clay. Medium to coarse sand is found very near shore at the head of the canyon; while further out the canyon there is a rapid decrease in the sand content of the sediment. In the outer part of the canyon the material is largely silts with some sand and clay. Dredgings along the walls of the canyon have shown presence of numerous rock outcroppings. Rock types found include sandstone, siltstone, limestone, and biotitic granite [Cohee, 1938; Monteath, 1965].

The age and origin of the Monterey Submarine Canyon is a matter of some discussion among geologists. However, there is general agreement that the present canyon had its beginnings during the Pleistocene age. The exact process by which the canyon was formed is unknown. Some evidence indicates that the present submarine canyon originated by the fluming out of an ancestral canyon which had been filled with marine sediments [Starke, 1968]. Others believe the present canyon may have originated through faulting or by sub-areal erosion at a time when the rivers of the San Joaquin Valley were thought to have drained through Elkhorn Slough [Martin, 1964; Shepard and Emery, 1941]. Probably the actual origin is quite complex and involves a combination of these theories, and other yet unknown factors.

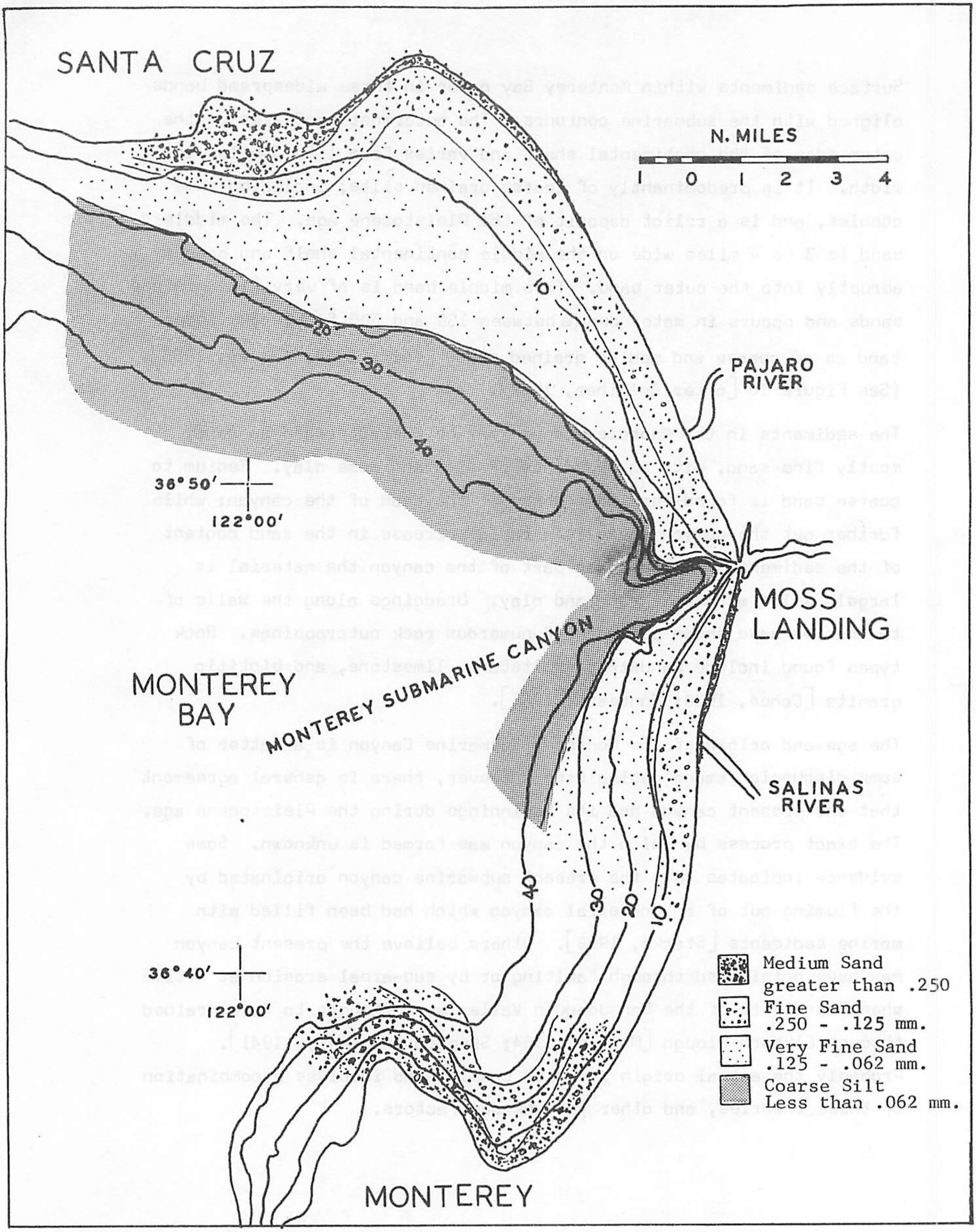


FIGURE 15. Sediments of Monterey Bay. Grain size distribution of surface sediments based on median diameter. (After Galliher, 1932)

B. Hydrology of the Monterey Bay Area

The California Current System is a part of the great clockwise circulation of the North Pacific Ocean. At high latitudes the waters move eastward under the influence of the strong westerly winds, and near the coast of North America these waters divide into two branches. The smaller component turns northward into the Gulf of Alaska, and the larger turns southeastward to become the California Current. The water which is brought south by the California Current System is cooler than the waters farther offshore [Reid, Roden and Wyllie, 1957]. It becomes warmer as it moves south due to insolation and to mixing with warmer waters from the west.

The California Current varies considerably in pattern from year to year. For example, in 1949 this current meandered far more, was narrower and stronger in the offshore area, and set up more intense eddies than it did in 1952. As a corollary, the countercurrent, which flows northward along the coast inshore, also was stronger in 1949 than in 1952 [CalCOFI,* 1953].

In Monterey Bay, which is well exposed to the ocean, water temperature appears to be largely controlled by the oceanographic conditions off coastal California [CalCOFI, 1953]. During the late fall and early winter, water surface temperatures in the Monterey Bay area average 11^{o} or 12^{o}C. These are constant for several months along long stretches of the coast. No distinct thermocline is present during this period; the temperature decreases evenly and very gradually with increasing depth, water of 9^{o} or 10^{o}C being characteristic at a depth of 300 feet (Figure 16).

From early March until August, upwelled water appears replacing surface waters moved offshore by prevailing offshore winds. During this period the temperature of the surface waters varies considerably from week to week, and even from day to day. With the advance of summer the surface layers are slowly warmed until temperatures of 15^{o} or 16^{o}C, or even higher, are common over shallow areas, and a marked thermocline develops (Figure 17). The prevailing temperature at 300 feet during the time of upwelling is 8^{o}C.

* California Cooperative Oceanic Fisheries Investigations

Rarely as early as April, but usually by July, warm water appears at the surface in the bay. As the season progresses the effects are felt in the deeper waters as well. Often in September, and even in August and October, warm water is replaced for short periods of time by colder water (Figure 18). During these times when warm water conditions are best developed, any temperature depressions that do occur are of minor magnitude. However, the variations appear over very short distances, especially on sides of headlands where small patches of the previously predominant water exists as unflushed residues. This non-upwelling period is normally characterized by temperatures of 14^{o} or $15^{o}C$ at the surface and $10^{o}C$ at a depth of 300 feet (Figure 19). The thermocline is usually not strongly developed, except early in the season.

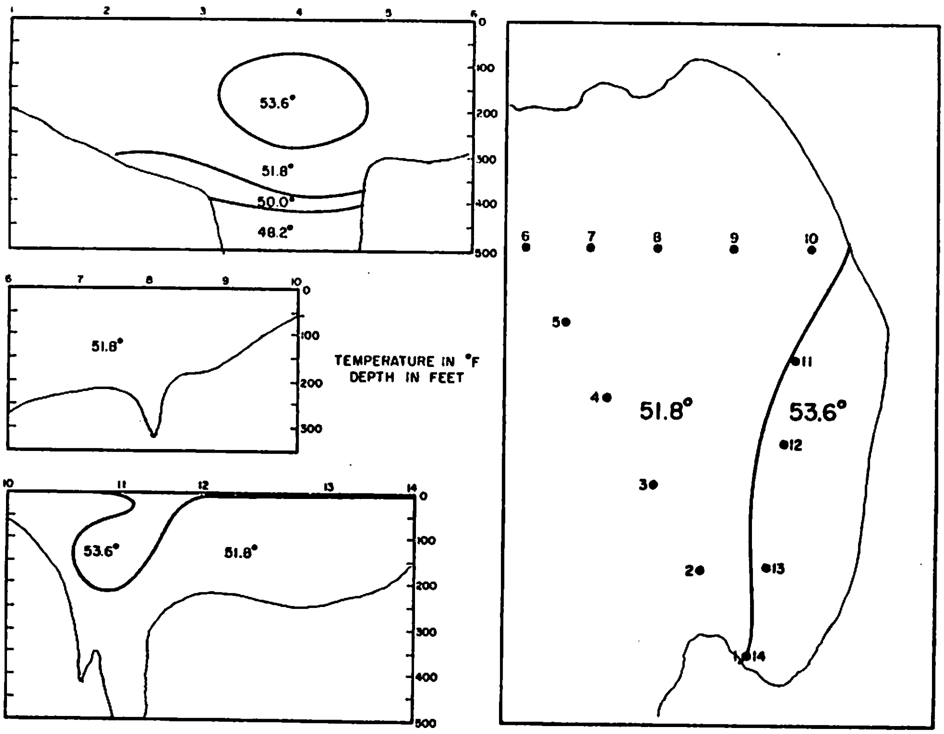


Figure 16. Late fall and early winter conditions, Monterey Bay. Note that no distinct thermocline is present. Water of 9° C (approximately 51° F) is characteristic at a depth of 300 ft. (from CalCOFI report, 1953)

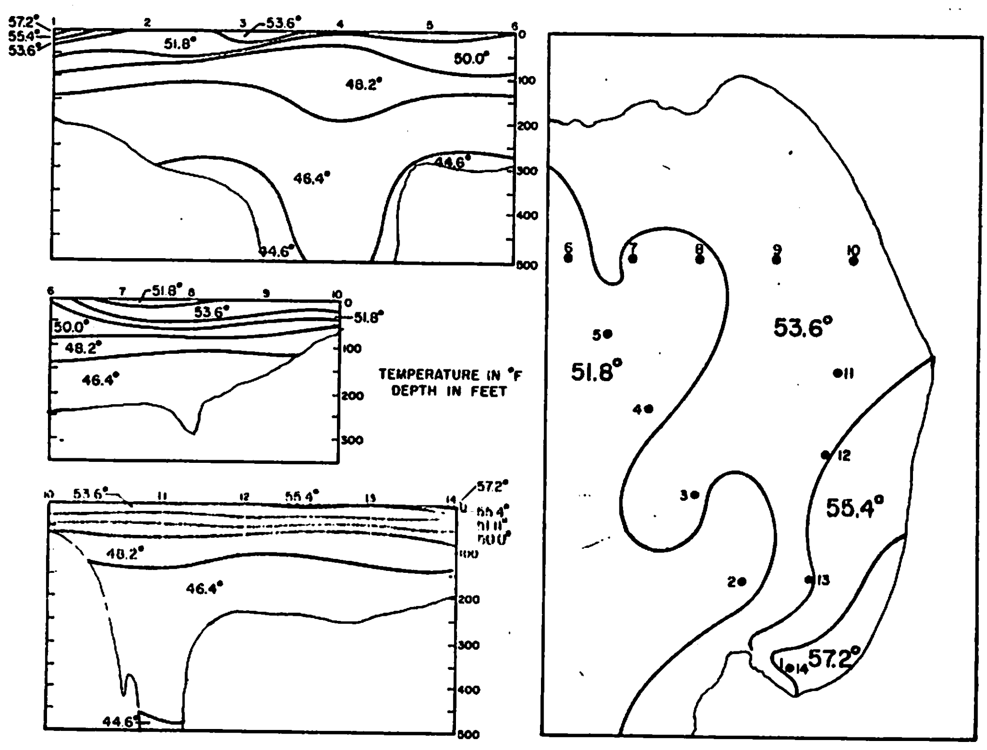


Figure 17. Summer conditions, Monterey Bay. Prevailing temperatures at 300 ft during this time are lower than during late fall and early winter (compare to Figure 16 above) (CalCOFI 1953)

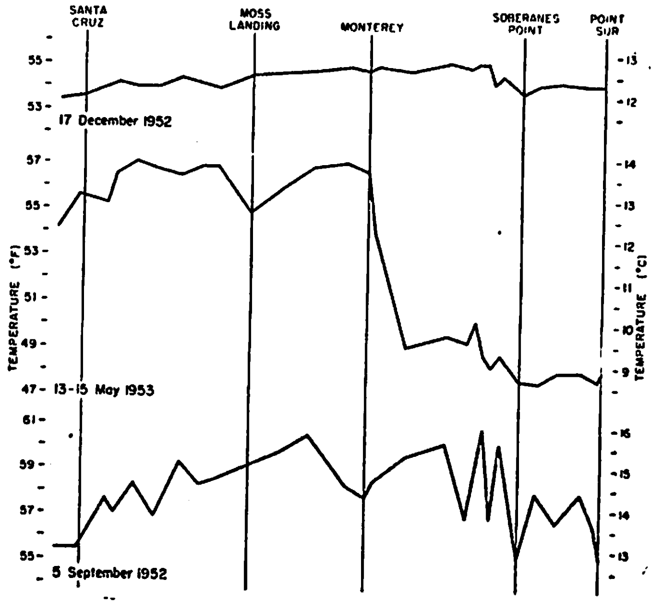


Figure 18. Surface ocean water temperature in the vicinity of Monterey at three seasons of the year. (from CalCOFI report, 1953)

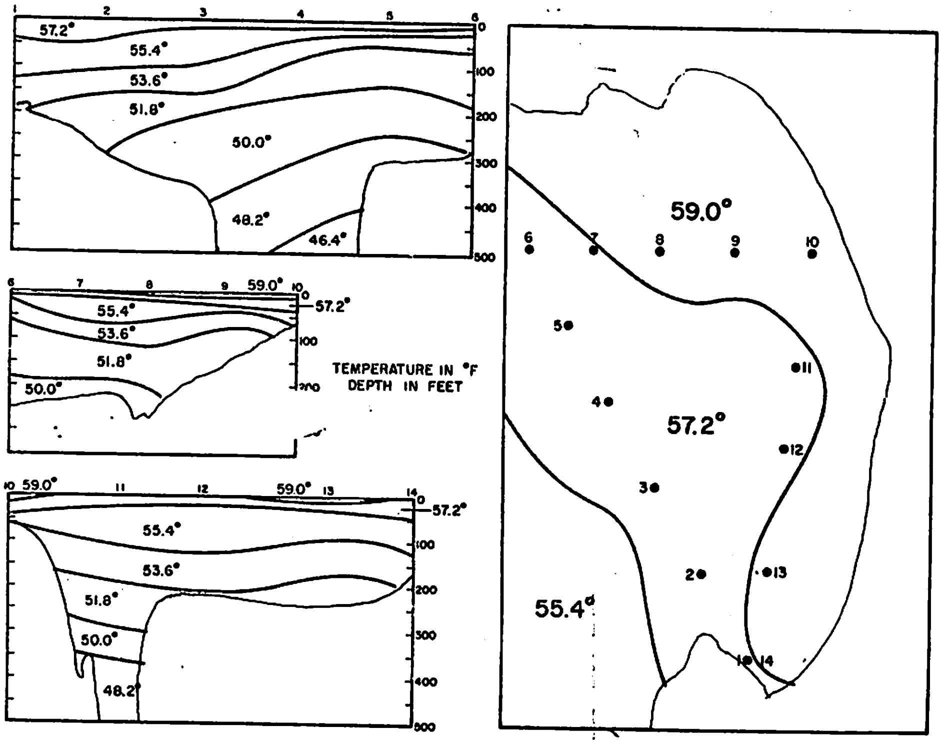


Figure 19. Summer upwelling period in Monterey Bay. Conditions normally characterized by comparatively warm waters at surface and at depth. (from CalCOFI report, 1953)

C. Monterey Bay Fisheries

1. Commercial fisheries

There are three major types of commercial fishing in the Monterey Bay area: trawl, troll, and roundhaul. The otter trawl is the most commonly used type of trawl in this area and the types of fish taken are primarily bottom fish, including rockfish, Dover sole, English sole, rex sole, sand sole, sanddabs, and California halibut. The trolling method is used in the salmon and albacore fisheries. The roundhaul fishery primarily uses small seines and lampara nets; the major species taken by this method are anchovy and squid. Principal species in the commercial fisheries are described briefly below [see also Frey, 1971].

Salmon (Oncorhynchus spp.)

The king and silver salmon fishery is one of the state's most valuable fisheries, ranking second only to California's extensive tuna fisheries. Salmon are generally taken at depths of from 5 to 30 fathoms. May is the month of peak landing in Monterey Bay.

Dover sole (Microstomus pacificus)

The Dover sole fishery is primarily a deep water fishery, with most of the catch taken at depths between 290 and 360 fathoms.

The Monterey Bay area contributes only a small portion of the state's total Dover sole catch. Between 1961 and 1965 the period of greatest catch in this area extended from May through September.

English sole (Parophrys vetulus)

The English sole is one of the more desirable of the trawl-caught flatfishes. Between 1961 and 1965 the peak catches occurred during August and October in the Monterey Bay area. Catches generally occurred in depths of from 40 to 50 fathoms, but high catches were recorded as deep as 130 fathoms.

Petrale sole (Eopsetta jordani)

This species is another of the highly desirable flatfishes taken by trawling. High catches are made off Moss Landing in 40 to 50 fathoms of water, and moderate catches are made southwest of Santa Cruz in 30 to 50 fathoms of water.

The Monterey area produced highest catches during August and September, and March through May in the years 1961 to 1965.

Rockfish (Sebastes spp.)

Fifty-one species of rockfish are found along the California coast [Phillips, 1968]. Five of these species are of importance to commercial fisheries: bocaccio, chilipepper, splitnose, widow, and speckled rockfishes.

Monterey Bay is the largest rockfish producing area in the state accounting for 27% of California's rockfish landings.

Sablefish (Anoplopoma fimbria)

The sablefish ranges from northern Baja California northward to Alaska and forms the basis of a moderate but important fishery from California to Alaska. The sablefish is not extensively fished south of Monterey [Phillips, 1968]. Monterey Bay averaged 331 thousand pounds per year between 1962 and 1966.

Lingcod (Ophiodon elongatus)

The lingcod ranges from northern Baja California to northwestern Alaska and is a moderately important California commercial species. Monterey area landings have averaged 127,593 pounds during the years 1957 to 1966.

Pacific sardine (Sardinops caeruleus)

Prior to 1945 there was an extensive sardine fishery in the Monterey Bay. Since the 1945-46 season, the Monterey fishery declined to a fraction of its former magnitude. On June 7, 1967 a moratorium on sardine fishing became law. The law allows 15% or less, by weight, of sardines to be taken incidentally with other fish.

Northern anchovy (*Engraulis mordax*)

Fishing gear employed by anchovy fishermen in Monterey Bay consists of lampara or purse seine roundhaul nets. The lamparas are ineffective when fished in water exceeding 20 fathoms deep. Months of greatest catch generally extend from May through July.

The commercial anchovy catch is utilized for live and cut bait in both sport and commercial fisheries, as fresh market fish, for reduction into meal and oil, for canning for both human consumption and pet food, and for fish food in state trout hatcheries.

Market crab (*Cancer magister*)

The commercial fishery for market crab extends from Alaska to Avila Beach, California. Market crab landings in the Monterey area are insignificant, when compared to the more productive San Francisco - Bodega Bay area, contributing an average of only 33 thousand pounds annually between 1957 and 1966. The small landings made in the Monterey area are very likely due to the fact that Monterey is located near the southern distributional limit of the market crab where the crab population is relatively sparse.

Squid (*Loligo opalescens*)

Highly productive fisheries for the squid occur in central and southern California. In the 10-year period from 1957 through 1966 annual Monterey landings ranged from 2.2 million to over 14.2 million pounds, averaging 7.8 million pounds annually. These accounted for 61% of California's commercial squid landings. The magnitude of the squid landings in Monterey Bay to date has been limited by the size of the market rather than the size of the population available to the fishery.

Historically, fishing gear for squid in Monterey Bay has consisted of several types of roundhaul nets. Recently, however, California's commercial fishing regulations limit gear used to take squid in the southernmost portion of Monterey Bay to lampara nets. This gear is generally fished to a maximum depth of about 20 fathoms. Peak fishing generally occurs from May through August. The commercial market includes fresh, canned and frozen squid for both domestic use and export to foreign markets.

2. Sport fisheries

Salmon (*Oncorhynchus* spp.)

Salmon rank number one as the most prestigeous and sought-after of our ocean game fish in central California. Monterey accounted for 2.8% of all California party boat salmon landings in the years 1962 to 1966. The Monterey area has averaged 2,157 salmon annually in the same period of years.

Lingcod (*Ophiodon elongatus*)

The lingcod is the bottom fishing anglers' most prized catch. This fish ranked number one in weight during the 1957 to 1961 survey [Miller and Gotshall, 1965]. Lingcod are found principally in rocky reef areas from shallow depths to depths in excess of 330 feet. The area off Monterey and Carmel is one of the most productive areas in the state for lingcod.

Rockfish (*Sebastes* spp.)

Rockfish are the mainstay of the "bottom fishing" party boats. The areas off Monterey - Carmel and off Santa Cruz are some of the most productive areas in the state.

Clam digging

Pismo clams are taken along beaches in Monterey Bay from Rio del Mar to the Salinas River. Counts of clam diggers have shown as many as 1500 present at one time along the beaches from Rio del Mar to the Salinas River.

Horsenecks, Washingtons, and geoducks are taken in Elkhorn Slough.

Appendix B provides detailed statistics on fish landings for the Monterey Bay area, mostly from Odemar, et al, 1968. That reference may be consulted for additional data.

D. Mammals of Monterey Bay

Following is a list of mammals commonly seen in Monterey Bay. These animals may be permanent residents or may appear on a seasonal basis.

Enhydra lutris	Sea otter
Zalophus californicus	California sea lion
Eumetopias jubata	Steller sea lion
Phoca vitulina	Harbor seal
Mirounga angustirostris	Northern elephant seal
Callorhinus ursinus	Northern fur seal
Delphinus delphis bairdi	Common or Baird dolphin
Phocoenoides dalli	Dall porpoise
Phocoena phocena	Harbor porpoise
Lagenorhynchus obliquidens	White-sided dolphin
Eschrichtius gibbosus	California gray whale
Balaenoptera physalus	Fin whale
Megaptera novaeangliae	Humpback whale
Orcinus orca	Killer whale
Balaenoptera acutorostrata	Minke whale
Kogia breviceps	Pygmy sperm whale
Balaenoptera borealis	Sei whale
Physeter catadon	Sperm whale

E. Monterey Canyon Sector Studies, February-June 1971
(Gary McDonald, Graduate Teaching Assistant)

1. Data collection

Data were collected for the purpose of determining seasonal, small scale effects of upwelling at the head of the Monterey Submarine Canyon as well as the changes resulting from sewage outfalls and the influx from the Pajaro and Salinas rivers. Nonconservative tracers (e.g. dissolved phosphate, nitrate, silicate, etc.) and conservative tracers (e.g. temperature and salinity) are being used to determine the relationship of circulation in Monterey Bay to upwelling episodes and to the discharge from sewage outfalls and rivers.

In the central bay area eight stations were occupied on each of four monthly cruises during February to May 1971; during the same period five stations were occupied in the north bay on each of four monthly cruises. Stations in the central bay area are located over the Monterey Submarine Canyon and near the mouths of the Pajaro and Salinas rivers (Figure 20; also see Progress Report July 1970-February 1971, Appendix C7-9, for detailed description of stations). Stations in the north bay are located from the Pajaro River mouth northward to Santa Cruz Harbor. Standard oceanographic sampling depths were used at all stations (e.g. 0, 5, and 10 meters on shallow stations and 0, 10, 20, 30, 50, 75, 100, 150, and 200 meters on deeper stations) with sampling as near the bottom as feasible. Similar water chemistry programs carried out in Elkhorn Slough and the Pajaro River are described elsewhere in this report.

2. Analysis techniques

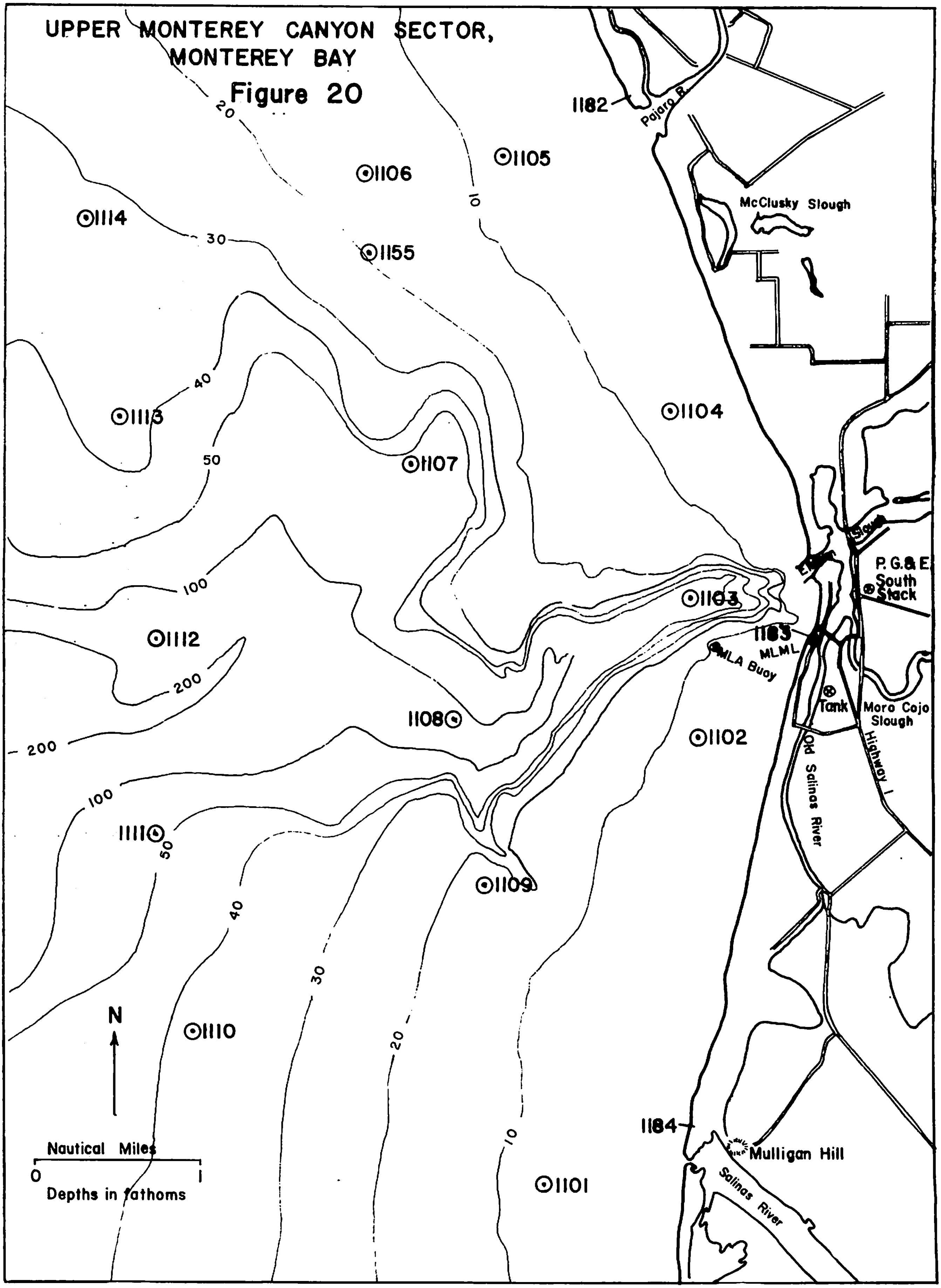
The Moss Landing Marine Laboratories chemistry laboratory was fully equipped to make the analyses outlined below. Water sampling techniques and laboratory chemical analyses adopted are those considered best by our faculty for non-automated operations. Table I provides a synopsis of numbers of hydrographic observations for all sectors of the Sea Grant program. The laboratory was set up in such a way that student research assistants enrolled in the research participation class could carry out the analyses under the supervision of the chemical technician.

TABLE I

Synopsis of Sea Grant Hydrographic Observations Indicating Number of Samples for Each Factor

Area	MONTEREY BAY	ELKHORN SLOUGH	PAJARO RIVER	TOTALS
Cruises	14	9	7	30
Stations Occupied	69	146	37	252
Depths Sampled	447	259	81	787
Temperature	288	237	72	597
Salinity	259	256	63	578
O_2	255	254	58	567
PO_4	301	213	48	562
NO_3	301	213	48	562
NO_2	301	213	48	562
NH_3	255	193	48	496
SiO_2	256	213	48	517
Chlorophyll	297	79	--	376

Hydrographic casts were made using 5-liter plastic Niskin bottles equipped with reversing thermometers. Sampling depths were determined by wire angle measurements and unprotected thermometer readings. Salinities were determined with a Beckman Instruments induction salinometer, using Eau de Mer Normale as the standard. Salinity samples were stored for 1 to 2 weeks in tightly stoppered citrate of magnesia bottles prior to analysis. Oxygen determinations were made immediately after each cruise using a slight further modification of Carpenter's [1965] modification of the Winkler method. Water for nutrient chemistry was routinely filtered aboard ship with glass fiber filters, then quick-frozen on board the vessel and kept frozen at $-10^{\circ}C$ for up to one month before analysis. Reactive phosphorous was determined by the method of Riley and Murphy [1962], reactive silicate by Strickland and Parsons' [1968] modification of Mullin and Riley's [1955] method, nitrate by the method of Wood, Armstrong, and Richards [1967], and nitrate by a slight modification of the method of Bendschneider



UPPER MONTEREY CANYON SECTOR,
MONTEREY BAY
Figure 20
1182
Pajaro R.
McClusky Slough
1105
1106
1114
1155
1113
1104
1107
1103
1183
MLML
MLA Buoy
P.G.&E.
South
Stack
Tank
Moro Cojo
Slough
1112
1108
1102
Old Salinas River
Highway 1
1111
1109
1110
N
1184
Mulligan Hill
Salinas River
Nautical Miles
0
1
Depths in fathoms
1101
10
20
30
40
50
100
200

and Robinson [1952]. The method of Solórzano [1969] was slightly modified for ammonia determination.

Detailed instruction sheets have been developed for each of these laboratory analysis techniques. Copies may be obtained if desired from Mr. David Seielstad, Oceanographic Technician, Moss Landing Marine Laboratories.

3. Results

With only four month's data it is not yet possible to form conclusions regarding the circulation in the study area, the fate of the materials released into this area, or the relation between the circulation and the biota. As a first step toward accomplishing these goals, the data are being assembled into a data report, the first of which will be issued at the completion of 12 months of sampling. This data report will consist of tabular data and an atlas of figures illustrating these results.

Our preliminary results show the strong influence of localized sources of nutrient-rich waters near sewage outfalls and the effects of upwelling at the head of Monterey Submarine Canyon. With the beginning of the first upwelling episode in March we observed the expected nutrient enrichment of the surface water over the head of the canyon and, unexpectedly, a simultaneous decrease in the nutrient concentrations in the northern bay near Santa Cruz. During this upwelling period, the surface waters in the northern bay may have been displaced out of the bay by the relatively nutrient-poor surface waters previously located over the head of the canyon, or the nutrient concentrations in the northern bay waters may have been decreased by rapid phytoplankton growth. Further observations will be required to resolve this question.

These first months of work have shown that the sampling design is proper (within practical logistic limitations) and that it will be worthwhile to continue this progam. These first studies also have demonstrated the need to determine tidally influenced changes at the head of Monterey canyon since these tend to obscure the results of our necessarily non-synoptic, one-ship hydrographic cruises. An investigation of these tidal changes is planned for the summer of 1971. The sampling program will be changed slightly to incorporate plankton work and hydrographic sampling into single cruises.

