

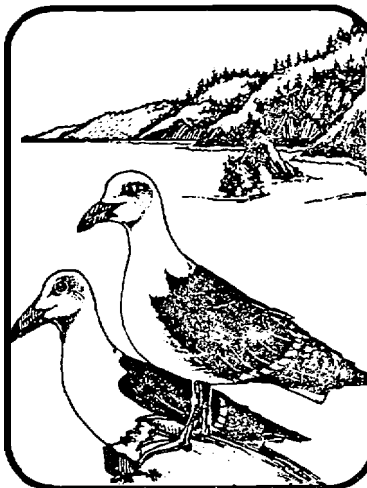
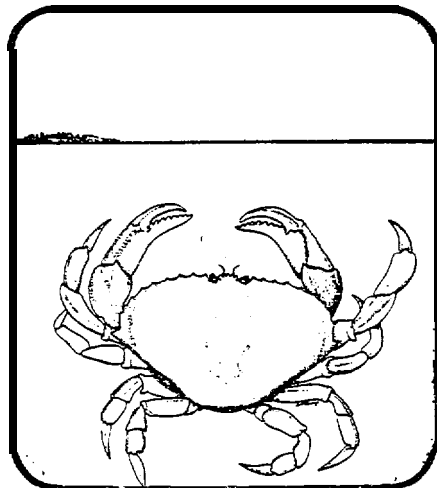
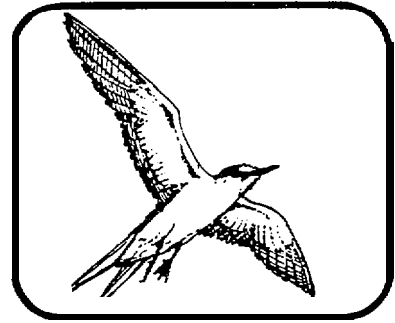
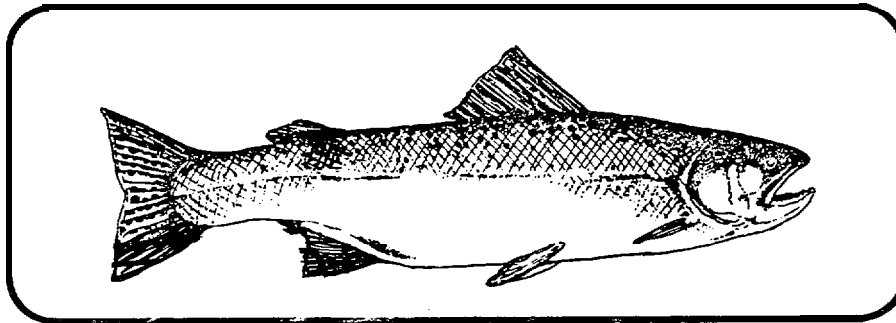
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Biological Services Program

FWS/OBS-80/46

An Ecological Characterization of the Central and Northern California Coastal Region VOLUME II, PART 1 REGIONAL CHARACTERIZATION



Bureau of Land Management
Pacific Outer Continental Shelf Office
and
Fish and Wildlife Service

U.S Department of the Interior

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues that impact fish and wildlife resources and their supporting ecosystems. The mission of the program is as follows:

- To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wildlife resources, particularly in respect to environmental impact assessment.
- To gather, analyze, and present information that will aid decisionmakers in the identification and resolution of problems associated with major changes in land and water use.
- To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

Information developed by the Biological Services Program is intended for use in the planning and decisionmaking process to prevent or minimize the impact of development on fish and wildlife. Research activities and technical assistance services are based on analysis of the issues, a determination of the decisionmakers involved and their information needs, and an evaluation of the state of the art to identify information gaps and determine priorities. This is a strategy that will ensure that the products produced and disseminated are timely and useful.

Projects have been initiated in the following areas: coal extraction and conversion; power plants; geothermal, mineral, and oil-shale development; water resource analysis, including stream alterations and western water allocation; coastal ecosystems and Outer Continental Shelf development; and systems inventory, including National Wetland Inventory, habitat classification and analysis, and information transfer.

The Biological Services Program consists of the Office of Biological Services in Washington, D. C., which is responsible for overall planning and management; National Teams, which provide the Program's central scientific and technical expertise and arrange for contracting biological services studies with states, universities, consulting firms, and others; Regional Staff, who provide a link to problems at the operating level; and staff at certain Fish and Wildlife Service research facilities, who conduct in-house research studies.

Cover Design by Dan Hayes

October 1981

ECOLOGICAL CHARACTERIZATION OF THE
CENTRAL AND NORTHERN CALIFORNIA
COASTAL REGION

Volume II, Part 1
Regional Characterization

Prepared by

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PREFACE

The stated objective of this study is to obtain and synthesize available environmental and socio-economic data which identify, describe, and analyze the important living resources, ecological processes, and their interrelationships in the middle and northern California region.

This report was prepared for the U. S. Fish and Wildlife Service and the Bureau of Land Management of the Department of Interior. The report will be used primarily by these agencies to evaluate the potential ecological consequences of urban, industrial, and commercial development plans for the study area. The report also will be useful for a much larger audience. Coastal zone, river basin, and harbor planners, scientists, and the general public should find this document useful.

This report is a compilation of existing information assembled to meet the objective of preparing an integrated ecological data base. The information is prepared as an overview of ecological concepts, components, and processes. The bibliography also provides a data base which readers can use in their search for more information concerning environmental problems.

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ORGANIZATIONAL OUTLINE - VOLUMES I-V

APPROXIMATE
STUDY AREA:

Coastal California from the California-Oregon border south approximately 550 miles to Point Conception and from the minus 1,000 meter contour line offshore inland to the crest of the coastal mountain ranges, for a total of about 22,500 square miles.

APPROACH:

Ecological integration of information into one data base on physical-chemical features and processes, biological resources, and socio-economic activities of the central and northern California coastal region.

REPORT:

Volume I - Basic Ecological Contents

Refresher and snort courses in basic physical-chemical, ecological, and socio-economic concepts.

Volume II - Part 1 - Regional Characterization

Description of physical-chemical processes and features, ecosystems and species and areas of concern, and socio-economic features and activities of central and northern coastal California.

Volume II - Part 2 - Species Accounts

Species accounts emphasizing natural and human factors limiting distribution and abundance for rare, endangered, threatened, fully protected, commercial, and recreational species, and other species of ecological interest.

Volume III - Part 1 - Habitats

Descriptions of each of the habitats comprising the marine, estuarine, lacustrine, palustrine, and terrestrial ecosystems of the study area including characteristic species, ecosystem models, food webs and Descriptions of abiotic and socio-economic factors .

Volume III - Part 2 - Community Composition Lists

Computer generated annotated listings of the important species that occur in each major type of habitat within the study area. Species listings include life history information and references.

Volume IV - Watersheds and Basins

Site-specific information and maps on the 22 watersheds and 5 ocean basins that comprise the study area, illustrating physical, biotic, and socio-economic data.

Volume V - Data Source Appendix

Definitions and descriptions of forms, methodology, and products of automated data processing of bibliographic and annotated species information and description of gaps in the physical, biological and socio-economic data in the literature.

SUMMARY OF THE ECOLOGICAL CHARACTERIZATION STUDY

The objective of this study is to describe and integrate information on the physical-chemical, biological, and socio-economic features of central and northern coastal California. The emphasis is ecological, stressing the interrelationships among plants and animals and their environment. Special emphasis for the central and northern coastal California regional characterization was directed toward providing sufficient information to evaluate potential impacts of man's activities in the coastal region. Coastal zone management plans, water resource projects, and outer continental shelf oil and gas development are examples of significant and potential man-induced changes proposed for the study region.

This study was undertaken as part of a national program to characterize the coastal regions of the United States. Although styles of presentation and format of the various studies differ with geographic area and intended use of the study results, the ecological characterization concept remains consistent. The study area was described as coastal California from the California-Oregon border south to Point Conception and from the minus 1,000-meter contour line offshore inland to the crest of the coastal mountain ranges.

The study culminated in a report on the following copies:

Volume I	- Basic Ecological Concepts
Volume II	- Part 1 - Regional Characterization
	- Part 2 - Species
Volume III	- Part 1 - Habitats
	- Part 2 - Community Composition Lists
Volume IV	- Watersheds and Basins
Volume V	- Data Source Appendix

Site-specificity of data presented in the report increases as the reader progresses from Volumes I through IV. The report volumes, however, are not necessarily meant to be read from cover to cover, but rather to serve as a reference work. An individual reader can refer to the report at any one of the following levels: generalized explanation of basic ecological concepts (Volume I), regional description of coastal California (Volume II), Part 1, individual species accounts (Volume II, Part 2), habitat description (Volume III, Part 1), community composition (Volume III, Part 2), or watershed or ocean basin description (Volume IV). The contents of each volume are briefly described below.

VOLUME I - BASIC ECOLOGICAL CONCEPTS

Volume I outlines the basic ecological components, processes and activities that are operating in the natural and man-made world of the study area. Volume I serves as a refresher or short course on basic ecological concepts that can help to put the rest of the report in perspective. It was anticipated that the reader of this volume would, through academic training and/or experience, have a general understanding of basic physical-chemical, biological and socio-economic concepts.

Volume I is not a summary of the other volumes of the report. The other volumes may be used without the benefit of the concepts described in Volume I. An understanding of each basic component of an ecosystem, however, will further the reader's comprehension of the interrelationships among physical-chemical, biological, and socio-economic components of the ecosystem.

The authors were requested in the preparation of this volume to use the conceptual planning model developed for the Ecological Characterization of the Pacific Northwest Coastal Region (Ryckman, Edgerley, Tomlinson & Associates, 1978). They were also urged to use as much of Volume I of the Pacific Northwest report as possible in preparing the California Ecological Characterization. In some respects the basic

request has been followed, except the authors felt it necessary to start anew on the chapters on biological concepts (Chapter 2) and on air quality (Chapter 5) and to modify Chapters 3 and 4, physical-chemical processes. The impact of deteriorating air quality on plants and animals (including man) is a significant issue in California as are the concepts associated with air pollutants and their effects on natural and man-made systems.

The biological concepts chapter (Chapter 2) discusses how ecological processes may be viewed at the level of the individual organism, the species population, biotic community, or the ecosystem. Volumes II through IV of this report view organisms as components of ecosystems but draw from all approaches in viewing ecological principles. Many valuable references are cited in both Chapters 2 and 5 to provide the interested reader with recent pertinent literature.

Chapters 6 through 9 of this volume introduce the reader to major socio-economic topics by use of models (e.g., natural resource, basic industry, services, population, transportation, forest practices, commercial fisheries, recreation, agriculture, extractive and mineral industries). A section on the modeling of offshore oil and gas production is provided.

VOLUME II, PART 1, REGIONAL CHARACTERIZATION

This volume consists of five chapters. Chapter 2 is a regional overview of central and northern coastal California. It is a brief summary of the material contained in the rest of the report. The approach is ecological, combining physical-chemical, biological, and socio-economic features, processes, and activities. Chapter 2 identifies and places in perspective the important features and processes that characterize northern and central coastal California.

Chapter 3 in this volume outlines all of the important physical-chemical features and processes that form, control, or influence the central and northern California coastal region. Major topics included geological, physical, and chemical oceanography: estuarine processes; hydrology and water quality; climatology and air quality; and geology and seismology.

Chapter 4 uses models of each of the major kinds of systems - marine, estuarine, riverine, lacustrine (lakes), palustrine (shallow ponds), and terrestrial - to characterize the biological environment of the study area. Each model shows the interrelationships among physical-chemical, biological, and socio-economic features and processes. Emphasis has been placed on the physical factors that control or influence biological features and processes. Important species and areas of ecological concern are identified. Important species are those that have received legal distinction as rare, endangered, threatened, or fully protected species or as commercial or recreational (sport) species or are representative or characteristic species of specific habitat types. Each designated species is described in a species account in Volume II, Part 2. Areas of ecological concern are specific sites designated by governmental agencies or private organizations. Such sites are recognized as important wildlife habitat, critical habitat of a rare or endangered plant or animal species, research areas, refuges (marine life or wildlife), preserves, anadromous salmonid fish habitat. Descriptions and specific locations of hundreds of areas of ecological concern may be found in Volume IV of this report.

Chapter 5 describes important socio-economic features of the northern and central California coast including forestry and forest products, fisheries, recreation, agriculture, extraction and mineral industries (e.g., offshore oil and gas development), transportation and energy utilities, service activities, social and cultural features, and land use.

The Regional Characterization (Volume II, part 1) is meant to serve two purposes. First, it is a transition between the basic concepts and models described in Volume I and the more specific information found in the rest of the volumes. It applies these basic concepts to the central and northern coastal California study area. Secondly, it provides an overview of the environmental setting of the study area. The wide diversity of the study area is revealed in discussions on climatic conditions; geology and soils; land use and population distribution; plants, animals and their habitats; economic and employment conditions; resources, and many other topics.

VOLUME II, PART 2, SPECIES ACCOUNTS

This volume of the report contains accounts of approximately 200 plant and animal species that live within the central and northern California coastal region. Plants and animals that have been designated as rare, endangered, threatened or fully protected by the state or federal governments are described. Also described are sport species that are hunted or fished, and commercial fish, shellfish, fur-bearers and trees. The accounts also include descriptions of pest or fouling species. Other plant or animal species included in this volume are dominant or characteristic species in their respective habitats.

A brief account for each species includes information on distribution, abundance, resource use and ecological characteristics. Whenever data were available, a discussion of the natural and human factors affecting abundance and distribution of the species is included. The concept of limiting factors is important considering the potential threat to a species posed by man-made developments and habitat disturbance. Management techniques and studies which are or will be used to influence species numbers are identified.

Information on species in this volume should be used in two different ways. First, the potential for man- or nature-induced changes can be ascertained for some species. Such an analysis would be particularly significant for rare, endangered, or threatened species. Secondly, the information may be used to help ascertain the effects of man- or natural-induced changes on a habitat type and how the changes affect the more dominant or characteristic species.

VOLUME III, PART 1, HABITATS

Ecosystem models prepared for each of the five aquatic systems and for the terrestrial system were presented in Volume II, Part 1, Regional Characterization. To apply these generalized system models to the California coastal region, classification schemes were used to identify each of the specific and recognized habitat types within each system. Each of the habitat types was described in some detail. Aquatic areas were classified into five systems: marine, estuarine, riverine, lacustrine (lakes), and palustrine (ponds), and then into many finer categories (habitat types) based on a modified version of Cowardin, et al. (1979), Classification of Wetlands and Deep Water Habitats of the United States. Terrestrial areas were classified into 15 cover types and 46 habitat types based on a modified version of C. Heath and Haller (1975), An Annotated List of California Habitat Types.

To use Volume III, Part 1 most effectively when examining a site-specific project, Volume IV - Watersheds and Basins, Chapters 3 through 29 should be consulted to ascertain from the vegetation or surficial geology maps the distribution of habitats for a specific location. The reader then can review the appropriate habitat section(s) of Volume III. Each habitat type includes a description of characteristic plants and animal species as well as food webs that identify the interrelationships among the species. Important habitat-specific abiotic processes and features that control habitat operations are discussed. Socio-economic activities which may infringe on the operation of the habitat type are also identified. Land use categories are described in the last chapter of this volume.

VOLUME III, PART 2, COMMUNITY COMPOSITION LISTS

In addition to the brief listings of characteristic plant and animal species found in each habitat type discussion of Volume III, Part 1, a more extensive listing of species for each habitat type is offered in this volume of the report.

Many thousands of plant and animal species are found within the central and northern California coastal region. Preparation of a useful list of species required identifying and recognizing the most common or characteristic species of the region. In addition to the common or characteristic plants and animals, the list also included commercial, recreational, and rare, threatened, endangered, and fully protected species. An annotated species data entry form was prepared for each species chosen. Entries on the form include scientific and common names, taxonomic division, intermediate group name, distribution by watershed or basin, legal status, habitat, feeding habits, trophic level, abundance, habitat use, and literature references.

VOLUME IV, WATERSHEDS AND BASINS

Central and northern coastal California is such a large and diverse region that it is subdivided into smaller units for ease in presenting site-specific information. Land areas were subdivided into watershed units and ocean areas into basins determined by offshore geology.

A separate chapter was prepared for each of 22 watersheds and 5 offshore basins, and each contain site-specific information. Chapters on the watersheds contain information on terrestrial, freshwater and estuarine physical-chemical processes and features, biological resources, and socio-economic activities. Chapters about the basins contain information on intertidal, pelagic and subtidal benthic physical-chemical processes and features, biological resources, and socio-economic activities.

Watershed chapters contain descriptions of geology, soils, climate, tsunami hazard, hydrology, water quality, and other topics. The biological resources section of each watershed description contains information on selected species and areas of ecological concern. Preserves, reserves, refuges, conservation areas, sites of known scientific and educational value, anadromous fish spawning areas, wild and scenic rivers, important nesting sites, and waterfowl and shorebird concentrating locations are described and mapped as areas of ecological concern. Socio-economic descriptions include land use, economics, population, environmental issues and other topics, both existing data and trends.

The vegetation and areas of ecological concern were mapped for each watershed. By inspecting the appropriate vegetation map for a specific area and referring to the habitat descriptions (Volume III, Part 1), community composition lists (Volume III, Part 2) and species accounts (Volume II, Part 2), the reader can ascertain the kinds of plants and animals occurring in an area, including possible rare or endangered species. The maps of areas of ecological concern along with the maps and narratives of physical and socio-economic conditions can complete the background picture for any general area chosen for inspection.

The basin chapters (24 through 29) contain similar kinds of information, but with a greater emphasis on substrate distribution maps which can be used with Volume III, Habitats, and Volume II, Part 2, Species, to determine the kinds of organisms present at a specific site. Emphasis has been placed on areas of biological significance (designated by California State Water Resources Control Board), marine refuges and ecological preserves (California Fish and Game Commission) as areas of ecological concern.

VOLUME V, DATA SOURCE APPENDIX

Volume V provides the reader with information about the methods used to prepare the bibliographies and annotated species lists (i.e., community composition lists). It contains a list of persons contacted during data gathering. It also discusses the lack of information known about the central and northern coastal California region.

The bibliographies that accompany Volume I through IV of this report were prepared using automated data processing. Each volume includes a complete list of references cited. Chapter 2 in this volume describes the forms used to arrange the bibliographic information into a computer-accessible format. While the bibliographic entries are listed alphabetically, the computer records may be searched and sorted for the various types of information included on the "bibliographic data entry form." This chapter also contains the documentation for the use of FAMULUS, the computer program utilized in manipulating the bibliographic data. FAMULUS was developed for and is being used by the U. S. Forest Service, Pacific Southwest Forest and Range Experimental Station, Berkeley, California.

Chapter 3 of Volume V describes the computer input form and documents the use of SYSTEM 2000, the computer program that was used to manipulate the information on the annotated species list forms. The contents of these forms were outlined earlier in this summary. Rather than preparing a list of species, the species were aggregated by habitat types into community composition lists. These lists are to be found in Part 2 of Volume III. With the assistance of automated data processing the species can be sorted by trophic level, legal status, species group or other parameters on the data entry form.

Chapter 4 of Volume V is the Data Gaps Report. It contains an appraisal of the state of knowledge on the central and northern California coastal region. The consensus in the report is that ecological data are sorely lacking. While basic data vary from totally inadequate on some topics to comprehensive for others, the understanding of interrelationships among physical-chemical, biological, and socio-economic parameters has not begun to be adequately explored in the literature. The influences of man and his activities on the natural environment are not at all well understood. In the Data Gaps Report emphasis was given to identifying the informational inadequacies in the literature related to potential onshore and offshore impacts of OCS oil and gas exploration and development.

SUMMATION

The study was undertaken to draw together the basic information needed to evaluate the environmental consequence of any action proposed for central and northern coastal California. The study itself did not evaluate projects and was not intended to be an environmental impact assessment, report, or statement prepared under state or federal regulations. The documents that comprise this report provide the reader with a basic reference for coastal California and the bibliographies provide lists of more specific references that can be consulted if needed.

Chapter 1

USER'S GUIDE

This volume serves two purposes. First, it is a transition between the basic concepts described in Volume I and the specific information found in the rest of the volumes. It is the application of the basic concepts to the central and northern coastal California study area. Second, the Regional Characterization provides an overview of the environment of the study.

This volume has been subdivided into four major chapters. Chapter 2 is a regional overview of central and northern coastal California. It is a brief summary that integrates the material contained in all the volumes of the report. The approach is ecological; i.e., integrating physical-chemical, biological, and socio-economic features, processes, and activities, into one discussion.

Chapter 3 in this volume outlines all of the important physical-chemical features and processes that form, control or influence the central and northern California coastal region. Major topics include: geological, physical and chemical oceanography, estuarine processes, hydrology and water quality, climatology and air quality, and geology and seismology.

Chapter 4 uses models of each of the major kinds of systems; i.e., marine, estuarine, riverine, lacustrine, palustrine, and terrestrial to characterize the biological environment of the study area. Each model shows the interrelationships among physical-chemical, biological, and socio-economic features and Processes. Emphasis has been placed on the physical factors that control or influence biological features and processes. Species of concern and areas of ecological concern are introduced. Detailed information on these topics is found in Volumes II, Part 2; III, Part I; and IV.

Chapter 5 describes important features of the socio-economic environment of the northern and central California coast including forestry and forest products, fisheries, recreation, agriculture, extraction and mineral industries, transportation, service activity, social and cultural features, and land use.

Chapter 2

REGIONAL SUMMARY

The coastal California region encompasses the area from the California-Oregon border south to approximately Point Conception and from the minus 1,000-meter depth contour offshore inland to the first crest of the coastal mountain ranges. This long narrow study area covers 3 degrees of midtemperate latitudes and is dominated by two features -- the Pacific Ocean and the North and South Coast Ranges. The approximately 22,000-square-mile study area includes about 760 miles of coastline, 13,000 square miles of ocean, and 9,000 square miles of land.

COASTAL GEOMORPHOLOGY

Most of the study area is found within a single geomorphic province, the coast ranges, except near the Oregon border where the Klamath Mountain geomorphic province extends to the coastline and includes the study area. The North and South Coast Ranges show strong northwest-southeast trends, divided by the San Francisco Bay system of straits and waterways.

The mountain chain is dominated by two dissimilar kinds of sedimentary rocks: the widespread Franciscan formation, significant for its role in developing the continental margin through sea-floor spreading and plate tectonics, and a granitic sequence which correlates with the Sierra Nevada Mountains. The San Andreas and other major faults have had a major influence on geology and landforms in the coastal regions. Along most of the coastline the mountains rise abruptly from the sea except in areas where a narrow, discontinuous coastal plain faces the ocean. Valleys, ridges, and major streams tend to parallel the coastline. Only minor streams enter the sea at right angles.

California is part of the seismically active circum-Pacific geologic belt whose high seismic activity is explained by the theory of plate tectonics. The San Andreas fault zone is the juncture of the oceanic plate and the continental plate. The interaction of plates has led to the current character of California's geomorphology as well as to its continuing seismic activity. The California coastal region has had over 100 strong, potentially damaging earthquakes in its recorded history.

The hazards and potential for tsunami damage exist along the entire coastline of California, but vary in intensity depending upon the coastal terrain, nearshore topography and extent of development within the inundation zone.

The coastline in the study area is relatively straight and uninterrupted. The only major projecting headlands are Cape Mendocino and Points Arena, Reyes, Sur, Buchon and Conception. The major embayments are San Francisco, Tomales, Monterey, Estero and San Luis Obispo Bays. Estuaries are few in number and small in size except for San Francisco and Tomales Bays. The coastline ranges from rocky shore and steep seacliff to low relief sand beaches with an occasional bay or estuary with fine mud substrata.

Offshore, the Continental Shelf and slope are submerged extensions of the North and South Coast Ranges. Usually the Continental Shelf is only a few miles wide. North of Cape Mendocino the shelf is wider and off of the Golden Gate it is 30 miles wide. Cutting both the Continental shelf and slope are submarine canyons. Monterey Canyon, the largest submarine canyon along the entire western Pacific shore, begins within a half-mile of the coast and extends to a depth of 3,650 meters (12,000 feet). Other major submarine canyons are Delgada Canyon (south of Cape Mendocino), Noyo Canyon, Bodega Canyon, Sur and Lucia Canyons (south of Carmel) and Arguello Canyon.

Immediately offshore the substratum grades from relatively coarse nearshore sediments (dominated by sand, gravel, cobble and rock) to finer silt and clay fractions with increased depth and distance from shore. Coarser nearshore sediments are largely terrestria in origin, resulting from degraded rock material. The distribution of these substrata are highly dependent on local bathymetry and current

conditions. The finer sediments of the deeper offshore areas tend to consist of shells of microscopic organisms that settle to the bottom and accrete. Each substrate type supports its own distinctive animal community and, within the zone of light penetration, its own plant community.

The major sources of beach sand are from streams and rivers and secondarily from shells and cliff erosion. Most of the northern California streams flow year-round and carry sediments to the shoreline. Many streams south of San Francisco are blocked by stream mouth spits which contribute sediments only when the spit is breached at high flow. Littoral (along the shore) sediment transport is a function of stirring agents (waves and turbulence) within the surf zone and longshore currents. As a result of wave direction, the dominant littoral drift is from north to south along the California coast except north of Cape Mendocino where sediment moves from south to north during the winter months.

COASTAL OCEANOGRAPHY

Marine Processes

The major current offshore of the study area is the California Current system and its associated subsystems, the California Countercurrent and the Davidson Current. The California Current is the eastern boundary flow of the clockwise north Pacific gyre. Its southward flow begins near the Oregon-Washington border and continues along the coast to Point Conception where it turns southwest. The wind and atmospheric pressure cell-driven current varies from 600-1,000 kilometers (375-625 miles) in width, exerts transport influence to depths of between 100 and 500 meters (approximately 330-1,640 feet) and moves at velocities ranging from approximately .5-.9 kilometers per hour (0.25-0.5 knot).

The south-flowing California Current is overlaid by a persistent nearshore current of opposite directional flow known as the California Countercurrent. The current is 40-50 kilometers (25-31 miles) wide, moves at less than approximately 0.2-0.5 kilometer per hour (0.1-0.25 knot), and exerts its transport influences from depths of about 200 meters (650 feet) to the bottom. The other major current is the Davidson Current, a seasonal (November to February) surface manifestation of the California Countercurrent. It results when the California Current weakens in its southern flow and moves offshore; the inshore Davidson Current then flows northward at approximately .9-1.2 kilometers per hour (0.5-0.75 knot).

Although horizontal transport in the ocean water offshore of California is accomplished by currents, vertical transport is accomplished by wave and tidal mixing and upwelling and downwelling. The effects of wave and tidal mixing are limited to the nearsurface layers. The tidal cycle along the California coast is semidiurnal, having two unequal high and low tides within each 24-hour period. Horizontal currents and accompanying vigorous turbulence and vertical mixing may develop locally due to tidal movements and local coastal configuration and bathymetry. Wind-generated surface wave action can result in violent, turbulent mixing of the ocean's upper layer.

Of greater importance to vertical exchange within offshore waters are the upwelling/downwelling processes resulting from prevailing wind and current patterns in conjunction with the earth's Coriolis effect. During periods of strong southward-moving winds and nearshore current there is a net offshore transport of surface water with the resultant coastal upwelling of cool, nutrient rich deeper water to the surface. Such upwelling has a widespread influence over the physical-chemical and biological processes along the coast. There are only a few upwelling coasts in the world. They occur along the shores of California, Morocco, southwest Africa, Peru, and the Arabian peninsula. All of these regions are noted for their extremely high primary and secondary biological productivity. They include some of the biologically richest areas and support some of the greatest fisheries in the world. Upwelling effects are strongly related to coastal configuration and local bathymetry. Areas of strongest upwelling occur along southern margins of projecting capes and headlands (e.g., Cape Mendocino) and at the heads of submarine canyons (e.g., Monterey Bay).

Ocean water temperatures along the California coast respond to seasonal current changes, wind direction, insolation and upwelling. Winter water temperatures, 11°C to 13°C (52°F-55°F) are elevated above expected seasonal lows because of the intrusion of warm, saline waters of the Davidson Current. Upwelling during spring and summer reduces the temperature of waters near the surface that have been warmed by high summertime insolation.

The offshore water column adjacent to the California coast conforms generally to the normal three-layered structure of epipelagic, mesopelagic and bathypelagic zones. The principal physical factors used to delineate these different vertical zones are light penetration, temperature and salinity. In California offshore waters, the epipelagic zone (with comparatively low salinity and warmer temperatures relative to the deeper zones) extends from the surface to between 100 and 150 meters (328 to 491 feet) depth. The mesopelagic zone, with insufficient light for photosynthesis, extends approximately to a depth of 500 meters (1,640 feet). The bathypelagic zone, a region of total darkness, extends from the mesopelagic to the bottom.

The vertical stratification and vertical and horizontal transport mechanisms are major controlling factors in biological productivity and community structure in those plants and animals (pelagic species) that live within the ocean water column. The productivity of the water column organisms, wave activity and/or current velocity, and substratum type control the occurrence, distribution and community structure of the ocean floor-dwelling (benthic) plants and animals. Temperature, salinity, dissolved oxygen content, and suspended organic and inorganic materials are also important factors.

Marine Biota

Seasonal variation in physical and chemical factors is accompanied by seasonal changes in the characteristics, habits, and abundance of organisms. Within the California Current system the seasonal variation can be separated into three periods. During the upwelling period (mid-February through July) the typical spring high productivity is maintained throughout the summer in response to nutrient replenishment from upwelling waters. The enriched high productivity of coastal waters supports the bulk of the commercial fishing industry. The greatest biomass of plankton occurs along the north coast, particularly in the area from Cape Mendocino to San Francisco. During the oceanic period (August through mid-November) and the Davidson period (mid-November through February) productivity diminishes.

The California Current can be broadly envisioned as a transition zone between subarctic and subtropical water masses and organisms, with a predominance of subarctic forms occurring in the north and subtropical and equatorial forms appearing in the south. The greatest rate of change occurs in the Point Conception area. The California Current is highly complex with seasonal, annual and long-term variations, many of which are not predictable. The plants and animals that comprise the pelagic communities include a wide variety of taxonomic categories. The most important elements of the phytoplankton (drifting plants) are diatoms and dinoflagellates. The zooplankton (drifting animals) include minute protozoans, worms, molluscs, jelly fishes and siphonophores (a kind of hydrozoan), and the egg and larval stages of most benthic and nektonic (swimming) animals. Nektonic organisms include fishes, squids and marine mammals.

The organisms and communities of subtidal benthic areas are distributed on the basis of depth, light intensity, nutrient availability, substratum type, and wave action. For example, algae and kelp are found on consolidated substrata (bedrock or boulders) where sufficient light is available, whereas eelgrass is found in shallow bay waters on unconsolidated (mud) substratum.

Shallow water benthic California communities associated with consolidated substrata are generally dominated by attached filter-feeding forms (e.g., mussels, rock scallops, tunicates, tube-building serpulid worms) which utilize the particulate content of the water column as a food source; and by grazers (e.g., limpets, sea urchins, abalones) which feed on attached micro- and macro-algae. Important mobile predators are starfish and crabs. These communities generally are associated with fairly active water movement, which supplies them with the suspended particulate material upon which the filter feeders rely. Conversely, these organisms cannot tolerate water of high turbidity and suspended inorganic sediments.

Unconsolidated coarse substrata (e.g., gravel and sand) support mixed communities of attached and unattached filter feeders, selective detritus feeders (ingesting particular organic matter on the sediment surface) and carnivore/scavengers. Although the species compositions of these communities are highly variable depending on factors such as substratum particle size, current strength, wave action, water depth, and particulate content of the water column, forms typically encountered are bivalve molluscs, gastropod molluscs, tunicates, sea stars, and basket stars (ophiroids), tubicolous amphipods, polychaete worms, sea cucumbers, sand dollars (echinoids) and crabs.

Finer unconsolidated substrata (silt to clay range) are also characterized by mixed faunal assemblages consisting of deposit feeders (ingesting the sediment directly for the organic matter it contains), selective detritus feeders, filter feeders, and carnivore/scavengers. The proportions of the different feeding types within these communities are variable depending on such factors as depth, substratum particle size, current velocity, particulate content of the water column, organic carbon content of the sediment, and salinity. In general, deposit feeders and selective detritus feeders tend to dominate within fine substrata communities.

Substratum types, particularly unconsolidated ones, and their associated floral and/or faunal assemblages are rarely distinct and clear-cut but tend to overlap and intergrade with one another, or to occur in locally patchy distributions. Although the benthic and pelagic communities have been discussed separately, they are intimately connected. The deep water benthic community is dependent upon the epipelagic community for its food supply. Food is supplied to the depths by a rain of particles (ranging from protozoans to whales in size and food content). Intermediary food links between the surface waters and depths are vertically migrating organisms. Many benthic and deep sea organisms rely on the food-rich surface layers for the early survival of their larval forms. Shallow water benthic habitats are likewise intimately connected to the pelagic environment as a source of nutrients for algal growth, particulate food for filter feeders, etc. The early life stages of most shallow water benthic organisms, as with the deeper forms, are planktonic.

The distribution (zonation) of intertidal species is dependent upon the same factors that affect other benthic species, but with the added dimension of factors such as duration of exposure to air and the degree of exposure to wave action. The feature most characteristic of the intertidal area is the distribution of species into "bands" or zones. The size of a zone depends upon the slope of the shore and the height of the tides. Four zones have been described for California intertidal waters. Factors affecting zonation are light intensity and quality; substrata type; sea and air temperatures; relative humidity; precipitation; salinity; the availability of nitrogen, phosphorus, and other metabolites; availability of free carbon dioxide and dissolved oxygen; pH; water movement; tidal exposure; tidal rhythm; wind; and inter- and intraspecific competition.

To simplify comprehending the biotic and physical-chemical aspects of the California coastal marine system, a number of classification schemes have been developed. The hierarchical classification scheme (modified from Cowardin, *et al.*, 1979) used in this study places the marine environment in a number of categories based on whether the habitat is open water (pelagic) or ocean bottom (benthic), intertidal or subtidal, vegetated or unvegetated and in substrate type.

The California coastal marine system supports many thousands of plant and animal species, a few of which are recognized as diminished in number (rare or endangered) or of recreational, commercial or ecological significance. Some of these species have received special attention under law.

The productive California coastal waters support a number of recreational and commercially important finfish (salmon, anchovy, tuna, sole, flatfish, rockfish) crustaceans (crab, shrimp), molluscs (squid, abalone) and plants (kelp). Designated rare and endangered species found in/above coastal waters include sea otter, a number of species of whales, northern elephant and Guadalupe fur seals, short-tailed albatross, California brown pelican, and Aleutian Canada goose. In addition to recognized specific species, governments and private organizations have designated a number of areas as areas of ecological concern (under a variety of named categories -- marine life refuges, reserves, areas of special biological significance, sanctuaries and others) that receive some form of protection.

Acute or chronic disturbances of the California coastal physical/biological system may result from a number of sources, either man-caused or natural. Natural perturbations include uncommonly severe climatic fluctuations leading to droughts, severe storms, floods, or temperature extremes, nearshore or marine volcanism and associated tidal waves or tsunamis. Human-induced perturbations include over-fishing, chemical pollution (e.g., municipal and industrial effluents, pesticides), organic pollutants (e.g., organic wastes, including municipal sewage discharge and oil), thermal pollution (e.g., cooling waters and other heated effluents), radioactive pollutants and physical disturbance (e.g., dredging, filling, construction of breakwaters) that result in mechanical disturbances and transformations of local habitat.

COASTAL CLIMATOLOGY

Along the coast of northern and central California, most of the rainfall is in the winter, and summers are warm and dry. The amount of rainfall varies widely from year to year, and the general climate is temperate, moderately warm. Climatic variations of temperature and precipitation occur latitudinally within the study area, with distance inland from the coast, with increase in altitude and with numerous micro-climatic factors. The macroclimatic variations are due to the wide latitudinal range (8°) of the study area in that the region is in a transition zone between the midlatitudes and the subtropics. The climatic type (called Mediterranean) of California is unique because no other humid climate type has a summer drought and a rainfall maximum in winter.

The Pacific Ocean has a moderating effect on air temperatures so that temperatures are generally cool and infrequently cold or hot. Throughout the most coastal portions of the study area the mean annual range in temperature is only a few degrees greater than the diurnal range. Distance from the coast significantly affects local climate: inland areas have greater ranges and extremes of temperature. Inland areas are more removed from the cool marine layer of air and ocean fogs. The more northern portions of the study area generally have lower temperatures than the southern portions.

The two kinds of temperature inversions (i.e., region in air mass where temperatures increase with altitude) characteristic of the California coastal area are low-level (surface or ground inversion) and high-level (elevated inversions). Low-level inversions are favored on clear winter nights and are commonly associated with frosts. Elevated inversions are associated with adverse air quality conditions during the summer. Fog frequency in northern and central California shows a seasonal variation with most fog occurring in the summer. Winds along the California coast average approximately 15 kilometers per hour (8 knots) except for exposed areas (e.g., Point Arena, Point Reyes, Point Conception) where winds average 18 kilometers per hour (10 knots).

Most storms along the California coast are winter frontal storms that originate in the area south of the Aleutian Islands. Almost all precipitation is concentrated from November to April. From May to October, coastal California is dominated by a Pacific High which effectively prevents frontal disturbances from entering the area. A wide range in mean annual precipitation occurs within coastal California with precipitation decreasing with decreasing latitude. The coastal area north of San Francisco Bay receives in excess of 51 centimeters (20 inches) mean annual precipitation and is considered to be an area of sufficient available moisture. Over 152 centimeters (60 inches) of precipitation is common in over half of the area north of San Francisco Bay and may be as high as 229-254 centimeters (90-100 inches). Most precipitation is in the form of rain. The coastal area south of San Francisco is generally semiarid (25-51 centimeters [10-20 inches] of annual precipitation) and is considered to be moisture deficient. Higher rainfall amounts are found at higher elevations in the coastal mountains. Periodic drought conditions can occur in specific portions or all of the coastal area.

Air quality in central and northern coastal California is generally good. The north coast air basin (Sonoma County north to the Oregon border) has the best air quality along the coast with the only serious pollution problem being particulate in Mendocino County. The San Francisco Bay Area basin (Marin County south to Santa Cruz County) has the poorest air quality of the study area although the immediate coastal portion of the air basin is relatively good. The high pollutant concentrations in the basin (derived from both mobile and stationary sources) are usually found inland from the coast with the exception of high ozone readings which are basinwide and may include the coast. In the north-central air basin (portions of Monterey County) ozone is the major air pollutant, with particulate a problem in rural areas. In the south-central air basin (portions of San Luis Obispo and Santa Barbara Counties) the coastal areas do not have serious air pollutant problems except for particulates in the Santa Maria-Lompoc area.

COASTAL HYDROLOGY

The coastal study area was subdivided into 22 watershed units based on the major streams and rivers of the area. Watershed units in this study, however, encompass only the most coastal subbasin of the entire watershed for the named river or stream. Many small streams enter the ocean directly and are not tributary to the named watershed unit rivers. The larger river systems within the study area are located in the northern watershed units and have extensive tributary systems that extend far beyond the eastern boundaries of the study area. The largest river system in California, the Sacramento-San Joaquin Rivers, enters the study area through the San Francisco Bay Delta complex.

The northern watersheds receive high average annual precipitation and the rivers carry a large volume of runoff. Because the rock formations of the North Coast Range are relatively impermeable and large alluvial valleys are usually lacking, runoff is large and the rivers have large discharges during the rainy season. The southern watersheds are located in areas of semiarid climate and the rivers are smaller and have much lower discharges than in the north. Most of the larger rivers of the southern one-third of the watershed units have lower segments which flow across broad alluvial plains that are infiltrated by stream waters. Some of the rivers do not have enough flow during the dry summer period to reach the sea.

Most of the study area streams are located in rural areas. Almost every stream in the study area has been affected to some degree by human impacts on the watershed. In the northern watershed units extensive deforestation has had a major impact on stream discharge and sediment loads. In the southern watersheds extensive agricultural development has resulted in the diversion of runoff waters and degradation of water quality.

The rivers of the study area flood periodically because of the concentration of precipitation from November to April. Flooding in the lower sections of many study area streams (e.g., Russian, Smith, Klamath, Eel) is caused by tides and is sometimes augmented by wind. Many of the large rivers of the watershed have been dammed in their upper reaches for water supply and flood control. In addition to dams, stream diversions provide domestic, agricultural and industrial water supplies.

Water quality in coastal California streams is generally good. The number and severity of water quality problems caused by point source discharges has markedly decreased in the last several years. The major water quality problems yet to be solved are nonpoint source problems which are geographically widespread, difficult to define and are the result of long-held land practices such as sediment and debris washed into streams as a result of logging practices, groundwater mineralization and seawater intrusion into formerly usable groundwater aquifers at numerous points along the coastline.

In the north coastal area major water quality problems relate to the sensitivity of water uses requiring clean water (e.g., oyster rearing, anadromous fish spawning and public water supplies). Factors threatening clean water uses include logging, mining and construction, sand and gravel operations, wastewater effluent disposal, and construction and operation of reservoirs.

In the southern central coastal portions of the study area, bacteriological contamination of coastal waters has been a problem in Monterey Bay in localized areas and along the south San Luis Obispo County shore. Eutrophication problems are evident in the lower reaches of some streams (e.g., Salinas River and San Luis Obispo Creek). In the general areas around Monterey Bay and San Antonio Creek increased sedimentation, nutrient levels, turbidity and mineralization are caused by agricultural practices.

Few natural freshwater lakes are located within the watershed units of the study area. The absence of lakes is largely the result of the well-integrated drainage systems in the North and South Coast Ranges. Most of the lakes are located on the coastal plains, had their origins as coastal lagoons and may have brackish water. Some small dams and reservoirs are found within the study area.

Groundwater aquifers are few in number and small in supply. Most of the study area consists of mountainous terrain underlain by bedrock, not conditions known to provide extensive groundwater reserves. The known groundwater basins are located primarily at the mouths of major rivers on the coast. Some of these coastal aquifers show evidence of ocean salinity intrusion.

The abundance of moisture in the winter, combined with moderate temperatures, is conducive to chemical weathering of the geological materials of the coastal area. The chemical weathering of the relatively weak rocks (primarily rocks of the Franciscan formation) results in the abundant production of clay. In the moist regions north of San Francisco the clay is commonly saturated with water and highly erodible. The concentration of rainfall in the winter season is of notable significance to the mass wasting process in the study area. Coastal California has some of the highest rates of mass wasting in the world. The combination of steep, tectonically unstable slopes comprised of weak geologic materials subject to intense rainfall concentrations provides conditions which favor massive landslides, slumping, mudsliding, creep and fall of weathered detritus and soil. In addition, because of the dry summer period, the vegetational cover is subject to frequent wildfires. In the aftermath of such wildfires, the slopes are bare and exposed to the full intensity of winter rains. In the year immediately following a wildfire on a slope, a tremendous increase in mass wasting activity on the exposed slopes is common.

Clearcut lumbering has had much the same effect as wildfire on mass wasting and erosion in the coastal slopes north of San Francisco. Steep slopes are particularly susceptible to mass wasting of cut and fill slopes at highway and other construction sites.

The steep topography, high rates of mass wasting and concentration of precipitation in the winter season provide the potential for high erosive energies for sediment carried in study area streams. Erosion rates of North and South Coast Ranges streams are generally very high compared to streams in other parts of the United States. The Eel River, for example, may have the highest erosion rate of any river of similar size within the coterminous United States.

COASTAL ESTUARIES

Where marine and the freshwater aquatic systems meet, estuaries can develop in partially enclosed bodies of marine or brackish water. Approximately 10-20 percent of the Pacific coastline is comprised of estuarine areas (lagoons, river mouths, and protected bays). San Francisco Bay represents 88-89 percent of the total area covered by estuaries in California. Four to five percent occurs north of San Francisco Bay, primarily Humboldt Bay. The remaining 7 percent occurs between San Francisco Bay and the Mexican border. The major estuaries within the study area south of San Francisco Bay include Morro Bay and Elkhorn Slough.

Physical conditions in these estuaries are dominated by the type of substratum, water circulation patterns, salinity and temperature. In estuaries, the distribution of the biota is largely controlled by tidal currents, freshwater inflow, and salinity.

Sedimentary deposits may be terrestrial or marine derived with tidal velocities determining particle size distribution. Water circulation in the estuary is dominated by a two-layered circulation pattern (fresh water on top of sea water) caused by the opposing freshwater flows and tidal inundation and wind stress, tidal amplitude, configuration of estuary bottom and Coriolis forces (results in fresh water flowing seaward to the right of the estuaries' center and the "up estuary" flow of higher salinity water occurring to the left of center). Salinity distribution patterns within an estuary are influenced by the ratio of river to tidal flow, the strength of tidal current, and the width and depth of the estuary. The shallow depth of estuaries subjects the waters to the strong influences of land air temperature and solar heating, resulting in increased seasonal and diurnal temperature ranges.

The depositional budget for estuaries is generally positive (i.e., accretion is occurring) and is controlled by the physical characteristics of the area. Recent man-caused modifications to California watersheds (e.g., logging, dredging, filling, construction and overgrazing) have severely accelerated natural rates of deposition. Approximately 60-85 percent of the total marshland in California has been "reclaimed" to upland. The deposition of sediment provides a substratum for vascular plants like cordgrass and pickleweed to develop, transforming mudflats to marsh.

The plant and animal species that are found in estuaries can be marine, freshwater, estuarine or anadromous species. Their distributions depend on physical factors as well as biological factors such as inter- and intraspecific competition. True estuarine species have wider tolerances for fluctuating physical conditions, such as salinity, than either fresh or saltwater species. Estuarine species are often good colonizers since changing physical conditions in estuarine areas open new habitats.

Many coastal marine fish species use estuaries seasonally, primarily for spawning or nursing areas during the fall and winter. Coastal marine fish commonly using California coastal estuaries are sharks, rays, smelts, surfperch, rockfish, gobies, sculpins and flatfish, as well as the northern anchovy and Pacific herring. Anadromous species such as some salmon and trout use the estuary as an acclimatization zone to facilitate the physiological changes necessary to make the transition from salt to fresh water and/or fresh to salt water.

A large variety of birds use California estuaries. Of particular interest are shorebirds that feed on intertidal habitats during spring and fall migrations. Gulls and terns, ducks and other water-associated birds, raptors, wading birds and songbirds use the marshes, mudflats and open water areas primarily as feeding grounds.

Legally protected rare, endangered or fully protected species that frequent California estuaries are the salt marsh harvest mouse, California clapper rail, California black rail, salt marsh yellow throat, white-tailed kite, peregrine falcon and bald eagle. Two snail species have been proposed for endangered status. The fish and birds of the estuary are supported by abundant and diverse populations of phytoplankton, zooplankton and invertebrates.

A hierarchical classification scheme used in this report describes the various habitat types in the estuaries. The system corresponds to the scheme developed for the marine environment and is based upon substratum or vegetational composition and tidal inundation.

The size and quality of California coastal estuaries have been greatly diminished by man's activities. Some of the most significant of these activities have been the diking and filling of estuaries, alteration of water flows and the discharge of toxic substances. Increased recreation use, particularly off-road vehicle use, camping and intensive day use, have in some cases diminished estuarine values.

Increased sedimentation brought about by agricultural, industrial, residential and energy resource development has destroyed shallow water and intertidal estuarine habitats. Nonpoint discharges (e.g., stormdrain, agricultural runoff) contribute substantial pollutant loads that may degrade estuaries. Estuaries are particularly sensitive to oil spills and other toxic substance discharges because of the limited flushing rates in semienclosed bodies of water.

To protect some of the remaining estuarine areas, governmental agencies and private organizations have set aside areas of ecological concern called preserves, reserves and refuges.

COASTAL RIVERS

The various streams and rivers of the study area watershed units support a variety of freshwater aquatic habitats. The habitats of the riverine systems have been subdivided into four major categories: tidal, lower perennial, upper perennial and intermittent. Each of the four categories can be further subdivided based on substratum, vegetation and other hierarchical classification categories similar to the marine environmental classification scheme. Tidal riverine habitats are best developed in streams with extensive floodplains and gentle gradients. Substrates usually consist of mud or sand. Detritus imported from upstream areas is generally an important energy source, in addition to phytoplankton, attached algae and vascular plants. The biotic community is similar to estuaries.

Lower perennial habitats of coastal streams typically meander through a floodplain and have slow current velocities, perennial flows and mud or sand bottoms. The biotic community supported in lower perennial stream sections is similar to the tidal riverine except there is less invasion by brackish water-tolerant species. Both tidal and lower perennial stream segments may be very short or lacking in many study area coastal streams, particularly the small streams that enter the ocean abruptly from the coast range without flowing through floodplains.

Upper perennial habitats are probably the most extensive riverine habitats in the study area. They support diverse communities of algae, invertebrates, and fishes. Substrates are of rock, cobbles or gravel and gradients are higher and current velocities faster than downstream lower perennial stream segments. Typical fish species include steelhead/rainbow trout and sculpins. Salmon are found in the larger northern coast streams. Intermittent stream habitats are similar to upper perennial streams except for seasonality of flow. All intermittent stream biota must have adaptive mechanisms for enduring or avoiding the seasonal dry periods.

Major human influences on riverine systems in coastal California include: 1) stream channelization, which reduces habitat volume and diversity, 2) water diversions (effects have been more severe in southern coastal streams), and 3) watershed alterations by urbanization, logging and grazing that may cause vegetation loss, increased stream sedimentation, degraded water quality, water temperature increase, and barriers to fish migration.

Two freshwater aquatic species found in the study area have received legal recognition as rare or endangered species: California freshwater shrimp and the threespine sticklebacks. A number of riverine fish species are important recreational or commercial species in California: salmon, trout, striped bass, American shad, white sturgeon and others. Habitats of anadromous fish species are considered to be areas of ecological concern.

The substantial variability of the aquatic environment of the study area is more than matched by the tremendous variability in the terrestrial environment. The wide diversity of topography, soils, local climates, elevations and disturbance histories is superimposed on the latitudinal variation in regional climate over 8 degrees of latitude. The resulting heterogeneity of local site conditions often produces geographically discontinuous types of vegetation and associated animals. Complex mosaics of radically different kinds of habitats are common.

COASTAL UPLANDS

A hierarchical classification scheme, based on Cheatham and Hailer (1975), was used in this study to categorize terrestrial vegetation. The scheme is based on the premise that vegetation structure and composition are integrated expressions of the environmental conditions operating at a particular site. At an intermediate level in the classification scheme, 15 terrestrial "cover types" are recognized. A cover type encompasses all systems with similar vegetation structure, life-form composition and gross environmental characteristics.

There are eight of the cover types that exhibit "azonal" distribution in the sense that they occur in small sites throughout the study area due to unusual local climate, soil or moisture conditions. Meadows and seeps, riparian forests, perennial and seasonal wetlands, supratidal beach, coastal foredune complex, coastal dune scrub and closed-cone conifer forests are all "azonal" cover types.

The other seven cover types are widespread with broader-scale distribution patterns. Broad-leaved evergreen forests are common throughout the study area, occurring inland in the north and near the coast in the south. Coastal conifer forest is the predominant cover type in the area north of San Francisco Bay, especially near the coast and at low elevations. It also occurs at some immediate coastal locations in the southern portion of the study area. Predominant cover types of the southern half of the study area are coastal shrubland and chaparral. These also occur north of San Francisco Bay but are more restricted in distribution. Somewhat less common but widespread throughout the study region are grasslands (inland, dry sites), oak woodland (inland, dry sites) and lower montane conifer forest (high elevations).

Within the State of California there are many endemic plant species (approximately 30 percent of all vascular plant species found in California are found nowhere else) as well as a tremendous diversity of flora. Endemic species can be either long surviving relic species or newly evolving species. The north coast is known to support a relatively large number of relic species. Local areas along the central coast of California noted as areas of endemism are: 1) Sonoma County from Pitkin Marsh near Sebastopol, westward through the redwood area south of the Russian River and along the coast near Bodega Bay, 2) the Santa Cruz Mountains from Año Nuevo Point eastward, 3) the Monterey Peninsula and the coast southward to the Little Sur River, and 4) central portion of Santa Lucia Mountains (Stebbins and Major, 1965).

Some of the endemic plant species are present in such low numbers or confined to such a small area that they have been designated as rare or endangered by state and/or federal governmental agencies. By the close of 1979, a number of species within the study area had been designated rare or endangered by the State of California. The U. S. Fish and Wildlife Service had a number of species (some overlap with state-designated species) listed as candidates for rare or endangered status.

Each habitat type is populated with wildlife species whose environmental requirements are fulfilled all or in part by a particular habitat type or combination of types. A list of characteristic wildlife species has been prepared for each cover or habitat type. Wildlife species designated as rare or endangered species are the Morro bay kangaroo rat, ringtail, California condor, golden eagle, California least tern, Santa Cruz long-toed salamander, Alameda striped racer, San Francisco garter snake and the Lotis blue, Mission blue, San Bruno elfin and Smith's blue butterflies. A number of snails and butterfly species have been proposed for inclusion on the list.

Terrestrial areas of ecological concern in the study area fall into three categories: 1) areas of special biological importance to wildlife including Critical Habitat of proposed or designated rare or endangered species, habitat supporting unique species or species of concern, habitat which is diminishing in supply in California that is supporting a significant variety of species and key nesting or concentration areas for species of concern; 2) research natural areas established by various public and private agencies; and 3) areas of identified in the Inventory of California Natural Areas prepared by the California Natural Areas Coordinating Council.

Large areas within northern and central coastal California have been cleared or had the natural vegetation greatly modified by logging, agricultural development, grazing, firewood cutting, fuel break and road construction, urbanization, mining, groundwater pumping and other human activities. Loss or modification of the natural vegetation has resulted in changes in wildlife abundance and species composition.

COASTAL SOCIOECONOMICS

The socio-economic environment of the central and northern California coastal region is shaped by the presence of natural resources of value and the expansion and encroachment of urban areas, particularly in the vicinity of the San Francisco Bay Area. The region is generally characterized by low population densities (compared with those of the highly developed San Francisco Bay Area) although relatively dense population occurs in the larger urban areas of Eureka, Santa Cruz and Monterey. In most of the coastal region economic activities and settlement patterns are dominated by natural resources. The socio-economic environment of the region shows considerable variation both in terms of the particular resources which are dominant and in terms of the degree to which urban influences have led to economic diversification. The northern area (Del Norte, Humboldt, Mendocino and northern Sonoma Counties) is strongly dependent on the forestry and forest products industry, which has been typified by cyclically and seasonally fluctuating levels of activity. Agriculture, fisheries and recreation, which also show seasonal and cyclical fluctuations in level of activity, are also important sectors of the north coast economy. In the rest of the study area agriculture, fisheries and recreation are relatively more important.

In all parts of the coastal region, growing immigration of retirees and seasonal residents (considered as part of the recreation sector) and state and federal transfer payments and grants are important sources of imported income. Unemployment and seasonal employment are more widespread than in major urban areas in the rest of California and income levels are generally lower. In addition to economic activities directly based on natural resources, government (mainly in the form of higher education and research institutions) and miscellaneous nonresource based manufacturing, have become important basic (export) sectors of the economy in some coastal areas containing urban centers.

The economically valuable natural resources of the region include the very extensive forests, estuarine and marine finfish and shellfish, some extensive areas of productive agricultural land, limited mineral deposits, and a shoreline suitable at several points for ports or small harbors. The natural recreation attractions of both coastal (estuaries, dunes and beaches) and inland areas, historic sites, and fish and wildlife constitute highly valuable resources. In the north coastal region, the overwhelming predominance of the forest resource is diminishing as old growth on private lands is harvested. The reduction in harvestable timber and a reassessment of the value of the forest resource for uses other than timber harvest are contributing to a shift in the way the region's natural resources are valued. A similar shift in public values may be occurring relative to the land, fresh water, estuarine and marine resources of the entire region as the importance of, and the interactions between, the basic agricultural fishery activities in the coastal region become better understood. A fundamental change occurred with passage of the California Coastal Act in 1976. This legislation recognized the value of coastal natural resources for a variety of uniquely coastal-related uses and recognized the need to protect ecological communities from increasing pressure for urbanization and other development.

Demand for all of the region's natural resources is increasing. At the same time, because of growing understanding both of the effects of over-exploitation and of conflicts between uses, limitations are being placed on resource extraction. Such limitations, and changes in policy regarding the manner in which resources should be used, have led to declining production levels and unemployment both in the resource-dependent basic industry and in related service sector changes (often referred to as economic dislocations). Adjustment to such dislocations and to cyclic and seasonal fluctuations tends to be difficult and costly due to the region's lack of diversification and its population's traditional ties with a few basic industries.

Much of the coastal region is relatively isolated from major population and industrial centers. Transportation routes are limited; fuel and power are mainly imported from outside the region, and the population density is low. Major sources of capital have tended to be national forest industry firms or local processors strongly dependent on them. Much of the region's economic activity in the agriculture, fisheries, recreation and mining industries is carried out by self-employed individuals who lack extensive capital resources. Participation in the labor force, except where the recreation industry is dominant, tends to be lower in the region than in more urbanized areas of the state. This not only reflects the generally limited employment opportunities but also represents a potentially valuable human resource.

Basic industries are those which produce goods and services for export outside the local economy and result in the import of "new" money. Basic industries may involve the harvesting or other use of natural resources or may be more dependent on technology, manpower and secondary manufacture of raw materials. Natural resource use industries generally characterize the coastal region where, with the exception of sand, gravel, and rock for local construction use, each of the economically and culturally valuable resources is in demand by markets outside the study area. The traditionally dominant industries have been the forestry and forest products, fisheries, agricultural, and recreation industries. The relative ranking of the dominant industries as well as mineral industries, transportation involving external markets, and diversified manufacturing varies among the watersheds.

The forestry and forest products industry has been declining for a number of years. Employment in the industry is expected to continue to decline. The long-term outlook for forestry is the subject of debate, depending upon assumptions regarding management of the industry. The economic effect of efforts to diversify industrial activity in the northern California coastal region through increasing emphasis on recreation, aquaculture, and crop growing does not yet appear to be significant. Agriculture and recreation activities have, however, shown steady growth in most parts of the region. The fisheries industry, while traditionally experiencing cyclical, as well as seasonal, fluctuations, has not shown significant growth. Greater control over the resource through recent extension of the territorial limit for fishing to 200 miles may stimulate the investment necessary to industry expansion. Mining has not been a significant generator of employment or income in the region. This may be changed, however, if significant development of offshore oil and gas resources occurs. Changing demand and world supply conditions, however, are stimulating re-opening of some old mines and development of others as well as generating increased interest in offshore resources.

Little success has been experienced by coastal communities attempting to diversify their economies through attraction of industries which are not directly dependent upon coastal resources. In a few watersheds, government activities in the form of military installations, colleges and marine research institutions contribute significantly to the coastal economy. Throughout the region, due to a combination of relatively high unemployment levels and relatively low income levels, government transfer monies are an important external source of income.

The basic industrial activity of the region supports a relatively well-developed service sector. The relationship between the basic and service sectors in terms of employment and income (the multiplier) is difficult to determine. This is largely because employment in the basic sector (agriculture, fisheries, and recreation) can only be estimated. In addition, a portion of the production in these industries is locally consumed and some trade and service activities serve both the local population and tourists and so are partially "basic". It would appear, however, that the typical regional employment multiplier is on the order of 3.0, which means that for any job added in a basic industry, approximately two more are supported in activities which supply local goods and services.

The watersheds close to the major San Francisco Bay Area employment center, Lagunitas Creek in Marin County and San Gregorio in San Mateo County, represent an unusual situation. To some extent, local services are supported by the income of residents who commute from these areas to the San Francisco Bay Area to work. To some extent, also, these watersheds are dependent on externally provided trade and service activities. This pattern also exists to a more limited extent in coastal communities in Mendocino, Sonoma, Santa Cruz, Monterey and San Luis Obispo Counties. The pattern makes reasonably accurate calculation of multipliers difficult and of less relevance than in more discrete economies.

The central and northern California coastal region is relatively sparsely populated, with a concentration of urban centers along the coast. In several watersheds, the population is made up of a relatively high proportion of elderly people. For this reason, and also due to limited employment opportunities, percentage of residents in the labor force tends to be lower than the average for the state. In many parts of the region low labor force participation rates, high unemployment, and severe seasonal fluctuations in employment contribute to median family and per capita personal income levels significantly below state averages.

Recent trends in coastal region population have been influenced by coastal zone development restrictions since passage of Proposition 20 in 1972, which established a statewide coastal zone commission, and of the California Coastal Act in 1976 which passed responsibility for preparing detailed coastal planning programs to local government in the coastal zone. Both the rate and the pattern of population growth have been affected by policies which have emphasized infilling existing communities and restricted development in intervening areas.

Chapter 3

PHYSICAL - CHEMICAL ENVIRONMENT

GEOLOGICAL OCEANOGRAPHY

Bathymetry

The oceanic portion of the study area includes the continental shelf and slope area, and extends from the Oregon border to Point Arguello (see Figure 3-1) . The study area extends from the shoreline of California to the 1,000 meter (m) , i.e., 3,300 foot (ft) depth in the Pacific Ocean. The continental shelf is the area extends from the shoreline to the 200 m (660 ft) depth and covers approximately 19,000 square kilometers (sq km), i.e., 7,400 square miles (sq mi). The continental slope area within the study area includes approximately 18,000 sq km (6,800 sq mi) .

Bathymetric contours for each ocean basin are shown in Vol. IV, Chapters 25 through 29, Geological Oceanography.

The five ocean basin units comprising the oceanic part of the study area are the Eel River, Point Arena, Bodega Bay, Santa Cruz, and Santa Maria as described below and in each of the ocean basin unit chapters, Vol. IV, Chapters 25 through 29 respectively.

Morphology

The continental margin of northern and central California has a narrow shelf generally less than 50 km (30 mi) wide which slopes seaward at an average inclination of 3 degrees.

The continental shelf can be characterized by five major areas: 1) the area north of the Gorda Escarpment (described below) , 2) the area between the Gorda Escarpment and Point Reyes, 3) the Gulf of the Farallones, 4) the area south of Pigeon Point to Cape San Martin, and 5) the Arguello Plateau.

The northernmost area (Area 1) has a fairly narrow shelf 19 to 40 km (12 to 25 mi) wide, and is cut by only one submarine canyon; the Eel submarine canyon's head is located 10 km (6 mi) offshore.

The northern portion of Area 2, which includes the Gorda Escarpment, has a narrower shelf about 11 km (7 mi) wide. The Gorda Escarpment extends for more than 120 km (75 mi) seaward of Punta Gorda. The escarpment is a north facing slope with a maximum height of about 1800 m (6,000 ft) , The northern area 2 shelf is cut by a few large submarine canyons, including the Mendocino and Mattole Canyons at the Gorda Escarpment, and the Delgada Canyon's head located just north of Point Delgada at 2 km (1.2 mi) offshore. The Delgada Canyon transports sediment to the Delgada deep sea fan. The shelf widens to about 40 km (25 mi) near Point Reyes. The submarine canyons in this area are farther offshore, located on the continental slope.

Area 3 includes the widest shelf area along the California coast, about 50 km (30 mi). The shelf is a broad bank of sandy and silty sediments and shell fragments. The Farallon Islands are located on the bank.

Area 4 has a very narrow shelf area about 6 km (4 mi) wide and is cut by a number of submarine canyons. Monterey bay includes the largest of these canyons, the Monterey Submarine Canyon. The canyon's head is located about 4 km (2.5 mi) offshore. Certain portions of Monterey Canyon have relief similar to portions of the Grand Canyon in Arizona.

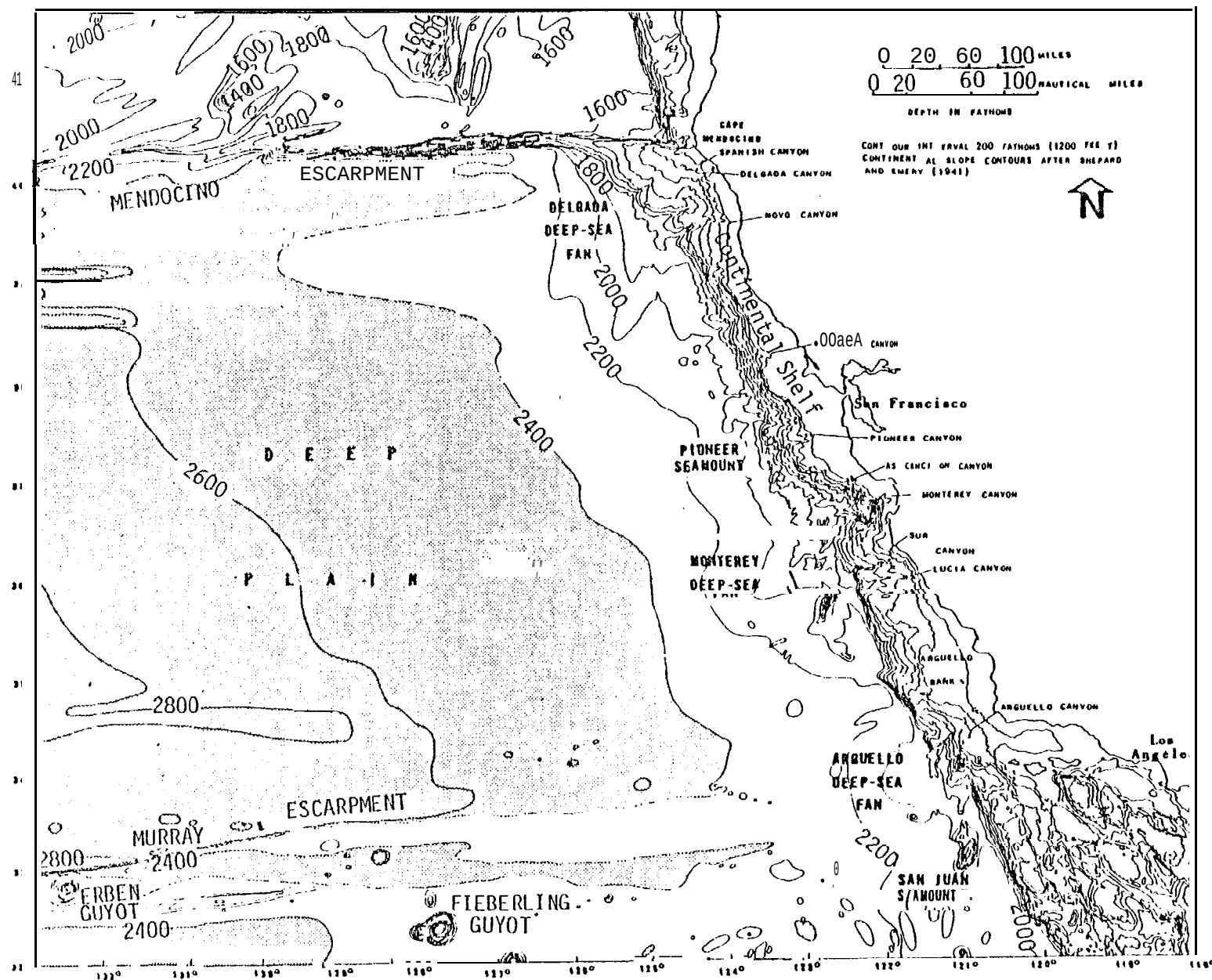


Figure 3-1. Principal Morphological Features of the Sea Floor Bathymetry of Coastal California (Rusnak, 1966)

The Arguello Plateau forms a broad bank which cannot be considered part of the continental shelf, but rather is a gentler part of the upper continental slope with an average gradient of 6.5 degrees through its 50 km (30 mi) width (Rusnak, 1966).