Research participants involved in the Monterey Submarine Canyon area were: Jim Koch, B.A. Otis, Chris Richard, Sherm Seelinger, Dev Texiera, and Dave Thomas, all senior or graduate students at the Moss Landing Marine Laboratories.

Cruises in the Monterey canyon sector were on the following dates:

16 February	Hydrographic cruise
9 March	Biological cruise
16 March	Hydrographic cruise
13 April	Hydrographic cruise
4 May	Biological cruise
11 May	Hydrographic cruise

F. North Monterey Bay Area Sector Studies, February-June 1971
(Roger Hilaski, Graduate Teaching Assistant)

1. Organization of data collection team

In the first four months of base line data collection, the north Monterey Bay team successfully completed four hydrographic cruises and two biological cruises, surveyed five selected beaches, and reduced the data from each of these components. This team included one senior biology student, one graduate engineering student, and four public high school science teachers engaged in the program for in-service training purposes. They were:

Stephen Clark	Teacher Monterey High School	Monterey
Jim Grady	Graduate Engineering Student	San Francisco
Stephen Pace	Senior Biology Student	Moss Landing
Pauline Sinclair	Teacher Salinas Junior High School	Salinas
Mike Weesner	Teacher Monterey High School, and Assistant to the Principal	Monterey
John Whisler	Teacher Monterey High School	Monterey

The team's performance was excellent in every respect. Members worked with a maximum of efficiency and minimum of error even under the trying conditions of often rough seas on the cruises. All research activities in the field and laboratory were carried out on saturdays.

The team was originally subdivided into two groups of three individuals each. We found this to be the most workable number in the field and in the laboratory. Each group completed an assignment for the particular day. Assignments were changed weekly so that by the end of the term each team member had participated in all phases of data collection and analysis. Separation into two groups became less definite by mid-term due to considerable overlapping of activities and some trading of assignments to accomodate individual needs and preferences. A true team evolved with very effective interaction.

2. Hydrographic data collection

Hydrographic sampling and analysis followed a four-week cycle commencing with each hydrographic cruise. Cruise dates were:

20 February
20 March
17 April
15 May

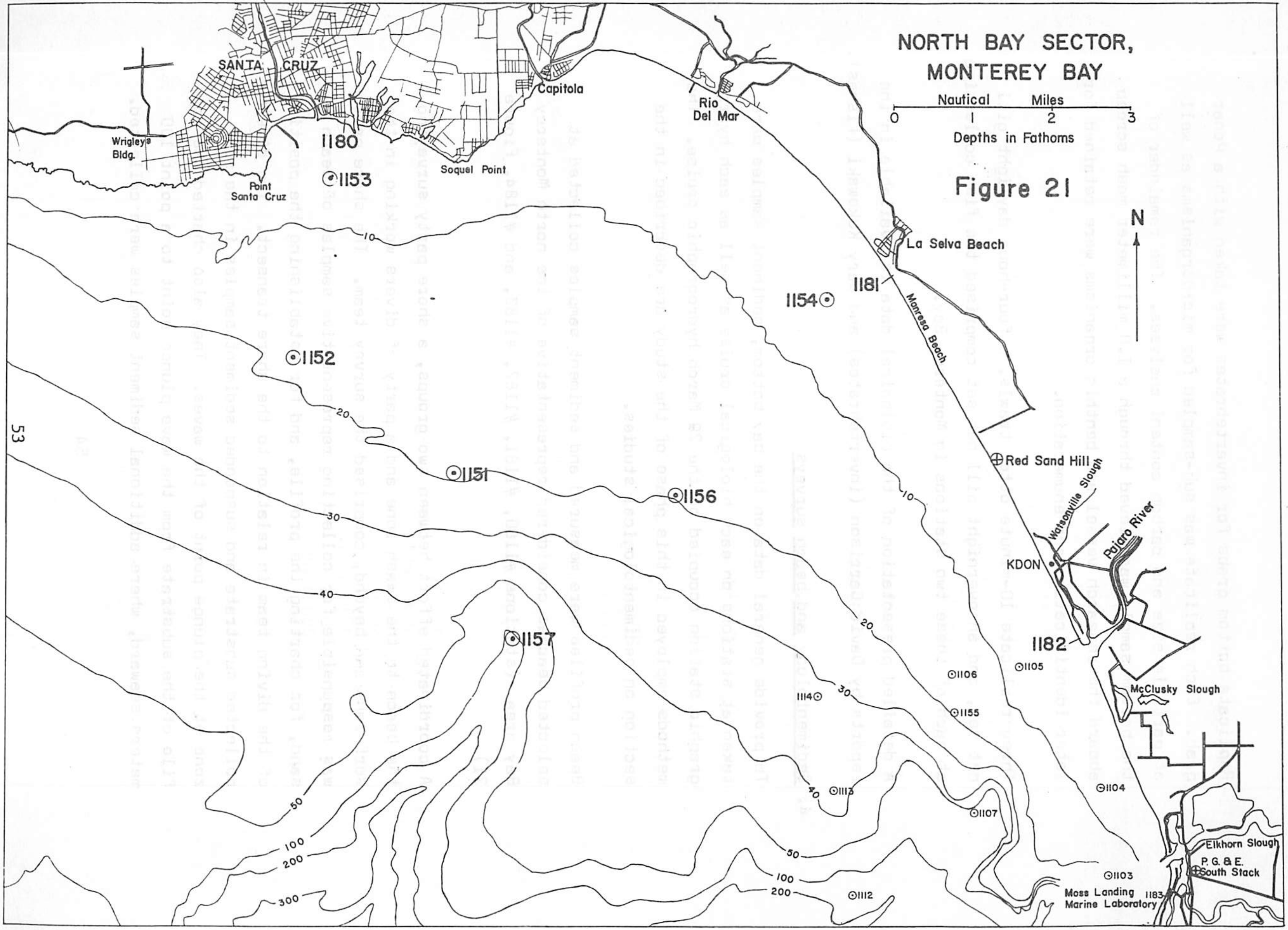
The hydrographic work in the north bay sector is a parallel to the study in the Monterey canyon sector employing the same sampling techniques, handling procedures, and methods of analysis.

Five stations were occupied regularly on the cruise dates: #1152, #1153, #1154, #1155, and #1156 (Figure 21). Station #1157 was occupied on an optional basis, sampled only if sufficient time remained in the eight-hour cruise day. It is recommended that station #1157 be added to the sequence of regularly occupied stations. Station #1151 was deleted from the regular sequence after the first cruise because the position was considered too close to station #1152 and duplication of effort and data could therefore be avoided. Station #1156 replaced #1151.

In the three weeks between hydrographic cruises, samples were processed in the chemistry laboratory and data reduced and entered on the standard summary form (as outlined in the Monterey canyon section of this report).

3. Biological data collection

Two stations, #1105 and #1155, were selected as biological collection stations for the north bay team. Both were occupied twice during the semester: 27 March and 8 May. For comparison purposes, these stations were selected to parallel the two in the Monterey canyon sector, one station lying just outside the 10-meter depth curve, the other just beyond the 30-meter curve. They differed in that the north bay's stations are situated off an undifferentiated beach area whereas the Monterey canyon stations are near mouth of the Pajaro River. Additionally, station #1105 was occupied 27 February and 2 April for fish collecting only.



NORTH BAY SECTOR, MONTEREY BAY

Figure 21

Replicate bottom grabs for invertebrates were taken with a Ponar grab. Each replicate was sub-sampled for microorganisms as well as particle size and carbon content analyses. The remainder of the bottom sample was sieved through a 1.0 millimeter mesh screen aboard the research vessel and benthic organisms were retained for later identification and enumeration.

Three replicate 10-minute otter trawls, a four-hour daylight gill net set, and an overnight gill net set comprised the fish collecting at each of these two stations in Monterey Bay.

A detailed presentation of the biological data is available in the reports by David Garrison (invertebrates) and Gary Kukowski (fishes).

4. Sedimentology and beach surveys

To provide general data on the bay bottom, sediment samples were taken at stations on each biological cruise as well as each hydrographic station occupied on the 20 March hydrographic cruise. The methods employed in this phase of the study are described in the section on sedimentological studies.

Beach profiles were measured and sediment samples collected at selected beaches considered representative of the north Monterey Bay area (stations #1180, #1181, #1182, #1183, and #1184, Figure 21).

A coordinated effort between two groups, a shore party surveying the beach to the swash zone and a party of divers working in the surf zone and beyond, comprised the survey team. The shore party was responsible for collecting representative samples of beach sand, for charting the profile, and for establishing the position of the diving team in relation to the shore transect. The divers collected substrate and suspended sediment samples in the surf zone at the plunge point of the waves. They also charted the profile of the substrate from the wave plunge point to a point 100 meters seaward, where additional sediment samples were collected.

The diver participation in this portion of the program was led and organized by Stephen Pace, a member of the Laboratories' SCUBA marine research team.

The unique and untried nature of this diver research approach necessitated a trial and error development of materials and techniques. The first survey conducted on 27 February was only a partial success. After surveying two beaches, the divers overturned their work raft and were forced to retire for the day. The second survey conducted on 8 May was completed without incident with appropriately modified procedures.

Three of the beaches measured have shown little change during the brief observation period. However, the beach at Santa Cruz (station #1180) has demonstrated a gain in beach sand. This may indicate that this beach undergoes typical summer buildup and winter depletion due to onshore - offshore movement of sand. Over the same period, the Salinas River-mouth beach (station #1184) showed loss of sand. This suggests that this beach is strongly dependent on the Salinas River for its sand supply. Winter storm run-off supplies sand to the beach. In spring and summer, when the run-off ceases, a sand bar forms across the river mouth cutting off the sand source, and the beach begins to lose sand through wave action and longshore transport.

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IV. A SHALLOW COASTAL EMBAYMENT: ELKHORN SLOUGH STUDIES

(Richard Smith, Graduate Teaching Assistant)

A. Introduction and General Rationale for the Program

In recent years the need for a detailed and careful monitoring of man's impact on his environment has become increasingly evident. The concentration of pesticides in the food chain and the deleterious effects of heavy metals on the biosphere have awakened "modern man" to his ultimate plight if he continues his laissez faire attitude toward his enviornment. "Growth, for the sake of growth, is the ideology of a cancer cell": an appropriate warning to all species.

In the Monterey Bay area, although the population densities have not yet approached the levels of large metropolitan areas, the list of environmental violations is constantly increasing. A few of these man-induced imbalances are:

Destruction of the sardine fishery.

Closing of Monterey beaches for water contact sports due to inadequate sewage disposal methods.

Survival of the brown pelican threatened by high concentrations of DDT.

Rejection of Moss Landing Harbor-Elkhorn Slough as a commercial shellfish-producing area due to poor water quality.

Recent extensive fish kills in the lower Salinas River.

Obviously there is need for an objective and continuous assessment of the tenuous ecological equilibrium. This assessment is required not only for the identification of polluters and hazardous conditions, but for base line data from which more reasonable decisions regarding future development may be drawn.

Social and political institutions have finally begun to respond. Numerous conservation organizations have been formed. State organizations have been formed. State organizations such as the county health departments and water quality control boards have traditionally been involved in maintaining water quality, and their efforts are being expanded. More recently, a new generation of local or regional cooperatives have been established including the San Francisco Bay Conservation and Development Commission (BCDC), the San Francisco Area Association of Bay Area Governments (ABAG), and locally the Association of Monterey Bay Area Governments (AMBAG), all taking a larger view of state and regional responsibility for the environment.

The Sea Grant program at Moss Landing Marine Laboratories is a federally-funded project which also takes this larger view of the environment and approaches environmental data collection and analysis through a broad array of scientific disciplines. The project has four major objectives, as described by Dr. John Harville in the Moss Landing Marine Laboratories Sea Grant proposal:

1) To compile and organize data now scattered in various governmental and educational papers.
2) To code and store this information for easy retrieval and to pass currently valuable information on to the public.
3) To initiate an environmental survey of the five diverse sub-areas of the central Monterey Bay area. *
4) To provide educational experience at various levels ranging from field techniques for teachers to thesis research for graduate students.

A research leadership team was assembled and detailed planning activities were begun in September 1970 toward a goal of full scale operation by February 1971. This is a progress report on our first year's activities.

B. Description of Elkhorn Slough--a Shallow Coastal Embayment

Elkhorn Slough is a shallow, tide-influenced, coastal embayment (Figure 11, page 30) lying approximately halfway between Monterey and Santa Cruz, California, at $36^{o}48'$ N latitude, $121^{o}47'$ W longitude. The slough extends inland approximately 4.2 miles having a path length of about 6.9 miles. Salicornia marsh and tidal mud flats extend the length of the slough as indicated on Figure 22. An outlet channel is maintained by

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* The five environmental subdivisions are: 1) Sea-air-land zones of contact, 2) Shallow coastal embayment - Elkhorn Slough, 3) Rivers and estuaries - Pajaro River, 4) Shallow waters of Monterey Bay, and 5) Submarine canyon and open coast.

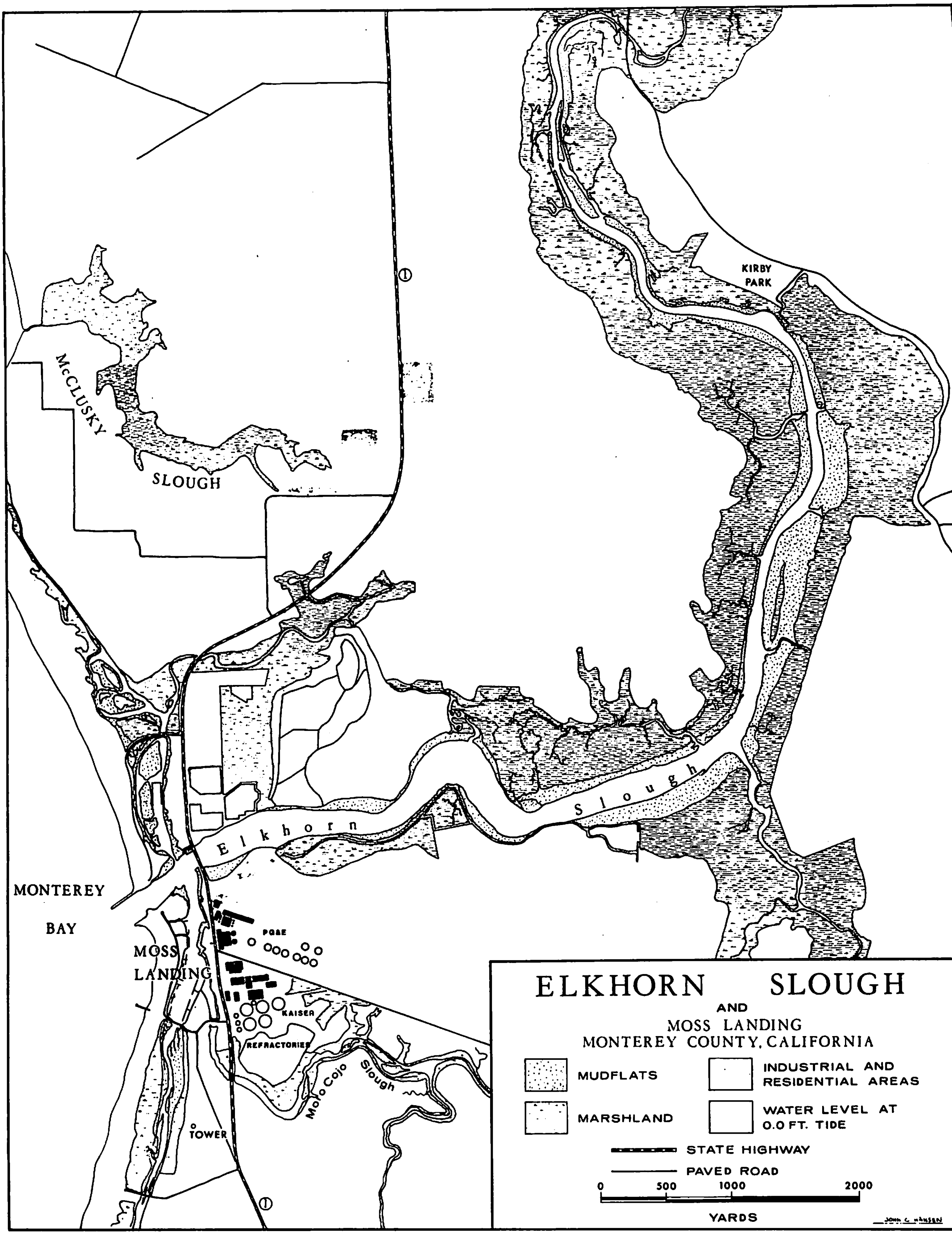

McCLUSKY
SLOUGH
KIRBY
PARK
Elkhorn
Slough
MONTEREY
BAY
MOSS
LANDING
PG&E
KAISER
REFRACTORIES
Moro Cojo
Slough
TOWER
ELKHORN SLOUGH
AND
MOSS LANDING
MONTEREY COUNTY, CALIFORNIA
MUDFLATS
MARSHLAND
INDUSTRIAL AND
RESIDENTIAL AREAS
WATER LEVEL AT
0.0 FT. TIDE
STATE HIGHWAY
PAVED ROAD
0
500
1000
2000
YARDS

FIGURE 22

the Army Corps of Engineers at a depth of 5 meters and a width of 165 meters at mean lower low water [Stump, 1967]. This inlet, along with an area south of the inlet in the Old Salinas River channel, is maintained by the Corps as a harbor for commercial fishing vessels and private yachts. The volume of the south harbor area was calculated by Stump [1967] for several tidal levels (Table II). The north harbor is shallow (less than 1 meter) except for a small private marina, the Elkhorn Yacht Club, and the channel leading to it.

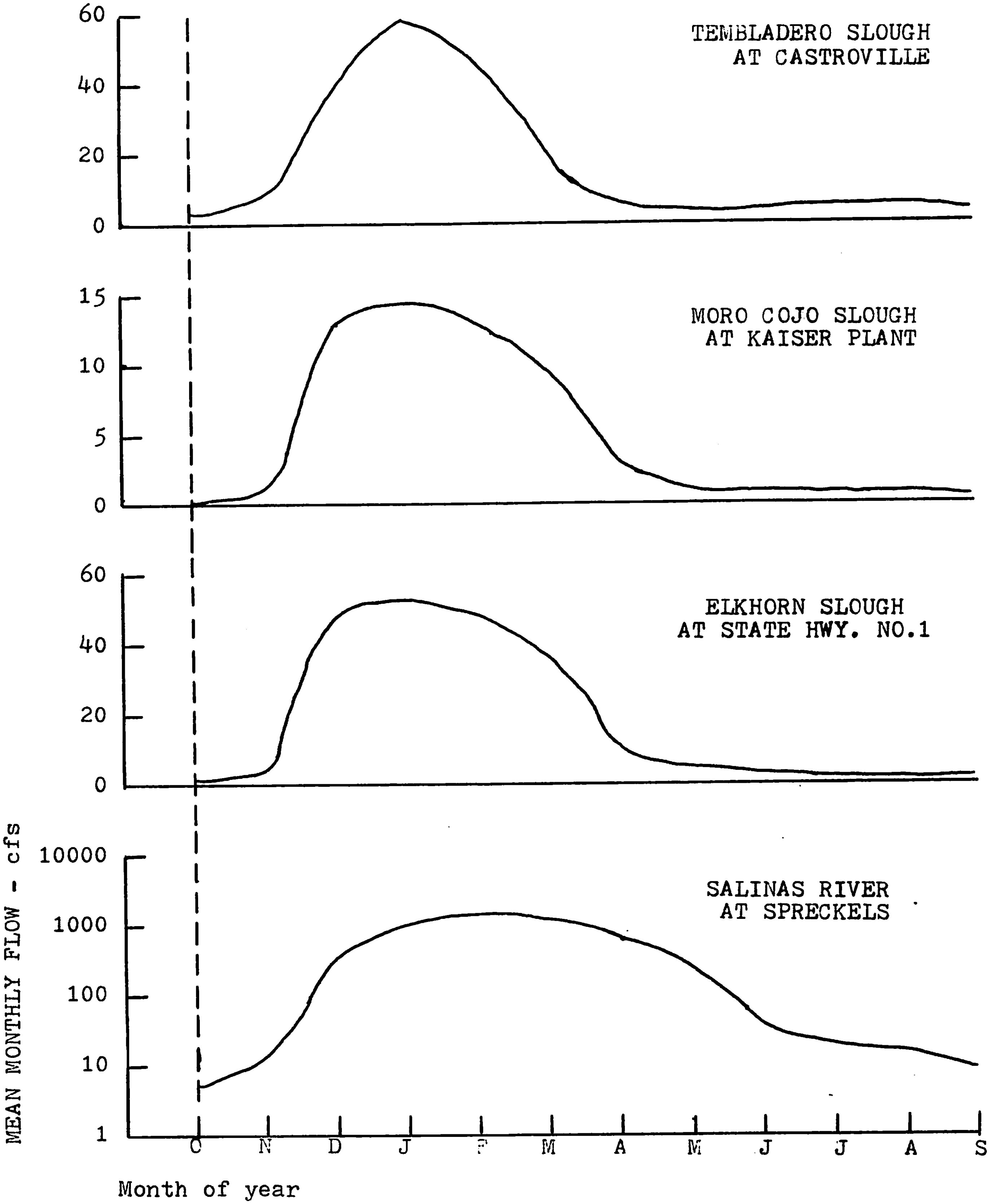
TABLE II

South Moss Landing Harbor Area and Volumes

AREA at mean low low water	$1.76 \times 10^6 ft^2$	$1.62 \times 10^5 m^2$
VOLUME at mean low low water	$8.80 \times 10^7 gal$	$4.02 \times 10^5 m^3$
VOLUME INCREASE ON 1.65 M TIDE from mean low low water	$5.60 \times 10^7 gal$	$2.46 \times 10^5 m^3$
TOTAL VOLUME AT +1.65 M above mean low low water	$14.40 \times 10^7 gal$	$6.48 \times 10^5 m^3$

Calculated by Arthur Stump from Moss Landing Harbor Maintenance Dredging Contour Map, U S Army Engineering District, San Francisco, Corps of Engineers, San Francisco, California: Drawing No. 1-14-1-16.1 Ammendment No. 1 April 17, 1967.

The drainage basin for the slough is small, only 226 square miles [Wong, 1970]. Hydrographs for the contributing streams are given in Figure 23. The land in the vicinity of the slough is primarily used for agricultural purposes. To the south are large artichoke fields near sea level which contribute high concentrations of nutrients to the slough as irrigation drainage. Dairies and cattle-grazing acreage occupy most of the rolling grass-covered hills east of the slough and, to the north, a variety of crops including strawberries, artichokes and Brussels sprouts are grown on a fertile remnant of uplifted alluvium. To the west is Monterey Bay, rimmed by sand dunes, and the Pacific Ocean.



AVERAGE ANNUAL HYDROGRAPHS OF FRESH WATER STREAMS (WRE 1969)

FIGURE 23

The tides in the Monterey Bay area are mixed, with two highs and two lows per day. Mean sea level is 2.8 feet above mean lower low water, which is the tidal datum for this coast. The mean tidal range is 3.5 feet, and the mean range between higher high water and lower low water is 5.3 feet [Wong, 1970].

Appendix C contains a variety of background information on the study area including industrial pumping rates, recreational resources, water discharge requirements, ultimate land use, and a schematic diagram of the Kaiser magnesium extraction operation.

C. Economic History of Moss Landing

Moss Landing has had a varied history ranging from fishing and whaling to magnesia extraction. Starting about 1860 records of attempted development may be found. The first, ironically, was a land-development scheme. Paul Lazere bought approximately 300 acres from the State of California near the present Monterey Salt Works. He subdivided the land and tried to sell lots. Lazere's plans did not work out and he finally sold his holdings to the Vierra family whose descendants still live in the area.

In 1886 Captain Charles Moss, the town's namesake, came to the area and built a warehouse to serve as depot for grain shipments from the Salinas Valley. The collected grain was transferred to schooners waiting offshore. This proved to be a very profitable operation for Captain Moss. Small flat-bottomed steamships were used in the lower Salinas River and in the Elkhorn and Moro Cojo sloughs to help gather cargo.

In 1917 a whaling station was set up at Moss Landing, and in 1930 fish processing canneries were started. During this same period, attempts to start an oyster industry were made. This practice is still being attempted, however it has never quite passed the trial stages.

The Moss Landing of today differs considerably from that described above. The first major changes came in 1946-1947 when the present mouth of the harbor was dredged by the Army Corps of Engineers. The dredging took place several hundred yards south of the original outlet, which is now filled in with sand dunes. Limited industrial development of Moss Landing began at approximately the same time. In 1942 Kaiser Refractories had opened their magnesia extraction plant. In 1950 Pacific Gas and Electric Company began using sea water pumped from the harbor for cooling steam-driven electric generators. Moss Landing Marine Laboratories, a consortium of five California State Colleges, was opened in 1965. The present land and water use is presented in Table III. *

TABLE III

Present Land Development of Monterey County Service Area No. 46

CLASSIFICATION	AREA, ACRES	PERCENT OF TOTAL
Industrial	530	7.3
Commercial	36	0.5
Recreational	108	1.5
Residential	45	0.6
Agricultural	4544	62.8
Unclassified[1]	1967	27.3
TOTAL	7230	100.0

[1] Includes the water of Elkhorn Slough

Present Annual Water Use Within Monterey County Service Area No. 46[2]

WATER USER	WELL WATER million gallons	SEA WATER million gallons (from south harbor)
Pacific Gas & Electric	147	493,000
Kaiser Refractories	543	13,150
Moss Landing Harbor District	19.3	-0-
Agriculture	2220[3]	-0-

[2] Does not include private well usage for residential or commercial uses.

[3] Approximated (acres times use-rate)

[Water Resources Engineers, 1968]

* Information on the history of Moss Landing was gathered from the Salinas Library (Salinas, California) historical file on Moss Landing.

D. Climate

In CALIFORNIA'S MANY CLIMATES, Felton [1965] describes the climate of the Monterey Bay region as "The typical marine climate, beloved by many above all other types of climate to be found in California, [which] prevails here in its nearly perfect form". This description is especially true in the Moss Landing area. The moderating influence of the sea limits the mean summer maximum at Watsonville to 71°F and the mean winter minimum to 37°F. The average precipitation data for Watsonville and Castroville are summarized below:

Average Monthly Seasonal Precipitation

	JUN	JUL	AUG	SEP	OCT	NOV
Castroville	0.06	0.01	0.02	0.13	0.58	1.32
Watsonville	0.12	0.02	0.05	0.27	0.83	1.90

	DEC	JAN	FEB	MAR	APR	MAY	SEASON
Castroville	3.80	4.91	3.79	1.99	0.70	0.50	17.81
Watsonville	4.36	4.40	3.99	2.98	1.53	0.55	21.00

[Elford and Stilz, 1968]

The net effect of the wet-winter, dry-summer seasonality found here can be observed in the slough. In the winter, when the rainfall is at its maximum, estuarian circulation develops with salinity observations of 20-25% common. During the dry season (May through October) hypersalinity develops in the shallow upper portions of the slough.

E. Geomorphology

The geomorphology of the Monterey Bay area is interesting and highly complex. Even the taxonomic classification of Elkhorn Slough is complicated by its origin and ephemeral circulation patterns. The most comprehensive definition of an estuary is given by Prichard [1967]: "An estuary is a semi-enclosed coastal 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." The slough certainly fits this description at least part of the year. From another point of view, though, the slough might be classified as a lagoon which is typified by shallow depths and fairly stable brackish water. At best, a qualified description would be that it is a tidally influenced lagoon or a seasonal estuary.

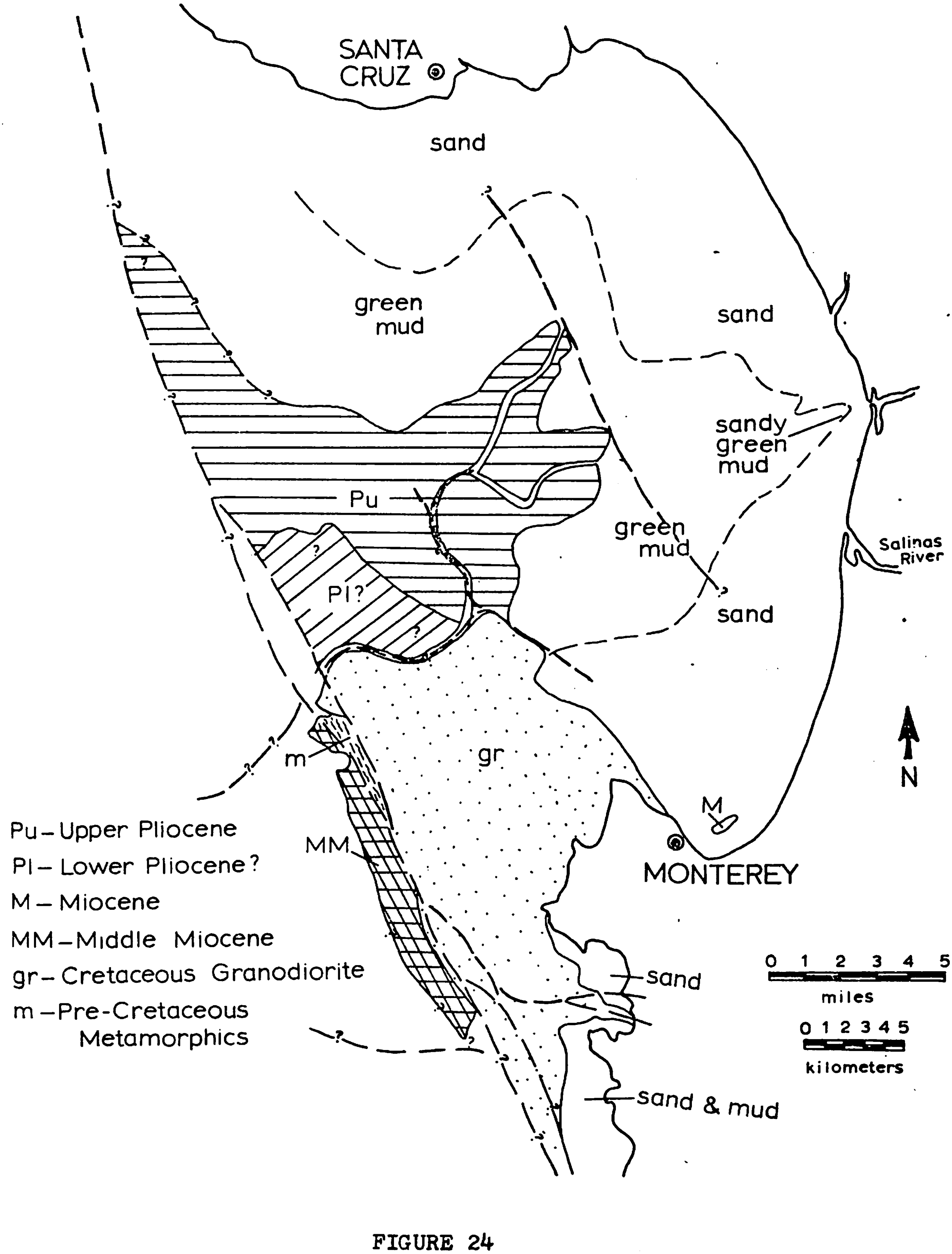


FIGURE 24

Geologic map based on samples from sea floor and extrapolation from outcrops on shore. (After Greene, 1970)

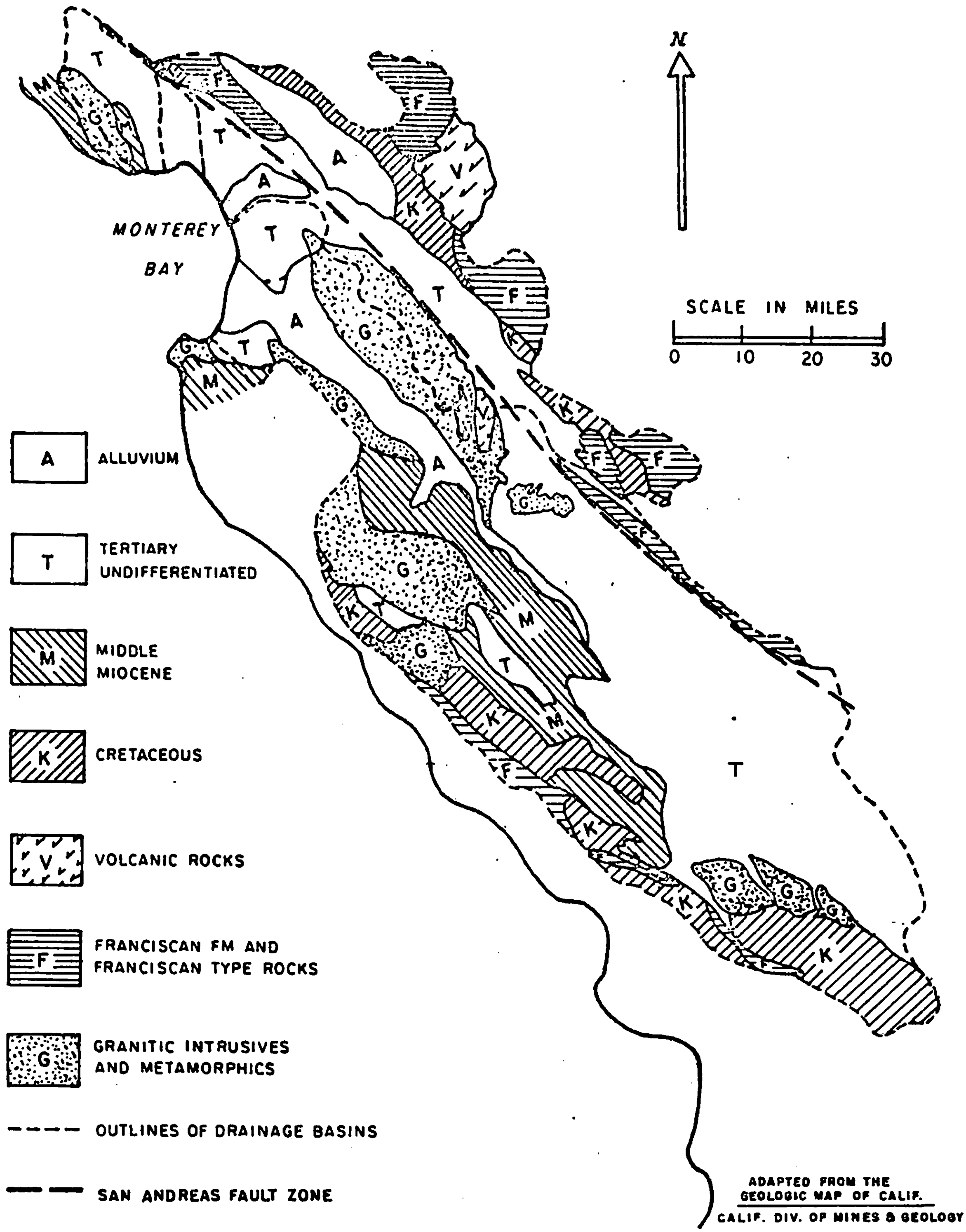


FIGURE 25

Generalized geology of the Monterey Bay drainage basins (After Greene, 1970)

The origin of Elkhorn Slough must be considered in terms of three major features: the Salinas River and valley; the Pajaro River; and the Monterey Submarine Canyon, the head of which is within one-quarter mile of the harbor mouth. Figures 24 and 25 provide some insight into the geology of the area.