The portion of the continental slope above the 1000 meter (3,300 ft) depth is included in the study area. The slope can be categorized into four basic areas: 1) the area north of the Gorda Escarpment, 2) the area between the Gorda Escarpment and Pigeon Point, 3) the area from Monterey Bay to Cape San Martin, and 4) the Arguello Plateau.

Area 1 has a gentle continental slope, cut by only one submarine canyon, the Eel Submarine Canyon. The slope forms two broad plateaus.

Area 2 has a steeper slopes, cut by numerous submarine canyons. A few of the canyons, such as the Delgada submarine canyon head nearshore; however, most originate near the top of the continental slope, including the Spanish, Noyo and Bodega Canyons.

Area 3 has rugged topography and is cut by many submarine canyons, including the Monterey and Sur canyons. The area appears complexly folded (see structure below).

Area 4, the Arguello Plateau, cannot be easily divided into continental shelf and slope areas. As described above, it has a gentle slope (about 6.5 degrees) through its 50 km (30 mi) width.

The Gorda Escarpment is a large east-west trending scarp which is related to the Mendocino Fracture and Fault zone. This feature is discussed in Vol. IV, Chapter 25, Geological Oceanography.

The continental shelf of northern and central California contains six late Tertiary structural "basins" that are extensions of onshore basins. These basins are, from north to south, the Eel River, Point Arena, Bodega, outer Santa Cruz, Santa Cruz and Santa Maria; they formed the basis for designation of the ocean basin units. The structural trend of the basins is general north to northwest and is related to movement on the San Andreas Fault (see Vol. II, Chapter 3, Seismicity).

The structure of the continental margin is related to the geologic history of the continental margin, which is briefly summarized below. See Seismology, and Vol. I, Geology glossary for definition of geologic terms.

The Late Mesozoic to Early Tertiary history of the continental margin of northern and central California was dominated by the subduction of the Farallon Oceanic Plate, that is the Farrallon plate was sinking and over-ridden by the continental plate, forming a subduction trench. Volcanic and plutonic igneous activity occurred east of the subduction zone. Volcanic and sedimentary debris were transported westward and deposited into the subduction trench at the continental margin. Subduction of the trench sediments probably continued until Oligocene time, followed by uplift and erosion of the continental shelf. Volcanic activity continued during the late Oligocene and early Miocene.

Early Miocene marine sedimentation began with extensive expansion of the ocean, that swept eastward across the eroded continental shelf, at least from Point Sur north to the Oregon border. In late middle Miocene time, initial uplift and then subsidence of the western continental margin and formation of the ocean basins occurred. Some of the structures within the ocean basins were probably formed concurrently with the uplift. Formation of the basins is probably related to the start of transform faulting on the San Andreas Fault System (see Vol. II, Chapter 3, Seismology). Marine sedimentation and subsidence probably continued, at least in the western half of the shelf, until late Pliocene time, when uplift and structural deformation occurred. Quaternary (Pleistocene and Recent) sand, gravel and shell fragments have been deposited over much of the continental shelf (Hoskins and Griffiths, 1971).

The continental shelf from Point Conception to just south of Point Arena has a granitic basement. Granite is a hard igneous rock composed of feldspar and quartz. The granitic basement results in a rigid, block-faulted structure for the strata overlying the basement. The continental shelf north of Point Arena to the Oregon/California border has a metasedimentary basement. Metasedimentary rocks are sedimentary rocks which have been partially altered by metamorphism. For example, sandstone is metamorphosed to quartzite, shale to slate, and limestone to marble. The northern basins with metasedimentary basements are complexly folded (Hoskins and Griffiths, 1971).

Sediments and Substrates

Thick marine sediment beds overlie the basement rock. The beds consist mainly of deep-water sand and shale (Welday and Williams, 1975; Hoskins and Griffiths, 1971).

The nearshore surface lithology of the ocean basin units consists mostly of granitic, metasedimentary and Franciscan Formation rock. The rock outcrops are located generally above depths of 18 m (60 ft). Farther offshore, sand generally occurs to approximate depths of 55 to 76 m (180 to 250 ft). Mud is the substrate in deeper water. Gravel and shell bottoms are located in scattered areas. The shell bottom includes whole shells, shell fragments, shell sand and coral. The surface lithology of the continental margin is given in each ocean basin unit (see Vol. IV, Chapters 25 to 29, Sediments and Substrate) (Welday and Williams, 1975).

PHYSICAL OCEANOGRAPHY

Much of the nearshore physical and chemical oceanography data along the California coast comes from the California Cooperative Oceanic Fisheries Investigations (CalCOFI) reports and atlases. CalCOFI is a program sponsored by the State of California under the direction of the State's Marine Research Committee. Unfortunately, very little data exist from cruises north of San Francisco. Figure 3-2 shows the basic station plan of CalCOFI.

The stations are arranged on lines running offshore approximately southwesterly and oriented almost perpendicular to the coast. Stations are normally 6.4 kilometers (km), i.e., 4 miles (mi), apart and identified by a number following the line number (line number separated from station number by a decimal point) according to a scheme whereby one unit equals 6.4 km (4 mi). The initial station for the numbering system is station 60 on each line. Station 80.55 indicates a station on line 80 that is 32 km (20 mi) shoreward of station 80.60, and a station numbered 80.65 is 32 km (20 mi) seaward of station 80.60.

The CalCOFI cruise-numbering scheme consists of a four digit number. The first two digits indicate the year and the last two digits indicate the month. Cruise 6301 was a cruise during January of 1963 while cruise 6304.05 was a cruise during April and May of 1963.

California Current System

Most of the ocean surface is dominated by east-west currents such as the Equatorial currents. These currents are deflected when they encounter the continents, and the water flows are split into boundary currents, flowing more or less north-south. Eastern boundary currents are relatively weak compared to the swift western boundary currents, and therefore, the separation between coastal- and open-ocean circulation tends to be more diffuse. The California Current is an eastern boundary current about 600 to 1,000 km (370 to 620 mi) wide and 100 to 500 m (300 to 1,640 ft) deep (Gross, 1977; the Interagency AD HOC Task Force, 1973; Wooster and Reid, 1963). In regions such as California where eastern boundary currents exist, prevailing winds at certain times of the year blow surface waters away from ocean-basin margins. Subsurface waters move upward to replace surface waters in a process known as upwelling.

Four sources provide water to the California Current system. The offshore waters of the northern part of the California Current come from the sub-Arctic water mass. Waters from the central Pacific water mass mix with sub-Arctic water as the current moves southward. Equatorial Pacific water enters the system as a subsurface current from the south, inshore of the California Current. The fourth major water source is upwelling of mid-depth ocean waters all along the California coast.

The circulation pattern and temperature-salinity structure along the central and northern California coast undergo fluctuation over the annual cycle. These fluctuations are in response to seasonal changes in the hemispheric atmospheric pressure cells (see Climatology). Winds blow from high pressure areas to low pressure areas. Changes in the strength and location of these cells cause seasonal changes in the winds along the California coast. The North Pacific (Hawaiian) high pressure cell strengthens during summer at approximately 37° N. Latitude, 150° W. Longitude and weakens during winter when it shifts towards the southeast. During summer the semi-permanent continental thermal low situated over California strengthens (see Figure 3-39 and 3-40). Prevailing west-northwest to north-westerly

is one where eddies and gyres are characteristic. Between Cape Mendocino and the Oregon border, no data exist which would support the Davidson Current as a surface manifestation of the California Undercurrent. Therefore, the existence in northern California of the Davidson Current-California Undercurrent system is inferred by continuity considerations.

In spring and fall when the strong north winds strengthen the south-flowing California Current, a narrow countercurrent flows northward close to the coast at a depth of 200 m (660 ft). This undercurrent can be seen on the monthly mean geostrophic current charts. Its waters are warm, with a high salinity and a low oxygen content. The California Undercurrent is prevalent from southern Baja California to Pt. Conception and at times extends to Cape Mendocino (40° N. Latitude). Mean speeds of the Undercurrent are low, 5 to 10 cm/sec (0.2 to 0.3 ft/sec) (Schwartzlose and Reid, 1972). The flow in summer is well-developed with a width of 40 to 50 km (25 to 30 mi).

Nearshore Circulation

The characteristics of currents in the California nearshore region are determined by the alignment of the coast, the width of the continental shelf, oceanic currents, topography, bathymetry, winds, tides, density structure, waves and river discharge. At any location or time, one or more of these forces can predominate to influence local currents. Tidal currents predominate in constricted areas such as entrances to bays and estuaries. Inshore of the California Current, gyres or eddy circulations are common. The density structure of the nearshore waters varies with the season, and density determines geostrophic currents. Sea and swell waves are the primary mechanism driving the currents within the surf zone. Winds are an important mechanism for driving surface currents any time of the year when windspeed exceeds 1 to 2 m/sec (3 to 7 ft/sec).

During the upwelling and oceanic periods, large circulation cells and gyres form between the main oceanic current and the shore. These circulation cells often develop in the lee of promontories and result in the reversal of currents in the nearshore regions. Large gyres extending as far as 210 km (130 mi) from shore makes it difficult to distinguish oceanic and nearshore circulation.

Satellite and aircraft photography has helped document patterns in California coastal currents. Satellite imagery is available from Landsat-1 (formerly Earth Resources Technology Satellite, ERTS), NASA Ames U-2 flights, and NASA's Johnson Space Center aircraft flights. Landsat-1 and U-2 imagery graphically illustrate the California Current as well as the nearshore surface currents, when suspended material acts as a detectable tracer. The interpretation of the images requires some subjectivity to infer current direction from a single photograph; the locations and sizes of the currents are not measured but inferred by the suspended sediment distribution pattern.

Nearshore current patterns for the California coast during the oceanic, Davidson and upwelling current periods are shown in Figures 3-3 to 3-8. Similar current patterns have been drawn for each month.

Tides. Tides are the periodic rise and fall of the earth's ocean resulting from forces of the moon and sun acting on the rotating earth. A tidal curve is graphically formed by plotting the height of the water surface as it rises and falls with time. A tidal curve from San Francisco (Figure 3-9) illustrates that the coast of California has mixed tides. Mixed tides have two high tides and two low tides per tidal day (24 hours 50 minutes), but the highs are usually different in height, and the low tides also differ. The higher of the two high tides is called higher high water (HHW); the other is called lower high water (LHW). See vol. I, Chapter 4, Figure 4-7 and Table 4-1. A similar nomenclature exists for the lower tides - lower low water (LLW) and higher low water (HLW).

Tide tables for the West Coast of North and South America (NOAA, 1979) contain the daily predicted times and heights of the high and low waters at selected reference stations in California. Humboldt Bay and San Francisco are reference stations within the study area. An example of a tide table (January 1 and 2 of 1979) is shown in Table 3-1. Approximate times and heights of the tides at locations other than Humboldt Bay and San Francisco can be calculated by either adding or subtracting time or tide height as indicated in Table 3-2 to the values given for the appropriate reference station. If a tide is negative, it is indicated by a minus sign.

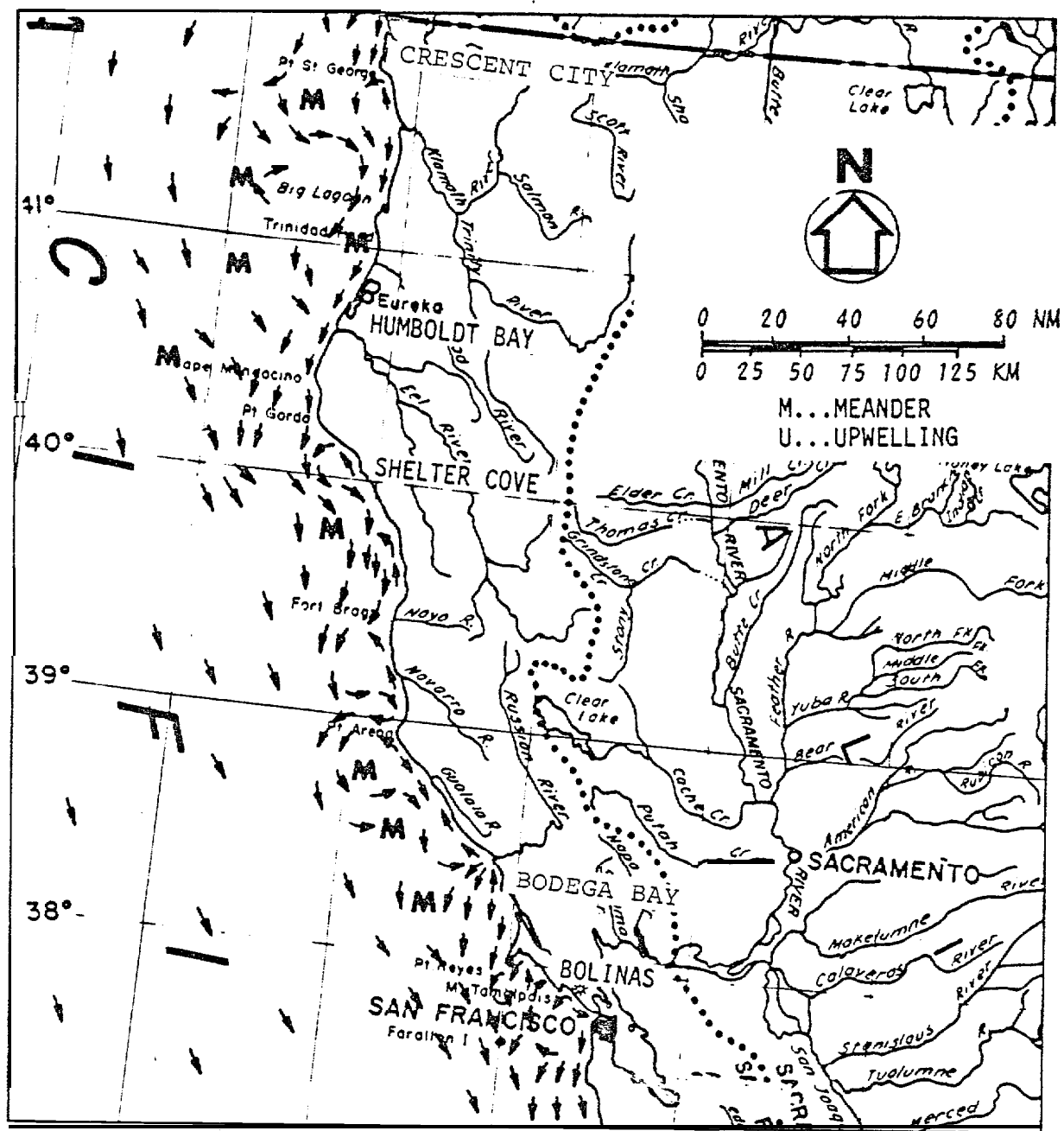


Figure 3-3. Generalized Northern California Surface Currents for the Oceanic Season (August-November; Pirie and Steller, 1977)

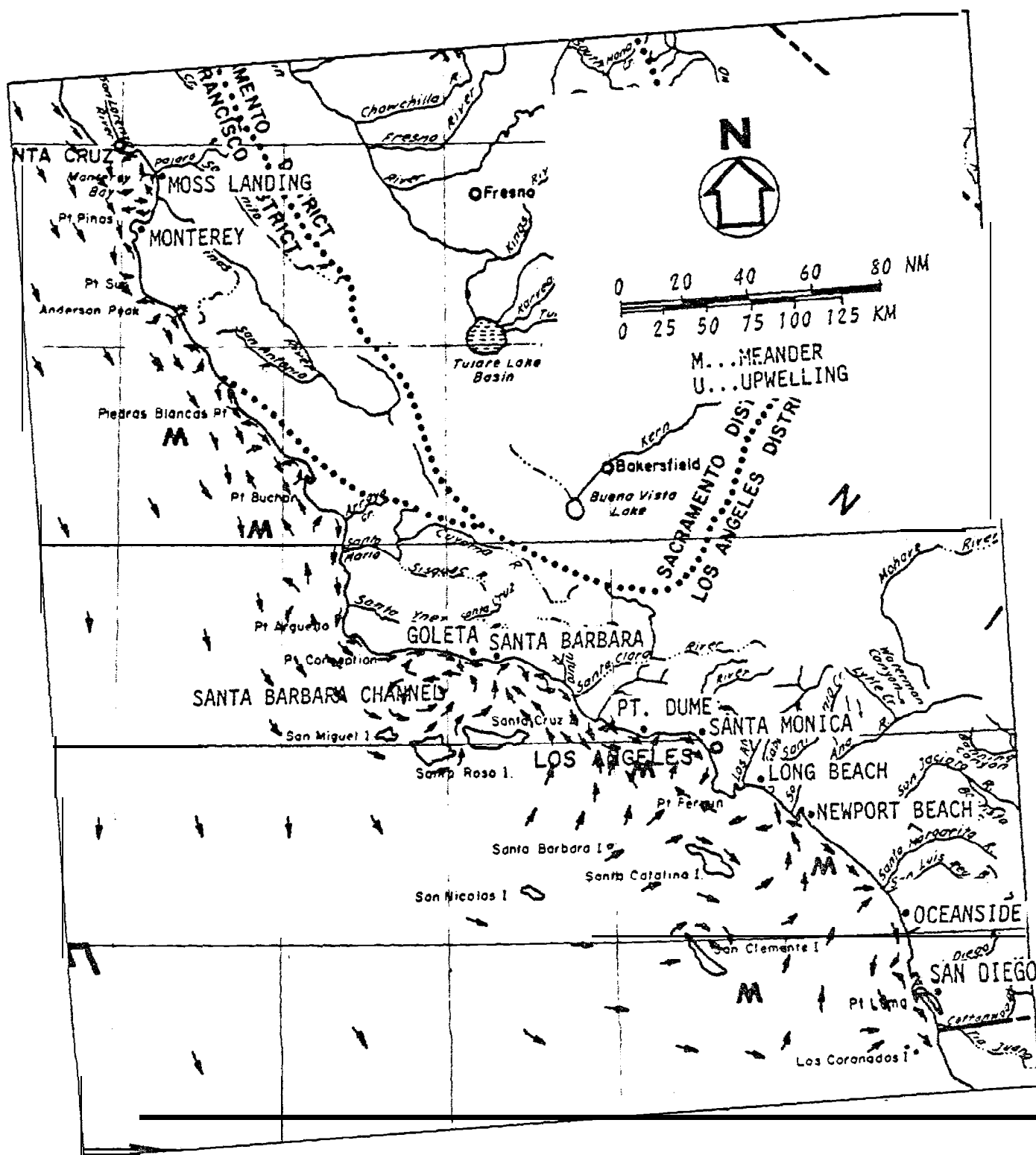


Figure 3-4. Generalized Central California surface
 Currents for the Sea son (August-November;
 1977)
 Pirie and Steller,

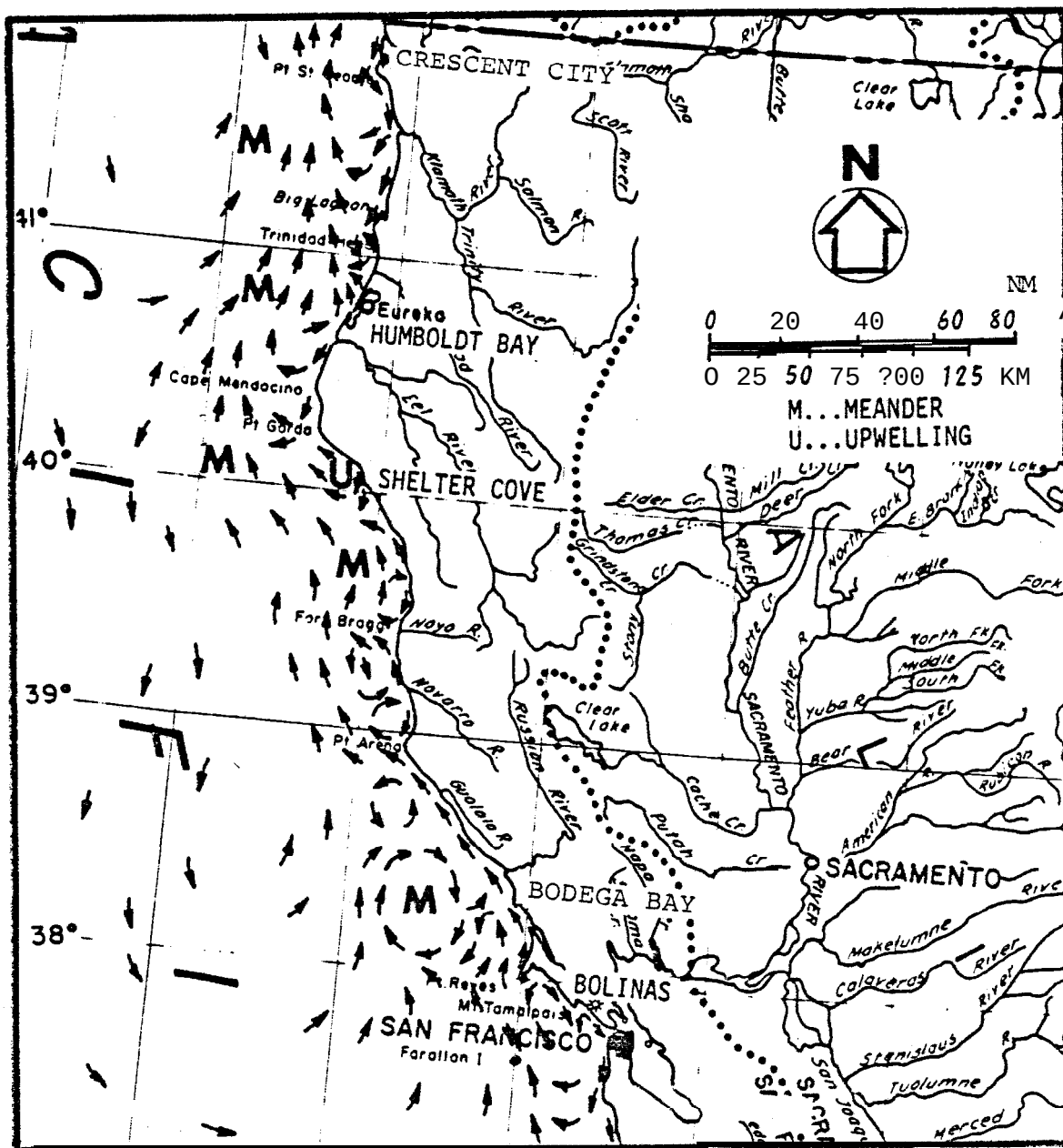


Figure 3-5. Generalized Northern California Surface Currents for the Davidson Season (November-February; Pirie and Steller, 1977)

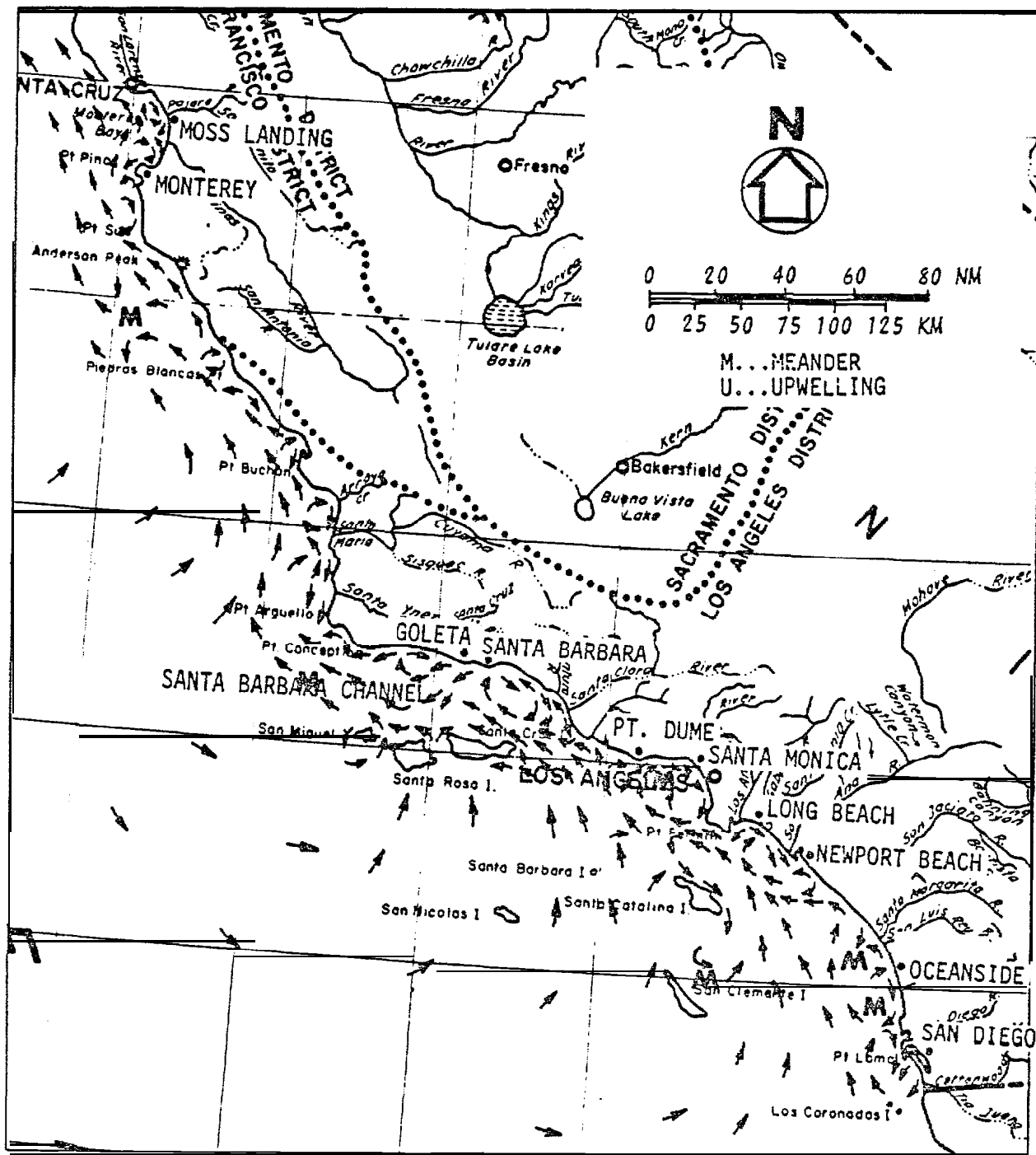


Figure 3-6. Generalized Central California Surface Currents for the Davidson Season {November-February; Pirie and Steller, 1977}

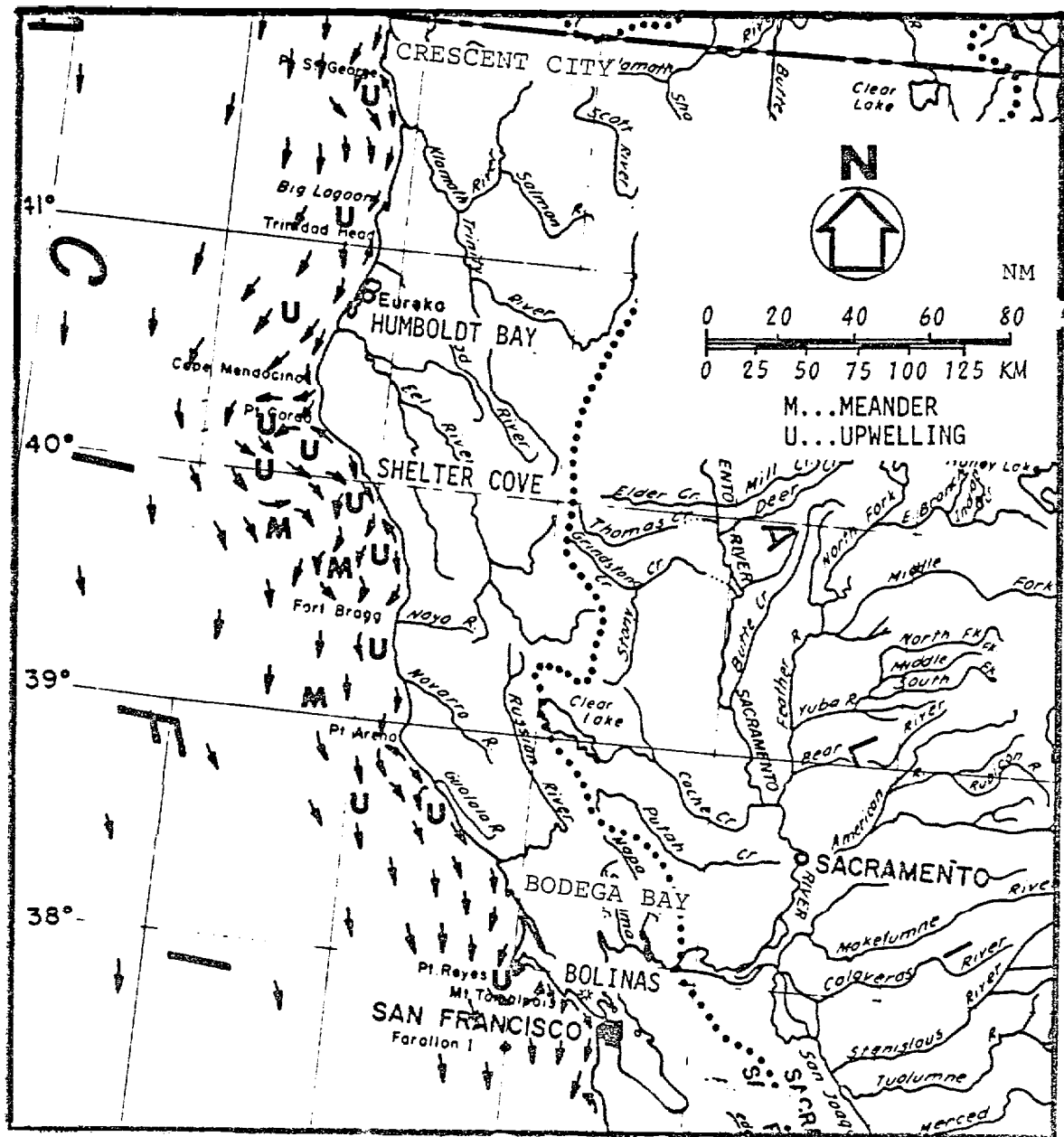


Figure 3-7. Generalized Northern California Surface Currents for the Upwelling Season (February-August; Pirie and Steller, 1977)

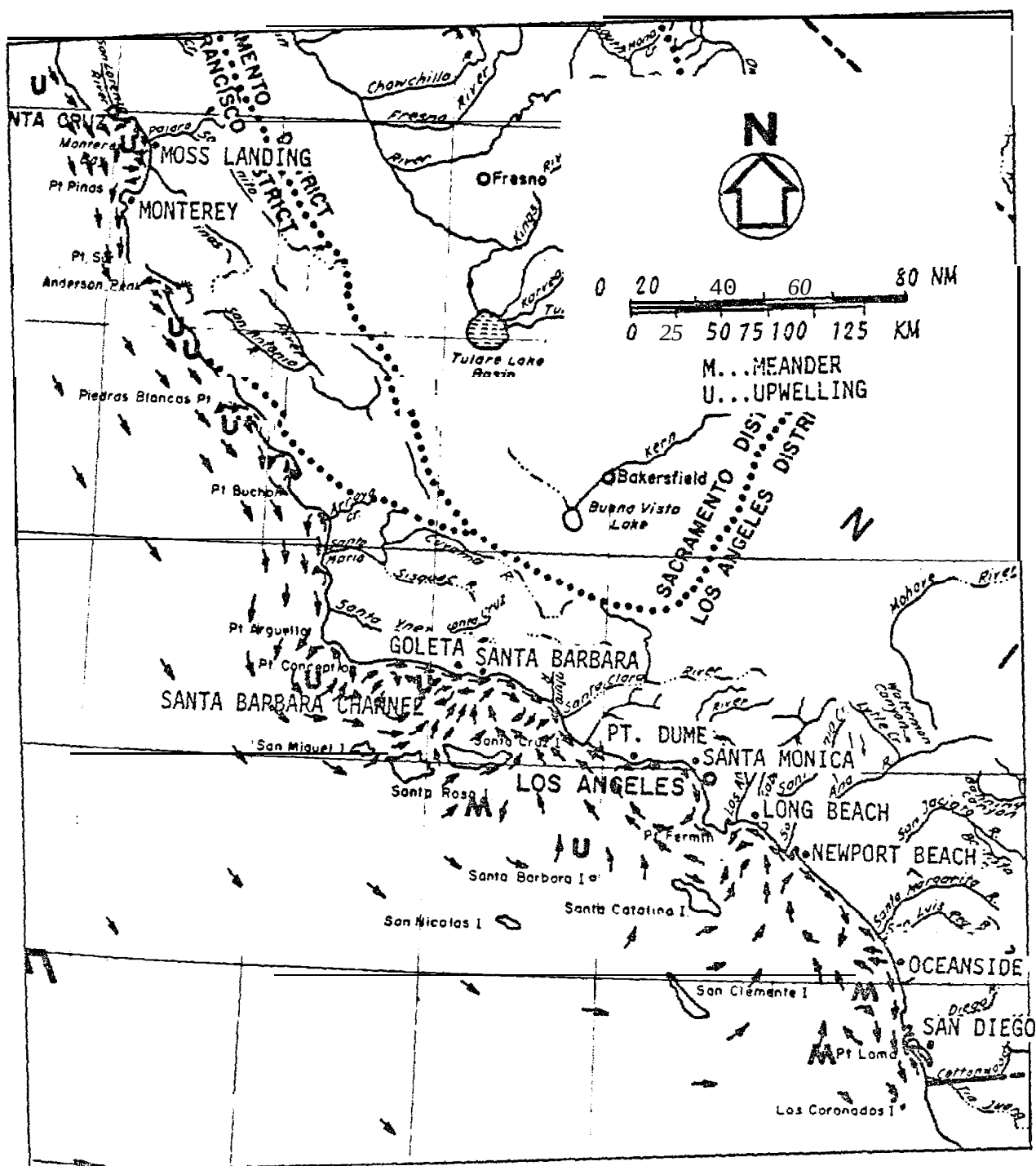


Figure 3-8. Generalized Central California Surface Currents for the Upwelling Season (February-August; Pirie and Steller, 1977)

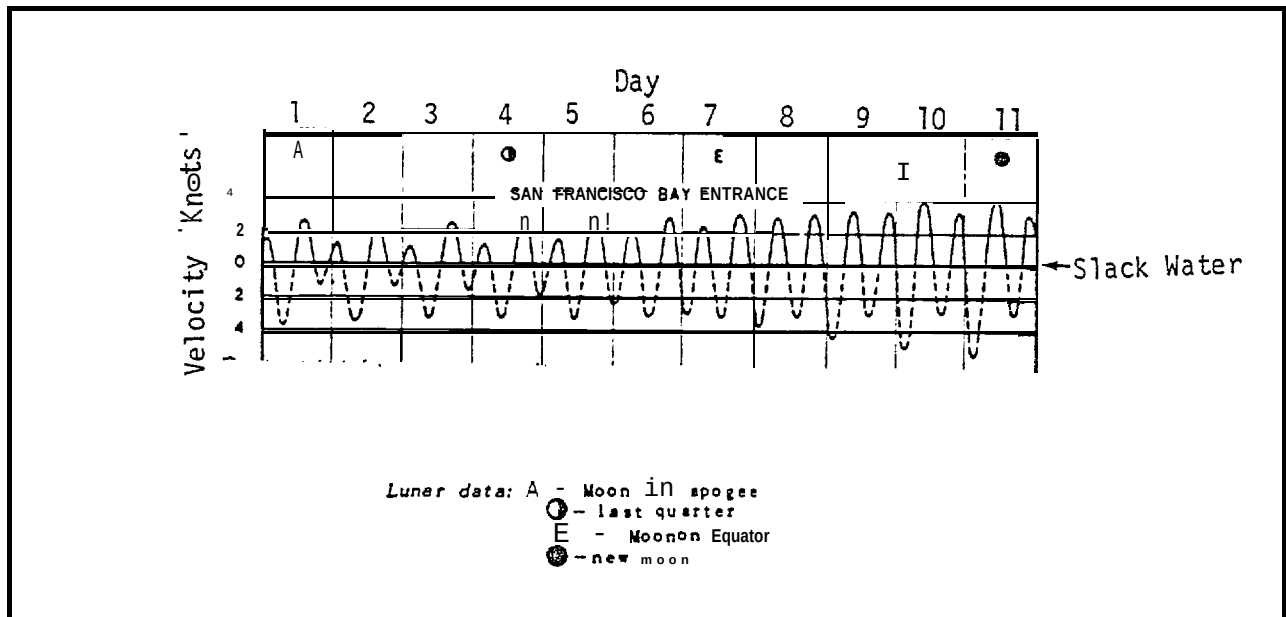


Figure 3-9. Typical Current Velocity Curves for the San Francisco Bay Entrance During Flood and Ebb Tide Stages (NOAA, 1978)

Table 3-1. Tide Table for San Francisco Bay
Showing Day, Hour, and Tidal Height (ft.)

DAY	January	
	Hour	Feet
1st	0212	6.1
	0732	2.6
	1317	7.5
	2020	-1.0
2nd	0302	6.2
	0830	2.5
	1413	6.9
	2108	-0.5

The datum from which the predicted heights are calculated for the Pacific Coast of the United States is the mean of the lower of the two low waters of each day. Nautical charts show the depth of water as referred to a low water datum; to find the actual depth of water at any time, the height of the tide should be added or subtracted (if tide is negative) to the charted depth. Changes in winds and barometric conditions cause variations in sea level from day to day. In general, onshore winds or low pressure, as indicated by a low barometer reading, cause the heights of both the high and low waters to be higher than predicted. Offshore winds or high pressure, as indicated by a high barometer reading, cause the heights to be lower.

Tidal Currents. Tidal currents are horizontal water movements associated with the tides or the rise and fall of the sea surface. The reversal in the direction of tidal current flow is visible near coasts. Tidal currents are generally the strongest currents in coastal regions. The flood current occurs as the tide level increases in height and the current usually moves toward the shore. As the tide level decreases the ebb current develops and is usually a movement of water away from shore. A period of no current, known as slack water, occurs each time the tidal current changes direction. Figure 3-9 shows variations in the tidal current from day to day for the entrance to San Francisco Bay. Currents along the California coast have a diurnal inequality, i.e., the difference in velocity of two consecutive flood or two consecutive ebb maximums. This inequality varies directly with the moon's declination; consequently it is less evident when the moon is near the Equator.

For stations on the outer coast usually little difference exists between the time of high or low water and the beginning of flood or ebb current. The time of slack water may differ by several hours from the time of high or low water for places in narrow channels, landlocked harbors, or on tidal rivers. For areas located on a tidal river or bay, the time of slack water may differ from 1 to 3 hours from the time of high or low water. Pacific Coast of North America and Asia, Tidal Current Tables, (NOAA, 1978) give the predicted times of slack water and the predicted times and velocities of maximum current - flood and ebb - for each day of the year at a number of stations on the Pacific coast. San Francisco Bay entrance is the only such station in the study area, and a portion of this table is given as an example in Table 3-1. Approximate times of slack water and time and velocity of maximum current for other places in the study all can be calculated by adding or subtracting (indicated by minus sign) values shown in Table 3-3 from values given for San Francisco Bay entrance.

Tidal currents are altered by winds or river runoff. River runoff prolongs and strengthens ebb currents because more water must move out on the ebb than comes in on the flood. The strength of a tidal current also depends on the volume of water that must flow through an opening, such as the mouth of an estuary, and the size of the opening. Tidal currents dominate circulation in some California areas such as Humboldt Bay and San Francisco Bay.

In the open ocean, tidal currents are not restricted by the coastline and exhibit rotary patterns different from the reversing currents observed in coastal areas. Open ocean tidal currents or coastal tidal currents are the tidal currents

Table 3-2. Tidal Time and Height Differences, Ranges, and Mean Tidal Level for Northern and Central California (Now, 1979)

No.	PLACE	POSITION		TIME DIFFERENCES		VELOCITY RATIOS		MAXIMUM CURRENTS			
		Lat.	Long.	Stock water	Maximum current	Maximum flood	Maximum ebb	Flood		Ebb	
				h. m.	h. m.			Direction (true)	Average velocity	Direction (true)	Average velocity
	CALIFORNIA COAST	N.	W.					deg	knots	deg	knots
75	Point Arguello-----	34 34	120 40	-2 20	-2 20	0.2	0.2	005	0.5	185	0.5
80	Point San Luis-----	35 09	120 46	-2 00	-2 00	0.2	0.2	305	0.5	125	0.5
85	Point Piedras Blancas-----	35 40	121 18	-1 30	-1 30	0.2	0.2	315	0.5	135	0.5
90	Point Sur-----	36 18	121 55	-1 10	-1 10	0.2	0.2	325	0.5	145	0.5
	MONTEREY BAY										
95	Point Pinos-----	36 38	121 57	Current too weak and variable to be predicted.							
100	Point Santa Cruz, 2 miles south of ----	36 56	122 01								
	CALIFORNIA COAST—Continued										
105	Ano Nuevo island, 2 miles SW. of----	37 05	122 22	Current too weak and variable to be predicted.							
110	Point Montara, 2 miles west of -----	37 32	122 34								
	CALIFORNIA COAST—Continued										
530	Point Reyes S-----	38 00	123 02	-1 10	-1 10	0.3	0.3	320	1.1	140	1.1
540	Point San Pedro S-----	38 34	123 21	-1 20	-1 20	0.3	0.3	325	0.9	145	0.9
545	Point Arena S-----	38 57	123 45	-1 30	-1 30	0.3	0.3	330	1.1	150	1.1
550	Point Cabrillo I S-----	39 21	123 50	-1 40	-1 40	0.3	0.3	345	1.0	165	1.0
355	Cape Ventana I-----	39 44	123 50	-1 50	-1 50	0.3	0.3	325	0.9	145	0.9
560	Point Delgada S-----	40 00	124 04	-1 35	-1 35	0.3	0.3	325	1.0	145	1.0
565	Punta Gorda S-----	40 40	124 22	-1 35	-1 35	0.3	0.3	335	1.1	155	1.1
570	Cape Mendocino Lt., 4.6 miles W. of *	40 26	124 30	---	---	---	---	---	---	---	---
575	Tablazo B Light S-----	40 42	124 17	-1 10	-1 10	0.3	0.3	010	0.9	190	0.8
	HUMBOLDT BAY										
580	Humboldt Bay entrance -----	40 45	124 14	-1 00	-0 45	0.6	0.6	125	1.6	310	2.0
585	Point Humboldt, channel west of -----	40 45	124 14	-1 10	-0 55	0.5	0.3	195	1.4	225	1.0
590	Eureka, channel W. of -----	40 42	124 11	-1 05	-0 55	0.6	0.5	015	1.8	210	1.6
595	Eureka, channel north of -----	40 48	124 10	-1 15	-1 05	0.2	0.2	105	1.5	285	0.5
600	Sampson channel I-----	40 49	124 11	-1 00	-1 10	0.4	0.3	045	1.2	205	1.1
	CALIFORNIA COAST—Continued										
605	Trinidad Head S-----	41 03	124 10	-0 55	-0 55	0.3	0.3	X!	1.0	165	1.0
610	Redding Rock Light S-----	41 21	124 11	-0 50	-0 50	0.3	0.3	010	0.9	190	0.9
615	St. George Reef S-----	41 49	124 20	-0 40	-0 40	0.3	0.3	005	1.0	155	1.0

* Data do not apply during freshets.

† Data approximate.

"See "Coastal Tidal Currents," p. 235.

Table 3-3. Tidal Current Time Differences, Velocity Ratios, and Maximum Currents for Northern and Central California (NOAA, 1978)

No.	PLACE	POSITION		Time				RANGES		Mean Tide Level
		Lat.	Long.	Time		Height		Mean	Di-	
				High water	Low water	High water	Low water			
				h. m.	h. m.	feet	feet	feet	feet	feet
	CALIFORNIA									
	Outer Coast									
	on LOS ANGELES									
487	Po i nt Argue 1 I O-----	34 35	120 39	+0 44	+0 41	*0.96	*0.96	3.5	5.2	2.7
489	W i l l a Beach, San Luis Obispo Bay-----	35 10	120 44	+0 47	+0 52	*0.98	*0.98	3.6	5.3	2.8
491	Porro Beach, Estero Bay-----	35 24	120 52	+0 55	+0 54	*0.96	*0.96	3.5	5.2	2.8
493	San S imeon-----	35 38	121 11	+0 59	+0 56	*0.96	*0.96	3.5	5.2	2.7
495	Carmel CAVE, Carmel Ba y-----	36 31	121 56	+1 11	+1 11	*0.96	*0.96	3.5	5.2	2.8
	on SAN FRANCISCO									
497	Monterey, Monterey Bay-----	36 36	121 54	-1 16	-0 58	-0.5	0.0	3.5	5.3	2.9
499	Santa Cruz, Monterey Bay-----	36 58	122 01	-1 19	-1 04	-0.5	0.0	3.5	5.3	2.8
501	San Nuevo ls I and-----	37 06	122 20	-1 28	-1 10	-0.6	-0.1	3.5	5.2	2.7
503	Tr i nceton, Ha I fmoon Bay-----	37 30	122 29	-1 10	-0 56	-0.2	0.0	3.8	5.5	3.0
505	Southeast Farallon Is l and-----	37 42	123 00	-0 43	-0 25	-0.2	0.0	3.8	5.6	3.0
507	San Franc i sco Bar-----	37 46	122 38	-0 39	-0 37	-0.1	0.0	3.9	5.6	3.0
509	Ocean Beach, outer coast-----	37 46	122 31	-0 53	-0 41	+0.2	0.0	4.2	6.0	3.2
671	Bol i nas by-----	37 54	122 41	-0 29	-0 17	0.0	0.0	4.0	5.7	3.1
673	Bolinas, Bol i nas Lagoon-----	37 55	122 41	-0 20	to 31	0.74	0.73	3.0	4.4	2.3
675	Po i nt Reyes-----	38 00	123 01	-1 05	-0 37	0.0	+0.1	3.9	5.7	3.1
677	Toma I es Bay entrance-----	38 14	122 59	-0 16	+0 10	0.88	0.91	3.5	5.4	2.7
679	Marsha I I, Toma I es Bay-----	38 10	122 54	+0 34	+1 10	-0.5	-0.1	3.6	5.4	2.8
681	Inverness, Toma I es Bay-----	38 06	122 51	+0 36	+1 18	-0.5	-0.2	3.7	5.7	2.8
683	Bodega Harbor entrance-----	38 18	123 03	-0 42	-0 22	-0.1	+0.1	3.8	5.7	3.1
685	Fort Ross-----	38 31	123 15	-0 55	-0 36	-0.1	0.0	3.9	5.7	3.0
667	Po i nt Arena-----	38 57	123 44	-0 46	-0 27	0.0	0.0	4.0	5.8	3.1
689	Al b I on-----	39 14	123 46	-0 35	-0 25	0.0	0.0	4.0	5.8	3.1
691	L i t t l e River Harbor-----	39 16	123 47	-0 35	-0251	0.0	0.0	4.0	5.8	3.1
693	Mendoc i no, Mendoc i no Bay-----	39 18	123 48	-0 42	-0 27	0.0	0.0	4.0	5.8	3.1
695	Fort Bragg Land 1 rig-----	39 27	123 49	-0 34	-0 26	+0.1	0.0	4.1	5.8	3.1
696	Koyo River-----	39 25	123 48	-0 35	-0 18	to. 7	+0.1	4.1	6.0	3.2
697	Westport-----	39 3a	123 47	-0 35	-0 28	0.0	0.0	4.0	5.8	3.1
699	She I ter Cave-----	40 02	124 04	-0 43	-0 23	+0.3	+0.1	4.2	6.0	3.3
701	Depe Mendoc i no-----	40 26	124 25	-0 32	-005'	0.0	0.0	4.0	5.7	3.1
	on HUMBOLDT BAY									
703	Se I R I ver entrance-----	40 38	124 19	-0 36	-0 32	-0.1	0.0	4.4	6.3	3.4
	Humboldt Bay									
705	Entrance-----	40 46	124 15	-0 14	-009	-0.2	0.0	4.3	6.2	3.3
707	HUMBOLDT BAY (South Jetty)-----	40 45	124 14					4.5	6.4	3.4
709	F i e I ds Land i rig-----	40 43	124 13	+0 03	+0 03	+0.3	-0.1	4.9	6.7	3.6
711	Hookton S lough-----	40 41	124 13	+0 10	+0 09	+0.5	0.0	4.8	6.6	3.6
713	Bucksport-----	40 46	124 12	+0 07	+0 07	+0.1	0.0	4.6	6.5	3.5
715	Eureka-----	40 48	124 10	+0 29	+0 32	+0.3	0.0	4.8	6.7	3.5
716	Samoa-----	40 49	124 11	+0 32	+0 21	+0.6	0.0	5.1	7.0	3.8
717	Arcata Wharf-----	40 51	124 07	+0 43	+0 36	+0.6	+0.1	5.0	7.0	3.8
719	Tr i n I i ad Harbo-----	41 03	124 09	-0 37	-0 40	+0.1	0.0	4.6	6.4	3.5
721	Crescent Ci ty-----	41 45	124 12	-0 32	-0 29	+0.6	0.0	5.1	6.9	3.7

*Ratio.

†Data apply only during low river stages.

found 8 to 32 km (5 to 20 mi) from the coast. Open ocean tidal currents are rotary currents and in a period of 12.5 hours will have set in all directions of the compass. The tidal current offshore of California usually changes direction in a clockwise manner. Instead of slack-water periods with no current as in coastal areas, periods occur when the current is at a minimum. Tidal currents in the open ocean are usually weaker, about 30 cm/sec (60 ft/min) .

Bottom Currents. Bottom currents are produced by the wind, tides, gravity and local currents such as the California and Davidson Currents. The flow of a bottom current is periodically affected by local events such as river discharge or turbidity flows. As a current flows over the ocean bottom, the velocity will increase as the bottom topography opens into basins or valleys and decrease as the flow encounters a ridge or an escarpment. Table 3-4 presents extreme bottom current particle velocities for various depths (with orders of confidence) likely to occur over a century along the California coast. The Eel River and Point Arena basins contain areas with high bottom current velocities; these are discussed in Volume IV, Chapters 25 and 26 (Bourke, et al., 1977) .

Table 3-4. Extreme Bottom Current Particle Velocity (cm/sec) Likely to be Observed Over a Century Along the California Coast (from Riffenburgh, 1973)

Confidence Bound (Probability)	Depth			
	200	100	50	20
0.80	337	329	249	228
0.90	348	340	260	292

Sustained bottom current speeds of 0.6 cm/sec (0.2 in/sec) and maximum near 1.7 to 2.3 cm/sec (0.7 to 0.9 in/sec) have been recorded in the study area. The dominant northward drift and relative lack of variability in monthly bottom current averages indicate the existence of a year-round northward flowing near-bottom current near the coastline.

Upwelling. Coastal upwelling is characteristic of broad, diffuse eastern boundary currents such as the California Current. Coastal upwelling is the process whereby water from below the surface ascends to replace surface waters moving offshore by the process of Ekman transport. Sverdrup (1938) found that nearshore regions where horizontal surface flow cannot compensate for waters driven offshore, the balance of water is maintained by the ascent of subsurface water. Upwelling waters have a higher oxygen and nutrient content and a lower temperature than surface waters. Upwelling effects on nutrients, temperature and oxygen, salinity and density are discussed in Chemical Oceanography . When wind blows over water it exerts a force on the surface in the direction of the wind. At some depth in the water both the current and the frictional forces associated with it become negligibly small. The entire layer above that depth, in which friction is important, is termed the Ekman layer. Within the Ekman layer net movement of water is theoretically at a right angle (90°) to the wind direction while the surface current movement in shallow coastal waters is usually about 45° to the wind direction while the surface current movement in shallow coastal waters is usually at an angle of about 45° to the wind direction. This is caused by frictional forces and the Coriolis effect. Along the California coast, coastal mountains deflect the surface winds so that they blow parallel to the coast. The winds blow toward the Equator, and thus, Ekman flow is offshore or to the right off the California coast. Several studies were conducted to develop empirical expressions relating wind velocity and surface drift current speed (Tomczak, 1965; NOS, 1978; Blaskovick, 1973). For engineering purposes one generally assumes that the wind drift current speed at the surface is 3 to 4% of the wind speed. In coastal regions, the Ekman transport of surface waters causes upwelling.

Wickett, et al., (1968) and Wickett and Thomson (1971) developed surface transport and Ekman transport charts for the North Pacific Ocean covering the years of 1946-1949 and 1970, respectively. A separate chart exists for each month of the year showing the direction of water movement by vector representation.

Because wind magnitude and direction vary seasonally, coastal upwelling varies both regionally and seasonally. Upwelling is dominant along the California coast during periods of strong north and northwest winds, mid-February through August. Major upwelling occurs in May and June off the central California coast and in June and July off the northern California coast (Reid et al., 1958). The most intense upwelling sites are south of capes and peninsulas and near submarine canyons. The upwelling zone extends out to 50 to 100 km (30 to 60 mi) offshore. When the axis of the northerly winds is close to shore, the upwelling zone width will be narrow. Upwelling area width decreases with increasing latitude (Bourke, et al., 1977).

Wooster and Reid (1963), Bakun (1973), and Bakun, et al. (1974) used surface temperatures and offshore Ekman transport to describe the locations and seasonal timing of the major coastal upwelling regions in terms of "upwelling indices." South of Cape Blanco, Oregon (43° N latitude), an abrupt increase in offshore Ekman transport occurs in June and July, and sea surface temperatures are suppressed until upwelling begins to subside in August.

Major upwelling in the study area occurs during the upwelling season at Crescent City, Cape Mendocino, Fort Bragg, Point Arena, Drakes Bay, Half Moon Bay and Monterey Bay. Cape Mendocino has the maximum upwelling intensity for any area along the California coast. During spring, a gradual warming of surface waters normally occurs along the coast (Bourke, et al., 1977). Figure 3-10 indicates upwelling areas along the California coastline. An extensive offshore upwelling occurred during April 1973 and extended from Crescent City to south of San Francisco. This upwelling created an abnormality in the general warming trend (Pirie and Steller, 1975).

Upwelling can extend out to the Continental Slope but usually occurs over the inner Continental Shelf. Upwelling waters originate from as deep as 200 to 300 m (656 to 984 ft) but usually come from depths of less than 100 m (330 ft) but usually come from depths of less than 100 m (330 ft). Intense upwelling, apparent in alternating low and high temperatures, indicates that the phenomenon occurs in tongues or streaks. During upwelling water temperatures along the coast can be up to 5° colder than surface water 25 to 30 km (16 to 19 mi) out to sea (Bourke, et al., 1977).

The vertical speed of upwelling water near the coast is approximately 10-3 cm/sec. Figure 3-11 shows a summary of annual temperatures at two stations off the coast of California. These temperatures were observed at 10 m (33 ft) below the surface every month for 13 years (1950-62). In each of the summaries, the

- 1) straight horizontal line is the 13-year mean water temperature,
- 2) curved solid line is the mean monthly temperature,
- 3) curved broken lines are one standard deviation from the mean,
- 4) dots are observed temperature values,
- 5) correlation coefficients are given.

Station number 70.52 is nearest to the coast and the upwelling effects are the most obvious; colder temperatures occur from April into September. Station 70.70 is seaward of the intense upwelling which is still apparent by the relatively cool maximum temperatures. The temperature minimum here is in February- March and the maximum is in September.

Slope Currents. Differences in the level of the sea produced by lighter density water overlying denser water induce slope currents. During the fall and winter months, river discharges, particularly in northern California, are of sufficient magnitude to cause slope currents.

Swells and Seawaves

The Pacific anticyclone (high pressure cell) is important to wave generation along the California Coast, especially during summer when it dominates the meteorological circulation. During these months, the predominant wave action is generated by the prevailing west-northwest to north-west winds along the coast (National Marine Consultants, 1960).

Extratropical cyclones (low pressure storms) are the most important source of storm waves reaching the California coast. These storms usually originate near Japan and proceed eastward across the Pacific to the Gulf of Alaska. Sea waves generated in the southwest sectors of these storms reach California but usually show a steady decrease in energy intensity southward along the coast (National Marine Consultants,

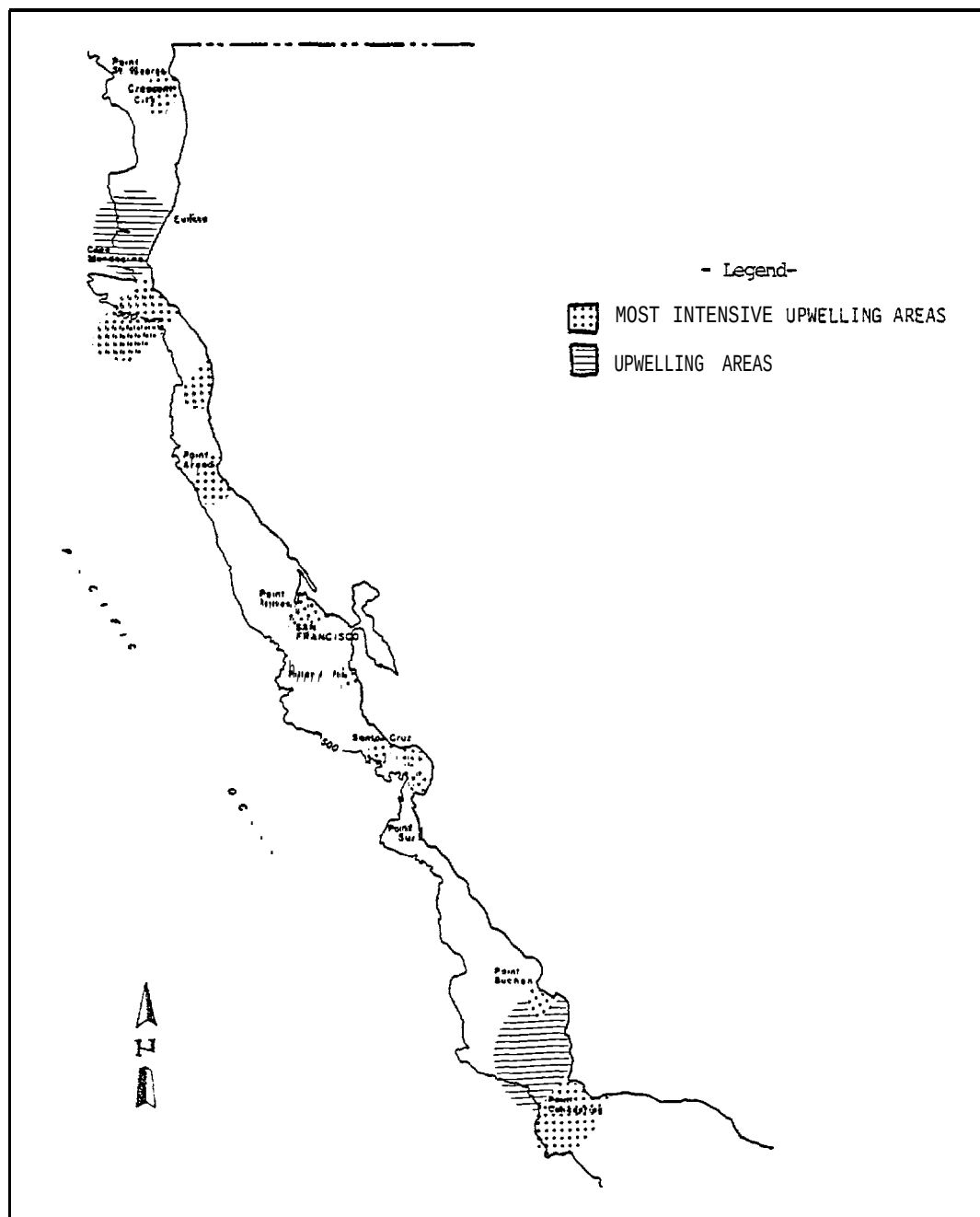


Figure 3-10. Coastal Upwelling Areas for Northern and Central California

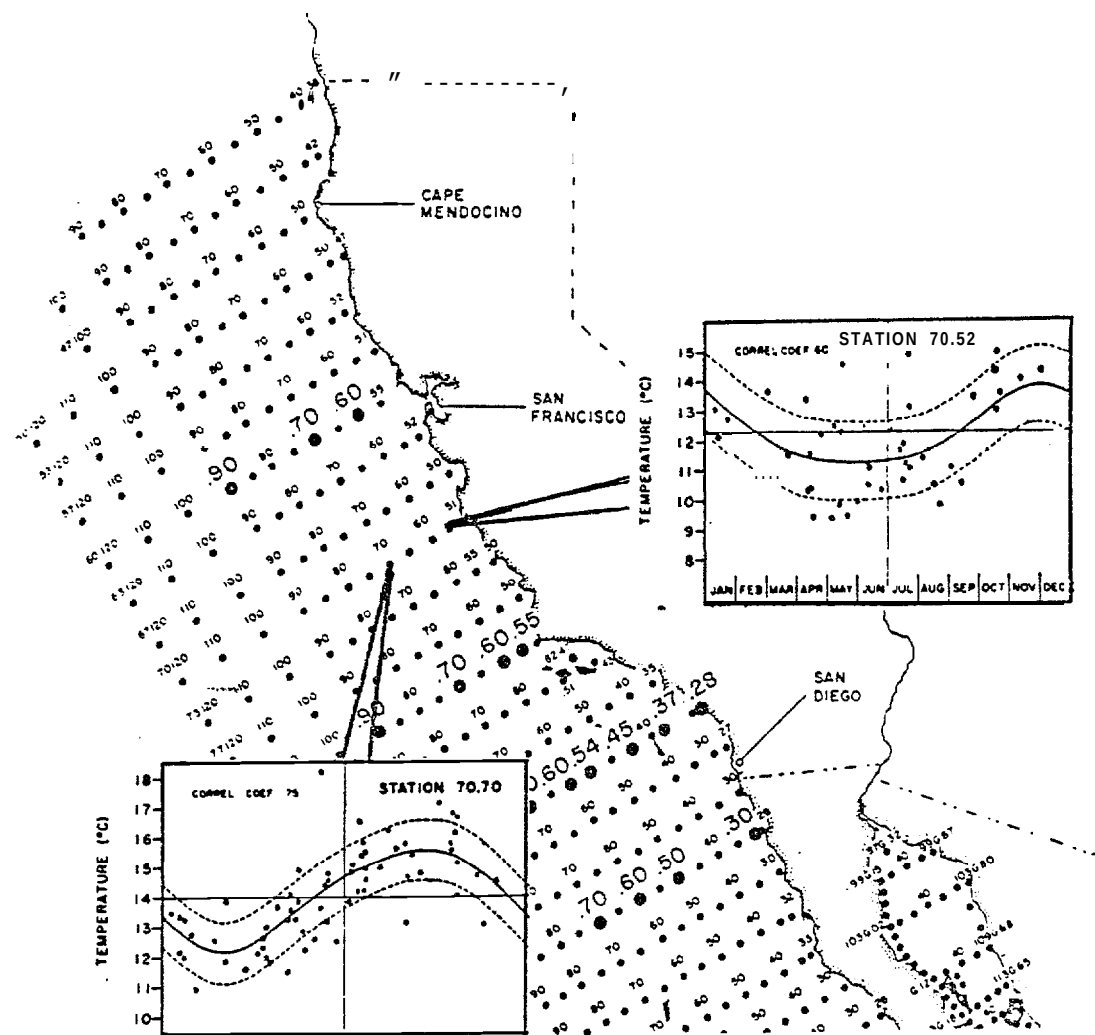


Figure 3-11. Water Temperature (°C) Summaries of CALCOFI Data Showing the Influence of Cool Upwelling Waters for Two Stations Near Pt. Sur. (Interagency Ad Hoc Task Force, 1973)

1960). The winds associated with these extra-tropical storms seldom attain hurricane force, although some coastal locations in northern California (Cape Mendocino and Point Reyes) have recorded gusts to 160 km/hr (100 mi/hr) at times. The extent of the extratropical storm in terms of duration and fetch can produce hurricane magnitude waves that last for a long period (Bourke, et al., 1977).

Wave Characteristics. National Marine Consultants (1960) hindcasted three years of weather maps to obtain ocean wave statistics for seven deep-water stations along the California Coast (see Figure 3-12). Hindcasting is the process of statistically analyzing data from past years into a form that can be used to forecast future conditions. These data are presented as monthly average frequency distribution tables and annual average tables and wave roses. The annual average wave directional roses for stations 1 to 5 are presented in Figures 3-13 to 3-17. The directional rose in the center of each diagram shows a frequency distribution of wave direction. The histograms surrounding the rose are a frequency distribution of wave height for each direction. Two such diagrams are presented for each station, one for sea waves and one for swells. Frequencies are given as percent of total time based on 365.3 days a year.

National Marine Consultants (1960) also hindcasted the ten most severe storms affecting stations 1, 2 and 3 during the period 1951-60. The maximum significant wave height calculated for each storm at each station is shown in Table 3-5. These hindcasted storms form the basis for severe wave climate calculations for the California coast. These data indicate that wave heights during severe storms are similar for California coastal areas north of San Francisco. The intensity of waves is an important factor influencing coastal processes. Johnson (1972) states that the total deepwater wave power (sum of sea and swell) available at the shoreline is about constant northward of 40° latitude. Southward of this latitude the deepwater wave power decreases with decreasing latitude. These conclusions are based on National Marine Consultants data (1960).

Table 3-5. Maximum Wave Heights (ft.) for Ten Most Severe Storms
Affecting Three Selected Stations Off Northern California
During the Period 1951-1960
(from National Marine Consultants, 1960)

Date	Wave Height		
	Station 1	Station 2	Station 3
Dec 1951	26	20	18
Dec 1952	22	20	16
Jan 1953	20	21	20
Feb 1954	23	21	18
Mar 1956	20	20	15
Feb 1958	20	19	18
Apr 1958	20	24	26
Nov 1958	21	21	20
Feb 1959	20	23	20
Feb 1960	32	34	33

¹Station No's. 1, 2 and 3 on Figure 3-12.

The direction of wave approach changes upon entering shallow water. This process, known as wave refraction, occurs because the part of the wave still in deeper water moves faster than the part that has entered the shallower water. The crest of the wave becomes parallel to the bottom depth contours in shallow water. See Vol. 1, Chapter 4, Waves.