Prior to 1908 the Salinas River emptied through what is now Moss Landing Harbor. It has also been suggested that the Pajaro River once drained the "Great Interior Valley" of California [Lawson, 1924]. This theory is further substantiated by deep-well records and gravity anomaly data which indicate a deep valley of sediments lying beneath the slough to a depth of at least 7000 feet [Starke and Howard, 1968]. Obviously the origin of the slough is related to all of these features, with the Salinas River and the postglacial rise in sea level playing the most recent role.

F. Environmental Data Collection

"Environmental data collection" is a commonly used catchall phrase requiring more definition to provide specific meaning. In the study of Elkhorn Slough our collection of environmental data has been based on assessing the environment from three points of view: hydrology, benthic environs, and fish distribution.

1. Hydrologic sampling

Nine hydrologic stations are indicated on Figure 26. These were chosen for scientific as well as practical reasons. The seasonal and diurnal variations in the physical hydrology of the slough are highly variable. Given limited manpower and equipment, stations were chosen so that the full gradient of conditions could be sampled and so that relative impacts of various external influences on the water quality might be assessed. Average depth of the slough at low water ranges from approximately 1 meter at the upper end to more than 4 meters near the mouth. Tidal incursions of 4 to 6 feet occur twice daily. With these factors in mind, the nine stations were sampled monthly during slack high water, at the surface, 1 meter below the surface, and 1 foot off the bottom (with middle sample omitted in shallower depths).

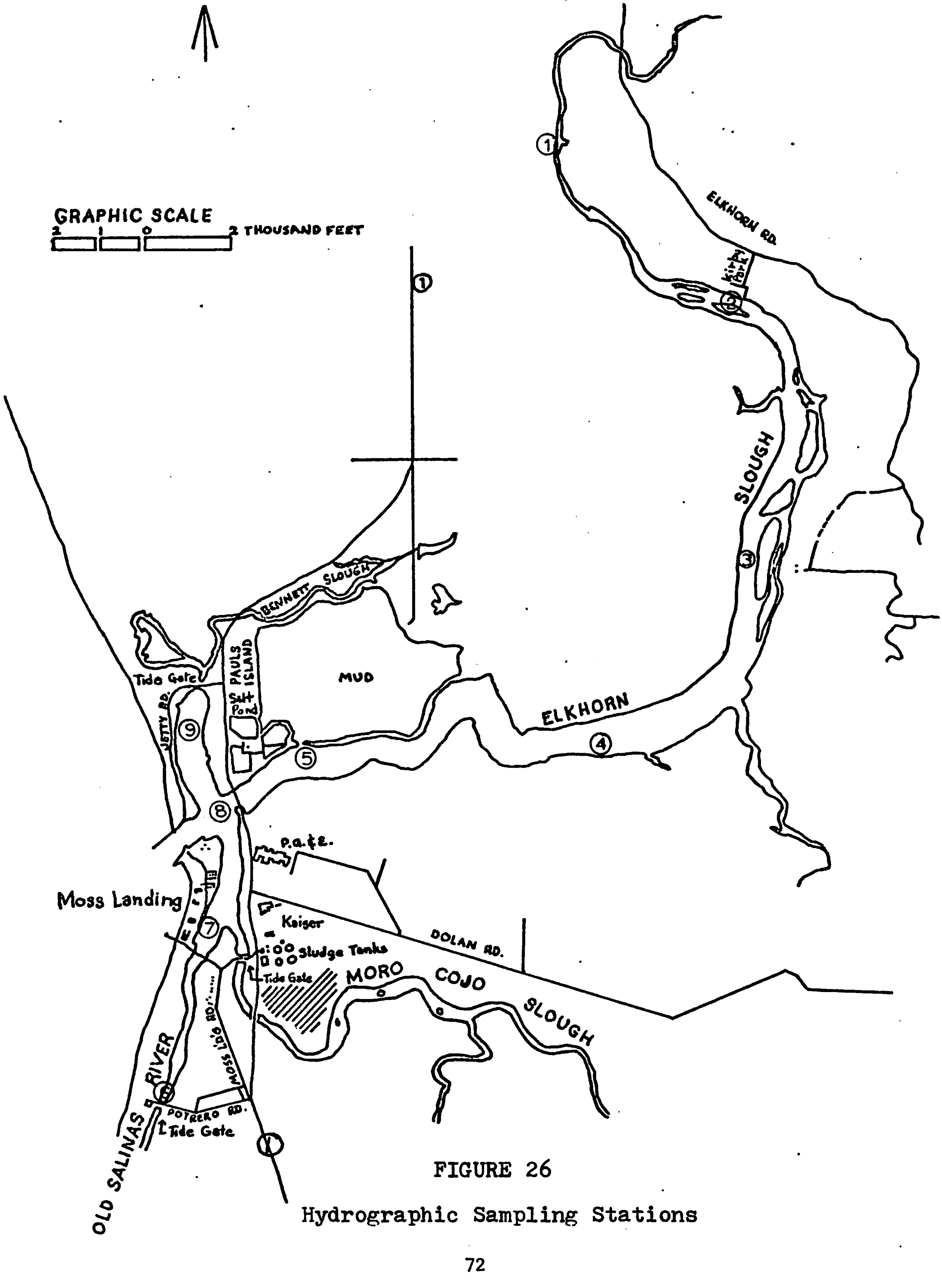


FIGURE 26

Hydrographic Sampling Stations

In addition to the extended sampling program of the seasonal hydrology, quarterly short-term intensive investigations of the diurnal and tidal variations in the physical properties of the water mass are being carried out at stations marked on the map by asterisks.

A summary of parameters sampled follows:

PARAMETER	METHOD OF ANALYSIS
Salinity	Induction salinometer
Temperature	Standard centigrade thermometer calibrated to 0.1°C
Dissolved oxygen	Winkler method [U.S. Hydrographic Office, 1968]
Nutrients: ammonia, nitrate, nitrite, silicate, phosphate	Colorimetric determination Beckman D.U. [Strickland, 1960]
Water transparency	Secchi disk
Air temperature	Standard centigrade thermometer

HYDROLOGIC SAMPLING FOR INTENSIVE SHORT-TERM STUDIES

Current tidal studies to determine the tidal excursion, lag, and current velocities.

24-hour monitoring of water chemistry to determine diurnal and tidal cycle variations in the properties listed above.

2. Benthic survey

In general the Elkhorn Slough benthic survey parallels in objectives those of the Monterey Bay segment of the Sea Grant program. Benthic sampling is concentrated along transects anchored to selected hydrographic stations. General procedures are as follows:

BIOLOGICAL ANALYSIS

Determination of adequate sample size by random sampling in area of station.

Once correct sample size is determined, samples are sieved through 1 mm sieve and sorted into groups. [Chartock, 1971; California Department of Fish and Game, personal communication.]

GEOLOGICAL ANALYSIS

Particle size analysis

Emery settling tube used for coarse fraction, 2mm to 0.031 mm [Emery, 1938].

Pipette analysis used for fine fraction [Royse, 1970].

Organic carbon analysis determined through total oxidation with chromic acid [Allison, 1935; Royce, 1970].

Carbonate analysis by gaseometric determination of CO_2, and atomic absorption analysis for calcium and magnesium [Angino, 1967].

3. Fish distribution studies

See Section VI for details of these investigations.

G. Logistics of Data Collection

Organization and collection of the wide variety of data involved in this project is interesting and educational, but sometimes frustrating. Continuing problems relate to inadequacy of equipment and lab space, conflicting schedules, and shortage of time in general. However, as the semester progressed, our growing efficiency surpassed our original expectations in all areas.

The primary source of manpower came from the Research Participants assigned to this study area. Four of these participants (John Berney - high school biology teacher, Warren Long - biology teacher, Dan Lovick - language instructor, and Bill Giguiere - graduate student) studied Elkhorn Slough for a semester under the direction of Graduate Teaching Assistant Richard Smith and received three units credit for their excellent help.

A summary of the semester's activities follows: (Saturdays were the scheduled work days.)

2/20 Orientation, reconnaissance, benthic sampling

2/27 Hydrologic sampling, oxygen analysis, invertebrate sorting

3/6 Meteorological data reduction, sediment analysis, collection of fishes

3/13 Nutrient analysis, invertebrate sorting
meteorology data reduction

3/20 Fish sorting and identification, invertebrate sorting, sediment analysis, general data reduction

3/27 Hydrologic sampling, oxygen analysis, data reduction

4/3 Easter holiday

4/10 Easter holiday

4/17 Nutrient analysis, data reduction

4/24 Hydrologic sampling, fish collection, oxygen analysis

5/1 Invertebrate sampling, fish collection, sediment sampling

5/8 Nutrient analysis, data reduction

5/15 Sediment analysis, fish sorting, invertebrate sorting

5/22 Hydrologic sampling, oxygen analysis, data reduction

5/29 Nutrient analysis

It should also be mentioned that for short term projects, such as the 24-hour survey of three hydrologic stations which took place 27-28 March, many additional volunteers were recruited from other sources. Mr. Berney's and Mr. Long's high school students supplied some of the extra help, interested friends and Moss Landing Marine Laboratories students interested in specific problems for term projects were also among those recruited. Some of the term paper subjects are listed below:

Impact of Pacific Gas and Electric Thermal Effluent on Fish Distribution: Joel Cohen and Ronald Larocca

Suspended Sediment Transport over a Tidal Cycle: Lee Clark

Phytoplankton Standing Crop: Sandra Owen

Polychaete Distribution: Al Hodgson

H. Tentative Hydrologic Results

(Refer to Sections VI and VII for results of fish and benthic segments of data collection.)

Elkhorn Slough is a complex system affected by tides, land drainage, industrial pumping, and evaporation. Placed in another perspective, assuming industrial influence to be constant, these factors can be reduced to those which are seasonal, diurnal, and tidal in nature. Conclusions based upon data thus far collected must of course be considered tentative, but some initial impressions are worth noting.

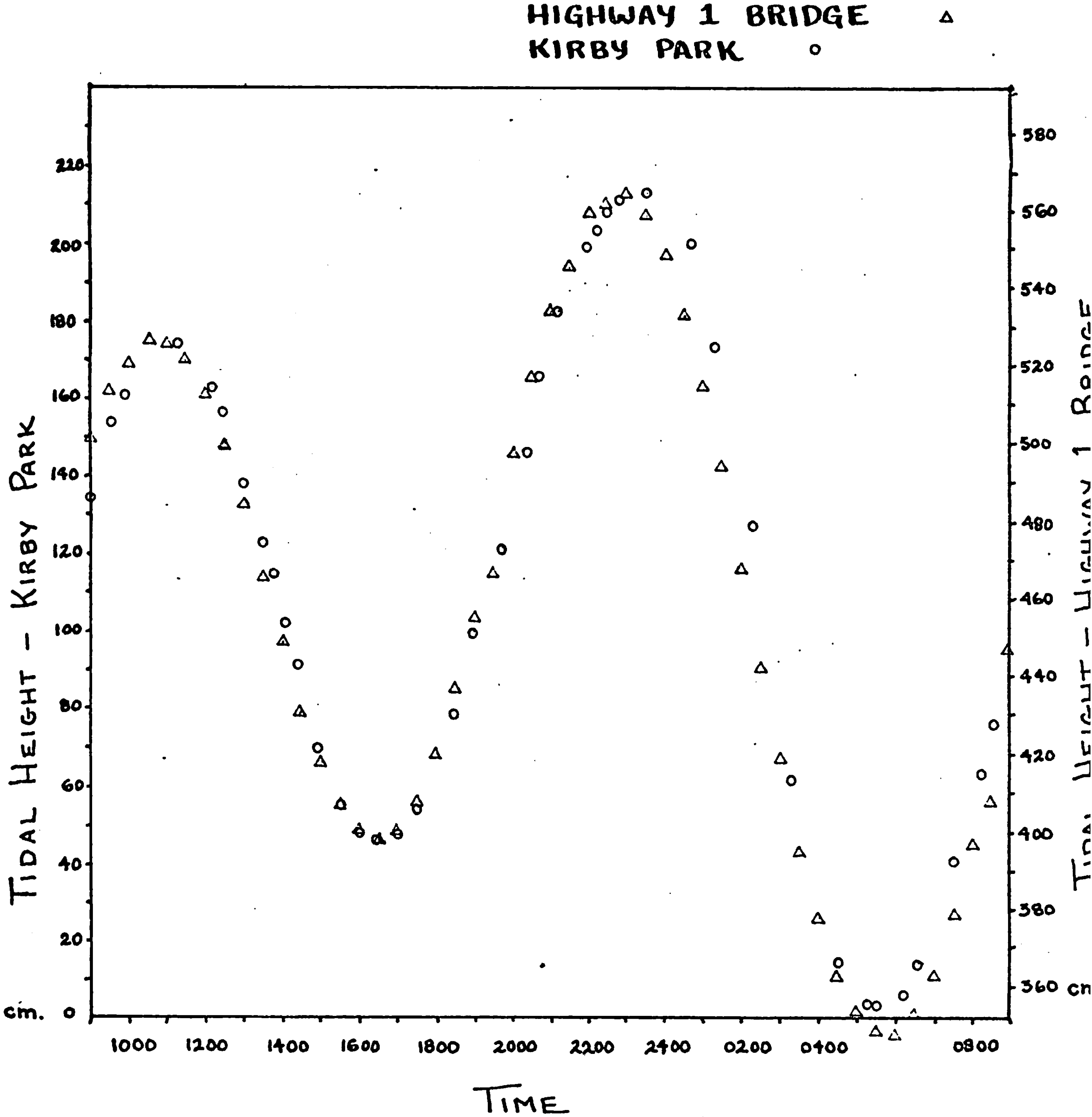
A 24-hour survey of the hydrology of the slough was completed 28 March. Some of the results are presented graphically on the following pages. During this 24-hour period, the three stations were sampled each hour for salinity, temperature, dissolved oxygen, and transparency; every two hours, nutrient and chlorophyll samples were taken. In addition, at two of the stations, tidal height and current velocities were measured. Plots of this data clearly indicate the interplay of tidal and diurnal influences. Salinity fluctuates with the tide, while dissolved oxygen reaches only one maximum and one minimum per day (Figures 27,28).

The nutrient chemistry points out the diversity of the hydrologic environments. At the Sandholdt Bridge station, physical mixing of high-nutrient - low-salinity water with offshore water is indicated by the linear trend of the phosphate vs salinity curve (Figure 29). At Kirby Park, biological uptake and release of nutrients seems to be in dominant control; the phosphate vs apparent oxygen utilization plot indicates a gram-atom ratio of approximately 280 oxygens to 1 phosphate, very close to the average oxygen to phosphate ratio found in phytoplankton.

Seasonal data are available for only about half of the full year needed for analysis and preliminary discussion. Fortunately a few samples were taken before the onset of winter storms and a seven-month comparison can be made. Figure 30 shows the seasonal nature of the slough's salinity distribution. The salinity decreases with distance up the slough from November through April, but the May samples indicate a reversal of this trend. It will be very interesting to ascertain the magnitude of this reversal as the dry season proceeds. It should be noted as well that replenishment of nutrients will become more difficult during these months of no surface run-off, and one would expect limiting conditions for various plankters to develop. Silicate and nitrate levels are beginning, in the May-June period, to approach zero.

FIGURE 27: TIDAL HEIGHT -VS- TIME

MAR. 27-28, 1971



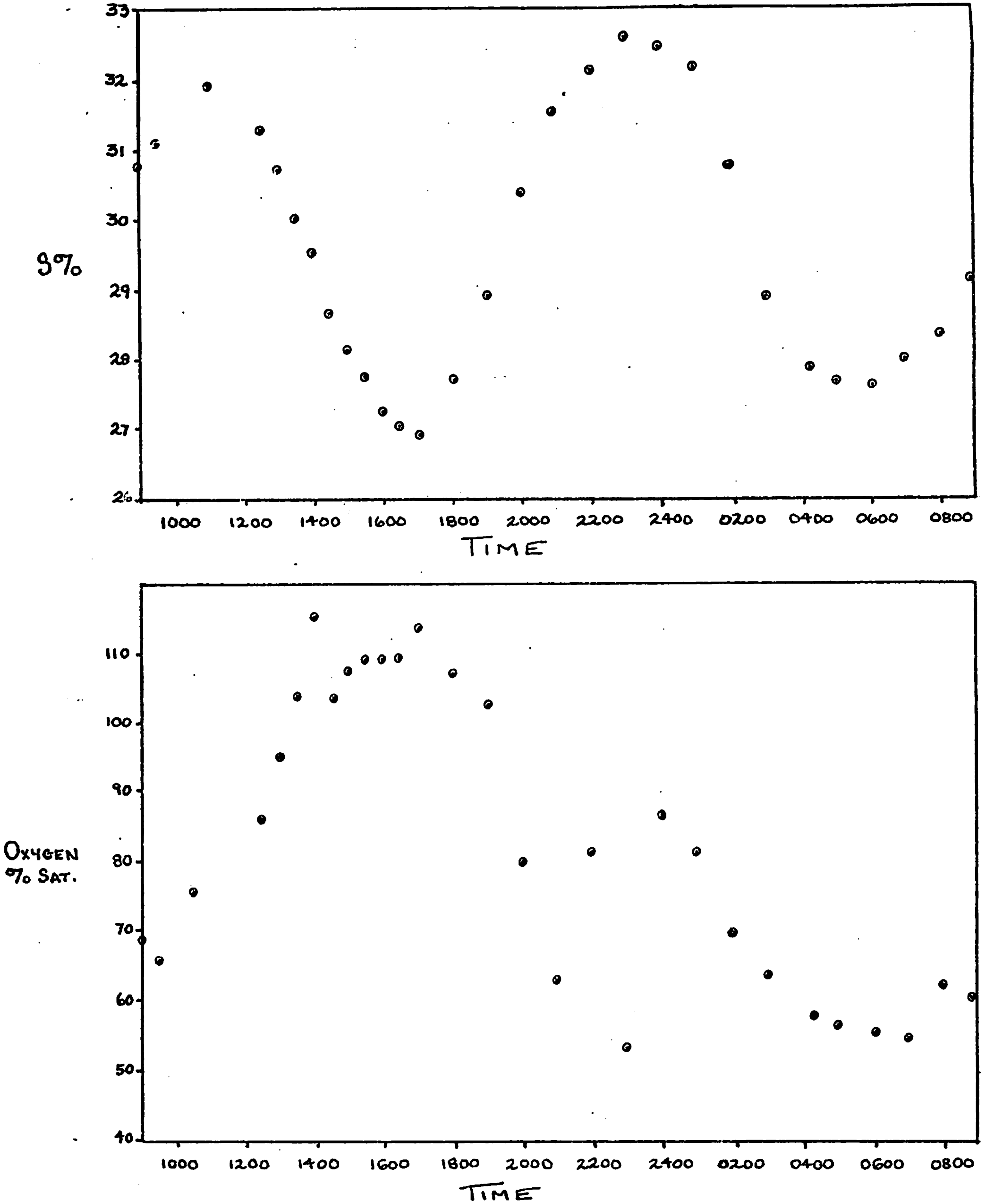
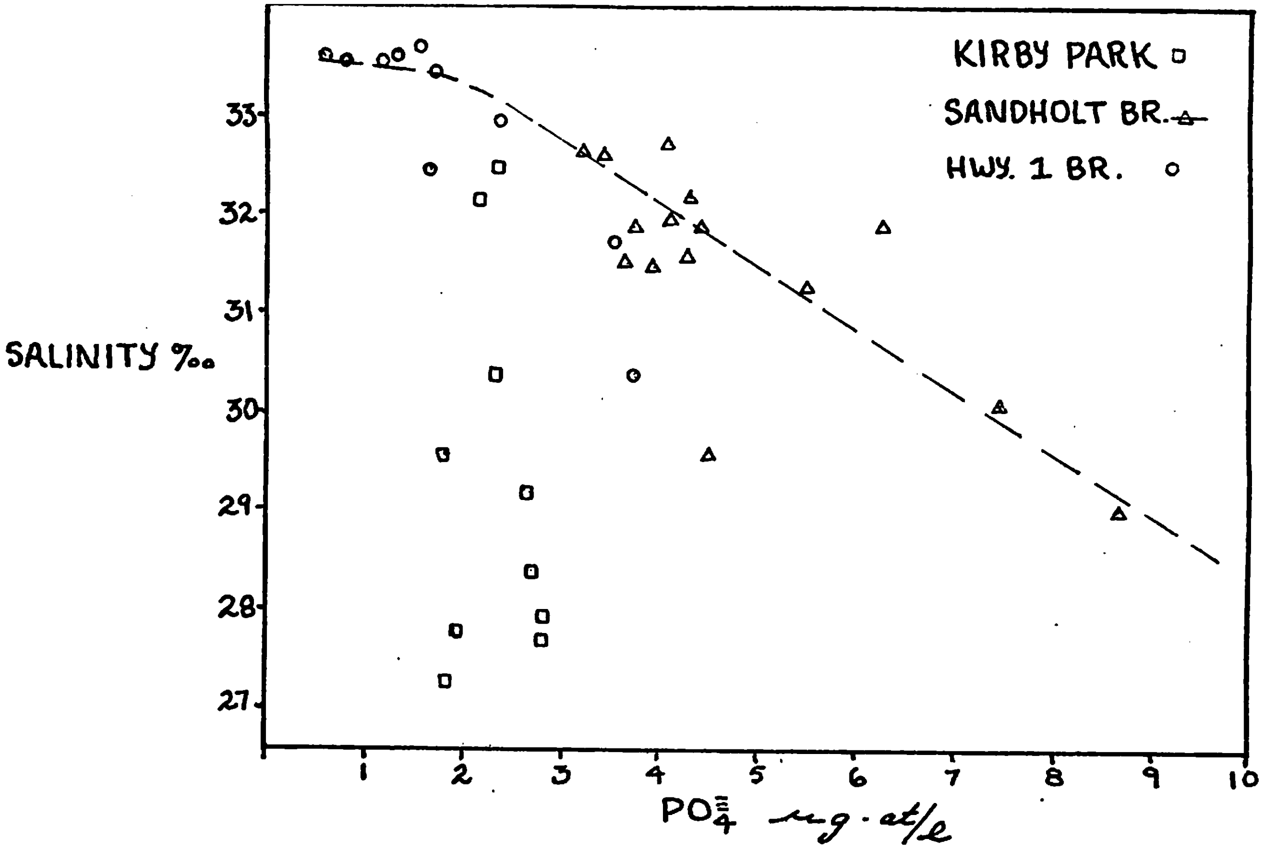


FIGURE 28

SALINITY & OXYGEN -VS- TIME
SAMPLES TAKEN AT KIRBY PARK
3/27-28 1/2 m. DEPTH



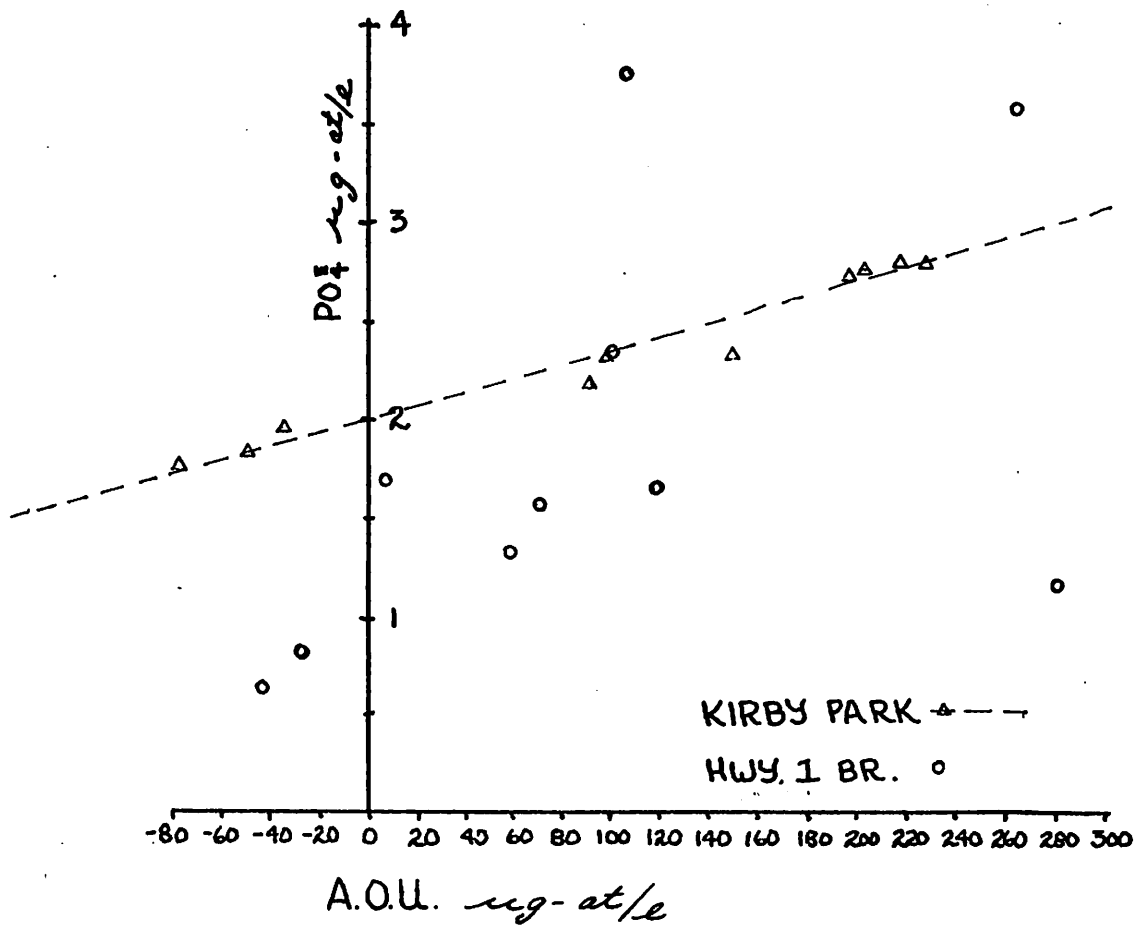
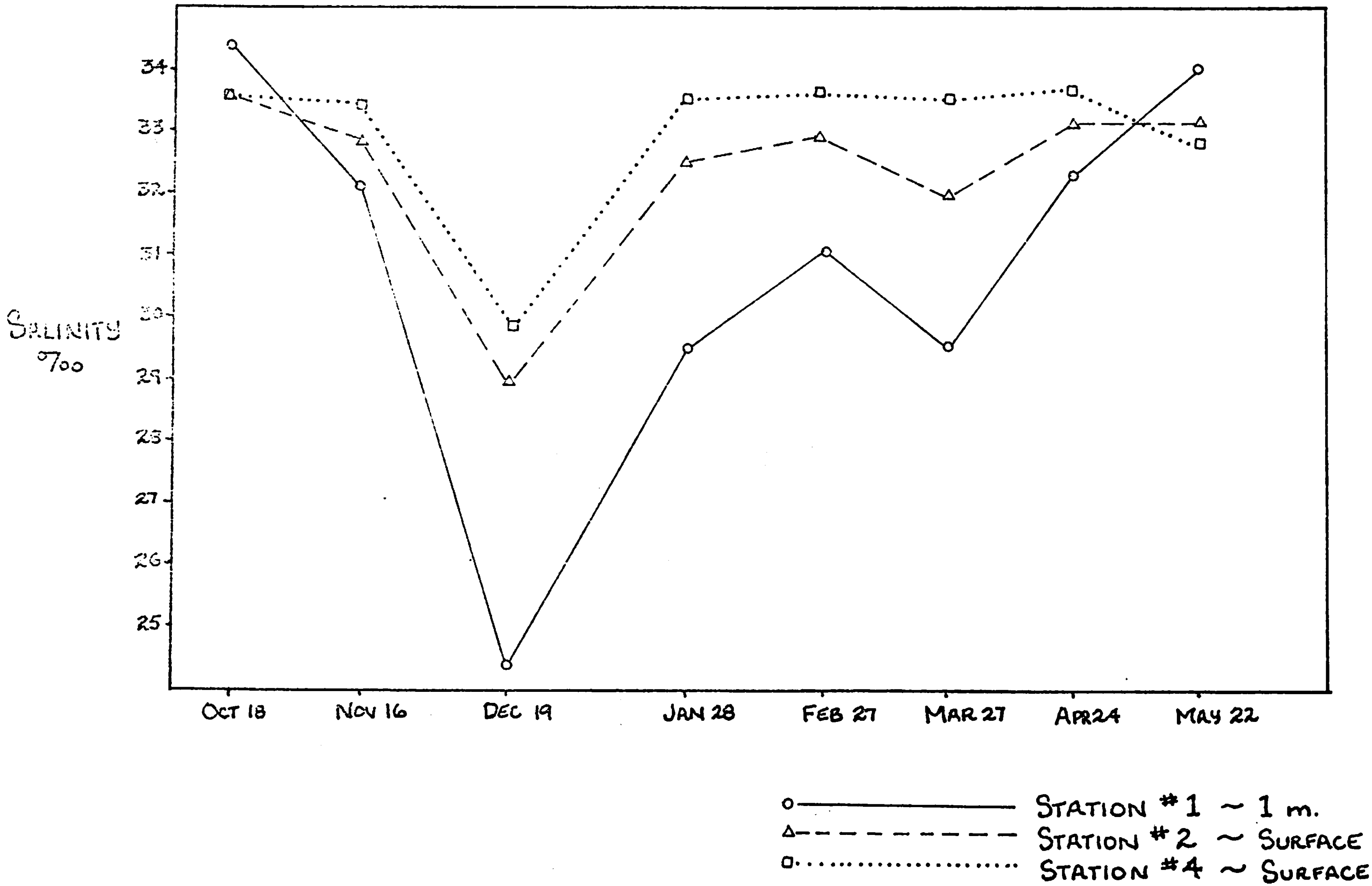


FIGURE 29: Phosphate-salinity and phosphate-oxygen relationships

Upper: Phosphate-salinity
Lower: Phosphate-apparent oxygen utilization (AOU)
AOU=saturation value for oxygen at the observed temperature and salinity minus observed oxygen level expressed in μg-at/l.