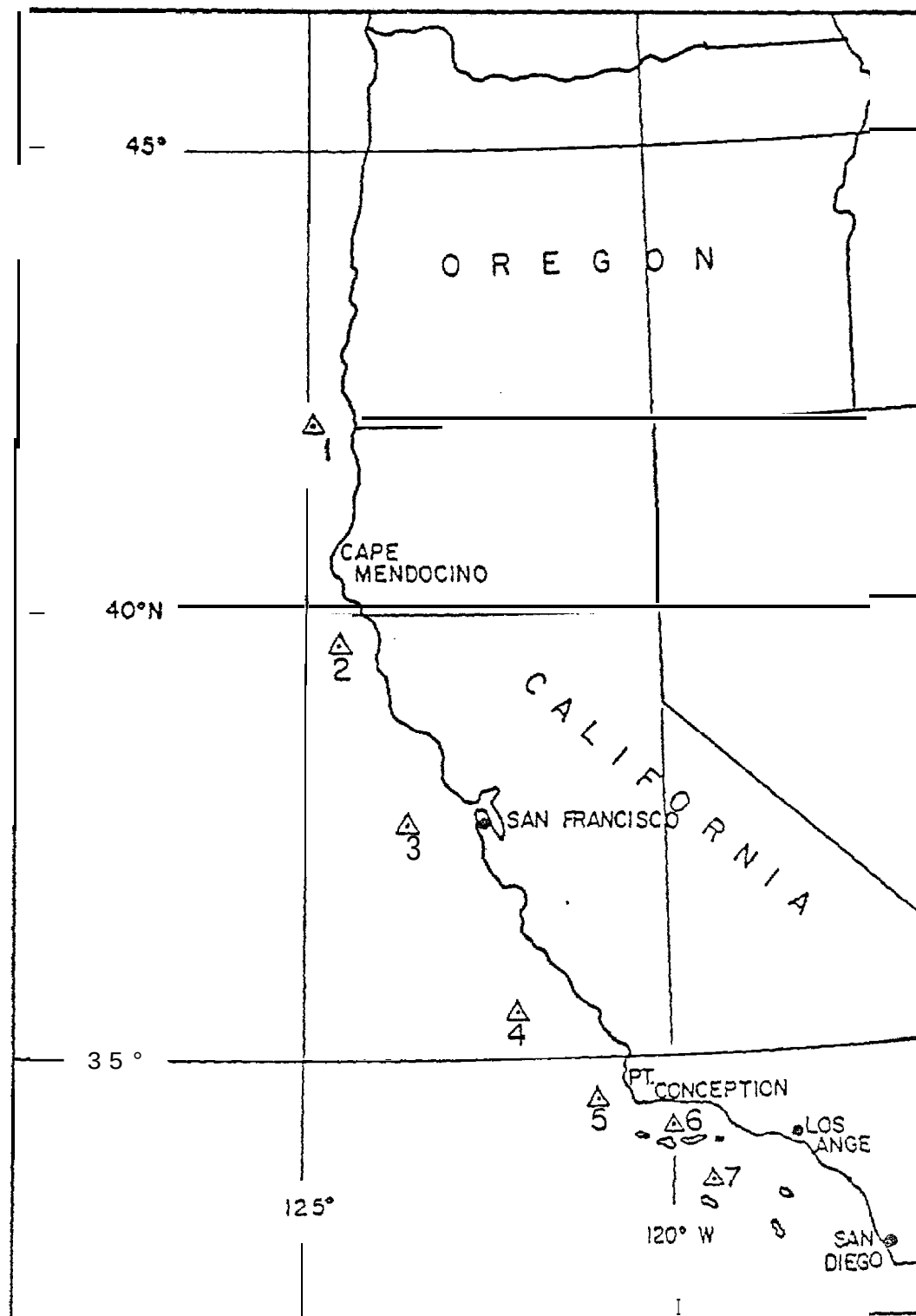


Figure 3-12. Location of National Marine Consultants Hindcast Stations--(see Table 3-5 and Figures 3-13 to 3-17; National Marine Consultants, 1960)

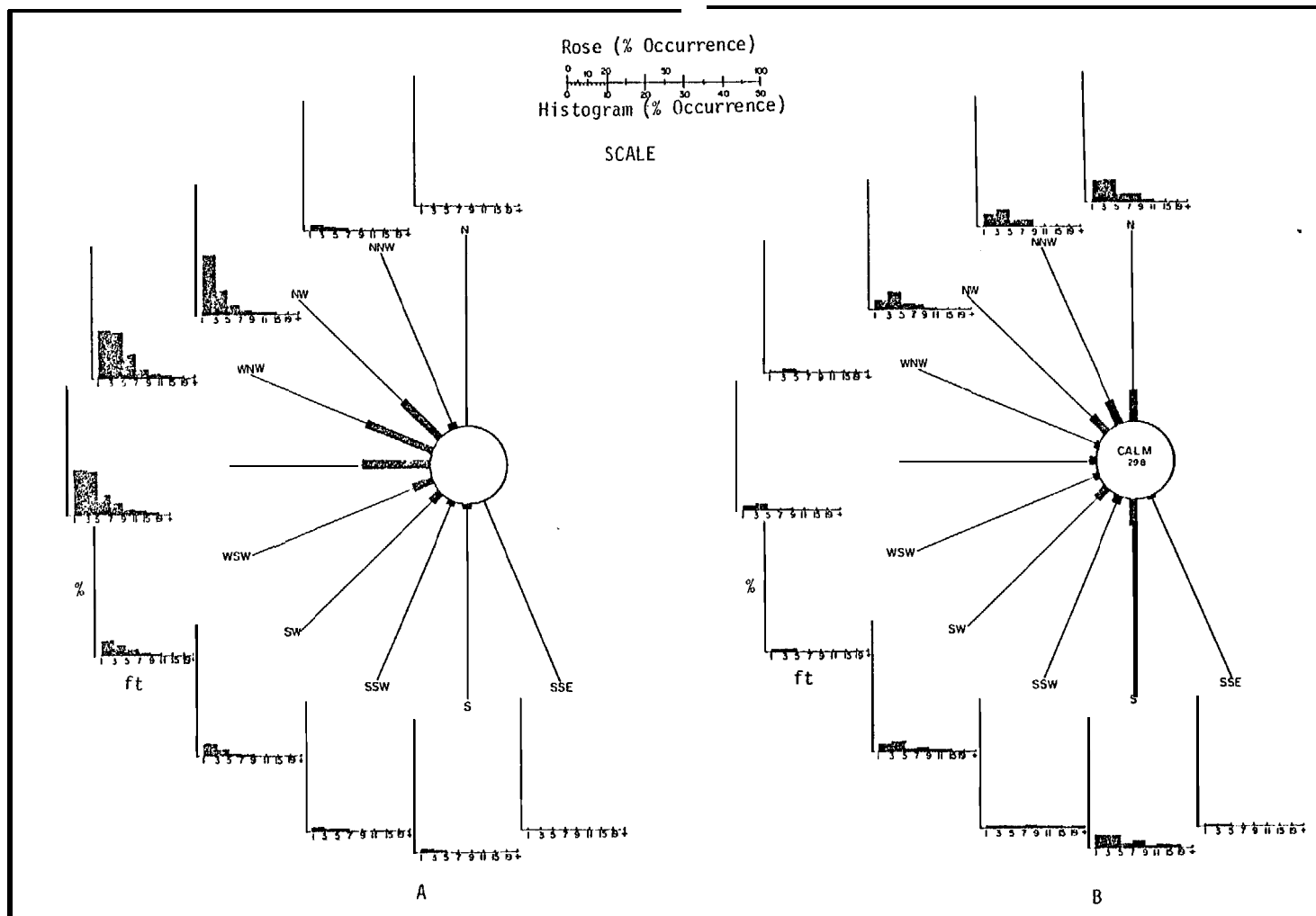


Figure 3-13. Average Annual Swell (A) and Sea (B) Roses for Hindcast Station 1, California-Oregon Border (see text for figure explanation; National Marine Consultants, 1960)

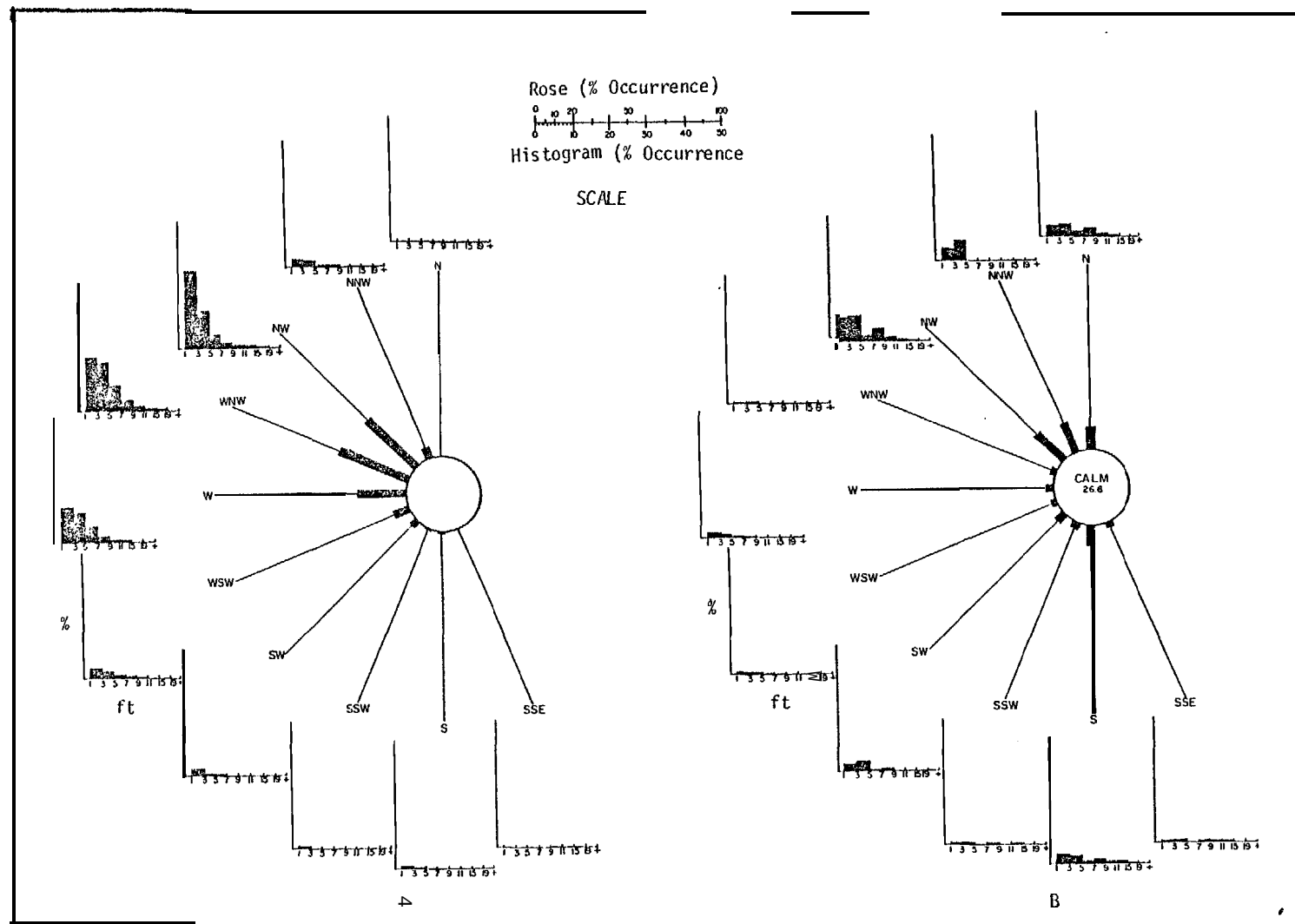


Figure 3-14. Average Annual Swell (A) and Sea (B) Roses for Hindcast Station 2, Humboldt Bay (see text for figure explanation; National Marine Consultants, 1960)

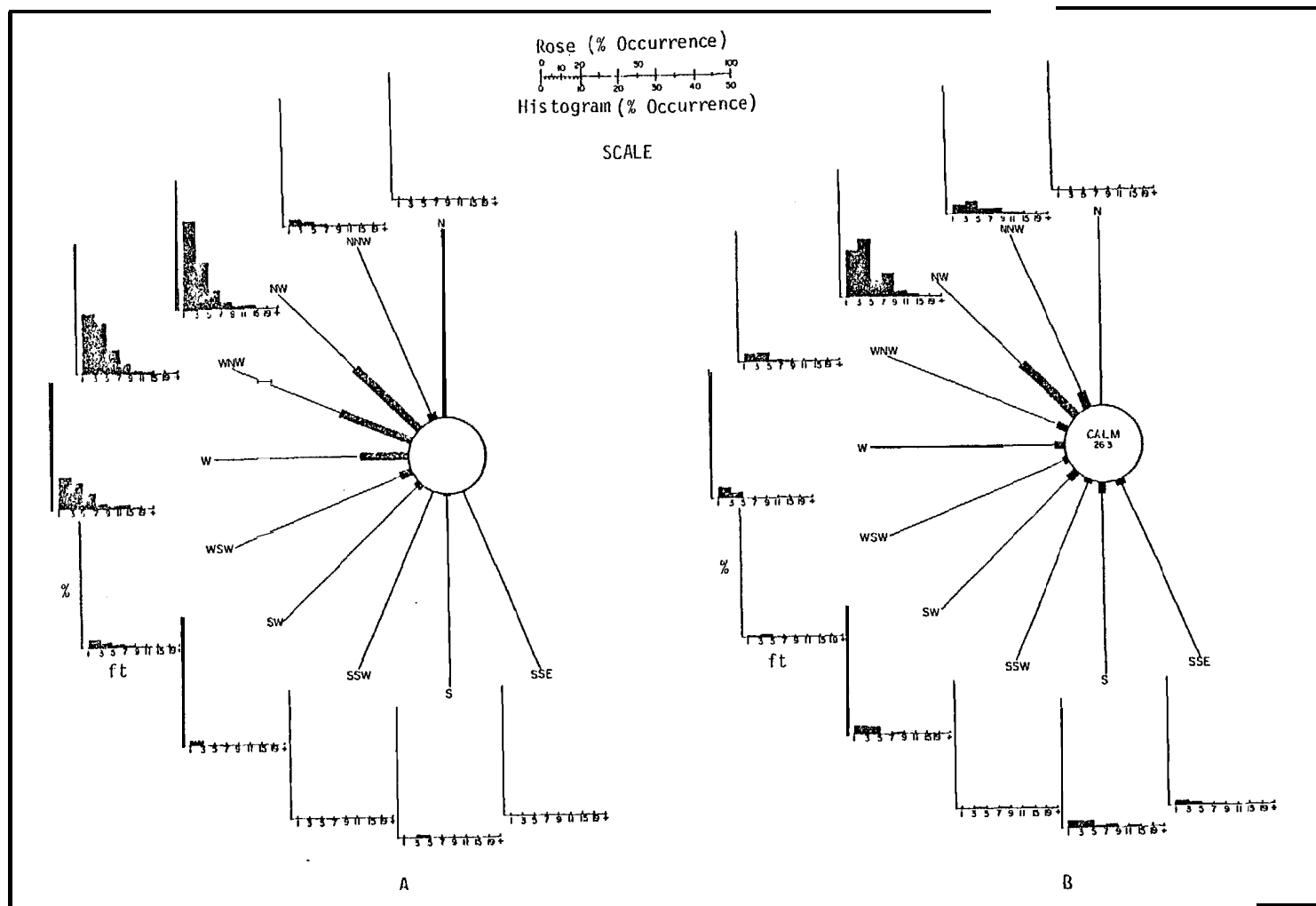


Figure 3-15. Average Annual Swell (A) and Sea (B) Roses for Hindcast Station 3, San Francisco (see text for figure explanation; National Marine Consultants, 1960)

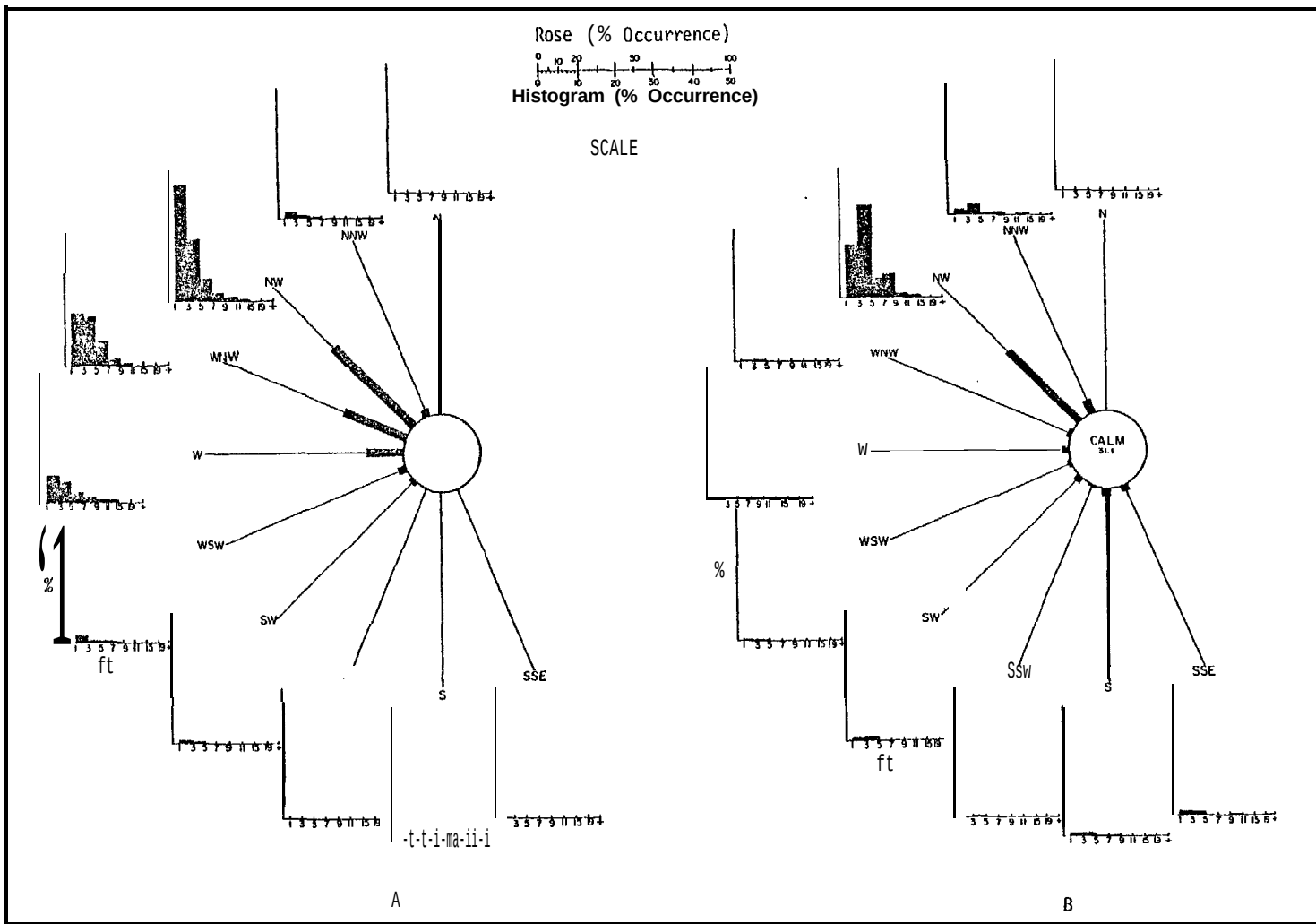


Figure 3-16. Average Annual Swell (A) and Sea (B) Roses for Hindcast Station 4, San Luis Obispo (see text for explanation; National Marine Consultants, 1960)

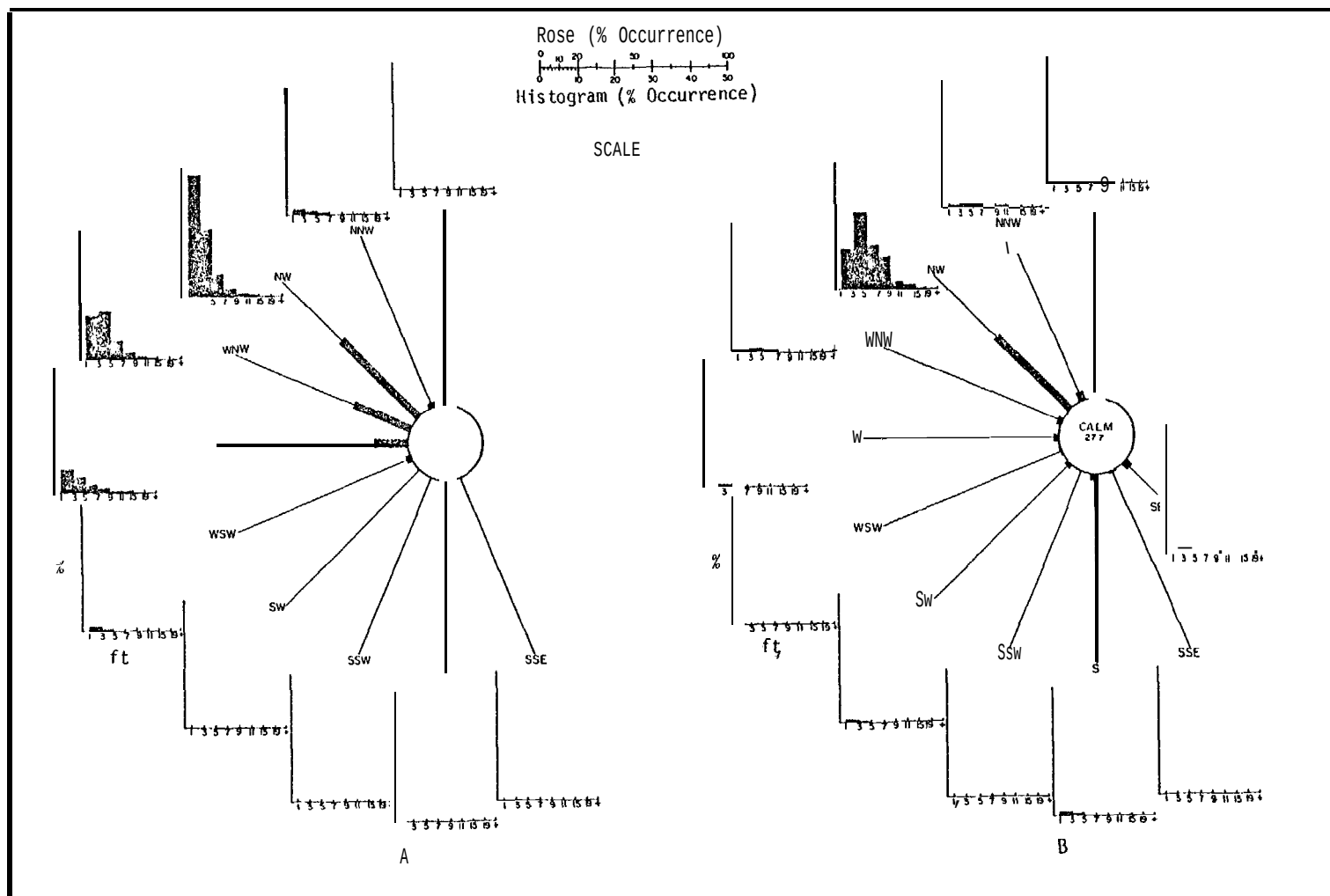


Figure 3-17. Average Annual Swell (A) and Sea (B) Roses for Hindcast Station 5, Point Conception (see text for explanation; National Marine Consultants, 1960)

The wave hindcasts represent wave conditions in deep water. The waves must be shoaled and refracted if they are to represent wave conditions in shallower water near the coast. The refraction of waves is dependent on the local bathymetry so that each location along the coast must be studied separately. Where a promontory juts out from the coast, waves tend to converge at the headland, leading to a selective erosion of the headlands. Where a submarine valley cuts into a sloping beach there is divergence of the wave fronts. All improved inlets and harbors have refraction diagrams completed for these locations; the refraction diagrams are available from the U.S. Army Corps of Engineers. Refraction diagrams are also made for construction projects such as piers and outfall pipes.

Additional references on California wave data can be found in Bourke, et al., (1977). The California Coastal Engineering Data Network (DNOD, 1977b) documents nearshore wave characteristics and has one station in the study area - Santa Cruz Harbor.

Tsunami

Over 500 tsunami (see Vol. I, Chapter 4, Tsunami) have been reported within recorded history. Most occurred in the Pacific Ocean because the zones of greatest submarine seismic activity are the fault zones predominately found in the Pacific Ocean. The tsunami generated by the Alaskan earthquake of 1964 arrived at high tide and reached 19.7 feet (6 m) above the mean high water level in Crescent City, California, killing 11 people. That tsunami event caused major damage along the California coast including inside San Francisco Bay. A hazard and potential for tsunami damage exist along the entire coastline of all five ocean basin units in the study area. The hazard and damage potential vary, depending upon the coastal terrain, the nearshore topography, and the extent of development within the inundation zone.

Predicted tsunami runups vary greatly along the coast, even within a few miles. In the study area, the 100-year runups range from 1.2 m to 4.3 m (4 ft to 14 ft) and 500-year runups range from 1.8 m to 8.5 m (6 ft to 28 ft). These data are based on numerical modelling techniques (Houston and Garcia, 1978). Crescent City is the only California Coastal location with sufficient records to predict future tsunami. Most developed coastal areas are located on headlands and bluffs higher than the predicted runups. The greatest risk and potential for tsunami damage exist at harbors and boat facilities, and at a few low-lying communities, for example Crescent City. See also tsunami discussion in Vol. I, Chapter 4, Tsunami and with each watershed unit (Vol. IV, Chapters 3 - 24, Tsunami) and each ocean basin unit (Vol. IV, Chapters 25 - 29, Tsunami).

Oceanic and Coastal Sediment Transport

Sediment Transport at Beaches. Sediments are transported along and form distinctive geomorphological features of the coast. The five most common geomorphological coastal features characterizing the California coast as summarized by the Department of Navigation and Ocean Development, State of California (DNOD), are: 1) littoral (along the shore) cells terminating in submarine canyons; 2) deltas stabilized between headlands; 3) crescent (crenulate or arcuate) bays; 4) crenulate spits; and 5) parallel alignments. Figure 3-18 is an illustration of each feature.

1) Littoral transport or drift is the movement of sediments along the coast, and is the result of waves breaking at an angle to the coast and generating a littoral current (see Vol. I, Chapter 4, Coastal and Oceanic Sediment Transport). Littoral cells terminating in canyons form a complete system. Sediments are supplied usually from a river and move downcoast due to wave action. Sediments form a continuous sandy beach until they reach a submarine canyon extending into the nearshore. The head of the canyon serves as a sink, siphoning off the sand and effectively blocking littoral transport of sand. Littoral cells are essentially closed systems in the alongshore direction. Within the study area, Point Santa Cruz to Monterey Canyon and Pines Point to Monterey Canyon have been identified as major littoral cells terminating in submarine canyons. In addition, Cape Mendocino to Mattole Canyon and Puntos Gorda to Delgada Canyon appear to be littoral cells,

2) Large delta areas are characteristically formed by large rivers flowing into the ocean over broad low plains. Along the rocky California coast, delta flood plains commonly are located between two rocky headlands which provide partial wave protection and partial sediment barriers. Equilibrium conditions can exist with sediment from the river balancing sediment losses transported around the headlands.

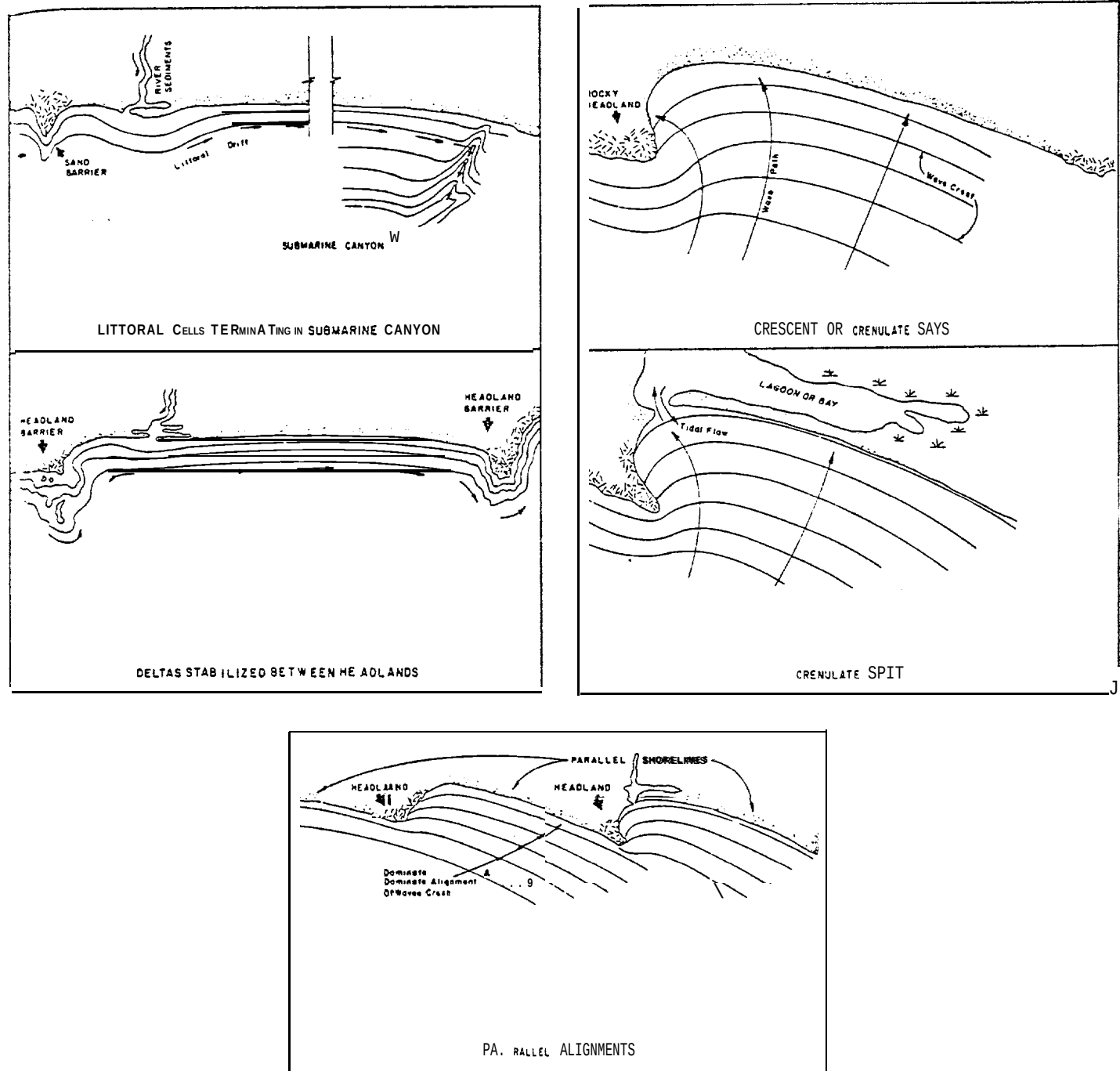


Figure 3-18. Geomorphological Features of California (DNOD, 1977a)

Large floods result in accretion, but the sand is moved out of the cell by waves. These systems appear to be reasonably stable in terms of the gross shoreline position, but river flooding can move the location of outlets and substantially alter the lagoon configuration. Six major deltas of this type are identified along the northern California coastline including: 1, the Smith River Delta between Point St. George and Pyramid Point; 2, Redwood Creek Delta, including Big and Stone Lagoons, between Patricks Point and Mussel Point; 3, the Humboldt Bay complex of deltas, composed of the combined deltas of the Salt, Eel and Mad Rivers, and Little Creek, between False Cape and Tepona Point; 4, the Bear River between Cape Mendocino and False Cape; 5, the Mattole River Delta between Punta Gorda and Mattole Point; 6, the Ten Mile River Delta from Laguna Point to Ten Mile River Bluff.

3) Crescent or crenulate bays are formed down coast of a headland or rocky outcropping when there is a sediment supply and waves approach predominantly from one direction. An equilibrium configuration is reached when the beach matches the refraction pattern of the waves around the outcropping. Major examples of crenulate bays in Northern California are the bay at Crescent City (modified by breakwater), Shelter Cove at Point Delgada and Half Moon Bay.

4) Crenulate spits are a special landform associated with the crenulate bay where tidal marshes or lagoons are situated inshore of the curving coastline. The spit encloses the curved coastline (see Figure 3-18) and the tidal inlet becomes stabilized near the protecting headland. Examples of this form are Bodega Bay, Bolinas Bay and Drakes Bay.

5) Beaches tend to an equilibrium alignment perpendicular to the incident waves. With a sufficient sediment source and predominant wave direction, individual shorelines of beaches will have a parallel alignment between rocky headlands. After reaching equilibrium, excess sand will be carried around the headlands or inland. Formation of dunes may occur wherever the land behind the coast is low and flat and there is a sufficient sediment source. Examples of parallel beaches include: 1, Manchester State Beach, north of Point Arena (sediment input from Garcia River at the downcoast end and dune field losses); 2, Ten Mile River Beach (input from Ten Mile River at upcoast end and large dune fields); 3, beaches along Pelican Bay, north of Point St. George (input from Smith River at upcoast end and heavy dune fields); 4, Salmon Creek Beach, north of Bodega Head (dune fields); 5, beaches north of Point Sal and Mussel Point (input from Santa Maria River and extensive dunes); 6, beaches north of Purisima Point (limited input and dunes); 7, beaches north of Point Pedernales and Point Arguello (input upcoast from Santa Maria River and dunes),

Sediment Sources. The major source of beach sand is from streams and rivers. Secondary contributions come from shells and cliff erosion. Northern California has more rainfall than other parts of California (see Precipitation). In that area, major rivers flow throughout the year and carry sediments to the shoreline. South of San Francisco (some researchers have placed the boundary as far north as Cape Mendocino), many streams and rivers are blocked by stream-mouth spits which are breached only occasionally by short periods of strong flow. During flood periods a new supply of sediments is brought to the beaches where it joins the littoral system. Central California streams and rivers therefore do not have a great influence on adjacent beaches throughout much of the year, but they influence beach mineralogy during periods of heavy flow.

Littoral Transport. A review of the wave climate, and hence the winds that generate the waves, is necessary in order to understand the differences in littoral processes observed along the California coast. A permanent high-pressure zone persists in the eastern Pacific (see Climatology, Pressure and Winds and Physical Oceanography, California Current System).

The direction of the waves during the winter is dependent on location along the California coast. South of Cape Mendocino, the predominant waves are from the west and northwest. North of Cape Mendocino, the winds can have a strong northerly component, resulting in waves from the south part of the time (National Marine Consultants, 1960). As a result of these wave directions, the dominant littoral drift is from north to south in most of the study area. However, north of Cape Mendocino, a reversal of the predominant littoral drift direction may occur and sediment moves from south to north during winter months. The intensity of waves is the greatest in northern California and generally decreases southward. Figures 25-6, 26-3, 27-6, 28-4, and 29-3 in Vol. IV, Chapters 25 through 29, Sediment Transport, indicate the direction of littoral drift within each of the five ocean basin units.

Sediment Budgets and Heavy Mineral Studies. Yancey and Lee (1972) have summarized the heavy mineral studies along the Central California Coast and Coast Ranges extending from the Russian River to Monterey Bay (no heavy mineral studies were conducted north of the Russian River). Included in their study were the works of Sayles (1965), Yancey (1968) and Wilde, et al. (1969). Five major heavy mineral assemblages are deduced, four apparently derived from major geologic terrains within the Coast Ranges of California and the fifth derived from the Sierra Nevada of California and transported via the Sacramento-San Joaquin River system to the coast (see Vol. II, Sediments, Figure 3-47). Each assemblage is named for the combination of minerals that appears to define it. The transport of the minerals is generally to the south in response to the prevailing northwesterly waves impinging on the coast. Reversals (to the north) occur in the lee of headlands at Bodega Head, Drakes Bay, and Bolinas Bay.

Judge (1970) studied the heavy minerals as indicators of shore processes between Monterey and Los Angeles. Beach sediments between Monterey Bay and Pt. Conception may be divided into five heavy-mineral provinces. The epidote (for definition, see Vol. I, Chapter 3, Mineralogical Composition of Sediments) province extends from the central part of the area to Point Conception. Hornblende and augite provinces exist north to Monterey. It was found that the primary sources of sand supplied to the beaches are from rivers and sand moved downcoast by longshore transport. In general, the rivers supply sediment to the beaches only during short periods of high discharge, and therefore the mineralogy of the river sands does not correlate well with that of adjacent beaches. The predominant direction of littoral transport is southward; however, reversals occur locally.

Continental Shelf Sediment Transport. No data exist on the transport, deposition, or resuspension of sediments over the middle and outer continental shelves of Central and Northern California (Andrews, 1977). Most of the relatively few sediment samples have been taken from the easier-sampled nearshore region. Between the Eel and Klamath Rivers, the midshelf deposit is mostly silt with a thickness of about 14 m (46 ft) (Silver, 1969); the surficial sediment grades to silty-clay on the outer shelf. In the vicinity of the Russian River the few midshelf samples suggest a muddy substrate (Cherry, 1965).

Limited data exist off the Oregon coast (Komar, et al., 1972), Washington (Smith and Hopkins, 1972; Sternberg and McManus, 1972) and Southern California (Gorsline and Grant, 1972; Drake, et al., 1972) coasts. The results of the above studies are not completely applicable to the study area because the Southern California shelf is protected by the offshore Channel Islands and the Washington shelf is broader and has a more intense wave climate. However, some of the findings from these studies are applicable to the Central and Northern California shelf and are discussed below. The discussion which follows on continental shelf sediment transport processes is taken mainly from a collection of papers in the principal work on this subject, Shelf Sediment Transport: Process and Pattern (Swift, et al., 1972).

Ocean sediments move either as bedload in the near-bottom region or as suspended load which moves essentially with the flow. Suspended sediments are generally smaller grained than bedload materials. Near-bottom residual currents over the shelf and mass transport velocities induced by surface gravity waves transport sediments (Weggel, 1972). Wave motion is more significant in the shallow nearshore region where the wave-induced fluid motion is more intense at the bottom.

Creager and Sternberg (1972) have identified three environmentally distinct regions on the continental shelf off Washington. Nearshore, where water depths are less than 50 m (164 ft), sediment movement is mainly due to wave motion or wave surge. The sediments here are large being only about 10 percent silt. Between water depths of 50 to 145 m (164 to 476 ft.), the sediments are mostly silt (40 to 70 percent by weight) chiefly derived from river deposition. These mid-shelf sediments are transported by wind drift currents. On the outer shelf, in water depths greater than 145 m (476 ft.), the median grain size increases and the silt content decreases due to decreased supply. Wind drift current systems appear to dominate this zone also.

Sternberg and McManus (1972) re-evaluated the extensive near-bottom current meter data of Hopkins (1971) in light of sediment transport dynamics. They found that the stronger bottom currents were related to wind stress associated with storm conditions rather than wave surge. Current measurements 3 m (10 ft) above the sea floor indicated frequent occurrences of speeds in excess of 40 cm/sec (1.3 ft/sec) (the assumed threshold velocity of sediments) and greater than 80 cm/sec (2.6 ft/sec) during severe storms. When averaged over monthly and annual cycles, net

current directions were predominantly northward. Cross-shelf sediment dispersal was also indicated by the large directional variability. Maximum annual sediment particle displacement was estimated to be 220 km (140 mi) to the northwest.

Smith and Hopkins (1972) emphasized the importance of storms to the sediment transport process. On the central shelf, about 50 percent of the sediment is sand which moves as bedload (sediments dragged along the bottom) while 50 percent is silt which moves as suspended load. During a storm the net motion of the suspended load fraction is nearly twice as great as the bedload fraction. Assuming four severe storms per year, a typical silt particle is expected to move 80 km/yr (50 mi/yr) while an average particle would move 40 km/yr (25 mi/yr). During these severe storms, bottom materials a few millimeters to over a centimeter deep are eroded. Redeposition results in the silt settling back on top of the sand to form a layered, even graded, bed. Fine sand from the nearshore region is transported offshore only during severe storms when it moves as suspended load. Between storms, sand is trapped near the coastline by the onshore wave-driven bottom currents. The implication from the above study is that a severe storm occurring every few years might have more geological significance than a large number of moderate storms.

In contrast to the sediment motion by near-bottom wind drift currents suggested by Creager and Sternberg for the middle and outer continental shelf, Komar, et al., (1972) present evidence of bottom sediment reworking by wave motion out to depths as great as 204 m (669 ft). Ripple marks, aligned parallel to the coast, were found across the entire shelf off of Oregon. The shelf is relatively narrow there and the wave climate is severe. Bottom orbital velocities capable of rippling the sediments to water depths of 150 to 200 m (492 to 656 ft) were calculated to be commonly present during winter storm conditions. In summer, with reduced wave severity, rippling was expected up to bottom depths of 50 to 100 m (165 to 330 ft). In addition to causing rippling, the severe wave conditions could resuspend bottom sediments so that they then drift with the net current.

The finer sediments on the continental shelves typically are thought to be derived from the weathering and erosion of geologic materials on the land and their subsequent transport by rivers. Meade (1972) points out that this may be the case for some two dozen of the world's major rivers, but that elsewhere two other sources of suspended matter may be important. These two sources are organic matter produced in the waters of the shelf and Recent or relict bottom sediments which can be resuspended. Shubel and Okubo (1972) indicated that most river-borne suspended material is trapped in the estuaries of rivers and that material escaping the estuaries is transported across the shelves in suspension and deposited on the continental slope, continental rise, or sea floor. Belts of mud often found deposited on the mid-shelf arise from diffusive transport across the shelf to deposition sites where wave and tidal activity are relatively lower than on the inner or outer shelf. Outer shelf mud deposits are caused by higher than average concentrations occurring during advective mudstreams (McCave, 1972). Sediments can be transported from the shelf to the slope and rise through a variety of transport mechanisms such as cascading of cold water off the shelf in winter, water movement down submarine canyons, bottom Ekman layer transport downslope under major ocean boundary currents, and cascades of lutite flows (low concentration turbidity currents) (McCave, 1972).

Erosion and Man's Impact. A large part of the California shoreline undergoes erosion from natural causes. Waves eroding the coastline tend to level and straighten the land mass they encounter. This phenomenon is opposed locally by the sediments brought to the shoreline by coastal streams and rivers that create deltas extending into the ocean. Erosion, however, is predominant in coastal California. The rate of erosion is dependent upon climatic conditions and varies both seasonally and over periods of years. Major shoreline erosion tends to be episodic, occurring during periods of high waves. High waves coincide with spring tides, which occur only once or twice a year, and with major infrequent storms occurring once in 20 to 25 years (DNOB, 1977b).

On shorelines where the cliffs are directly exposed to the waves without a beach, cliff erosion depends on several factors. Rocks with high erodibility and unconsolidated sediments are particularly vulnerable to erosion. Some geologic materials deteriorate rapidly where exposed to the weathering effects of air and water. If there are varying degrees of hardness, indentations or sea caves are cut into the less resistant geologic formations, eventually causing collapse of the overlying harder materials. The angle at which bedding layers lie relative to the shoreline affects the probability of slides, particularly in shales, sandstone, and other sedimentary rock formations. Groundwater seepage, either from natural sources

or those induced by man (such as irrigation or septic tanks), can weaken the formation. Retreat of a shoreline will be slower if the cliffs are high and massive (lacking bedding planes, joints and faults); it will take longer for the waves to remove the large quantities of material. If the sea cliffs are of uniform material the waves are likely to straighten the shoreline; whereas, if there are varying degrees of hardness, indentations will be cut into the less resistant material, creating coves, and leaving the harder materials as protruding headlands or promontories. Wave erosion of a cliffed coast produces a gently inclined surface of bedrock called a plinth terrace or wave-cut terrace. The terrace is submerged just below the water surface and is backed by steep cliffs. Along the tectonically active coast of California, series of old marine terraces which have been uplifted above the present sea level are characteristic. The upraised marine terraces have a step-like configuration, and each terrace represents an erosion cycle which was interrupted by the uplift of the coastline. The rate of cliff retreat is difficult to measure and depends upon a number of factors such as geology, groundwater seepage, and exposure to wave energy. Cliff erosion occurs only periodically under attack of storm waves, and it may not be obvious unless it occurs next to some fixed point such as a structure or has been photographed at different points in time. Little is known about the erosion rate along most of the coast, except where development has been endangered by erosion. Only a few sections of the California shoreline have been monitored over a period of time (DNOD, 1977a).

A common feature of the rocky California coastline is a landform type termed a stack or sea stack. The landform is a small island of resistant rock which is the remnant of cliff erosion and retreat. Sea stacks are commonly used by birds and mammals as congregating areas. Wave erosion eventually erodes the stack away, reducing it to the same level as the wave-cut terrace at its base. A less common feature, but also a characteristic landform of the California coastline is the sea arch. A sea arch is an arch created by the differential erosion of rock. Waves erode the rock at the base of the formation, excavating the arch. The landform is common where more resistant rock overlies weaker rock. Eventually wave erosion removes the basal support of the arch and it collapses, leaving two stacks as remnant landforms.

The greatest impacts caused by man on littoral processes have been harbor development for commerce and recreation, and flood control systems to protect the flood plains of coastal streams. Breakwaters and jetties alter the movement of sand along the shore (see, for example, the discussion of the impacts of jetty construction on Morro Bay, Vol. IV, Chapter 19, Estuaries and Lagoons). The sand may be trapped inside in the form of shoals, offshore in the form of bars, and on the up-current side of a jetty which acts as a dam to alongshore transport. If the sand does not bypass the improved harbor, the downcoast beaches are deprived of their sand supply and erode. The structures may also alter the wave patterns due to reflection and diffraction so that the adjacent shoreline will readjust until it reaches a new configuration in equilibrium.

The U.S. Army Corps of Engineers mapped land use, ownership, beach material, and erosion areas for the coast of California in their National Shoreline Study (CORPS, 1971),

Flood control measures on rivers and streams that empty into the ocean reduce the sediment supply to the beach by trapping sediment in reservoirs and reducing the flood flows. Stream capacity for moving sediment does not increase proportionately to stream flow but instead increases to approximately the sixth power of the flow velocity. Hence, it is the floods that move large quantities of sand to the beaches. Controlled flow to avoid floods, although possibly allowing the same total discharge over the year, greatly reduces the sediment carrying capacity of the stream. Flood control systems affect beaches to varying degrees. If a beach is dependent on a certain quantity of sand to sustain its size and shape, a small reduction in supply can result in serious erosion. The general processes and relationships are understood, but each case is different.

Other factors affecting sediments at beaches, but to a much lesser degree, are sand mining and destabilization of sand dunes, Magoon, et al., 1973, reviewed the coastal sand mining from the Oregon border to Monterey. South of Monterey the only mining is located at the Santa Ynez River (Bowen and Inman, 1966). Sand mining is a net loss to the littoral regime and can result in deleterious effects if the sand is not replaced by nature.

Sand dunes are nature's store of sand created over geological time. The sand dunes can be stabilized by natural vegetation or plantings by man. Destruction of

dune vegetation by recreational vehicle and other human uses, can result in destabilization of the dune. The sand can then be blown inland or offshore and lost from the littoral system. Erosion is generally only recognized as a problem if it affects man. Since most of the California coast is in a state of natural erosion, developments built too close to the shoreline will eventually have erosion problems.

Basin Studies. Specific information is available for a large number of beaches from studies conducted primarily by the University of California and the U.S. Army Corps of Engineers. There is a general lack of shelf sediment information.

The University of California beach studies are reported in a large number of Hydraulics Laboratory Reports and cover the area from the Oregon border to Point Lobos. The U.S. Army Corps of Engineers (1965) in a cooperative beach erosion study for Northern California studied the geomorphology, wave climate, beach profiles and sediment characteristics at 22 beaches between Shelter Cove and Point Año Nuevo. The U.S. Army Corps of Engineers in 1975 extended the cooperative Beach Erosion Study to include beaches between Point St. George to Point Lobos.

A Littoral Environment Observation (LEO) program was initiated in California in 1967. LEO is a cooperative effort of the State of California and the U.S. Army Corps of Engineers (Szuwalski, 1970). The objective is to establish a bank of repetitive, systematic measurements of meteorological and oceanographic forces affecting the shoreline and the response of the shore to these forces. The data collected are being used as a base to analyze physical characteristics of the shoreline and the littoral processes affecting it. Twenty State Park Beaches are included in the LEO program.

The Department of Navigation and Ocean Development, State of California (DNOD) has published an atlas on littoral transport, coastal geomorphology and erosion problem areas (DNOD, 1977a). A discussion of sediment transport for each ocean basin unit is presented in Vol. IV, Chapters 25 through 29.

Density of Seawater

The vertical density structure of California coastal waters closely parallels that of the temperature structure. Isopycnals (contour lines of equal density) ascend toward the coast. Where isopycnals descend near the coast below the 100 m (330 ft) depth an apparent association exists with a poleward undercurrent (Wooster and Reid, 1963).

Temperature and salinity are discussed in Chemical Oceanography.

CHEMICAL OCEANOGRAPHY

Much of the nearshore physical and chemical oceanography data along the California coast comes from the California Cooperative Oceanic Fisheries Investigations (CalCOFI) reports and atlases (see Chapter 3, Physical Oceanography).

Chemical Composition of Sea Water

Wyllie and Lynn (1971) determined mean surface-layer depths from CalCOFI data for each month. They defined the mean surface-layer depth as the depth where the temperature differs from that at the sea surface by more than 1.1 degree Celsius (°C) or 2 degrees Fahrenheit (°F). One must realize that this is an "artificial" definition created for the purpose of Wyllie and Lynn's study and does not always represent the true surface or mixed layer depth. Figure 3-19 shows mean surface-layer depths for the months of January, May and September between San Francisco and Point Conception. Those months were chosen to represent the Davidson Current period, the upwelling period and the oceanic period respectively. The temperature found at 10 m (33 ft) is representative throughout the layer, the mean thickness of which is given by those charts. In January, the surface-layer depth extends to 70 m (230 ft) whereas the maximum nearshore surface-layer depth in May and September is 30 m (98 ft).

Temperature, salinity, oxygen and phosphate data for depths to 1,500 m (4,921 ft) have been compiled from the National Oceanographic Data Center's (NODC's) oceanographic station data files (Churgin and Balminksi, 1974). Those data were obtained primarily from Nansen casts (a Nansen bottle is a water sampling instrument)

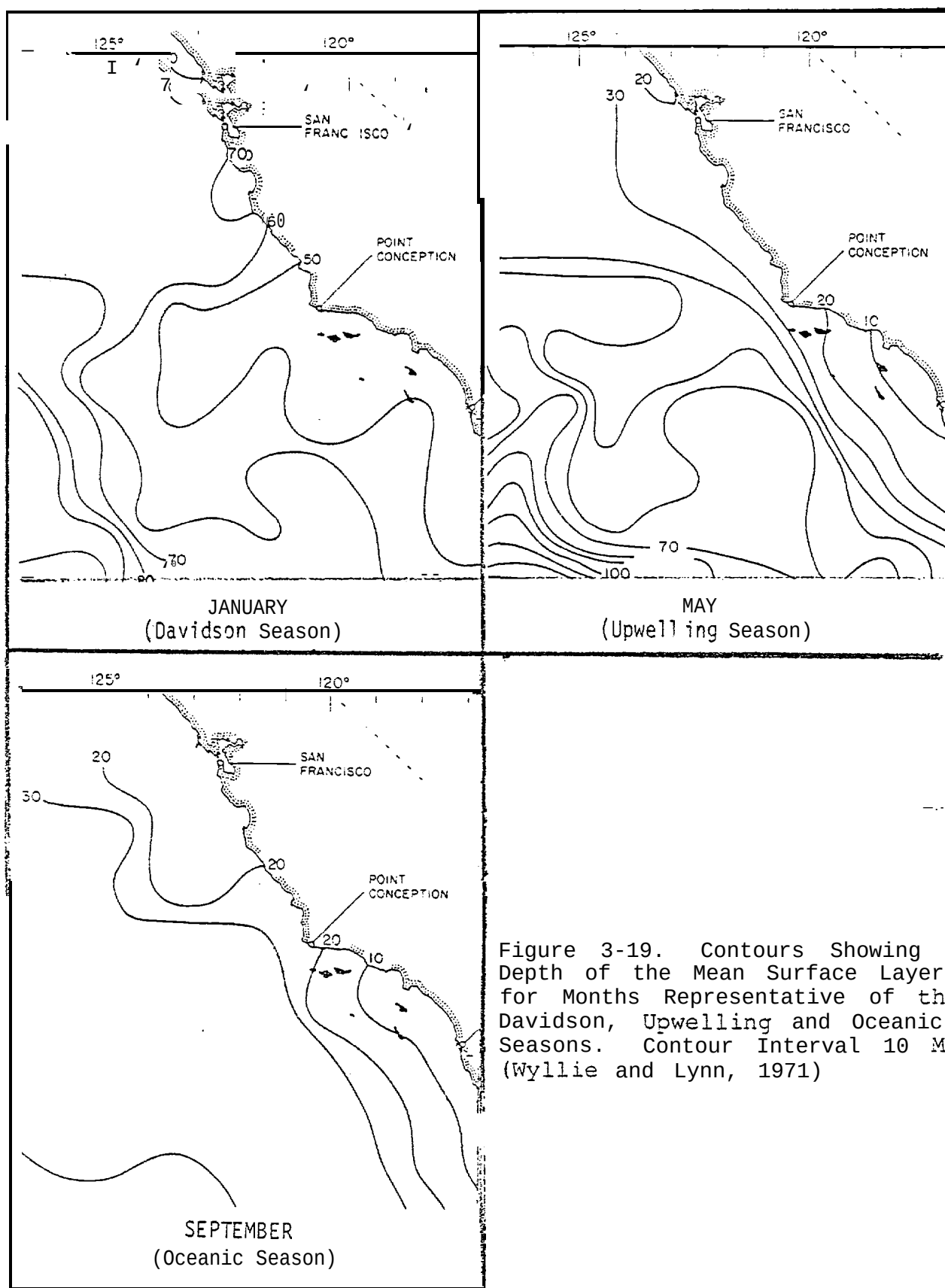


Figure 3-19. Contours Showing the Depth of the Mean Surface Layer for Months Representative of the Davidson, Upwelling and Oceanic Seasons. Contour Interval 10 Meters. (Wyllie and Lynn, 1971)

over a period of more than 50 years (from before 1920 to 1970), and are presented as temperature-salinity composites, vertical array summaries, station distribution plots and histograms. Temperature, salinity, oxygen and phosphate annual vertical array summaries and histograms are presented in the discussion for each ocean basin unit in the study area (see Vol. IV, Chapters 25-29, Chemical Oceanography).

Temperature

Ocean water temperatures along the California coast respond to seasonal current changes, wind direction, insolation and upwelling. Winter water temperatures are elevated above expected seasonal lows because of the intrusion of warm, saline waters of the Davidson Current. Upwelling during spring and summer reduces the temperature of waters near the surface that have been warmed by high summertime insolation.

The thermal structure is similar for most coastal profiles in that temperatures near the surface are lower nearshore causing isotherms to ascend toward the coast. The general coastward rise of the thermocline is indicative of the distribution of mass associated with the equatorward geostrophic circulation (Wooster and Reid, 1963).

Ten-meter isotherms for the offshore areas of California based on CalCOFI cruise data are presented in Figure 3-20 (Willie and Lynn, 1971). Ten-meter temperatures were averaged for the years 1950 to 1959 to produce the mean isotherms for June and October, at which time the upwelling and oceanic periods respectively occur. This ten-year period was adopted by the Eastern Pacific Oceanic Conference, EPOC, Lake Arrowhead, CA, 1959, as the reference period for the surface water temperatures of the Pacific Ocean. The January-February isotherms for 1960 are considered to be representative of the Davidson Current period.

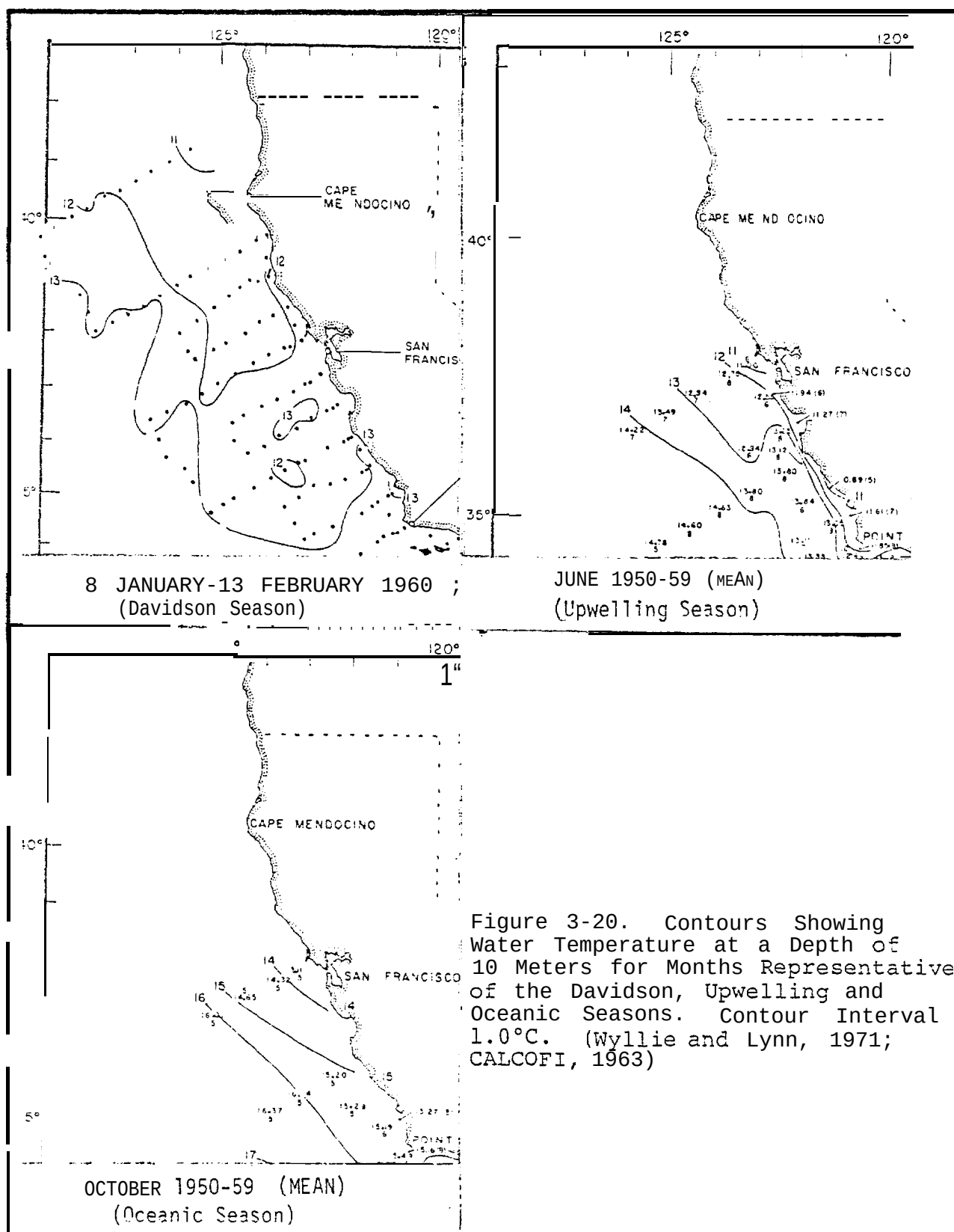
Isotherms tend to parallel the coast, with cooler water temperatures closer to shore. In general, the coolest water temperatures occur off of California in the winter, 11° to 13°C (52° to 55°F), and the warmest water temperatures occur in the fall, 14° to 16°C (57° to 61°F), after upwelling has ceased. Surface water temperatures only vary a few degrees between nearshore waters, i.e., within 97 km (60 mi) of the coast, and offshore waters. Seasonal maximum temperatures of 14° to 15°C (57° to 59°F) occur inshore and maximums of 16° to 18°C (61° to 64°F) occur offshore. The maximum temperatures occur later in central and northern California than in southern California.

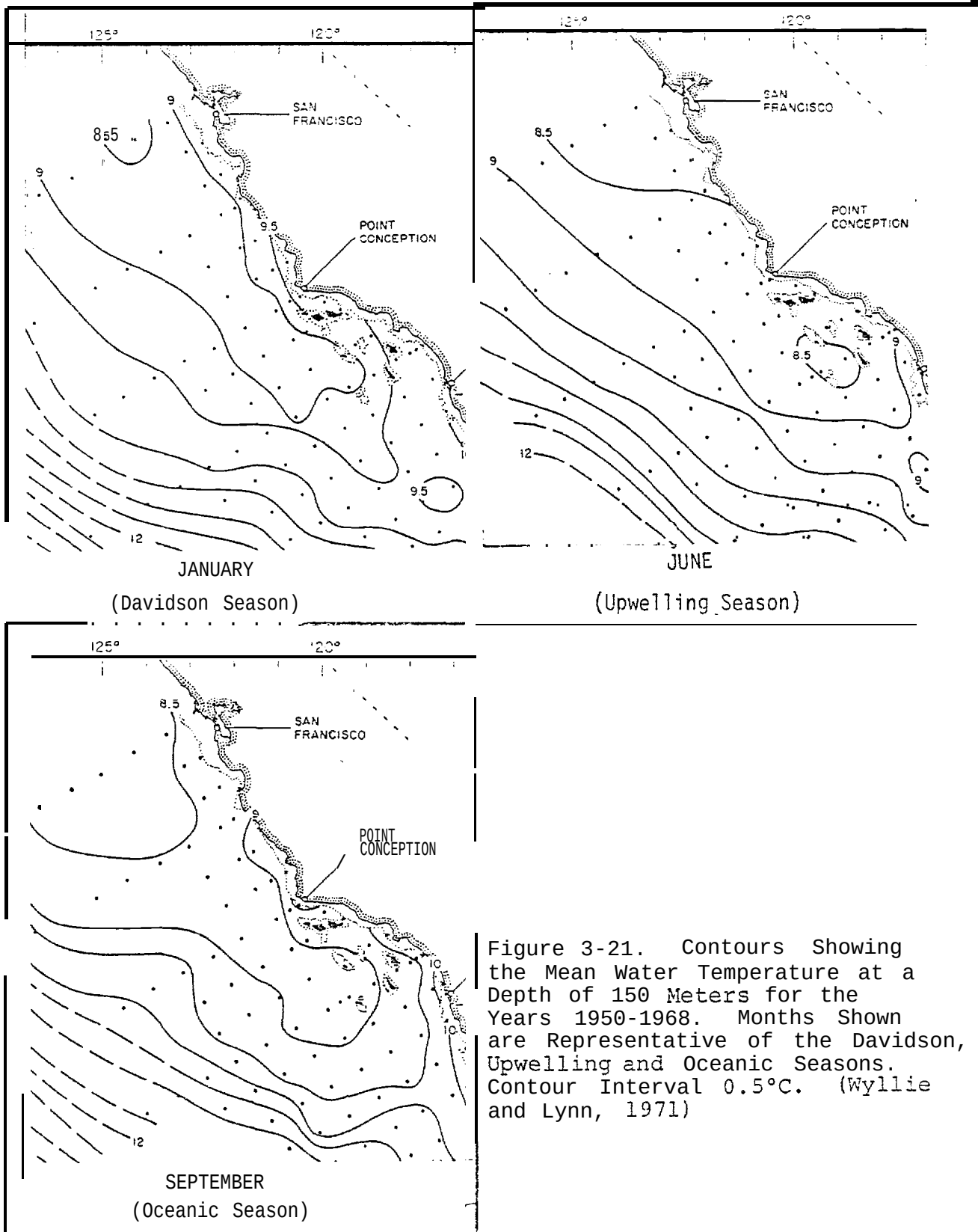
When upwelling occurs in spring and summer, the near-coastal water temperatures are colder than winter water temperatures. This relationship exists (see Figure 3-20) during the month of June for water temperatures in the area between Point Conception and San Francisco. Cooler water temperatures are especially apparent between San Francisco and Point Arena where maximum upwelling occurs in California.

Mean 150-meter depth isotherms for the coast of California from 1950 to 1968 are shown in Figure 3-21 (Willie and Lynn, 1971). Coastal water temperature at the 150-meter (492-ft) depth varies only 1°C (1.8°F), from 8.50 to 9.50°C (47° to 49°F). Near-coastal waters at this depth have similar temperatures during the Davidson Current (January) and oceanic current (September) periods, but during the upwelling period (June) cooler waters are close to the shoreline.

The offshore distribution of temperature is not well researched for the northern California coast. Near-coastal waters during winter in northern California have a mean temperature of 9°C (48°F), whereas the offshore mean water temperature beyond 185 km (116 mi) is about 12°C (53°F). From July to November, nearshore water within 93 km (58 mi) of the coast has a temperature between 10° to 14°C (50° to 57°F). Northern California water temperatures during the upwelling period are about 8 to 9°C (46 to 48°F) (Bourke, et al., 1977).

Periodically an anomaly or large variance from the normal or mean conditions occurs in the physical-chemical characteristics of oceanic waters. Figure 3-22 compares monthly mean 10-meter temperatures for the years 1950 to 1959 to actual observed temperatures at two CalCOFI stations off Point Conception. During the years 1967 to 1968, surface water temperatures were abnormally low throughout the two-year period.





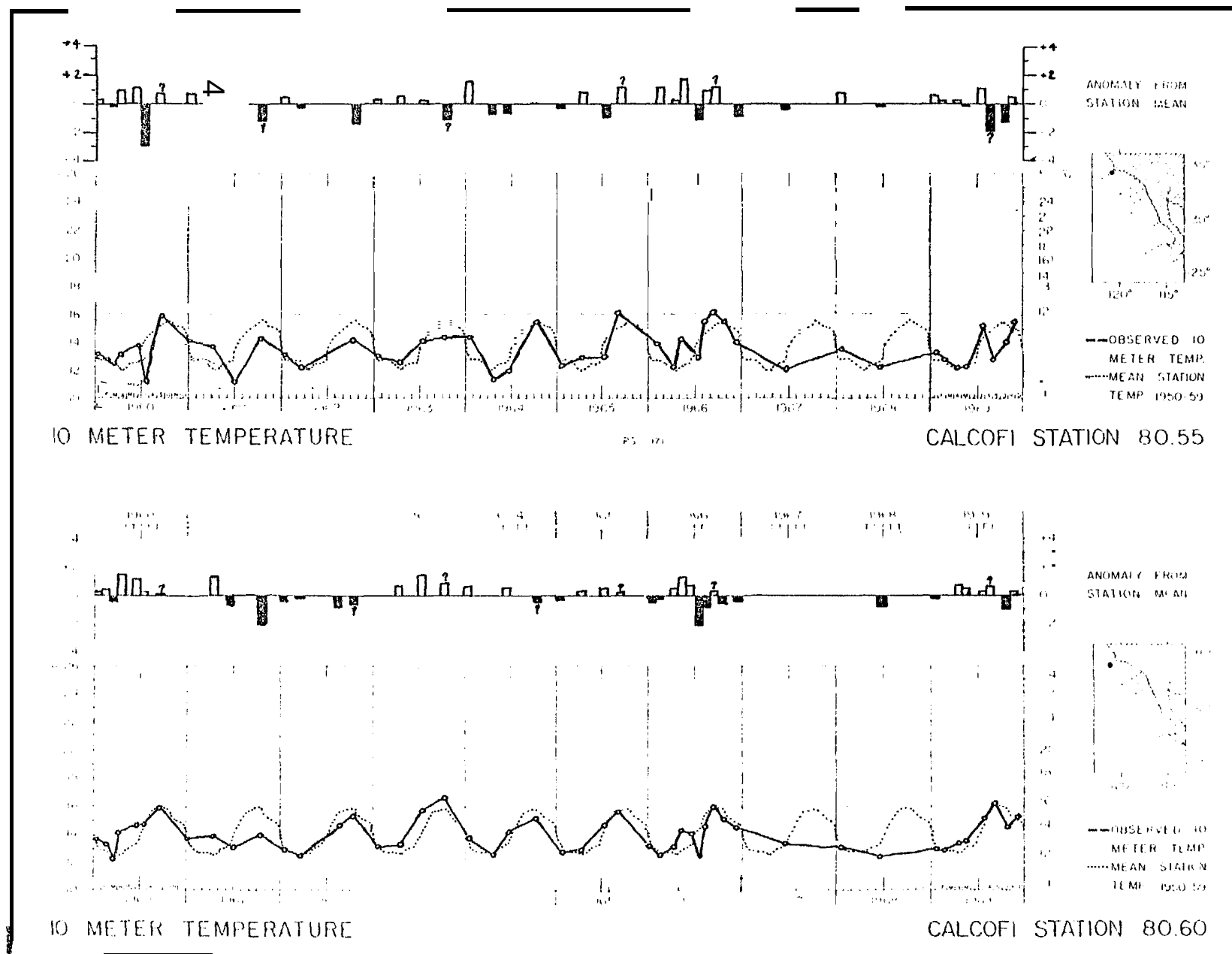


Figure 3-22. Temperature Anomalies for the Years 1950-59 at Two CALCOFI Stations Near Point Conception (Wyllie and Lynn, 1971)

Salinity

The mean seasonal salinity range in waters off of California is small, and non-seasonal fluctuations predominate. Isohalines (contours of equal salinity) tend to parallel the coast. Ten-meter mean surface salinity contours were developed for the years 1950 to 1959, and are presented in Figure 3-23 (Wyllie and Lynn, 1971). Minimum salinities occur along the coast in winter and spring, while minimums of 33.0 to 33.2 parts per thousand occur in April and May seaward of upwelling regions. In late summer the shore area reaches a salinity maximum of 33.4 parts per thousand. Maximum salinities in excess of 33.6 parts per thousand occur in coastal upwelling regions in June and July, that is, two months after the period of minimum temperature (Bourke, et al., 1977). Mean 150-m salinity contours indicate an onshore salinity gradient ranging from 33.5 to 34.0 parts per thousand (Figure 3-24). Maximum salinities for that depth are attained at coastal areas during upwelling (June) and oceanic (September) current periods.