FIGURE 30

SEASONAL TRENDS IN SALINITY ~ STATIONS 1,2&4
OCTOBER, 1970 ~ MAY, 1971



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V. PAJARO RIVER

(Scott Dailey, Graduate Teaching Assistant)

A. General Description

The Pajaro is relatively typical of west coast rivers, with heavy fresh water run-off during rainy winter months and much decreased flows during the dry summer season. The lower reaches of such rivers form true estuaries, but with great seasonal fluctuation in salinity gradients due to these variations in fresh water input.

The Pajaro River drains approximately 1300 square miles of Central California through its many tributary streams and rivers. The mouth of the Pajaro is on the central Monterey Bay coast near Watsonville. This town is a rapidly growing agricultural and food-packing center of about 16,000 inhabitants and is the only large town in the Pajaro valley basin. While the Pajaro River flows generally westward from its origin near Pacheco Pass in the Diablo Range, its major tributaries drain valleys along the generally north-south orientation typical of California's coastal mountain ranges.

The largest tributary is the Uvas-San Benito system, which drains the rich agricultural lands situated between the Santa Cruz-Gabilan ranges and the Diablo Range. This long valley extends from Morgan Hill in the north to the origin of the most distant source streams some 100 air miles southeast. The Uvas-San Benito valley accounts for 1200 of the 1300 square mile drainage area of the Pajaro. The remaining area is drained by the Corralitos-Salsipuedes system and comprises the Pajaro River Valley Basin. These two drainage basins join at Chittenden Pass, some 13 miles from the mouth of the Pajaro.

From Chittenden Pass the Pajaro flows along a generally east-west axis toward the bay. At Watsonville, 6 miles from the bay, it is joined by the Corralitos-Salsipuedes Creek. It is the purpose of this paper to examine some of the many factors and processes which influence the estuarine environmental condition of the Pajaro from this confluence near Watsonville to its Monterey Bay terminus, 6 miles to the southwest (Figure 31).

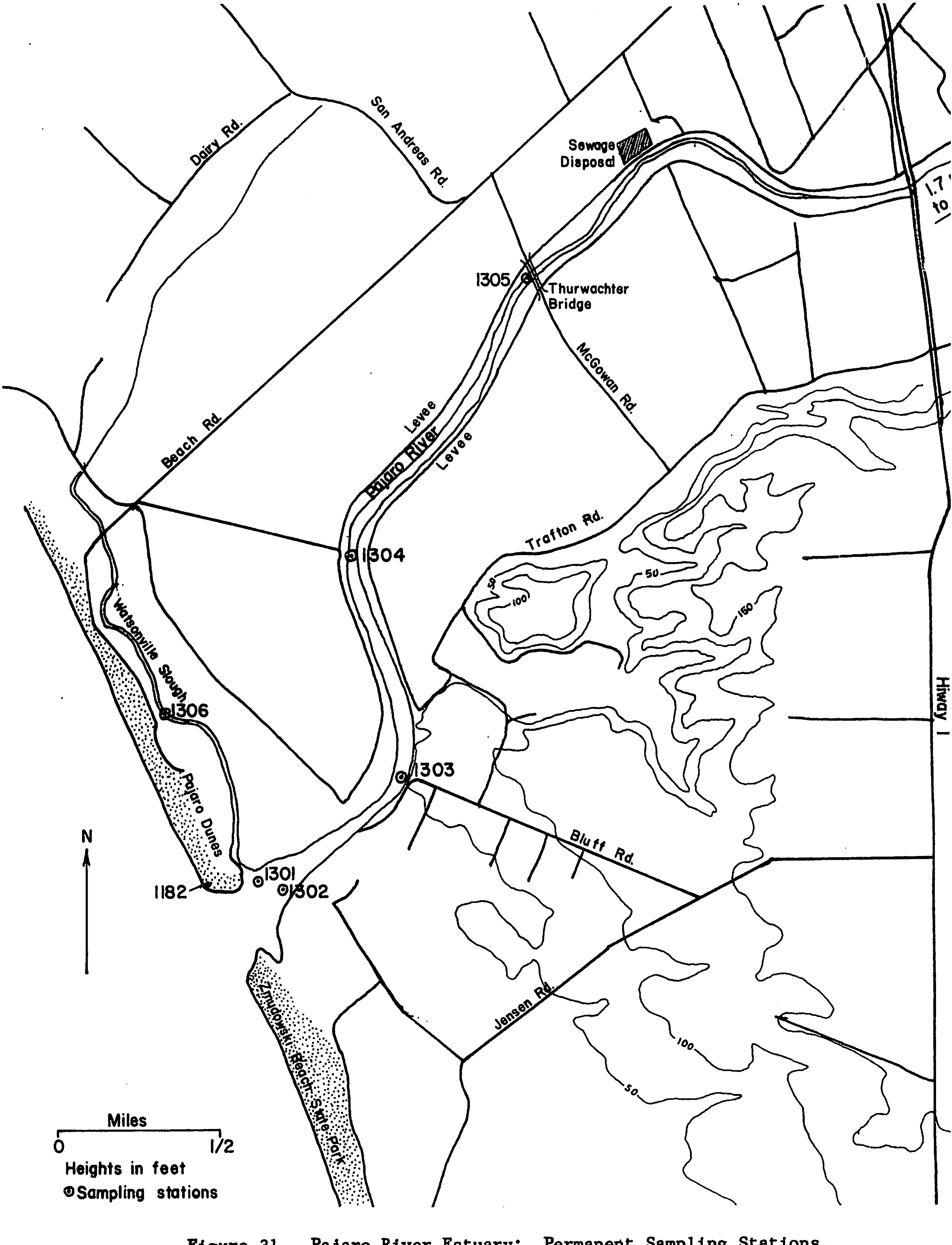

Figure 31. Pajaro River Estuary: Permanent Sampling Stations.

B. Hydrology

The estuarine portion of the Pajaro is approximately 2.5 miles long. It is confined to a flood control channel by levees which have been constructed on both sides of the river except for an 0.4 mile section near the mouth. The width of the channel is about 100 meters. During non-flood periods, and at low tides, the river follows a sinoidal pattern between these levees similar to river meander patterns described by Leopold [1966]. Water depths and flow rates in the estuary are strongly influenced by semidiurnal tides, as is the velocity and volume of river flow. The tidal influence is most acute during the summer months when the riverine contribution is minimal. High tide conditions enlarge the channel opening in the spring resulting in improved circulation and mixing in a manner similar to that described by Bowden [1967]. Man-devised methods are now being used to keep this channel open in order to create better mixing and flushing of the estuarine waters. The Pajaro fits closely to Reid's definition of a lagoon [Reid, 1961; also Smith, 1966].

Estuarine circulation has been investigated and described by many including Postma [1966], McPherson [1960], Pyatt [1958], and Ketchum [1951]. Postma noted that estuarine circulation takes place in the region where distinct vertical stratification occurs--fresh to brackish water near the surface, and brackish to salt water near the bottom. The river water, carried seaward in the upper water layers, tends to reduce the "salt wedge" [Mangledorf, 1967] through vertical mixing. Salinity readings acquired during the course of this study indicate that this situation exists in the Pajaro.

Dramatic changes occur in the Pajaro River and estuary following the first seasonal rains. Almost overnight the trickling stream can become a full river. This flood-stage potential is a matter of major concern to farming and residential areas which rely on the previously mentioned levees for protection.

Surface water exchange between the estuary and bay is augmented by an unknown, but perhaps significant, volume of sub-surface exchange. Considerable salt water intrusion into the upper water tables of the Pajaro basin has been described by some investigators [Greene, 1970; Ford, 1970].

C. Geology

Many geologists believe that the Pajaro River was at one time the major drainage for the great Central Vally of California, a function now served by the Sacramento-San Joaquin system. Stark and Howard [1968] considered the Pajaro a major erosive agent in the formation of the Monterey Submarine Canyon. Emergent mountain ranges and other tectonic factors are thought to have shifted this major drainage role to the Sacramento-San Joaquin system, so that today the Pajaro drains only its local valleys. The most westerly of these valleys is the Pajaro River basin lying between the Santa Cruz Range and Monterey Bay. This rich agricultural basin evolved as a major flood plain due to its low elevation above the sea and the resultant shallow river gradient [Baldwin, 1963]. Most of the present sediments in the basin are valleyfill materials, deposited since upper Miocene [Greene, 1970]. Riverine erosion transports these materials to the bay and to beaches near the mouth of the river [Garner, 1967].

The estuary substrate is composed of sand and larger particles over most of its area, with clay and organic materials confined to the banks, peripheral mudlats and upper estuary. Initial sediment studies indicate extensive clay and fine sediment deposition along both estuarine banks.

D. Morphology

The Pajaro River estuary can be considered to begin in the upper limit of tidal influence near the Thurwachter Bridge, approximately 2.5 river miles above the river mouth (Figure 31). From the Thurwachter Bridge the river flows southwesterly along a gentle stream gradient, then bends sharply southward. At this bend is a relatively deep hole, popular with local steelhead anglers, known as Foster's Hole. During non-flood periods water depth in Foster's Hole is about 2 meters in contrast to depths of less than 1.5 meters in adjacent river segments.

Below Foster's Hole, the river flows slowly southeastward about 0.5 mile. It then bends again 90° southwest to empty into Monterey Bay. This lowest river section, approximately 0.5 mile long, constitutes a shallow lake-like tidal lagoon having a mean depth of less than 2 meters and width of approximately 60 meters during non-flood periods. This lagoon connects to Monterey Bay by a channel which varies with water flow conditions from narrow, meandering form in the dry season to broad flood condition after winter storms.

In 1971, following a mild winter during which the river never approached flood conditions, this connecting channel was narrow and sinuous in early spring. By late April, high spring tides and strong westerly winds had combined to cut a deeper and straighter channel across the crescent-shaped bar at the river mouth and to increase interchange of water between the lagoon and Monterey Bay. This increased flow dropped water levels in the river so that by 22 May, at the peak of a 3.9 feet tide, depths in the north-south portion of the estuary averaged only about 0.5 meter.

E. Preliminary Biological Notes

At the upper end of the estuary, fresh water organisms predominate. Frogs (tadpoles), fresh water turtles, aquatic insects, and fresh water fishes have been observed and collected in the vicinity of the Thurwachter Bridge. Typical river-bank riparian associations line the Pajaro estuary except for the lowest half-mile where they are replaced by low-growing coastal vegetation and sand banks. The wooded sections have high recreational potential, though only limited boating and camping is now pursued due to difficulties of access. Steelhead fishing takes place at selected locations along both banks, although fishermen have noted that in recent years the number of fish taken per unit of effort has been declining. The wooded areas along the bank support a diversified array of riparian plants and animals. [See the U.S. Army Corps of Engineers ENVIRONMENTAL REPORT: A PRELIMINARY REPORT ON THE PAJARO RIVER FLOOD CONTROL PROJECT; AUGUST 1970, for a listing of species.]

Unfortunately heavy pesticide and herbicide applications to increase crop production have taken a heavy toll of biotic communities along the Pajaro. Man-initiated changes in land use and other effects brought about by human encroachment have placed severe pressures on these riparian associations as well as upon river flora and fauna. The animals that continue to live in these habitats are those most able to adapt to the constant changes which occur both naturally and because of human activities.

River margins are rich in organic matter but appear to lack significant shellfish populations; however, shell remnants indicate extensive shellfish beds in the past. Species diversity in the littoral zone appears lower than might be expected suggesting severe environmental pressures from pollution or other factors. Life in the lower estuarine area appeared to be at lowest levels during the fall period before the seasonal rains. Throughout the estuary and its shoreline, insects and small animals appeared to be most abundant in mid-winter and early spring. This abundance may be related to the normal seasonal sequence in spraying and the effects of summer agricultural run-off to the Pajaro River. During late summer, residues from agricultural chemicals appear to reach a peak which may significantly reduce insect and other animal populations of the estuary. Winter rains purge these relatively concentrated pesticide and herbicide residues from the fields and streams of the Pajaro basin in a cycle that somewhat reverses the normal winter-summer dormancy-growth cycles. There is a major need for further study of the relationships of these cycles to the hydrology of the estuary, since careful investigation of estuarine hydrology should consider three relatively independent water sources: stream flow, agricultural drainage, and tidal influence [Caspers, 1967; Bowden, 1967].

F. Historical Review

Incomplete records indicate that a tribe of indians who called themselves Nootsum were the earliest known inhabitants of the Pajaro Valley. The Nootsum, like most other coastal tribes, cultivated a little maize, but for the most part relied on hunting and fishing to provide their subsistence.

It is not known with certainty whether Captain Vizcaino explored the Pajaro Valley in 1602 when he discovered Monterey Bay, but it has been established that the Portola Expedition "rediscovered" the Pajaro Valley in their overland expedition to San Francisco Bay. The diary of Father Juan Crespi attests to the fact that he and about 60 other members of the Portola group reached the future site of Moss Landing on 8 October 1769 and turned inland to the Pajaro Valley. He noted and described the river and the surrounding lands "...beyond the river was a very verdant and pleasant plain well covered with oaks, alders, and sycamores, and other species not known to us." [Orr, 1952]

The Spanish governors granted extensive ranchos to army officers who administered important civil positions of the Monterey Bay area. Two major ranchos bordering the Pajaro were Rancho Bolsa del Pajaro and Rancho Salsipuedes.

Recent history in the Pajaro Valley began with the settlement of Watsonville in 1852. The hundred-year period from 1852 to 1952 is well described in a publication, WATSONVILLE - THE FIRST HUNDRED YEARS, which incorporates the principal historical data as it appeared in the Centennial Edition of the Watsonville Register-Pajaronian, 2 July 1952.

The Pajaro Valley has in the past been a major potato and grain producing area. Apples became a primary crop just before the turn of the century, continuing to dominate in upland areas, although the lower valley plain areas are now devoted primarily to lettuce and artichoke production. Strawberries are extensively cultivated on the gentle slopes above the valley plain.

The earliest records of the Spanish missions in this area indicate that irrigation measures were applied to improve agricultural productivity. Pajaro River tributaries were dammed or diverted during the eighteenth century by mission farmers such as those at San Juan Bautista. Since that time many artificial mechanisms and man-made projects have been incorporated into the Pajaro drainage system. These include dams, reservoirs, canals, and extensive levee systems. Data relative to these projects are included in PAJARO RIVER BASIN, CALIFORNIA, U.S. Congress, House Document 491.

These projects are now being evaluated in terms of their ecological impact. The ENVIRONMENTAL STATEMENT, a preliminary report issued by the U.S. Army Corps of Engineers [August 1970] cites several environmental problem areas noting that "...pollution, contamination and deterioration of the channel are the greatest public nuisance at times between active stream flows and the mid-year periods of marked desiccation, since there is not sufficient flow to dilute deleterious materials in or entering the system." The estuarine hydrologic forces are not adequate to carry the pollutant materials to the bay [Diachisin, 1954], and the continuous buildup of these materials inhibits the number and types of animal populations at the expense of algae growth [Filice, 1959]. This view, that it is not the organic matter in the sewage itself that is the main cause of pollution but, rather, the effects brought about by this fertilization, has also been noted by Baalsrud [1967].

Preliminary studies by the boards of health in Monterey and Santa Cruz counties have noted that high concentrations of pesticide residues exist in bay waters near the mouth of the Pajaro [Joint Report by the Boards of Health, Monterey and Santa Cruz Counties, 1970]. Specific data are lacking about origin, types, and quantitative amounts of pesticides and other deleterious chemicals which may exist in the Pajaro.

G. Pajaro Study Team

Although some preliminary investigation and background studies had been accomplished by Sea Grant staff personnel and students, the major field investigation effort did not commence until February 1971. The Pajaro River study team was organized from five students enrolled in the research participation class plus a Graduate Assistant team leader.

Field trips, collection and analysis of data, and other facets of the Sea Grant program were planned through consultation with faculty and other team leaders. The Pajaro study plan was designed to parallel the investigations of the Elkhorn Slough group, with field and laboratory work also scheduled on saturdays.

Participants on the Pajaro team were science teachers particularly concerned with environmental problems and students working toward science teaching careers. Team members were:

Robert Ballering	Student Marine Science	Novato
Robert Byington	High School Teacher Oceanography	Santa Cruz
Ted Celmer	Junior High School Teacher Science	Salinas
Ray Kruse	High School Teacher Biology	Sunnyvale
Dave Schumaker	High School Teacher Science	Felton

The Pajaro team contributed extensively to the overall environmental data collection program. The schedule called for one field trip per month to gather data from the hydrologic sampling stations and to collect water samples for nutrient analysis. These field trips were augmented by others for collection of animal and sediment specimens and samples.

Since these data encompass only a brief portion of the annual cycle, their detailed analysis at this time is not appropriate. All data are filed in the Sea Grant archives and will be reported at a later date when observations for a calendar year are available. Preliminary and highly tentative conclusions are summarized in the following section.

H. Tentative Conclusions, Pajaro River

1. Oxygen concentrations were highest during the winter months. The highest readings were found upstream in shallow high-velocity-flow areas (stations #1304, #1305).

2. Water transparency in the estuary and river varies inversely with precipitation. The lowest Secchi disk readings occurred shortly after precipitation in the watershed areas on 27 March, while the highest readings occurred after several days of little or no precipitation (27 February).

3. Seine and gill net captures (see fish summary, pp 102-103) indicate a considerable array of fish species still live in the Pajaro despite increasing pollution.

4. Field observations indicate that the bay barrier opening of the river mouth moves southward from January to mid-April. In late April, 1971, tidal action cut across the meanders and moved the mouth to a position in line with the central longitudinal axis of the estuary.

5. Concentrations of nutrients in the estuary and Watsonville Slough are extremely high; the highest levels were found at station #1306 in the Watsonville Slough area.

6. Field observations along the levee roads and estuary banks indicate that bank and shore animal life is more abundant in the spring than in the fall.

7. Benthic organisms appear to be sparce and scattered. No community, niche, or succession patterns have yet been established. (See benthic summary, pp 111, 113).

8. From a review of past histories of the Pajaro (U.S.G.S. Water Resources tabulations), it is apparent that rather low volumes of water enter the estuary from upstream during non-flood periods. At no time in 1970-1971 did the water height exceed 100 cm on the stream gauge erected at station #1307. The amount of water that flowed into the estuary in previous years (1968-1969, 1969-1970) had been considerably greater. Thus riverine and estuarine conditions can be seen to vary considerably, not only on a seasonal basis but from year to year.

9. Salinity readings indicate vertical stratification in the estuary which is more pronounced in the winter than in the spring. The late April "opening of the river mouth" allowed more mixing by tidal action and decreased vertical stratification extremes.

10. Water temperatures in the Pajaro show more variation horizontally (distance from the mouth) than vertically (depth). The Pajaro is a shallow estuary; the greatest depth was found to be 2 meters (stations #1301, #1304). When the Corralitos Trunk, emanating from Freedom and the North Pajaro Basin, enters the Pajaro River, an increment in cold water occurs.

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VI. FISHES SAMPLING PROGRAM

(Gary Kukowski, Graduate Research Assistant)

A. Introduction

The areas sampled for fishes during the spring semester of 1971 were the Pajaro River, Elkhorn Slough and Monterey Bay. Most stations in the areas were sampled at least twice during the semester, but different types of gear were utilized because of special sampling problems of each area. Appendix D list the sampling stations, dates, and gear involved for each area. Some of the collected fishes were worked on the day sampled, all others were frozen or preserved in formalin until it was possible for the Research Participants to obtain the necessary data from them.

B. Methods and Materials

1. Gear

Sampling gill nets were used in all three study areas. A small-mesh and a larger mesh series, which were made at the Laboratories, were used separately or joined into a single net if desired. The small-mesh series consisted of 1-inch, 2-inch, and 4-inch stretch mesh, each panel of different mesh size 10 meters long. The large-mesh series had 1.5-inch, 3-inch, and 6-inch stretch mesh, each panel also 10 meters long. All nets were 6 feet deep, equipped with a lead-core line as well as a polypropylene float line to which additional floats were attached as needed. Nets were designed to fish on the bottom and were usually anchored at both ends with Danforth anchors with lines leading from these to floats at the surface. In Monterey Bay sets, one of the lines was attached to a large float (made from a "hoppity-hop" ball) and weighted bamboo pole buoy with flag for easy recovery.

Both day and night gill net sets were made, with time in the water variable due to logistical problems of pickup. On overnight sets the buoys were equipped with a blinking light.

The second type of gear, used only in Monterey Bay, was a 20-feet (foot line measurement) otter trawl, bag and cod-end of 1.5-inch and 1.0-inch stretch mesh respectively, and a bag liner of 0.38-inch stretch mesh. The otter boards were attached to the net mouth with 33-feet mud lines and connected by 66-feet bridle lines to the single towing cable of the research vessel. The amount of cable and speed of trawling were dependent on the depth of the sampling area with an average scope of about 1:4 and speed of 3 knots. Three trawls, each of 10 minutes duration, were made at each station sampled.

Beach seines were used only in the Pajaro River and Elkhorn Slough. The seine was fabricated at the Laboratories with detachable wings to provide either a short net of 90 feet or a longer unit of 200 feet. The 90-feet section had a 1-inch stretch mesh and was equipped with a bag of the same mesh size. The two wings had 3-inch stretch mesh.

Beach seines were laid out parallel to shore. The line from one end was taken ashore, the net laid out near the opposite shore, parallel to the shoreline, then the line for the other end brought ashore.

For reconnaissance purposes a 50-feet, 0.75-inch stretch-mesh beach seine equipped with a bag was used in Elkhorn Slough. In the shallow parts of the Pajaro River, a small 20-feet, 0.5-inch stretch-mesh beach seine was also used.

2. Areas sampled

Stations sampled for fishes in the three study areas were selected from the permanent stations sampled for hydrographic data. Four stations in Monterey Bay were sampled intensively in order to concentrate resources available for effective replication of data (see Appendix D). Samples were taken twice during the semester for three of these stations; three times for the fourth.

In the Pajaro River, six different stations were sampled during the semester, but only one was sampled twice. This failure to resample the other stations was partly due to gear failure problems, but mostly due to the presence of steelhead fishermen and consequent potential of public relations problems. A more extensive series of stations were sampled in the Pajaro than in other areas in order to determine as many of the species of fishes present in the river as possible.

Three stations were sampled in Elkhorn Slough twice during the semester, a fourth reconnaissance station was sampled once.

3. Manpower resources

Due to the considerable manpower requirements for fishes sampling, it was necessary to obtain outside help to augment the regular Sea Grant Research Participants. Mr. Patrick Mallory of San Jose State College brought six of his students to help in the retrieval of overnight gill net sets in Monterey Bay as well as processing of data from these fishes. Mr. John Berney (one of the Sea Grant Research Participants) of Leland High School, San Jose, brought eight of his students to assist in the same manner. Dr. R.L. Hassur of San Jose State College and his ichthyology class assisted in the sampling of several stations during two of their field trips. Other persons who added to the Sea Grant data file on the fishes in the areas sampled include: Ron Larocca and Joel Cohen, who gathered data from various stations as part of their own graduate studies; Dave Lewis and Daniel Varoujean, who contributed data from Monterey Bay; and Dr. William Broenkow's oceanographic techniques class, which processed data for the fishes from their two biological cruises on Monterey Bay.

4. Preservation procedures

Since it was usually impossible to process data for fishes collected on the same day they were collected, specimens usually were preserved until manpower became available. Early in the semester, fishes were fixed in 10% formalin (1 part formalin to 9 parts water). As soon as a freezer could be obtained, fishes were frozen without formalin treatment, thus reducing costs for formalin and avoiding problems with formalin fumes and corrosive action on the skin of fish processors. This also permitted return of excess specimens to the ecosystem after data had been obtained from them.

5. Data obtained

For all fishes collected, species was determined. For each species the number of individuals, total mass, minimum and maximum weights and lengths, and length frequencies were recorded. When it was easily determinable, or could be noted when a species was spawning, sex was recorded. All data were processed in the laboratory rather than in the field.

All lengths taken were total length (length from tip of snout to tip of compressed tail with the fish fully extended on its side on a flat surface). Lengths were recorded on a measuring board fitted with a strip of plastic calibrated with transverse lines one centimeter apart. An end-piece on the board acts as a stop for the nose of the fish. Measurements can be recorded rapidly by laying each fish of a species on the board, marking the point of the end of the tail on the plastic sheet, and tallying the number of marks per centimeter interval after all individuals have been measured. For convenience, data are recorded as whole centimeters, whereas the actual mean length would be 0.5 centimeters less.

An autopsy balance was used to obtain weights to the nearest 10 grams. (Thus, fish recorded as 50 grams included all whose weight ranged from 45 to 55 grams, or in the range of 50 ± 5 grams.) Fish that weighed less than 5 grams were not recorded.

A spring balance milk scale was used for fishes too large for the autopsy balance (9 kilograms). Weights were measured to the nearest one-tenth of a pound and then converted to grams.

References used to identify the fishes are indicted in the literature cited for this section. All names are according to The American Fisheries Society [1970].

All data first were placed on laboratory work sheets and then transferred to special forms with spaces corresponding to computer punch cards. These are of two types, one with all the above data except length frequencies, and the other for length frequencies.

6. Disposition of samples

After all data were obtained, the samples were disposed of variously. Fishes valuable for future local reference were added to the Moss Landing Marine Laboratories reference and teaching collections. Others were donated to the San Jose State College collections. Many were dissected for their otoliths by a graduate student at Moss Landing as part of her thesis work. Excess specimens were made available to public school teachers in the Research Participation class for use in their own classrooms. All osmerids were sent to Dr. Warren Freihofer at Stanford University for his nervous system researches. Some specimens were used as bait in various other studies or for food for fishes kept alive at Moss Landing. Those not utilized in any of the above ways were returned to the ecosystem. Arrangements have been completed for all fishes collected from Monterey Bay in the future to be preserved and sent to San Francisco State College for incorporation into their large permanent collections.

C. Results

Because the sampling period covered in this report is short, it is inappropriate at this time to attempt a detailed analysis of sampling results. However, species lists for the several stations, and dominant species both in per cent of total individuals and per cent of total biomass for each station will be presented. Data for each station represent combination of results from total sampling over the four-month period.

1. Pajaro River

Eleven species were found at the six sampling stations. Table IV lists the species as well as the stations and sampling dates. Table V shows the dominant species as per cent of total individuals, and of total biomass, for each station.

2. Elkhorn Slough

Twenty-four species were found at the four stations. Table VI lists the species, stations, and sampling dates. Table VII shows the dominant species for each station.

3. Monterey Bay

Forty-four species were found at the four stations. Table VII lists the species, stations, and sampling dates. Table IX shows the dominant species for each station. A per cent similarity index [Whittaker, 1952] was calculated for the data from all the otter trawls taken during th sampling period. The mean per cent similarity index for all replicated trawls was 70.4%, with a standard deviation of 20.5%. The index indicates that on the average 70.4% of the fishes captured in one replicate trawl will be the same species as those taken in any other; this would seem to be good replication. From this indication, and from an over-all comparison of the results of each of the three trawls taken at all stations sampled on all dates, it appears that it will be possible to reduce the number of replicate trawls to two. This would allow the addition of two new sampling stations with the same level of sampling effort.

TABLE IV

Fishes Collected in the Pajaro River
20 February 1971 - 17 April 1971

		Station Date	1301 4/17	1306 2/20	1303 2/20	1303 3/27	1304 3/27	1305 3/27	1307 2/20
1	Clupea harengus pallasi	Pacific herring			*				
2	Salmo gairdneri	Steelhead	*				*	*	
3	Cyprinus carpio	Carp						*	*
4	Lavinia exilicauda	Hitch						*	*
5	Ptychocheilus grandis	Sacramento squawfish							*
6	Catostomus occidentalis	Sacramento sucker						*	
7	Gasterosteus aculeatus	Threespine stickleback							*
8	Cymatogaster aggregata	Shiner perch	*	*	*	*	*		
9	Leptocottus armatus	Pacific staghorn sculpin	*		*	*			
10	Atherinops affinis	Topsmelt		*		*	*		
11	Platichthys stellatus	Starry flounder	*	*	*	*	*		

TABLE V

Dominant Species Found in the Pajaro River
20 February 1971 - 17 April 1971

STATION NUMBER	SPECIES	% OF TOTAL NUMBER TAKEN at that station	% OF TOTAL BIOMASS TAKEN at that station	COLLECTING DATES
1301	Starry flounder	79.6	91.2	17 Apr
	Shiner perch	13.6	5.6	
	Steelhead	4.6	2.8	
	Pacific staghorn sculpin	2.3	0.4	
1306	Starry flounder	78.6	88.2	20 Feb
	Shiner perch	14.3	5.2	
	Topsmelt	7.1	6.6	
1303	Topsmelt	62.4	77.1	20 Feb and 27 Mar
	Shiner perch	17.1	8.0	
	Starry flounder	13.7	11.4	
	Pacific herring	3.4	1.8	
	Pacific staghorn sculpin	3.4	1.7	
1304	Shiner perch	64.7	21.5	27 Mar
	Starry flounder	17.6	7.5	
	Topsmelt	13.7	7.1	
	Steelhead	3.9	63.9	
1305	Starry flounder	42.9	36.0	27 Mar
	Steelhead	19.0	8.4	
	Hitch	14.3	7.1	
	Sacramento sucker	14.3	27.6	
	Carp	9.5	20.9	
1307	Hitch	90.2	87.9	20 Feb
	Sacramento squawfish	3.9	2.4	
	Threespine stickleback	3.9	0.2	
	Carp	2.0	9.5	

Note: Refer to Figure 31, page 86, for station locations in the Pajaro River.

TABLE VI

Fishes Collected in Elkhorn Slough
23 February 1971 - 6 May 1971

	Species	Common name	1201 3/6	1201 4/24	1204 3/6	1204 5/6	1209 2/23	1209 3/6	1206 5/1
		Station Date							
1	*Mustelus californicus*	Gray smoothhound			*	*			
2	*Triakis semifasciata*	Leopard shark		*	*	*			
3	*Myliobatis californica*	Bat ray		*					
4	*Clupea harengus pallasi*	Pacific herring	*						*
5	*Engraulis mordax*	Northern anchovy							*
6	*Hypomesus pretiosus*	Surf smelt							*
7	*Atherinops affinis*	Topsmelt					*		
8	*Atherinopsis californiensis*	Jacksmelt	*	*	*	*			
9	*Syngnathus californiensis*	Kelp pipefish						*	*
10	*Morone saxatilis*	Striped bass		*					
11	*Trachurus symmetricus*	Jack mackerel							*
12	*Cymatogaster aggregata*	Shiner perch	*	*	*	*			*
13	*Embiotoca jacksoni*	Black perch	*	*		*		*	
14	*Hyperprosopon argenteum*	Walleye surfperch		*					
15	*Micrometrus minimus*	Dwarf perch				*			
16	*Phanerodon furcatus*	White seaperch			*	*			
17	*Rhacochilus toxotes*	Rubberlip seaperch				*			
18	*Ophiodon elongatus*	Lingcod						*	
19	*Leptocottus armatus*	Pacific staghorn sculpin	*	*		*	*	*	
20	*Scorpaenichthys marmoratus*	Cabezon						*	
21	*Citharichthys stigmaeus*	Speckled sanddab						*	
22	*Paralichthys californicus*	California halibut						*	
23	*Hypsopsetta guttulata*	Diamond turbot						*	
24	*Platichthys stellatus*	Starry flounder					*	*	*

TABLE VII

Dominant Species Found in Elkhorn Slough
23 February 1971 - 6 May 1971

STATION NUMBER	SPECIES	% OF TOTAL NUMBER TAKEN at that station	% OF TOTAL BIOMASS TAKEN at that station	COLLECTING DATES
1201	Pacific herring	41	8	6 Mar
	Jacksmelt	33	29	and
	Shiner perch	16	--	24 Apr
	Leopard shark	4	55	
	5 other species	6	--	
	6 other species	--	8	
1204	Shiner perch	36	--	6 Mar
	Jacksmelt	21	16	and
	Pacific staghorn sculpin	11	--	6 May
	Leopard shark	8	46	
	Gray smouthhound	6	19	
	White seaperch	6	--	
	Rubberlip seaperch	6	13	
	2 other species	6	--	
	5 other species	--	6	
1206	Shiner perch	56	39	1 May
	Pacific herring	39	50	
	Starry flounder	2	3	
	4 other species	3	--	
	Jack mackerel	--	7	
	3 other species	--	1	
1209	Topsmelt	94	93	23 Feb
	Starry flounder	2	3	and
	Speckled sanddab	1	--	6 Mar
	Pacific staghorn sculpin	--	1	
	7 other species	3	3	

TABLE VIII

Fishes Collected in Monterey Bay
27 February 1971 - 8 May 1971

			Station 1105 Date 4/2	1105 5/8	1154 3/9	1154 5/4	1155 2/27	1155 3/13	1155 5/8	1156 3/9	1156 5/4
1	*Eptatretus stouti*	Pacific hagfish						*	*	*	
2	*Mustelus henlei*	Brown smoothhound					*			*	
3	*Squalus acanthias*	Spiny dogfish					*			*	
4	*Torpedo californica*	Pacific electric ray							*	*	*
5	*Raja binoculata*	Big skate				*	*	*	*		
6	*Raja inornata*	California skate							*		
7	*Alosa sapidissima*	American shad						*			
8	*Clupea harengus pallasi*	Pacific herring		*		*	*				*
9	*Engraulis mordax*	Northern anchovy				*	*			*	
10	*Oncorhynchus tshawytscha*	Chinook salmon				*				*	
11	*Spirinchus starksi*	Night smelt	*	*	*	*	*	*		*	*
12	*Porichthys notatus*	Plainfin midshipman							*	*	*
13	*Merluccius productus*	Pacific hake							*		*
14	*Microgadus proximus*	Pacific tomcod			*	*	*	*		*	*
15	*Otophidium taylori*	Spotted cusk-eel						*		*	*
16	*Atherinopsis californiensis*	Jacksmelt				*					
17	*Syngnathus californiensis*	Kelp pipefish			*					*	
18	*Genyonemus lineatus*	White croaker		*	*	*	*	*		*	*
19	*Cymatogaster aggregata*	Shiner perch			*		*	*	*	*	*
20	*Hyperprosopon anale*	Spotfin perch			*	*		*	*		*
21	*Phanerodon furcatus*	White seaperch				*		*		*	*
22	*Zalembius rosaceus*	Pink seaperch		*				*		*	*

(continued)

TABLE VIII

Fishes Collected in Monterey Bay
27 February 1971 - 8 May 1971
(continued)

			1105 4/2	1105 5/8	1154 3/9	1154 5/4	1155 2/27	1155 3/13	1155 5/8	1156 3/9	1156 5/4
		Station Date									
23	*Peprilus simillimus*	Pacific pompano						*	*	*	*
24	*Sebastes auriculatus*	Brown rockfish					*				
25	*Sebastes melanops*	Black rockfish					*				
26	*Sebastes paucispinis*	Bocaccio						*	*		
27	*Anoplopoma fimbria*	Sablefish							*		
28	*Ophiodon elongatus*	Lingcod				*		*	*		*
29	*Zaniolepis latipinnis*	Longspine combfish									*
30	*Icelinus quadriseriatus*	Yellowchin sculpin								*	
31	*Leptocottus armatus*	Pacific staghorn sculpin				*		*	*	*	
32	*Odontopyxis trispinosa*	Pygmy poacher						*			
33	*Stellerina xyosterna*	Pricklebreast poacher			*		*				
34	*Citharichthys sordidus*	Pacific Sanddab		*				*	*	*	*
35	*Citharichthys stigmaeus*	Speckled sanddab	*		*	*	*	*		*	*
36	*Eopsetta jordani*	Petrale sole							*	*	*
37	*Glyptocephalus zachirus*	Rex sole							*		
38	*Microstomus pacificus*	Dover sole							*		*
39	*Parophrys vetulus*	English sole	*	*	*	*	*	*	*	*	*
40	*Platichthys stellatus*	Starry flounder	*	*		*			*		
41	*Pleuronichthys decurrens*	Curlfin sole	*			*		*	*	*	*
42	*Pleuronichthys verticalis*	Hornyhead turbot							*		
43	*Psettichthys melanosticus*	Sand sole	*		*	*		*	*	*	
44	*Symphurus atricauda*	California tonguefish						*		*	*

TABLE IX

Dominant Species Found in Monterey Bay
27 February 1971 - 8 May 1971

STATION NUMBER	SPECIES	% OF TOTAL NUMBER TAKEN at that station	% OF TOTAL BIOMASS TAKEN at that station	COLLECTING DATES
1156	Pacific sanddab	39	23	9 Mar
	Night smelt	12	--	and
	English sole	11	16	4 May
	Plainfin midshipman	8	3	
	Pink seaperch	8	--	
	White croaker	7	7	
	24 other species	15	--	
	Brown smoothhound	--	16	
	Lingcod	--	12	
	Spiny dogfish	--	5	
	Petrale sole	--	3	
	22 other species	--	15	
1155	Night smelt	57	7	27 Feb
	White croaker	10	28	13 Mar
	Pacific sanddab	7	14	and
	Pacific tomcod	7	4	8 May
	English sole	6	16	
	Spotfin perch	4	--	
	33 other species	9	17	
	Big skate	--	14	
1154	Night smelt	74	8	9 Mar
	Speckled sanddab	7	5	and
	White croaker	6	30	4 May
	Northern anchovy	5	5	
	Spotfin perch	2	--	
	Pacific tomcod	1	--	
	Lingcod	1	--	
	13 other species	4	19	
	Sand sole	--	14	
	English sole	--	10	
	Chinook salmon	--	9	
1105	Night smelt	55	3	2 Apr
	Speckled sanddab	20	4	and
	Curlfin sole	8	39	8 May
	Starry flounder	4	17	
	English sole	4	18	
	Pacific sanddab	3	4	
	White croaker	3	7	
	Sand sole	2	7	
	2 other species	1	1	

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VII. BENTHIC SAMPLING PROGRAM

(David Garrison, Graduate Research Assistant)

A. Introduction

Regular sampling of the benthic communities began in February 1971. Stations in each of the three areas of study (Elkhorn Slough, Pajaro River, and Monterey Bay) were scheduled on a bimonthly basis. (Actual dates of sampling are shown in Table X.)

Following the outline of suggested sampling priorities and scope for data collection presented in the first half-year progress report (Appendix 14, Section 8a-e), the program to date has consisted of the following steps:

1) Establishing sound sampling procedures
    a) appropriate equipment
    b) adequate replication of samples

2) Establishing uniform procedures for sample processing

3) Rough sorting of organisms to major groups
    a) enumeration
    b) wet-weight biomass determination

4) Preserving rough sorted materials and preparing them for further taxonomic analysis by specialists.

The three areas being sampled are quite different from one another in regard to the environmental gradients that are being crossed in the sampling program. The seaward end of the Pajaro River is an estuary and shows salinity gradients ranging from sea water to fresh water. Samples were taken in waters showing sea water salinities to near-fresh water conditions. Elkhorn Slough shows more consistent salinities, but the large areas of exposed mud and sand flats are subject to variations in exposure within the ranges of the tidal changes. The gradients in Elkhorn Slough are further complicated by changes in particle size from coarse sand to fine silt and mud areas over a short distance. Slough stations sampled to date lie in the deeper channels covered at high tides by a water depth of at least one meter.

In contrast to these areas, the shallow water stations in Monterey Bay are not subjected to large environmental fluctuations of salinity and temperature, and the sediments are fairly homogeneous over large areas.

Primarily as a result of the problems of sampling the Pajaro River and Elkhorn Slough, and because there is a wealth of previous experience on sampling techniques appropriate for Monterey Bay, the three areas are at different stages in the establishment of the benthic program. [For Monterey Bay sampling techniques, see Chartock, 1971; Mayer, 1969; Houck, 1969, and others engaged in Kaiser Refractories, Pacific Gas and Electric Company, and California Department of Fish and Game studies at the Moss Landing Marine Laboratories.]

Since only percentage composition for major phylogenetic groups has been determined at this early stage in the total project, only superficial comparisons between stations can be drawn.

TABLE X
Benthic Stations Sampled and Processed
During Period February-June 1971

AREA	STATION NUMBERS	SAMPLE DATE	SORTING DATE
Monterey Bay	1155	2 Mar	30 Mar
		13 Mar	27 Mar
		8 May	unsorted
	1154	9 Mar	16 Mar
		4 May	18 May
	1156	9 Mar	16 Mar
		4 May	11 May
	1105	8 May	29 May
Pajaro River	1301	6 Mar	unsorted
		17 Apr	15 May
	1304	6 Mar	15 May
		17 Apr	8 May
Elkhorn Slough	1201	20 Feb	27 Feb
	1207	23 Feb	unsorted
	1209	1 May	partially processed

Total sampling days * 10
Total stations visited 15
Total samples taken 75
Total samples rough sorted 60
Samples remaining to be processed 15

* Sampling days for fishes and invertebrates are considered, since often groups were sampled simultaneously.

B. General Procedures for Processing Benthic Samples

General procedures that were followed in the benthic survey (with some modifications to meet specific regional sampling problems which are discussed in the following section) are:

1. Five to ten replicate samples taken at each station
2. Subsamples removed from undisturbed samples for
   - sediment analysis
   - microfaunal enumeration
3. Rough volume for each sample determined to the nearest 100 cc
4. Rose Bengal dye and isotonic $MgCl_2$ added to each sample for staining and anaesthetizing organisms
5. Samples washed through 1 mm-mesh screens
6. Organisms retained by screens transferred to glass containers and preserved in 10% formalin (1:9 dilution)
7. Organisms rough sorted into major groups (see Appendix E:1-2), enumerated, and wet-weight biomass determined
8. Rough sorted organisms preserved in 40% isopropyl alcohol and arranged for further sorting of dominant groups (Appendix E:3).

C. Regional Sampling Studies

1. Monterey Bay

Monterey Bay stations #1105, #1154, #1155, and #1156 were sampled regularly for benthic macrofauna (organisms greater than 1 mm). Five replicate samples were taken from the boat at anchor using a Ponar grab (mouth area, 500 cm^2) that had been modified by making the fixed back screen removable allowing withdrawal from the undisturbed sample of a subsample for microfauna and sediment analyses.

Still on board the vessel, after removing the microfauna-sediment subsample which was immediately preserved in 10% buffered formalin, the volume of each macrofauna sample was measured, solutions of rose Bengal dye and $MgCl_2$ (Appendix E:3) were added, and the samples were then sieved by washing them through 1 mm-mesh screens with filtered seawater. Samples were sorted later, and numbers and biomass for major groupings were determined (Appendix E:4-5).

Superficial considerations of the data show that between the stations in the Monterey Bay the dominant groups differ considerably (Appendix E:1), but in general the dominant organisms belong to the major groups Polychaeta, Crustacea, and Mollusca. In all cases the infauna (polychaetes and mollusks) make up a dominant portion of the sample. Appearances of large numbers of Crustacea in some of the samples requires some evaluation of the seasonality of these epifaunal forms.

2. Pajaro River

Stations #1301 and #1304 were the regularly sampled biological stations on the Pajaro River (Figure 31, page 86). Five replicate samples were taken at equally spaced intervals across the river at the station location. Each replicate was subsampled for microfauna enumeration and particle size. In addition, the depth at each replicate location was recorded. Processing of the samples followed the general procedures described previously.

The first series of samples was taken with a 150 cc "mud snapper" grab. Thereafter a more satisfactory sample was obtained using a Birge-Ekman dredge (mouth area, 35 cm^2) which produced sample volumes from 700 to 3750 cc.

Large amounts of leaf litter at station #1304 made screening of the samples extremely difficult. Gross changes at station #1301 due to substrate movement [Scott Daily, personal communication] should be considered in evaluation of data over a long time period. At this time there are not sufficient data to make significant benthic evaluations for the Pajaro River.

3. Elkhorn Slough

Sampling in Elkhorn Slough was subject to a number of problems and various techniques were attempted. The first samples were taken at station #1201 (Figure 26, page 72) using a hand corer of 36 mm diameter and 20 cm depth. Five replicates were taken in the soft mud of the main channel. Samples were processed in the standard manner. Rough sorting yielded surprisingly few organisms; 3 species and a total of 16 individuals.

Sampling in the upper end of the slough presents difficulties because the largest area consists of mud flats too soft for walking and too shallow for a boat. Furthermore, the sticky silt-clay consistency of the samples all but defies sieving operations. The patchiness of organism distribution and the difficulty in sample processing necessitates spending large amounts of time for little return.

Intensive sampling in the area of station #1204 was accomplished by Hodgson [unpublished report, 1971]. A different approach to sampling was attempted at station #1209. On the mud-sand flat near this station, random points were located in a 100 m^2 area. Five replicate "milk carton cores" (10 x 10 x 20 cm) were taken, and tidal elevation was recorded for each point. These samples have been only partially processed and significant data are not available.

The technique used at station #1209 seems to be the most appropriate for sampling the intertidal areas of Elkhorn Slough. However, the number of samples needed is in excess of the time we are able to spend in normal data collection for this area. Perhaps better sampling could be accomplished by individual workers as was done by Hodgson at station #1204.

D. Coding and Data Reduction

For coding final data for computer storage and manipulation, we have developed our own form, CT-5. For taxonomic coding we have elected that one established for use by the Gulf Coast Research Laboratory [Christmas and Eleuterius, undated].

During the course of this first sampling period, a listing of local organisms was compiled and forwarded to the above institution for assignment of code numbers. In addition, our CT-5 form is currently being revised to accomodate benthic data more conveniently.

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VIII. PLANKTON STUDIES

(Mary Silver, Ph.D., Assistant Professor of Biological Oceanography and Judy Hansen, Graduate Research Assistant)

We have completed three months of sampling in Monterey Bay and have analyzed many of the data. A routine sampling program has been established and we hope to expand the scope of the present studies in the next year. We believe a few tentative conclusions may be made from the present data.

A. Summary of Data Collection Methods and Materials

1. Phytoplankton biomass

The standing crop of phytoplankton was estimated using flourometric methods [Holm-Hansen et al, 1965]. Samples for phytoplankton were taken in north and central Monterey Bay on three plankton cruises and six hydrographic cruises. Three to fifteen samples of unfiltered seawater (500 to 1000 ml) were obtained at each station depending upon the water depth and the type of cruise (Table XI). The water samples were filtered at sea onto glass fiber filters, the filters frozen, and the flourescence of the filtered material later determined in the laboratory at Moss Landing using a Turner flourometer, Model III. The flourescence was related to chlorophyll a content using the conversions of Strickland and Parsons [1965].

Two additional studies were made to determine the short-term variability of phytoplankton biomass. Station #1108 was sampled twice on 12 April within 2 hours. During the week of 10 May, Station #1103 was sampled at approximately 24-hour intervals for six consecutive days.

2. Phytoplankton identification (to be carried out at a later date)

One hundred milliliters of unfiltered seawater were preserved from aliquots of the water analyzed for phytoplankton biomass. These samples will be concentrated using the Utermöhl method and the phytoplankton identified and enumerated using an inverted, phase-contrast microscope. Samples have been taken on all cruises listed in Table XI except for those on 13 April, 17 April, and

TABLE XI

<u>Number of Depths Sampled for Chlorophyll Analysis</u>

		CENTRAL BAY					NORTH BAY					
STATION		1101	1103	1105	1108	1112	1152	1153	1154	1155	1156	1157
15 March	H	4	9	4	12							
20 March	P						4	3	3	4	4	8
12 April	P	5	14	5	14-14							
13 April	H	3	8	3	12							
17 April	H							3	2	4	4	
10 May	P	5	15	5	15							
11 May	H	3	8	3	8	9						
12 May	P		15									
13 May	P		15									
14 May	P		15									
15 May	H		15				4	3			4	
DEPTH OF CAST (meters)		10	100	10	200	200	30	10	10	30	30	175

P = Plankton Cruise
H = Hydrographic Cruise

11 May. Samples for phytoplankton identification also were taken on a hydrographic cruise to the north bay on 20 February.

The larger phytoplankton also were sampled using a quarter-meter net with a 35-micron mesh size. Vertical net hauls were made from 15 meters to the surface at all stations on hydrographic and plankton cruises.

3. Zooplankton sampling

Zooplankton tows were obtained with a half-meter net having a mesh size of 500 microns. The tows were made at 3 knots with 15 meters of wire out; since most of the area sampled is generally shallower than 12 meters, and 3 to 10 minute hauls were made, the length depending upon the abundance of zooplankton. The tows are expected to yield only rough, qualitative estimates of the zooplankton groups. Zooplankton hauls were taken on the plankton cruises on 12 April and 10 May. As with phytoplankton, detailed identification will be carried out at a later date.

4. Light penetration measurements

Light penetration was measured with a 30-centimeter Secchi disk on all plankton and hydrographic cruises. Photometer readings were also taken at a number of stations on the plankton cruises to permit comparisons of the Secchi depth with the 1% light extinction depth.

5. Bathythermograph profiles

Bathythermograph profiles were taken on all plankton cruises at stations #1103 and #1108. The profiles were obtained to allow comparisons of the temperature structure with distribution of the phytoplankton in the water column.

B. Summary of Data Collection Results

1. Phytoplankton biomass

The standing stock of chlorophyll a in the upper 10 meters is shown in Table XII for stations in central and northern Monterey Bay. The standing stock was calculated from the discrete chlorophyll values by trapezoidal integration. The standing stock of chlorophyll a for the entire water column is shown in Table XIII.

The number of water samples taken per station was greater on the plankton cruises than on the hydrographic cruises (Table XI). In order to examine the effect of the number of water samples on the estimation of standing stock, the chlorophyll measurements from the plankton cruises were studied in greater detail. The standing stock of chlorophyll was estimated using different numbers of samples per station, the most reasonable* sampling depths being chosen for the calculation. The standing stock was estimated from combinations of two to fifteen samples for the trapezoidal integration. Table XIV indicates the standing stock estimates as a function of the number of samples considered. On the standard hydrographic cruises, eight samples were taken at stations #1103 and #1108, and three samples were taken at stations #1101 and #1105. The mean difference in estimate of standing stock between eight samples (at depths routimely examined on the hydrographic cruises) and the total number of samples taken on the plankton cruises was 6% and 4% for the deeper stations #1103 and #1108 ($SD_{\bar{x}}$ = 1.3 and 1.7 respectively) and 11% and 10% ($SD_{\bar{x}}$ = 6.6 and 3.6 respectively) for #1101 and #1105, the shallower stations. The average numerical difference in terms of milligrams of chlorophyll a, however, between the "hydrographic cast" and the "plankton cast" was 7 mg/m^2 ($SD_{\bar{x}}$ = 1.8) for the deeper stations and 3 mg/m^2 ($SD_{\bar{x}}$ = 0.7) for the shallower stations.

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* We subjectively chose the depths on the basis of our past experience with chlorophyll distributions and before we had examined the present samples in detail.

TABLE XII

Phytoplankton Standing Stock in the Upper 10 Meters*
(milligrams chlorophyll a/m^2)

STATION	Central Bay 1101	Central Bay 1103	Central Bay 1105	Central Bay 1108	Central Bay 1112	North Bay 1152	North Bay 1153	North Bay 1154	North Bay 1155	North Bay 1156	North Bay 1157
15 March	53	46	48	34							
20 March						113	70	40	38	56	103
12 April	20	17	21	24-24							
13 April	25	31	17	19							
17 April							16	61	84	62	
10 May	13	22	36	12							
11 May	35	14	28	9	8						
12 May		19									
13 May		9									
14 May		9									
15 May		7				59	54	33	28	16	

* In those instances in which the deepest sample was shallower than 10 meters, the standing stock was extrapolated to 10 meters.

TABLE XIII

Total* Standing Stock of Phytoplankton in the Water Column
(milligrams chlorophyll a/m^2)

	CENTRAL BAY					NORTH BAY					
STATION	1101	1103	1105	1108	1112	1152	1153	1154	1155	1156	1157
15 March	43	479	49	467							
20 March						232	70	40	148	154	471
12 April	20	59	21	121-123							
13 April	25	94	17	51							
17 April							16	49	84	166	
10 May	13	61	36	116							
11 May	35	52	28	73	45						
12 May		72									
13 May		41									
14 May		43									
15 May		30				85	53	33	67	42	
*TO A DEPTH OF (meters)	10	100	10	200	200	30	10	10	30	30	175

TABLE XIV

Effect of the Number of Samples on the Estimation of Phytoplankton Standing Stock
(milligrams chlorophyll a/meter^2)

The accuracy of measurement of standing stock in the water column is a function of the number of samples taken, if discrete samples are used for the calculation.

Only the standing stocks for the stations occupied during plankton cruises are considered here.

NUMBER OF SAMPLES	2	3	4	5	6	7	8	9	10	11	15
Station #1101											
CHLOROPHYLL A STANDING STOCK (mg/m^2)											
15 March	43	45	47								
12 April	18	24	21	20							
10 May	10	14	14	12							
Depths Sampled 10 May: 0,3,5,7,10 meters											
DEPTHS CONSIDERED*	0m 10m	5m	3m	7m							
Station #1103											
CHLOROPHYLL A STANDING STOCK (mg/m^2)											
15 March	337	249	271	360	357	358	361	364			
12 April	74	49	46	43	47	46	45	46			
10 May	144	66	63	59	62	62	62		61		61
12 May	179	129	133	95	91	88	84		74		73
13 May	52	39	38	34	38	39	42		41		41
14 May	43	39	39	44	49	48	46		45		43
Depths Sampled 10 May: 0,3,5,7,10,15,20,25,30, 35,40,50,65,90,100 meters											
DEPTHS CONSIDERED*	5m 100m	20m	10m	50m	0m	30m	65m	**	15m 25m		3m 35m 7m 40m 90m

(continued)

TABLE XIV

Effect of the Number of Samples on the Estimation of Phytoplankton Standing Stock
(milligrams chlorophyll a/meter^2)

(continued)

NUMBER OF SAMPLES	2	3	4	5	6	7	8	9	10	11	15
Station #1105											
CHLOROPHYLL A STANDING STOCK (mg/m^2)											
15 March	41	44	39								
12 April	25	22	22	21							
10 May	28	31	32	36							
Depths Sampled 10 May: 0,3,5,7,10 meters											
DEPTHS CONSIDERED*	0m 10m	5m	3m	7m							
Station #1108											
CHLOROPHYLL A STANDING STOCK (mg/m^2)											
15 March	507	611	591	468	443	428	424	436		435	
12 April	193	229	226	142	131	114	110		112		
10 May	192	110	112	120	114	114	125		118		116
Depths Sampled 10 May: 0,3,5,7,10,15,20,25,35, 50,75,100,125,150,200 meters											
DEPTHS CONSIDERED*	10m 150m	20m	0m	50m	100m	35m	200m	***	5m 75m	****	3m 15m 7m 25m 125m

* The "depths considered" include those listed for the sample plus all depths listed in columns to the left. (e.g. Station #1101, depths considered for 3 samples are 5m, 0m and 10 m.) The "depths considered" refer to the sampling depths of 10 May and closely approximate those of 15 March and 12 April.

** 12 meter depth, these two samples only.

*** 15 meter depth, this sample and "15 samples" only.

**** 3 meters and 12 meters, this sample only.

2. Variability studies

The chlorophyll standing stock at station #1103 is shown for six consecutive days in Table XV. The average biomass for the period was 60 mg chlorophyll a/m^2, and the average difference between the standing stock on consecutive days was 15 mg chlorophyll a/m^2 ($SD_{\bar{x}}$ = 4.9).

TABLE XV

Variations in Chlorophyll Concentration
(milligrams/$meter^3$)
at Station #1103 over a Six-Day Period

DEPTH (meters)	10 MAY	11 MAY	12 MAY	13 MAY	14 MAY	15 MAY
0	2.57	1.79	0.56	1.88	2.55	1.21
3	2.08		3.78	0.91	0.95	
5	2.55	1.24	2.49	0.73	0.53	0.52
7	2.48		2.43	0.60	0.47	
10	1.23	1.32	2.19	0.49	0.51	0.37
15	0.62		1.23	0.37	0.28	0.36
20	0.55	0.47	1.21	0.38	0.39	0.26
25	0.59		0.31	0.31	0.25	0.36
30	0.46	0.39	0.69	0.45	0.34	0.22
35	0.45			0.41	0.39	0.17
40	0.43		0.36	0.33	0.34	0.32
50	0.36	0.36	0.22	0.26	0.50	0.25
65	0.37	0.34*	0.31	0.38	0.38	0.18
90	0.29		0.30	0.36	0.34	0.30
100	0.34	0.31	1.10	0.31	0.34	0.20
CHLOROPHYLL A STANDING STOCK IN WATER COLUMN (milligrams/m^2)						
	61	52	72	41	43	30

*sample taken at 75 meters

The estimates of standing stock at station #1108 on 12 April for two replicate casts are shown in Table XVI. The estimates of chlorophyll a/m^2, measured to a depth of 150 meters (the deepest sample), were identical for the 14-bottle casts. The chlorophyll concentrations, however, differed between the two casts at all sampling depths.

TABLE XVI

Chlorophyll Concentration
as Measured by Replicate Casts at Station #1108
12 April 1971

DEPTH (meters)	CHLOROPHYLL A CONCENTRATION (milligrams/m^3) Cast 1	Cast 2
0	1.76	2.37
3	2.67	1.92
5	2.22	2.90
7	2.72	2.07
10	2.25	3.05
15	1.55	2.28
20	2.47	1.71
25	0.78	--
30	0.73	0.71
50	0.68	0.41
75	0.38	0.20
100	0.26	0.57
125	0.33	0.31
150	0.28	0.32
	CHLOROPHYLL A STANDING STOCK IN WATER COLUMN (milligrams/m^2)	
	106.77	106.77

The variability of chlorophyll standing stock over a one-day period is also indicated from the comparison between measurements taken on 10 May and 11 May, and on 12 April and 13 April (Tables XII and XIII).

3. <u>Light penetration studies</u>

Secchi depth is plotted against the 1% light extinction depth in Figure 32. A regression for the data is best approximated by the line $Y = 6.5 + 2.4x$, where Y = depth (meters) of 1% light as measured by the photometer, and x is the depth (meters) at which the Secchi disk is no longer visible. The 95% confidence limits on the value of the slope are 3.8 to 0.9. Since the intercept is not significantly different from zero ($p > 0.05$ that intercept equals zero), the regression may be forced through the origin and the more resonable "best fit" line to the data and the origin is now $Y = 3.5x$.

4. <u>Distribution of chlorophyll in the water column</u>

The standing stock above the 1% light level may be compared with the stock below that level (Table XVII). The depth of 1% light was determined directly in those instances in which photometer measurements were made. In those cases in which only a Secchi depth measurement was taken, the 1% light level was estimated by multiplying the Secchi depth by 3.5 (see above).

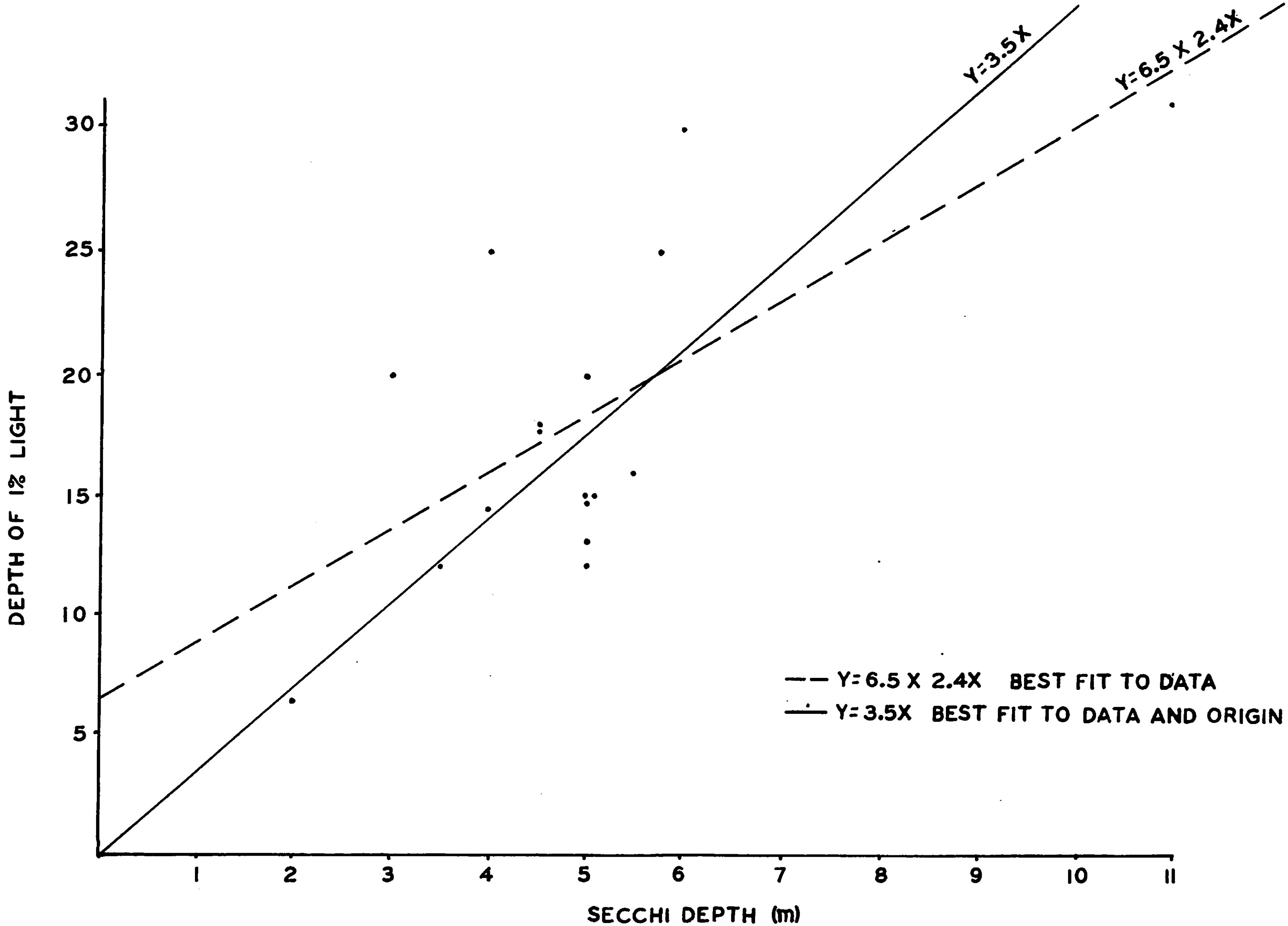

FIGURE 32: The relationship between the Secchi depth (meters) and the 1% light depth (meters).