The California Current is the only eastern boundary current in which salinity generally increases with depth nearshore. Therefore, surface salinity increases when upwelling occurs. A complicated pattern of salinity minima and maxima is located offshore of California (Wooster and Reid, 1963).

Oxygen

Subarctic water flows from the north in the surface layers of the California Current and has a high oxygen content of greater than seven milliliters per liter (ml/l), a high phosphate content of greater than one micro-Mole (μM) phosphate, and low temperature and salinity. Mixing takes place with warm, salty, nutrient-poor central Pacific water. As one moves down the coast, surface waters are dominated more by central Pacific water characteristics, Equatorial Pacific water that is low in oxygen and high in phosphate comes up the coast from the south at a depth of about 200 m (656 ft). Coastal upwelling brings cold, more saline, waters from depths of 200 to 300 m (656 to 984 ft) to the surface (Traganza, et al., 1977).

Surface waters of the California Current are saturated with oxygen down to the thermocline. The oxygen content of the water generally decreases with depth down to an oxygen minimum layer between 700 and 1,000 m (2,300 and 3,300 ft). Beneath the minimum layer there is a gradual increase in oxygen content with depth. The oxygen content of the deep ocean waters is constant for hundreds of meters (Traganza, et al., 1977).

Seasonal variations in oxygen content are mostly caused by seasonal temperature variations causing a change in saturation value (Reid, et al., 1958). The oxygen content of cold winter waters in the surface layers of the California Current exceeds the summer concentration by 1 ml/l.

A subsurface maximum of oxygen develops in late spring and summer, and a high oxygen content continues through fall and early winter. This maximum usually occurs at depths corresponding to the lower part of the wind mixed layer, 50 m (120 ft) (Traganza, et al., 1977). Seasonal variations also occur at depths as shown by Figure 3-25. CalCOFI has mapped the 150-meter monthly mean oxygen content of seawater for the years 1950-1968; this 150-meter depth was chosen because it is the standard oceanographic level nearest the maximum depth (140 m or 460 ft) sampled by the standard CalCOFI zooplankton net. A decrease in the oxygen content of the surface layer is sometimes observed in local areas due to the upwelling of water low in oxygen content during the upwelling season (spring and summer for central and northern California, respectively) (Traganza, et al., 1977).

Nutrients

High nutrient concentrations in the surface sea water layer are found seasonally along the California coast and correspond to seasonal changes in atmospheric and physical oceanography processes. A phosphate maximum usually occurs close to the oxygen minimum. In offshore areas in the vicinity of Point Conception and the area from Monterey to San Francisco, high nutrient concentrations are found from April to May and from October to November (Figures 3-26 to 29). These high concentrations correspond to the upwelling period and the oceanic period. Nutrient concentrations at greater depths, e.g., 100 m (328 ft), do not vary as much as surface concentrations (see Figures 3-30 to 3-33).

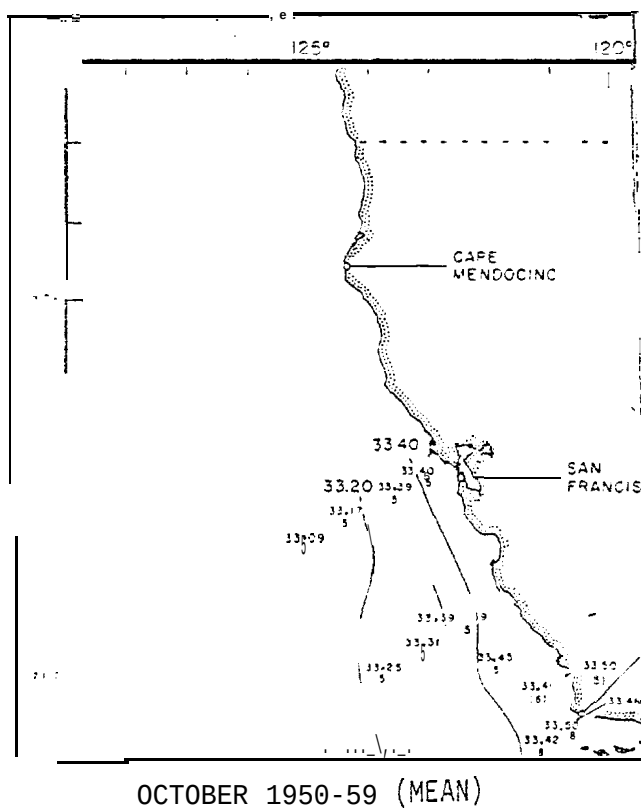
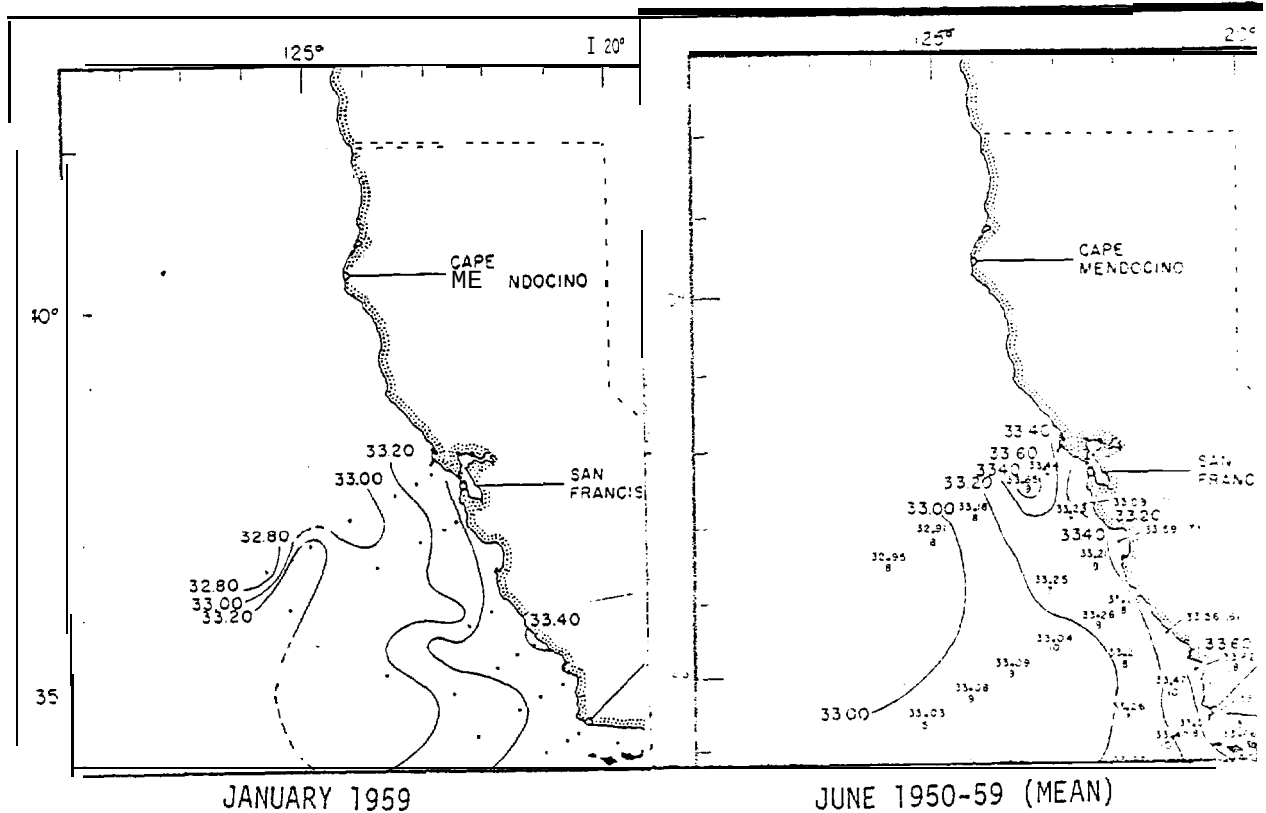


Figure 3-23. Contours Showing Water Salinity at a Depth of 10 Meters for the Years 1950-59. Contour Interval 0.2 Parts per Thousand. (CALCOFI, 1963)

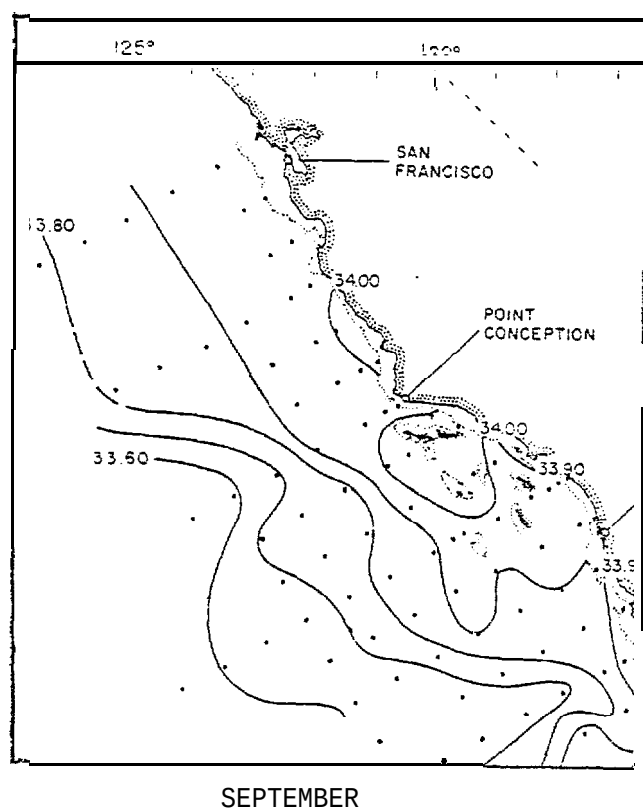
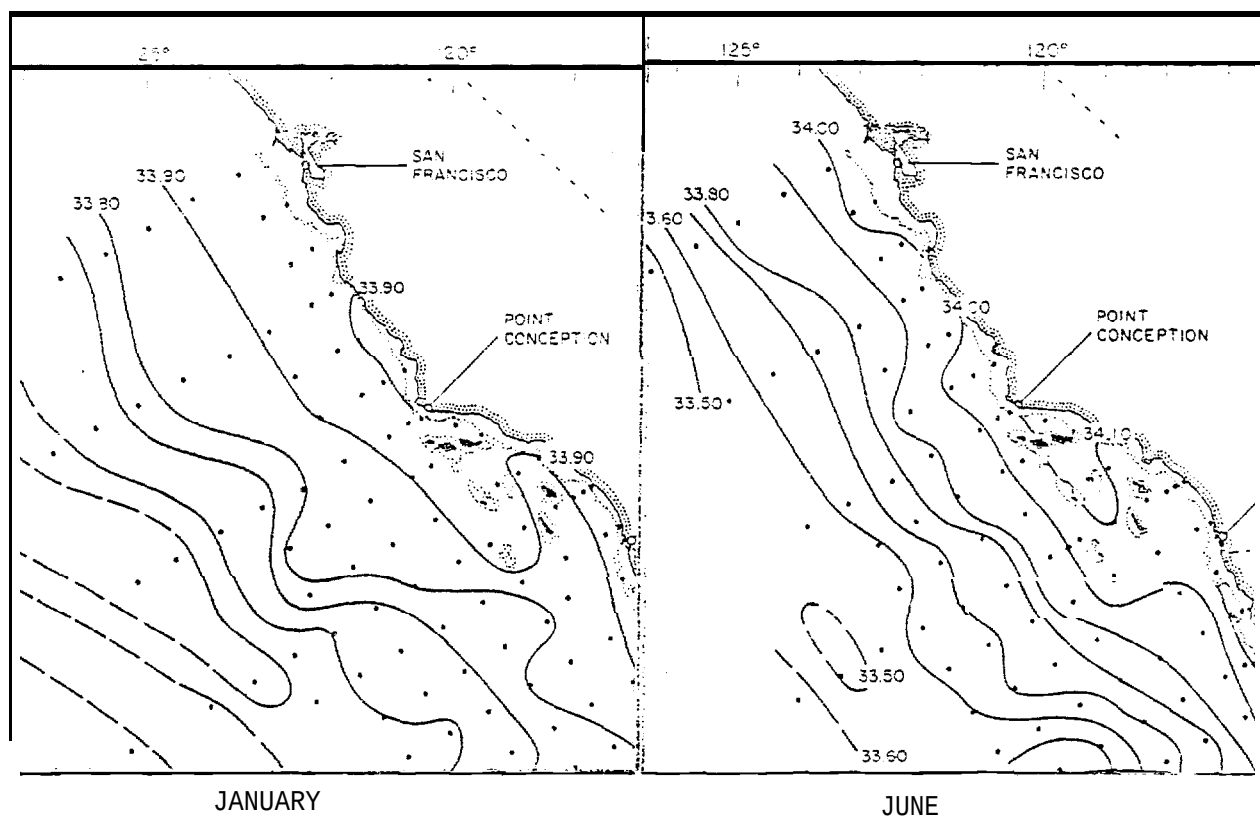


Figure 3-24. Contours Showing Mean Water Salinity at a Depth of 150 Meters for the Years 1950-1968. Contour Interval 0.10 Parts per Thousand. (Wyllie and Lynn, 1971)

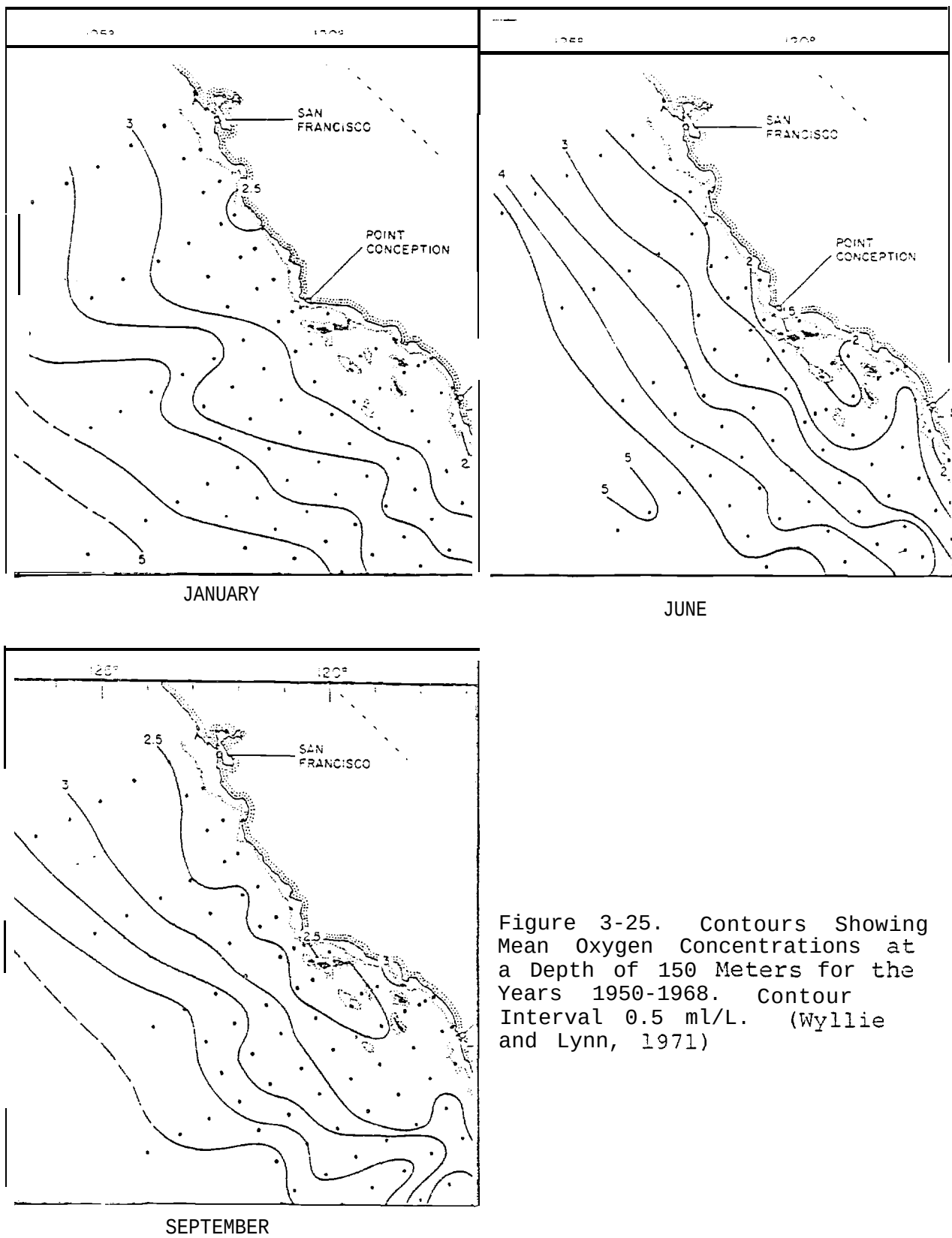
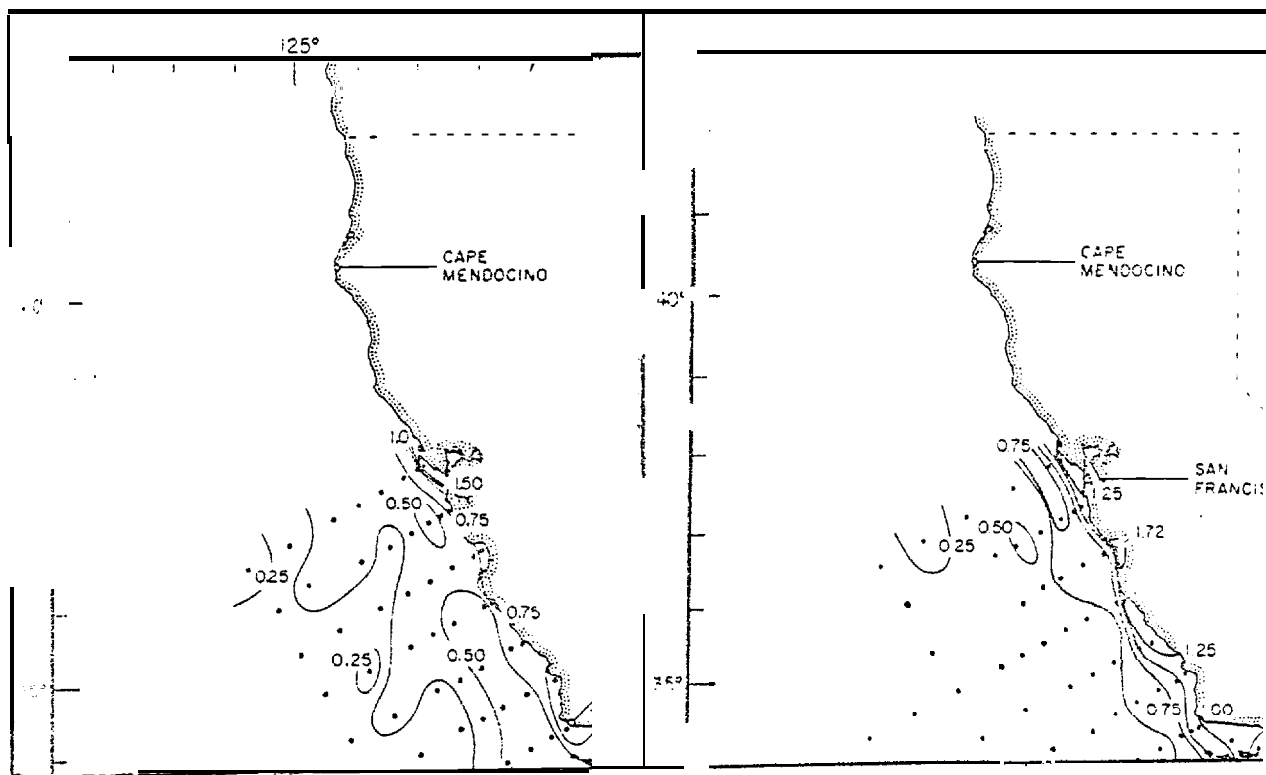
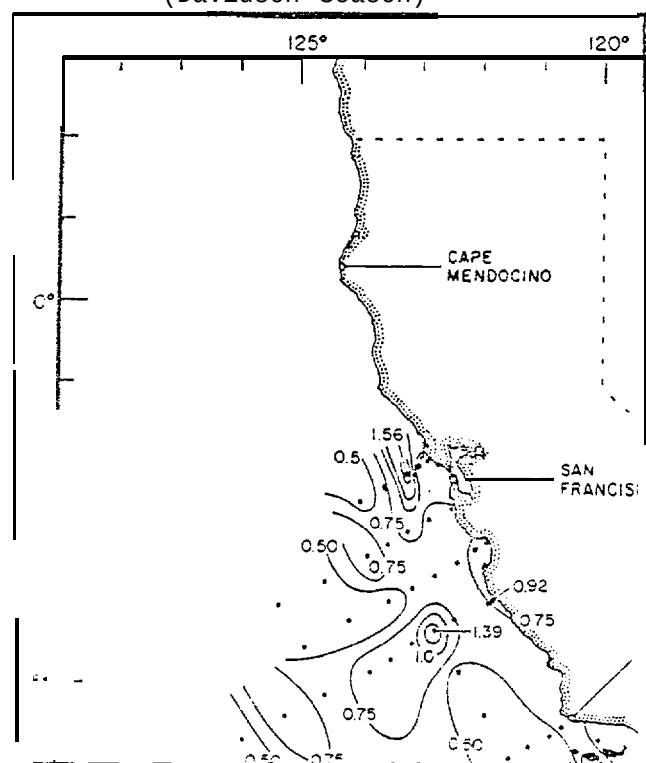


Figure 3-25. Contours Showing Mean Oxygen Concentrations at a Depth of 150 Meters for the Years 1950-1968. Contour Interval 0.5 ml/L. (Wyllie and Lynn, 1971)



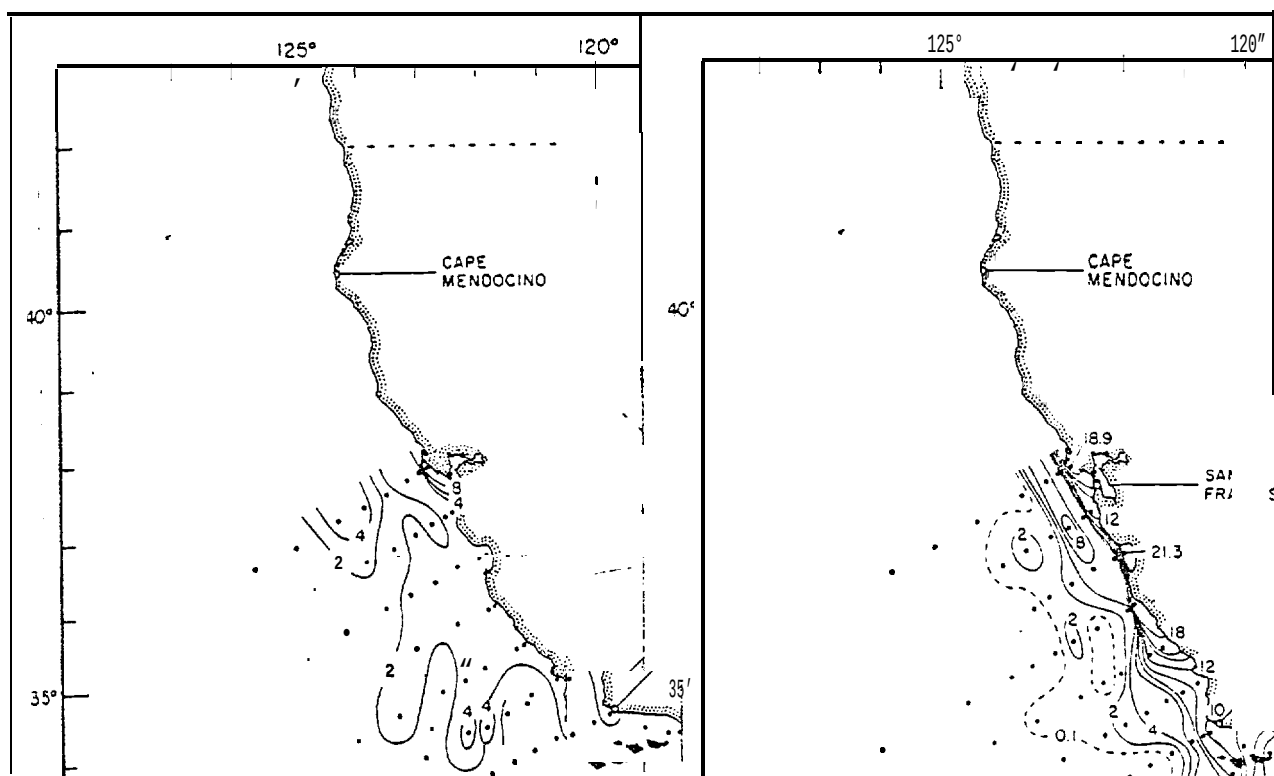
6-30 JANUARY
(Davidson Season)

5-29 MAY & 9-28 JUNE
(Upwelling Season)



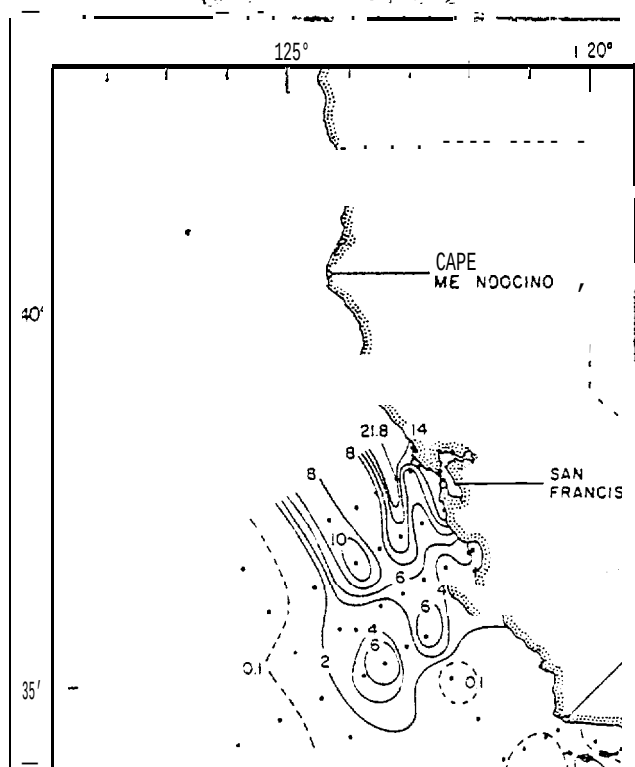
6 AUGUST-8 SEPTEMBER &
11 SEPTEMBER-7 OCTOBER
(Oceanic Season)

Figure 3-26. Contours Showing Phosphate-P Concentrations at a Depth of 10 Meters for Months Representative of the Davidson, Upwelling and Oceanic Seasons. Contour Interval 0.25 Microgram-atoms per Liter. (Thomas and Seibert, 1974)



6-30 JANUARY
(Davidson Season)

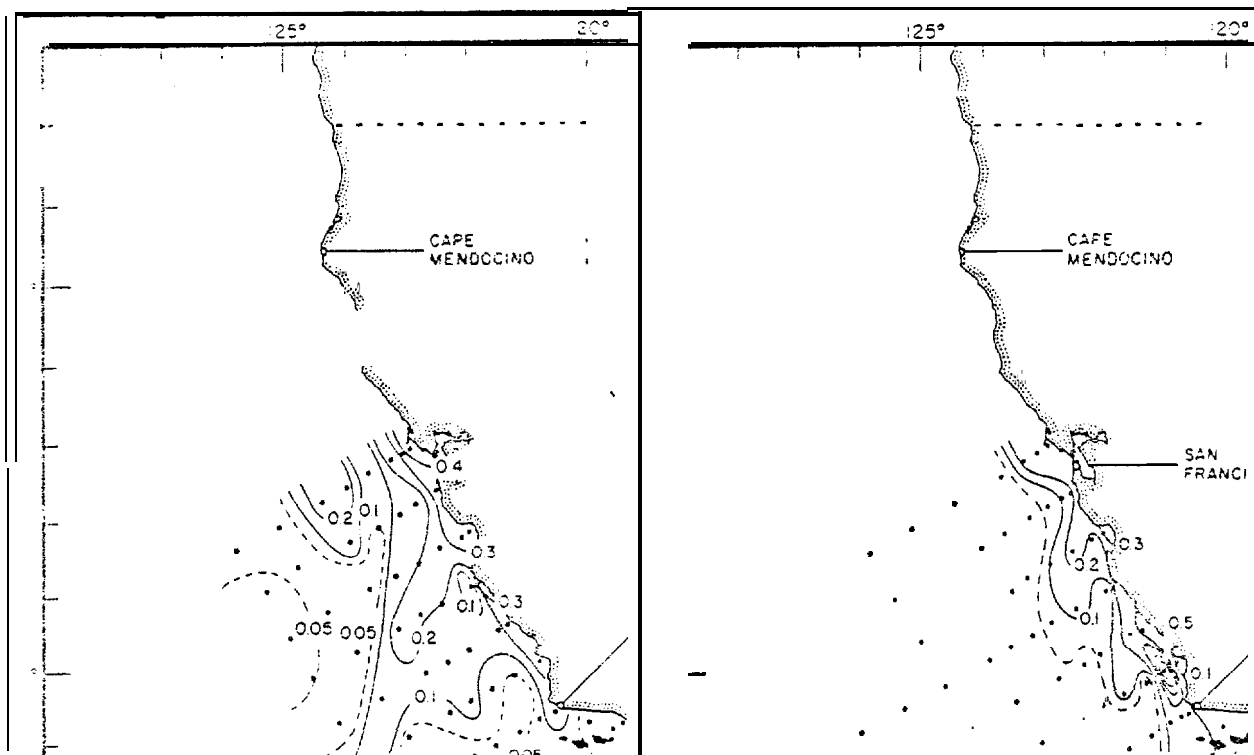
5-29 MAY & 9-28 JUNE
(Upwelling Season)



6 AUGUST-8 SEPTEMBER &
11 SEPTEMBER-7 OCTOBER

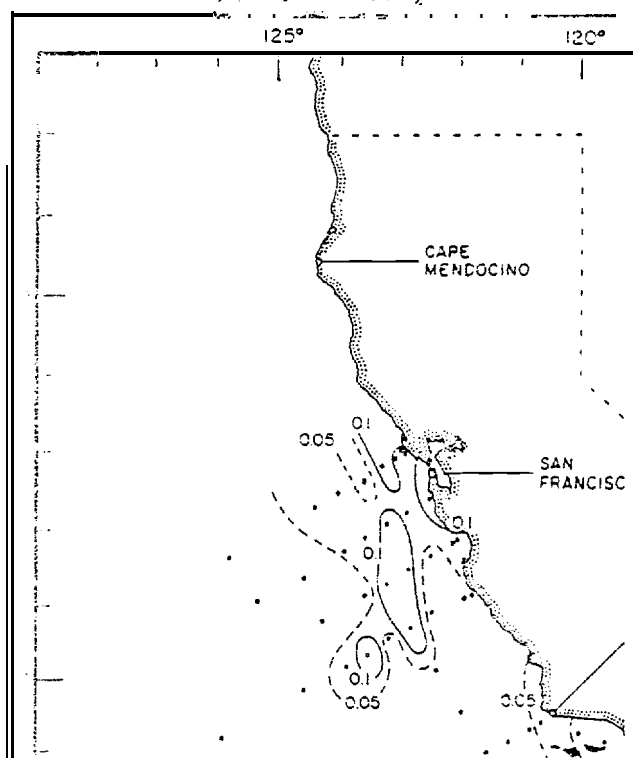
(Oceanic Season)

Figure 3-27. Contours Showing Nitrate-N Concentrations at a Depth of 10 Meters for Months Representative of the Davidson, Upwelling and Oceanic Seasons. Contour Interval 2 Microgram-atoms per Liter. (Thomas and Seibert, 1974)



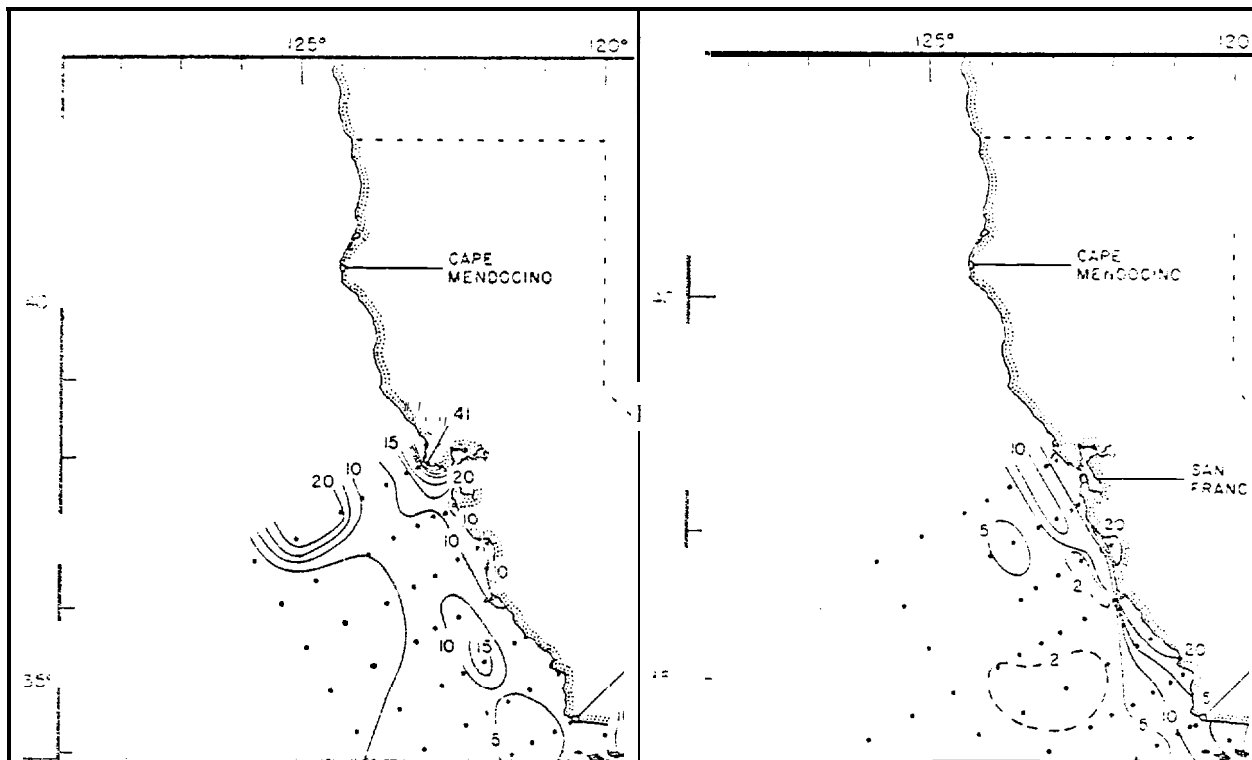
6-30 JANUARY
(Davidson Season)

5-29 MAY & 9-28 JUNE'
(Upwelling Season)



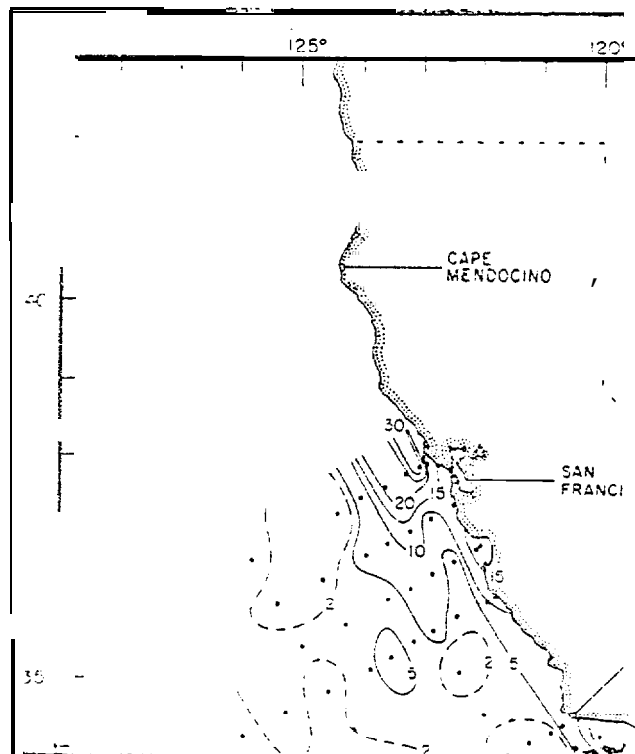
6 AUGUST-8 SEPTEMBER &
11 SEPTEMBER-7 OCTOBER
(Oceanic Season)

Figure 3-28. Contours Showing Nitrite-N Concentrations at a Depth of 10 Meters for Months Representative of the Davidson, Upwelling and Oceanic Seasons. Contour Interval 0.1 Microgram-atoms per Liter. (Thomas and Seibert, 1974)



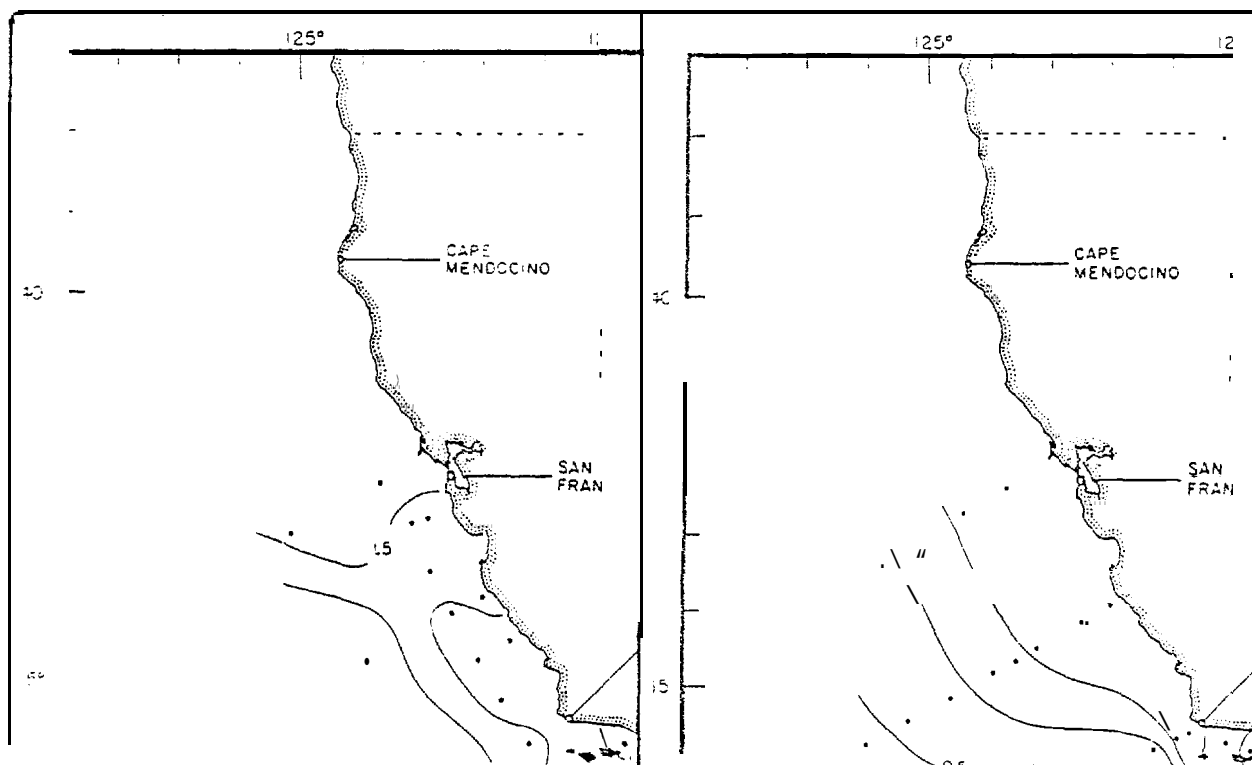
6-30 JANUARY
(Davidson Season)

5-29 MAY & 9-28 JUNE
(Upwelling Season)



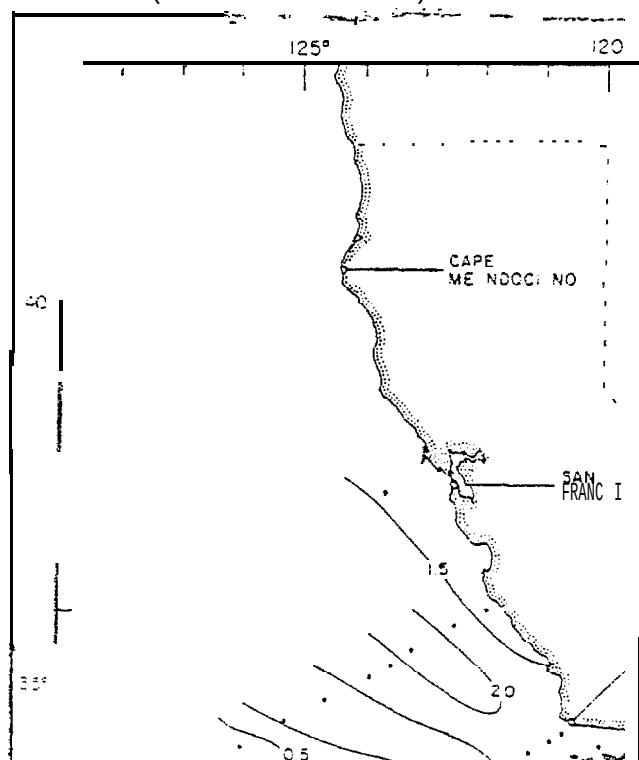
6 AUGUST-8 SEPTEMBER &
11 SEPTEMBER-7 OCTOBER
(Oceanic Season)

Figure 3-29. Contours Showing Silicate-Si Concentrations at a Depth of 10 Meters for Months Representative of the Davidson, Upwelling and Oceanic Seasons. Contour Interval 5 Microgram-atoms per Liter. (Thomas and Seibert, 1974)



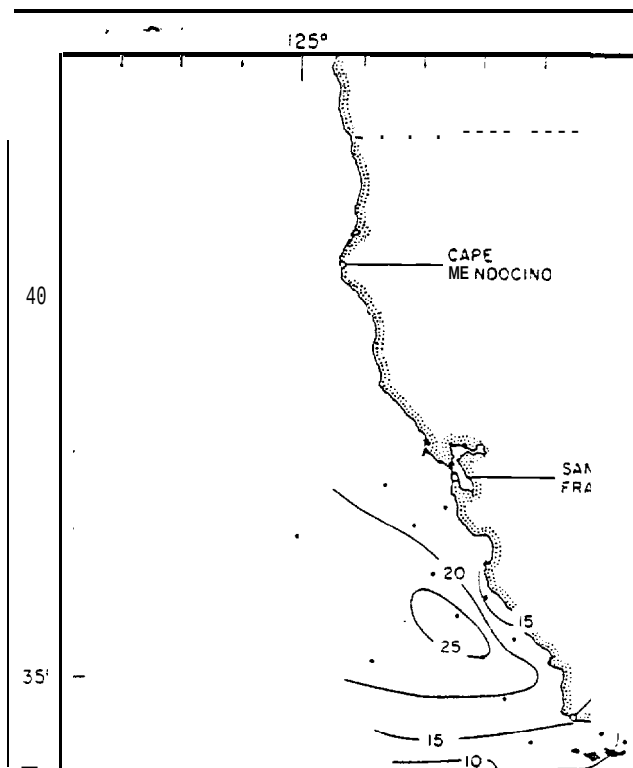
6-30 JANUARY
(Davidson Current)

5-29 MAY & 9-28 JUNE
(Upwelling Season)

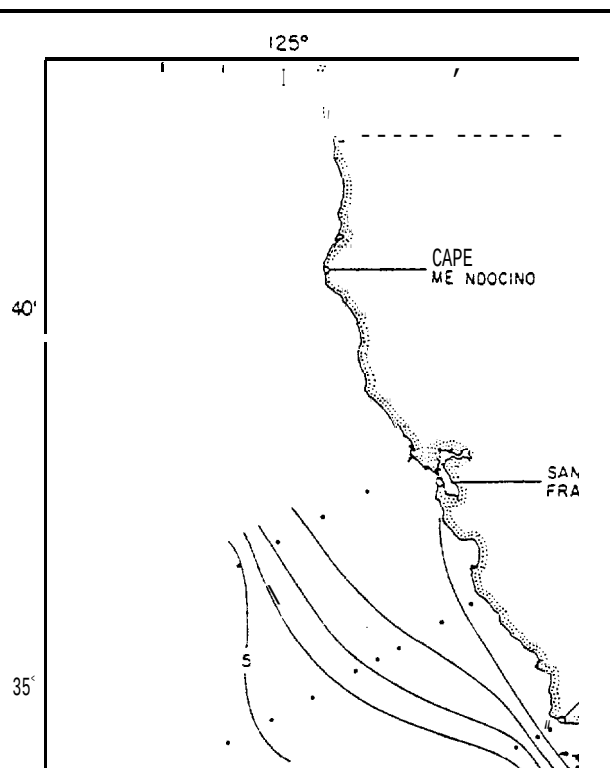


6 AUGUST-8 SEPTEMBER &
11 SEPTEMBER-7 OCTOBER
(Oceanic Season)

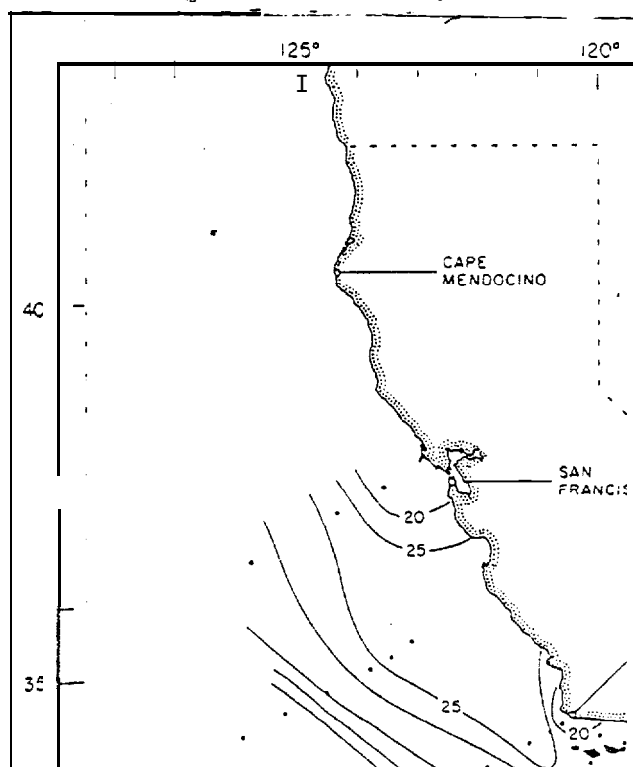
Figure 3-30. Contours Showing Phosphate-P Concentrations at a Depth of 100 Meters for Months Representative of the Davidson, Upwelling and Oceanic Seasons. Contour Interval 0.5 Microgram-atoms per Liter. (Thomas and Seibert, 1974)



6-30 JANUARY
(Davidson Season)



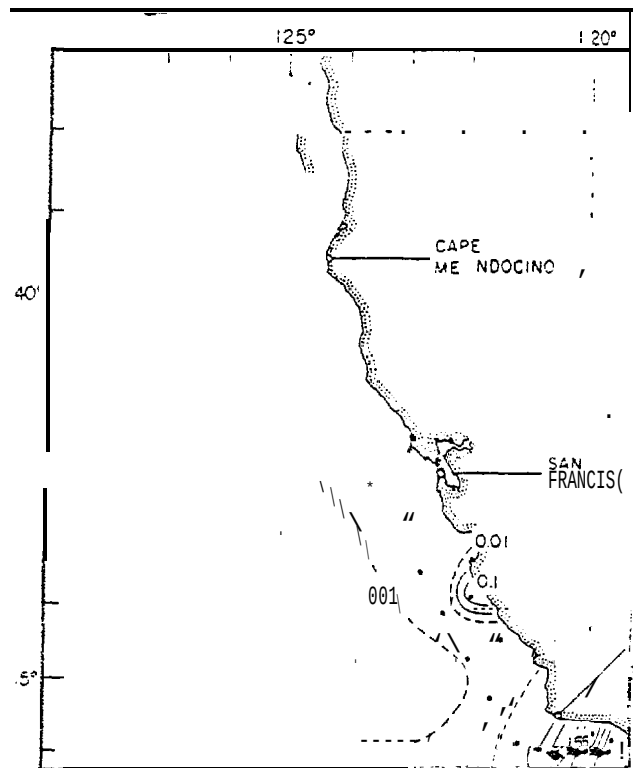
5-29 MAY & 9-28 JUNE
(Upwelling Season)



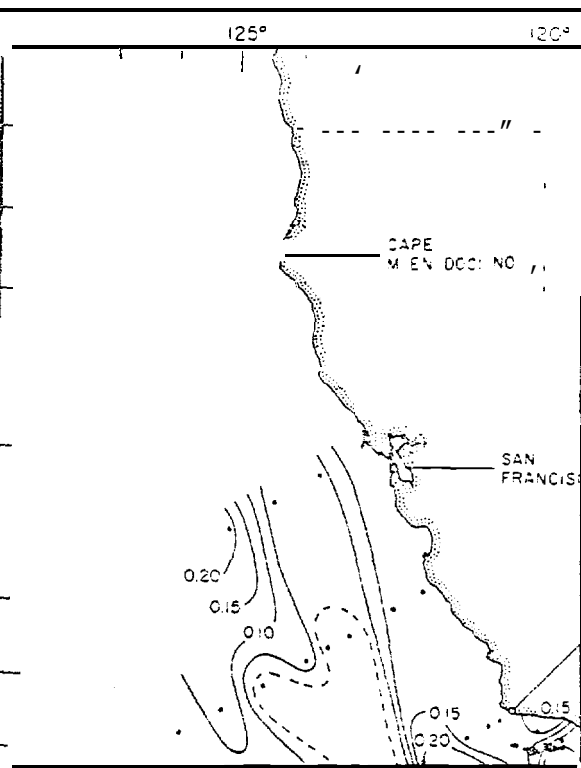
6 AUGUST-8 SEPTEMBER &
11 SEPTEMBER-7 OCTOBER

(Oceanic Season)

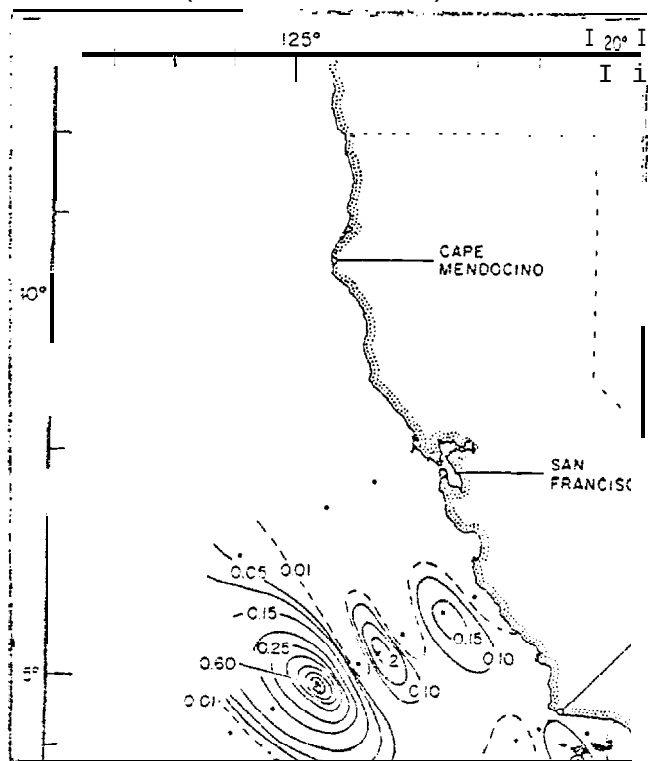
Figure 3-31. Contours Showing Nitrate-N Concentrations at a Depth of 100 Meters for Months Representative of the Davidson, Upwelling, and Oceanic Seasons. Contour Interval 5 Microgram-atoms per Liter. (Thomas and Seibert, 1974)



6-30 JANUARY
(Davidson Season)

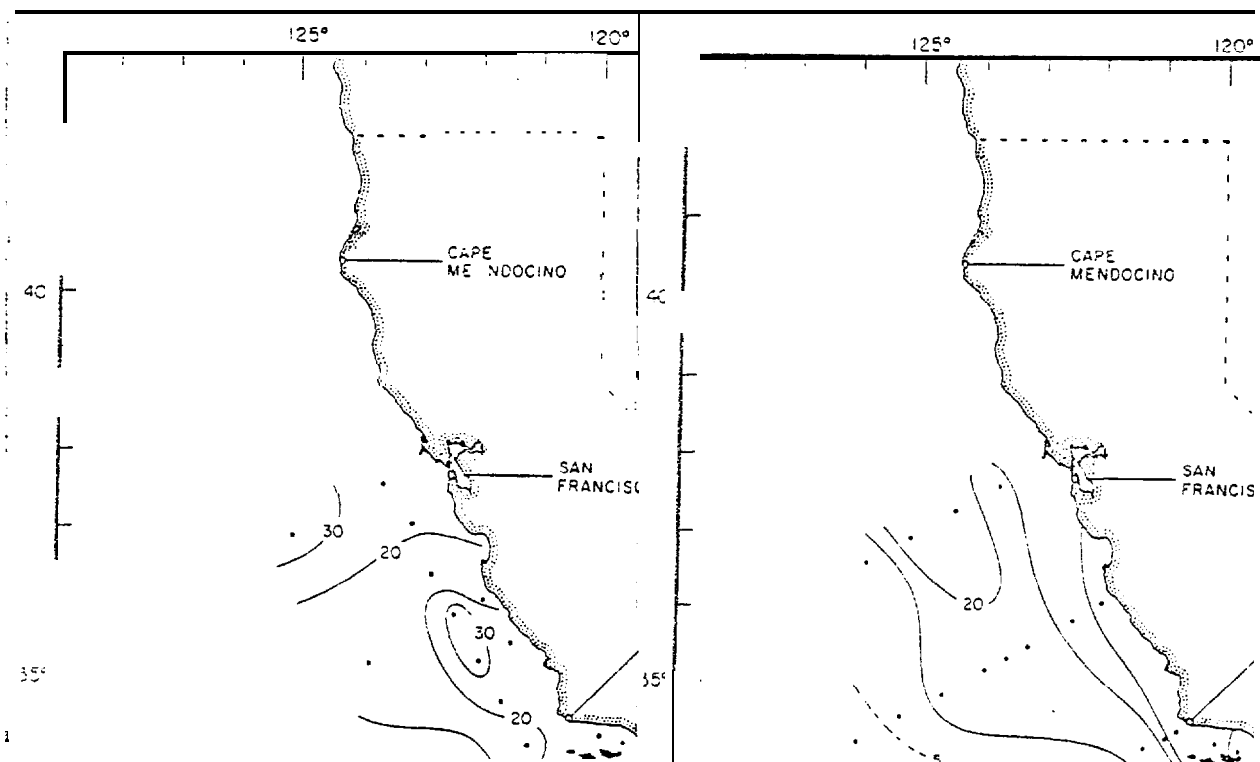


5-29 MAY & 9-28 JUNE
(Upwelling Season)



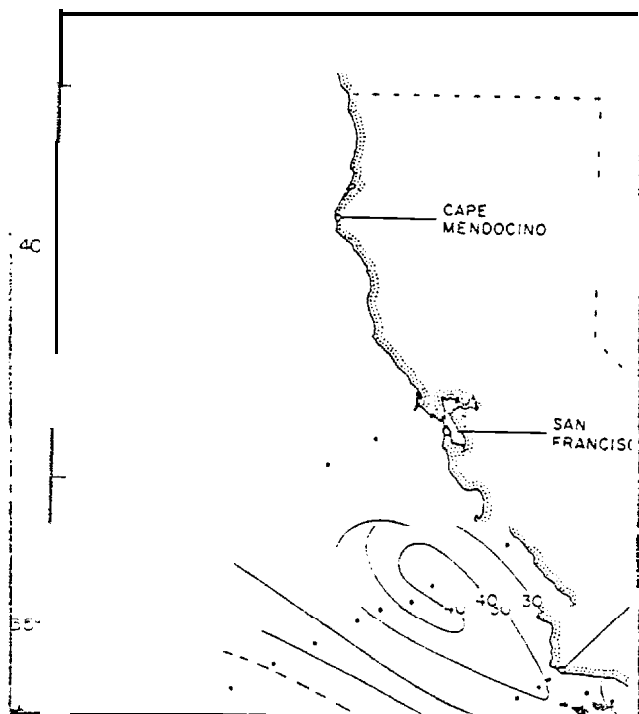
6- AUGUST-8 SEPTEMBER &
11 SEPTEMBER-7 OCTOBER
(Oceanic Season)

Figure 3-32. Contours Showing Nitrite-N Concentrations at a Depth of 100 Meters for Months Representative of the Davidson, Upwelling and Oceanic Seasons. Contour Interval of 0.01 Microgram-atoms per Liter. (Thomas and Seibert, 1974)



6-30 JANUARY
(Davidson Season)

5-29 MAY & 9-28 JUNE
(Upwelling Season)



6 AUGUST-8 SEPTEMBER & 11 SEPTEMBER-7 OCTOBER
(Oceanic Season)

Figure 3-33. Contours Showing Silica te-Si Concentrations at a Depth of 100 Meters for Months Representative of the Davidson, Upwelling and Oceanic Seasons. Contour Interval 10 Microgram-atoms per Liter. (Thomas and Seibert, 1974)

During the Davidson Current period (fall-winter) nutrient concentrations at the surface are low except offshore of San Francisco. The high values near San Francisco could result from nutrient input to the nearshore area from San Francisco Bay during periods of high winter runoff (Traganza, et al., 1977).

The upwelling of nutrient-rich mid-depth waters increases the concentration of nitrate, phosphate and silicate in the 10-meter surface layer. Upwelling occurs almost continuously throughout the year in coastal areas from Baja California north to Monterey Bay. Upwelling is at a maximum off southern and central California in June. The upwelling season is shorter north of San Francisco, occurring in March through October, with a peak in July. Cape Mendocino is identified as the area of strongest upwelling along the California coast. Because upwelling waters have more nutrients than surface waters, CalCOFI data (Thomas and Seibert, 1974) show a direct relationship between coastal upwelling periods and high nutrient distribution patterns. In late spring and early summer, phytoplankton and diatom blooms greatly decrease nutrient concentrations in surface waters. Nutrient concentration in surface seawater during July decreased to 0.25 to 0.50 micro-gram atoms per liter ($\mu\text{g-at/liter}$) for phosphate, 0.1 to 4 $\mu\text{g-at/liter}$ for nitrate, and 2 $\mu\text{g-at/liter}$ for silicate near San Francisco. Very high nutrient values off of San Francisco and southwest of Monterey Bay may result from renewed or intermittent upwelling in the area and/or from nutrient-rich waters flowing down the coast from summer upwelling sites north of California (Traganza, et al., 1977).

Plant nutrient content in the upper part of the Pacific Ocean is related to divergence of water at the surface. Nutrient contents are high in the region of atmospheric cyclones, low in the regions of anticyclones, and high in regions of equatorial and coastal upwelling. The California coastal zone is a major nutrient-rich upwelling region in the Pacific Ocean. Nutrient concentrations are lowest in the "mixed layer", with a sharp increase at the pycnocline to a maximum concentration below the pycnocline, (Reid, 1962). Data on the vertical distribution of phosphate along the California coast can be found in a U.S. Department of Commerce Atlas (Churgin and Halminski, 1974).

Inorganic forms of the elements phosphorus, nitrogen and silicon are the most important nutrients regulating the photosynthetic supply of organic matter to the oceanic food chain.

The most abundant form of nitrogen in the sea is dissolved, gaseous, elemental nitrogen, N_2 . Few marine species utilize nitrogen in this form. Nitrate (NO_3) is the most common usable form of nitrogen, although most phytoplankton will preferentially use ammonium (NH_4). Nitrate is believed to be the usual limiting nutrient for phytoplankton production of organic matter (Traganza, et al., 1977).

Inorganic phosphorus occurs in sea water as orthophosphate. Inorganic phosphorus in association with clay minerals in sediments may enrich estuaries and nearshore waters. Phosphate may be adsorbed onto organic matter, and organic detritus contains a wide range of phosphorus compounds.

Silicon is present in seawater in solution as silicic acid, i.e., $\text{Si}(\text{OH})_4$; as suspended living and dead diatom, silicoflagellate, and radiolarian structures; and as inorganic minerals. Most of the suspended silicon eventually enters organic sediments.

In 1969 CalCOFI made nutrient measurements for almost every month of the year along the California coast south of San Francisco (Thomas and Seibert, 1974). Nutrient data were sketchy prior to this sampling effort. Data are presented for a 10 m (33 ft) depth, for an integrated value over 0 to 50 m (0 to 164 ft) and for a 100 m (328 ft) depth. The 10 m nutrient data represent the surface layer. The distribution of nutrients for 0 to 50 m (0 to 164 ft) is similar to that for 10 m (33 ft) and gives a general idea of the nutrients available to phytoplankton in the euphotic zone. The euphotic zone is the near-surface layer of water that receives enough light for photosynthesis to occur. The 100 m (328 ft) distribution is representative of nutrients in the mixed layer. Nutrient concentrations at this depth vary more due to physical than biological processes and indicate nutrient levels that might enter the euphotic zone as a result of upwelling or vertical mixing. Figures 3-26 to 3-33 show 10 m and 100 m nitrate, nitrite, phosphate and silicate concentrations along the California coast for the months of January, May through June, and August through October of 1969. Those months were chosen as being representative of the Davidson Current period, the upwelling period and the Oceanic period respectively. Thomas and Seibert (1974) also summarize nutrient data prior to 1969.

Water Quality

The US. Environmental protection Agency began the National Mussel Watch program in 1976, and the State Water Resource Control Board's Mussel Watch project is patterned after the federal program. The purpose of the Mussel Watch programs is to document and assess long-term trends in selected indicators of the quality of coastal marine and estuarine waters. Ocean water quality data are also monitored in the areas of some ocean National Pollutant Discharge Elimination System permit discharges. Extensive water quality data are available where predesign/predischarge studies are being conducted (see Water Quality discussion in Hydrology).

Ocean water quality along the coast of California included in this study area is generally good. Heavy metal and pesticide levels are high in the Bodega Bay ocean basin unit near the mouth of San Francisco Bay. Water quality problems occur where wastewater discharges do not yet comply with federal and state laws; such areas are Humboldt, San Francisco, and Monterey Bays. Ocean water quality for the five ocean basin units is discussed further in Vol. IV, Chapters 25 to 29.

Oceanic pollution by metals has been observed primarily in coastal waters as a consequence of industrial and domestic sewage discharges and direct dumping of wastes. The one exception is lead. Most lead entering the world's oceans is from lead aerosols introduced via the burning of leaded gasoline. The most likely sources of man-induced silver in the marine environment are wastewaters from photographic processing and electronics industries. Zinc is used in paints, galvanizing processes, alloys, anodes, and the photoengraving and photographic process. It appears that California mussels bioaccumulate relatively elevated mercury levels via marine mammal excrement and therefore high mercury levels in mussel tissue are found near pinniped colonies. The primary use of cadmium is in electroplating. Many of the reactive heavy metals are rapidly removed from coastal waters to the underlying sediments with biological and inorganic solid phases. This sedimentation process can account for the lack of heavy metal buildup in coastal waters.

Since the United States has banned the use of DDT, DDT levels in coastal waters of California have decreased. DDT pollution levels peaked in 1968 and have been declining since 1970 in most estuaries (Goldberg, 1976). PCB'S (polychlorinated biphenyls) and other halogenated hydrocarbons enter the ocean via rainfall and direct discharges of waste. PCB's are used as dielectrics for transformers and capacitors and as hydraulic fluids. PCB use has declined in the United States and "closed-system" applications are being carried out with more safeguards against loss to the environment. The effect of these actions on PCB concentrations in the ocean is not known (Goldberg, 1976). Other halogenated hydrocarbons are used in pesticides and herbicides.

There are three general sources of petroleum-containing hydrocarbons to the ocean system: man-generated substances; hydrocarbons produced by marine organisms; and hydrocarbons that seep in naturally through the sea floor. Petroleum hydrocarbon pollution in the coastal waters of the study area is limited to urban runoff, occasional refinery accidents, and the discharge of oil tanker ballast water. There is no offshore oil development in the study area. Offshore oil development in California is centered in Santa Barbara, and coastal waters there have greater petroleum hydrocarbon pollution from local natural and man-made sources than occurs in the study area.

Secchi Depths. Coastal waters have higher turbidities than open ocean waters because coastal waters have sources of turbidity from the land. Wastewater discharges, surface water discharge from rivers and streams, sand and other suspended solids entrainment and high concentrations of organic detritus all contribute to nearshore turbidity. Within the first meter (3.3 ft) of seawater, about 60 percent of the entering insolation is absorbed and about 80 percent is absorbed in the top 10 m (30 ft). Near coasts, the presence of dissolved pigments ("yellow substance" of organic origin) strongly inhibits transmission in the violet and blue ranges of light (Gross, 1977).