TABLE XVII

Chlorophyll a Standing Stock (milligrams/meter^2) in and below the Euphotic Zone

STATION	1103		1108		1112		1152		1155		1156		1157	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b
15 March	57	422	48	419										
20 March							149	83					138	333
12 April	25	34	56	65										
13 April	49	45	22	29										
20 April									56	28	90	76		
10 May	30	31	26	90										
11 May	18	34	16	58	16	29								
12 May	37	35												
13 May	15	26												
14 May	11	32												
15 May	8	22					67	18	39	28	22	20		
DEPTH OF SAMPLING (meters)	100		200		200		30		30		30		175	

a = above the depth of 1% surface light
b = below the depth of 1% surface light

C. Discussion

The standing stock of phytoplankton in inshore Monterey Bay varied from 39 to 479 mg chlorophyll a/m^2 during the sampling period from March through April (Table XIII). Average chlorophyll concentrations in the upper 10 meters ranged from 0.9 to 10.3 mg chlorophyll a/m^3 (Table XII). These chlorophyll a concentrations are within the range expected for fertile, coastal waters [Strickland, 1965]. The chlorophyll concentrations in the north bay were generally higher during this period than those in the central bay. These higher concentrations in the north bay corresponded to higher nutrient levels in this area, and may be related to the discharge of sewage there. (See section on nutrients, pp 49-50).

The chlorophyll data also indicate that large quantities of phytoplankton occurred below the 1% light level in March 1971. The reasons for these high concentrations in deep waters are unknown but may be related to the upwelling that occurred at this time.

The phytoplankton concentrations in the central bay were similar to those found in Elkhorn Slough in March but were considerably lower than those found in Elkhorn Slough in April [Owen, 1971].

The use of eight discrete samples appears to produce estimates of phytoplankton standing stock that are very similar to those estimates obtained by the use of a maximum of fifteen samples. Therefore, eight samples, the number taken routinely on the hydrographic cruises, may be adequate for estimating stocks at the deep stations. The estimation of other properties (e.g. the depth of the chlorophyll maximum) may be much less precise using casts of this few a number, however. The difference between estimates using the number of bottles typical of hydrographic cruises versus the numbers used on plankton cruises is greater in terms of percentage of total standing stock, but smaller in terms of milligrams of chlorophyll a for shallow stations than for deep stations.

The Secchi disk appears to be subject to a great deal of error when compared with the photometer. If one assumes that the Secchi depth should equal zero when the photometer reading is immediately below the surface, then the best fit regression to our data indicates that the depth of 1% light (as measured by the photometer) is 3.5 times the Secchi depth. This value is the same as the one suggested by Holmes [1970] for Secchi depths of 5 meters or less in turbid, coastal waters.

The variability in chlorophyll a standing stock between successive days appears quite high (Tables XII, XIII, XV). The data would suggest that extreme caution be used when considering that the standing stock measured on any given day is representative of the stock over a month's time.

D. Future Plans

We hope to continue routine sampling at the same stations in Monterey Bay. The following changes and additions will be made to the present program in Monterey Bay:

1. The plankton and the hydrographic data will be collected on joint cruises and the same stations and depths will be sampled for nutrient and chlorophyll data.
2. We will initiate monthly measurement of productivity (C_{14}) at several stations in the central bay.
3. We will make additional variability studies in order to determine the change in standing stock over a full tidal cycle as well as studies to determine the variability on a daily basis.
4. We will make quantitative zooplankton tows in order to estimate the biomass of planktonic herbivores.

In Elkhorn Slough we plan to initiate routine monthly sampling for phytoplankton standing stock and zooplankton. These samples will be taken at the hydrographic stations currently being sampled, and will be obtained in conjunction with the hydrographic sampling program.

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IX. SEDIMENTOLOGICAL STUDIES

(Dr. Robert E. Arnal, Professor of Marine Geology, and James Locke, Graduate Research Assistant)

In accordance with objectives outlined in the 1970-71 PROGRESS REPORT [Harville, 1971], studies on the sedimentology of samples collected in the benthic sampling program and development of a continuing beach monitoring program were primary functions of the Sea Grant Research participation teams at the Moss Landing Marine Laboratories during the spring semester 1971. Staff members participated directly in these studies in addition to their advisory and supervisory roles. Major organizational tasks included the development of facilities, resources, and methods for carrying out the stated objectives.

A. Field Techniques

The benthic sampling program for Monterey Bay, Pajaro River, and Elkhorn Slough studies included subsampling for subsequent particle-size and organic carbon analyses.

Five permanent beach transect stations (PROGRESS REPORT, Appendix C-10) were established and data collected for two periods during the spring semester. In addition, particle-size analyses were run on samples collected in conjunction with the profiling of the beaches. Development of procedures and direct supervision of the beach profiling and sampling program was carried out by Mr. James Locke under the general supervision and direction of Dr. Robert Arnal.

1. Beach studies

Beach configuration studies were carried out using the surveying technique recommended by Emery [1961]. This method measures the slope of the beach at five-foot intervals using the sea surface horizon as a reference level. A horizontal plane is established from which the slope can be measured. Data collected during the spring surveys were plotted for general interpretation. Similar data will be accumulated during the coming year and conclusions will be developed at the end of that period.

Collection of samples along beach transects for subsequent particle-size analyses was accomplished by spacing the sampling according to the following pattern: a) a sample on the storm berm, b) a sample on the high berm or on the highest washmark as indicated by dead kelp or driftwood, and c) three samples spaced regularly between the water's edge and the high berm. A group of divers obtained additional samples at the outer plunge point of the waves and at the mooring point of the diver support raft. Beach sand sampling was accomplished by taking a 4-inch core with a 1.5-inch internal diameter plastic core liner at three locations near the designated sampling areas. One core was taken directly on the profile line, and the others were taken 10 feet on either side of the profile line. Diver sampling of substrate was accomplished by the use of a coffee can corer developed at the Laboratories.

Initial problems with the samoling and profiling techniques in the sub-surface zone did not permit effective data collection in the first sampling period. However, the final sampling period proceeded with exceotional efficiency requiring abandonment of only one subsurface transect due to abnormal surf conditions.

For the final collection period the location of the subsurface transect was determined by sextant angles from the ends of measured base lines alongshore.

2. <u>Diving techniques for securing subsurface profiles and sediment samples</u>

The diving team first anchored the diving support raft opposite the end of the transect line at a safe distance outside the surf. They then extended shoreward a 100-meter line, marked at 10-meter intervals. If the 100-meter line did not reach the plunge point, the divers proceeded to that point towing the line behind them. They then sampled the bottom sediments at the plunge point and took a water sample to determine the amount of suspended material. Another bottom sample was taken at the seaward end of the line and a larger water sample was taken for suspended material. As the divers returned to the support raft, depth measurements were taken at the

10-meter intervals by direct reading of sensitive depth gauges worn on the wrist.

The method of obtaining the sediment samples was developed at the Moss Landing Laboratories: a coffee can is attached at the bottom to a wooden handle which is used to plunge the canister into the sediments. An air hole in the bottom is then plugged and the canister removed from the bottom with a complete core inside. A plastic lid is placed over the open end and the sample returned to the support raft with little chance of loss or disturbance.

B. Laboratory Analyses

1. Grain-size analyses

Subsamples taken for particle-size analyses were handled according to the flow chart shown in Figure 33. Removal of the soluble salts was accomplished by simple decantation after settling samples in distilled water two or three times. The samples were then treated with 32% hydrogen peroxide to remove organic matter. Addition of the peroxide was continued until a reduction in the frothing was observed. This process in some cases took 1 to 2 days time. The samples were then "topped up" with distilled water and gently heated overnight to remove excess peroxide. Mechanical dispersion was achieved by mixing on a commercial malt mixer for 5 to 10 minutes in a known volume of standard concentration sodium hexametaphosphate $(NaPO_4)_6$. Following a 24-hour check on the dispersion, the sample was wet-sieved through a 0.062 mm sieve into a graduated cylinder. A standard pipette analysis [Rittenhouse, 1933] was then run on the sample following a 24-hour check on dispersion and possible flocculation.

With this procedure, flocculation was eliminated. Early experience in Elkhorn Slough had shown a serious flocculation problem and hence would have complicated the analyses if extensive pretreatment were not undertaken. One obvious disadvantage is the longer time required for the pretreatment period.

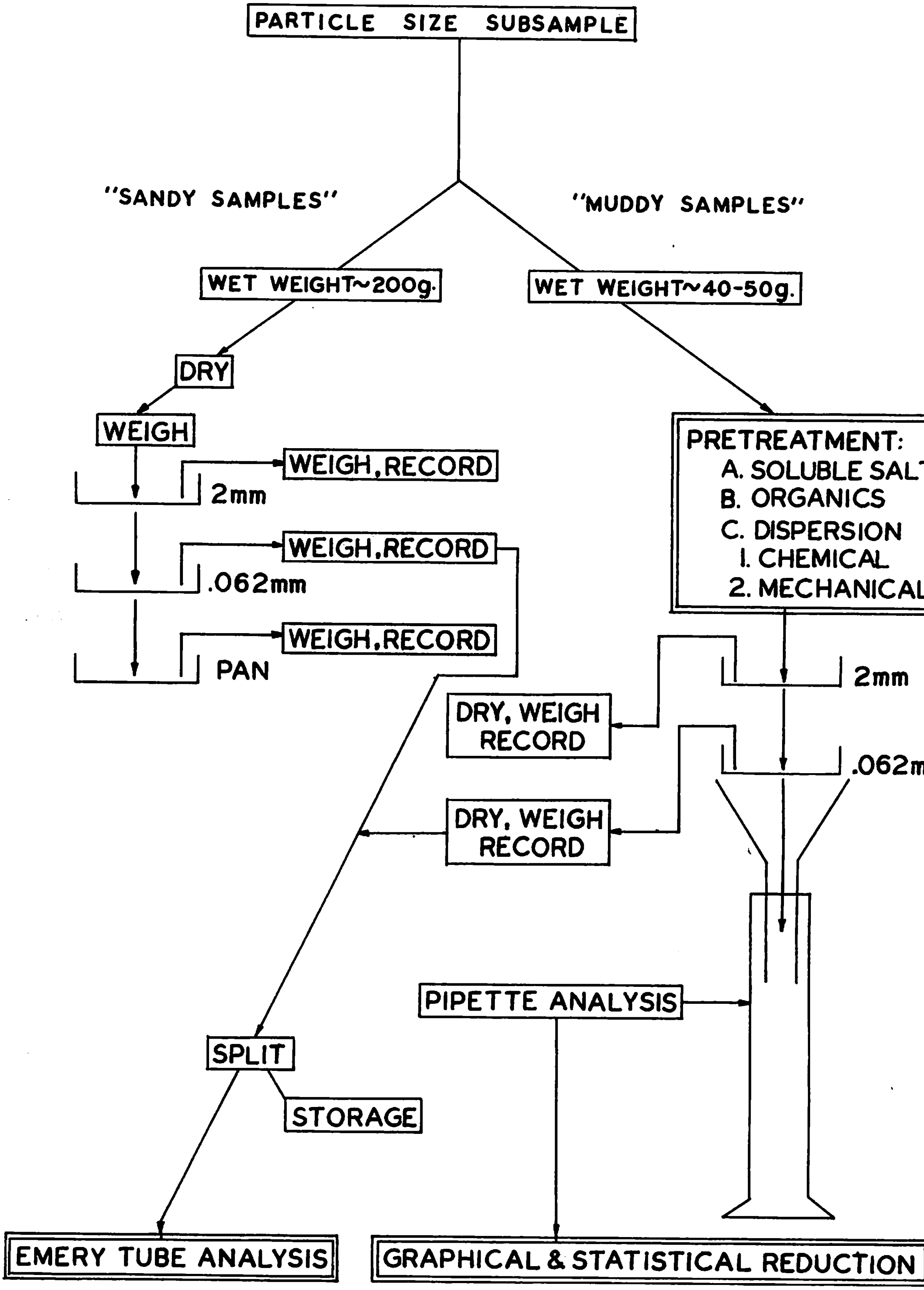

Figure 33. Flow diagram for processing sediment samples.

The coarser than 0.062 mm fraction was oven-dried and weighed. Reduction in size was accomplished by using a modified Otto microsplitter. Analyses of the size distribution in the 2.0 to 0.062 mm fraction was carried out using the tube method [Emery, 1938]. Material greater than 2.0 mm was sieved out and weighed.

Data from the pipette analysis and the Emery tube analyses were processed and plotted as cumulative curves. Standard measures for analysis of the frequency distribution were recorded from the cumulative curves; median diameter and Trask [1932] quartiles made up the basis for calculation of parameters.

Relative proportions of sand, silt and clay were plotted on a ternary diagram following Shepard's [1954] classification scheme.

All sedimentary analyses data is filed in the Moss Landing Marine Laboratories' archives for subsequent reference.

2. Organic carbon

The analyses of the organic carbon content of the sediments were delayed pending development of a safety hood in the sediment lab, and no analyses were carried out during the semester. Subsamples were saved from all samples for subsequent analyses when the manpower becomes available.

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X. DIVING SUPPORT PROGRAM

(Patrick Albin, Moss Landing Marine Laboratories Diving Instructor and Diving Master)

The advanced SCUBA Marine Research class at Moss Landing Marine Laboratories included three integral phases: lecture and seminar, field laboratory, and service projects. (See Appendix F for course outline.)

A. Lecture-Seminar Phase

Formal lectures were given weekly by the instructor to provide the necessary exchange of technical data and techniques. Following the lectures, seminar and discussion time was utilized to further the exchange of techniques in the light of the personal SCUBA experiences brought by each student to the class and relevant to the lecture topic. In a field as innovative and new as SCUBA in marine biological research, this section provided exploratory approaches valuable to all phases of the class. Some of these techniques will be included in the lecture portion of future classes. The seminar section also provided students with the theory, estimation, planning, and management of field work.

Records of lectures and discussions were filed in a permanent log book. All criticism and dissenting opinions also were included. The lecture-seminar section also provided a complete review of the prior week's field work and this was recorded.

B. Field Laboratory Phase

The class was divided into four teams of two students each, following the format of the approved "buddy" method of SCUBA diving. The teams then could be combined into larger units under specific group leaders when the situation warranted. Thus organized, the class as a whole followed each seminar planning session with a 9-hour field laboratory. In this way planned operations were always conducted in the ocean environment. All in-field class dives stressed the need for complete follow-through. Records of time, place, conditions, visibility, and organization were kept in the permanent log book so that each field laboratory session could be examined at the next seminar session. Field laboratory activities covered the theory and practice of mapping and navigation; compass courses and transect line handling; sampling; lifting, drilling, and cementing underwater; laying permanent transects; a mock decompression dive; and laying an artificial reef. All field laboratory sessions were held at the Monterey Breakwater with the exception of the mock decompression dive which was held off the Santa Cruz Pier.

The field laboratory dives were structured to help the students gain experience in skills and techniques applicable to underwater work in marine research. All laboratory work was done under direct supervision and evaluation of the class instructor.

C. Service Projects Phase

The service project phase commenced after the first few class sessions. The students established a service request board which evaluated proposals submitted by faculty and students at Moss Landing Marine Laboratories. The proposals were projects which could only be carried out with the help of a competent SCUBA team familiar with advanced techniques. The projects were usually done by small teams of two to four divers although the entire class was involved in planning. These projects were critiqued at the weekly seminar sessions. Most of the projects were directly related to the Sea Grant research program. Reports were made by the divers involved.

The service projects gave the students access to much wider experience in marine science diving that the structured class alone could hope to. Because the projects were submitted from widely varied sources, the students had the opportunity to evaluate extremely different situations and consider all parameters which could affect each project. It was during this phase that the students became a research team as differentiated from a class.

Projects involving the class included sediment studies inside the surf zone, polychaete surveys, current meter installation and removal, artificial reef placement and anchoring, gear evaluation, and retrieval of materials lost at sea.

Most of these projects are still in process and will require more underwater support. Divers with the skills acquired from the SCUBA Marine Research class are ideal candidates for the work required of such environmental studies.

XI. SPECIAL STUDENT RESEARCHES

(Dr. Mary Silver, Assistant Professor of Biological Oceanography)

A number of graduate students participated in ML 255, Researches on Monterey Bay, and conducted projects which contribute to the research goals of the Sea Grant program. These studies involve the collection of data that will contribute significantly to the general knowledge of the environment of Monterey Bay and Elkhorn Slough. Some of the papers are concerned with the development of methods suitable for data collection in the area, and other studies are preliminary research projects which will be developed later for a master's thesis. These research projects already have yielded important information and the reports will be available in the archives at Moss Landing Marine Laboratories. A number of these studies will be continued, either as individual research projects or as ones which will be included in the general data collection carried out through Sea Grant for the coming year.

Brief abstracts of these researches are provided in the following pages.

A. Gary Kukowski: A Checklist of the Fishes of the Monterey Bay Area Including the San Lorenzo, Pajaro and Salinas Rivers and Elkhorn Slough

A checklist of fishes in the Monterey Bay area is being compiled from the literature. The bibliography will include records from the California Fish and Game quarterly and from other selected journals as well as from local fish collections. To date the author has found over 250 species recorded for the area from more than 80 different sources. These species are primarily fresh and marine shallow-water forms; the records for most mid-water and bathypelagic species remain to be compiled.

B. Daniel Varoujean: Survey of the Avian Fauna of Monterey Bay

A survey of the sea birds of Monterey Bay was initiated to determine when various species visited the bay and whether the occurrence of various species corresponded to particular plumage phases. The study was begun in February and near-weekly observations were made in three transects (harbor, nearshore, and offshore) until May. A total of 40 species were observed during the survey; most of the species occurred in more than one transect. During the study the numbers of adult-plumaged individuals declined (except for the Brandt's cormorant) indicating that the species observed are not year-long residents.

C. Evelyn C. Hansen: Chemical, Physical and Biological Parameters of Three Coastal Ponds in the Monterey Bay Area

A study of brackish coastal ponds (Laguna del Rey in Seaside, McClusky Slough near Moss Landing, and Schwan's Lagoon in Santa Cruz) was conducted in March and April 1971. Samples from the upper meter of each pond were taken at weekly intervals for seven consecutive weeks for determination of phosphate, silicate, nitrate, nitrite, dissolved oxygen, and salinity. One core was taken from each pond for measurement of sediment size, organic carbon content, and identification of microfauna. One seine was hauled in each pond and the fishes identified.

Phosphate concentration varied from 0.1 to 5.0 µg-atoms/l, silicate from 0.1 to over 100 µg-atoms/l, nitrates from 9 to 42 µg-atoms/l, nitrites from 0.5 to 1.00 µg-atoms/l, oxygen from 4 to 13 µg-atoms/l (43 to 121% saturation.) These nutrients showed no consistent trends during the weeks of the survey. The phosphate and silicate concentrations differed significantly in the different ponds; the nitrate, nitrite, and oxygen concentrations did not differ. The salinity differed significantly between the ponds, and in two ponds there was a significant increase in salinity in the seven-week period. The benthic samples indicated that the sediments were composed chiefly of clays and were poorly sorted. The fish populations in the different ponds appeared to differ markedly.

D. Ronald Larocca and Joel Cohen: A Preliminary Study of the Effects of the Pacific Gas and Electric Company Warm Water Outfall on the Ecology of Elkhorn Slough

A study was conducted near the Pacific Gas and Electric Company outfall in Elkhorn Slough to determine the extent of the warm water plume. A station grid of 125 points was sampled with a temperature probe on three days in April and May. The temperature data indicated that the warm water plume was affected by both winds and tides. At no time during the study did the temperature of the discharged water exceed the ambient by $2^{\circ}C$. A more important source of warm water in the slough appears to be the water from the upper shallow reaches of the slough.

E. P.J. Schultz: Surface Current Study, Moss Landing, California

Surface currents near Moss Landing were studied during February, April and May by means of drift poles and a continuously recording current meter. Drift poles were tracked for several hours on four days and indicated northward flowing currents of approximately 30 cm/sec during flood tides and southward moving currents of approximately 20 cm/sec. The continuously recording current meter was anchored 9 meters below the surface in 16 meters of water, 1.8 kilometers southwest of the Marine Laboratories. Twenty-five hours of continuous record were obtained indicating that current speeds were dominated by tidal components; the speeds varied between 10 to 50 cm/sec during the period, and the velocity measurements indicated a net southward transport of water. Two 24-hour observations were obtained with the current meter for surface currents at the end of Sandholdt Pier. The data indicated variable current speeds of 5 to 15 cm/sec and showed no tidal components; these results are due presumably to the turbulence generated by the structure of the pier.

F. B.A. Otis, Jr. Determining Beach Profile Measurements by Photographic Measurements

A new photographic method for measuring beach profiles was investigated. Two beaches with established bench marks were photographed from a reference point using a wide-angle lens. The resulting slides were projected on a calibrated screen and the changes in beach topography were noted over the study period of three months. However, unexpected distortion in the peripheral edges of the slides did not allow quantitative comparisons of the beach profiles. The author suggests that the method be investigated further, since the technique could enable rapid analysis of beach topography.

G. John Oliver and Pete Slattery: An Investigation of Sampling Design and Technique for the Subtidal Benthos of a Sandy Beach

A study was conducted to determine an adequate sampling design for measurement of infaunal diversity in the nearshore benthos at 8 to 9 fathoms off Moss Landing. A coffee-can coring device was designed which produced satisfactory samples for polychaetes and amphipods. A total of 16 replicates were taken in a 100 m^2 area and the cumulative species diversity of polychaetes for the replicates was plotted; eight or ten replicates appear to be satisfactory to characterize the area. The diversity of polychaetes was 2.5 (Shannon-Weaver Index) for the area using eight to fifteen replicates. The diversity indices were not significantly different between replicates in 1 m^2, 5 m^2, or 100 m^2 subareas of the total sampling area. Moreover, the variance of replicates in these three different-sized areas were not significantly different from each other. Therefore, the diversity of polychaetes appears to be relatively homogeneous within the 100 m^2 area.

Future plans by the authors for studying the sandy, subtidal benthos will involve a survey of the polychaetes and amphipods of the area. Twenty-three species of polychaetes have been recognized and eleven species of amphipods. Preliminary sampling for amphipods was done during three months in spring when reproductive peaks would be expected. The number of ovigerous females of the dominant _Paraphoxus daboius_ and _Eohaustorius sencillus_ indicated that there was active reproduction but suggested that only one brood per female per year was produced. Further studies may indicate elongate reproductive periods in Monterey Bay.

H. Alfred T. Hodgson: _A Sampling Technique for the Qualitative Analysis of the Annelid Fauna Inhabiting Intertidal Mud Flats_

This paper presents the results of a study conducted in preparation for an intensive survey of the annelid fauna inhabiting the intertidal mud flats of Elkhorn Slough. A sampling method was sought which would provide adequate sampling for determination of annelid species diversity in such an environment. The results indicated that five to six cores, approximately 20 cm in length, could adequately sample the annelid fauna. Moreover, this number of cores may also be used to characterize the annelid diversity in a 100 m^2 area. The diversity of the annelid fauna was about 1.5 (Shannon-Weaver Index) and a total of eleven species were found in the area.

Additional data based on one 20-centimeter core indicated the presence of high standing stocks of chlorophyll _a_ in the mud. Maximum chlorophyll concentrations of 38 μg chlorophyll _a_/cm^3 were found in the upper cubic centimeter of mud, and concentrations were high to a depth of 20 centimeters (7 μg chlorophyll _a_/cm^3).

I. Sandra Owen: A Chlorophyll *a* and Phaeophytin *a* Study in Elkhorn Slough

Phytoplankton samples were taken at nine stations in Elkhorn Slough during March and April to determine standing stocks of plant pigments and to correlate these with nutrients in the slough. The phytoplankton samples were taken in conjunction with a monthly nutrient sampling program. The chlorophyll *a* concentrations in the slough averaged 1.3 mg/m^3 for March and 10.7 mg/m^3 for April; phaeophytin *a* concentrations averaged 1.1 mg/m^3 for March and 8.9 mg/m^3 for April. Pigment concentrations were not significantly different at the surface and at one meter in the slough.

A 24-hour survey was conducted in March to determine the short-term variability of phytoplankton concentration at three stations. The phaeophytin concentrations remained relatively constant, whereas the concentrations of chlorophyll varied between 0 to 4 mg/m^3. During the 24 hours no diurnal or tidal effects were observed in the pigment concentrations. However, significant correlations were noted between chlorophyll concentrations and nitrate, salinity, and temperature. The explanation for these correlations is not known.

XII. PUBLIC INFORMATION AND INTERPRETATION SERVICES

(Doris Baron, Librarian, Moss Landing Marine Laboratories)

A. Monterey Bay Bibliography

This document is a 300-page publication listing scientific and general papers, reports, books, and miscellaneous publications which deal directly or indirectly with the Central California Coast. References which are known to contain specific data on Monterey Bay are so indicated. It has required more than three years of effort, with final steps completed through Sea Grant support.

The main body of the bibliography consists of approximately 2000 citations arranged by subject according to Library of Congress classification. A major exception to the Library of Congress system is that the sytematic divisions for the section on zoology were adapted from GENERAL ZOOLOGY, Fourth Edition, by Tracy I. Storer and Robert L. Usinger, McGraw Hill, New York, 1965, and from A LIST OF COMMON AND SCIENTIFIC NAMES OF FISHES FROM THE UNITED STATES AND CANADA, Second Edition, by the American Fisheries Society, Committee on Names of Fishes, Ann Arbor, Michigan, 1960.

An author index and subject index are provided to facilitate use of the publication. Appendices list references which were located too late to be integrated into the main bibliography.

In order to make periodic up-dating of the bibliography as convenient as possible, IBM key-punch cards were used for the list of references and the author index. The key-punching program was designed to permit mechanical insertion of new citations into the original list in proper subject-matter sequence. Supplements are planned annually and complete revisions at three-year intervals.

This project has been a joint endeavor of the Moss Landing Marine Laboratories and the Association of Monterey Bay Area Governments which assisted materially with funding of bibliographic researchers and publication costs.

The recipients of the bibliography have been enthusiastic and generous with notification of additional citations and suggestions for improvement of the first revision of the bibliography.

Plans for the first supplement are already well under way. Emphasis will be placed on locating new unpublished, as well as published, citations and in making a concentrated effort to locate libraries where this material can be consulted.

1. Approximately 75 additional citations have been located and cards have been typed so that the key punch operator can punch the IBM cards.

2. A bibliography of Monterey Bay containing approximately 350 citations on the geology of the Monterey area has been submitted by a student in the Library School at San Jose State College.

3. Staff members of the Water Resources Center Archives Library, University of California, Berkeley, have offered their assistance and use of their catalog for locating additional citations.

4. It is hoped that the catalog of the library of the California Acadamy of Sciences in San Francisco can also be searched for citations pertinent to the bibliography.

5. Several marine stations have promised lists of student papers and theses which date back for many years. These will be new citations and will be catalogued and available for interested students at the appropriate marine bases.

6. The systematic searching (in published indexes, etc.) that was carried out in specific publications for the original bibliography will be continued. Some of the searching has already been done in OCEANIC INDEX.

At the same time that work is progressing on the first supplement, we are preparing to revise and update the first edition, especially with respect to location of copies of the cited material as well as determination of whether a citation is related specifically to Monterey Bay.

The suggestion has been made that possibly the geographical boundaries for related references whould be extended south to include the southern boundary of San Luis Obispo County and north to Sonoma County including Bodega Bay. The would extend the over-all usefulness of the bibliography.

Steel cabinets to store the IBM punch cards have been purchased so that they will be protected adequately until the revision is printed.

B. Report Literature Organization

For the organization of all Sea Grant-sponsored reports, a system (which will also be adopted for all technical and scientific reports in the library collection) has been established. It is a coordinate index system with subject indexes being composed of uniterms or descriptors entered on coordinate index cards. This has proved to be one of the best subject cataloguing systems to use for this particular type of literature.

Catalog-card-style indexes to reports by corporate author, title, and personal author are also part of the system.

The system has been devised so that a machine retrieval program could at any time be initiated to supplement or replace the coordinate index card.

Necessary card catalog equipment for the project has been purchased.

C. Reprint File

A concentrated effort is being made to collect all reprints which deal directly or indirectly with the Central California Coast. We have developed an extensive reprint file with an author index. (Subject indexes to journal papers have not been developed locally because the published journal indexes (BIOLOGICAL ABSTRACTS, OCEANIC INDEX, and our own BIBLIOGRAPHY, etc.) are readily available either in our library or in other local area libraries.) The reprints pertaining to Monterey Bay and the Central California Coast are first added to the MONTEREY BAY BIBLIOGRAPHY supplement and then are incorporated into the reprint file where they are filed alphabetically by author in steel files.

D. Archives - Data Forms

A legal-size steel locking file has been ordered and all data collected under the Sea Grant program will be labelled and identified and filed systematically. This will help to eliminate duplication of effort and will prevent the loss or destruction of valuable data which tends to be scattered when not organized and stored in a centralized place.