During periods of high precipitation, large amounts of terrestrial runoff discharges sediment into the marine environment. Associated with these high runoff conditions, river plumes are created which have an aerial extent of tens of miles into the marine environment. Increased turbidity from these plumes increases light attenuation and decreases salinity within the plume area.

The most frequently used optical measurement in the ocean is the Secchi depth, the depth in meters at which a white disc (30 cm or 1 ft in diameter) disappears from

view. Secchi depth measurements are often used as an indication of turbidity. Figure 3-34 shows Secchi depth contours for the year 1969 off of California. The euphotic depth is the depth to which sufficient light penetrates for photosynthetic processes to function. The euphotic depth contains one percent of the surface light intensity, and is assumed to occur at three times the Secchi depth (Owen, 1974). Coastal waters usually have a Secchi-disc depth disappearance of 2 to 10 m (6.6 to 33 ft), whereas open ocean water and river water have Secchi-disc disappearance depths of 50 m (164 ft) and 1 m (3.3 ft) respectively (Pickard, 1975).

ESTUARINE PROCESSES

General Characteristics and Classification

The shoreline of California is largely mountainous with few embayments. Estuaries are generally small and distant from one another; San Francisco Bay and Tomales Bay are exceptions.

Whether or not a particular inlet is open, closed or only periodically open appears to be related to the opposing forces of the tide and waves and river outflow. The ebb flow of the tide tends to open an inlet; whereas wave energy, which is a function of the wave climate, tends to direct littoral drift into the inlet and cause closure. Johnson (1972) summarizes hydraulic information on California coastal inlets and presents various calculations dealing with the development of a general criterion of inlet closure.

Little information exists on the classification of California estuaries. The National Estuaries Sanctuary Program distinguishes the estuaries north of Cape Mendocino from those to the south. San Francisco Bay is considered by them to be unique. Also estuaries located south of Cape Conception are considered as another group. Various classification systems have been devised; some are described in Vol. I, Chapter 4, Estuarine Classification. Caldwell (1955) examined the tidal currents of numerous coastal inlets in the United States and classified the inlets into three basic types:

- Class 1 - Entrance backed by long estuaries and with tidal flow moving freely past entrance.
- Class 2 - Entrance backed by short estuary and with tidal flow moving freely past entrance.
- Class 3 - Entrance constricted sufficiently to prevent free movement of tidal flow past entrance.

Caldwell considered San Francisco Bay to be like Class 1 and Humboldt Bay to be like Class 2. Many of the small lagoons and estuaries in California are Class 3, "seasonal estuaries." These water bodies are enclosed except in winter months when storm waves and fresh water storm flows breach their sand bars to allow inflow of ocean waters. Esteros Americano and de San Antonio, Big Lagoon, Stone Lagoon, Santa Ynez Estuary, Pescadero Marsh, and Lakes Earl and Talawa are "seasonal estuaries."

The estuarine environment is formed by an interaction of sea, land, and freshwater, and is a region with steep and variable gradients in environmental conditions. Physical and chemical factors that dominate in estuaries are bottom type, extent of tidal influence, wave size, current strength and its role in sedimentation, salinity distribution, water retention by sediments, temperature, and dissolved oxygen, pollutant, and other ion concentrations.

A number of authors, including Stommel, Pritchard, and Ketchum, classified estuaries by the physical character of their water circulation. The basic factor in determining the type of circulation is the effect of tidal currents relative to river flow. In the absence of other influences, river water tends to flow seawards as a layer of freshwater separated by an interface from the salt water below. This interface is called the pycnocline. Tidal currents produce turbulent mixing which breaks down the interface between the river water and salt water and mixes them. Two other factors influencing the interaction between river flow and tidal currents are the physical dimensions of the estuary and the Coriolis effect. The Coriolis effect is generally negligible in narrow estuaries (Bowden, 1976).

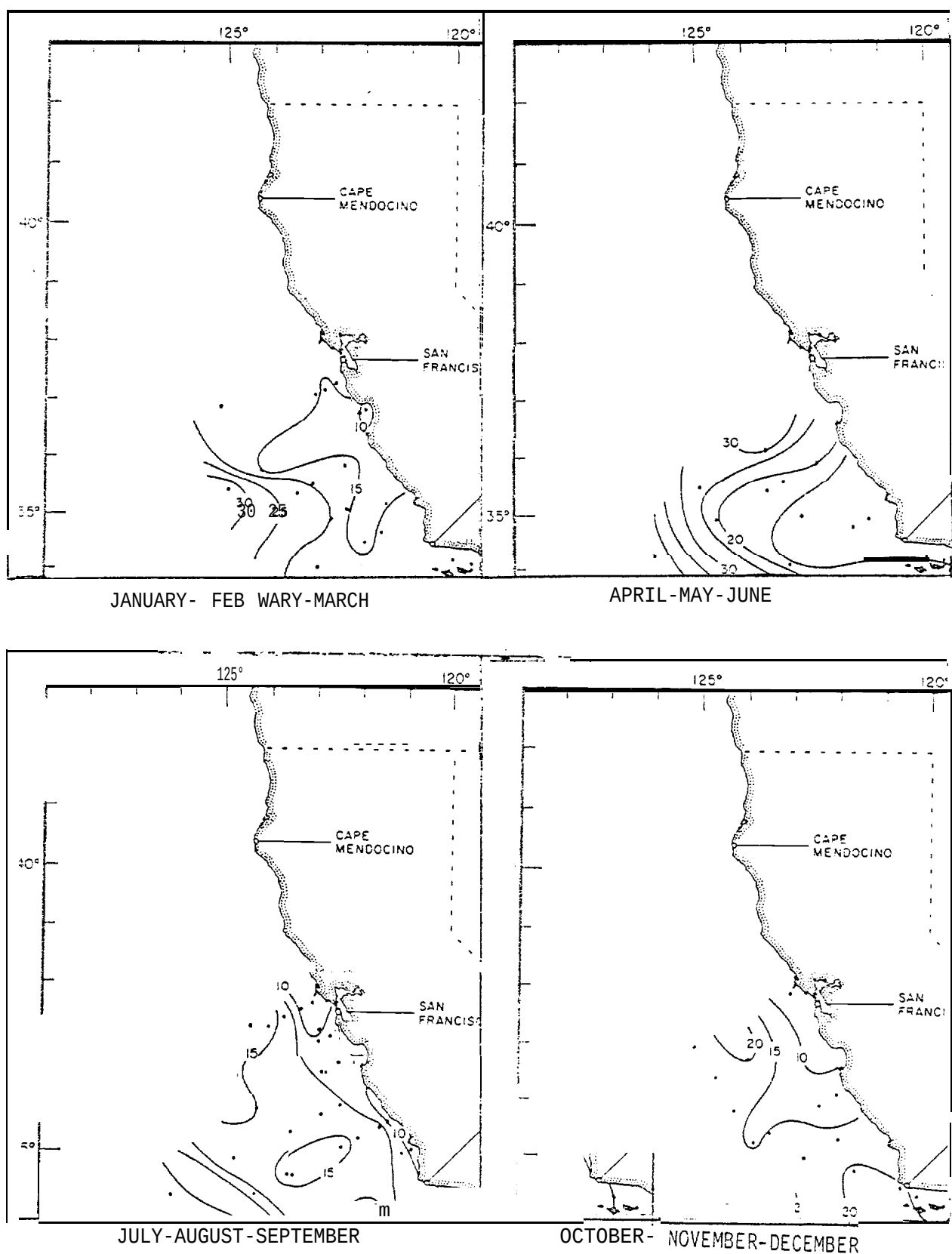


Figure 3-34. Five-Meter Contours Showing Secchi Depth Readings for Different Months (Owen, 1974)

With regard to salinity characteristics, estuaries in California are of two types: well mixed or stratified (see Vol. I, Chapter 4, Estuarine Classification). Rivers flowing into estuaries north of Santa Cruz flow most of the year, while many estuaries below Santa Cruz have freshwater flows only during the rainy season. Those estuaries receiving freshwater input most of the year probably are in a category somewhere between slightly to highly stratified estuaries. Southern estuaries with little or no summer freshwater input are probably dominated by tidal currents and are vertically mixed estuaries. Estuaries that become closed off from the ocean during summer months are probably vertically stratified. Salinity stratification has been documented in Big Lagoon when it is closed off from the ocean, the narrows area between Lakes Earl and Talawa, and Moss Landing Harbor and the Old Salinas River Channel (Elkhorn Slough upstream is well mixed all year long) (Monroe, et al., 1976; Monroe, et al., 1975; Smith, 1973).

Geomorphology

Sediment transport and deposition is seasonal in response to climatic and hydrographic variations. Maximum deposition occurs in winter for most of the estuaries in the region when river runoff is highest, littoral (along the shore) drift is from north to south, and the highest velocity winds are from the west and southwest. Sand dunes on the barrier bars at the entrance to many estuaries are eroded by winter winds and the sand is blown into the estuaries or washed offshore by wave motion. The contribution of suspended sediments from river flow is greatest in winter. When a stratified system exists, the landward bottom currents are strongest, and intrusion of marine sediments into the estuaries is greatest. This intrusion occurs at times of high river discharge (i.e., winter) in all but the high gradient estuaries. In the high gradient estuaries, the river flow may completely overpower the tidal exchange, and prohibit any significant seawater and marine sediment intrusion. When a well-mixed condition exists, there is a net non-tidal seaward drift at all depths, and sedimentation from marine sources is reduced.

Natural indicators such as sediment texture and composition can be used to roughly model the winter and summer patterns of sediment transport within most estuaries of northern California. Marine sands, identified by the presence of yellow grains and certain key heavy minerals, are transported from the tidal entrance up the low gradient river channels during the winter. A partly-mixed estuarine condition exists in the winter, permitting the upstream penetration of saltwater and marine sands. During the summer, when river flow is reduced, the estuary is mixed from surface to bottom (dominated by tidal forces) and there is a net seaward movement at all depths. Consequently, very little marine sediment enters the estuary at this time. Maximum deposition of riverine and marine sediments takes place in estuaries during winter and spring. Wind blown sand also is carried from the coastal dunes into the estuary, and then further transported by tidal currents.

Estuarine sediments contain an organic fraction, consisting of algal particles, small pieces of roots, remnants of planktonic animals, and so on. In northern California wood chips, sawdust, and bark are also significant, especially in estuaries where wood processing industries are or have been located. These organic sediments are especially concentrated in areas where log rafting (for storage) has been common. The organic fraction sometimes constitutes a large volume of the estuarine sediment, and it leads to the formation of suspended flakes in which mineral particles are enclosed in fibrous networks. Nevertheless, the organic fraction is always considerably smaller in estuarine muds than the mineral fraction, which usually exceeds 90 percent by weight,

Of historical interest in California is the hydraulic gold mining in the Sierra Nevada mountains and resulting sedimentation of the streams, rivers, and ultimately bays and estuaries. The hydraulic mining started in about 1856, reached a peak in 1884 after which restrictions were placed on such methods because of the problems created. By 1910 this mining had essentially ceased, but sediments loosened and later washed by rains and those already introduced into the rivers had important effects for many years. A classical paper was prepared by Gilbert (1917) in which he documented the shoaling in the San Francisco Bay due to the mining debris. He estimated that in 1914 there was still 450 million yards of debris that would be eroded into the Bay system. He forecast that it would take up to 50 years for this remaining debris to reach the Bay system at an average of 11 million yards per year, declining to 8 million yards when the debris had been cleared in 1964.

Upstream developments that reduce the vegetative cover of the land will increase the sediment yield of the land, and therefore increase the rate of sedimentation

within the estuaries. Significant developments of this type include clearcut logging and associated road building, agriculture, and urban developments.

Hydrospheric Features

Physical Processes. Tidal flow into and out of California estuaries follows the mixed tidal pattern. The shape and size of estuary bodies and entrances determine tidal current patterns. A shallow entrance may mean that low tide is higher in the estuary than in the ocean, while a narrow entrance may limit the height of high tide and cause high tide to occur in the estuary much later than on the open coast. The fastest currents within an estuary are midstream, where the least frictional resistance from the banks occurs.

Winds have an important influence on estuarine circulation and mixing by causing a net transport of water in the direction the wind is blowing. Wind-driven waves increase the intensity of vertical mixing and cause a change in the usual salinity stratification (Bowden, 1976).

The height of oceanic waves may be reduced as the sea enters an estuary by frictional drag along the shores, dissipating the wave energy and by deflection of the waves against a headland or promontory (McLusky, 1971).

Chemical and Temperature Characteristics. Salinity variation is probably the most distinctive of all the characteristics typifying estuaries. The complete range of salinities from freshwater (less than 9.5 parts per thousand) to sea water (33 to 37 parts per thousand) is found in estuaries. Salinity values within an estuary vary both vertically and horizontally (as shown in Vol. I, Chapter 4, Figure 4-5) and are transient values. The salinity at any given point in an estuary is an accurate measure of the degree of dilution of sea water by freshwater.

The temperature within an estuary is variable because of the presence and mixing of two bodies of water with different temperatures. The regular flux of fresh and salt water in an estuary usually assures an ample supply of dissolved oxygen for aquatic organisms.

An estuary is a region of mixing between two aqueous solutions of very different chemical composition. The chemical properties of river water are variable, both geographically and temporally, whereas those of sea water are relatively constant. River waters contain more plant nutrients and organics (mainly in the form of humic material derived from leaching of soil, than sea water. Sea water has an abundance of major ions, such as Cl^- , Na^+ , SO_4^{2-} , Mg^{+2} , Ca^{+2} , K^+ , HCO_3^- , and SiO_2 . Estuarine muds are a reservoir of phosphorus. River and sea water contain about the same amount of trace metals (Phillips, 1971).

Estuaries are fertilized in three main ways: (1) river waters leach plant nutrients from the soil and transport them to the estuary; (2) pollution, originating either locally within the estuary or indirectly through the river, adds nutrients to estuary water; and (3) during the upwelling season, upwelled waters bring nutrients from below the euphotic zone where nutrient concentrations are higher than at the surface (Bowden, 1976).

The input of nutrients to estuaries by rivers is important, but the input of nutrients to the ocean is small in comparison to the ocean's overall nutrient supply. Stratified estuaries are a nutrient trap or a trap for suspended matter. Particles entering the estuary with river water sink into more saline water with a net landward flow. Many particles are returned to the surface by turbulence. The cycle may be repeated several times before the particles are washed out to sea. Organic particles are decomposed within the cycle and regenerate nutrients which are used again in the same surface layers. Nutrients are conserved through this cycle and productivity in the estuary is increased (Phillips, 1971).

An overview of engineering approaches to estuarine processes such as tides, waves, diffusion, sedimentation, pollution, and estuarine modeling can be found in Ippen (1968).

Water Quality. Water quality in an estuary is influenced by the quality of river water flowing into the estuary, marine water quality, and natural and man-caused inputs into the estuary. Water quality monitoring systems in California are discussed under 'Water Quality in Hydrology'. The water quality in a specific California estuary is discussed in Vol. IV under Estuaries and Beaches, Hydrospheric

Characteristics for the appropriate watershed unit. The National Technical Information Service (NTIS) distributes an annotated bibliography on estuarine pollution (USDI, Office of Water Resources Research, 1973).

HYDROLOGY

General Hydrology and Hydrologic Processes

Regional Water Balance. The water budget (or balance) is the relationship of the inputs and outputs of moisture in a watershed or other hydrological unit. Precipitation is the primary input, with contributions from streamflow when the unit is not closed. Outputs include runoff, evaporation (from water bodies and the ground surface), transpiration (from vegetation) and infiltration. Moisture losses from evaporation and transpiration are commonly combined in concept and referred to as evapotranspiration. The natural water demand is minimal during the wet winter and at a maximum in the dry summer, so that most of the coast, along with the rest of the state, experiences both a surplus and deficiency in water balance each year (Kahrl, et al., 1978). In general, precipitation exceeds potential and actual evapotranspiration during the low sun period from the end of October to the beginning of April, thereby creating a moisture surplus and runoff. The reverse occurs during the high sun period between April and October; potential and actual evapotranspiration exceed precipitation and thereby create a moisture deficit (Greenland and DeBlij, 1977). See also the discussion of moisture regions in Climatology.

Evapotranspiration removes moisture from the system directly into the atmosphere, thereby reducing the amount available for runoff and streamflow. These outputs are greatest in summer, and are minimal in the wet season. As a result, most winter precipitation in the coastal area leaves the system as runoff, streamflow and infiltration. Summer outputs are drawn primarily from whatever moisture has been stored in surface or groundwater reservoirs. Where water surpluses are great enough to withstand summer demands, year-round streamflow can be maintained.

In the north coast area (generally north of San Francisco), the mean annual runoff is greater than 25 centimeters (cm), that is, 10 inches (in) per year, and from about the Eel River Basin north, ranges from 102 cm (40 in) to 203 cm (80 in). Because little precipitation occurs as snow in the Coast Ranges (thereby eliminating a natural means of moisture storage), runoff rapidly follows precipitation in the winter. As a result, 75 to 90 percent of all runoff occurs before March 31, the approximate end of the rainy season (Kahrl, et al., 1978). However, average annual evaporation is less than 127 cm (50 inches) per year, and evapotranspiration is low, generally 0.3 to 0.4 cm (0.12 to 0.16 inches) daily in summer (half the rate of the Central Valley), so flow is maintained despite the small amount of summer runoff.

In the central coast area, (from San Francisco south to Point Conception), the pattern is similar. Precipitation is much less, and mean annual runoff ranges from 25 cm (10 in) in the north to 5 cm (2 in) in the south. Here too, most runoff occurs before March 31. Annual evaporation ranges from under 127 cm (50 in) near San Francisco to 152 cm (60 in) in the south, with evapotranspiration consistent throughout the area, generally 0.4 to 0.5 cm (0.16 to 0.20 in) daily in July. The magnitude of precipitation, which allows for water surpluses in the north coast area, is not present in the central coast area. A water deficit occurs throughout the region except in the watersheds which are fed from the Santa Cruz Mountains, and in the Morro Bay watershed, where annual precipitation is up to 102 to 127 cm (40 to 50 in) in the Santa Lucia Range. Many rivers are dry in the summer, and a few are dry much of the year. Precipitation is not enough to offset natural demands in summer, and man-made demands remove even more water.

Groundwater

Most of the study area is comprised of mountainous terrain underlaid by bedrock materials. Those areas have few aquifers (see Vol. I, Chapter 4, Groundwater) and, thus, are areas of minor groundwater supply. The areas underlaid by igneous and metamorphic rocks do not have aquifer systems at all. Rather than alternating beds of water-bearing rock and aquicludes, the groundwater is primarily contained in the fractures, joints, faults and shear zones of the rock and, thus, the rocks have limited storage capacity and yield only small supplies of groundwater (Ford, 1978a).

The major groundwater basins in the study area include ten small areas located primarily at the mouths of major rivers at the coast. These major groundwater basins include (north to south): the Smith River Valley, the Mad River Valley, the Eureka Plain, the Eel River Valley, the Pajaro Valley, the Salinas River Valley, the Arroyo Grande Valley, the Santa Maria River Valley, San Antonio Creek Valley, and the Santa Ynez River Valley. General information is available on most relevant parameters and detailed information is available for some localized areas within the watershed units regarding water supply and quality. In the large Salinas River Valley general information is available on all relevant parameters of the basin and detailed information is available on some parameters. With the exception of the Salinas River Valley the groundwater basins generally have a known total storage capacity below one million acre feet. The storage capacity for groundwater in most of the mountainous areas is, however, unknown. Extensive withdrawal of groundwater within the study area is made by drilling wells into the aquifers. In some portions of the study area, notably in the southern drainage basins of the Salinas and Santa Maria River Valleys, overdraft of groundwater is a problem. Artificial recharge of groundwater has been introduced into the Salinas Valley to maintain the storage of groundwater and prevent further decline of the groundwater table (Ford, 1978b).

The quantity of minerals in solution in the water in a particular groundwater basin is expressed as total dissolved solids (TDS), generally expressed in milligrams per liter (mg/l). TDS values range widely within the watershed units. In general, the four northern major groundwater basins have low TDS values, whereas the southern groundwater basins have high TDS values. For example, the Smith River Valley groundwater basin has a TDS range of 33 to 175 mg/l, whereas the San Antonio Creek Valley groundwater basin has a TDS range of 129 to 38,600 mg/l (Kahr1 et al., 1978), TDS can impose a significant constraint upon the potential use of the groundwater resource. In some basins, however, the presence of trace minerals, such as boron, can severely impair the use of the resource even though the overall concentration of TDS is low. An example is the Salinas River Valley groundwater basin.

The California Department of Water Resources (DWR) is responsible for obtaining and maintaining data on groundwater supply and quality. Much of the information is obtained with cooperation from federal and local agencies. DWR offices are located in Red Bluff, Sacramento, Fresno and Los Angeles. Inquiries regarding water well drilling contractors should be directed to the State Contractor's Licensing Board which has offices located in principal cities throughout the state.

Runoff

Rivers. Within the study area, streams are perennial (for definition of terms, see vol.I, Chapter 4, Runoff) if their drainage basins are located within regions receiving mean annual precipitation of 102 cm (40 in) per year (Rantz, 1972). The large master streams of the study area and most major tributaries of streams in the northern portion of the study area are perennial streams. Some master streams in the southern portion of the study area are perennial in their middle sections but intermittent in their lower segments in part due to removal of water by water projects and in part due to their flow into semi-arid lowland valleys. Base flow, as a factor in the regimen of streamflow, is qualified on the basis of the percentage of mean annual runoff that occurs during the dry months of August and September. If the sum of the August and September runoff exceeds 3.0 percent of the annual runoff, base flow is considered to be well-sustained; if the percentage is between 1.5 and 3.0, base flow is considered to be fairly well-sustained; if the percentage is less than 1.5, base flow is considered to be poorly sustained (Rantz, 1972).

Within the study area, streams are intermittent if their drainage basins are located within regions receiving mean annual precipitation of 25 to 102 cm (10 to 40 in) (Rantz, 1972). The minor tributaries of master streams in the northern portion of the study area and the major and minor tributaries of master streams in the southern portion of the study area are generally intermittent streams. In the northern watershed units, the intermittent flow of streams generally is the result of the small size of the drainage basins of the streams. Sufficient runoff and groundwater supply cannot be gathered to sustain the flow all year. In the southern watershed units, intermittent flow results not only from the small size of some drainage basins but also from the semi-arid climate which supplies insufficient precipitation to maintain flows all year.

Ephemeral flow occurs in the minor tributaries of streams in the study area. Ephemeral flow is generally associated with drainage basins receiving less than 25 cm (10 in) average annual precipitation (Rantz, 1972). Such arid areas are found

locally within the study area, principally in the southern portions of the study area. Throughout the study area, ephemeral streams are those with small drainage basins and short courses.

The largest river systems within the study area are located in the northern watershed units. Those rivers include an extensive system of tributaries which extend far beyond the eastern borders of the defined watershed units. The northern watersheds are areas which receive large amounts of average annual precipitation and produce a large amount of runoff. Because the rocks of the Coast Ranges are relatively impermeable and large alluvial valleys are largely lacking in the northern portion of the study area, runoff is large and the rivers have large discharges during the rainy portion of the year.

In the central portion of the study area, the Sacramento-San Joaquin River system is the largest river system of the state and enters the coastal zone in San Francisco Bay and discharges into the ocean at the Golden Gate of San Francisco.

In contrast to the northern watersheds, the southern watershed units are located in areas of semi-arid climate. Most of the rivers have their headwaters in mountain ranges where the average annual precipitation is moderate and their middle and lower segments in low valleys with a semi-arid climate. The rivers are of smaller size as a rule and have lower discharges. Most of the larger rivers of the southern watershed units have lower segments which flow across broad alluvial plains into which the streams' waters infiltrate. Some of the rivers have insufficient flow during the dry summer period to reach the sea.

Thirty-four streams within the study area have been treated as emphasized streams in Volume IV. The emphasized streams include (north to south) the Smith River (Chapter 3), Klamath River and its tributary Blue Creek (Chapter 4), Redwood Creek, Little River, Mad River (Chapter 5), Eel River (Chapter 6), Mattole River (Chapter 7), Ten-Mile River, Noyo River, Casper Creek, Big River, Navarro River, Garcia River (Chapter 8), Gualala River (Chapter 9), Russian River and its tributary East Austin Creek (Chapter 10), Salmon Creek (Chapter 11), Lagunitas Creek (Chapter 12), San Gregorio Creek, Pescadero Creek (Chapter 14), Waddell Creek, San Lorenzo River (Chapter 15), Pajaro River (Chapter 16), Elkhorn Slough (Chapter 17), Salinas River (Chapter 18), Carmel River (Chapter 19), Little Sur River, Big Sur River, Big Creek, San Luis Obispo Creek (Chapter 20), Santa Maria River (Chapter 21), San Antonio Creek (Chapter 22), and Santa Ynez River (Chapter 23).

Most of the streams are located in rural areas. Almost every stream in the study area has been affected to some degree by human impact on the watersheds. In the northern watershed units, extensive deforestation has had a large impact on stream discharge and sediment loads. In the southern watersheds, extensive agricultural development has resulted in extraction of runoff waters and degradation of water quality.

Significant urban development exists in several of the watershed units in this study area. Most sources agree that urban development can have a dramatic impact on stream hydrology, primarily by altering runoff and, in turn, altering peak discharges. The impacts are greatest when most, or all, of a drainage area is urbanized. Such is the case around much of San Francisco Bay. In most of the study area, however, only a small percentage of the total drainage area of any watershed unit is urbanized, even in the developed areas around Humboldt and Monterey Bays. A few small streams are significantly urbanized, but records are poor or nonexistent. The effects of urban development on any watershed can be predicted, if levels of flood discharges are known (Waananen and Crippen, 1977).

Gaging station data for all watershed units were obtained from the USGS computer files (WATSTORE) and from the Water Data Records for California, published annually by water years (October to September) (USGS, 1977; 1978b). All data are available at the USGS library or through the Water Resources Division in Menlo Park, California. Stream gaging data for each watershed unit in the study area are presented in Vol. IV, Chapters 3 through 24.

All flood data were obtained from the USGS pamphlet Magnitude and Frequency of Floods in California (Waananen and Crippen, 1977) which is available free from the USGS Water Resources Division in Menlo Park, California. Flood data for each watershed unit in the study area are presented in Vol. IV, Chapters 3 through 24.

In this study, flow duration curves were made for discharge in the periods May 1 - July 31, and August 1 - October 31, for the period preceding any major recorded water

project on the emphasized river (pre-project), the period following such a project (post-project), and any periods between projects (inter-project). The graphed curves are intended to reveal any great changes in flow duration which could possibly result from the water projects,

The rivers of the study area tend toward periodic flooding because of the concentration of precipitation in the November to April period. In the mountainous terrain of the study area, most human settlements are located on floodplains because the terrain is flat. In addition, river valleys are commonly used as sites of roads, railroads and airports. Because the sediment deposited by rivers (alluvium) is generally fertile soil, floodplains are areas of agricultural development. For these reasons the natural flooding of rivers takes a high toll in damage to human settlements, agriculture, transportation networks and sometimes human life. In addition, human activities commonly aggravate the flooding situation. Human settlements and roads cause an increase in impermeable surfacing which adds to runoff. Acute problems of this nature have arisen in urbanized areas of California. In rural areas, vegetation removal related to timber harvesting, mining, overgrazing and agriculture result in increased runoff and increased sediment transport. The latter adds to flooding problems because the sediment is deposited in stream channels and thereby reduces their capacities, creates obstructions to flow and raises the height of the channel bottom.

In general, the large drainage basins of the study area have larger floods than the small drainage basins. The Sacramento-San Joaquin has the largest floods in California. Exceptions to the generalization regarding the relationship between area and flooding occur in the study area. For example, the drainage area of the Klamath River basin is approximately four times larger than that of the Eel River, but the record peak flow of the Eel River exceeds that of the Klamath by 1.35 times. Also the annual peak flow of the Eel River has exceeded that of the Klamath in numerous years. In these basins, intense rainfall seldom occurs uniformly over all parts of a large basin, but intense rainfall may cover most of the watershed of moderate size. Thus, the smaller basin of the Eel River may be entirely included within a single intense storm and the resulting runoff reaches flood levels in the downstream segments because all the tributaries contribute high runoff. The larger Klamath River basin may have high precipitation in some sections which results in high runoff contribution to lower segments of the river from those tributaries, but other tributaries contribute much lower flows and the flow is somewhat balanced as a result (Kahri et al., 1978).

Flooding in the lower sections of many streams in the study area is also caused by tides. When peak flow periods coincide with high tides the flooding potential is high. When tides are high at the mouth of a river, the flow from upstream segments is obstructed and the upstream waters flood. Such conditions occur periodically in the lower segments of the Russian, Smith, Klamath, Eel River and other streams. Similarly, winds may drive stream waters or estuarine waters upstream with similar result. Wind-induced flood conditions are not uncommon in the study area because most streams have a flow toward the west which is opposed by the westerly winds of storms systems entering the state which drives coastal waters eastward onshore.

The Federal Insurance Administration (FIA) bases its flood insurance programs on design for the 100-year flood. The FIA issues flood hazard boundary maps which delineate the areas subject to inundation by 100-year flood waters and 100-year tsunami. Within the study area only the Eel River has a recorded 100-year flood. Smaller floods are more common. For example, the Klamath River has had four 10-year floods in 62 years of record, three of which occurred in the successive years of 1970-1973. One of those floods was the 50-year flood and one was the 25-year flood. Years in which flooding was extensive in the study area were 1955, 1964-1965, 1969 and 1970-1973 (Kahri et al., 1978).

Lakes and Reservoirs. Few natural freshwater lakes are located within the watershed units of the study area. The absence of lakes is largely the result of the well-integrated drainage systems in the Coast Ranges. The river systems have thoroughly dissected the mountains and eroded away the natural barriers which commonly lead to the formation of lakes. The Coast Ranges were not glaciated during the Pleistocene like the Sierra Nevada and Trinity Range, and therefore, lack the numerous lakes which characterize the landscapes of those mountains. Most lakes within the study area are located on the coastal plains. Some of the lakes are related to the formation of river deltas, such as Lake Earl-Talawa on the Smith River delta. Some lakes are related to landsliding which results in the natural damming of a water course. Most lakes have their origins as coastal lagoons which have been completely cut off from the sea by barrier sand dunes, such as Oso Flaco Lake and the

group of lakes at the Pismo-Nipomo sand dune field. Because of their proximity to the ocean, many of those lakes have brackish water. Few of the lakes within the study area are of large size. Most are shallow, and some contain water only intermittently.

Water Projects. Many of the large rivers of the watershed units have been dammed in their upper segments for purposes of water supply and flood control. The rivers which have large dams include the Klamath, Mad, Eel, Russian, Lagunitas (Creek), San Lorenzo, Salinas, Carmel, Arroyo Grande, Santa Maria and Santa Ynez Rivers. Because those projects significantly affect the discharge of their affected streams, the discussion of discharge of the emphasized streams in the watershed units includes analysis of the pre-project period and the post-project period. In addition, some streams have had several projects constructed during their history. In such cases, the flows between the projects, i.e., the inter-project period of record, is considered.

In addition to damming, most rivers of the watershed unit have had extraction of water for purposes of domestic, agricultural and industrial water supply. Some rivers have had the flow in their upper segments diverted to other water basins in California, such as the Trinity-Klamath River and the Russian River. Other rivers, such as the Russian River, have had water transferred into them from other river basins or plans exist to do so in the future, such as the Santa Maria River.

Sediment Transport

The stream of the watersheds throughout the study area are generally characterized by relatively large sediment loads. The large loads are the product of several factors. 1) The concentration of precipitation in the winter period commonly results in large amounts of runoff. The concentration of runoff in the winter and spring in turn causes extensive mass wasting and erosion of slopes. The sediment is conducted to the stream systems and eventually into the channels of large streams. The above situation is enhanced by periodic flooding. 2) The streams of the watershed units generally have relatively steep gradients and, therefore, have much erosive energy. 3) Much of the study area is comprised of relatively weak materials including the rocks of the Franciscan Formation, Monterey shale and other formations which are subject to extensive mass wasting and erosion and produce abundant sediment. The southern watershed units also contain extensive alluvium which is easily eroded during flood conditions. 4) Much of the study area is subject to phenomena which disrupts the vegetation cover including periodic wildfires, clear-cut timber harvesting, mining, overgrazing of livestock, and other human activities.

As a result of the above factors the study area has some of the highest denudation rates in the United States, second only those of the Colorado River Basin. The Pacific slopes region has an average total denudation rate of 9.1 cm (3.6 in) per 1,000 years (Judson and Ritter, 1964). The Eel River carries the highest recorded average annual sediment load per square mile of drainage area in the coterminous United States. The large rivers of the northern watershed units all have high sediment loads. Most of that sediment is transported during the periods of peak and moderate flow. At that time the sediment includes large-sized material (sand, pebbles, cobbles, and boulders), fine-sized silt and clays, dissolved solids and material in solution. As discharge decreases, the streams transport only the fine fractional material, dissolved solids and material in solution. The materials are carried to the sea where the coarse fraction is deposited on the continental shelf and becomes entrained in the processes of littoral drift. The fine-sized fraction joins with the salt water and undergoes flocculation and falls out. The smallest fractions (clays) are carried the farthest out on the continental shelves.

Many of the streams have insufficient flow in summer to carry their sediments to the sea. Those streams are primarily located in the southern watershed units. The entire load of the stream may be deposited before reaching the sea and be deposited in the channel and behind barrier sand bars at the delta.

Water Quality

Water quality conditions in California were generally good for water years 1976 and 1977. Most of the state's waters met standards during these years even though they were drought years. The number and severity of water quality problems caused by point source discharges has markedly decreased in the last several years, due

primarily to enforcement activities under the State's Porter-Cologne Act and to the stimulus to facility construction provided by grants from the State's Clean Water Bond Fund and the federal construction grant funds.

The major water quality problems facing the State of California in the next decade will be the most difficult to resolve. These are nonpoint source problems, which are generally geographically widespread, difficult to precisely define, and usually the result of long-held land use practices. Examples are: sediment and debris washed into streams as a result of logging practices; groundwater mineralization due to many causes; increasing salinity in the Colorado River which supplies water to large areas of southern California; increasing salinity of the Salton Sea, endangering fish life and the local recreation industry; and seawater intrusion into formerly usable groundwater aquifers at numerous points along the coastline (SWRCB, 1978b).

Drought conditions, such as experienced in water year 1976 and 1977, decrease water quality in California streams. Slow stream velocities and shallow depths cause streams to exceed normal temperature ranges. Higher stream temperatures affect stream life, especially fish. Decreased dilution capacity aggravates pollution problems by increasing pollutant concentrations over normal levels.

There are three Regional Water Quality Control Boards (RWQCB) in the study area. The North Coast Region containing the Klamath River Basin and North Coastal Basin is Region 1. The San Francisco Bay Region is Region 2, and the Central Coastal Region is Region 3 (see Figure 3-35). Each RWQCB is responsible for monitoring all discharges into receiving or navigable waters and administers State-Federal certification of conformance with water quality standards for projects requiring a Federal permit, i.e., National Pollutant Discharge Elimination System (NPDES). NPDES permits are required for all discharges of waste to surface waters by Section 402 of the Federal Water Pollution Control Act (PL 92-500). The State Water Resources Control Board (SWRCB) has authority over each RWQCB.

Each RWQCB has a basin plan that discusses water resources development and use, water quantity and quality problems, beneficial uses, water quality objectives, point and nonpoint source measures, surveillance, and environmental sensitivity (SWRCB, 1975b; SWRCB, 1975c; SWRCB, 1975d; SWRCB, 1975e; SWRCB, 1975f, SWRCB, 1975g). The California State Water Resources Control Board (SWRCB) published a Program for Water Quality Surveillance and Monitoring in California in 1975 (SWRCB, 1975a). The SWRCB's Annual Water Quality Inventory for water years 1976 and 1977 describes the water quality monitoring programs instituted during those years (SWRCB, 1978b). California State Agencies' Water Quality Related Activities Proposed for Fiscal Year 1978-79 discusses all the State agencies and their water quality programs (SWRCB, 1978a).

The following paragraphs on the three RWQCB basins in the study area discuss the general water quality in each basin. Refer to individual watershed units (Vol. IV, Chapter 3, Hydrology, Water Quality) for more detailed information on river and stream water quality within a watershed.

North Coast Basin (1). In the North Coast Basin, headwaters of most streams are located in the Klamath Mountains and in the California Coast ranges. Water quality characteristics are reasonably consistent from year to year and exhibit fairly strong seasonal fluctuations reflecting the high winter rainfall characteristics of this region. Excessive mercury concentrations throughout the North Coastal Basin may be due to natural weathering of the mineral rich Coastal Geochemical Province with augmented input from some human activity (McCleneghan and Rectenwald, 1979). Levels of aluminum, iron, manganese, and nickel were higher in northern California and negatively correlated with silver, lead, and zinc concentrations (SWRCB, 1979).

The North Coast Regional Water Quality Control Board has divided their area into two parts - the Klamath River Basin (1A) and the North Coastal Basin (1B).

Because of their widespread occurrence and actual interference with beneficial uses, sedimentation, turbidity, and debris are the Klamath River Basins most serious water quality problems. About 40 percent of the basin's sediment production is attributed to man's activities, such as logging and road construction and maintenance. Although no current water quality problems due to mining are known, mining activities have a high potential for causing water quality problems. Many of the mines in the Basin are being reworked for gold as a result of rising world gold prices. Sedimentation and turbidity problems can develop from surface mining, erosion of tailings, and sand and gravel extraction operations. Heavy metals and other minerals in mine drainage or leachate from tailings are potential problems in

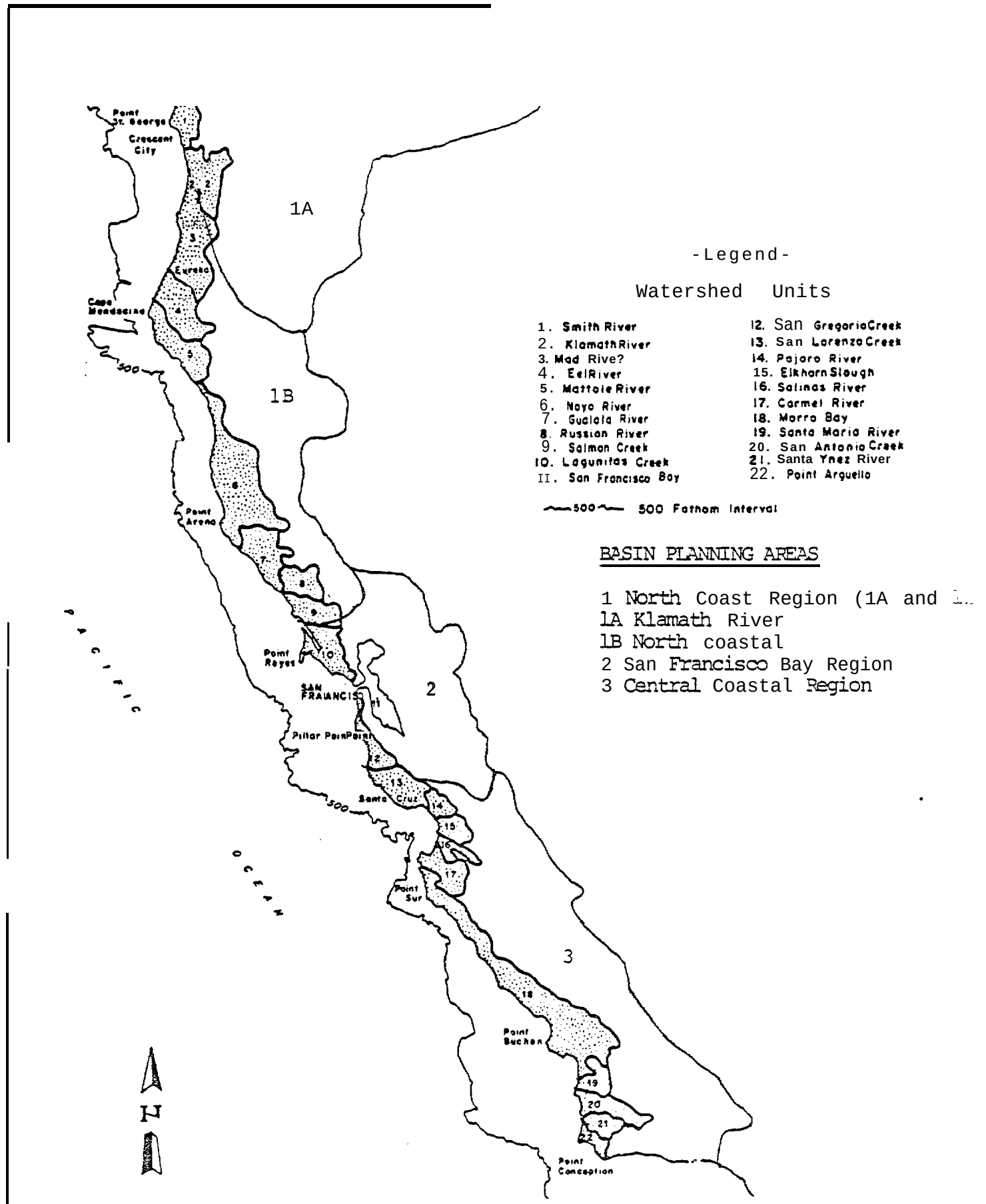


Figure 3-35. Regional Water Quality Control Board Basin Planning Areas (SWRCB, 1973b)

the Smith River and Klamath River watershed units (SWRCB, 1975a) . Mining waste discharges are potentially toxic to aquatic life and cause low pH values in water, Figure 3-36 shows areas affected by sedimentation and mining wastes.

The major water quality problems within the North Coastal Basin (1B) are related to the sensitivity of water uses requiring clean water, i.e., oyster rearing, anadromous fish spawning and public water supplies. Factors affecting these and other water uses include logging, mining and construction, sand and gravel operations, wastewater effluent disposal, and construction and operation of reservoirs . The north coastal region contains a number of areas where excessive siltation occurs naturally because of the unusual combination of high precipitation, deeply incised valleys, and unstable soil conditions. Dissolved minerals are typically low in the north coastal streams and reservoirs. Mineral constituents of north coastal streams are dominantly of a calcium-bicarbonate classification and are very low in terms of percent sodium. Most of the surface waters are soft, but total hardness values in excess of 100 mg/l as calcium bicarbonate occur during low flow period. Low dissolved oxygen concentrations and high coliform bacteria concentrations are problems in some areas (SWRCB, 1975d) .

Following the North Coast Regional Water Quality Control Board's prohibition of waste discharges from any source into North Coastal streams, the remaining water quality problems in this basin are non-point source (due to an area-wide problem rather than to specific points of waste discharge) (SWRCB 1978b).

San Francisco Bay Basin (2). Much of the San Francisco Bay Basin is urbanized or in the process of urban development. Watersheds in the coastal range of the San Francisco Peninsula are mostly undeveloped and serve as a water reservoir. The only remaining area in the San Francisco Bay Basin with substantial undeveloped surface water supplies is the coastal drainage of southern San Mateo County. Water in the principal streams is generally good and suitable for domestic, agricultural and industrial uses. Most water is bicarbonate in character with calcium generally the predominant cation. Dairy waste discharge into streams in the Lagunitas Creek watershed unit causes eutrophication problems. Wastewater discharge and surface water runoff have caused some water quality problems in the coastal bays and lagoons north of San Francisco.

Central Coast Basin (3). The Central Coast Basin (3) contains the remaining watershed units in the study area. Bacteriological contamination of coastal waters has been a problem in the Monterey Bay area in localized areas and along the south San Luis Obispo County shore. Eutrophication problems are evident in the lower Salinas River below Spreckles and in the lower reaches of San Luis Obispo Creek due to non-point sources. Some streams, such as the Salinas River, are naturally highly mineralized and contribute to the excessive salinity of local groundwaters. Figure 3-37 indicates areas in the study area where turbidity, sedimentation, nutrient levels, and mineralization problems are caused due to agriculture. Most streams in the Central Coastal Basin are intermittent; there are periods during the summer months when little or no flow exists in the stream channels. For some streams the flow that exists during the dry season is composed of irrigation runoff or wastewater treatment plant effluent (SWRCB, 1975e).

The Primary Water Quality Monitoring Network. To assess the extent and nature of the State's water quality problems, and to measure improvements brought about by pollution abatement activity, California has established water quality monitoring programs.

The Primary Water Quality Monitoring Network provides for surveillance of selected streams, lakes and coastal waters. Parameters being monitored are field conditions (such as temperature and pH) , minerals, minor elements, nutrients, pesticides, bacteriological and certain biological and miscellaneous determinations. Monitoring frequencies vary according to need from monthly to annually. Streams and lakes were ranked to indicate their importance to the State in terms of water quality. Twenty-eight streams in California were ranked Priority I (highest priority) . The Eel River, Klamath River, Russian River, Salinas River, and San Lorenzo River are Priority I. Priority II and III streams have also been designated, but monitoring on Priority II streams will not occur until funds are available. Priority I streams with water quality standards violations for dissolved oxygen, electrical conductivity, and pH are shown in Table 3-6.

Water Quality and Effluent Limited Classification. Water Quality Limited Segments and Effluent Limited Segments were established by the Regional Boards using available water quality data and the following criteria. A Water Quality Limited

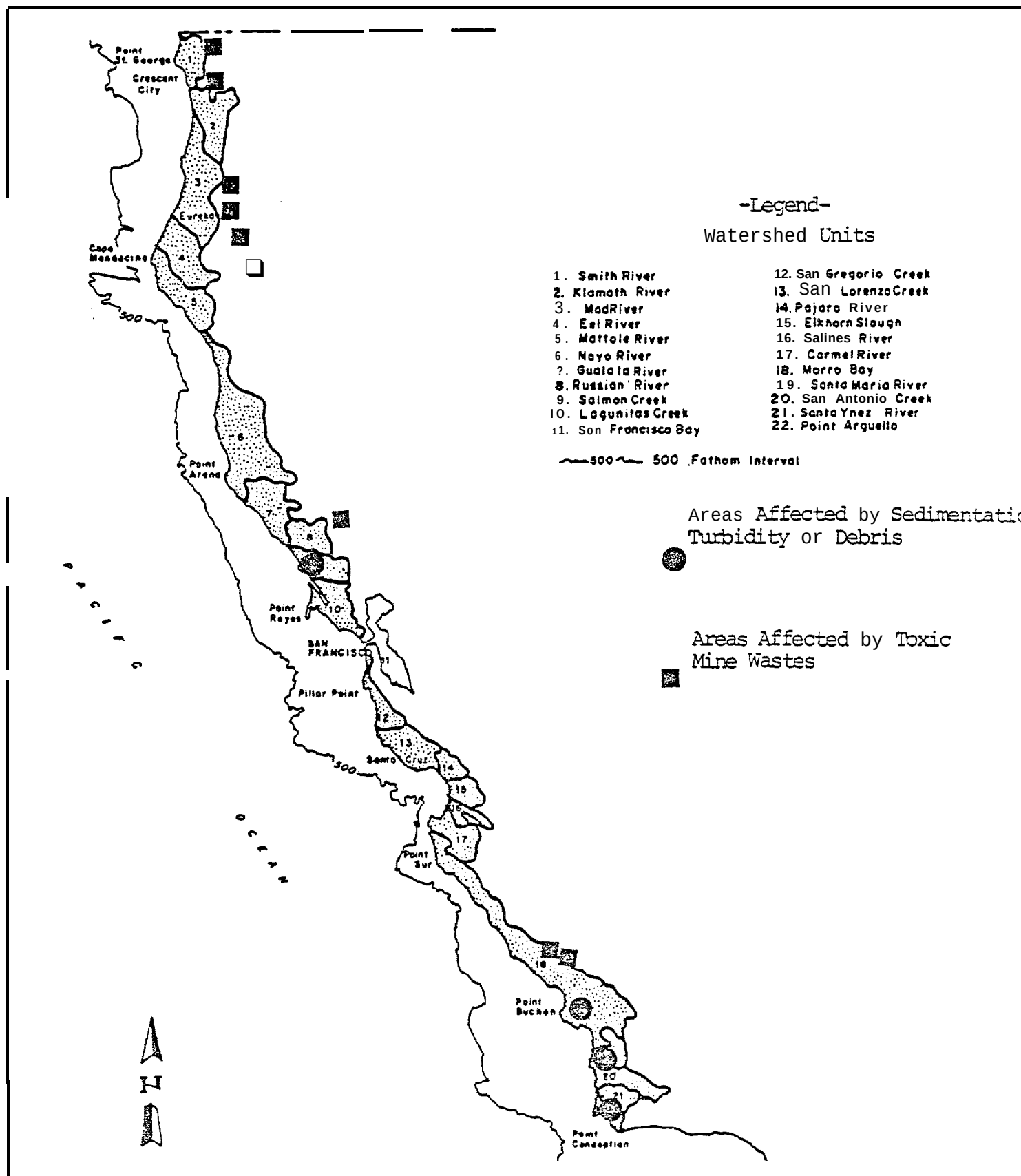


Figure 3-36. Areas Affected by Sedimentation, Turbidity or Toxicity from Mining Wastes (SWRCB, 1978b)

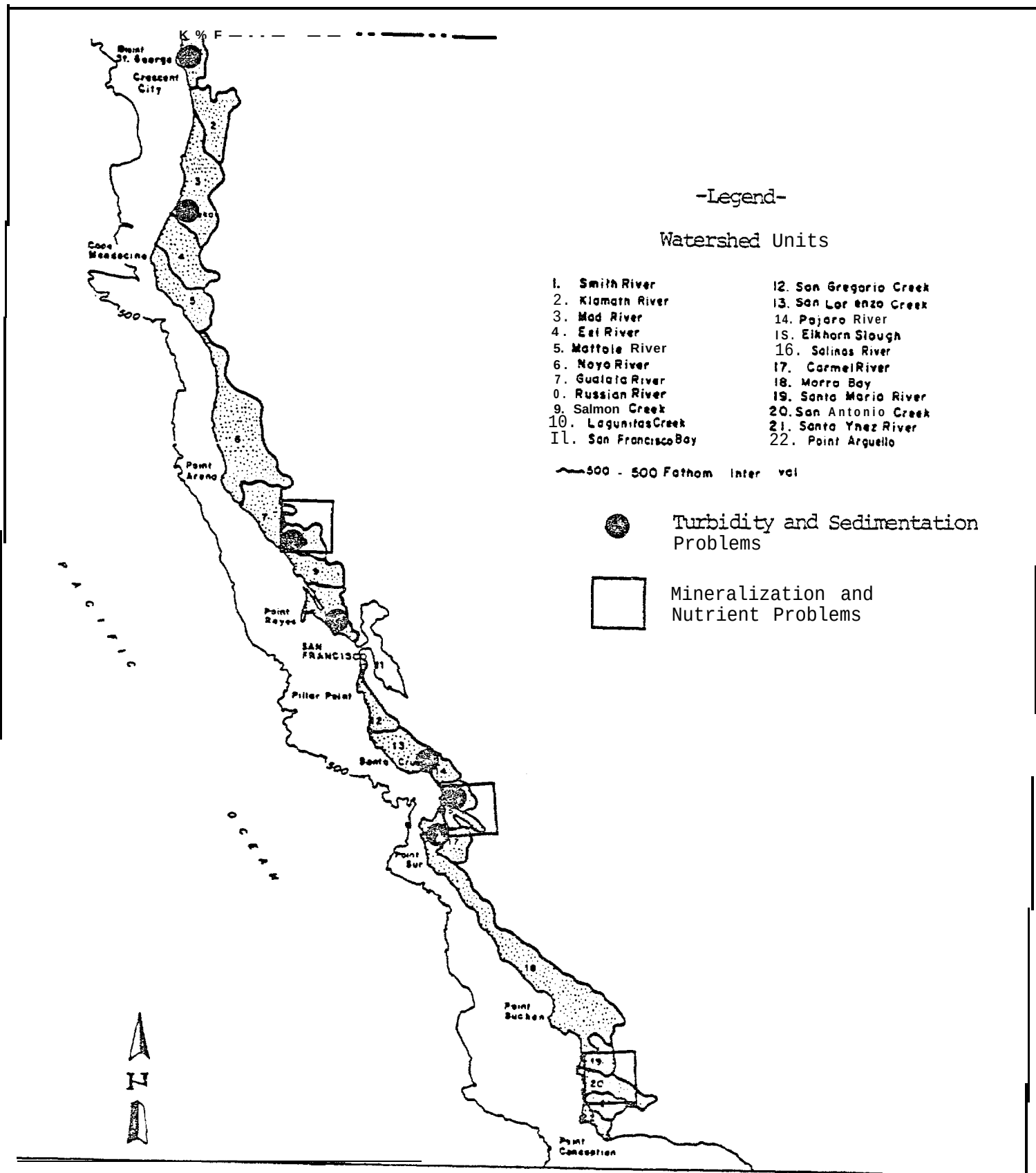


Figure 3-37. Water Quality Problems, Including Turbidity, Sedimentation, Mineralization, and Nutrient Problems, Caused by Agricultural Practices (SWRCB, 1978b)

Segment is a stream segment where it is known that present water quality does not provide for recreation in and on the waters and for protection and propagation of fish, shellfish, and wildlife. July 1983 treatment levels will be insufficient to provide the water quality necessary to meet these goals also.

Effluent Limited I stream segments include segments that probably qualify for Water Quality Limited classification but documentation is not available. This classification is applied to any segments with suspected violations or threats to any water quality objective identified in the basin plans; to segments presently in violation of standards, but where July 1977 and/or July 1983 treatment levels will be sufficient to provide the water quality necessary to meet the goals of PL 92-500; and to segments presently in compliance, but where documentation substantiates a trend

Table 3-6. Summary of Water Quality Standards Violations
In Priority I Streams, Water Years 1976 and 1977
(from SWRCB, 1978b)

Stream	Station	Water Year	Parameter	value ¹	Standard	Remarks
Eel River	F6110000	1976	Electrical Conductance	2S3	225	Median Value
		1977	Electrical Conductance	284	225	Median Value
Klamath River	F3110000	1977	Dissolved Oxygen	1.1	8.0	Minimum Value
Russian River	F9150000	1976	Dissolved Oxygen	9.9	10.0	Median Value
		1977	Dissolved Oxygen	8.7	10.0	Median Value
		1977	Electrical Conductance	300	250	Median Value
Salinas River	D2132510	1977	Dissolved Oxygen	4.0	7.0	Minimum Value
		1977	pH	8.4	8.3	Maximum Value

¹ Units: Dissolved oxygen in milligrams per liter
Specific conductance in micromhos per centimeter
Hydrogen ion concentration, pH, in standard units.

toward violation of a water quality objective identified in a basin plan. All remaining water bodies and segments are classified Effluent Limited II. There are no Water Quality Limited Segments in the study area although Laguna de Santa Rosa (Water Quality Limited Segment) is close to the Russian River watershed unit. Effluent Limited Segments in the study area are listed in Table 3-7.

Point and Non-point Sources of Pollution. Pollution sources can be divided into point and non-point sources. Point sources of water pollution are caused by one or more discharges at a given point, such as sewage treatment plant or industrial outfalls. Sediments near point source discharges act as a sink and concentrate settling polluted material. These areas may show an increasing pollutant gradation as one moves from the point source into a basin or onto a deep-sea fan. A number of California municipalities had to upgrade their sewage treatment plants and wastewater discharges because of the Federal Water Pollution Control Act Amendments of 1972. Very detailed predesign/predischarge reports covering water quality and physical and chemical oceanography for the localized area near certain wastewater discharges are available for Humboldt, San Francisco, San Mateo, Santa Cruz, Watsonville, Morro Bay, Monterey Bay, Carmel Bay, Pismo Beach, and San Luis Obispo. These reports are listed in the appropriate ocean basin unit (see Vol. IV, Chapters 25, 28, and 29).

Table 3-7. Effluent Limited Segments of 'Water
Bodies in Coastal Northern and Central
California (from SWRCB, 1978b)

Segment Name	Reg ion	Beneficial use Affected ¹	Source ²	Comments
Tomales Bay - Walker & Lagunitas Creeks	2	G	NP	Coliform
Bolinas Lagoon	2	G,Q	P, NP	Coliform
San Lorenzo River	3	A,B,C,J M,N,P,Q,R,T	NP	Nutrients Turbidity, Coliform Suspended Solids
Aptos-Sequel Coastal Liner Pajaro River	3	--	P	--
Monterey Bay	3	A,B,Q,T	NP	Sodium, Pesticides Nutrients, TDS ³
Lower Salinas River	3	G,Q,R	P, NP	Bacteria, Pesticides
Carmel River	3	I,P,R	P	DO, Coliform, Nutrients TDS, Toxics
San Luis Obispo Creek	3	A,Q,R	NP	Bacteria, TDS
Lower Santa Maria River	3	B,I,M,N,Q,R	P, NP	DO, pH, Nutrients, Bacteria
	3	A,B,C,I,P,Q,R,T	P, NP	Solids, Pesticides Nutrients

- 1 A = Municipal and domestic supply
B = Agricultural supply
C = Industrial service supply
G = Shellfish harvesting
I = Warm freshwater habitat
J = Cold freshwater habitat
M = Fish spawning
N = Fish migration
P = Wildlife habitat
Q = Water contact recreation
R = Non-contact water recreation
T = Groundwater recharge

- 2 NP = Non-point source
P = Point source

- 3 TDS = Total dissolved solids

Non-point sources of water pollution are pollution inputs from large areas to a body of water, i.e., storm water runoff or air pollution fallout. Because the Federal Water Pollution Control Act has fairly effectively cleaned up major point source polluters through the building of secondary or more advanced treatment plants, non-point source pollution is becoming the major water quality problem in the study area. Non-point source water quality problems are also harder to solve because they often involve "ways of life".

Water Quality Parameters, The following is a discussion of some of the more common water quality parameters, how they are measured and why they are important. The decomposition of organic wastes in water requires oxygen and lowers the dissolved oxygen content (DO) content of water. This is called the biochemical oxygen demand (BOD). BOD and DO are usually expressed as milligrams per liter (mg/l) or parts per million (ppm). A DO concentration of 4 mg/l is about the lowest concentration that

will support a varied freshwater fish population. The minimum DO concentration for a well-rounded fish population (including game fish) is 5 mg/l (EPA, 1976). Fish behavior, growth and reproduction are all affected by DO levels and fluctuations. The National Technical Advisory Committee on Water Quality Criteria, Federal Water Pollution Control Administration, recommended that the minimum DO level in estuaries should not be less than 4 mg/l.

Biostimulants (plant nutrients such as nitrates and phosphates) can cause excessive aquatic plant growth and can thus lead to lowered DO levels.

Turbidity is a measurement of the suspended matter in water. Suspended particulate include clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. Reduced light penetration can reduce plant photosynthesis. Suspended particulate if sufficiently concentrated may have several effects on aquatic organisms. These include the potential to: 1) clog gills and impair respiratory exchange in fish and invertebrates; 2) clog filter-feeding mechanisms in invertebrates; 3) reduce the growth and survival of larval stages of fish and shellfish; and 4) reduce settling of larvae. Turbidity measurements can be expressed in secchi disc depths, amount of suspended solids, and turbidity units.

Water hardness is caused by the polyvalent metallic ions dissolved in water. In fresh waters these are principally calcium and magnesium although other metals such as iron, strontium, and manganese contribute to the extent that appreciable concentrations are present. The concept of hardness comes from water supply practice. It is measured by soap requirements for adequate lather formation and as an indicator of the rate of scale formation in hot water heaters and low pressure boilers. Hardness commonly is reported as an equivalent concentration of calcium carbonate (CaCO_3). A classification of water by hardness content is: soft (0 to 75 mg/l CaCO_3), moderately hard (75 to 150 mg/l CaCO_3), hard (150 to 300 mg/l CaCO_3), and very hard (300 mg/l CaCO_3). Natural sources of hardness principally are limestones which are dissolved by percolating rainwater made acidic by dissolved carbon dioxide (EPA, 1976).

Toxic substances usually refer to potentially toxic heavy metals and/or trace elements such as lead, mercury, cadmium, etc. There are other toxics also such as cyanide, pesticides and herbicides (e.g., DDT, mirex, parathion and chlorophenoxy herbicides). Although the basic action of heavy metals probably involves the inhibition of different enzyme systems, the more obvious effects are variable and can be divided into structural changes, inhibitory effects and behavioral changes. The toxicity of heavy metals generally increases with higher temperature and decreasing salinity of the water. Filter feeding organisms and predatory animals at the top of the food chain concentrate heavy metals and trace elements.

Petrochemicals include a diverse mixture of hydrocarbons with variable solubilities, persistence, and toxicities. Many toxic pesticides such as chlorinated hydrocarbons are manufactured from petrochemicals. The potential effect of these substances on aquatic organisms includes: direct kill by coating, asphyxiation, or contact poisoning; direct kill by exposure to water soluble fractions; destruction of food sources; or sublethal effects such as reproductive failure and reduced resistance to infection and other stresses. Extensive oil slicks can reduce the DO in waters beneath the slick. The DO reduction is usually not enough to be harmful to aquatic organisms. Most oil entering the water washes up into a narrow zone along the shoreline. Some settles to the bottom where certain fractions continue to be released to overlying waters for months or years.

Coliforms are used to indicate water contamination from human or other animal fecal wastes. Coliforms are used as indicator organisms for pathogenic bacteria and viruses. Coliform contamination in the study area is caused by inadequate sewage systems and septic tanks, surface runoff from urban areas and from dairy and livestock areas, and inadequately treated wastewater discharges. Coliforms also affect the usefulness of waters for body contact recreation such as swimming. The fecal coliform level should not exceed an average of 200 per 100 ml with no more than 10% of the values exceeding 400 per 100 ml. Criterion for shellfish water quality is an average of 70 total coliforms per 100 ml with no more than 10% of the values exceeding 230 total coliforms per 100 ml (EPA, 1976). The fecal coliform tissue standard of 230 MPN per 100 grams (the same standard for commercial shellfish tissue is contained in the U.S. Food and Drug Administration) may be used as a basis for posting shellfish beds -with signs to notify shellfishermen of possibly harmful shellfish bacterial levels. Typhoid, cholera, shigella, salmonella and

gastroenteritis are examples of bacterial diseases that may be transmitted from water to humans by shellfish. Coliform measurements are expressed in terms of Most Probable Number (MPN) - an estimate based on certain probability formulas - or as total coliforms per 100 milliliters as measured by the membrane filter technique.

Mussel Watch and Toxic Substance Monitoring Programs. Environmental research has indicated that bivalves may be valuable as indicator organisms for pollution in coastal marine waters. These organisms concentrate numerous pollutants to a marked degree over seawater levels. In 1976 the U.S. Environmental Protection Agency began the National Mussel Watch program - a surveillance of U.S. coastal regions for their pollutant contents using species of mussels (Mytilus) and oysters (Ostrea and Crassostrea). Heavy metals, transuranic nuclides, petroleum hydrocarbons, and halogenated hydrocarbons were tested for in organisms. Thirty-one stations occur within the study area; twenty of these stations are in San Francisco Bay (see Figure 3-38). This program is now in its third year.

Results of the first year of the National Mussel Watch program are discussed below. No significant seasonal variations of heavy metal concentrations or halogenated hydrocarbons were observed based on monthly samples taken at Bodega Head. No zones of high general levels of metal pollution were discussed, although locally high levels of individual metals were frequently observed. Elevated values of DDT residues in mussels collected between San Francisco and San Diego can be traced to municipal wastewaters discharged in the past from a manufacturing plant in Los Angeles (Goldberg, et al., 1978).

PCB concentrations within the study area were only high at South San Francisco Bay, 590 parts per billion (ppb). Levels of radionuclides (^{241}Am and $^{239,240}\text{Pu}$) for the West Coast were much higher than for the East or Gulf Coast samples. These higher levels of radionuclides in West Coast shellfish are thought to be due to higher concentrations of transuranic elements or greater biological availability in western U.S. coastal environments than in the East or Gulf Coasts (Goldberg, et al., 1978).

The SWRCB's State Mussel Watch project is modeled after the National Mussel Watch, and its purpose is to provide the state with a system to document and assess long-term trends in selected indicators of the quality of coastal marine and estuarine waters. The State Mussel Watch project analyzed for arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, thallium, tin, zinc, aluminum, iron and manganese in the California mussel (Mytilus californianus) from thirty-two stations along the California coast. Samples were collected on four occasions in 1977 and 1978. The emphasis of the State Mussel Watch project is upon monitoring concentrations of trace metals and organics in biota from SWRCB's designated Areas of Special Biological Significance (ASBS) and other areas which are generally excluded from known pollutant point sources.

Nineteen stations of the State Mussel Watch are in the study area (see Figure 3-38). The concentrations of silver, lead, and zinc in mussel tissue show a general increase from stations in northern California to stations in southern California. The only existing guidelines for shellfish standards are the proposed interim U.S. Food and Drug Administration (FDA) alert levels. These proposed interim alert levels guidelines are intended as an indicator of shellfish-growing area degradation, and are not necessarily related to toxic or lethal metal levels in shellfish meats. Proposed FDA interim alert levels (dry weight) are 8.7 $\mu\text{g/g}$ for cadmium, 11.6 $\mu\text{g/g}$ for lead, and 175 $\mu\text{g/g}$ for zinc. FDA interim alert levels for cadmium were exceeded at Pacific Grove Marine Gardens ASBS, Farallon Islands ASBS, and Bodega Marine Life Refuge ASBS, while zinc levels were exceeded at Pacific Grove Marine Gardens ASBS. Proposed interim FDA alert levels were not exceeded in mussel tissue for copper and chromium. There are no proposed interim alert levels for silver, nickel, aluminum, iron or manganese. Stations with elevated concentrations are discussed in detail in vol. IV, Chapters 25 through 29. The term "elevated" refers to tissue metal concentrations which are statistically different ($P < 0.05$) from other subsample sets (Stephenson, et al., 1979).

The classic approach of water column testing is often ineffective in identifying toxic substances because toxicants usually occur in very low concentrations in the environment, and water analyses are often not sensitive enough to detect them. Since some chemicals are persistent and/or can be biomagnified, and they can have environmental effects that greatly exceed the effects of low concentrations in the water column. Biomagnification is the process whereby the concentration of a substance increases in organisms as it passes to organisms at higher levels in the

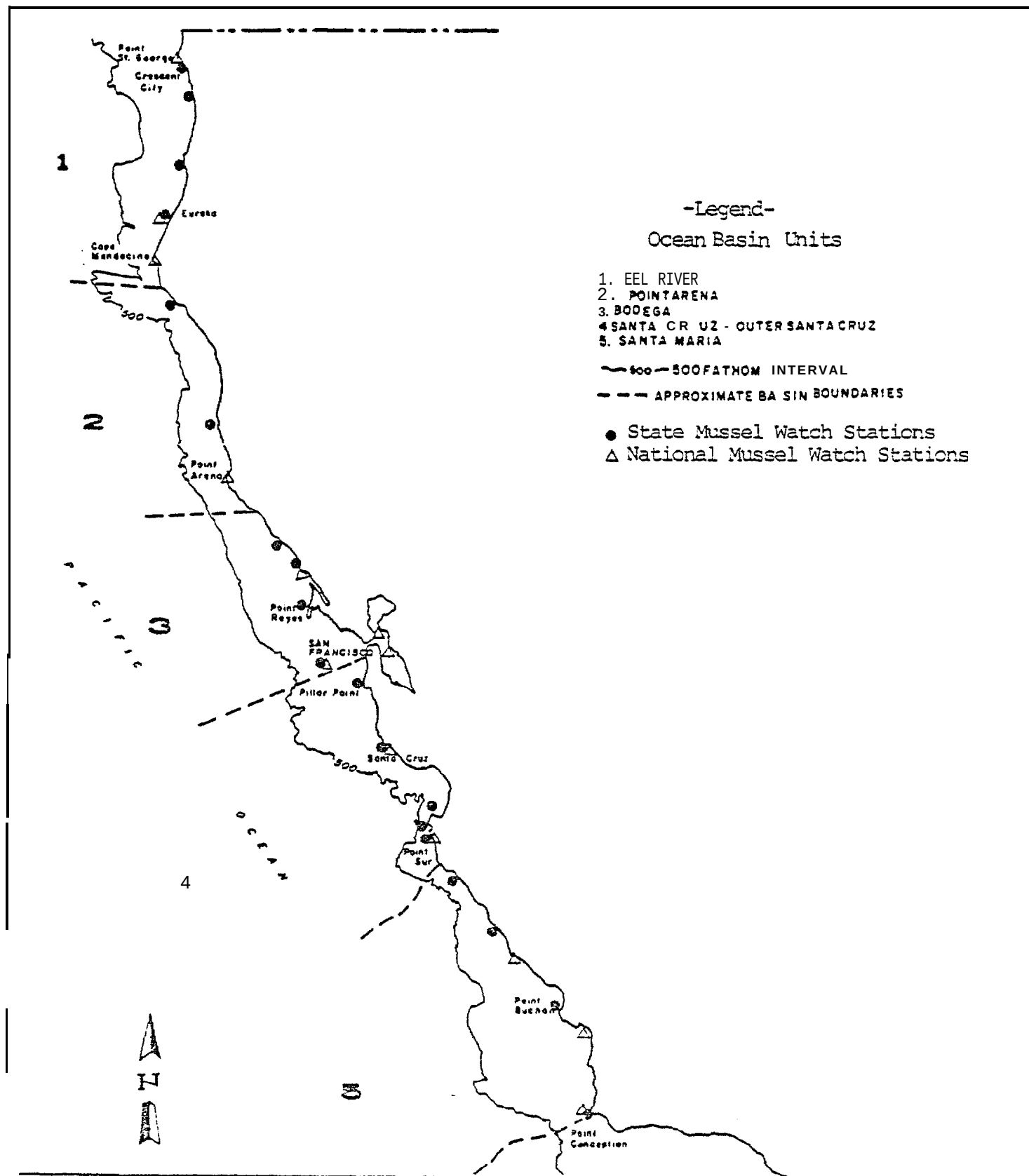


Figure 3-38. Locations of National and State Mussel Watch Stations
 (Goldberg, et al., 1978; Stephenson, et al., 1979)

food chain. Toxicant concentrations are not static, and instantaneous water sampling is unsatisfactory to determine the presence or absence of these materials with time. The measurement of toxicants in the water is inadequate to fully ascertain their effects on aquatic biota.

Tissue analysis of aquatic organisms gives a better idea of toxic substance concentrations in the environment than just water samples, because it reflects biomagnification and exposure over time. California's Statewide Primary Monitoring Network Program tests for toxic substances in bottom sediments, benthic (bottom dwelling) invertebrates, forage fish, and predatory fish. Elevated levels of toxic substances were found in all five Priority I Streams in the study area.

The U.S. Food and Drug Administration (FDA) has established maximum levels for some toxic substances in human foods. These levels are based upon certain assumptions as to the quantities of food consumed by humans and upon frequency of consumption. FDA limits are intended to protect people from chronic effects of these toxicants. The EPA and National Academy of Science (NAS) developed recommended maximum concentrations of some toxic substances for protection of the organism containing the material and the predator species that might consume the contaminated organism. Table 3-8 lists EPA, NAS, and FDA guidelines for toxic substances that are known to be a problem in California. For many elements, widely accepted tolerance limits for aquatic organisms have not been established. If no limit for a compound has been established, elevated concentrations were defined by the Primary Monitoring Network as concentrations exceeding one standard deviation above the mean concentration of that parameter in similar organisms sampled statewide (Woodard, 1979).

Table 3-8. Established FDA, EPA or NAS Guidelines
For Toxic Substances

Toxicant	EPA or NAS Guideline ug/gm (ppm)	FDA Guideline ug/gm (ppm)
Mercury	0.5	1.0
DD T	1.0	5.0
Polychlorinated Biphenyls	0.5	2.0
Chlordane	0.100	0.3 (tentative)
Toxaphene	0.1	5.0
Aldrin	0.1	0.3

Water Quality Data Sources. There are a number of water quality data sources in California. The U.S. Environmental Protection Agency (EPA) maintains a computerized water quality data storage and retrieval system called STOrage RETrieval System (STORET). The STORET system has two main divisions - one for water quality data and the other for information about point sources of pollution discharge. State agencies, EPA, U.S. Geological Survey (USGS), and other federal agencies that routinely sample and analyze water quality at fixed sampling stations input data to STORET. California State agencies that input data to STORET include the Regional Water Quality Control Boards (RWQCB), the State Water Resources Control Board (SWRCB), and the Department of Water Resources (DWR). Data collected on Primary Network streams are input into STORET. A variety of retrieval programs are available. An index program will print station location and name, agency monitoring the station, and all the data for the station within a specified retrieval area. Other programs provide analysis of data by graphical display, regressions, seasonal comparison, time trends, and comparison of observed data with water quality standards. Station locations can be mapped on the computer. The Director of the Surveillance and Analysis Division at EPA Region IX office in San Francisco should be contacted in order to make use of STORET.

The SWRCB inputs their own water quality data into STORET and has a Data Management Department which can call out and run programs on all STORET data. STORET is the statewide system for management of water quality data.

The Department of Water Resources (DWR) has a computer-based system, Water Data Information System (WDIS), that manages surface water quality data, groundwater level measurements, and groundwater quality data. Data are presently entered, stored, and retrieved at the Department's computer center in Sacramento. DWR's Index to Sources of Hydrologic Data (1978b) summarizes information statewide about sources of hydrologic data including water quality. All of California's surface water quality stations are not represented in WDIS, and all historic and local agency data have not been entered yet.

The USGS publishes Water Resources Data for California (1977, 1978b) on a yearly basis, and these publications contain water quality data. The National Stream Quality Accounting Network (NASQAN) is a federally funded accounting network designed by the USGS to meet many of the information demands of agencies or groups involved in national or regional water quality planning and management. Areal configuration of the network is based on the river-basin accounting units designated by the Office of Water Data Coordination in consultation with the Water Resources Council. Primary objectives of the network are: (1) to depict areal variability of water quality conditions nationwide on a year-by-year basis, and (2) to detect and assess longterm changes in stream flow and stream quality. Stations in this network are USGS monitoring stations. The following five NASQAN stations are in the study area (USGS, 1979) :

11532500 Smith River near Crescent City
11530500 Klamath River near Klamath
11467000 Russian River near Guerneville
11159000 Pajaro River at Chittendon
11152300 Salinas River near Chualar.

The U.S. Geological Survey (USGS) also has the responsibility for implementing the National Water Data EXchange (NAWDEX). Membership organizations in NAWDEX include organizations from the Federal, State, interstate, local governmental, academic, and private sectors of the water-data community. NAWDEX is the computerized data storage system that should eventually contain most water quality data for California under one numbering system. At the present time not all agencies have input their data into NAWDEX, and therefore a NAWDEX number has not been assigned to many stations. This means that one has to use more than one data system and water quality station numbering system to acquire all the water quality data for a given area. The California NAWDEX assistance center is at the USGS Water Resources Division in Menlo Park.

NAWDEX also has access to the following large water-data bases:

(1) USGS's national computerized data system called WATER Data STORage and REtrieval (WATSTORE). This system contains a Daily Values File with daily observations of stream-flow, water-quality, sediment discharge, and ground-water level data; a Water Quality File with chemical analysis of both surface and groundwater; a Peak Flow File with annual peak observations of stream-flow and river-stage data; and a Ground Water Site Inventory File with well inventory data.

(2) EPA's STORET System.

(3) Bibliographic data services for Oceanic and Atmospheric Scientific Information System (OASIS) and Environmental Data INDEX (ENDEX) through the Environmental Data and Information Service (EDIS) of the National Oceanic and Atmospheric Administration (NOAA).

(4) Bibliographic data service relating to water resources activities is provided by the Water Resources Scientific Information Center (WRSIC) of the U.S. Department of the Interior's Office of Water Research and Technology.

The alphanumeric codes for inland water quality stations are NAWDEX codes; these stations are listed in STORET by these codes. The first four digits represent a DWR code from the Index to Sources of Hydrologic Data (DWR, 1978b). The next two digits further identify the station under this code system. The letter R stands for receiving water. The remaining alphanumeric code is either a station number or name assigned by the sponsoring agency or a number or name assigned by the SWRCB.

Locations of inland water quality monitoring stations are mapped on USGS and SWRCB Planning and Research Section maps.

Wastewater discharger's water quality monitoring stations are also plotted on USGS and SWRCB maps. The alphanumeric code for these stations begins with WB which stands for Water Board. The next two digits are the Regional Water Quality Control Board's (RWQCB) number, and the next seven digits are the National Pollutant Discharge Elimination System (NPDES) permit number. The remaining digits are the station number as designated in the NPDES permit. The actual discharger's monitoring data are available from the RWQCB in which the station is located.

Some USGS stations monitor water quality and are classified by the eight-digit USGS numbering system. Annual Water Resources Data for California reports are published and contain water quality data for these stations (USGS, 1977, 1978b),

Marine and estuarine water quality monitoring stations location maps are available from the SWRCB's Planning and Research Section. The first number of the code for each station indicates the RWQCB number, and the remaining numbers further identify the station within the Regional Board area. The Inventory of Marine/Estuarine Water Quality Monitoring Stations for California (1976) lists these stations by number with information on the sponsor and types of water quality parameters being measured (SWRCB, 1978b).

Data in the EPA STORET system for water quality stations in the study area were used to determine areas with water quality harmful to humans and aquatic organisms. Water quality criteria have been developed based on beneficial uses for water. Domestic use and aquatic organism use usually require better water quality (stricter criteria) than agricultural or industrial uses. The number of times a water quality parameter exceeded (in the case of dissolved oxygen fell below) the indicator value listed in Table 3-9 are determined for each station within its period of record. Table 3-9 shows the beneficial use that would be affected by an exceedance of an indicator value. If a parameter had only one or two "exceedances" for a station during its period of record, the parameter has not caused a water problem. Several "exceedances" for one or more parameters over each year for several years indicates a water quality problem. An exceedance for total hardness indicates hard water which is not necessarily a water quality problem. If dissolved oxygen values fell below the indicator value only a few times during the period of record at a station, organisms in the water are probably not dying from lack of oxygen. Excesses occurring several years ago for a parameter do not necessarily indicate that a water quality problem still exists at the station. Several "exceedances" for a toxic substance such as arsenic, chlordane, or cadmium in one year probably indicate an accident, discharge or spill occurred during that year. If "exceedances" for a toxic substance occur over several years, a defined water quality problem exists. Only one "exceedance" of a highly persistent and toxic substance such as chlordane is necessary to extensively damage aquatic organisms, bioaccumulate, and possibly affect humans using the water and eating contaminated organisms. Results of this analysis are discussed in the watershed units, Vol. IV, Chapters 3 through 24.

Water Quality Criteria and Standards. Domestic-use water quality criteria and standards are developed to protect public health. Mandatory requirements are set for toxic or potentially harmful substances (public health) and recommended limits are set for substances that are a matter of public taste or aesthetics (public welfare). The word "criterion" represents a parameter concentration or level associated with a degree of environmental effect upon which scientific judgment may be based. In water quality work "criterion" means a designated concentration of a constituent that when not exceeded will protect an organism, an organism community, or a prescribed water use or quality with an adequate degree of safety. A "standard" connotes a legal entity for a particular reach of waterway or for an effluent discharge. A water quality standard may use a water quality criterion as a basis for regulation or enforcement, but the standard may differ from a criterion because of local conditions such as naturally occurring organic acids, economic considerations, or degree of safety desired for an ecosystem (EPA, 1976). A parameter guideline or recommended limit are the same as criteria, i.e., no legal status.

Table 3-10 lists the U.S. Public Health Service Standards for drinking water. These standards are for water as it is delivered to the customer. Recommended criteria for raw water supply sources are slightly different (see Table 3-11). These criteria reflect variations in the economic and technical feasibility of removing the different materials.

Table 3-9. Water Quality Indicator Values Used in Computer Analysis

Parameter	Indicator value ¹	Beneficial Use For Indicator Value
Dissolved Oxygen	700 ug/l ²	Coldwater fish
Temperature	24 degrees C	Salmonid survival
PH	9.0	Freshwater organisms
Nitrate, NO ₃ -N	200 ug/l ³	Salmonid egg and fry survival
Nitrite, NO ₂ -N	40 ug/l ³	Salmonid egg and fry survival
Total phosphates (P)	50 ug/l	Prevent development of aquatic plants
Total alkalinity, CaCO ₃	20,000 ug/l	Freshwater organisms
Total hardness, CaCO ₃	150,000 ug/l	Moderately hard water
Total dissolved solids	250,000 ug/l	Domestic water supplies-public welfare
Total Ammonia, NH ₃ -N	20 ug/l	Freshwater organisms
Cyanide	5.0 ug/l	Freshwater and marine organisms
METALS		
Arsenic	50 ug/l	Freshwater fish-food organisms
Barium	1,000 ug/l	Domestic water supply-public health
Beryllium	11 ug/l	Freshwater fish-soft water
Boron	750 ug/l	Lethal to minnows
Cadmium	0.4 ug/l	Freshwater organisms soft water
Copper	25 ug/l	Most fish
Chromium	50 ug/l	Domestic water supply-public health
Iron	300 ug/l	Domestic water supply - public welfare
Lead	50 ug/l	Domestic water supply-public health
Manganese	50 ug/l	Domestic water supply-public welfare
Mercury	0.05 ug/l	Freshwater Fish
Nickel	100 ug/l	Freshwater and marine organisms
Selenium	10 ug/l	Domestic water supply-public health
Silver	20 ug/l	Stickleback-lethal
Zinc	420 ug/l	Salmon-lethal
ORGANICS		
Aldr in	0.003 ug/l	Freshwater and marine organisms
Chlordane	0.004 ug/l	Marine organisms
DD T	0.001 ug/l	Freshwater and marine organisms
2,4-D	100.0 ug/l	Domestic water supply-public health
2,4,5-T	10.0 ug/l	Domestic water supply-public health
Dieldrin	0.003 ug/l	Freshwater and marine organisms
Demeton	0.1 ug/l	Freshwater and marine organisms
Endosulfan	0.001 ug/l	Marine organisms
Endr in	0.004 ug/l	Freshwater and marine organisms
Guthion	0.01 ug/l	Freshwater and marine organisms
Heptachlor	0.001 ug/l	Freshwater and marine organisms
Lindane	0.004 ug/l	Marine organisms
Malathion	0.1 ug/l	Freshwater and marine organisms

Table 3-9. Water Quality Indicator Values Used in Computer Analysis
(continued)

Parameter	Indicator value ¹	Beneficial Use For Indicator Value
Methoxychlor	0.03 ug/l	Domestic water supply-public
Mirex	0.001 ug/l	Freshwater and marine organisms
Parathion	0.04 ug/l	Freshwater and marine organisms
Toxaphene	0.005 ug/l	Freshwater and marine organisms
Phenol	1.0 ug/l	Public welfare and fish flesh tainting
Phthalate Esters	3 ug/l	Freshwater and marine organisms
Polychlorinated Biphenyls	0.001 ug/l	Freshwater and marine organisms

- 1 The beneficial use having the standard criterion with the lowest Concentration was chosen as the indicator value. These values are from Quality Criteria For Water (EPA, 1976) except where otherwise indicated.
- 2 Concentrations below the indicator value for dissolved oxygen were determined. Concentration above the indicator value for all other parameters were determined.
- 3 These values are from Koch, et al. (1978) Beneficial Uses and Water Quality Criteria

Table 3-10. U.S. Public Health Service Drinking Water Standards, 1962
(from Miller and McGrew, 1977)

Parameter	Suggested Limit That Should Not be Exceeded	Cause For Rejection
<u>Bacterial</u>		
Coliform content	1 MPN/100 ml	
<u>Physical</u>		
Color	15 units	
Taste	Unobjectionable	
Threshold odor number	3	
Turbidity	5 units	
<u>Chemical</u>		
Alkyl benzene sulfonate	mg/l	mg/l
Arsenic	0.5	
Barium	0.01	0.05
Cadmium		1.0
Chloride	0.01	0.01
Chromium (hexavalent)	250	
Copper		0.05
Carbon chloroform extract ¹	0.2	
Cyanide	0.01	0.2
Fluoride ²	0.7-1.2	1.4-2.4
Iron	0.3	
Lead		0.05
Manganese	0.05	
Nitrate		10
Phenols	0.001	
Selenium		0.01
Silver		0.05
Sulfate	250	
Total dissolved solids	500	
Zinc	5	

¹Organic contaminants.

²The concentration of fluoride may be between 0.6 and 1.7 mg/l, depending on the listed annual average maximum daily air temperatures.

Table 3-11. Recommended Water Quality Criteria for Raw Water Supplies
(from Miller and McGrew, 1977)

Parameter	Recommended Maximum Limit
Ammonia	0.5 mg/l
Arsenic	0.1 mg/l
Coliform (total, geometric mean)	20,000 MPN/100 ml
Barium	1 mg/l
Cadmium	0.10 mg/l
Chloride	250 mg/l
Chromium (total)	0.05 mg/l
Color	75 units
Copper	1 mg/l
Cyanide	0.2 mg/l
Fluoride	1.4-2.4 mg/l
Methylene blue active substances	0.5 mg/l
Iron	
0.3 mg/l	
Lead	
0.05 mg/l	
Manganese	0.05 mg/l
Mercury	0.002 mg/l
Nitrate	10 mg/l
Phenols	1 ug/l
Selenium	0.01 mg/l
Silver	1 ug/l
Sulfate	250 mg/l
Zinc	
5 mg/l	

The quality of water required for industrial use varies widely depending on the industry and the use. Such requirements are too different to allow generalization.

Agricultural water supplies must be suitable for crop, orchard, and pasture irrigating; stock watering; and support of other ranching and farming operations. Table 3-12 shows guidelines for judging irrigation water quality. Interpretations are based on possible effects of constituents on crops and/or soils. Guidelines are flexible and should be modified when warranted by local experience or special conditions of crop, soil, and method of irrigation.

Criteria for aquatic habitats are difficult to establish since the response of organisms to water quality varies with species, size, age, and physiological conditions. Larvae and juvenile stages are usually more sensitive. Salmonid fish are often the most sensitive species. Tables 3-13 to 3-15 give criteria for freshwater and marine organisms.

Table 3-12. Guidelines for Interpretation of Quality of Water for Irrigation
(from Miller and McGrew, 1977)

Problem and Related Constituent	Water Quality Guidelines		
	No problem	Increasing Problems	Severe
Salinity¹			
EC of irrigation water, mmho/cm	0.75	0.75-3.0	3.0
Permeability			
EC of irrigation water, mmho/cm	0.5	0.5	0.2
SAR ²	6.0	6.0-9.0	9.0
Specific ion toxicity³			
From root absorption			
Sodium (evaluate by SAR)	3	3.0-9.0	9.0
Chloride			
me/ 1	4	4.0-10	10
mg/l	142	142-355	355
Boron, mg/l	0.5	0.5-2.0	2.0-10.0
From foliar absorption (sprinklers)			
Sodium			
me/ 1	3.0	3.0	--
mg/l	69	69	--
Chloride			
me/ 1	3.0	3.0	--
mg/l	106	106	--
Miscellaneous⁵			
NH ₄ ⁺ - N, mg/l for sensitive crops	5	5-30	30
NO ₃ ⁻ - N, mg/l (only with overhead sprinklers)			
me/l	1.5	1.5-8.5	8.5
mg/l	90	90-520	520
pH	normal range	6.5-8.4	--

1 EC is Electrical Conductivity. Assumes water for crop plus needed water for leaching requirement (LR) will be applied. Crops vary in tolerance to salinity. Refer to tables for crop tolerance and LR. The mmho/cm x 640 = approximate total dissolved solids (TDS) in mg/l or ppm; mmho x 1,000 = micromhos.

2 SAR (sodium adsorption ratio) is calculated from a modified equation developed by U.S. Salinity Laboratory to include added effects of precipitation and dissolution of calcium in soils and related to CO₃ + HCO₃ concentrations

To evaluate sodium (permeability) hazard:
$$SAR = \frac{Na}{\frac{Ca + Mg}{2}} \quad 1 + (8.4 - pH_c)$$

pH_c is a calculated value based on total cations, Ca + Mg, and CO₃ + HCO₃. Calculating and reportins will be done by reporting laboratory.

SAR can be reduced if necessary by adding gypsum. Amount of gypsum required (GR) to reduce a hazardous SAR to any desired SAR (SAR desired) can be calculated as follows:

$$GR = \frac{2Na_2}{SAR \text{ desired}} - (Ca + Mg) \times 234$$

Note: Na and Ca + Mg should be in mg/l. GR will be in lbs. of 100 percent gypsum per acre foot of applied water.

- 3 Host tree crops and woody ornamental are sensitive to sodium and chloride (use values shown) . Most annual crops are not sensitive (use salinity tolerance tables) . For boron sensitivity, refer to boron tolerance tables.
- 4 Leaf areas wet by sprinklers (rotating heads) may show a leaf burn due to sodium or chloride absorption under low humidity/high evaporation conditions. (Evaporation increases ion concentration in water films on leaves between rotations of sprinkler heads.)
- 5 Excess N may effect production or quality of certain crops: e.g., sugar beets, citrus, avocados, apricots, etc. (1 mg/l NO₃ - N = 2.72 lbs. N/acre foot of applied water.) NO₃ with overhead sprinkler irrigation may cause a white carbonate deposit to form on fruit and leaves.

Table 3-13. Water Quality Criteria for Freshwater Organisms
(from Miller and McGrew, 1977)

Parameter	Value
TDS	1500 mg/l (fresh waters)
pH	6 to 9
Alkalinity	20 mg/l
DO	
Warm-water biota:	5 mg/l general 4 mg/l short periods during 24 hr.
Cold-water biota:	7 mg/l spawning areas 6 mg/l general 4-5 mg/l periods less than 6 hrs.
Turbidity	
Warm-water biota:	50 units added
Cold-water biota:	10 units added
Toxic Materials	
Pesticides:	$\frac{1}{10}$ to $\frac{1}{100}$ of 48-hr TL _m
ABS (detergent) :	$\frac{1}{7}$ 48-hr. TL _m
LAS (detergent)	0.2 mg/l or $\frac{1}{7}$ 48-hr TL _m
Non-persistent materials:	$\frac{1}{10}$ 96-hr TL _m maximum $\frac{1}{20}$ 96-hr TL _m after mixing
Persistent materials:	$\frac{1}{20}$ 96-hr TL _m maximum $\frac{1}{100}$ 96-hr TL _m after mixing

Table 3-13. Water Quality Criteria for Freshwater Organisms
(continued)
(from Miller and McGrew, 1977)

Temperature	
Warm-water biota:	
Streams	5 degrees F rise
Lakes	3 degrees F rise
Cold-water biota:	
Spawning areas	0 degrees F rise
non-spawning areas	Same as for warm-water biota
Maximum temperature:	
93F	Catfish, gar; white and spotted bass; carpsucker; threadfin; gizzard shad.
90F	Largemouth bass, drum bluegill, crappie.
84F	Pike, perch, walleye, small mouth bass, sauger.
80F	Spawning for catfish, buffalo, threadfin, and gizzard shad.
75F	Spawning for largemouth, white and yellow, and spotted bass.
68F	Migration routes of salmonids, egg development of perch and small mouth bass.
55F	Spawning and egg development of salmon and trout.
48F	Spawning and egg development of lake trout, northern pike, sugar, and Atlantic salmon.

¹ TL_m: Median tolerance limit: the concentration of a test material at which 50 percent of the test animals are able to service under test conditions for a specified period of exposure.

Table 3-14. Water Quality Criteria for Marine and Estuarine Organisms
(from Miller and McGrew, 1977)

Parameter	Value
Salinity	10 percent change over natural value
pH	6.7 to 8.5, less than 0.1 unit change
DO	
Coastal waters:	5 mg/l
Estuaries:	4 mg/l
Toxic Materials	
Pesticides:	$\frac{1}{100}$ 48-hr TL _m
Metals:	$\frac{1}{100}$ 96-hr TL _m
Ammonia:	$\frac{1}{20}$ 96-hr TL _m
Cyanide:	$\frac{1}{10}$ 96-hr TL _m
Sulfide:	$\frac{1}{20}$ 96-hr TL _m
Non-persistent materials:	$\frac{1}{20}$ 96-hr TL _m
Persistent materials:	$\frac{1}{100}$ 96-hr TL _m
Temperature	
Autumn, Winter, Spring:	4 degrees F increase
Summer:	1.5 degrees F increase
Rate of Change:	1 degree F per hour

¹ TL_m: Median tolerance limit: the concentration of a test material at which 50 percent of the test animals are able to service under test conditions for a specified period of exposure.

Table 3-15. Toxic Metal Concentrations Not To Be Exceeded
In Aquatic Life Habitats, mg/l¹
(from Miller and McGrew, 1977)

Metal	Freshwater		Mar ine
	Hard (100 mg/l CaCO ₃	Soft (100 mg/l CaCO ₃	
Cadmium ²	0.03	0.004	0.0002
Chromium ³	0.05	0.05	0.05
Copper	0.03	0.01	0.01
Lead	0.03	0.03	0.01
Mercury ⁴	0.002	0.0002	0.0001
Nickel	0.4	0.1	0.002
Zinc ⁵	0.2	0.004	0.02

- 1 values cited are 90 percentile values except as noted in qualifying not "d".
- 2 Lower cadmium values not to be exceeded for crustaceans and waters designated fish spawning are 0.003 mg/l in hard water and 0.0004 mg/l in soft water.
- 3 The maximum permissible value for waters designed shellfish harvesting shall be 0.01 mg/l.
- 4 Total mercury values should not exceed 0.05 ug/l as an average value; maximum acceptable concentration of total mercury in any aquatic organism is a total body burden of 0.5 ug/l wet weight.
- 5 Value cited as objective pertains to nickel salts (not pure metallic nickel) .

CLIMATOLOGY

General Meteorology, Climatology and Climatic Regions

General Meteorology and Climatology. The geographical position of California in subtropical to lower mid-latitudes on the west coast of the continent endows it with a climate which is described as "Mediterranean" after the European region of somewhat similar climate, or as subtropical dry summer. The chief characteristics of the climate of coastal California are 1) a concentration of the year's precipitation in the winter season, 2) summers which are nearly or completely dry, 3) moderate temperatures with a relatively low range in the temperature, and 4) great variability in precipitation from year to year. Those climatic characteristics are described below.

The characteristics of the California climate result from the State's location on the poleward side of the subtropical high pressure cell (Pacific anticyclone). That location places California between the subsiding air from aloft associated with the anticyclone's stable eastern side on the one hand and the rain-bringing cyclones (low pressure cells) of the mid-latitude Westerlies winds on the other. As the Pacific anticyclone intensifies in summer, the Westerlies are forced northward, carrying storms and rainy weather away from California. Thus, in summer, California is joined to the dry subtropics and has constant clear days only rarely broken by storms.

In autumn, the Pacific anticyclone weakens and thereby allows the intrusion of the stormy Westerlies to enter the state. In winter, the Westerlies allow the passage of frequent frontal storms. The storms are associated with cyclones generated by the circum-polar jet streams (currents in the atmosphere generally at an altitude of 10 to 50 kilometers (km), i.e., 30,000 to 45,000 feet (ft)), particularly in a fairly persistent atmospheric pressure trough in the Gulf of Alaska called the Aleutian Cyclone. The frontal storms bring masses of marine polar (symbolized by mP) air into the state with their characteristics of cool, rainy weather. California, particularly in the southern part, is occasionally influenced by the subtropical jet stream and by marine tropical (mT) air masses, which bring warm, wet weather.

The above characteristics generally apply to the entire study area but local variations in climate within the area are common. Climatic variation of temperature and precipitation occurs latitudinally within the study area, with distance inland from the coast, with increase in altitude, and with numerous factors which can be grouped under microclimatology. The wide latitudinal range of the coastal zone in the study area is important to climate because the region lies on the margin of the subtropics and the mid-latitudes, each of which are characterized by greatly different climates. In that sense, California is located in a transitional climatic zone and, thus, has some of the characteristics of the climatic regions both to the north and south, but the true character of neither. The California (or Mediterranean) climate type is unique, as no other humid climate type has a summer drought and a rainfall maximum in winter. Distance from the coast significantly affects local climate. As a rule, inland areas have greater ranges and extremes of temperature because they are more removed from the moderating effect of the Pacific Ocean. In addition, inland stations are more removed from the cool, humid marine 'layer of air and oceanic fogs. Altitude affects climatic variation by creating a general reduction in temperature (excluding for the moment the effects of temperature inversions) with increase in altitude (a process called adiabatic cooling). The environmental lapse rate is the average rate of temperature reduction with increase in altitude in the atmosphere; it is generally an adiabatic temperature reduction of about 6.4 degrees Celsius ($^{\circ}\text{C}$) per 1,000 meters (m) i.e., 3.5 degrees Fahrenheit ($^{\circ}\text{F}$) per 1,000 ft rise. Of equal significance is the effect of that temperature reduction with increased altitude on precipitation. Because cool air can hold less moisture than warm air, a decrease in the temperature of an air mass caused by a rise to higher altitude results in condensation of the moisture and possibly precipitation. Moisture-laden air masses entering California from the west in winter rise to higher altitudes when they are forced over the Coast Ranges (a process called orographic uplift), are cooled and precipitate. As a result, the higher portions of the Coast Ranges have greater precipitation as a rule than their lower slopes. A map of average annual precipitation distribution in California reveals the pattern of summit ridges of the Coast Ranges by positioning of the high isohyets (lines of equal precipitation).

Information on the climate of the study area is based upon statistical summaries of meteorological data collected over a period of years at weather stations. Large gaps exist in the data because the number of weather stations in the study area is small and they are unevenly distributed. Most weather stations are located at airports and near large settlements. Most stations collect only data on precipitation and temperature. Fewer stations collect data on climatic elements such as wind, fog and cloud cover, insolation, pan evaporation and humidity. Table 3-16 is a list of the primary weather stations located within the study area and the years of record for data on temperature and precipitation.

Climatic Regions. The climate of the study area is classified according to various criteria. The most common description of climate in textbooks and technical papers is the classification system of W. Koeppen. The Koeppen system features a shorthand code of letters designating major climate groups and subgroups based on temperature and precipitation. Under the Koeppen system or its variation, the Koeppen-Geiger system, the climate of the study area is described as a Csb-type, that is humid mesothermal climate with a dry summer (Strahler, 1975). Under this designation, the "C" indicates that the average temperature of the warmest month exceeds 10°C (50°F) and the average temperature of the coldest month lies between 18°C (64.4°F) and -3°C (26.6°F); the "s" signifies that the driest month occurs during the warmest 6 months and the amount of precipitation received during the driest month is less than 4 centimeters (cm), i.e., 1.6 inches (in) and less than one-third the amount received during the wettest month of the coldest 6 months; and the "b" signifies that the average temperature of the warmest month is less than 22°C (71.6°F), but at least 4 months have an average temperature greater than 10°C (50°F) (Strahler, 1975).

The Koeppen climatic system (and numerous variations on it) is the most commonly used classification but it has severe limitations in that it is based primarily on temperature and does not agree with the vegetation types in some areas of the world (Gates, 1972). For purposes of ecological characterization, the less commonly seen climatic Classification of C. W. Thornthwaite and J. R. Mather has greater utility. Under the Thornthwaite-Mather system, climate is described according to precipitation effectiveness, that is the availability of water as related to the need for water by vegetation. The system of climatic classification involves the computation of a moisture index (Ire) which takes into account the seasonality of water availability and water need. The moisture index is calculated as follows:

Table 3-16. Weather Station Index
(from NOAA, 1978)

STATION 1	WATERSHED UNIT	YEARS OF RECORD	
		TEMPERATURE	PRECIPITATION
Ben Lomond No. 4	San Lorenzo	7	7
Big Sur State Park	Morro Bay	--	64
Black Mountain 2 SW	San Gregorio Creek	--	24
Carmel Valley	Carmel River	20	20
Cazadero 3w	Gualala River ²	--	8
Crescent City 1N	Smith River	78	89
Crescent City 7ENE	Smith River	--	23
Eureka WSO Cl	Mad River	92	92
Fort Bragg	Noyo River	44	86
Fort Dick	Smith River	--	20
Fort Ord	Carmel River	11	11
Fort Ross	Gualala River	29	104
Graton	Russian River	82	83
Guerneville No. 2	Russian River	--	8
Half Moon Bay	San Gregorio Creek	38	39
Klamath	Klamath River	29	36
La Honda	San Gregorio Creek	--	29
Lompoc	Santa Ynez River	32	32
Los Alamos	San Antonio Creek	--	70
Monterey	Carmel River	31	31
Monterey FAA AP	Carmel River	7	7
Morro Bay Firs Dept.	Morro Bay	19	19
Muir Woods	Lagunitas Creek	--	38
Occidental	Salmon Creek	--	39
Orrick Prairie Creek Park	Klamath River	42	42
Paloma	Carmel River ²	--	39
Pismo Beach	Morro Bay	29	29
Point Arena	Noyo River	21	21
Point Arguello Light Sta.	Arguello	--	37
Salinas FAA AP	Elkhorn Slough	19	105
Salinas 3E	Elkhorn Slough	20	20
San Clemente Dam	Carmel River	--	40
San Francisco	San Gregorio Creek	19	20
Richmond/Sunset			
San Gregorio 2S?3	San Gregorio Creek	24	24
San Luis Obispo Poly	Morro Bay	84	109
Santa Cruz	San Lorenzo	106	101
Santa Maria WSO AP	Santa Maria River	36	36
Scottia	Eel River ²	53	53
Shelter Cove Aviation	Mattole River	5	5
Spreckels Highway Bridge	Elkhorn Slough	--	73
Upper Mattole	Mattole River	--	91
Watsonville Waterworks	Pajaro	72	86
Wrights	San Lorenzo	--	60

¹ Includes all NOAA stations in study area that were open through 1978, except Carmel Valley (closed June 1978), La Honda (closed Sept. 1978) and Monterey FAA AP (closed Dec. 1978).

² Station lies just outside this watershed.

$$Im = \frac{S - D}{n} \times 100$$

where S is the water surplus (runoff), D is the water deficiency and n is the biotic and atmospheric demand for water (i.e., potential evapotranspiration). The potential evapotranspiration is the amount of water that would be used by plants and evaporated for the given temperature conditions if unlimited amounts of water were available. The values of the moisture index can range from -254 cm (-100 in) where no

precipitation occurs to more than 254 cm (100 in) where rain falls in large quantities. A moisture index of zero indicates that neither surplus nor deficit occurs (Thorntwaite and Mather, 1955).

Using the above climatic classification system, the study area can be subdivided into moisture index regions. The five northern watershed units are a perihumid region with a moisture index greater than 254 cm (100 in), in other words, moisture availability is greatly in excess of potential evapotranspiration. The region between Cape Mendocino and Point Reyes is a humid region with a moisture index of 51 to 102 cm (20 to 40 in). The area near San Francisco Bay is a moist subhumid region with a moisture index of 0 to 51 cm (0 to 20 in).

The region south of San Francisco Bay is a moisture deficient area on the whole. Most of the region is a dry subhumid area with a moisture index of -51 cm to 0 (-20 to 0 in). In other words, potential evapotranspiration exceeds the available moisture. The vegetation of the area is adapted to the actual evapotranspiration, that is, the amount of water which actually passes through the earth-plant-atmosphere system. Because of the difference between potential and actual evapotranspiration, the vegetation in that area must obtain moisture during the dry season from stored groundwater in order to survive. The native plants in those regions are also physiologically adapted to reduce water use and water loss. The stored groundwater is derived from the high winter precipitation at which time a surplus of moisture occurs. The Salinas Valley, a short distance inland from Monterey Bay, is an area which is classified as arid and has a moisture index of -102 to -152 cm (-40 to -60 in). It has the greatest moisture deficit within the study area. The southernmost portion of the study area including the region between Santa Maria and Point Conception is a dry subhumid area with a moisture index between -51 and 0 cm (-20 and 0 in). High mountains within the region south of San Francisco Bay generally are moist subhumid areas with moisture indices between 0 to 51 cm (0 and 20 in) (Thorntwaite and Mather, 1955).

Atmospheric Pressure and Winds

Pressure. Figures 3-39 and 3-40 show the approximate geographic position of the Pacific High Pressure cell (anticyclone) in winter and summer. In the winter, the anticyclone weakens and migrates south and occupies a smaller geographic area, thereby allowing storm systems to reach the California coast. In the summer, the semi-permanent Pacific anticyclone (high pressure cell) is well-established. Positioned off the northern California coast, the cell deflects low pressure (storm) systems far to the north of the state.

Wind. Figure 3-41 shows that mean annual wind speed is about 15 kilometers per hour (km/hr) (8 knots) for most of the California coastline, reaching 19 km/hr (10 knots) for the most exposed areas (Point Arena, Point Reyes, Point Conception), and from 11 to 15 km/hr (6 to 8 knots) for Del Norte and northern Humboldt Counties (DWR, 1979b).

Tables 3-17 and 3-18 show, respectively, data on extreme winds and average wind directions for selected stations in the study area (DWR, 1978a). The winds entering California are generally from the west or northwest during the winter, at which time the Westerlies influence the state. Winds are named for the direction from which they flow (in contrast to oceanic currents which are named for the direction toward which they flow), thus, the Westerlies blow from the west and toward the east.

Sterns

Most storms in California are frontal storms, which most commonly originate in the Pacific Ocean between 35°N and 45°N Latitude, in a region south of the Aleutian Islands. Cyclones (low pressure cells) that reach California also originate in the Gulf of Alaska and off the Pacific Northwest. The study area experiences about 4 cyclonic passages per month in the winter (December to March) (Jenkins, 1977). Cyclonic passage is less frequent during the rest of the year.

Cyclones often remain offshore, although the accompanying frontal system reaches land. Thus the frequency of frontal passage is greater than that of cyclonic passage. A rough gauge of frontal passage frequency is the mean number of days with precipitation greater than or equal to 0.25 cm (0.10 in). Such data for three stations are summarized in Table 3-19. Since a single front may produce a stern

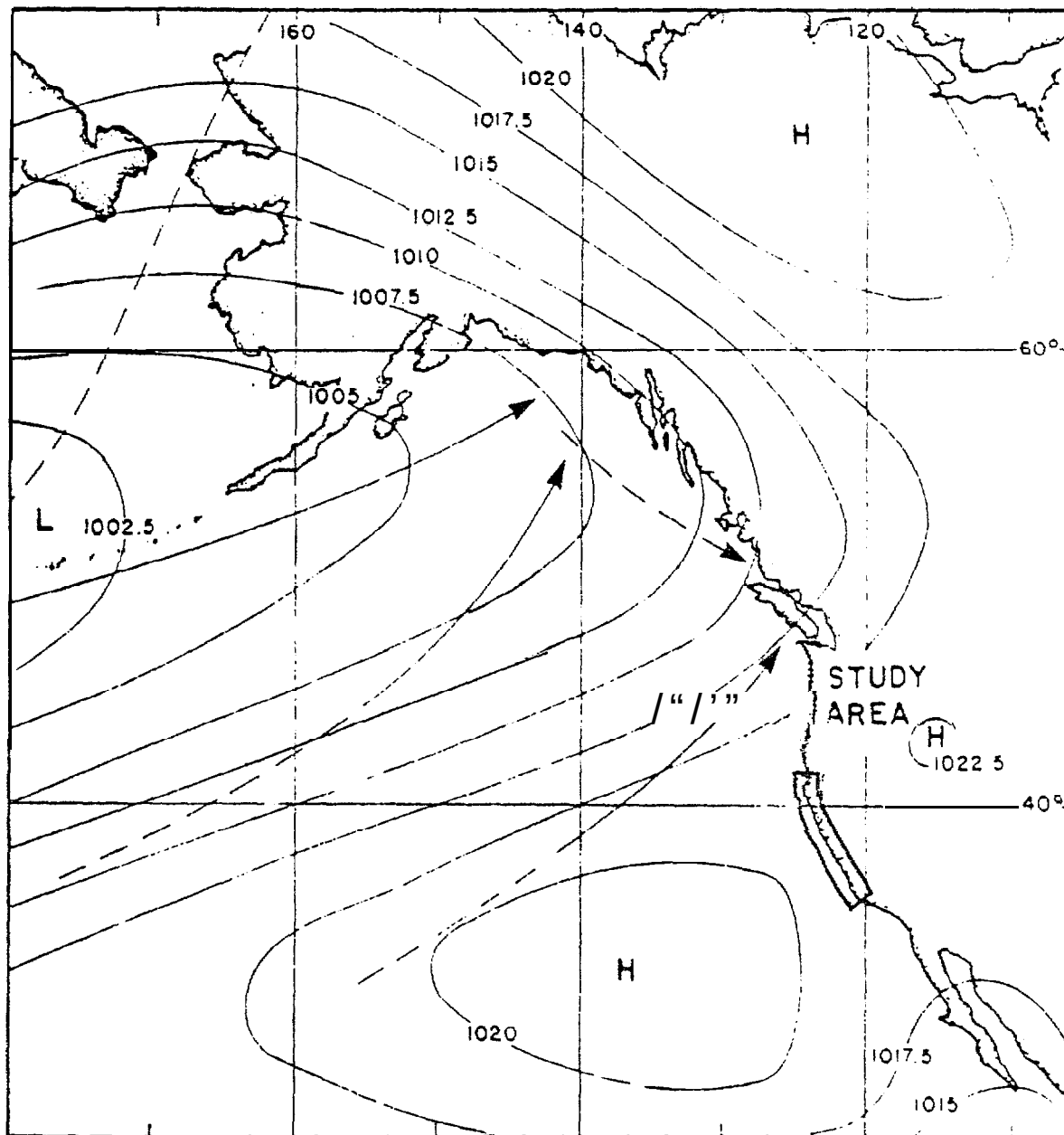


Figure 3.39. Mean Surface Atmospheric Pressure Pattern and Surface Low Pressure Tracks (Storm Paths) for January in the North Pacific (Isobars are in millibars; 1000 mb = 750 mm of Mercury) {RETA, 1978b)

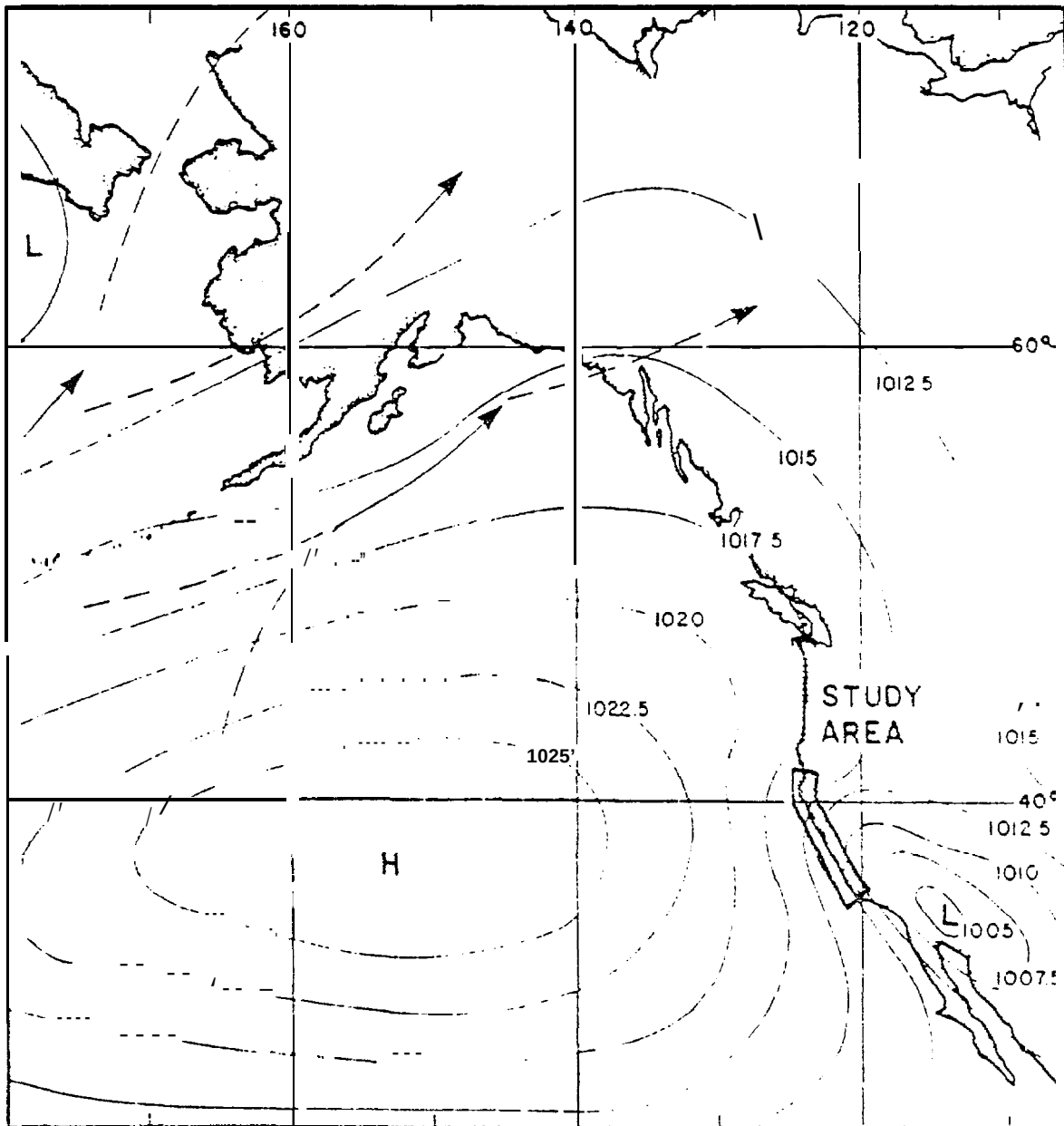


Figure 3-40. Mean Surface Atmospheric Pressure Pattern and Surface Low Pressure Tracks (Storm Paths) for July in the North Pacific (Isobars are in millibars; 1000 mb = 750 mm of Mercury) (RETA, 1978b)

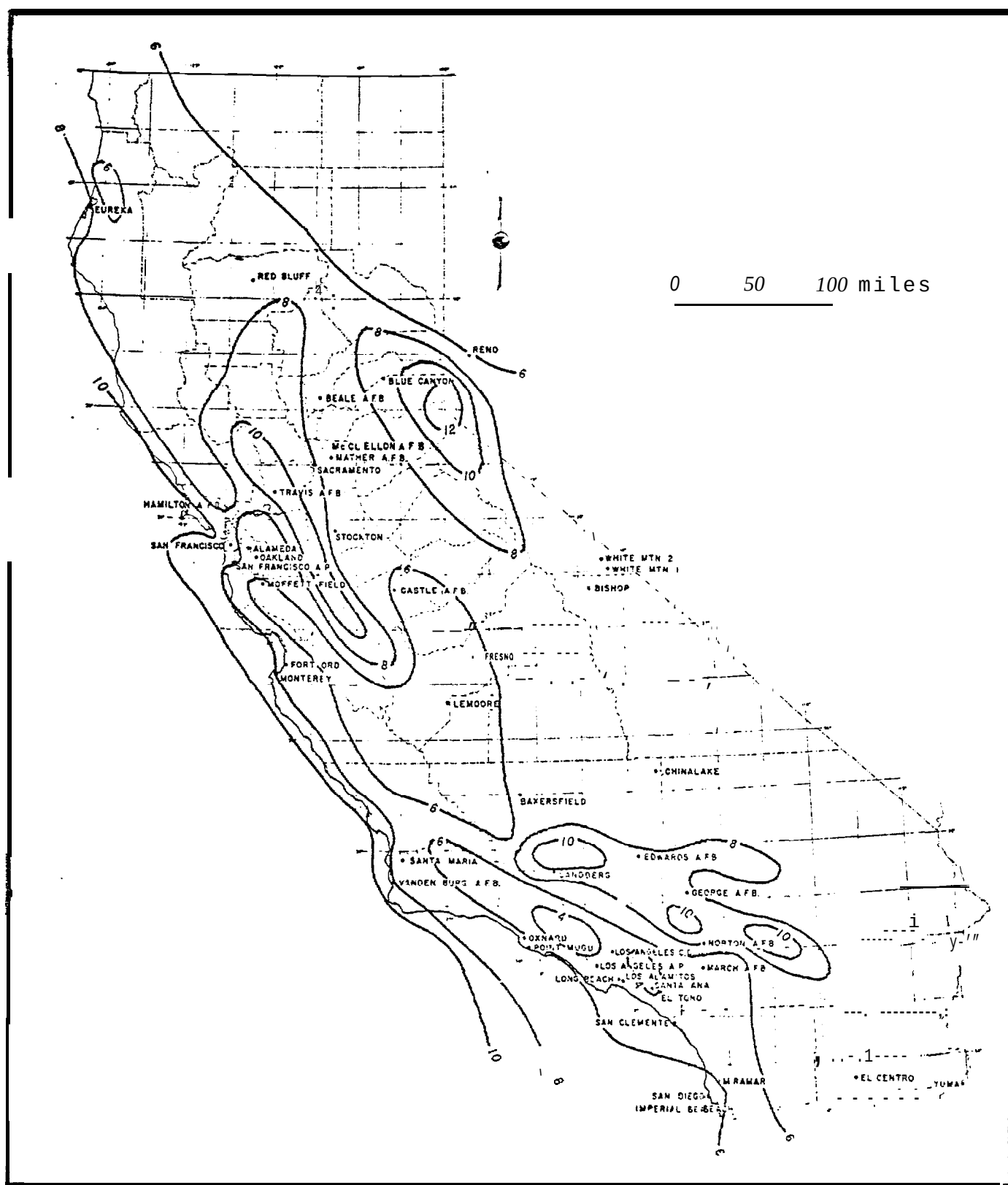


Figure 3-41. Mean Annual Wind Speed (in Knots) in California
(California Department of Water Resources, 1979b)

Table 3-17. Mean Fastest Wind Velocity,
Average Annual Wind Speed and Velocity Ratio
(from DWR, 1978d)

Station	Mean Fastest Wind ¹ (mph) ²	Average Annual Wind (mph) ²	Standard Deviation	Ratio ³
Eureka	43.4	6.8	5.4	6.4
San Francisco AP	45.2	10.5	7.7	4.3
Santa Maria AP	36.1	7.0	5.7	5.2

¹Fastest mile is the one-mile passage of wind with the highest speed.

²miles per hour

³Ratio is fastest mile velocity divided into average annual wind velocity.

Table 3-18. Percentage Frequency of Wind Direction in
Eureka, San Francisco and Santa Maria
(from DWR, 1978d)

Direction from which wind blows	Station		
	Eureka	San Francisco	Santa Maria
N	13.4	1.7	2.2
NNE	3.0	1.8	2.3
NE	3.7	3.3	2.6
ENE	1.8	2.4	1.8
E	3.2	2.4	6.7
ESE	4.1	2.3	4.1
SE	9.9	3.7	4.6
SSE	7.6	2.7	1.8
S	6.3	3.5	1.6
SSW	5.0	3.2	1.3
SW	8.0	4.1	3.3
WSW	3.0	6.1	5.1
W	3.9	17.0	15.5
WNW	4.2	23.3	16.5
NW	9.0	13.0	6.7
NNW	9.3	2.0	1.5
Calm ¹	4.5	7.4	21.8

*Calm - wind of less than one knot (one mile per hour for Eureka).

delivering over one-tenth of an inch of precipitation for two or more consecutive days, the figures in Table 3-19 set an upper limit to frontal passage frequency.

Temperature

The coastal location of the study area endows the region with moderate temperature conditions. The Pacific Ocean has a moderating effect on temperatures so that the temperatures are generally cool and infrequently cold or hot. Throughout the coastal portions of the study area, the mean annual range in temperature is only a few degrees greater than the diurnal range in temperature. Figure 3-42 is a graphic display of the march of temperature at Santa Cruz. The temperature conditions at any given time are determined by the air mass affecting a given state. These air masses have their origins in higher latitudes (generally in the Gulf of Alaska) over chilly seas of the North Pacific Ocean. In addition, stormy cloudy weather is associated with marine Polar air masses, which significantly reduce insolation and, therefore, temperature. Occasional intrusions of marine Tropical (mT) air masses also

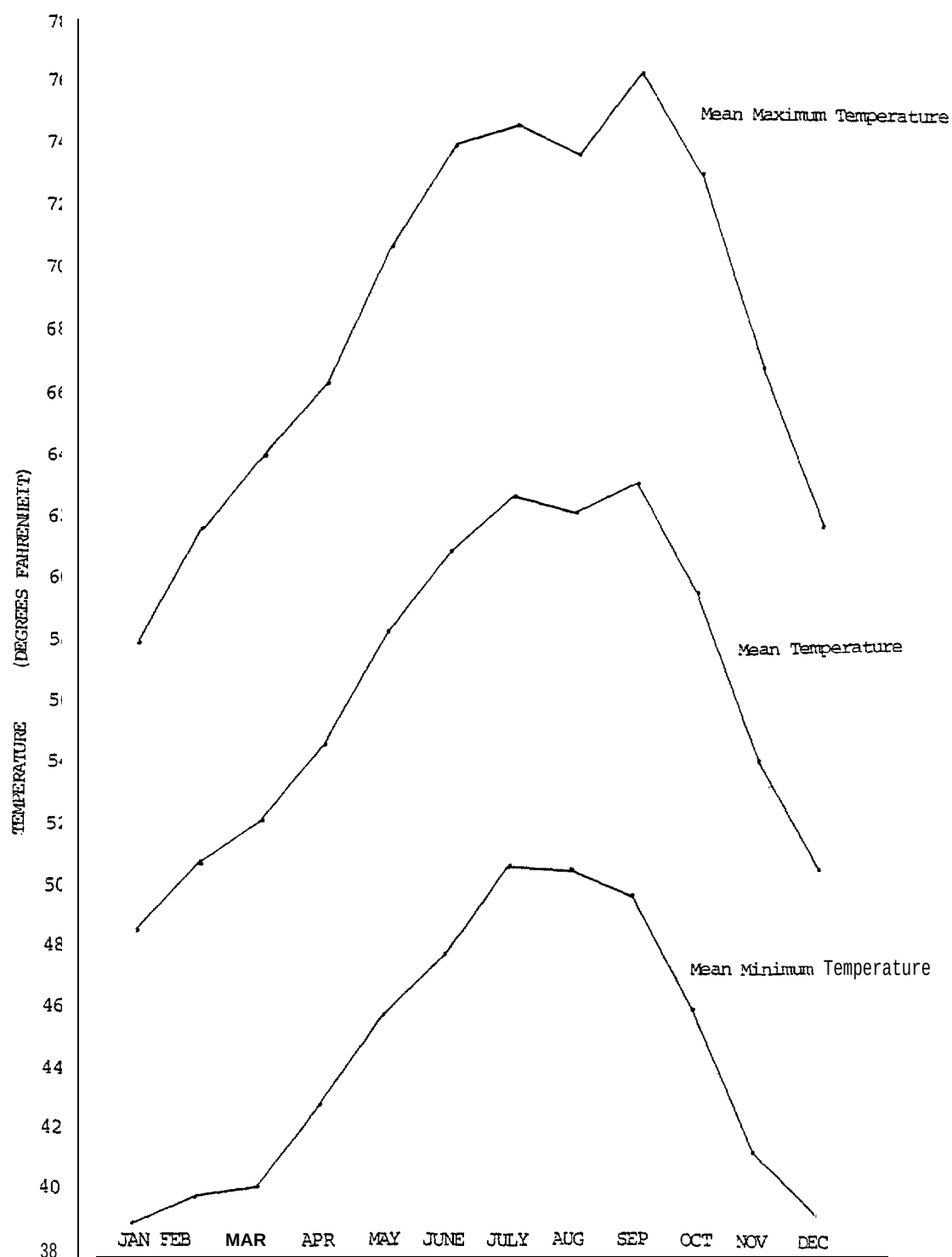


Figure 3-42. Air Temperatures (Mean, Mean Maximum and Mean Minimum) Temperature in Degrees Fahrenheit) at Santa Cruz, CA (US. Weather Bureau, 1964)

Table 3-19. Mean Number of Days with Precipitation
Greater Than or Equal to 0.10 Inches
at Eureka, San Francisco and Santa Barbara
(from Jenkins, 1977)

	Location		
	Eureka	San Francisco	Santa Barbara
January	14	9	6
February	10	7	5
March	10	6	3
April	6	3	3
May	4	2	1
June	2	--	--
July			--
August	--	--	--
September	3	1	1
October	6	2	1
November	7	3	2
December	10	6	3
ANNUAL	72	39	24

affect the study area in winter and on rare occasions in summer. Many of those air masses have their origins over the warm, tropical or subtropical Pacific ocean and consequently have relatively warm temperature characteristics.

The coldest weather in the study area is generally associated with infrequent intrusions of cold, continental Polar (cP) air masses from the east or northeast. Those air masses obtain their cold temperature characteristics in the mid-continental area of North America.

During the summer, the study area is characterized by clear weather and infrequent storms. The stable air conditions at that time are conducive to temperature inversions (see below). The temperatures along the coast are moderated by the intrusion of the marine layer with its coolness derived by contact of the air with the cool waters of the California current and cold upwelling waters. Frequent fogs along the coast also significantly reduce insolation, which additionally moderates the temperature. However, inland areas removed from the fog zone and areas of marine layer air are subject to high insolation receipt and the resulting high temperatures. The effect of topography on temperature conditions during summer is great. The high ridges of the Coast Ranges are generally parallel to the coastline and effectively block the intrusion of the marine layer to inland areas. While fog-bound coastal stations may have July maximum temperatures of about 10° C (50° F), stations located only a few kilometers inland but behind the front of the Coast Ranges may have temperatures of 38° C (100° F). However, where breaks are located in the Coast Ranges, the marine layer may extend a great distance inland. For example, the marine layer commonly penetrates as far inland as Sacramento through the gap in the Coast Ranges east of San Francisco Bay. Because subsidence inversion conditions are also characteristic of summer temperature conditions, topography indirectly influences the temperature. Stations located in valley bottoms may be located in cool marine layer air masses whereas nearby stations located on mountains above the lid of the inversion may have high temperatures.

The northern portions of the study area generally have lower temperatures than the southern portions. For example, the mean annual temperature at Klamath is 11.5° C (52.7° F) and at Lompoc 13.8° C (57.0° F). The mean January temperature at Klamath is 8.2° C (46.8° F) and at Lompoc 10.9° C (51.8° F). The mean July temperature at Klamath is 14.8° C (58.7° F) and at Lompoc 16.4° C (61.6° F). As a general rule the coolest month of the year at coastal stations is January and the warmest month is August or September. Mean maximum and mean minimum monthly temperatures generally vary by only a few degrees above the mean monthly temperature of coastal stations. Inland stations experience a wider range in temperature than coastal stations. Diurnal, monthly and seasonal ranges of temperature are generally greater than in coastal areas.

The growing season, defined as the period between the last killing frost (0°C or 32°F) of spring and the first killing frost of autumn is about 260 days long at the coast and 180 days long in the northern watershed units to 335 days along the coast and 250 days inland in the southern watershed units. These are mean figures, and in any given year the growing season may be of greater or lesser length. For this reason, specific calendar dates are not given for the first or last frosts of the year.

Temperature inversions are characteristic features of the California coastal zone. An inversion is a condition of the atmosphere in which the temperature does not decrease with increasing altitude above the ground at the environmental lapse rate, but rather increases with increasing altitude. See also Vol. I, Chapter 5, Atmospheric Stability and Temperature Inversions. Inversion conditions are associated with stability of the atmosphere because the cooler, (and, therefore, denser) air underlies warmer (and, therefore, lighter) air. Thus, vertical mixing of the atmosphere is prevented. Inversions create adverse conditions with regard to air quality because air pollutants at the surface cannot be dispersed upward and, therefore, concentrate in the lower, cooler air. (Strahler, 1975).

Inversions are of two types. Low-level temperature inversions (also called surface or ground inversions) occur when a cool air mass is located at the ground surface and is overlain by warmer air aloft. In ground inversion conditions, the temperature increases with increasing altitude until a reversal in the temperature gradient occurs (called the lid or cap of the inversion) beyond which the temperature decreases with increasing altitude. Low-level temperature inversions commonly result at night from rapid heat loss from the ground surface and basal air layer upward into space. Such conditions are favored on clear winter nights (Strahler, 1975). Killing frosts are commonly associated with low-level ground inversions. Topographic depressions are especially affected by the frosts because the cold, dense air settles into them.

The second type of temperature inversion is called a high-level, elevated, or above-ground (above surface) inversion. In an above-ground inversion a warmer air mass is located at the ground. The temperature of the air decreases with increased altitude until a zone is reached in which a reversal in temperature arises. In that zone, the inversion layer, the temperature increases with a rise in altitude. The inversion layer is the lid of the lower stagnant air. At the top of the inversion layer another reversal in temperature gradient occurs and from thereon temperature decreases with further increase in altitude. Above-ground inversions are created by atmospheric conditions in which air subsides from aloft. As the air subsides it warms. The subsiding air then comes in contact with the ground layer of air at the inversion layer. Atmospheric conditions favoring subsidence occur in California during the summer. Air from the Pacific anticyclone subsides along its eastern edge over California. For this reason, summertime inversions are created and, in turn, create adverse conditions for air quality. The inversion may be located approximately 150 to 300 m (500 to 1,000 ft) above the surface. The worst smog conditions occur when the height of the above-surface inversion is located near the ground surface. Some inversions have occurred below the 100 m (300 ft) height, causing air pollutants to be concentrated near the ground (Strahler, 1975).

Humidity and Fog

Mean monthly and annual relative humidity data at selected stations in the study area are shown in Table 3-20. For stations on the coast, mean relative humidity generally is highest during the summer months. Annual mean relative humidity is highest to the north.

Figure 3-43 shows July fog frequency along the northern and central California coast. Table 3-21 shows the seasonal variation in fog frequency for three selected stations in the study area. Hardwick, W. C. (1973) has developed computer-based maps which show monthly and annual distribution of the mean number of days with heavy fog (visibility restricted to one-fourth mile or less) in the continental United States. Annual occurrence of heavy fog ranges from 40 to 70 days along the coast of Del Norte and Humboldt Counties, to about 20 days in the San Francisco Bay Area, to over 70 days in the vicinity of Point Arguello and Point Conception (Hardwick, W. C., 1973).