A P P E N D I X   A

SEA-AIR-LAND ZONES OF CONTACT: METEOROLOGICAL ASPECTS

TABLE I

Weather Reporting Stations in the Monterey Bay Area
(after Elford and Stilz, 1967, 1968)

STATION	COUNTY	ELEV. (ft)	LAT. (N)	LONG. (W)	YEARS OF RECORD Precip.	Temp.
Aptos	Santa Cruz	290	36°59'	121°52'	31	
Arroyo Seco	Monterey	800	36°14'	121°29'	25	
Ben Lomond	Santa Cruz	504	37°05'	122°06'	27	27
Big Sur State Park	Monterey	220	36°15'	121°47'	30	
Black Mountain 2SW	Santa Clara	2331	37°14'	122°09'	10	
Black Mtn. Los Altos	Santa Clara	2618	37°19'	122°09'	10	
Boulder Creek	Santa Cruz	470	37°07'	122°07'	35	
Boulder Creek Locatelli	Santa Cruz	2200	37°08'	122°12'	23	
Buena Vista	San Benito					
Buzzard Lagoon	Santa Clara					
Calera Canyon	Monterey					
Campbell	Santa Clara	217	37°17'	121°57'	30	22
Capitola	Santa Cruz	56	36°58'	121°57'	11	
Carmel	Monterey					
Carmel Valley	Monterey	425	36°29'	121°44'	10	10
Castroville	Monterey	17	36°46'	121°45'	8	
Chittenden	San Benito					
Chittenden Pass	San Benito	125	36°54'	121°36'	18	
Cold Springs Camp	Monterey	3280	36°13'	121°41'	20	
Corralitos	Santa Cruz	264	36°59'	121°48'	7	
Corralitos Enos Ranch	Santa Cruz	730	37°00'	121°49'	13	
Coyote	Santa Clara	253	37°13'	121°44'	12	
Crest Ranch	Santa Cruz					
Davenport	Santa Cruz	273	37°01'	122°12'	5	wind
Del Monte	Monterey	40	36°36'	121°52'	30	20
Drake Ranch	Monterey					
Felton	Santa Cruz	275	37°03'	122°04'	34	
Fort Ord	Monterey					
Freedom 8NNW	Santa Cruz	1495	37°03'	121°49'	12	
Fremont Peak	Monterey					
Gilroy	Santa Clara	194	37°00'	121°34'	7	7
Gilroy 8NE	Santa Clara	1050	37°02'	121°26'	21	
Gilroy 14ENE	Santa Clara	1350	37°06'	121°20'	17	
Gonzales	Monterey	127	36°31'	121°27'	17	
Gonzales 9ENE	San Benito	2350	36°33'	121°18'	21	
Greenfield Baker	Monterey					
Greenfield L.E. Ranch	Monterey					
Greenfield Yard	Monterey					

Hames Valley	Monterey					
Harper Canyon	Monterey					
Hernandez	San Benito	2160	36°24'	120°50'	21	
Hernandez 7SE	San Benito	2765	36°18'	120°42'	26	
Hollister	San Benito	284	36°51'	121°24'	30	30
Hollister #2	San Benito	284	36°51'	121°24'	23	
Hollister Airport	San Benito	199	36°53'	121°24'		
Idria	San Benito					
Jolon	Monterey	960	35°58'	121°10'	40	
Kaiser Quarry	Monterey					
King City	Monterey	320	36°12'	121°08'	30	30
King City Yard	Monterey					
Lattonda	San Mateo					
Laurel	Santa Cruz	910	37°07'	121°58'	28	
Lockwood 2N	Monterey	1104	35°58'	121°05'	18	
Los Burros	Monterey	2820	35°53'	121°23'	14	
Los Gatos	Santa Clara	428	37°13'	121°59'	30	30
Los Gatos 4SW	Santa Cruz	2415	37°11'	122°02'	9	
Los Gatos 5SW	Santa Cruz	2300	37°10'	122°02'	9	
Los Vaqueros	Monterey	850	36°12'	121°19'	8	
Monterey	Monterey	335	36°36'	121°54'	12	14
Monterey NAF	Monterey	125	36°36'	121°51'	6	wind
Morgan Hill 2E	Santa Clara	225	37°08'	121°37'	29	
Morgan Hill 6WSW	Santa Clara					
Morgan Hill SCS	Santa Clara	350	37°08'	121°39'	18	
Moss Landing Marine Labs	Monterey					[evap wind]
Moss Landing P G & E	Monterey					wind
Mount Madonna	Santa Cruz	1800	37°01'	121°43'	17	
Mount Madonna Co. Park	Santa Cruz					
New Almaden	Santa Clara	340	37°11'	121°49'	18	
Pacific Grove	Monterey					
Paicines Ohrwall Ranch	San Benito	920	36°44'	121°22'	21	
Paloma	Monterey	1835	36°21'	121°30'	22	
Panoche	San Benito					
Paradise Road	Monterey					
Parkfield	Monterey	1485	35°53'	120°26'	24	
Pebble Beach	Monterey	165	36°43'	121°57'	16	13
Pigeon Point Lighthouse	San Mateo		37°11'	122°23'	25	fog record
Pinnacle Nat. Monument	San Benito	1307	36°29'	121°11'	25	25
Priest Valley	Monterey	2390	36°10'	120°41'	30	18
Prunedale	Monterey					
Quien Sabe HC	San Benito					
Rancho Quien Sabe	San Benito					
Roosevelt Ranch	Monterey					

Weather Reporting Stations (continued)

STATION	COUNTY	ELEV. (ft)	LAT. (N)	LONG. (W)	YEARS OF RECORD Precip.	Temp.
Salinas (Prec: 98 yrs)	Monterey	74	$36^{\circ}40'$	$121^{\circ}37'$	30	30
Salinas 2E	Monterey					
Salinas DeDampierre	Monterey					evap
Salinas FAA Airport	Monterey					wind
Salinas Yard	Monterey					
San Antonio Mission	Monterey	1060	$36^{\circ}01'$	$121^{\circ}15'$	8	8
San Ardo	Monterey	456	$36^{\circ}01'$	$120^{\circ}54'$	14	
San Ardo Yard	Monterey					
San Benito	San Benito	1360	$36^{\circ}31'$	$121^{\circ}05'$	22	
San Benito Willow Creek	San Benito	980	$36^{\circ}35'$	$121^{\circ}11'$	6	
San Clemente Dam	Monterey	600	$36^{\circ}26'$	$121^{\circ}43'$	22	
San Felipe Hwy Station	Santa Clara	365	$37^{\circ}01'$	$121^{\circ}20'$	21	
San Gregorio 3SE	San Mateo	355	$37^{\circ}18'$	$122^{\circ}20'$	10	10
San Jose	Santa Clara	95	$37^{\circ}20'$	$121^{\circ}53'$	30	30
San Juan Bautista	San Benito					
San Juan Bautista 3SSE	San Benito	550	$36^{\circ}49'$	$121^{\circ}31'$	22	
San Juan Bautista Mission	San Benito					
San Lucas	Monterey	406	$36^{\circ}08'$	$121^{\circ}01'$	12	
Santa Cruz	Santa Cruz	125	$36^{\circ}58'$	$122^{\circ}01'$	30	[30 humid
Sargent	Santa Clara	144	$36^{\circ}55'$	$121^{\circ}33'$	9	
Seaside	Monterey					
Slack Canyon	Monterey	1730	$36^{\circ}05'$	$120^{\circ}40'$	8	
Slack Creek	Monterey	1950	$36^{\circ}04'$	$120^{\circ}39'$	12	
Soledad	Monterey	195	$36^{\circ}26'$	$121^{\circ}20'$	12	
Soledad CTF	Monterey					evap
Spreckels	Monterey					
Spreckels Hwy Bridge	Monterey	60	$36^{\circ}36'$	$121^{\circ}41'$	30	36
Sunset Beach State Park	Santa Cruz	85	$36^{\circ}54'$	$121^{\circ}50'$	7	
Tequisquita Rancho	Santa Clara	244	$36^{\circ}59'$	$121^{\circ}28'$	7	
Tres Pinos	San Benito	517	$36^{\circ}47'$	$121^{\circ}19'$	12	
Upper Tres Pinos	San Benito					
Watsonville Waterworks	Santa Cruz	95	$36^{\circ}56'$	$121^{\circ}46'$	30	30
Wilder Ranch	Santa Cruz					
Wrights	Santa Clara	1600	$37^{\circ}07'$	$121^{\circ}56'$	30	

APPENDIX A

TABLE II

Average Monthly and Seasonal Precipitation in Inches

STATION	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	SEASON
Antelope Valley	0.04	0.02	0.10	0.30	0.60	1.60	2.02	2.22	1.51	0.62	0.19	0.09	9.31
Arroyo Seco	0.02	0.04	0.15	0.55	1.65	4.42	5.64	5.13	3.35	1.90	0.42	0.10	23.37
Big Sur State Park	-T-	0.03	0.39	1.78	3.42	8.10	8.63	8.02	5.86	3.25	1.09	0.28	40.85
Bradley	0.02	0.01	0.09	0.34	0.70	1.87	2.06	2.57	1.80	1.18	0.28	0.01	10.93
Bryson	0.03	0.02	0.17	0.61	3.20	4.31	4.55	3.89	2.93	1.93	0.35	0.03	22.02
Carmel Valley	0.03	0.05	0.34	0.49	2.12	2.37	3.37	3.40	2.47	2.18	0.48	0.14	17.44
Castroville	0.01	0.02	0.13	0.58	1.32	3.80	4.91	3.79	1.99	0.70	0.50	0.06	17.81
Chittenden Pass	0.01	0.04	0.44	0.81	1.91	3.41	3.92	3.11	2.72	1.64	0.54	0.05	18.60
Cholame Hatch Ranch	0.02	0.01	0.06	0.27	0.78	1.71	1.86	2.00	1.54	1.03	0.36	0.02	9.66
Cold Springs Camp	0.01	0.03	0.19	3.66	7.94	16.19	16.10	13.23	11.17	6.13	1.66	0.20	76.51
Del Monte	-T-	0.03	0.14	0.53	1.19	2.94	3.19	2.93	2.18	1.24	0.38	0.09	14.84
Gonzales	0.01	-T-	0.11	0.47	1.25	1.56	3.26	2.15	2.39	0.67	0.43	0.02	12.32
Gonzales 9 ENE	-T-	0.02	0.14	0.53	1.26	2.84	2.70	2.62	2.41	1.36	0.41	0.08	14.37
Hernandez 2 NW	-T-	0.01	0.12	0.56	1.50	3.31	3.04	3.04	2.47	1.66	0.38	0.09	16.18
Hernandez 7 SE	0.04	0.01	0.20	0.68	2.17	3.92	3.49	3.62	2.86	1.86	0.35	0.07	19.27
Hollister	0.01	0.02	0.18	0.49	1.30	2.67	2.57	2.48	1.87	1.13	0.35	0.08	13.15
Hollister #2	-T-	0.01	0.21	0.48	1.29	2.41	2.32	2.48	1.69	1.18	0.35	0.03	12.45
Jolon	-T-	0.02	0.29	0.77	1.69	2.72	3.95	2.95	3.34	1.01	0.51	0.04	17.29
King City	0.01	0.01	0.08	0.29	0.67	2.10	2.18	2.30	1.61	0.92	0.23	0.06	10.46
Lockwood 2 N	0.01	0.02	0.08	0.38	1.23	2.36	2.11	2.53	1.78	1.09	0.31	0.03	11.93
Los Burros	-0-	-T-	0.97	3.03	5.11	5.27	12.99	7.77	9.34	2.63	1.22	0.38	48.71
Lucia Willow Springs	0.01	0.03	0.41	0.88	2.44	4.77	5.11	4.24	3.82	2.49	0.69	0.02	24.91
Monterey	0.01	0.03	0.22	0.73	1.54	3.65	3.93	3.56	2.77	1.60	0.54	0.12	18.70
Nacimiento Dam	0.04	0.02	0.20	0.42	2.26	2.54	2.66	2.96	2.23	1.76	0.21	0.03	15.33
Paicines Ohrwall Ranch	0.01	0.03	0.21	0.57	1.58	3.08	2.75	2.78	2.24	1.35	0.49	0.03	15.12

(continued)

TABLE II (continued)

STATION	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	SEASON
Paloma	-T-	0.02	0.11	0.77	1.94	4.26	4.75	4.47	3.61	2.00	0.55	0.06	22.54
Parkfield	0.02	-T-	0.19	0.39	1.68	2.69	2.59	2.75	2.30	1.50	0.42	0.03	14.58
Parkfield 6 SE	0.02	0.02	0.15	0.55	0.97	2.60	3.70	2.97	2.30	1.02	0.39	0.12	14.81
Parkfield 8 NNW	-T-	-T-	0.31	0.48	1.93	3.52	3.12	3.47	2.16	1.65	0.36	0.01	17.01
Parkfield 7 NNW	0.06	0.05	0.21	0.45	1.85	2.18	2.53	2.24	2.08	1.16	0.33	0.01	13.15
Paso Robles	0.04	0.03	0.09	0.43	1.09	3.05	3.07	3.25	2.20	1.23	0.32	0.09	14.89
Paso Robles FFA	0.05	0.02	0.10	0.35	1.38	2.11	2.02	1.95	1.84	1.24	0.29	0.02	11.37
Paso Robles 5 NW	0.03	0.03	0.08	0.41	1.63	2.92	2.97	2.84	2.16	1.43	0.27	0.01	14.78
Pebble Beach	0.04	0.07	0.38	0.51	2.17	2.67	3.79	2.70	2.51	1.75	0.55	0.17	17.31
Pinnacles Nat. Monument	-T-	-T-	0.14	0.47	1.43	2.95	3.15	3.25	2.86	1.37	0.37	0.03	16.02
Point Piedras Blancas	0.02	0.04	0.10	0.83	1.44	3.31	3.98	3.85	3.20	1.62	0.47	0.04	18.90
Priest Valley	0.01	0.02	0.16	0.55	1.45	3.89	3.97	4.39	3.09	1.75	0.50	0.09	19.87
Salinas	0.02	0.04	0.21	0.53	1.13	2.80	2.98	2.65	2.07	1.22	0.41	0.08	14.14
San Antonio Mission	0.04	-0-	0.30	0.46	3.41	3.36	3.80	3.02	2.25	1.68	0.21	0.04	18.57
San Ardo	-0-	-T-	0.05	0.60	0.94	1.89	3.39	2.32	2.06	0.56	0.17	0.02	12.00
San Benito	0.01	0.01	0.10	0.54	1.04	2.73	2.36	2.56	2.05	1.24	0.33	0.06	13.03
San Benito Willow Creek	0.01	-T-	0.04	0.44	1.63	2.78	2.89	1.11	2.33	0.77	0.11	0.03	12.14
San Clemente Dam	-T-	0.02	0.23	0.78	2.00	4.46	4.47	4.43	3.19	1.91	0.49	0.07	22.05
San Juan Bautista 3 SSE	-T-	0.04	0.26	0.72	2.82	2.91	3.57	2.73	2.70	1.49	0.53	0.10	17.27
San Lucas	-T-	0.02	0.06	0.59	0.45	1.81	3.41	2.24	2.89	0.60	0.30	-T-	12.37
San Miguel	0.01	0.04	0.18	0.54	0.86	1.91	2.88	2.05	2.30	0.60	0.48	0.02	11.87
Sargent	0.06	0.01	0.12	0.48	1.16	4.55	6.00	3.12	3.69	0.76	0.73	0.07	20.75
Slack Canyon	0.01	0.01	0.14	0.46	1.24	3.28	2.97	3.36	2.11	1.23	0.48	0.06	15.35
Slack Creek	0.02	0.02	0.01	0.53	1.63	2.75	2.62	2.46	2.74	1.08	0.31	0.05	14.22
Soledad	0.04	0.02	0.14	0.30	1.17	1.89	2.03	1.84	1.44	1.20	0.31	0.10	10.48
Spreckels Highway Bridge	0.01	0.02	0.18	0.47	1.06	2.75	2.84	2.62	2.07	1.12	0.45	0.08	13.67
Sunset Beach State Park	0.01	0.02	0.21	0.66	1.49	4.04	4.07	3.46	2.24	1.27	0.50	0.11	18.08
Tres Pinos	-0-	-T-	0.08	0.25	0.83	2.21	4.26	1.69	2.28	0.51	0.47	0.06	12.64
Valleton	0.03	-T-	0.07	0.43	1.00	2.13	1.96	2.28	1.92	1.06	0.24	0.01	11.13
Watsonville Waterworks	0.02	0.05	0.27	0.83	1.90	4.36	4.40	3.99	2.98	1.53	0.55	0.12	21.00

Note: -T- = trace

from Elford and Stilz (1968)

APPENDIX A

TABLE III
Sources of Meteorological Data for the Monterey Bay Area

Agricultural Extension Service Office of Farm and Home Advisor 118 Wilgart Way Salinas, California 93901	Precipitation Temperature Special agricultural studies
California Air Resources Board 2180 Milvia Street Berkeley, California 94704	Air pollution data
Department of Water Resources State of California 1416 Ninth Street Sacramento, California 95817	Climatological data
Monterey County Flood Control and Water Conservation District 1270 Natividad Road Salinas, California 93901	Precipitation Temperature Evaporation
Monterey County Road Department 312 East Alisal Salinas, California 93901	Precipitation
Salinas California West Alisal and Church Street Salinas, California 93901	Precipitation
State Climatologist 50 Fulton Street, Room 557 San Francisco, California 94102	Climatological data Climatological studies
Monterey-Santa Cruz Counties Unified Air Pollution Control District 1270 Natividad Road Salinas, California 93901	Air pollution Wind

APPENDIX A

GLOSSARY

1. Westerlies - The prevailing wind direction over the ocean at the latitude of the United States is from the west (i.e. blowing to the east); these winds are called the prevailing westerlies.

2. Onshore - When a particular meteorological field changes from the sea to the land it can be said to have an onshore component.

3. Pacific High (or Pacific Anticyclone) - Air warmed by the hot sun over the equator rises and heads northward toward the arctic regions. Some of it cools off and sinks back down to the ocean surface several miles to the north of its initial source region. This "mountain" of cool air, weighing heavily on the water, is what is known as the Pacific High.

4. Coriolis Force - Coriolis force is an apparent force on moving particles (air in this case) arising solely from the earth's rotation. It acts as a "deflecting force", normal to the velocity, to the right of motion in the northern hemisphere. It cannot alter the speed of a particle; it is proportional (effectively) to the speed.

5. Upwelling - From March through May the Pacific High moves closer and becomes stronger while the Central Valley warms up. The effect of the northwest wind down the California coast is to push the surface of the ocean before it and create a strong current running southward down the shoreline like a river. This southward-moving ocean current veers offshore at about 45° angle due to the Coriolis force. In order to replace the surface currents moving away from the coast, masses of water (often 10-15° colder - since it comes from depths of several hundred feet - than sun-warmed surface) surge up from the bottom of the ocean creating a continual fountain of upwelling waters. [Gilliam, 1962]

6. Inversion - In meteorology, a departure from the usual decrease (of temperature in this case) or increase with altitude of an atmospheric property.

APPENDIX B

MONTEREY BAY AREA FISHERIES

TABLE I

Monterey Bay Area, Commercial Fish Landings in Pounds, 1957-1966
(after Odemar, et al, 1968)

FISH	1957	1958	1959	1960	1961
Anchovy	1,485,821	542,330	327,779	1,290,657	3,787,512
Bonito, Pacific	100	--	15,487	1,435	6
Cabezon	10,416	12,614	7,952	2,564	3,768
Croaker, white	144,301	147,815	89,252	73,576	238,138
Flounder	47,735	21,606	12,071	11,917	18,760
Flounder, arrowtooth	--	--	--	--	95
Greenling, kelp	281	2,505	--	--	153
Hake, Pacific	149,805	38,965	18,740	16,470	--
Halibut, California	19,981	12,663	9,218	3,926	9,957
Herring, Pacific	597,792	733,682	340,100	439,235	352,784
Lingcod	212,556	236,135	162,563	97,819	148,497
Mackerel, jack	2,319,417	3,203,199	10,906,375	2,265,144	3,650,940
Mackerel, Pacific	1,502	162,676	2,307,247	4,052,410	10,395
Perch	32,187	9,035	10,652	11,494	12,967
Pompano, Pacific	12,469	40,975	17,514	2,299	1,256
Ratfish	11,595	875	--	600	--
Rockfish	5,471,248	5,857,036	4,697,963	3,563,595	3,228,024
Sablefish	379,955	60,892	67,961	199,027	350,409
Salmon	431,215	277,181	269,688	815,778	654,577
Sanddab	140,151	48,669	173,340	64,228	111,984
Sardine	32,072	16,783,939	29,885,506	3,003,143	1,109,642
Sculpin, staghorn	--	--	--	--	--
Seabass, white	197,955	92,161	313,755	49,961	13,406
Shark	279,816	49,383	83,477	54,157	38,977
Skate	46,322	27,737	25,448	45,415	64,905
Smelt	96,050	35,935	29,545	28,975	33,465
Smelt, whitebait	36,633	96,589	809	4,249	12,611
Sole, Dover	10,301	730	2,420	49,647	59,642
Sole, English	498,446	255,713	200,857	264,517	206,715
Sole, petrale	157,795	110,394	90,339	157,943	111,439
Sole, rex	64,262	38,892	41,053	93,630	70,455
Sole, sand	495	--	--	--	240
Sole, miscellaneous	16,996	6,716	9,848	4,695	11,012
Swordfish	997	--	--	--	451
Tuna, albacore	2,121,882	2,190,201	2,292,733	2,893,920	1,871,750
Tuna, skipjack	--	--	410	18	--
Tuna, yellowfin	--	--	--	--	--
Turbot	1,997	--	363	--	--
Miscellaneous fish	85	333	663	49	--
Miscellaneous, animal food	--	--	--	--	9,717

(continued)

APPENDIX B

TABLE I
(continued)

FISH	1962	1963	1964	1965	1966
Anchovy	1,188,097	3,360,242	2,833,229	3,958,653	16,640,036
Bonito, Pacific	110	1,169	1,265	10,570	16,490
Cabezon	1,920	1,737	1,913	2,925	1,645
Croaker, white	71,052	49,802	87,525	81,419	98,045
Flounder	38,505	70,656	69,113	65,283	60,097
Flounder, arrowtooth	--	--	--	--	--
Greenling, kelp	40	--	--	--	--
Hake, Pacific	1,845	67,989	56,799	77,280	24,934
Halibut, California	47,181	62,361	42,919	94,065	92,656
Herring, Pacific	492,825	248,572	318,273	483,046	211,952
Lingcod	101,428	90,087	57,107	76,906	92,825
Mackerel, jack	2,049,729	1,652,202	2,584,160	2,751,937	1,234,731
Mackerel, Pacific	6,287	480	2,558	225	--
Perch	25,977	13,283	16,836	16,482	18,114
Pompano, Pacific	562	24,556	56,196	42,727	10,669
Ratfish	--	--	--	--	--
Rockfish	2,854,868	2,466,700	2,174,861	2,618,434	3,385,933
Sablefish	404,628	271,226	410,717	570,905	593,831
Salmon	308,369	512,354	378,421	491,899	188,518
Sanddab	127,863	130,435	112,212	119,345	249,646
Sardine	2,591,518	1,340,196	414,556	257,343	12,964
Sculpin, staghorn	--	--	--	--	--
Seabass, white	2,400	3,934	26,338	5,587	23,586
Shark	60,488	45,344	41,820	52,409	56,014
Skate	75,691	96,464	77,828	59,229	70,959
Smelt	21,554	33,181	36,751	24,010	16,287
Smelt, whitebait	23,669	--	--	--	--
Sole, Dover	57,872	82,355	67,116	85,583	135,380
Sole, English	269,855	390,453	389,787	433,684	452,922
Sole, petrale	166,822	233,611	200,837	276,432	299,493
Sole, rex	102,520	105,555	183,252	242,119	203,990
Sole, sand	--	260	763	703	6,475
Sole, miscellaneous	29,851	23,901	15,353	11,716	9,743
Swordfish	--	11,800	906	1,303	771
Tuna, albacore	2,685,605	5,840,787	2,272,440	3,492,049	2,995,389
Tuna, skipjack	--	--	--	--	1,500
Tuna, yellowfin	--	--	104	--	--
Turbot	70	330	1,090	370	395
Miscellaneous fish	7	1,610	206	--	195
Miscellaneous, animal food	122,495	83,360	46,880	48,475	--

(continued)

APPENDIX B

TABLE I
(continued)

Monterey Bay Area, Commercial Fish Landings in Pounds, 1957-1966

CRUSTACEAN	1957	1958	1959	1960	1961
Crab, market	93,792	127,064	124,199	54,680	16,039
Crab, rock	--	--	--	--	--
Prawn	767	911	--	--	--
Shrimp, bay	--	--	--	--	--
Shrimp, ocean	--	--	--	--	--
MOLLUSK					
Abalone	2,245	--	--	3,017	683
Clam, gaper	300	680	--	320	220
Octopus	12,064	3,572	--	--	75
Oyster, eastern	--	--	--	--	--
Oyster, giant Pacific	--	--	--	--	--
Oyster, native	--	--	--	--	--
Squid	11,956,541	3,902,936	14,252,042	2,235,935	3,686,284
Miscellaneous mollusk	--	--	100	105	--
TOTALS	27,096,340	35,132,739	66,787,469	21,856,550	19,897,950

CRUSTACEAN	1962	1963	1964	1965	1966
Crab, market	12,306	8,759	7,780	6,917	2,911
Crab, rock	152	1,081	643	211	511
Prawn	694	8,445	5,775	--	3,366
Shrimp, bay	--	--	--	697	--
Shrimp, ocean	--	--	--	--	--
MOLLUSK					
Abalone	125	1,863	410	--	--
Clam, gaper	480	--	--	--	--
Octopus	61	13,168	6,678	2,446	4,957
Oyster, eastern	--	--	--	--	--
Oyster, giant Pacific	4,908	3,937	8,449	5,864	1,978
Oyster, native	--	--	--	--	--
Squid	5,652,857	6,754,463	9,101,623	8,865,195	11,207,349
Miscellaneous mollusk	240	292	461	780	1,298
TOTALS	19,603,526	24,109,000	22,111,950	25,335,223	38,428,413

APPENDIX B

TABLE II

Monterey Bay Area, Numbers of Fish in Yearly Catch Landed by Party Boats, 1952-1970
(compiled from data provided by the California Department of Fish and Game office, Monterey)

FISH	1952	1953	1954	1955	1956	1957
Albacore						
Bluefin tuna						
Bonito						
Cabezon	1,784	1,067	826	472	3,449	1,550
California halibut						59
Flatfish, miscellaneous	5,006	34,231	4,796	1,789	1,657	1,853
Jack mackerel		327	183	4,669	9,199	331
Lingcod	5,737	4,948	6,531	6,018	9,729	10,663
Ocean whitefish						
Pacific mackerel			174	639	339	
Rockfish	162,635	124,394	144,631	170,636	152,514	174,511
Sablefish		2,428	1,432	1,085	3,928	
Salmon		1,404	5,631	22,999	36,428	11,634
Striped bass						
White croaker	13,846	4,595	1,444	1,104	2,026	1,621
White seabass						555
Yellowtail						
Others	1,465	632	299	422	2,094	471
ANGLER DAYS	27,139	21,639	24,267	35,252	43,613	32,133
BOATS		19	21	34	47	46

(continued)

APPENDIX B

TABLE II

Monterey Bay Area, Numbers of Fish in Yearly Catch Landed by Party Boats, 1952-1970
(continued)

FISH	1958	1959	1960	1961	1962	1963
Albacore						47
Bonito						
Cabezon	967	701		184	347	770
California halibut				47	14	
Flatfish, miscellaneous	545	393		785	1,142	655
Jack mackerel	1,825	1,168		1,223	1,000	552
Lingcod	11,993	7,271		4,663	6,557	4,531
Ocean whitefish					1	21
Pacific mackerel	895	1,319		293	239	635
Rockfish	272,260	252,443		158,032	188,938	180,260
Sablefish						
Salmon	6,258	4,140		5,439	5,522	917
Sriped bass						
White croaker	918					
White seabass	313	27				
Yellowtail		10				
Others	496	1,951		622	2,032	352
ANGLER DAYS	26,151	24,044		19,787	21,289	15,719
BOATS	31	33		24	27	24

(continued)

A P P E N D I X B

TABLE II
(continued)

FISH	1964	1965	1966	1967	1968	1969	1970
Albacore	29	92	1,495	602	797	5	20
Bluefin tuna							
Bonito		488	1,569	346	159	496	1,119
Cabezon	400	440	509	274	491	375	
California halibut	24		23	9	2	6	16
Flatfish, miscellaneous	2,660	1,324					71
Jack mackerel	1,663	1,750	350	1,709	834	3,417	
Lingcod	3,846	6,354	9,888	12,143	11,183	7,049	12,232
Ocean whitefish							
Pacific mackerel		27				31	26
Rockfish	155,877	199,786	265,070	270,032	237,358	276,098	289,116
Sablefish			10,461	3,676			
Salmon	1,663	408	227	3,023	1,806	1,847	310
Stiped bass	3						
White croaker							
White seabass							
Yellowtail							28
Others	4,334	7,295	4,139	2,961	6,942	10,511	9,775
ANGLER DAYS	16,794	16,831	27,570	27,864	25,401	28,370	28,019
BOATS	21	17	20	20	17	20	19

A P P E N D I X C

ELKHORN SLOUGH RESOURCES AND USES
(C-1 through C-6)

(A list prepared by the California Department of Fish and Game for Water Resource Engineers. January 1969)

Mr. Michael B. Sonnen
Associate Engineer
Water Resources Engineers, Inc.
1900 Olympic Boulevard
Walnut Creek, California 94596

Dear Mr. Sonnen:

Thank you for your letter of December 23, 1968, requesting information related to recreational aspects of water use in Moss Landing Harbor and Elkhorn Slough, Monterey County.

Our reply responds to each of the questions listed in your letter as follows:

1. Results of surveys, reports and observations of numbers of persons involved and numbers of days of historical involvement in the following recreational activities:

   (a) Water skiing - We do not know of any past or present water skiing on these waters.

   (b) Pleasure boating - We estimate 400 boat days with an average of 2 persons per boat are spent each year on these waters. Thus, about 800 man-days of pleasure boating are spent annually.

   (c) Fishing - Shore - 2,000 man-days
   Skiff - 2,400 man-days
   Pier - 4,000 man-days
   Jetty - 18,000 man-days

   Based on actual angler-use surveys conducted by our Department, total angling days spent annually in Elkhorn Slough and Moss Landing Harbor is 26,400. The jetty was included because water in the Elkhorn Estuary passes this point and must have an effect upon the fishing. A short distance from the mouth of Elkhorn Slough is Sandholdt Pier, which extends into the Pacific Ocean. This pier had 28,200 angler-days in 1958. Water from Elkhorn Slough mixed with ocean water also influences this fishery.

   (d) Hunting - Hunting season use on this area occurs from mid-October to about mid-January each year. In the slough proper, hunting is for migratory waterfowl. Marshy areas, upland areas and farm lands contiguous to the slough produce huntable populations of upland game such as quail, pheasant and rabbit.

On the waters of the slough it is estimated there are 250 man-days annually expended for waterfowl hunting. Nine private gun clubs on the periphery of the slough average about 1,100 man-days of hunting per year. On other lands it is estimated that there are 600 man-days of hunting. Thus, a total of 1,950 man-days is spent on the waters or nearby lands hunting wildlife that are directly dependent upon or associated with the waters of Elkhorn Slough. These estimates are based on actual surveys conducted by our Department within the last two years.

(e) Clamming - Based on estimates from our local Wardens and other Department personnel, sport-clamming for human consumption is estimated as 2,500 man-days per year under normal high water quality conditions. However, sport-clamming is down presently because of the well-publicized contamination of Elkhorn Slough and the subsequent Public Health quarantine which prevents the use of Elkhorn Slough shellfish for commercial purposes. Indeed, a survey of clamming under present conditions would not reveal a high use of clams for human consumption any more than a survey for swimming use conducted on an obviously polluted beach. We are hopeful that the recently adopted California State Water Quality Control Policy for these waters will result in the implementation of an adequate correction of this problem.

(f) Miscellaneous

(1) Bird Watching - Based on surveys made during the past two years, we estimate that 3,000 man-days are spent in bird watching. This includes the rather extensive use made by wildlife photographers in this area. The main period of bird watching is during the fall, winter and spring months when migratory water-associated birds are either passing through or spending the winter months here.

(2) Hiking - Based on surveys made during the past two years, we estimate that 300 man-days are spent annually in hiking and beach-combing. This does not include hiking accomplished by school groups or bird watchers.

(3) Nature Study - The only precise information we have on formal nature studies conducted in the Elkhorn Slough and Moss Landing Harbor is the use made by students at the local Moss Landing Marine Laboratories. During 1967, approximately 2,650 college student-use days were expended in this area. This includes all use during the normal academic year as well as summer school and workshops. In addition, our local Wardens estimate at least 1,000 high school student-days use is spent here annually.

Use of this area by students from the U.S. Naval Postgraduate School in Monterey, the University of California in Santa Cruz, Hopkins Marine Station and junior colleges is not known, but it may be considerable.

(4) Picknicking - An estimated 750 man-days are spent annually for this activity in this area.

(g) Swimming - This use is estimated to be about 250 man-days annually and consists mostly of use made by children.

2. Information on plans, programs, or policies for the future development of recreational activities for the waters and associated land areas of Elkhorn Slough and Moss Landing Harbor. -- As you may know the State Water Quality Control Board recently adopted a water quality control policy for interstate waters including the waters of Moss Landing Harbor and Elkhorn Slough. This policy recognized and resolved to protect from adverse water quality the following beneficial uses:

   (a) Scenic attractions and aesthetic enjoyment
   (b) Habitat for sustenance and propogation of fish, other aquatic organisms and wildlife
   (c) Fishing
   (d) Industrial water supply
   (e) Boating, shipping and navigation
   (f) Scientific study
   (g) General beach recreation, including swimming and water contact activities
   (h) Shellfish harvesting for human consumption.

   We strongly support this policy.

   With regard to plans and programs, this estuary is part of our new statewide Bay and Estuary Study Program, which was formulated to update our Department's published Wildlife Plan for California.

   We anticipate that this program will result in our Department recommending that certain estuaries, or portions of certain estuaries, be retained in their natural state. However, in all areas, including the Elkhorn Slough-Moss Landing area, we fully expect that orderly development of any kind can and will be accomplished in a manner that will protect the quality of water for all recognized beneficial uses including present recreational water activities. This view is in keeping with the already-mentioned policy as well as the State's recently adopted Anti-Degradation Water Quality Control Policy for all waters of the State.

3. Information relating to the populations and distribution of wildlife species in this area and to the relative demand for these species expressed by persons who seek them there.

   Seventy-five species of water-associated birds have been identified in Elkhorn Slough. In the slough and surrounding area an additional 40 species of land-associated birds have been seen. No estimate of the number of land-associated birds has been attempted. A count of water-associated birds in October, 1967, revealed 20,652 individuals using the slough. (Attached to this letter is a list of these species for your information.)

With regard to fish species, the most important fishes making up the sport catch in the estuary are:

- Rubberlip Perch
- Pile Perch
- Black Perch
- Jacksmelt
- Sand Sole
- Staghorn Sculpin
- Starry Flounder
- Walleye Perch
- Kelp Greenling
- Cabezone
- Striped bass and California halibut are heavily fished for, but are not common in the catch.