In general, fog occurs mostly in the summer (June to September) along the California coast. Fog is generally confined to the immediate coastal zone by the coastal mountains, although it may penetrate into coastal-facing valleys. Summer fogs are mostly advection fogs, that is, fogs created by the movement of air over a

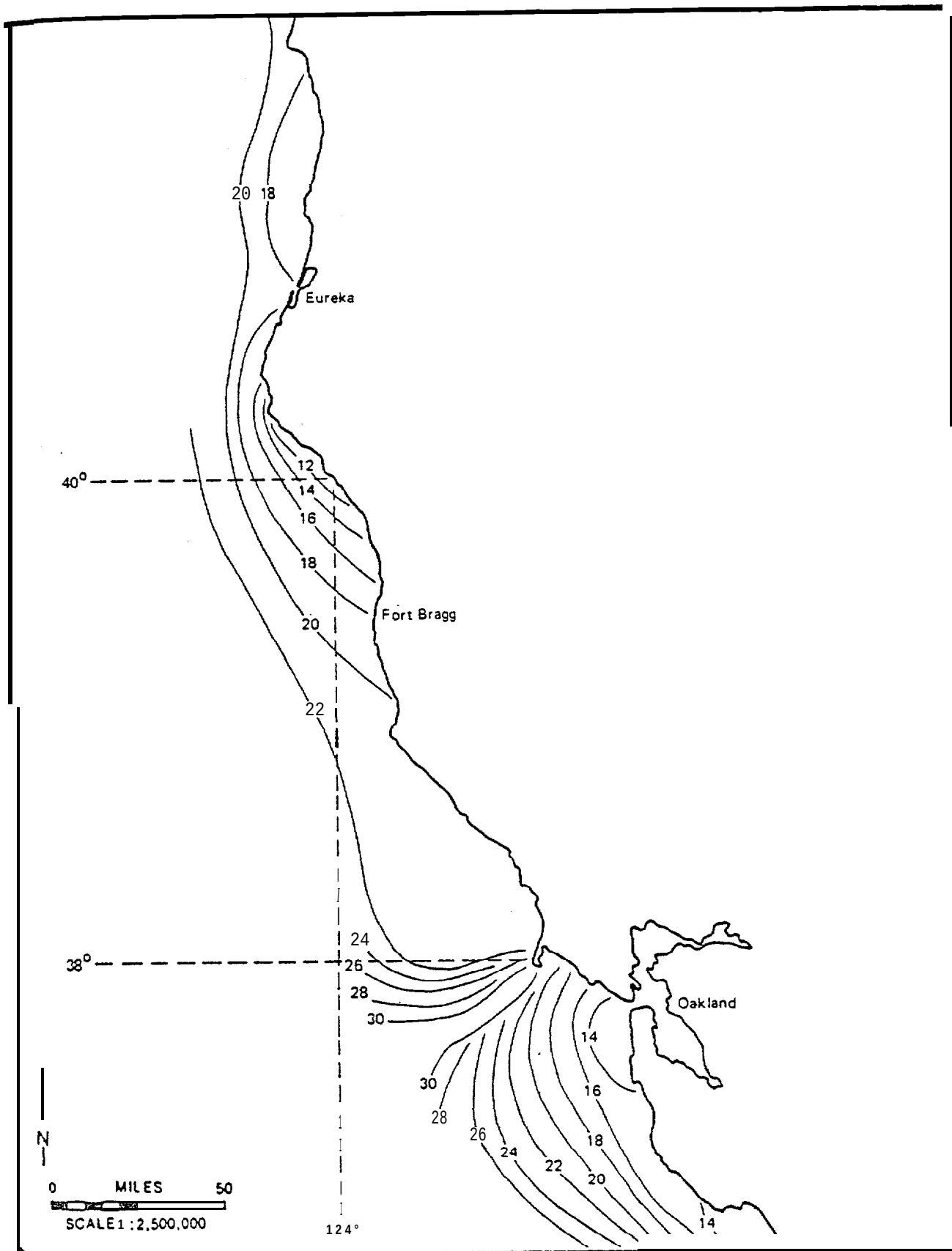


Figure 3-43. Incidence of Fog in July (Percentage of Observations when Figure Occurred) (Sheet 1 of 2) (Jenkins, 1977)

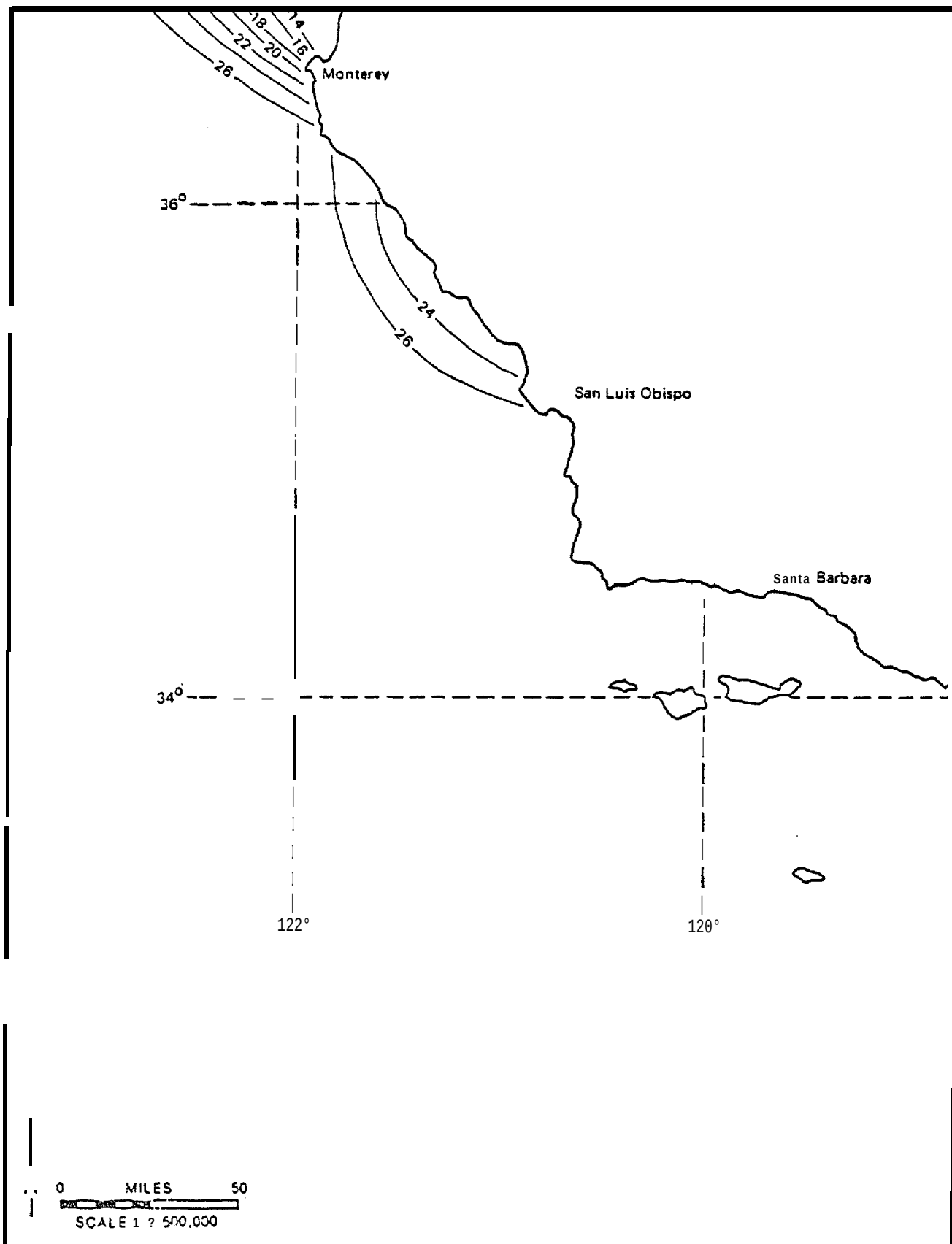


Figure 3-43. Incidence of Fog in July (Percent of Observations when Figure Occurred) (Sheet 2 of 2) (Jenkins, 1977)

Table 3-20. Monthly Mean Relative Humidity (in percent) for
Eight Airport Weather Stations in California
(from Goodridge, 1978)

Month	Arcata	Crescent City/ Jack McNamara Field	Fort Bragg	Fort Ord/ Fritzche AAF
January	81	86	76	75
February	83	85	81	78
March	81	81	78	75
April	84	83	81	70
May	84	84	86	77
June	87	86	87	78
July	89	86	87	80
August	89	88	82	83
September	87	88	79	80
October	86	86	82	76
November	84	84	80	77
December	84	83	73	77
ANNUAL	85	85	81	77

Month	Monterey Peninsula	Salinas Municipal	Vandenberg AFB	Watsonville Municipal
January	77	81	68	81
February	76	79	74	79
March	75	77	75	77
April	77	80	77	80
May	77	77	80	77
June	79	77	84	77
July	83	80	86	80
August	84	81	85	81
September	79	79	83	79
October	75	76	79	76
November	72	77	72	77
December	73	81	70	81
ANNUAL	77	79	78	79

surface with different temperature characteristics. The summer fogs are formed by the advection of the marine air layer over the chilly California current. The cool waters of the current chill the air layer and condensation of the moisture results in fog. The densest fogs occur when the offshore waters are very cool and the advection air masses are warm and moist. Such conditions are especially favored when upwelling of cold deep waters occurs during summer.

Winter fogs are radiational or frontal fogs and are infrequent in the study area. Radiational fogs are created by the reduction in temperature of clear, stagnant air generally at night. Frontal fogs are created when two air masses with dissimilar temperature characteristics collide. As one air mass overrides the other, the air mass is uplifted, cools and condenses (Strahler, 1975).

Precipitation

Precipitation is distributed unevenly throughout the year (see Figure 3-44). Almost all precipitation is concentrated in the November to April period. During that period, a series of frontal storm systems enters the State from the Pacific Ocean. Most of the storms are incursions of marine Polar air masses with abundant moisture content and enter the study area from the northwest. Occasional frontal

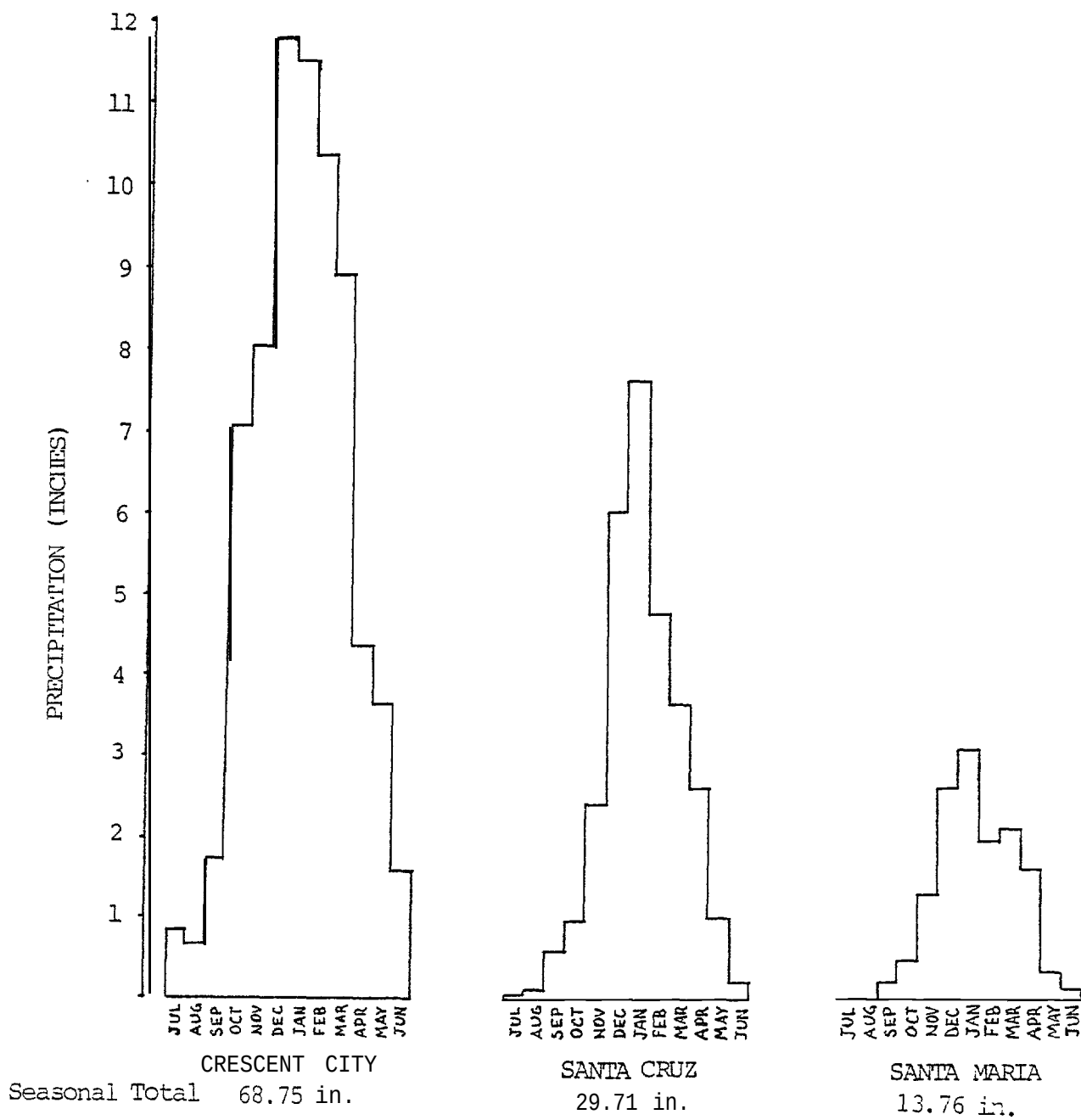


Figure 3-44. Monthly precipitation (Mean Monthly Precipitation in Inches) at Crescent City, Santa Cruz and Santa Maria, CA (Us. Weather Bureau, 1964; Elford and McDonough, 1974)

Table 3-21. Percentage of Time with Light, Moderate or Dense Fog¹
at Three Locations in California
(from Elford and McDonough, 1974, 1963a, 1963b)

	Eureka (1939-1942)	Point Arena (1937-1942)	Point Arguello (1935-1941)
January	5.4	3.1	4.8
February	2.2	1.6	3.5
March	4.8	3.4	9.2
April	3.4	5.8	12.1
May	5.1	12.3	9.7
June	8.0	12.4	23.8
July	23.9	24.7	38.6
August	30.6	24.4	31.4
September	19.7	10.2	19.5
October	27.7	12.3	12.9
November	15.3	5.4	6.5
December	14.4	5.6	4.6
ANNUAL	13.4	10.1	14.7

storms are incursions of marine Tropical air masses which enter the study area from the southwest or west. The marine Tropical air masses reach California less frequently than the marine Polar air masses, but are generally heavily laden with moisture and produce heavy precipitation. The Coast Ranges are the first mountain barriers in the paths of these storms, and precipitation is orographically induced as the moist air masses rise over their crests. The highest precipitation values are associated with the high summits and crests of the Coast Ranges. Generally lower precipitation is received in the low-lying areas. On the map of mean annual precipitation isohyets (an isohyet is a line of equal precipitation), are largely oriented parallel to the trend of the principal crests of the Coast Ranges.

During the May to October period, California is dominated by the Pacific anticyclone which effectively prevents frontal disturbances from entering the study area. Few storms reach California during the summer period, and conventional storm systems rarely develop in the stable air masses of the coastal zone. Moist air along the coast condenses to produce advectional fogs but the stable air conditions effectively prevent the uplift of the air masses to produce precipitation. As a result, the summer period is characterized by drought.

A wide range in mean annual precipitation characterizes the study area. In general, the portion of the study area north of San Francisco Bay receives more precipitation than the areas to the south (see Figure 3-45). The portion of the coastal zone north of San Francisco Bay is well-watered because it receives the precipitation from more storms than the southern watershed units. The northern part of the state is geographically closer to the zone of the Westerlies. The wet period begins earlier and ends later in northern California than in the southern part of the state. The entire portion of the study area north of San Francisco Bay is included with the region receiving over 51 cm (20 in) mean annual precipitation. Over half of that area receives over 152 cm (60 in), and about a quarter of that area (mostly in the northernmost watershed units) receives over 229 cm (90 in) of mean annual precipitation (see map in Kahl et al., 1978). The Coast Ranges of the Smith, Klamath, Eel and Mad watershed units receive over 279 cm (110 in) of average annual precipitation in their upper portions. The climatic region extending northward from San Francisco Bay coincides with the natural region of extensive forests of redwood and mixed evergreens with rhododendrons (Kuchler, 1977),

The portion of the study area south of San Francisco Bay is generally a semi-arid area. The 51 cm (20 in) isohyet is generally regarded as the boundary between humid and semi-arid regions. Most of the area south of San Francisco Bay is located in a region receiving 25 to 51 cm (10 to 20 in) of mean annual precipitation. Higher mean annual precipitation values are restricted to high areas

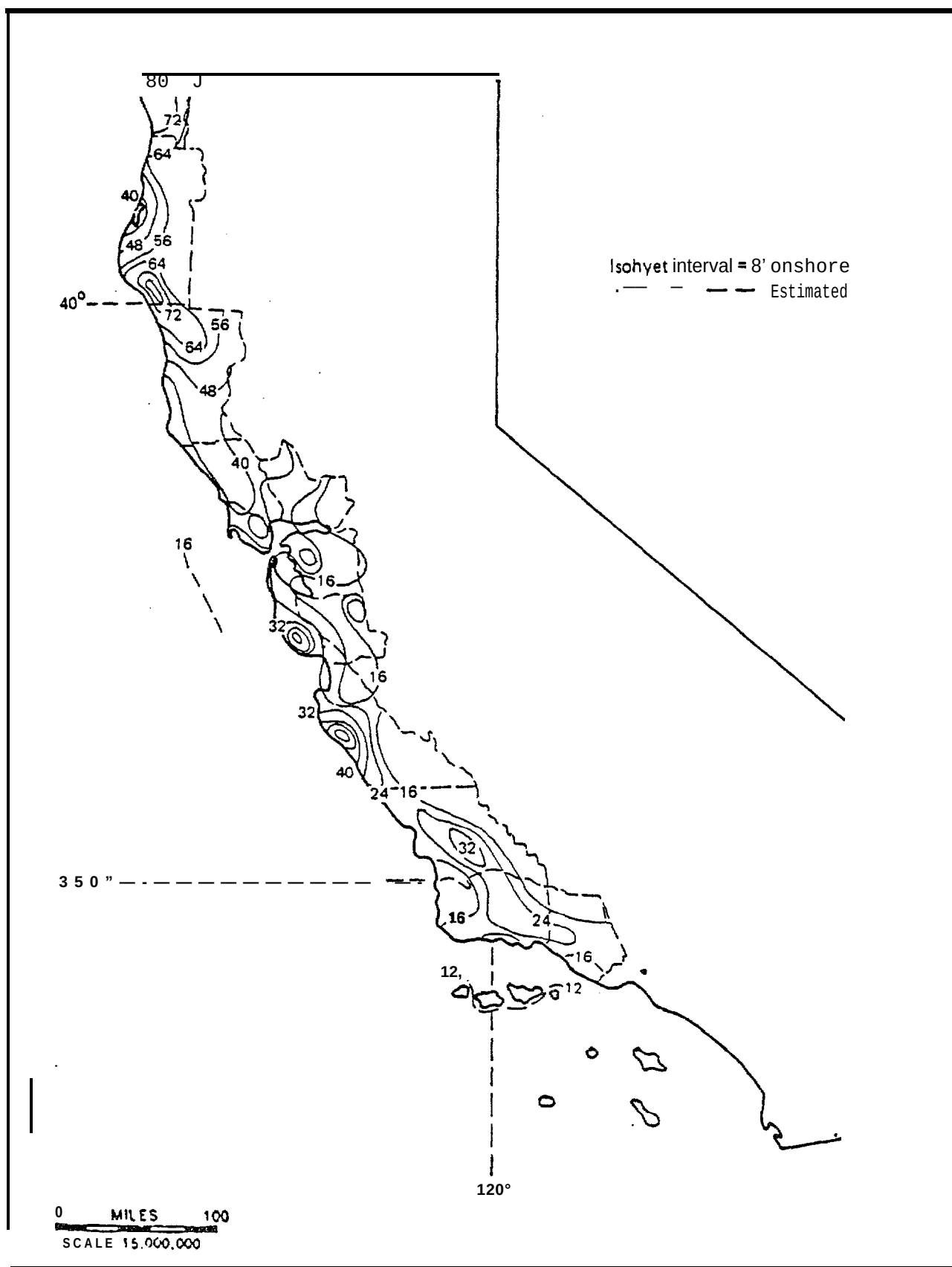


Figure 3-45. Average Annual precipitation (8-inch Isohyet) in Coastal California (Jenkins, 1977)

of the Santa Cruz Range, Santa Lucia Range, and Transverse Ranges. The high crests of the Santa Cruz Range receive over 127 cm (50 in) of mean annual precipitation. Some summits of the Santa Lucia Range obtain 152 (60 in). The portion of the Transverse Ranges within the study area receives over 51 cm (20 in) of mean annual precipitation (see map in Kahr1, et al., 1978). The climatic region extending southward from San Francisco Bay coincides with the natural region of southern oak forest, mixed hardwood forest, coastal sagebrush and coastal prairie scrub mosaic. The evergreen forest cover is less extensive than in northern California (Kuchler, 1977) .

California is subject to periodic drought conditions. A drought is difficult to define because the concept means different things to the people affected and because various organisms are differently affected by it. Droughts are created by extended periods of sub-normal precipitation. However, the precipitation regime of the climate in California is such that a mean value has little statistical significance because of the extreme variability of precipitation from one year to the next. In addition, drought conditions tend to be severe in only limited regions of the state at any one time and, thus, the southern portion of the study area may experience drought while the northern portion experiences above normal precipitation or even flooding.

By far the most severe drought was that which occurred in 1976-1977. The drought affected almost the entire state including the entire study area. For the state as a whole, the water year 1976 was the fourth driest year of record and the 1977 water year was the driest. The two dry years in succession produced the most severe drought of the century in the state. The drought which lasted from September 1923 to September 1924 was the second most severe drought in the century. The southern watershed units also had severe droughts in 1945-1951 and 1958-1961. Smaller droughts have occurred in local areas on a periodic basis (Kahr1 et al., 1978) . From 1828 to 1830 no rainfall occurred in the coastal area south of San Francisco for 22 months. Another drought in 1840-41 was almost as severe, when little rain fell for 14 consecutive months (Dodge, 1978).

Air Quality

Pollutant Types, Standards and Regulatory Framework. Photochemical oxidant air pollution is a regional phenomenon due to transport and diffusion by wind concurrent with the reaction process. Non-reactive pollutants such as carbon monoxide and particulate, on the other hand, are more localized and are quickly dispersed. The worst smog conditions are created where the mechanism for dispersal of the photochemical oxidant is hindered by atmospheric conditions and topography. High concentrations of photochemical oxidants occur in summer and fall and generally are associated with inversions (see Vol. IV, Chapters 3 through 24, Temperature) and with low wind speeds. Low wind speeds and topography aggravate smog conditions by restricting horizontal dispersal of pollutants and by contributing to inversion conditions. Generally, the worst smog conditions occur in low-lying basins surrounded by high mountains.

There are currently 12 air pollutants for which community exposure levels, or ambient air quality standards, have been established. A standard is a maximum limit for concentration of a pollutant in the ambient air. These pollutants and their standards are shown in Table 3-22. There are two sets of ambient air quality standards in California, state and national. State air quality standards are based on a series of staff reports by the California Air Resources Board (CARB), and national standards are based on the Air Quality Criteria series of documents prepared by the U.S. Environmental Protection Agency (EPA) . The Air Quality Criteria are currently undergoing review and revision in accordance with the Federal Clean Air Act amendments of 1977. This review has already resulted in the revision of the national ozone standard from 0.08 ppm to 0.12 ppm, which occurred in January 1979. The principal objectives of several of the air quality standards are shown in Table 3-23.

In cases where state and national air quality standards are different, the strictest one applies. State standards are not to be equaled or exceeded, and national standards are not to be exceeded more than once per year (except that annual standards are not to be exceeded) . There are two sets of national standards, primary and secondary, with different time schedules for their attainment. The objective of primary standards is to protect public health; secondary standards are to protect public welfare, including property, materials, climate, economic values and personal comfort (CARB, 1976c) .

Table 3-22. Ambient Air Quality Standards, 1979
(from California Air Resources Board, 1978a)

Pollutant	Averaging Time	California Standards ^{1,2}	National Standards ^{1,3}	
			Primary ⁴	Secondary ⁵
Oxidant ⁶	1 hour	0.10 ppm (200 ug/m ³)	--	--
Ozone	1 hour	--	240 ug/m ³ (0.12 ppm)	Same as Primary Standard
Carbon Monoxide	12 hour	10 ppm (11 mg/m ³)	--	Same as
	8 hour	--	10 mg/m ³ (9 ppm)	Primary
	1 hour	40 ppm (46 mg/m ³)	40 mg/m ³ (35 ppm)	Standards
Nitrogen Dioxide	Annual Average	--	100 ug/m ³ (0.05 ppm)	Same as Primary Standards
	1 hour	0.25 ppm (470 ug/m ³)	--	--
Sulfur dioxide	Annual Average	--	80 ug/m ³ (0.03 ppm)	--
	24 hour	0.05 ppm (131 ug/m ³) ⁷	365 ug/m ³ (0.14 ppm)	--
	3 hour	--	--	1300 ug/m ³ (0.5 ppm)
	1 hour	0.5 ppm (1310 ug/m ³)	--	--
Suspended Particulate Matter	Annual Geometric Mean	60 ug/m ³	75 ug/m ³	60 ug/m ³
	24 hour	100 ug/m ³	260 ug/m ³	150 ug/m ³
sulfates	24 hour	25 ug/m ³	--	--
Lead	30 day average	1.5 ug/m ³	--	--
	Calendar Quarter	--	1.5 ug/m ³	1.5 ug/m ³
Hydrogen Sulfide	1 hour	0.03 ppm (42 ug/m ³)	--	--
Hydrocarbons (Corrected for Methane)	3 hour	--	160 ug/m ³ (0.24 ppm)	Same as Primary Standards
	(6-9 a.m.)	--	--	--
Vinyl Chloride (Chloroethene)	24 hour	0.010 ppm (26 ug/m ³)	--	--
Ethylene	8 hour	0.1 ppm	--	--
	1 hour	0.5 ppm	--	--
Visibility Reducing Particles	1 observation	In sufficient amount to reduce the prevailing visibility to less than 10 miles when the relative humidity is less than 70%.		

-concentrations are expressed first in the units in which they were promulgated. Equivalent units given in parentheses are based on a reference temperature of 25°C and a reference pressure of 760 mm of mercury. ppm: parts per million (by volume). ug/m³: micrograms per cubic meter. mg/m³: milligrams per cubic meter.

²California standards are values that are not to be equaled or exceeded.

³National standards are values that are not to be exceeded more than once per year, except that annual standards are not to be exceeded.

⁴Primary standards are values to protect the public health with an adequate margin of safety.

⁵Secondary standards are values to protect the public welfare.

⁶Measured as ozone.

⁷At locations where the state standards for oxidant and/or suspended particulate matter are violated. National standards apply elsewhere.

⁸Prevailing visibility is defined as the greatest visibility which is attained or surpassed around at least half of the horizon circle, but not necessarily in continuous sectors.

Table 3-23. Objectives of Selected Air Pollutant standards
(from Williamson, 1973; and BAAPCD, 1977)

Pollutant	Objective
Photochemical oxidants (ozone)	To prevent eye irritation and respiratory difficulty, and to prevent damage to vegetation.
Carbon monoxide	To prevent interference with oxygen transport by the blood.
Nitrogen dioxide	To prevent health risk and improve visibility.
Sulfur dioxide	To prevent respiratory disease, damage to vegetation and material, and odor.
Suspended particulate	To improve visibility and prevent acute illness when present with sulfur dioxide.
Lead	To protect health.
Hydrogen sulfide	To prevent toxicity, material damage, and odor.
Hydrocarbons	To prevent oxidant formation.
Visibility reducing particles.	To improve visibility.

There are three levels of governmental regulation of air quality in California. The EPA, in addition to establishing national ambient air quality standards (NAAQS), has ultimate responsibility for implementation of the Federal Clean Air Act of 1970 and subsequent amendments (1977). The Clean Air Act and its amendments establish a schedule for emissions from new automobiles; require attainment of the primary NAAQS by 1982 (although an extension to 1987 is possible under certain conditions for photochemical oxidants and for carbon monoxide) in areas designated as "non-attainment"; require long-term maintenance of air quality in designated "air quality maintenance areas"; and establish an EPA permit system for large new stationary sources to ensure prevention of significant deterioration (PSD) in areas with good air quality. Non-attainment designations are based on recent and current excesses of NAAQS, and air quality maintenance area designations are also based on projected excesses of NAAQS.

The CARE has authority to establish ambient air quality standards and new-vehicle emission standards, which may be stricter than national standards; and to coordinate and oversee the activities of local air pollution control districts. The CARB has divided California into 14 air basins, which define areas having similar meteorological and geographical conditions and follow political boundaries where practical (CARE, 1975a). These air basins are shown on Figure 3-46. Within or contiguous with each air basin are single or multi-county air pollution control districts (APCDs) or, in some cases, air quality management districts (AQMDs). The APCDs/AQMDs within each air basin in the coastal area are shown in Figure 3-46. The CARE is responsible for incorporating local non-attainment and air quality maintenance plans into the state Implementation Plan (SIP), as required by the Clean Air Act and amendments.

The APCDs and AQMDs, through their rules and regulations and permit processes, have primary responsibility for regulating air pollutant emissions from stationary sources. Typical regulations include specific emission limitations for various pollutants from a variety of sources; a permit process for new and modified stationary sources (also known as new source review - NSR); and an air pollution episode plan, which specifies actions to be taken when any one of a set of hazardous air pollutant levels, or episode stages, is reached. The NSR process may require use of Best Available Control Technology (BACT) or emission offsets (reductions in emissions from existing sources) to ensure that the new or modified source would not cause ambient air quality standards to be exceeded. APCDs and AQMDs also participate in the development of non-attainment and air quality maintenance plans, which describe pollution control strategies necessary to attain and maintain the NAAQS.

Sources and Emissions. There are two main categories of sources of air pollutants: stationary sources and mobile sources. Stationary sources include point sources, which have one or more defined points of emissions and emit more than 25 tons per year of any pollutant; and area sources, which are small sources individually emitting less than 25 tons per year of any pollutant, or widely dispersed sources with no defined point of emissions (CARB, 1979b).

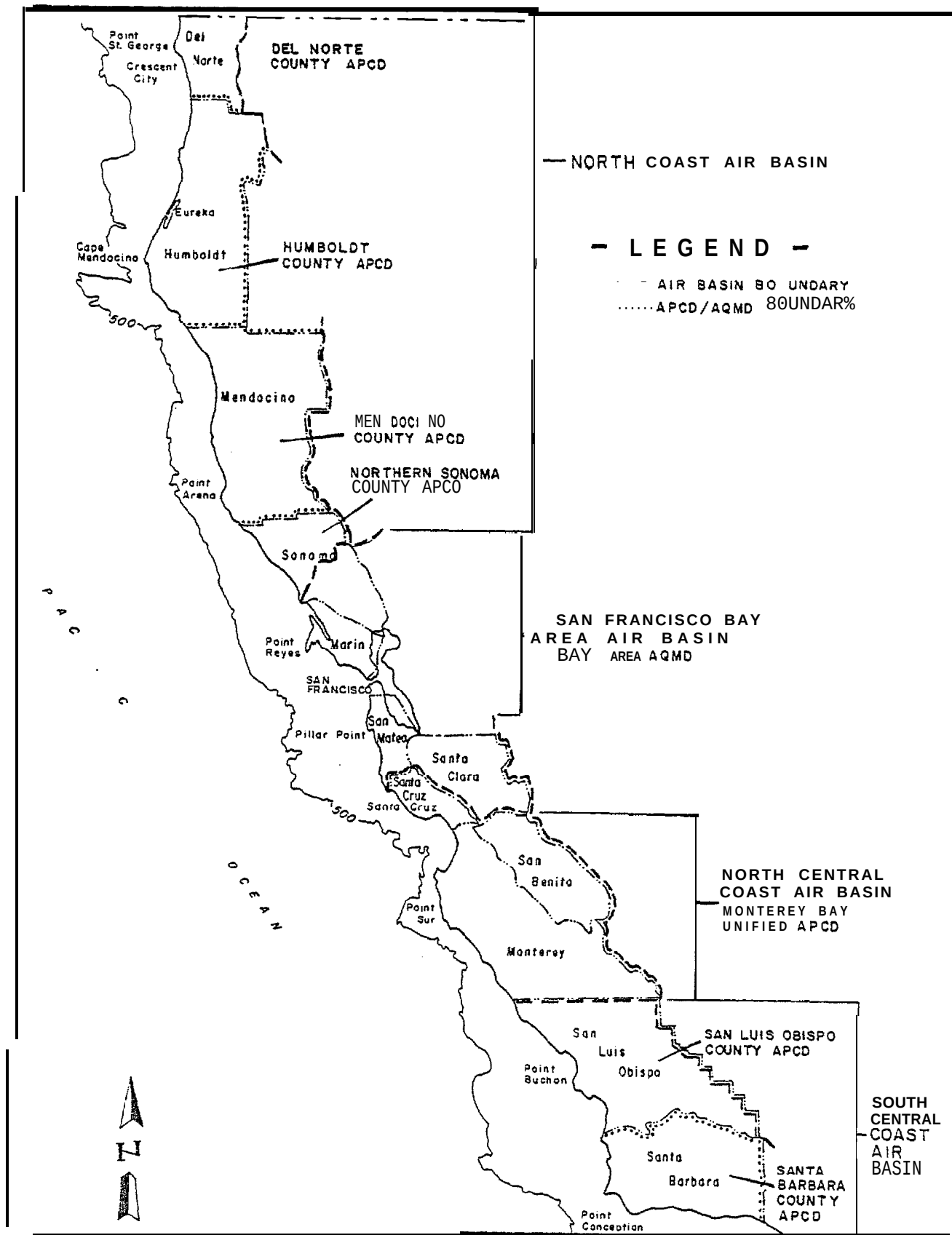


Figure 3-46. Air Basin Boundaries & APCD/AQMD Boundaries

Emissions of pollutants from ground-level sources result in high ground-level concentrations during conditions of atmospheric stability and low wind speeds, while emissions from elevated sources (stack) result in high ground-level concentrations during unstable atmospheric conditions with higher wind speeds.

Emissions of five pollutants, including total organic gases (TOG), nitrogen oxides (NO_x), sulfur oxides (SO_x), particulate, and carbon monoxide (CO) in 1976 have been inventoried according to 45 source categories by county and air basin. These categories are shown in Table 3-24. Inventories according to nine major source categories for the counties and air basins within the coastal area, and for the state, are shown in Tables 3-25 through 3-29.

Table 3-24. Emission Source Categories

Stationary Sources	Mobile Sources
Petroleum processes	On-road motor vehicles
Production	Light-duty passenger
Refining	Light and medium-duty trucks
Marketing	Heavy-duty gasoline trucks
Organic solvent use	Heavy-duty diesel trucks
Surface coating	Motorcycles
Dry cleaning	Other mobile sources
Decreasing	Off-road motor vehicles
Other	Commercial aircraft
Industrial processes	Military aircraft
Chemical	General aircraft
Metallurgical	Railroads
Mineral	Ships
Wood	
Food and agricultural	
Miscellaneous	
Pesticides	
Pesticide use	
Combustion of Fuels	
Power plants	
Petroleum industry	
Other industrial	
Commercial and institutional	
Residential	
Orchard heaters	
Waste burning	
Agricultural debris	
Forest management	
Range improvement	
Open burning	
Conical burners	
Incinerators	
Other	
Miscellaneous area sources	
Wildfires	
Structural fires	
Farming operations	
Construction and demolition	
Unpaved road travel	
Utility equipment	
Paved road travel	

Regional Air Quality. The CARB and the APCDs/AQMDs operate a number of air quality monitoring stations throughout the state. Data collected over the past few years at these stations was used by the CARB to classify areas as "attainment" or "nonattainment" with regard to the NAAQS for each of five major pollutants, in accordance with the Clean Air Act amendments of 1977 (see Pollutant Types, Standards, and Regulatory Framework). Areas where limited or no data exist are "unclassified". The classifications for the coastal areas are shown in Table 3-30. Air quality monitoring station data collected within the coastal area during 1976 through 1978

Table 3-25. California Total Average Emissions (Tons/Day¹) in 1976
(from California Air Resources Board, 1979b)

Emissions	TOG	NOX	Sox	PART	CO
STATIONARY SOURCES					
Petroleum Processes	767	23.1	126.0	5	86.7
Organic Solvent Use	885	0.8		4	1.6
Industrial Processes	115	42.9	140.0	195	509.0
Pesticides	167				
Combustion of Fuels	100	1,140.0	835.0	166	463.0
Waste Burning	117	3.8	0.3	116	897.0
Misc. Area Sources	175	19.5	1.1	8,090	1,370.0
Stationary Source Total ²	2,330	1,230	1,100	8,580	3,330
MOBILE SOURCES					
On-road Motor Vehicles	2,510	1,790	95	222	17,500
Other Mobile Sources	308	540	76	90	1,250
Mobile Source Total ²	2,820	2,340	171	312	18,800
GRAND TOTAL ²	5,140	3,570	1,270	8,890	22,100

¹Multiply by 907.2 to convert to kilograms per day.

²Totals may not equal sums due to rounding.

Table 3-26. North Coast Air Basin Average Emissions (Tons/Day) in 1976
(from California Air Resources Board, 1979b)

Emissions	TOG	NOX	Sox	PART	CO
STATIONARY SOURCES					
Petroleum Processes	8.7				
Organic Solvent Use	9.0				
Industrial Processes	2.8	1.3	5.7	6.4	8.2
Pesticides	0.5				
Combustion of Fuels	2.9	11.5	12.0	13.4	21.0
Waste Burning	10.1	1.1	neg	16.0	147.0
Misc. Area Sources	3.2	0.4	neg	143.0	22.6
Stationary Source Total	37.3	14.3	17.8	179	199
MOBILE SOURCES					
On-Road Motor Vehicles	29.3	24.2	1.2	2.8	205.0
Other Mobile Sources	2.3	3.7	0.4	0.4	9.2
Mobile Source Total	31.5	27.9	1.5	3.2	215.0
GRAND TOTAL	68.8	42.3	19.3	182.0	414.0

Negligible emissions are less than 0.05 tons/day

are summarized in tables in Vol. IV, Chapters 3-24, Air Quality. These data generally reflect the locations with the worst air quality conditions within the coastal area. No data exist for locations away from cities or other intensive human activities, but air quality in these locations within the coastal area can generally be assumed to be better than that near the monitoring stations.

Table 3-27. San Francisco Bay Area Air Basin Average Emissions (Tons/Day) in 1976
(from California Air Resources Board, 1979b)

Emissions	TOG	NOX	Sox	PART	co
STATIONARY SOURCES					
Petroleum Processes	85.7	7.5	50.3	1.7	neg
Organic Solvent Use	272.0	neg			neg
Industrial Processes	18.3	7.3	42.8	48.3	31.6
Pesticides	3.0				
Combustion of Fuels	6.6	237.0	89.5	17.8	35.9
Waste Burning	1.2	0.6		1.6	6.0
Misc. Area Sources	<u>22.7</u>	<u>2.5</u>	<u>0.3</u>	<u>671.0</u>	<u>210.0</u>
Stationary Source Total	410	255	183	741	283
MOBILE SOURCES					
On-Road Motor Vehicles	521.0	365.0	15.0	45.6	3,620
Other Mobile Sources	<u>42.9</u>	<u>65.0</u>	<u>14.3</u>	<u>15.6</u>	<u>176</u>
Mobile Source Total	564	430	29	61	3,790
GRAND TOTAL	974	685	212	802	4,080
Negligible emissions are less than 0.05 tons/day					

Table 3-28. North Central Coast Air Basin Average Emissions (Tons/Day) in 1976
(from California Air Resources Board, 1979b)

Emissions	TOG	NOX	Sox	PART	co
STATIONARY SOURCES					
Petroleum Processes	5.8				
Organic Solvent Use	17.7				
Industrial Processes	neg	1.4	0.8	3.7	
Pesticides	18.4				
Combustion of Fuels	2.2	74.2	60.5	7.5	8.4
Waste Burning	0.7	neg	neg	0.6	3.1
Misc. Area Sources	2.8	0.2	neg	<u>195.0</u>	23.6
Stationary Source Total	47.5	75.8	61.3	207	35.0
MOBILE SOURCES					
On-Road Motor Vehicles	51.3	38.4	1.6	4.6	356
Other Mobile Sources	<u>4.7</u>	<u>12.5</u>	<u>1.3</u>	<u>1.4</u>	<u>28.8</u>
Mobile Source Total	56.0	50.9	3.0	6.0	385
GRAND TOTAL	103	127	64	213	420
Negligible emissions are less than 0.05 tons/day					

The North Coast Air Basin has the best air quality of the four air basins in the coastal area. Vehicular emissions and photochemical air pollutants are not a serious problem in this air basin; past and present monitoring show that concentrations of oxidant, carbon monoxide, nitrogen dioxide, and sulfur dioxide are well within state and national standards (CNCABAPCC, 1977). Particulate is the major pollutant, especially in Mendocino County, which is particulate nonattainment.

Table 3-29. South Central Coast Air Basin Average Emissions (Tons/Day) in 1976
(from California Air Resources Board, 1979b)

Emissions	TOG	NOX	Sox	PART	CO
STATIONARY SOURCES					
Petroleum Processes	42.2	1.2	13.5	0.5	0.1
Organic Solvent Use	28.6	neg	neg	neg	neg
Industrial Processes	0.5	neg	neg	8.7	neg
Pesticides	15.5				
Combustion of Fuels	12.0	103.0	69.1	7.1	28.1
Waste Burning	3.6	neg	neg	3.0	19.7
Misc. Area Sources	<u>8.1</u>	<u>0.6</u>	neg	<u>365.0</u>	<u>63.4</u>
Stationary Source Total	111	105	82.8	304.0	111
MOBILE SOURCES					
On-Road Motor Vehicles	<u>99.6</u>	<u>76.4</u>	<u>4.5</u>	<u>9.2</u>	<u>685</u>
Other Mobile Sources	<u>10.6</u>	<u>22.8</u>	3.1	<u>2.9</u>	<u>50.1</u>
Mobile Source Total	110.0	99.2	7.6	12.1	735
GRAND TOTAL	221.0	204.0	90.4	396.0	846
Negligible emissions are less than 0.05 tons/day					

Table 3-30. Coastal Area Air Basins, APCDs/AQMDs,
and Attainment/Nonattainment Classifications
(from California Air Resources Board, 1978a)

Air Basin	APCD/AQMD	ox	Classification			Part
			CO	NO ₂	SO ₂	
North Coast	Del Norte County APCD	U	U	U	U	A
	Humboldt County APCD	U	U	U	U	A
	Mendocino County APCD	U	U	U	U	N
	Northern Sonoma County APCD	U	U	U	U	A
San Francisco Bay Area	Bay Area AQMD					
	Southern Sonoma County	N	N	A	A	A
	Marin County	N	N	A	A	A
	San Francisco County	N	N	?	A	N ²
	San Mateo County	N	N	A	A	A
	Santa Clara County	N	N	A	A	N ²
North Central Coast	Monterey Bay Unified APCD					
	Santa Cruz County	N	U	A	U	A
	Monterey County	N	A	A	U	A
	San Benito County	N	U	A	U	A
South Central Coast	San Luis Obispo County APCD	A	A	A	U	U
	Santa Barbara County APCD					
	North County, West Area	N	A	U	U	N
	North County, East Area	N	A	U	U	U
	South Coast Area	N	N	A	U	A

¹ Proposed classifications as of September 1979. N: nonattainment. A: attainment. U: unclassified.

² Secondary standards only.

The San Francisco Bay Area Air Basin has the worst air quality of the four air basins, although the coastal portion of this air basin is relatively good. The great majority of emissions, and resultant high pollutant concentrations, occur downwind (to the east) of the coastal area. Of the three nonattainment pollutants, carbon monoxide and particulate concentrations reflect local emission sources and are generally lower in the coastal area, while oxidant is a regional problem which does extend to the coast (ABAG, et al., 1979a).

The major air quality problem in the North Central Coast Air Basin is oxidant, a nonattainment pollutant, although it is believed that atmospheric transport from the San Francisco Bay Area is a substantial contributor to this problem (AMBAG, et al., 1978). Although it is classified as attainment, particulate is also a problem in rural areas.

Of the four coastal area air basins, air quality in the South Central Coast Air Basin is the least uniform within the basin. The coastal area of San Luis Obispo County does not have any serious air pollutant problems (no nonattainment classifications), although oxidant concentrations will require long-term maintenance. In contrast, all of Santa Barbara County is oxidant nonattainment. In addition, the Santa Maria - Lompoc area exceeds the particulate NAAQS, and the south coast urban area exceeds the carbon monoxide NAAQS (SBCOAP, 1979).

GEOLOGY AND SEISMOLOGY

Topography

The land forms of the study area can be generally and empirically described and classified according to their topographic elements. The chief topographic elements are slope and local relief. In general terms, slope can be defined as inclination of the land surface. Slope is expressed in various ways including degrees (0 degrees is flat, 90 degrees is vertical), percent of slope or gradient (0 percent is flat, 100 percent is 45 degrees, and a vertical cliff has a gradient of infinity) or as slope ratio of vertical rise to a horizontal unit distance (0:1 is flat, 1:1 is a 45 degree inclination, 1:0 is a vertical cliff).

For purposes of generalization, slope classes used in the topographic description of the watershed units (see Vol. IV, Geomorphology, Geology and Soils) are approximately defined by the following gradients: flat (0 to 2 percent), gentle (3 to 10 percent); moderate (11 to 20 percent) and, steep (over 20 percent). Generally, slopes with over a 10 percent gradient cannot be cleared of their vegetation cover without danger of erosion. Slopes with over a 20 percent gradient present severe restraints to development and are best left in a natural state for watershed protection.

Local relief is defined as the difference in elevation of the land surface within a given area. Local relief is a relative concept which depends on the size of the area under consideration and the nature of the topography. Local relief is sometimes confused with altitude. Altitude refers to the height of a given point on the earth's surface relative to mean sea level. The local relief refers to the difference between the highest point within a given area of the earth's surface relative to the lowest height within that same area. The height, therefore, refers to any given datum. For example, the surface of a flat-topped plateau may have great altitude but low local relief.

Other elements of the topography considered in description of the terrain include horizontal dimensions of landforms (terrain texture), patterns and orientations of features, transverse profile and surface materials. Slope, local relief and the other elements of the terrain are combined to describe the topography of the watershed units.

The topography of the study area can be categorized into three broad classes of land form; open low mountains, low mountains and high mountains (Hammond, 1963). Open low mountains have the primary characteristic of having 20 to 30 percent of the surface area in gentle slopes, and the secondary characteristic of local relief predominantly in the 300 to 900 meter (m) i.e., 1,000 to 3,000 foot (ft) range.

In the study area, open low mountains include areas where broad valleys are located between low mountain ranges, e.g. the Salinas River Valley and Santa Maria River Valley.

Low mountains have the primary characteristic of having less than 20 percent of their area in gentle slope and the secondary characteristic of local relief between 300 and 900 m (1,000 and 3,000 ft). Almost all of the topography is in slope, generally the slopes are moderate to steep. Valleys are narrow, often canyon-like. In the study area generally the only open valleys and gentle slopes are located along the coast, i.e., marine terraces and river deltas, for example the Smith River and Eel River deltas.

High mountains have the primary characteristic of less than 20 percent of the area in gentle slope and the secondary characteristic of 900 to 1,500 m (3,000 to 5,000 feet) of local relief. High mountains have few open valleys. The valleys are generally canyon-like with steep walls, narrow bottoms and V-shaped transverse profiles. Gentle slope in such mountains is generally restricted to narrow coastal terraces and river deltas in the study area. In general, four land form regions are located within the study areas.

1) Low mountains are located in the northern portion of the study area from the Oregon border south to the Mendocino Upland just to the north of the Russian River. The northern part of the region includes predominantly the Coast Ranges along the coast and the Siskiyou Range further inland to the east. The main crests and valleys generally have a northwesterly trend. Almost all land is in slope except for coastal plains including those located between the Smith River delta and Crescent City, the Klamath River delta, the Redwood Creek delta and the plains around Arcata-Humboldt Bay, the Eel River Delta, Garcia River delta and the plains around Point Arena. Small, narrow plains, including primarily marine terraces and river deltas, are located along the coast.

2) Open low mountains are located in the region between the Mendocino Upland on the north to the Salinas Valley and Monterey Peninsula on the south. The mountains are subranges of the Coast Ranges including Bolinas Ridge and the Marin Peninsula, Inverness Ridge, the San Francisco Peninsula, Montara Mountain, the Santa Cruz Mountains, Gabilan Range, Sierra de Salinas and Monterey Peninsula. Each of those ranges has a northwesterly orientation as do most major valleys such as the San Andreas Rift Zone and the Salinas Valley. The mountains are located between wide valleys, some of which are drowned and form large embayments such as Tomales Bay, San Francisco Bay and Monterey Bay.

3) High mountains are located along the coast from Carmel Valley on the north to about Estero Bay on the south. The mountains are the high crests of the Santa Lucia. The principal crests are oriented northwesterly. Almost all land is in slope except for a few small areas of coastal terraces.

4) Open low mountains are located around Estero Bay and along the coast south to Point Conception. The mountains include the low southern extension of the Santa Lucia Range, the Irish Hills-San Luis Range, Casmalia Hills, Solomon Hills, Murissima Hills, Santa Rita Hills and Santa Ynez Mountains. The major valleys include the San Luis Valley, Los Osos Valley, Santa Maria Valley, San Antonio Valley, and Santa Ynez Valley. The valleys are wide and generally have open flat floors.

The Santa Lucia Range has a northwesterly orientation, but south of Santa Maria the topographic orientation of mountains and valleys is primarily east-west and parallel to that of the Transverse Ranges of southern California.

Bedrock Geology and Structure

The California coastal area can be characterized into two major bedrock geology regions. The Franciscan Formation (described below) underlies most of the study area, while a granitic-metamorphic assemblage occurs in the Salinian block located west of the San Andreas Fault and east of the Sur-Nacimiento Fault, as described below. The following section is taken largely from Page (1966), Geologic terms are defined in the glossary at the end of Vol. I, Chapter 3, Geology. The Geologic Time Scale is shown in Vol. I, Chapter 3, Table 3-2.

The California Coast Ranges province includes many separate ranges, coalescing mountain masses and several major structural valleys. The province is underlain by two entirely different core complexes (basement rock complexes) : 1) a

Jurassic-Cretaceous eugeosynclinal assemblage which is the Franciscan assemblage; and 2) Early (?) Cretaceous granitic intrusive and older metamorphic rocks. The two unrelated incompatible core complexes are adjacent and separated by large faults. A thick blanket of Cretaceous and Cenozoic elastic sedimentary rocks conceal most of the basement rock. The geologic history of the province reveals intermittent crustal activity. Folds, thrust faults, high-angle reverse faults and strike-slip faults developed during Cenozoic deformation. The crustal activity and deformation is continuing today.

The history of the area is complex, and is not entirely understood. Four important geologic events are: 1) the Early (?) Cretaceous orogeny, marked by the intrusion of pluton of the granitic-metamorphic core complex; 2) presumed early Tertiary thrusting over very large areas; 3) prolonged Cenozoic strike-slip faulting with large cumulative displacement along the San Andreas Fault system; and 4) late Pliocene and Pleistocene folding and faulting.

The granitic-metamorphic core complex is a group of rocks which consist of regionally metamorphosed rocks and granitic plutons extending in an area several hundred miles northwest from the Transverse Ranges of southern California. The northernmost part is largely under the sea, extending to the edge of the continental shelf. The complex is bounded on the east by the San Andreas Fault and on the west by the Sur-Nacimiento Fault. The Salinas Valley is a prominent topographic feature of the area. The complex is called the Salinan Block.

The metamorphic rocks of the Salinan Block record the earliest history of any rocks in the Coast Ranges. The rocks are exposed in the Santa Lucia Range and consist of gneiss, schist, quartzite, marble and granulite. The rocks are believed to be metamorphic equivalents of shelf or miogeosynclinal sandstone, shale, and carbonate rocks. The age of the metamorphic rock is unknown, however, paleontological evidence suggests a Paleozoic age.

Granitic rocks are extensive in the Santa Lucia, Gabilan and Santa Cruz ranges and probably underlie much of the Cenozoic material in the Salinian block. The granitic rocks are predominantly quartz diorite and granodiorite. The exact age of the rock is unknown, but potassium-argon dating suggests a late Cretaceous age, thereby indicating that the rocks are younger than some Franciscan rock.

The Franciscan Formation eugeosynclinal core complex is a vast, diverse assemblage of eugeosynclinal rocks with unsystematic structure and lacking the regional metamorphism and granitic intrusions characteristic of the other core complex. The areal extent of the assemblage is greater than that of the granitic-metamorphic complex. Much of the northern Coast Ranges region and the southern portion of the Coast Range west of the Sur-Nacimiento Fault Zone consists of Franciscan Formation rocks with limited remnants of younger formations.

The Franciscan Formation is a disorderly assemblage of various characteristic rocks which have been deformed in certain areas, and is a heterogeneous mixture of igneous, metamorphic and sedimentary rock types. The Formation includes primarily sedimentary rock material but also contains igneous and metamorphic rock material. The following discussion describes the various Franciscan Formation components. The mineralogy of the Formation is discussed in Sediments.

The prevalent rock type in the Franciscan assemblage is sandstone, chiefly graywacke. The beds are generally 1 to 10 ft thick and often are separated by shale beds. The sandstone beds, however, are generally not internally layered. The sand grains in the graywacke are usually medium-sized and angular. Sorting is poor and usually more than 10 percent (by volume) of the rock is a fine matrix of chlorite and mica.

Shale may comprise about 10 percent of the Franciscan sedimentary rock; the composition has not been extensively studied. The shale occurs as layers between graywacke beds and may locally predominate over other rock types. Most of the shale is gray to black, silty, brittle and somewhat fissile.

Conglomerate is uncommon and occurs in small lens-shaped bodies in graywacke sequences and in tectonically deformed shale. The clasts include quartzite, black chert, and siliceous porphyritic-aphanitic rocks. Some conglomerates contain rounded clasts of graywacke, red and green chert, greenstone and rock containing jadeite or glaucophane.

Cherts of the Franciscan Formation are thin-bedded, green or red, closely jointed rocks commonly associated with the greenstones. The packets of beds form discontinuous lenses generally less than one mile in length. The chert is composed of chalcedonic quartz with scattered tests of Radiolaria and contains no clastic grains.

Limestones occur locally within the Franciscan Formation generally as small, discontinuous bodies. One variety called the Calera Limestone occurs locally in large masses. The Calera Limestone is light colored, fine grained and shows little elastic detritus, although bioclastics (elastics formed of organic matter) are found in some of the associated types.

Volcanic rocks comprise about one-tenth of the Franciscan Formation. The volcanic rocks are mafic, have been altered and are termed greenstone. Most of the rocks are pillow lavas, tuffs or breccias resulting from submarine volcanic eruptions, but some massive units occur which may be intrusive.

Certain types of 'uncommon metamorphic rocks are characteristic of the Franciscan Formation. Notable metamorphic rocks include glaucophane-bearing rocks, jadeitized graywacke and eclogite. Serpentine and other ultramafic rocks are common associates of the Franciscan assemblage. In certain places partly serpentinized dunite or peridotite dikes, sills and plugs appear to have been introduced as molten or "crystal mush" intrusion. In other instances, serpentine has been emplaced cold as sill-like bodies along faults, or as diapiric masses. Cold intrusion is indicated by lack of contact metamorphism and typical igneous contacts, and by the shear structure of the masses.

Small sections of Late Mesozoic marine sandstone, shale or mudstone and conglomerate flank the Franciscan core in some areas and is separated from the Franciscan core by faults.

The Cenozoic material is an overlying layer of thick, well-folded, sedimentary rocks. The sediments are predominantly nondistinctive sandstone and shale or mudstone; many of the formations are of restricted areal extent, and show marked changes in the composition over short distances. The Miocene-aged rocks are better preserved than rock of the earlier Tertiary. Characteristic formations of the Miocene include the Sandhollow Formation, a somewhat siliceous, organic mudstone; the Monterey Formation, a siliceous shale, with porcelanite, and chert; and Santa Margarita Formation, which is a white, quartzose arenite. The Miocene rocks contain extensive evidence of volcanic activity. Within the Monterey Formation there are layers of bentonite clay, an inch or less thick. Rhyolitic, dacitic, andesitic and basaltic lava flows and tuffs occur in several areas. The Pliocene rocks are various marine sedimentary rocks and also contain volcanic elastic debris, ash, and flows. Plio-Pleistocene deposits are coarse, poorly sorted and stratified, alluvial sediments.

Sediments

The sediments derived from the Franciscan Formation are a heterogeneous mixture of geologic materials derived from the varied parent rocks. Table 3-31 gives the mineral composition of the sedimentary and igneous rocks of the Franciscan Formation. By far the most abundant rock of the Franciscan Formation is graywacke, a sedimentary rock. Graywacke is a sandstone but its composition is not everywhere the same, and studies of Franciscan graywacke are not sufficient to describe all of the variations. Feldspar is generally the dominant mineral in Franciscan graywacke, and the feldspar comprises 9 to 46 percent of the elastic grains. The average amount of feldspar is about 43.5 percent. Plagioclase, sodic feldspar, is the only feldspar in many areas of graywacke outcrop. Orthoclase, potassium feldspar, occurs in some areas. The quartz in the Franciscan graywacke, can comprise 10 to 50 percent of the average composition is about 30 percent quartz. Some of the quartz is in chert or quartzite, and some of the feldspar is in rock fragments (Bailey, et al., 1964).

Rock fragments are an abundant part of Franciscan graywackes, with percentage values ranging from 2 to 55 percent. The most abundant rock fragments are fine-grained mafic volcanic (an igneous basaltic rock) rocks, apparently similar to, and possibly derived from the volcanic rocks within the Franciscan Formation. Altered volcanic glass fragments are common. Chert fragments also are common. Quartz diorite (an igneous granitic rock) and quartz-mica schists (a metamorphic rock) also are present in Franciscan rocks (Bailey, et al., 1964).

Table 3-31. Mineral Composition of Sedimentary and Igneous Rocks of the Franciscan Formation (from Mason and Berry, 1968)

Mineral	Composition
Biotite	$K(Mg,Fe)_3(AlSi_3O_{10})(OH)_2$
Chlorite	$(Mg,Fe,Al)_6(Al,Si)_4O_{10}(OH)_8$
Epidotite group	$Ca_2(Al,Fe)_3Si_3O_{12}(OH)$
Sphene	$CaTiSiO_5$
Apatite	$Ca_5(PO_4)_3(F,Cl,OH)$
Garnet	a group of minerals with general formula $X_3Y_2(SiO_4)_3$ where X may be Ca, Mg, Fe or Mn and Y may be Al, Fe or Cr
Hornblende	$NaCa_2(Mg,Fe,Al)_5(Si,Al)_8O_{22}(OH)_2$
Ilmenite	$FeTiO_3$
Magnetite	Fe_3O_4
Pyrite	FeS_2
Tourmaline	$Na(Mg,Fe)_3Al_6(BO_3)_3(Si_6O_{18})(OH)_4$
Zircon	$ZrSiO_4$

Heavy detrital mineral grains are found in the graywackes. The most abundant minerals appear to be biotite, chlorite, minerals of the epidotite group, sphene and zircon. Other minerals including apatite, garnet, hornblende, ilmenite, magnetite, pyrite, tourmaline and other uncommon minerals are widespread in distribution but are present in small amounts. The following table lists common minerals of the Franciscan Formation and their chemical composition.

Chemically, more than 60 percent of the graywacke is silica, SiO_2 , with about 13 percent Al_2O_3 , 5 percent Fe_2O_3 and FeO , 2 to 3 percent MgO , 2 to 3 percent CaO , 3 to 4 percent Na_2O , 2 percent K_2O and minor amounts of other chemicals.

Shale, including siltstone, comprises about 10 percent of the Franciscan sedimentary rock. Mineralogically, the Franciscan shales are similar to Franciscan graywacke, with a high proportion of angular mineral and rock fragments and only a small amount of clay minerals. The minerals are chiefly quartz and feldspar, with chlorite, and sericite (mica). The chemical composition of the shales is similar to that of the graywacke, with quartz comprising just over 60 percent of the rock, and other chemicals in amounts similar to those for graywacke. Chert and the shale interbedded with it comprise less than 0.5 percent of the entire assemblage of Franciscan rock. Chert is silica; about 95 percent of the material is SiO_2 .

Conglomerate, a sedimentary rock of sand and large rock fragments, is of limited extent in the Franciscan Formation. The fragments are of two types: 1) lithic types not originally part of the Franciscan Formation which must have been brought into the depositional area from elsewhere, and 2) lithic types in the Franciscan Formation, which are derived from the weathering of Franciscan rocks or from the introduction of similar foreign rocks. Included in the first category are quartzite, black chert and various quartz and feldspar porphyries which form a prominent part of most of the Franciscan conglomerates. In the second category are graywacke, shale, red and green chert, mafic volcanic rocks and glaucophane schist. The matrix of the conglomerate is identical to graywacke.

The volcanic rock of the Franciscan Formation is greenstone, which is basaltic and contains plagioclase and augite minerals with the chemical formula $Ca(Mg,Fe,Al)(Al,Si)_2O_6$. In addition, magnetite, ilmenite and sphene also are present in the greenstone (see Table 3-31 for their chemical composition). The predominant chemical in the greenstone is silica, SiO_2 , forming about 50 percent of the rock. The approximate percentage composition, of other greenstone constituents

are: TiO_2 , 2 percent; CaO , 4 to 11 percent; Na_2O , 3 to 5 percent, H_2O^+ , 1 to 6 percent; and other minor constituents.

Ultrabasic rocks, chiefly serpentinites and peridotites, comprise a significant part of the Franciscan rock and are widely distributed. The ultrabasic rocks are all intrusive igneous rocks. The peridotite, which has not been serpentinitized is composed of pyroxene and olivine minerals. Serpentinization has occurred in many of the rocks. Serpentine is a mineral with the chemical formula $\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$. The mineral has two forms: antigorite, which has a platy structure, and chrysotile which is fibrous and is used like asbestos. Serpentinite is rock formed by the serpentine. The serpentine is generally hard where it has not been sheared, but in most places extensive shearing (the rock is somewhat crushed and formed in near-parallel plate-like masses) has occurred. The weathering of ultramafic rocks produces detritus composed of quartz, clay minerals, some serpentine, and chemicals such as magnesium, calcium, sodium, potassium and iron (Mason and Berry, 1968; Bailey, et al., 1964). Soils produced by the weathering of serpentine rocks have unusual chemical characteristics. These soils have high magnesium content and low calcium content. Some plant species cannot grow on serpentine soils; other plant species are entirely restricted to that soil. Many of the latter plant species have been or are proposed for protection as threatened or endangered species.

Metamorphic rocks are rare in the Franciscan Formation. The best known Franciscan metamorphic rocks are the blue glaucophane schists. Besides glaucophane other minerals in the metamorphic rock are garnet, quartz, micas, hornblende, and sphene. The chemical compositions of the minerals in Franciscan metamorphic rocks are given in Table 3-32 (Bailey, et al., 1964; Mason and Berry, 1968).

Table 3-32. Mineral Composition of Metamorphic Rock of the Franciscan Formation (from Mason and Berry, 1968)

Mineral	Composition
Glaucophane	$\text{Na}_2(\text{Mg,Fe,Al})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$
Garnet	a group of minerals with general formula $\text{X}_3\text{Y}_2(\text{SiO}_4)_3$ where X may be Ca, Mg, Fe or Mn and y may be Al, Fe, Cr
Quartz	SiO_2
Micas	sheet silicates
Hornblende	$\text{NaCa}_2(\text{Mg,Fe,Al})_5(\text{Si,Al})_8\text{O}_{22}(\text{OH})_2$
Sphene	CaTiSiO_5
Serpentine	$\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$
Pyroxene	a group of minerals with the general formula $(\text{W,X,Y})_2\text{Z}_2\text{O}_6$ in which W may be Ca or Na; X may be Mg, Fe, Mn or L; Y is Al, Fe or T and Z is Si or Al.
Olivine	$(\text{Mg,Fe})_2\text{SiO}_4$

Detailed information on the composition of Franciscan Formation rocks can be found in Bailey, et al., 1964.

Weathering of the Franciscan Formation rocks results in the production of sediments dominated by quartz and clay minerals. Some partially weathered feldspar also is found in the sediments. Accessory minerals of the weathered Franciscan rock include hematite (Fe_2O_3) and limonite (FeO_2) and other minerals from the weathering of rock containing iron, glaucophane, sphene, garnet, hornblende, serpentine and other minor minerals.

The granitic and metamorphic rocks of the Salinian block would weather to sediments predominately composed of quartz, clay and iron oxides as described in vol. I, chapter 3, Sediments.

The most southerly exposure of Salinian basement rock is composed of about 30 percent quartz, 25 percent potassium feldspar; 35 percent oligoclase and 10 percent biotite. The expected sediment would be composed of about 30 percent quartz; the rest of the sediment would be clay material, some iron oxides, and minor amounts of feldspars and biotite (Compton, 1966).

The Sur series of the northern Santa Lucia Range contains minerals of the amphibolite and granulite facies; these facies consist of amphibole, plagioclase, augite and hypersthene. The chemical composition of these minerals is given in Table 3-33.

Table 3-33: Mineral Composition of the Sur Series Metamorphic Rocks
(from Mason and Berry, 1968)

Mineral	Composition
amphibole	a mineral of the general composition (W,X,Y) $7-8(Z_4O_{10})_2(OH)_2$ in which W = Ca and Na; X = Mg, Fe; Y = Fe, Ti, Al and Z = Si, Al
augite	$Ca(Mg,Fe,Al)(Al,Si)_2O_6$
hypersthene	$(Mg,Fe)SiO_3$
plagioclase	$(Ca,Na)(Al,Si)AlSi_2O_8$

The sediment derived from these rocks of the Sur series would contain abundant quartz and also would contain accessory amounts of the above minerals (Compton, 1966).

Five heavy mineral assemblages are found in the sediments of the central California coast (see Vol. II, Chapter 3, Oceanic and Coastal Sediment Transport); four of these assemblages are derived from the Coast Ranges and the fifth from the Sierra Nevada via the Sacramento-San Joaquin river system. These assemblages are: 1) hornblende-sphere, derived from granodiorite and quartz-diorite of the Salinian block; 2) hornblende-garnet, derived from mixed granitic and metamorphic rocks of the Salinian block; 3) glaucophane-jadeite, derived from Franciscan Formation rocks; 4) augite, derived from Cenozoic volcanic rock; 5) hornblende-augite-hypersthene, derived from volcanic and plutonic rocks of the Sierra Nevada east of the Central Valley. Figure 3-47 illustrates the heavy mineral provinces (Yancey and Lee, 1972).

Several other heavy minerals are included in the mineral assemblages. The minerals include hypersthene, augite, epidote and sphere which are present in all and minerals such as apatite, zircon and tremolite-actinolite are found in some of the assemblages. Table 3-34 gives the composition of these minerals (Yancey and Lee, 1972).

Soils

The major soil orders (see vol. I, Chapter 3, Soils) found in the study area are alfisols, entisols, inceptisols, mollisols, spodosols, ultisols and vertisols (SCS, 1975). Most soil information available for this study includes the physical description of site specific soils. These soils are then generalized into soil associations. Associations are groups of similar soils occurring in the same topographic sequence and named for the major soil series of that group. For example, the Los Osos association is an upland soil association containing mostly soils of the Los Osos series. Small amounts of other soils are frequently found with Los Osos soils, for example, Aptos or Fagan soils series may also be mapped as the Los Osos Association.

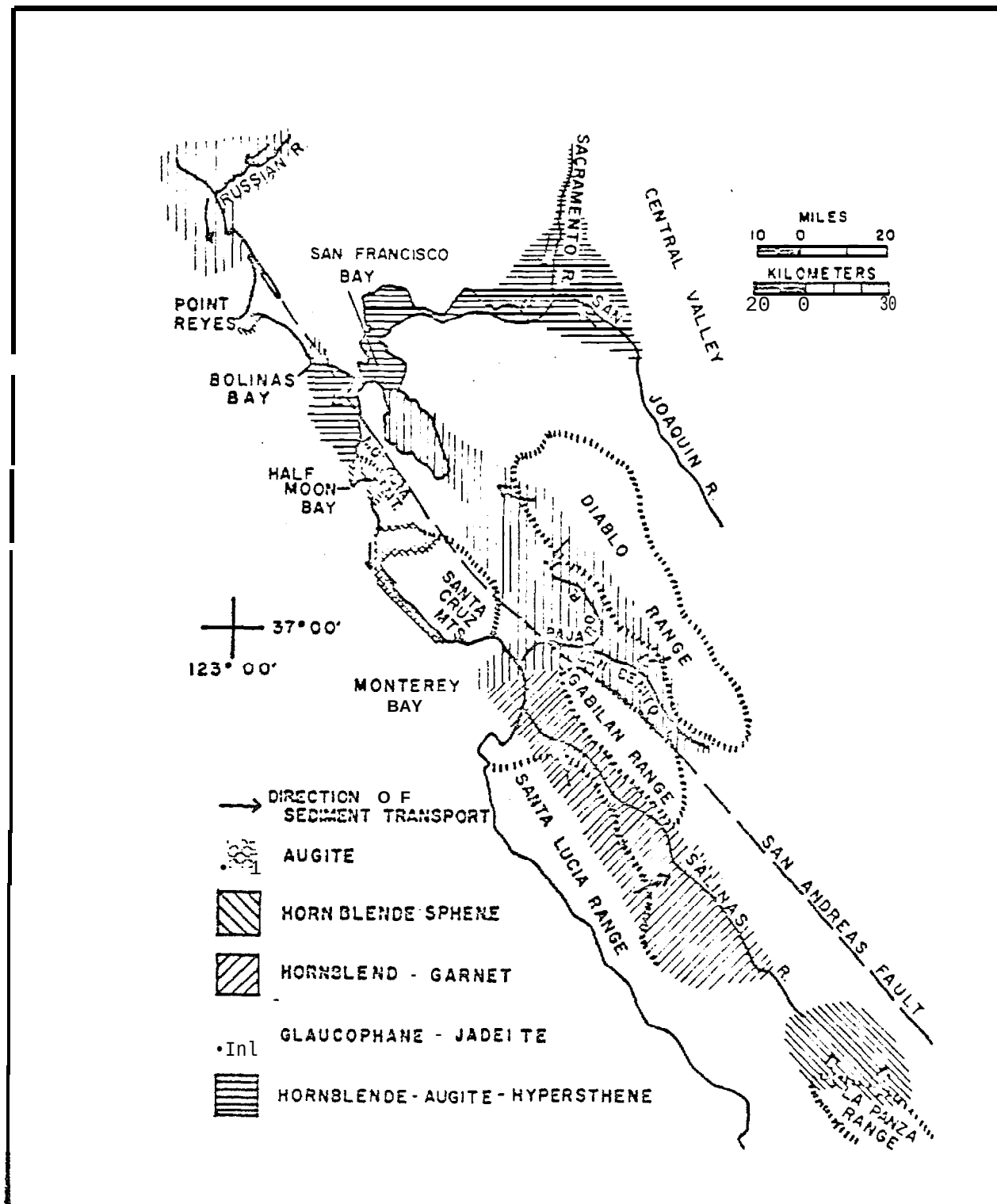


Figure 3-47. Recent Heavy Mineral Provinces of Central California.
(Yancey and Lee, 1972)

Table 3-34. Composition of Minerals
from the Heavy Mineral Provinces of Central California
(from Mason and Berry, 1968)

Mineral	Composition
jadeite	$\text{NaAlSi}_2\text{O}_6$
epidote	$\text{Ca}_2(\text{Al,Fe})_3\text{Si}_3\text{O}_{12}(\text{OH})$
apatite	$\text{Ca}_5(\text{PO}_4)_3(\text{F,Cl,OH})$
zircon	ZrSiO_4
tremolite-actinolite	$\text{Ca}_2(\text{Mg,Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$

Note: See also Tables 3-32 and 3-33 above.