Other species of fish occur in the slough, some of which are caught as sport fish, others do not enter the fishery but are important in the ecological web of the estuary. They are:

- Bat Ray
- Smoothhound Shark
- Anchovies
- Topsmelt
- Jacksmelt
- Boccacio
- Blue Rockfish juveniles
- Brown Rockfish juveniles
- Grass Rockfish juveniles
- Lingcod (pelagic stage)
- Jack Mackerel (pelagic stage)
- White Perch
- Dwarf Perch
- Herring
- Shiner Perch
- Rainbow Sea Perch
- Striped Sea Perch
- Calico Surf Perch

Most of the fish listed as being present in Elkhorn Slough use the slough as spawning grounds. A few species go out to deep water to spawn and return as juveniles or adults, but most depend on the slough for their successful reproduction in this area.

Species of shellfish that are commonly sought by sport clammers include:

- Washington
- Gapers
- Piddocks

A statement of present demand and use for these resources is contained in Section 1 of this letter.

With regard to your statement of persons who seek the use of these resources only in this area, we point out that the migratory waterfowl that may require this area as a feeding or resting place are sought by hunters all along the Pacific Flyway from Canada to Mexico. The availability of waterfowl habitat in this Flyway has reached critical low levels. Any reduction in habitat by poor water quality or any other cause is a corresponding reduction in the number of birds in the Flyway. Therefore, factors that reduce this resource in this area will not only affect the use by hunters in this area but will also affect use in other areas as well. This can also be said of bird-watching use, nature study use, or any other use of the migratory wildlife resources.

This concludes our response to your request for now; however, we are currently developing much more detailed knowledge about this area. We will be happy to furnish this information to you, upon request, as it becomes available.

Sincerely,

W. Shannon
Director

Attachments (2)

(Attachment 1)

Land-associated Birds of Elkhorn Slough, Monterey County

Scrub jay
Yellow-billed magpie
Common crow
Common bushtit
Bewick's wren
Long-billed marsh wren
Band-tailed pigeon
Mourning dove

Red shafted flicker
Say's phoebe
Horned lark
Violet-green swallow
California thrasher
Ruby-crowned kinglet
Water pipit
Loggerhead shrike
Starling
Audubon's warbler
House sparrow
Western meadowlark

Red-winged blackbird
Tricolored blackbird
Brewer's blackbird
House finch
American goldfinch
Brown towhee
Savannah sparrow
White-crowned sparrow
Golden-crowned sparrow
Swamp sparrow
Song sparrow

Golden eagle
Red-tailed hawk
Marsh hawk
Sparrow hawk
White-tailed kite
Short-eared owl
Quail
Pheasant

(Attachment 2)

Water-associated Birds of Elkhorn Slough, Monterey County

Belted kingfisher
White pelican
Brown pelican
Semipalmated plover
Snowy plover
Black-bellied plover
Killdeer
Ruddy turnstone
Black turnstone
Common snipe
Long-billed curlew
Whimbrel
Spotted sandpiper
Willet
Greater yellowlegs
Knot
Least sandpiper
Dunlin
Short-billed dowitcher
Western sandpiper
Marbled godwit
Sanderling
American avocet
Black-necked stilt
Wilson pharalope
Northern pharalope
Horned grebe
Eared grebe
Western grebe
Pied-billed grebe
Clapper rail
Virginia rail
American coot
Glaucous-winged gull
Western gull
Herring gull
California gull
Ring-billed gull
Mew gull
Bonaparte's gull
Heermann's gull
Forster's tern
Common tern
Least tern
Elegant tern
Caspian tern
Arctic loon
Red-throated loon
Common loon
Double-crested cormorant
Brandt's cormorant
Great blue heron
Common egret
Snowy egret
Black-crowned night heron
American bittern
Black brant
Snow goose
Mallard
Gadwall
Pintail
Green-winged teal
Cinnamon teal
American widgeon
Shoveler
Red-head
Canvasback
Scaup
Common goldeneye
Bufflehead
Oldsquaw
Winte-winged scoter
Surf scoter
Common scoter
Ruddy duck
Red-breasted merganser

APPENDIX C

EXCERPTS FROM DISCHARGE REQUIREMENTS ESTABLISHED BY THE CENTRAL COAST REGIONAL WATER QUALITY CONTROL BOARD FOR DISCHARGES IN THE MOSS LANDING AREA

(C-7 through C-10)

(After Appendix IX, Sanitary Engineering Investigation of Quality of Water and Shellfish in the Estuary System at Moss Landing, Monterey, California. October 1967)

A. Requirements adopted June 10, 1966, for:

General Fish Corporation
Santa Cruz Canning Company
Sea Products Company

1. Process waters other than clean cooling waters shall not be discharged into Moss Landing Harbor at any time.
2. The discharge into Monterey Bay shall be controlled to the extent necessary to prevent sludge deposits, nuisance conditions, or discoloration in the receiving waters as the results of floating, suspended, or settleable solids, oils, or grease.
3. The discharge shall not contain domestic sewage at any time.

B. Requirements adopted July 16, 1965, for:

Pacific Gas and Electric Company

1. There shall be no visible floating oil in the receiving waters, or along the shore as a result of this discharge.
2. The discharge shall not cause concentrations of substances in the receiving waters that would be deleterious to fish and aquatic life.
3. The discharge shall not cause concentrations of substances in the receiving waters which would impart a foreign taste to fish and aquatic life.
4. The discharge shall not cause a nuisance condition as the result of floating, suspended, or settleable solids, or discoloration of receiving waters.
5. Concentration of the wastes in the discharge to the ocean shall not exceed 0.1 of the 96 hour TLm, as calculated from the 96 hour TLm bio-assay tests on the wastes.
6. The pH of the discharge shall not be below 6.5 nor exceed 8.5.
7. The temperature of the receiving waters as a result of this discharge shall not be altered at any place from background levels to a degree known to be unfavorable for the preservation of the fish and other aquatic life found in these receiving waters.

C. Requirements adopted September 15, 1966, for Castroville County Sanitation District:

1. Samples of effluent shall not exceed --
   75 mg/l B.O.D., 5 day, $20^{o}C$
   60 mg/l suspended solids
   0.3 mg/l settleable solids

2. Effluent requirements may be exceeded by 20% of eight hour composite samples analyzed.

3. Effluent shall be continuously disinfected. A chlorine residual of 1.0 mg/l after thirty minute contact will be considered compliance with this requirement. The discharger shall made such tests as are necessary to demonstrate efficacy of disinfection practices.

4. Treatment and disposal of the sewage shall not result in production of obnoxious odors in quantities sufficient to reach populated or recreational areas.

5. Mosquito and other insect breeding resulting from treatment and disposal of sewage shall be controlled to the extent necessary to prevent a disease vector or nuisance problem from occurring.

6. Any failure of the treatment or disposal system shall be reported to the Monterey Health Department within twenty-four hours.

7. This discharge shall not cause concentrations of substances in the receiving waters which are toxic or otherwise detrimental to human, animal, plant, or bird life.

8. The discharge shall not create sludge banks in the receiving waters be deposition of solids.

9. The discharge shall not create slime growths in the receiving waters at any time.

10. The discharge shall be controlled to the extent necessary to prevent interference with the function of Tembladero Slough or the old Salinas River as a natural drainage channel.

11. The discharge shall be controlled to the extent necessary to prevent: (a) a condition which would deplete all of the dissolved oxygen in Tembladero Slough at any time; and (b) significant lowering of the dissolved oxygen of water in the old Salinas River to the extent that fish and aquatic life are adversely affected.

12. Any direct use of effluent for irrigation shall conform with "Regulations Relating to Use of Sewage for Irrigating Crops," Title 17, Chapter 5, Sections 7897 through 7899, California Administrative Code.

D. Requirements adopted January 21, 1966, for Sea View Terrace Subdivision:

1. Treatment and disposal of the sewage shall not result in production of obnoxious odors in quantities sufficient to reach populated or recreational areas.

2. Mosquito and other insect breeding resulting from treatment and disposal of the sewage shall be controlled to the extent necessary to prevent a disease vector or nuisance problem from occurring.
3. The public shall have no contact with sewage effluent as a result of the disposal operations or as a result of use of effluent for crop irrigation.
4. Use of effluent for irrigation shall conform with "Regulations Relating to Use of Sewage for Irrigating Crops," Title 17, Chapter 5, Sections 7897 through 7899, California Administrative Code.
5. The discharge shall be maintained on the designated land disposal area without overflow or bypass to other properties or drainageways at any time.
   a. The discharger shall determine the best system for spray disposal of the design flow, which will prevent runoff from the disposal area. Tests shall be made using fresh water, rather than sewage effluent.
   b. The discharger shall notify the Board that appropriate tests have been made and that it is ready to commence spray irrigation of sewage effluent. Experiment or trial applications of sewage effluent prior to completion of the above-noted tests are considered unacceptable for this discharge.
6. No raw sewage shall be discharged to the land disposal area at any time.
7. Bypass of raw or treated sewage effluent directly to any creek or drainageway shall be considered a violation of these requirements.
   a. Provision shall be made for auxiliary power supply or an acceptable alternate at the treatment and pumping works to insure treatment of wastes which will be applied to the effluent disposal area.
8. Dissolved minerals in the discharge shall be limited to such amounts that percolating wastes do not impair beneficial used of ground waters.
9. The discharger shall provide proof that adequate land disposal areas will be made available and dedicated for this purpose.
10. The discharger shall submit statements from responsible County agencies that an appropriate district will be formed should it be planned that an agency of the County will become the operator and/or owner of the system at some future date.
11. These requirements do not provide for waste discharge to other than the designated disposal area. However, if accidental spill or overflow should cause raw or treated sewage effluent to enter Elkhorn Slough, the Monterey County Health Department should be notified immediately.

E. Requirements adopted April 23, 1965, for Long Valley Oaks subdivision:

1. Treatment and disposal of the sewage shall not result in production of obnoxious odors in quantities sufficient to reach populated or recreational areas.

2. Mosquito and other insect breeding resulting from treatment and disposal of the sewage shall be controlled to the extent necessary to prevent a disease vector or nuisance problem from occurring.

3. The public shall have no contact with sewage effluent as a result of the disposal operations or as a result of use of effluent for crop irrigation.

4. Use of effluent for irrigation shall conform with "Regulations Relating to Use of Sewage for Irrigating Crops," Title 17, Chapter 5, Sections 7897 through 7899, California Administrative Code.

5. The discharge shall be maintained on the designated land disposal area without overflow or bypass to other properties or drainageways at any time.

   a. The discharger shall determine the best system for spray disposal of the design flow, which will prevent runoff from the disposal area. Tests shall be made using fresh water, rather than sewage effluent.

   b. The discharger shall notify the Board that appropriate tests have been made and that it is ready to commence spray irrigation of sewage effluent. Experiment or trial applications of sewage effluent prior to completion of the above-noted tests are considered unacceptable for this discharge.

6. No raw sewage shall be discharged to the land disposal area at any time.

7. Bypass of raw or treated sewage effluent directly to any creek or drainageway shall be considered a violation of these requirements.

   a. Provision shall be made for auxiliary power supply at the treatment and pumping works to insure continuous functioning of mechanical equipment.

8. Dissolved minerals in the discharge shall be limited to such amounts that percolating wastes do not impair beneficial uses of ground waters.

9. Prior to commencing operation of the sewerage works, the discharger shall submit evidence to the Board that a bona fide utility operating agency exists and that a general operating and maintenance plan for waste collection, treatment, and disposal systems has been adopted.

10. The discharger shall execute agreements which may be necessary with an operating or County Public Works Agency to assure effective and continuous operation and maintenance.

11. The discharger shall provide proof that adequate land disposal areas will be made available and dedicated for this purpose.

12. The discharger shall submit statements from responsible County agencies that an appropriate district will be formed should it be planned that and agency of the County will become the operator and/or owner of the system at some future date.

APPENDIX C

TABLE I

Industrial Flow Rates in South Moss Landing Harbor

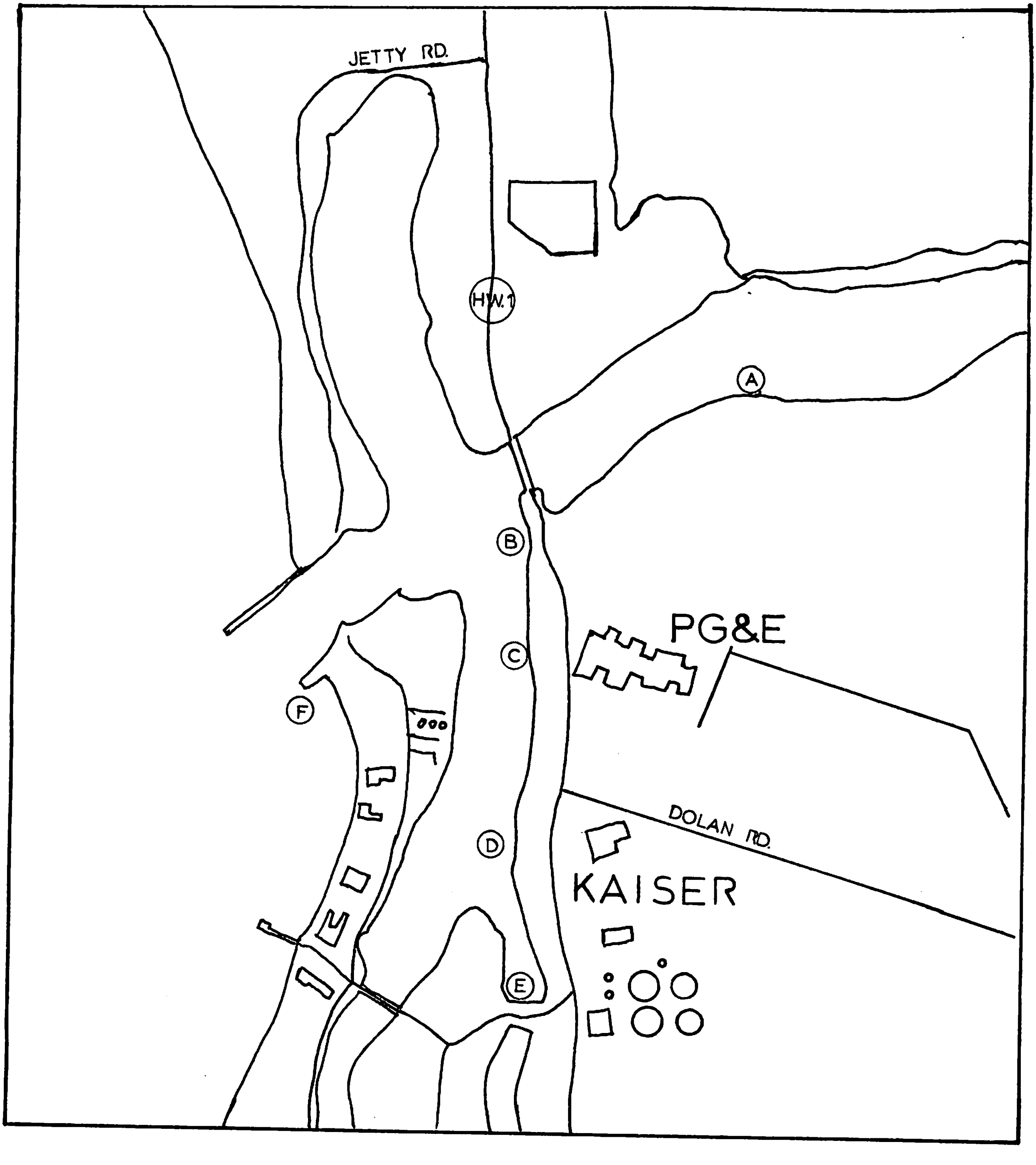
(From Moss Landing Harbor: Industrial Influence on its Circulation, Stratification and Chemistry by Arthur Stump, p 196.)

	GALLONS/DAY	METERS³/DAY
1. Kaiser Outfall Point E	2.24×10^7	8.00×10^4
2. Kaiser Intake Point D	2.23×10^7	8.00×10^4
3. Kaiser Fresh Water Addition	0.004×10^7	2.68×10^2
4. Pacific Gas and Electric Old Plant Intake, Point B and Outfall, Point A	55.0×10^7	2.51×10^6
5. Pacific Gas and Electric New Plant Intake, Point C and Outfall, Point F	43.2×10^7	1.97×10^6
6. Future Pacific Gas and Electric Company New Plant Intake at Point C and Outfall at Point F	86.4×10^7	3.94×10^6

(See figure, next page, for map indicating discharge points.)

APPENDIX C

Figure 1
Map of Moss Landing Harbor Indicating Industrial Discharge Points



APPENDIX C

TABLE II

Water Quality Characteristics of Kaiser Seawater Magnesia Plant Waste Discharge, Summer 1960

(From Water Resources Engineers First Progress Report. 1969)

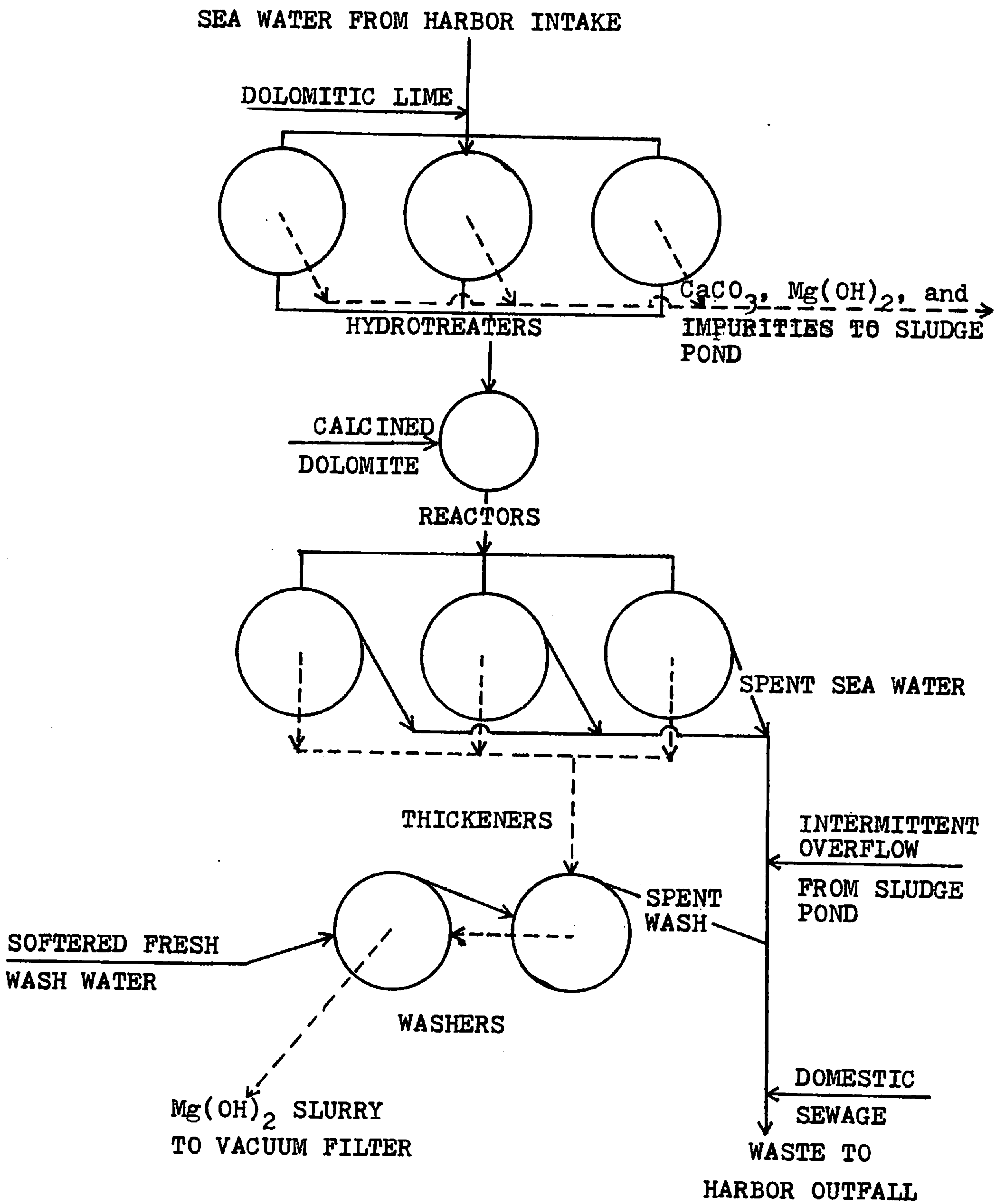
WATER QUALITY CHARACTERISTIC	AVERAGE VALUE	SEAWATER (MONTEREY BAY)
Physical		
Turbidity, units	52	6.0
Total suspended solids, mg/l	80	7.5
Specific gravity	1.021	1.023
Chemical		
pH	10.1	8.4
Chloride (Cl^-), g/l	18.0	18.8
Calcium (Ca^{++}), mg/l		
Total	2050	375
Suspended	5.5	0.44
Magnesium (Mg^{++}), mg/l		
Total	205	1295
Suspended	18.5	0.14
Total Iron (Fe), g/l	400	55
Dissolved Oxygen, mg/l	8.0	8.7
Biochemical Oxygen Demand, mg/l	0.7	1.6
Alkalinity, mg/l as $CaCO_3$		
$CO_3^{=}$-	60	5
HCO_3	55	109
Total	115	114
Biological		
Coliforms, MPN/100 ml	160	31.3

(See figure, next page, for flow diagram of plant operations.)

Appendix C

KAISER MAGNESIA PLANT PROCESS FLOW SHEET

(Adopted from report by Engineering Science, Inc. 1961)



APPENDIX C

TABLE III

Ultimate Land and Water Development of Monterey Service Area No. 46 and the General Study Area

(From Water Resources Engineers First Progress Report. 1969)

LAND CLASSIFICATION	COUNTY SERVICE AREA NO. 46		GENERAL STUDY AREA INCLUDING CSA 46	
	Acres	Per cent	Acres	Per cent
Industrial	3,990	55.0	7,260	10.8
Commercial	110	1.5	1,125	1.7
Recreational	540	7.5	1,645	2.4
Residential	185	2.5	4,000	5.9
Rural	1,595	22.0	40,960	60.7
Agricultural	-----	----	11,550	17.1
Unclassified	830	11.5	920	1.4
TOTALS	7,250	100.0	67,460	100.0

WATER USE UNIT VALUES

CLASSIFICATION	ULTIMATE DEVELOPMENT
Residential	125 gpcd
Commercial	1800 gad
Industrial	
Heavy	8000 gad
Light	3200 gad
Recreational	50 gad
Irrigated Farm Land	1340 gad

APPENDIX D

Sampling Schedule for Fishes

STATION NUMBER	SAMPLING DATE	TYPE OF GEAR	FOOTNOTE NUMBER	HOURS NET IN WATER
Pajaro River				
1301	17 Apr	Beach seine	1	
1306	20 Feb	Small gill net	2	4.5
1303	20 Feb	Large gill net	3	1.25
1303	27 Mar	Combined gill net	4	3.5
1304	27 Mar	Combined gill net	4	3
1305	27 Mar	Large gill net	3	3
1307	20 Feb	Beach seine	5	
Elkhorn Slough				
1201	6 Mar	Large gill net	3	3.25
1201	24 Apr	Large gill net	3	6.5
1204	6 Mar	Combined gill net	4	4.5
1204	6 May	Combined gill net	4	2.5
1209	23 Feb	Beach seine	1	
1209	23 Feb	Large gill net	3	2
1209	6 Mar	Beach seine	6	
1206	1 May	Beach seine	7	
1206	1 May	Combined gill net	4	4
Monterey Bay				
1105	2 Apr	Otter trawl	8	
1105	8 May	Otter trawl	8	
1105	8 May	Combined gill net	4	20.25 *
1154	9 Mar	Otter trawl	8	
1154	4 May	Otter trawl	8	
1154	4 May	Combined gill net	4	19.75 *
1155	27 Feb	Otter trawl	8	
1155	27 Feb	Combined gill net	4	2
1155	13 Mar	Otter trawl	8	
1155	13 Mar	Combined gill net	4	23.5 *
1155	8 May	Otter trawl	8	
1155	8 May	Combined gill net	4	4
1155	8 May	Combined gill net	4	20 *
1156	9 Mar	Otter trawl	8	
1156	9 Mar	Combined gill net	4	5
1156	9 Mar	Combined gill net	4	18.25 *
1156	4 May	Otter trawl	8	
1156	4 May	Combined gill net	4	4.75
1156	4 May	Combined gill net	4	20.25 *

Footnotes

1-90 ft long with 1 in. stretch mesh; bag with 1 in. stretch mesh
2-panels of 1,2, & 4 in. stretch mesh; each panel 10 m long, total 30 m
3-panels of 1.5, 3, & 6 in. stretch mesh; each panel 10 m long, total 30 m
4-a large and a small gill net combined
5-20 ft long with 0.5 in. stretch mesh
6-same as 90 ft seine but with two 55 ft wings of 3 in. stretch mesh added
7-50 ft long with 0.75 in. stretch mesh; bag with same mesh
8-20 ft wide; outside bag with tapering 1.5 to 1 in. stretch mesh; inside bag with 0.38 in. stretch mesh
* left in water overnight

APPENDIX E

BENTHIC STUDIES

Preliminary Sorting Groups for Benthic Samples

The following are the large taxonomic categories into which benthic samples are sorted in routine preliminary operations:

1. Coelenterata: Hydrozoa - Scyphozoa
2. Nemertea
3. Nematoda
4. Annelida: Polychaeta
5. Mollusca: Gastropoda - Pelecypoda - Scaphopoda
6. Arthropoda: Crustacea (Cumacea, Ostracoda, Isopoda, Amphopoda, Decapoda, Mysidacea, Other)
7. Echinodermata: Ophuroidea - Holothuroidea - Echinoidea
8. Sipunculida
9. Chaetognatha
10. Chordata: Tunicata
11. Other

Any given sample probably will not have representatives from all the groups listed, and there occasionally will be forms that are not included in the above listing.

Processing consists of sorting to the above groups, enumeration, and determination of wet-weight biomass.

A P P E N D I X   E

Procedure for Preliminary Sorting of Macrofauna Samples

1. Obtain several petri dishes
   1 x 1" or 2 x 2" nylon mesh squares (1 mm-mesh size)
   forceps
   probe
   10% formalin
   eye dropper
   mechanical counter
   rough-sorting data forms

2. Sort sample under the dissecting microscope, transferring organisms to the mesh screens in petri dishes. These dishes should contain 10% formalin (to prevent drying of organisms) and should remain covered. Major groups are sorted on separate mesh squares.

3. Record the number of organisms in the major groups on the rough-sorting data forms.

4. Determine wet-weight biomass as follows:

   a. Remove square mesh from petri dishes and place on dry blotting paper. Continue blotting and drying for 3 minutes. (This should remove most of the excess moisture from the organisms.

   b. Transfer the organisms to smaller squares of blotting paper (cut 1 x 1 inches). Weigh, recording weight to 0.001 gram.

   c. Remove organisms immediately to glass shell vials. Immediately reweigh the blotting paper, recording weight to 0.001 gram (paper and excess surface moisture).

   d. The weight determined in b, minus that determined in c, is recorded as wet-weight biomass on the rough-sorting data form.

The collection vials from one sample are to remain together, placed in an

5. The collection of vials from one sample are to remain together, placed in an appropriately sized container, and preserved in 40% isopropyl alcohol. (Samples may be preserved in alcohol after biomass is determined.)

6. Final data are transferred to CT-5 form for machine management.

APPENDIX E

Standard Solutions for Use in the Benthic Program

10% Formalin (4% Formaldehyde)

1 part full-strength formalin

9 parts water

Buffer full-strength with hexamethylenetetramine (1 pound to 1 gallon of full-strength formalin)

40% Isopropyl Alcohol with Glycerin

4 parts 99% isopropanol

6 parts distilled water

Add glycerin, 1 part to 19 parts of 40% solution

Rose Bengal Dye Solution, 5X Stock Solution

rose Bengal dye	10 grams
add water to	2.0 liters

Approximately 1-3 ml stock solution added to sample before sieving and about 1 ml after preserving of screened samples

Magnesium Chloride Solution, 5X Stock Solution

$MgCl_2$	730.0 grams

fresh water to volume 2.0 liters

Add 50-100 ml of stock solution to each sample prior to sieving

APPENDIX E

TABLE I
Summary Data for Completed Benthic Stations
Giving Numbers and Biomass for Preliminary Sorting Catagories
(Pooled Totals for Five Replicate Samples)

STATION	Monterey Bay #1105		Monterey Bay #1155		Monterey Bay #1155	
DATE	8 May 1971		2 March 1971		13 March 1971	
SAMPLE VOLUME	1900 cc		1005 cc		900 cc	
GROUP	NUMBERS	BIOMASS grams	NUMBERS	BIOMASS grams	NUMBERS	BIOMASS grams
Annelida						
Polychaeta	71	0.056	18	0.461	57	0.207
Mollusca		0.043		0.022		0.128
Gastropoda	4		--		8	
Pelecypoda	41		4		2	
Scaphopoda	--		--		--	
Arthropoda						
Crustacea		0.129		0.028		0.183
Ostracoda	80		4		16	
Cumacea	8		1		5	
Amphipoda	48		11		13	
Decapoda	--		1		3	
Others	5		12		4	
Echinodermata		0.006				0.010
Ophuroidea	1		--		2	
Holothuroidea	--		--		--	
Echinoidea	2		6		2	
Sipunculida						
Other			2			

(continued)

APPENDIX E

TABLE I
Summary Data for Completed Benthic Stations
Giving Numbers and Biomass for Preliminary Sorting Categories
(Pooled Totals for Five Replicate Samples)
(continued)

STATION	Monterey Bay #1154		Monterey Bay #1154		Monterey Bay #1156		Monterey Bay #1156	
DATE	9 March 1971		4 May 1971		9 March 1971		4 May 1971	
SAMPLE VOLUME	2200 cc		1700 cc		4700 cc		1775 cc	
GROUP	NUMBERS	BIOMASS grams	NUMBERS	BIOMASS grams	NUMBERS	BIOMASS grams	NUMBERS	BIOMASS grams
Annelida								
Polychaeta	27	0.089	65	0.221	194	1.423	78	0.373
Mollusca		0.122		0.709		0.111		0.126
Gastropoda	1		7		14		9	
Pelecypoda	61		87		22		14	
Scaphopoda					1		7	
Arthropoda								
Crustacea		0.368		0.418		0.153		0.303
Ostracoda	41		10		1		2	
Cumacea	7		1		2		2	
Amphipoda	1		2		21		11	
Decapoda	2		4		1		--	
Others	3		6		3		6	
Echinodermata						0.098		0.209
Ophuroidea					11		3	
Holothuroidea					3		2	
Echinoidea								
Sipunculida					8		245	0.284
Other	26		5		5		3	1.093

APPENDIX F

SCUBA MARINE RESEARCH
Course Outline

I **Diver Management**
- Leadership
- Evaluation
- Selection
- Field operations
- Safety

II **Job Management**
- Estimation
- Planning
- Safety
- Field operations
- Critique

III **Navigation**
- Use of compass
- Dead reckoning
- Position location without instruments
- Gross distance measurements

IV **Mapping**
- Search and location
- Line measuring

V **Transects**
- Types applicable
- Limitations
- Selection of types to use
- Emplacement
- Removal
- Data limitations

VI **Heavy Materials Movement**
- Lifting bags
- Lifting drums
- Rigging
- Nets
- Horizontal movement
- Vertical movement
- Movement without aids

VII **Permanent Markers**
- Cement
- Eye bolts
- Location
- Preparation of substrate
- Installation
- Starr drill usage
- Limitations

VIII **Night Diving**
- Safety
- Illumination systems
- Buddy procedures
- Night navigation

IX **Fish Entrapment and Narcotization**
- Types of fish
- Quanaldine administration
- Recovery procedures
- Specimen confinement
- Entrapping methods

X **Simulated Decompression Diving**
- Safety
- Dive planning
- Decompression planning and methods
- Technique limitations

XI **Artificial Reef Emplacement**
- Tire construction
- Large object movement
- Rigging
- Anchoring

XII **Service Projects**
- Service Sea Grant and MLML in special projects requiring research divers
- Participation in on-going research
- Greater range of exposure than could be achieved in structured class

NOTE: The above outline shows the main emphasis of the course. It does not reflect the integration of theory, techniques, or the learning repetition that was presented all through the course.