Nest of the study area north of Sonoma County has not been surveyed in detail (see Figure 3-48). Information about the soils in the nonsurveyed areas comes from the General Soil Map of California (Storie and Weir, 1951).

The soils along the California coast can be discussed by their topographic position. North of Sonoma County, most soils are located in coastal mountains covered with timber. Those soils are deep and are generally moderately fine to moderately coarse textured. The soils occur in a high rainfall zone and are thus characterized by medium to strong acid reactions.

The valley soils in the northern half of the California coast are deep alluvial soils high in organic matter. These soils are generally dark-colored, slightly acidic, loamy-textured and have an abundant nutrient supply.

Soils of the terraces (i.e. areas between valleys and uplands) are derived from alluvium and have dense subsoils. In the areas of moderate to high rainfall (over 63.5 cm/year, 25 inches/year), terrace soils are generally dark-colored, slightly acidic and covered with grass or trees.

A gradual change to lighter-colored soils occurs south of San Francisco Bay and is related to lower rainfall and the change from forest cover to grass cover. The upland soils from Sonoma County southward are residual soils of moderate depth, fairly high in organic matter and usually of fine to medium texture. Erosion is a potential hazard on almost all upland soils of the region. The natural vegetation prevents large losses of soil, but removal of the vegetal cover increases erosion. The southern Coast Range Mountains have some very shallow soils. Terrace soils south of Monterey Bay are usually brownish soils of neutral reaction with moderately dense subsoils. Valley soils of the southern region are generally brown, deep alluvial fan and flood plain soils with mostly loamy texture. Soils in coastal dunelands are sandy, light brown and highly susceptible to wind erosion,

Data on mineral and chemical composition of soils are site specific. Chemical analysis of soil is not a routine part of a soils survey and is undertaken only for specific ecological studies requiring such data. Soil fertility information is included in the interpretations of soil surveys with reference to overall quality rather than to the absolute quantity of given nutrients in the soil.

Geomorphic Processes

General Characteristics. The study area is both a geologically active area and an area of great geomorphic activity. The sharply rising Coast Ranges began their uplift only a few million years ago and the continuing earthquake activity provides evidence that the process continues today. The numerous raised, massive wave-cut terraces along the coast are evidence of uplift in the geologic past. The mountain-building (tectonic) activity along the coast of California is of great significance to geomorphic processes in the study area. The tectonic uplift provides initial relief which is in opposition to the degradation of the landscape by the geomorphic processes. That relief is what is available for the geomorphic processes of gradation to reduce the land to sea level in the run of geologic time. Thus, for every small uplift of the Coast Ranges, every stream draining the mountains will

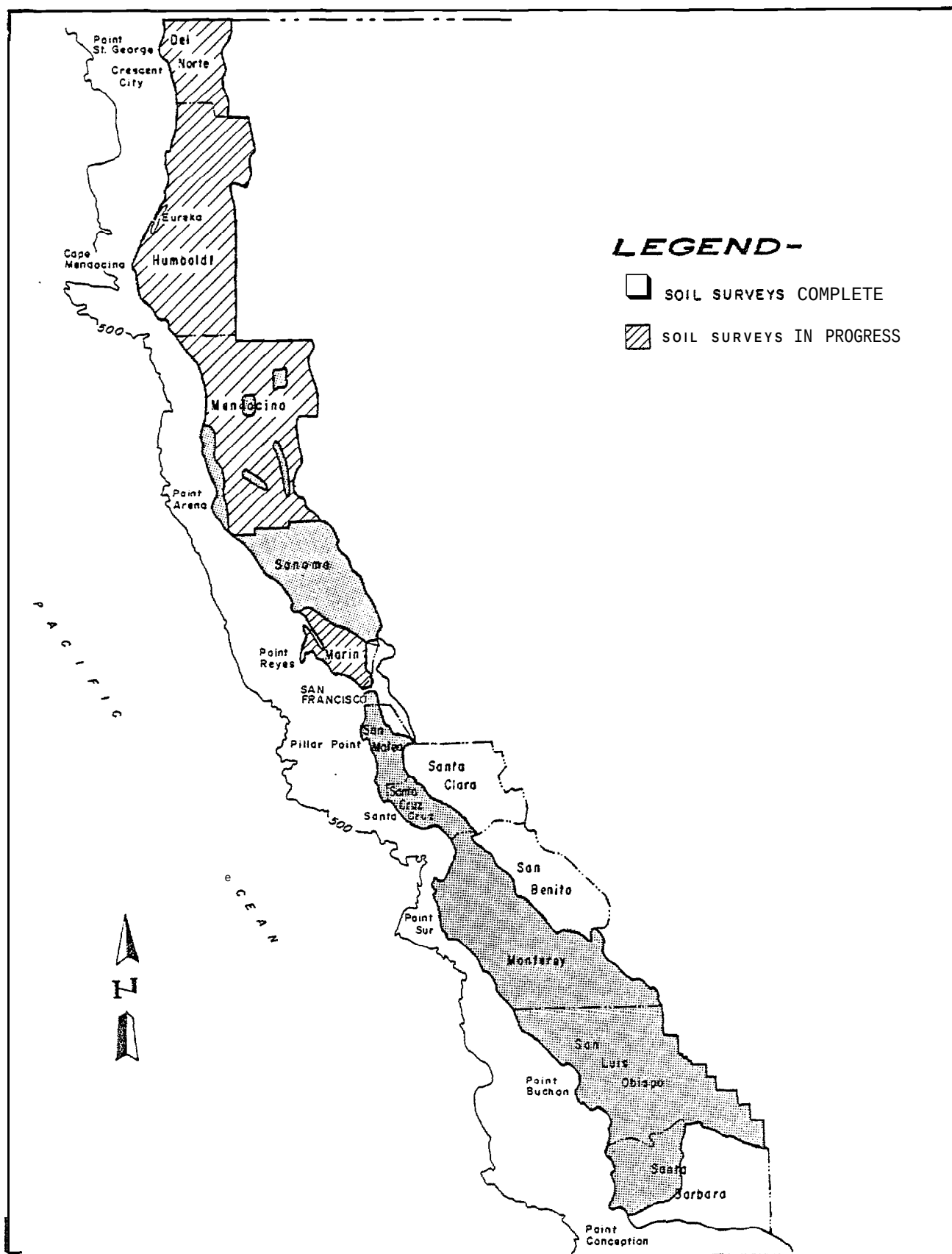


Figure 3-48. Location of Areas for which Detailed Soil Surveys Have Been Done Or Are in Progress (see individual watershed units for references compiled from state and county soil survey maps.)

readjust its channel in response to the added available relief within its drainage basin and all its tributaries will also undergo readjustment to keep pace with the erosion of the trunk stream. As the streams cut deeper into the mountains in response to tectonic uplift, the adjacent slopes undergo readjustment. Landsliding, slumping and mass wasting are enhanced 'because the bases of the slopes are undermined by fluvial erosion and the basal support of weathered rock and soil is removed (see Vol. I, Chapter 3, Landforms). In addition much of the geologic material comprising the Coast Ranges is non-resistant sedimentary, meta-sedimentary and metamorphic rocks which are relatively easily weathered and eroded.

Tectonic uplift of the Coast Ranges also has the effect of initiating renewed cycles of wave-erosion at the coast. As the cliffs are raised above sea level, the surf initiates attack on the base of the sea cliffs. In areas of bedrock along the coast a wave-cut notch is formed at the base of the cliffs. In areas of weaker rock the notch may be lacking as the basal material is eroded away. As the base of the sea cliffs is eroded the basal support is removed and collapse of the rocks and sediments results. The wave erosion along the coast tends to create planar features because of the depth limits of wave action. Such planar features are called plinth terraces or wave-cut terraces. The terraces are usually submerged except during periods of low tide. The surfaces of upraised marine terraces are former plinth terraces. Wave-cut terraces are generally backed by sea cliffs. Areas of resistant geologic material stand out from the shoreline as promontories or headlands, whereas areas of weaker materials are eroded into coves. Basal wave erosion commonly creates sea arches or natural bridges along the rocky sections of the coast. Basal erosion of the arches by waves causes the eventual collapse of the arch, leaving sea stacks. Sea stacks are small protuberances of resistant rock which stand as offshore islands and mark the former location of the shoreline. Some sea stacks are remnants of the legs of sea arches, but most are not (Bird, 1970).

Although much of the California coastline is characterized by tectonic uplift, most sections of the coast were submerged, mostly due to the post-glacial rise in world sea levels. San Francisco Bay is an example of an area which has been submerged below the sea. Sea level rose about 100 m (300 feet) following the last worldwide glacial epoch. Thus, although much of the the California coastline is undergoing uplift, many areas were drowned (submerged) by the rise in sea level. Geomorphic depositional environments were created in those areas of submergence. As the streams draining the Coast Ranges flow into their drowned mouths, they are forced to drop their sediment loads. The large embayments of the coast such as San Francisco Bay, Morro Bay and Humboldt-Arcata Bay are immense depositional basins.

Of equal significance to the tectonic conditions to the geomorphic processes of the study area is the climate of California. The primary geomorphic processes of weathering, mass wasting and erosion obtain their fundamental character from the climate. The marked seasonality of precipitation is of particular significance to modern geomorphic processes in the study area, and the Pacific slopes region has the second highest rates of total denudation in the United States, at approximately 9.1 cm (3.6 in) per 1000 years (Judson and Ritter, 1964).

Weathering and Mass Wasting. The abundance of moisture occurring in the winter combined with moderate temperature conditions at that time in the coastal zone are conducive to chemical weathering of the geologic materials of the Coast Ranges. Almost all chemical weathering involves water and that is available in abundant supply during the November to April period throughout most of the study area, and particularly in the northern watershed units. The chemical weathering of the relatively weak rocks of the Coast Ranges results in the production of weathered rock detritus and soil (see Sediments and Soils). Much of the study area is underlain by rocks of the Franciscan Formation which typically weathers easily and produces abundant clay. In the moist regions north of San Francisco, the clay is commonly saturated and is highly erodible (Hauge and Euphrat, 1979).

The concentration of rainfall in the winter season is of notable significance to mass wasting processes in the study area. Coastal California has some of the highest rates of mass wasting in the world. The combination of steep, tectonically unstable slopes comprised of weak geologic materials and subject to intense rainfall concentrations, during the winter, provides conditions which favor massive landsliding, slumping, mudsliding, creep and fall of the weathered detritus and soil (Dodge, et al., 1976). See Vol. I, Chapter 3, Figure 3-2 for illustration of these processes. In addition, because of the summer dry period, the vegetation cover is subject to frequent wildfires. In the aftermath of such wildfires, the slopes are laid bare and exposed to the full intensity of the 'winter rainfall. In the years following a wildfire on a slope, a tremendous increase in mass wasting activity on

the exposed slopes is common. The detritus and soil slide into the valley bottoms and choke the channels with sediment. As the vegetation reestablishes itself on the slopes, the mass wasting and erosion activity diminish until the next wildfire renews the cycle again. This relationship between mass wasting and wildfire has been a characteristic feature of the geomorphic environment of the study area particularly in the southern portions, throughout the entire post-glacial period. A discussion of the effects of fire on geomorphic processes is found in Cleveland (1977a).

Clear cut lumbering has had much the same effect as wildfire upon geomorphic processes of mass wasting and erosion in the northern portion of the study area (Huffman, 1977). The Forest Practice Act of 1973 requires that loggers submit a timber harvesting plan to the California Department of Forestry for review prior to logging on private lands. In addition, the California Environmental Quality Act of 1971 requires that an environmental impact report (EIR) be prepared for logging projects and other projects which could significantly alter the environment. The timber harvest plan must include information about the method of logging, erodibility of the soils, road construction and other data. Since 1976, the California Department of Forestry has contracted with the California Division of Mines and Geology to review timber harvest plans to assess the potential impact on mass wasting and erosion (Huffman and Bedrossian, 1979).

Poorly constructed roadcuts also cause a significant amount of slope failure in the study area and particularly in the wet portions of the study area north of San Francisco. When a slope is cut, support for the material above the cut is removed, and the slope is set out of equilibrium and continues to fail until a balance is reached. In the Coast Forest District (includes the area north of San Francisco), road cuts generally associated with timber harvesting and mining accounted for 75 percent of all cut failures and tractor trail cuts accounted for 25 percent of the failure. Steep slopes are particularly susceptible to mass wasting of cut and fills because of the proportionately greater impact associated with road building (Hauge and Euphrat, 1979).

Erosion. The concentration of precipitation in the winter season determines the character of the erosion of the Coast Ranges. Degradation of the landscape by stream (fluvial) erosion is a process of cut and fill. Cutting of valleys occurs because the flow of runoff from the slopes quickly consolidates itself into linear channels where erosive energy can be concentrated. In the Coast Ranges the available relief for erosion is great, and, thus, the potential erosive energy of the streams is also large. Most erosion occurs during periods of flood, which condition is favored by concentrated precipitation during the winter period. Thus the erosive energy of running water is primarily concentrated in the November-April period. Flowing water is the primary agent of erosion, but the tools of fluvial erosion are the sediment in the stream channels which abrade the banks and bottom of the channel. Generally the rivers have abundant supplies of sediment in their channels supplied by the mass wasting of slopes and erosion of tributary channels. Following flood periods, as the streams have diminished volume and velocity of flow, the load of sediment is dropped and the channels undergo aggravation of their channels until the next flood. For the above reasons, erosion rates of California Coast Range streams are generally very high compared to streams in other parts of the United States. The Eel River may have the highest erosion rates of any river of similar size within the coterminous United States.

Natural and man-induced erosion has stripped away soil in many areas of California, particularly in the upland areas. In much of northern California and in parts of central California coastal region, the topography is mountainous, the rocks are relatively young and unstable, and the annual rainfall is high or at least concentrated in the winter months. During the periods of high or concentrated rainfall, the soil and rock formations, which are often poorly consolidated, highly fractured, and structurally weak, become saturated and landslides commonly occur. Landslides can also be triggered by stream erosion which removes the slope toe and reduces the slope's stability by undermining the slope's basal support. After a landslide has occurred, the landslide scar is left bare and the surface geologic material is generally loosened. As a result, the potential for sheet and gully erosion is greatly increased (USDA, 1972). Landslides are common throughout the study area of the coastal zone but are especially frequent in the northern portions of the coast because of high rainfall (see Precipitation).

Stream bank erosion usually occurs by cutting into streambank of weak alluvium or by undercutting the toe of adjacent bedrock or terrace slopes. Landslides and streambank erosion are mainly the results of natural geologic and climatic factors. Sheet and gully erosion are also natural but in California are commonly accelerated

by man's disturbance or removal of the vegetal cover which leaves the bare soil highly susceptible to erosion. In the central portion of the California coast, the natural destruction of plant cover and ground litter by frequent natural and man-caused wildfires is a critical problem which adds significantly to erosion. Activities such as clear-out logging, overgrazing, faulty road construction, mining and quarrying, urban development, construction of dams and reservoirs, and poor farming practices have accelerated erosion in many areas throughout the coastal region by increasing runoff and sediment loads, altering natural slopes, inducing landsliding and removing the natural vegetative cover.

Figure 3-49 is a map of erosion activity of the central and northern coastal regions of California. Most of the coast is at least moderately susceptible to erosion. The southern portion of the central coastal region experiences severe erosion activity, due in part to the relatively sparse vegetation cover of the steep uplands in that area (California Region Framework Study Committee, 1971).

Sedimentation. Sedimentation occurs when the material is no longer carried by the transporting agent and is deposited. For example, sedimentation can occur when material moving downslope under the influence of gravity reaches the bottom of the slope or when water transporting the material loses energy and deposits the sediment. A large reduction in energy occurs in most streams where they flow from steep mountainous zones of the Coast Ranges onto the flat alluvial valleys or marine coastal terraces. In consequence, the streams drop part or all of their load in those areas.

Sediment deposition from the rivers is the source of beach sand replenishment. The fertile soils of alluvial plains and alluvial fans are also the result of such sediment deposition. The soils are given renewed fertility by the constant introduction of new sediment with each flood. However, damages from sediment and debris deposition also occur where man occupies alluvial plains and fans. Agricultural lands can be ruined temporarily by burial in sediment. Following floods, pipelines must be cleaned, pumps replaced and crops replanted. Urban communities also can be damaged by sediment and debris deposition. Two towns in northern California, Klamath and Klamath Glen, were completely destroyed by floodwaters and sediment in December, 1964. Roads and highways in the northern valleys and along the entire coast are frequently littered by debris and sediment following floods and also are highly susceptible to landslides in many areas. Deposition of sediment in reservoirs and along stream channels decreases their capacity and increases the danger of flooding in adjacent areas.

Natural erosion and sedimentation take place virtually everywhere geologic materials are exposed. High rates of erosion are found in areas of steep topography, sparse vegetation, and high amounts of rainfall or highly concentrated rainfall such as is found in many areas along the California coast (see Figure 3-49 - Erosion Activity). However, a disturbance of the natural environment often greatly accelerates erosion. Erosion and sedimentation in watersheds can be accelerated as a result of man's activities by removal or modification of the vegetative cover, by exposure of mineral soil and by a modification of drainage patterns. Among the major land uses which have harmed the coastal watersheds are hydraulic mining; poorly managed timber harvesting; unregulated or poorly regulated grazing; poorly managed cultivation; and poorly located, developed or maintained urban-industrial and transportation-utility uses. In essence, these activities involve over-use or misuse of the watershed areas (California Region Framework Study Committee, 1971).

The U.S. Geological Survey (USGS) operates and maintains many stream gaging stations along the California coast. Eight-digit numbers identify each station and were assigned in downstream order. Some USGS stream gaging stations are also fluvial-sediment sampling stations. These are listed in the USGS publication, An Inventory of Published and Unpublished Fluvial Sediment Data for California, 1956-70 (Porterfield, 1972).

Local, state, and Federal laws now restrict many of the harmful practices which have caused past erosion problems in the study area. New laws and regulations are now being considered to provide additional control. It is being demonstrated that timber harvest can be accomplished with very little adverse effect on natural watershed conditions including erosion. Profitable grazing, mining, and cultivation operations can also take place without causing increased erosion and loss of water quality. Careful, well-planned management is necessary. Coordinated planning efforts before development are also proving that non-resource uses, such as transportation and utility routes and urban-industrial areas, can be built in harmony with the environment. Some areas damaged by earlier misuse have not been stabilized

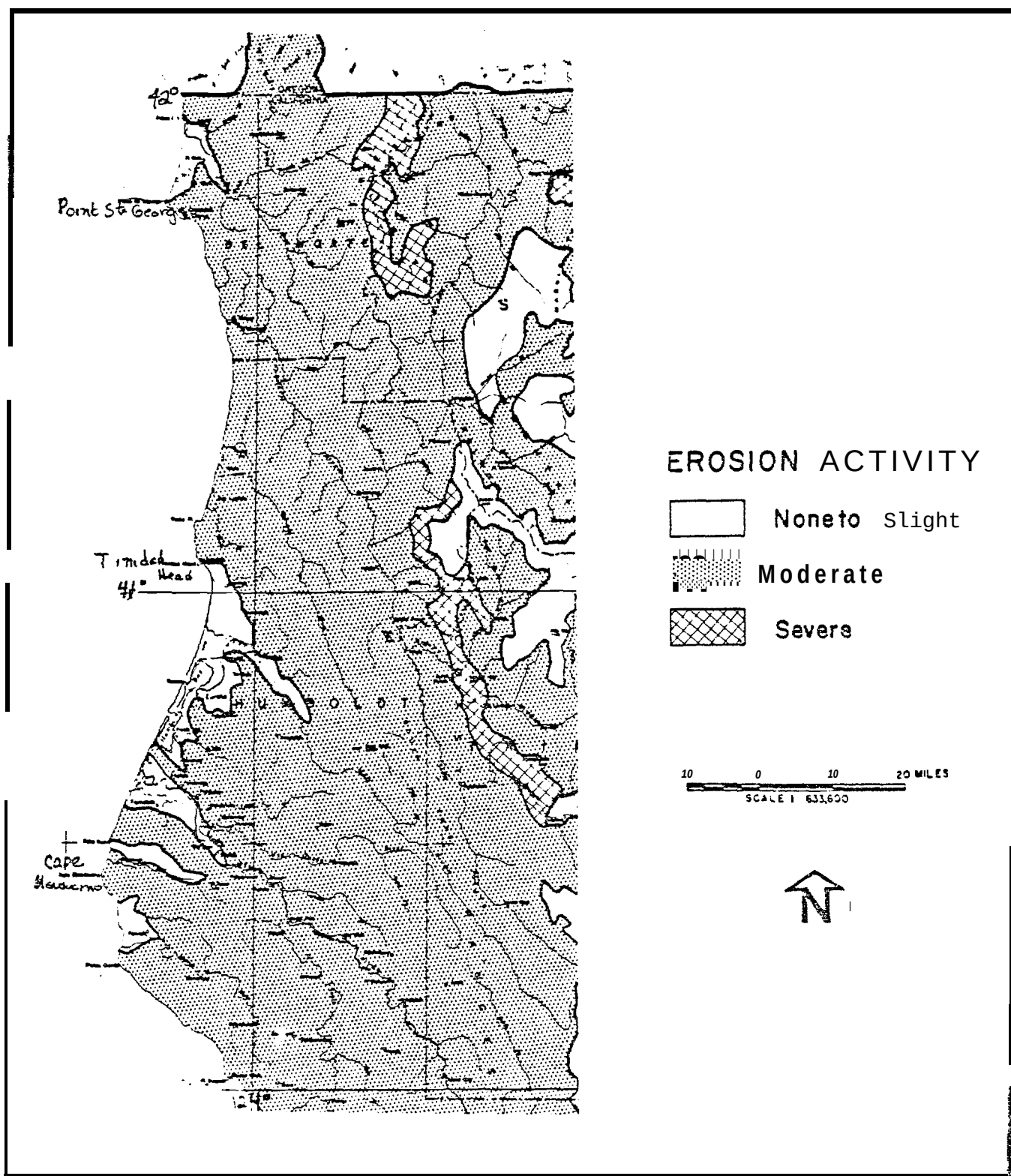


Figure 3-49 . Generalized Classes of Erosion Activity Along the California Crest
(California Region Framework Study Committee, 1971)

(Sheet 1 of 5)

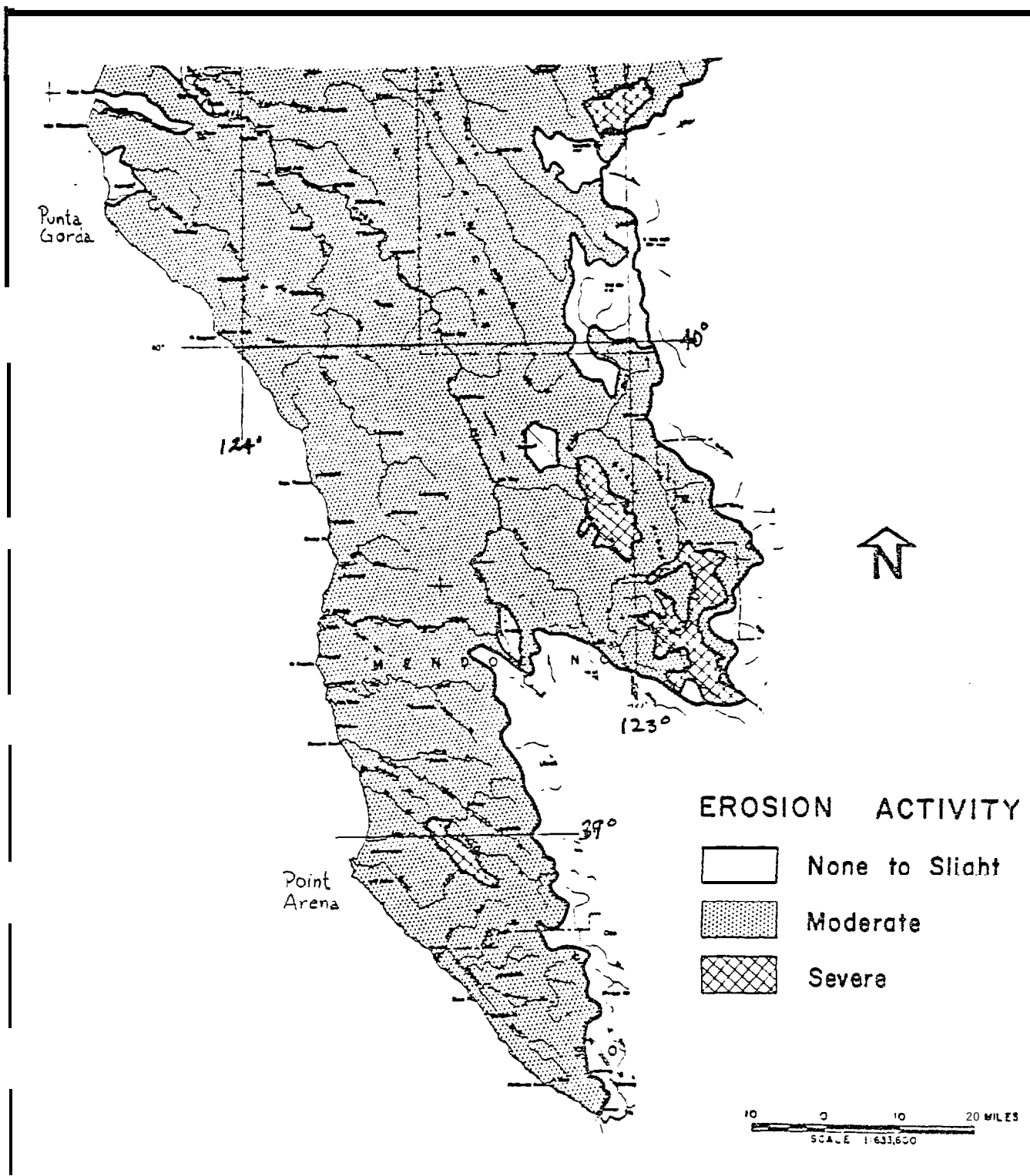


Figure 3-49. Generalized Classes of Erosion Activity Along the California Coast (California Region Framework Study Committee, 1971)

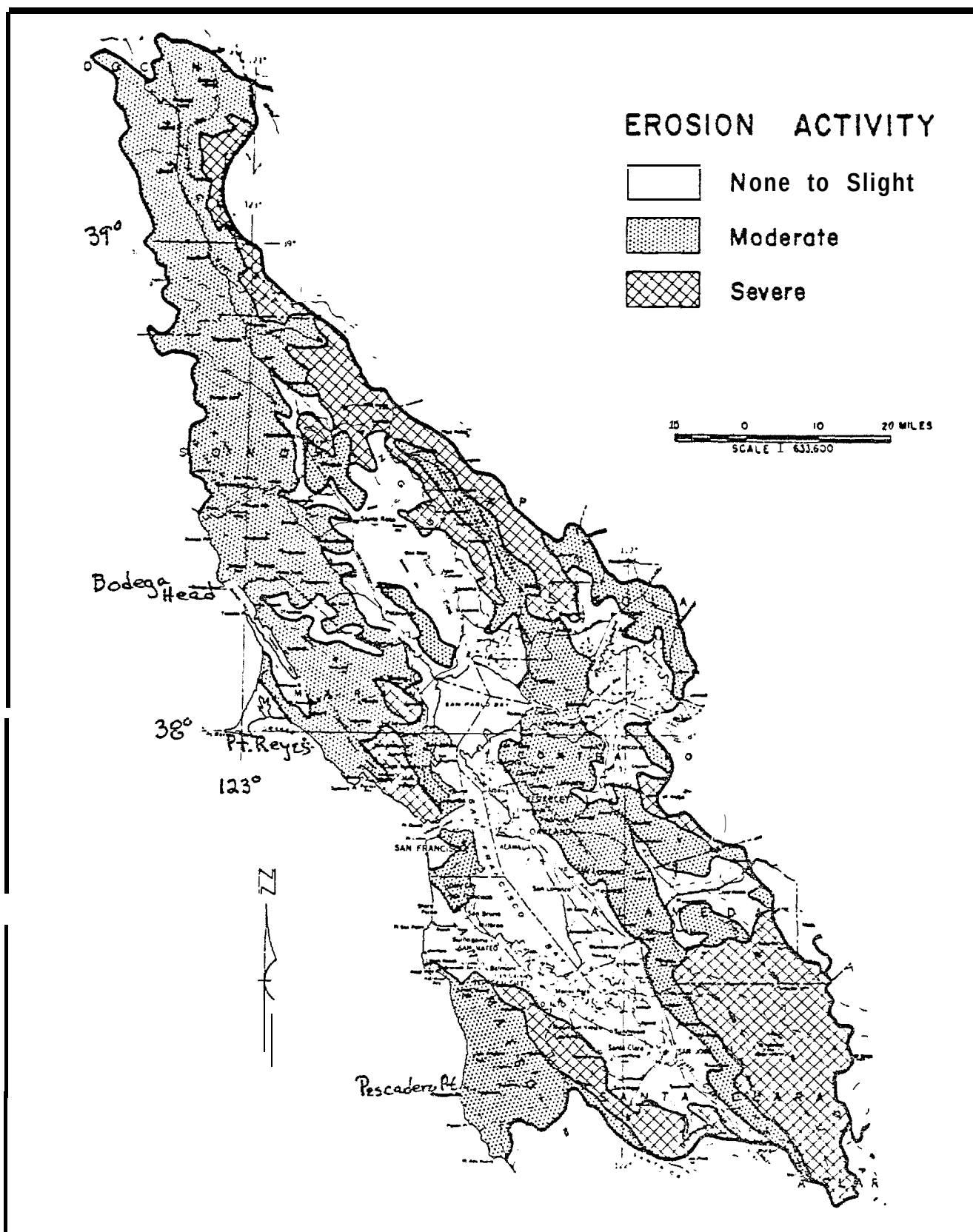


Figure 3-49. Generalized Classes of Erosion Activity Along the California Coast (California Region Framework Study Committee, 1971)

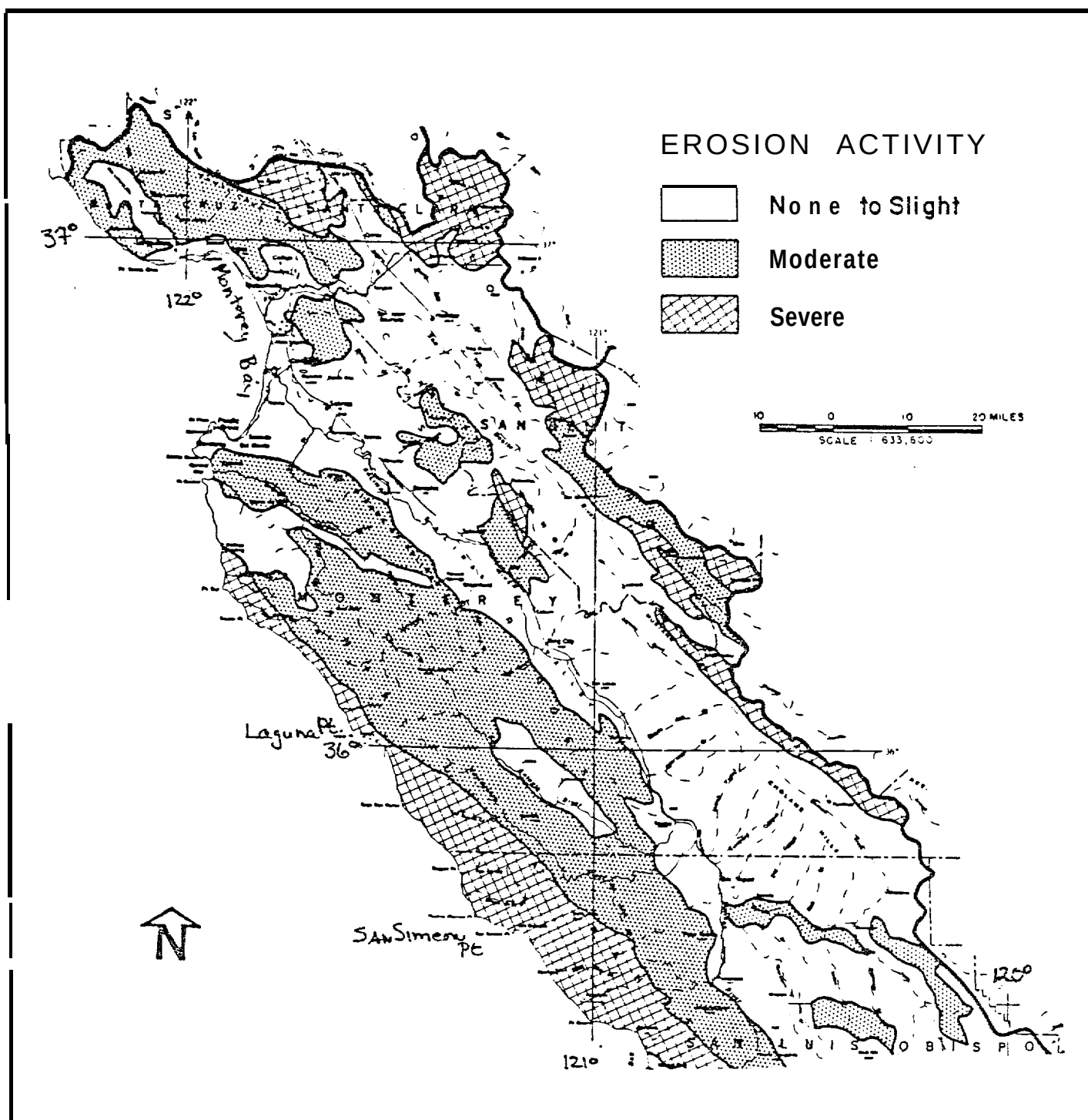


Figure 3-49. Generalized Classes of Erosion Activity Along the California Coast (California Region Framework Study Committee, 1971)

(Sheet 4 of 5)

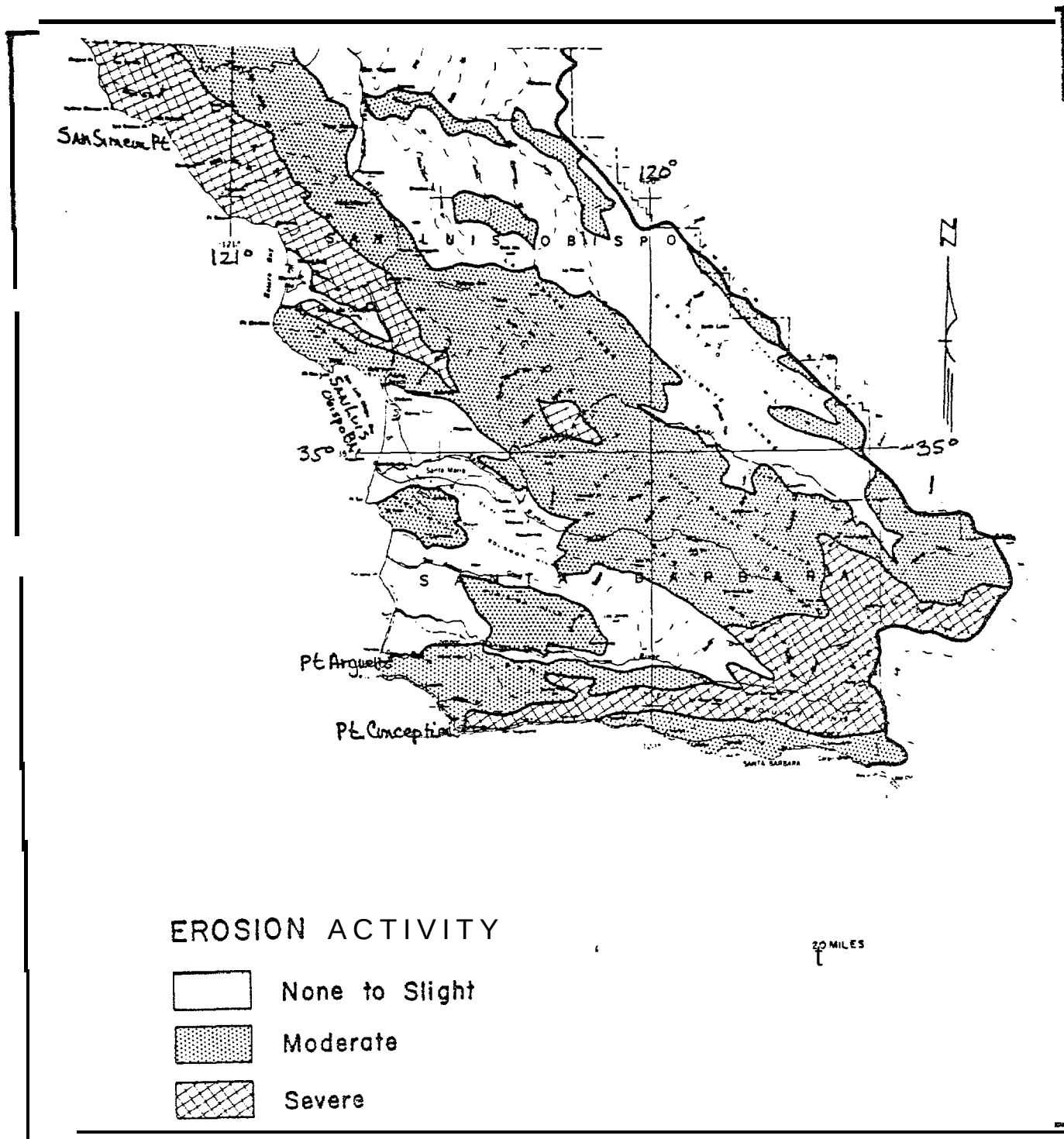


Figure 3-49. Generalized Classes of Erosion Activity Along the California Coast (California Region Framework Study Committee, 1971)

and restored to production by use of conservation practices (California Region Framework Study Committee, 1971).

Seismology

The California coastal region had over 100 strong, potentially damaging earthquakes in its recorded history. California is part of the seismically active circum-Pacific geologic belt which extends along the western coasts of South and North America, along the Aleutian island chain and the eastern perimeter of Asia. An explanation for the high seismic activity in this belt is the theory of plate tectonics (see Vol. I, Chapter 3, Geology).

The coast of California from Point Conception north to the Mendocino Escarpment is characterized by parallel movement with a transform-fault margin between the Pacific and North American tectonic plates. The San Andreas Fault zone is the juncture of the plates. The Pacific plate, largely an oceanic plate, includes the portion of California west of the San Andreas Fault. The Pacific plate is moving northwestwardly, while the North American plate moves westwardly. As a result of the motions between the two plates, a right-lateral movement is induced along the San Andreas Fault (see following section for an explanation of fault movement) (Shepard, 1973; Flint and Skinner, 1977).

North of Punta Delgada, the California coast is part of a complex border area which also includes the Oregon and Washington coasts. As the Pacific plate moves north relative to the North American plate, right-lateral movement occurs on the faults and rises, separating the two plates. Offshore from California, the Mendocino Escarpment and the Gorda Rise form the boundaries of a minor plate, the Gorda plate. The Gorda plate is influenced by the interaction between the North American and Pacific plates and may be a remnant of a once more extensive plate (RETA, 1978b).

At convergent plate junctions, subduction of the heavier oceanic plate occurs beneath the continental plate. Geophysical evidence suggests subduction is or was taking place along a line generally coinciding with the coast of North America between Cape Mendocino and Vancouver Island. The motion of the plates may either be slowed or presently inactive, a finding consistent with recent seismic activity levels in the area (RETA, 1978b).

The interaction of western North America with the Pacific plate has led to: 1) large horizontal motions along the San Andreas Fault, 2) concentrated rifting like that in the Salton Sea trough and the Gulf of California, 3) diffuse rifting and normal faulting accompanied by volcanism in the Basins and Range province of California, Nevada, Utah and Arizona, 4) large vertical uplift by overthrusting like that in the Transverse Ranges north and west of Los Angeles, 5) the generation of large igneous structures, such as the Sierra Nevada, and, 6) the incorporation of deep-sea trench material on the edge of the continent. Prior to about 30 million years ago, the oceanic-continental margin of California was a deep trench formed by the underthrusting of the oceanic plate beneath the continental plate. High mountains paralleled the coastline and large underthrusting earthquakes were associated with the subduction zone (Anderson, 1972). The oceanic rise system, a divergent area where new crustal material is produced, lay offshore of North America as a part of the northwest-moving Pacific plate.

About 30 million years ago the Mendocino and Murray fracture zones were activated by tensions in the Pacific plate. The section of the Pacific Plate between these zones began to move toward the continent. The continental rise ceased producing new material, and the trench along the California coast filled with sediments derived from the continent and volcanic rock (Anderson, 1972).

The northern section of the San Andreas Fault formed as the sedimentary and volcanic materials in the trench were uplifted and subjected to strong physical forces of deformation. This activity formed the Coast Ranges, much of which are underlain by the deformed and sheared rocks of the Franciscan formation. The formation remained attached to the Pacific plate, and thus is moving northwest with respect to the rest of North America along the San Andreas Fault. This section of the San Andreas Fault extends from Cape Mendocino to the area south and east of Santa Barbara where the San Andreas Fault turns from its northwesterly trend to an east-west trend (Anderson, 1972).

The formation of many subsidiary faults in the San Andreas Fault system, such as the Hayward, Calaveras, San Gregorio and other faults with orientations approximately

parallel to the San Andreas Fault occurred in response to forces created by the interaction of the Pacific and North American plates. The northwest trend of many of the structures in the eastern Pacific, including the northwest structural trend of the five ocean basins in central and northern California (see Vol. IV, Chapters 25 to 29, Geological Oceanography, Structure), resulted from the interaction of the North American and Pacific plates (Anderson, 1972) .

North of the Mendocino fracture zone, the California coast is characterized by a Pacific-Northwest type of boundary like that in Washington and Oregon, where a relatively complex border zone has developed. Two smaller plates, the San Juan de Fuca and the Gorda plates interact with the Pacific and North American plates in this area. The tectonic forces have caused folding, fracturing and uplift of the bedrock. Volcanic deposits in the area may also have resulted from these interactions. Subduction of the oceanic plates beneath the continental plate occurred in the past but appears to be limited or stopped now (RETA, 1978b) .

California has been divided into three zones of Expectable Earthquake Intensity which vary in severity from Zone I (least severity) to Zone III (CDMG, 1971). Table 3-35 explains the zone designations and Figure 3-50 illustrates the delineation of the zones in California.

Table 3-35. Maximum Expectable Earthquake Intensity in California
(from CDMG, 1971)

Zone	Probable Damage	Probable Maximum Intensity*
I	Minor to Moderate	VI or VII
II	Moderate	VII or VIII
III	Major	IX or X

*Modified Mercalli Intensity Scale (see Vol. I, Chapter 3, Table 3-5)

There are numerous active and potentially active faults in California. The San Andreas Fault is the largest active seismic feature in California. The fault extends from the Salton Sea in Imperial County, trends west-northwest and northwest on land and beneath the Pacific Ocean to Puntos Gorda in Humboldt County where the fault trend turns west into the Mendocino Escarpment (see Figure 3-51) (CDMG, 1973b).

Two of the three largest earthquakes in California were caused by movements on the San Andreas Fault. The 1857 Fort Tejon earthquake caused damage to every house in Santa Barbara. Thirty-foot stream channel offsets may have formed during this earthquake. The Fort Tejon earthquake fault break is not completely known, but available evidence suggests that the surface rupture extended from near San Bernardino to near Santa Barbara County, and northwest at least 350 km (220 miles) to Cholame, located approximately midway between Los Angeles and San Francisco. The estimated Richter magnitude of this earthquake is set at least 8.3, similar in magnitude to the 1906 San Francisco earthquake (Santa Barbara County, 1978c) .

On 18 April 1906, the San Francisco earthquake shook most of central and northern California. The fault break was traced from San Juan Batista north to Point Delgada. The Richter magnitude of the earthquake has been estimated at approximately 8.3. The earthquake caused damage throughout northern and central California, and was particularly damaging in the San Francisco Bay Area. The earthquake caused a number of fires which added significantly to the damage, injuries and deaths. An earthquake of this magnitude has not occurred since 1906 on the California Coast (URS/John A. Blume, 1974; Borchardt, 1975) .

The activity level of the San Andreas Fault varies along its length within the study area. Numerous small- and medium-sized earthquakes have occurred in the Hollister area . South of Hollister, measurable creep occurs along the San Andreas Fault. North of the Hollister area, and especially north of San Francisco, few earthquakes and no measurable creep have been or are occurring since 1906 along the San Andreas Fault. The lack of seismic activity is believed to indicate that much stress and strain forming along the fault are not being relieved by fault creep or

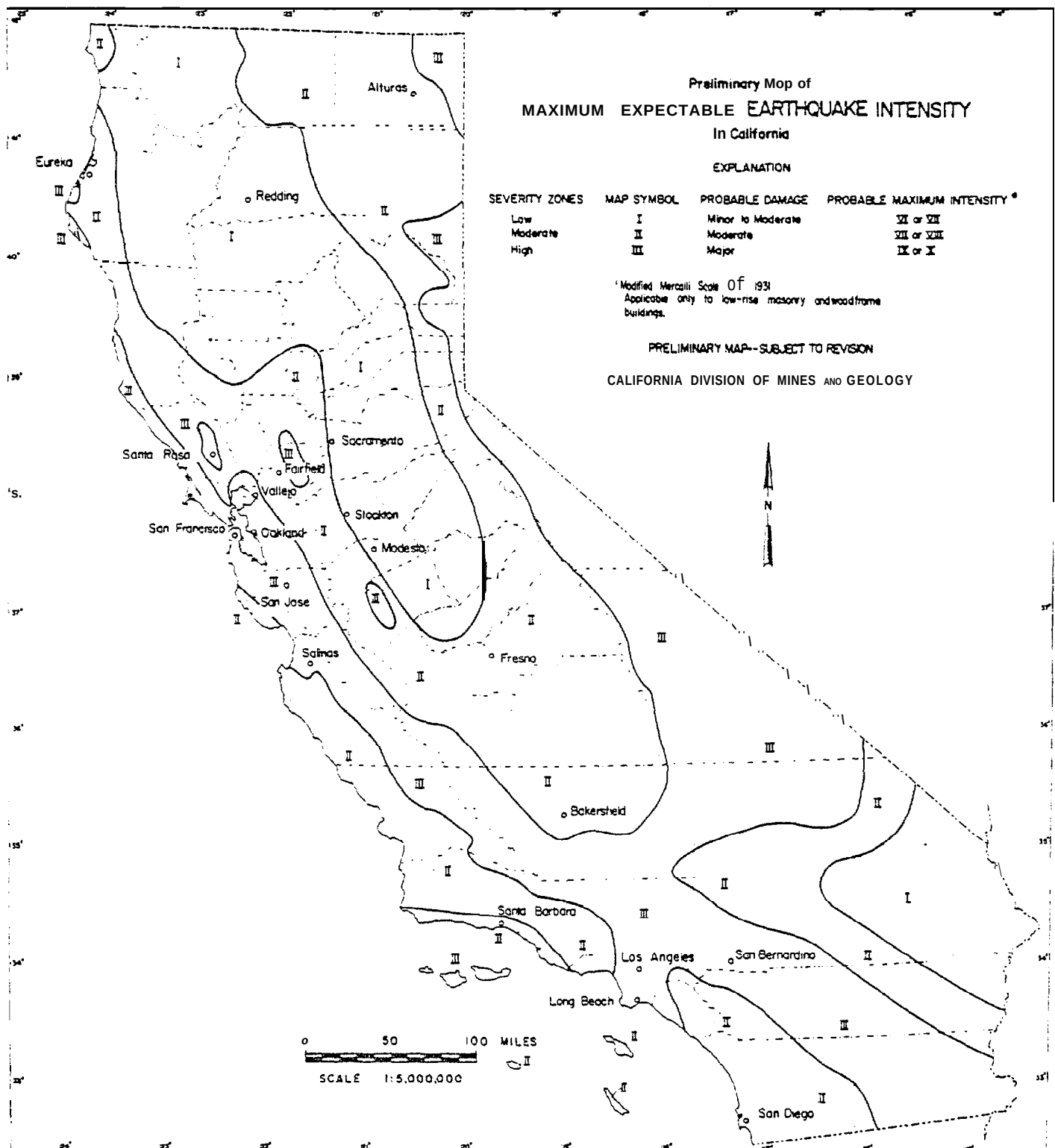


Figure 3-50. Map of Maximum Expectable Earthquake Intensity in California (CDMG, 1973a).

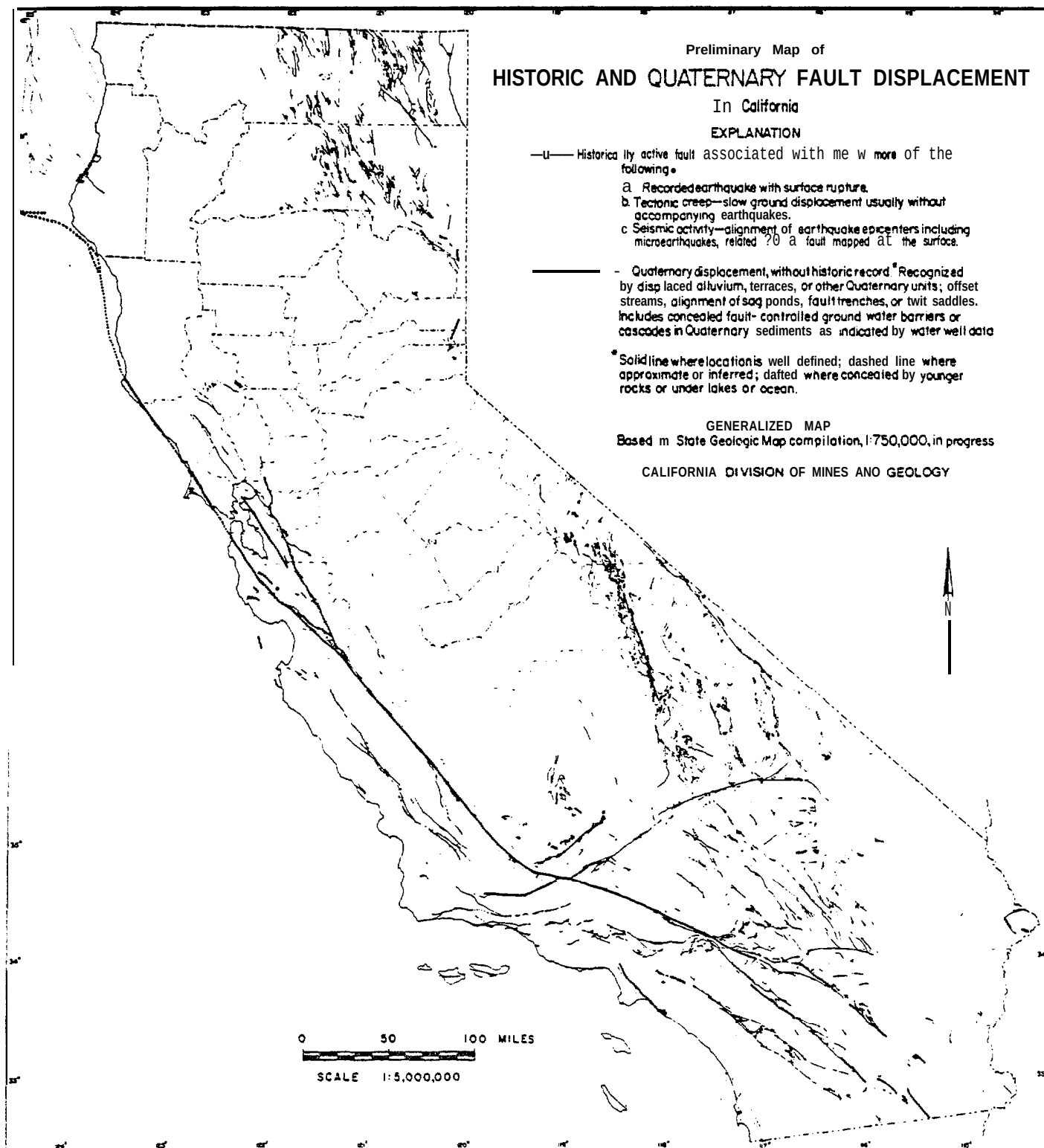


Figure 3-51. Historic and Quaternary Fault Displacement in California
(CDMG, 1973a)

small earthquakes. Where the fault is "locked" in this manner, some seismologists believe that a large earthquake may be the mechanism for release of strain (Borcherdt, 1975). An earthquake of Richter magnitude 6 or above is predicted in the near future for northern California. However, larger earthquakes have also occurred in southern California, for example, the 1857 Fort Tejon earthquake, and future large earthquakes are also expected there.

Other major earthquake-producing faults in California are described in Table 3-36 and in the watershed unit descriptions.

Table 3-36. Characteristics of Major Active Faults in the California Coastal Area
(from Santa Barbara County, 1978, and Borcherdt, 1975)

Fault	Length (km)	Activity Level/L/	Largest Recorded Historic Earthquake Magnitude, year	Maximum Credible Earthquake and Recurrence
San Andreas	1200	HA	8.3, 1906	8.5, 100-1000 yrs.
Big Pine	85	HA	7+, 1852	7.1, 200-400 yrs.
Santa Ynez	121+	A	7.3, 1927?/2/	7.2+, ?
Palo Colorado-San Gregorio	132	A	6.1, 1926/3/	7.4, 10-100 yrs.
Monterey Bay Complex	68 (across entire Bay)	A	6.1, 1926/3/	6.7, ? (Possibly less than 100 yrs.)
Hayward	116	HA	7+1/2, 1838	7, 10-100 yrs. (for mag. 6-7)
Calaveras	185	HA	6?/4/	7.3, 10-100 yrs. (for msg. 6-7)
Rodgers Creek Healdsburg	116	A	5.7?/4/	7 (prob. 10-100 yrs.)
Mendocino Fracture Zone	Unknown	A	7.6, 1915	7.5, approx. 100 yrs.

/1/ A = Active

HA = Historically Active

/2/ Uncertainty in location of epicenter provided that the earthquake may or may not have been located on the Santa Ynez fault.

/3/ Uncertainty in location of epicenter permits assignment of the earthquake (22 October 1926) to either the Monterey Bay or San Gregorio fault zone.

/4/ Uncertainty in location of epicenter does not allow definite assignment of the earthquake to the fault.

Historic Earthquake Epicenters Earthquakes which have Richter magnitudes greater than 4.0 and epicenters in or close to a particular watershed are described in each watershed unit. Figure 3-52 illustrates the epicenters in each watershed and ocean basin unit. Table 3-37 summarizes the location, date, time and Richter magnitude of earthquakes which occurred in coastal or near-shore California from 1900 to 1975 - with Richter magnitudes greater than 5.0.

Detailed information on particular earthquakes in California can be found in county seismic elements, United States Earthquakes (Coffman and Stover, 1975-1977), and Catalogue of Earthquakes in Northern California and Adjoining Areas, 1 January 1910 - 31 December 1975 (Bolt and Miller, 1975).

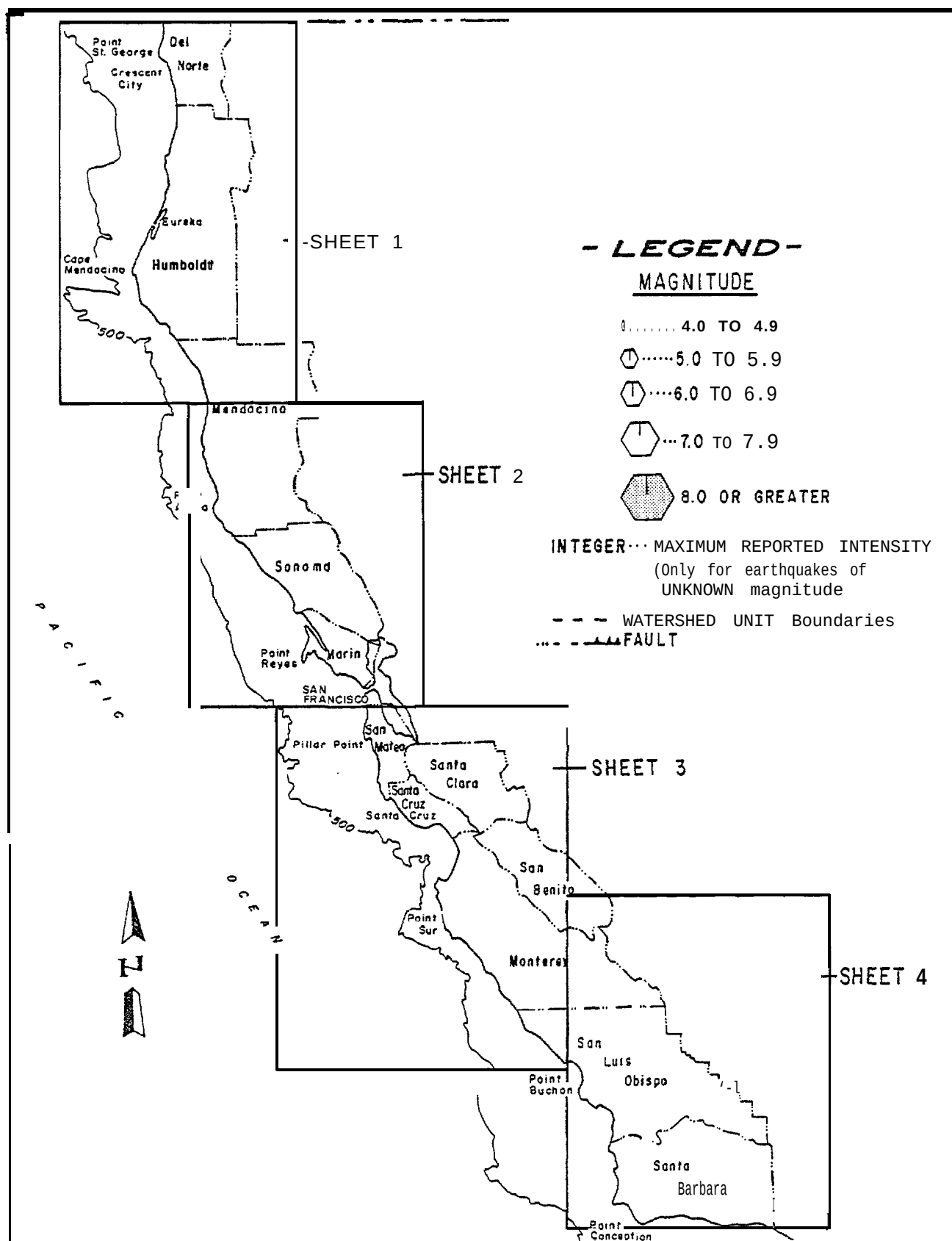


Figure 3-52. Historic Earthquake Epicenter Map. Index Sheet
(Real, et al. , 1978)

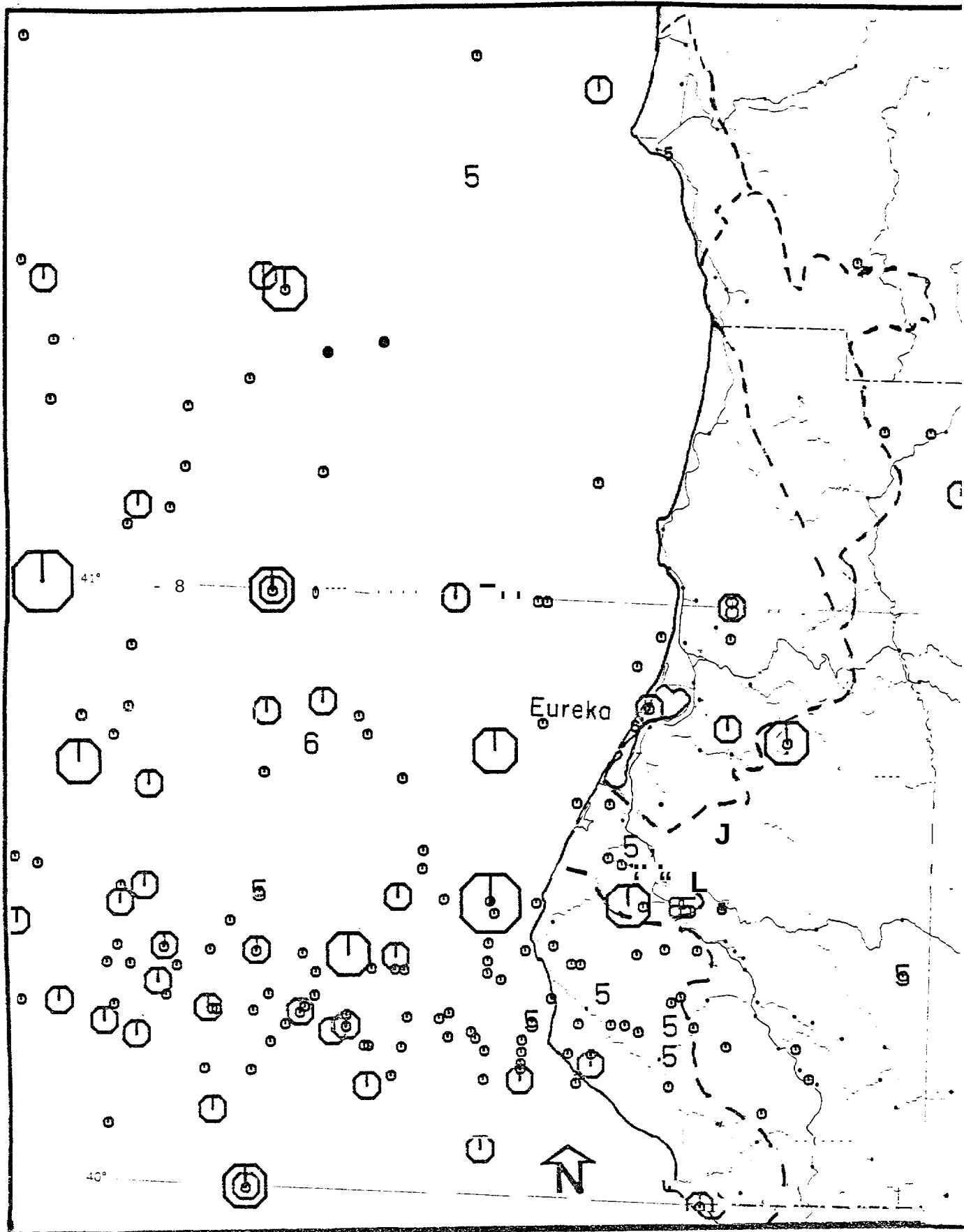


Figure 3-52. Historic Earthquake Epicenter Map. Sheet 1 of 4
(Real et al., 1978).

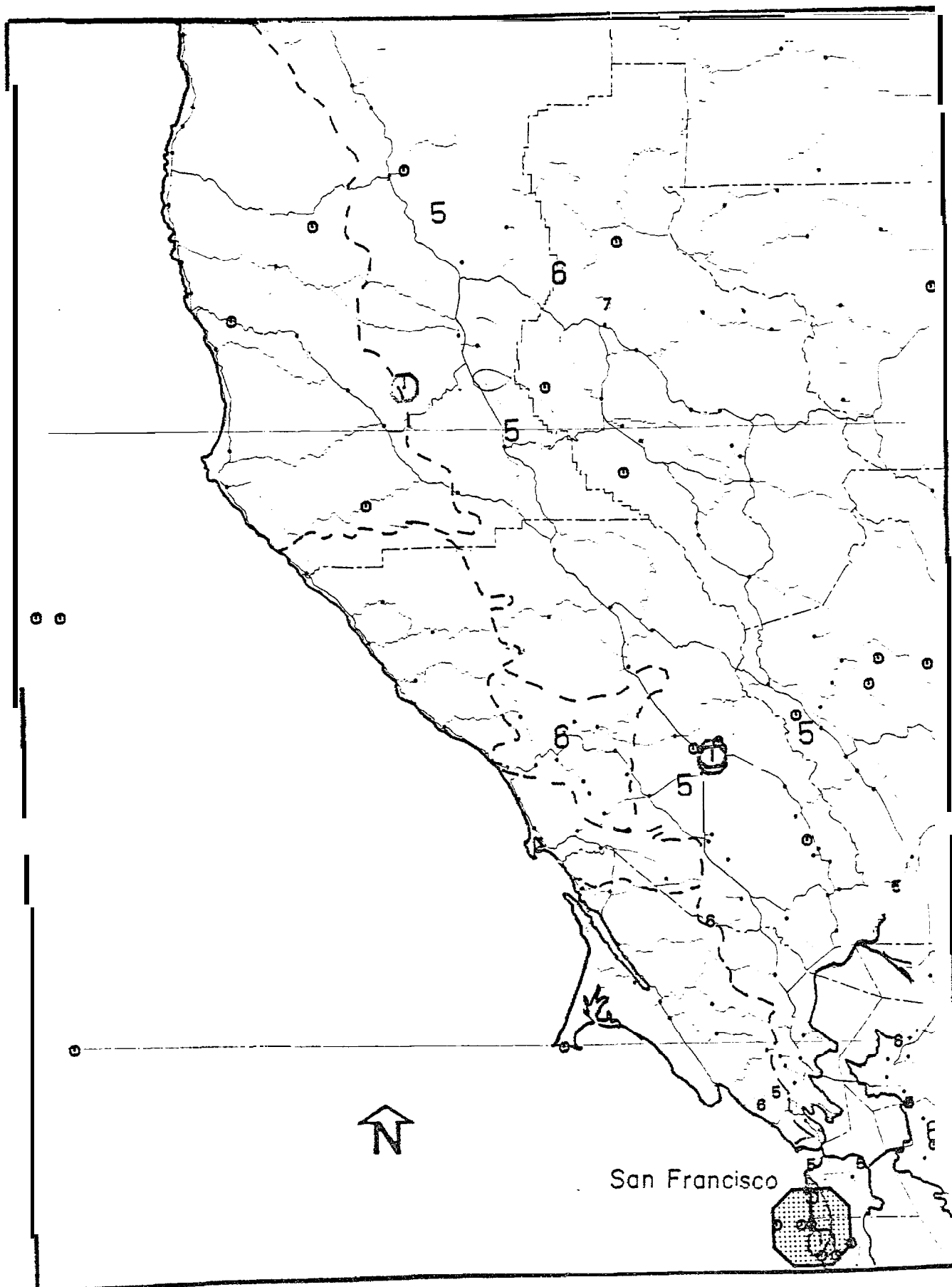


Figure 3-52. Historic Earthquake Epicenter Map. Sheet 2 of 4
(Real et al., 1978)

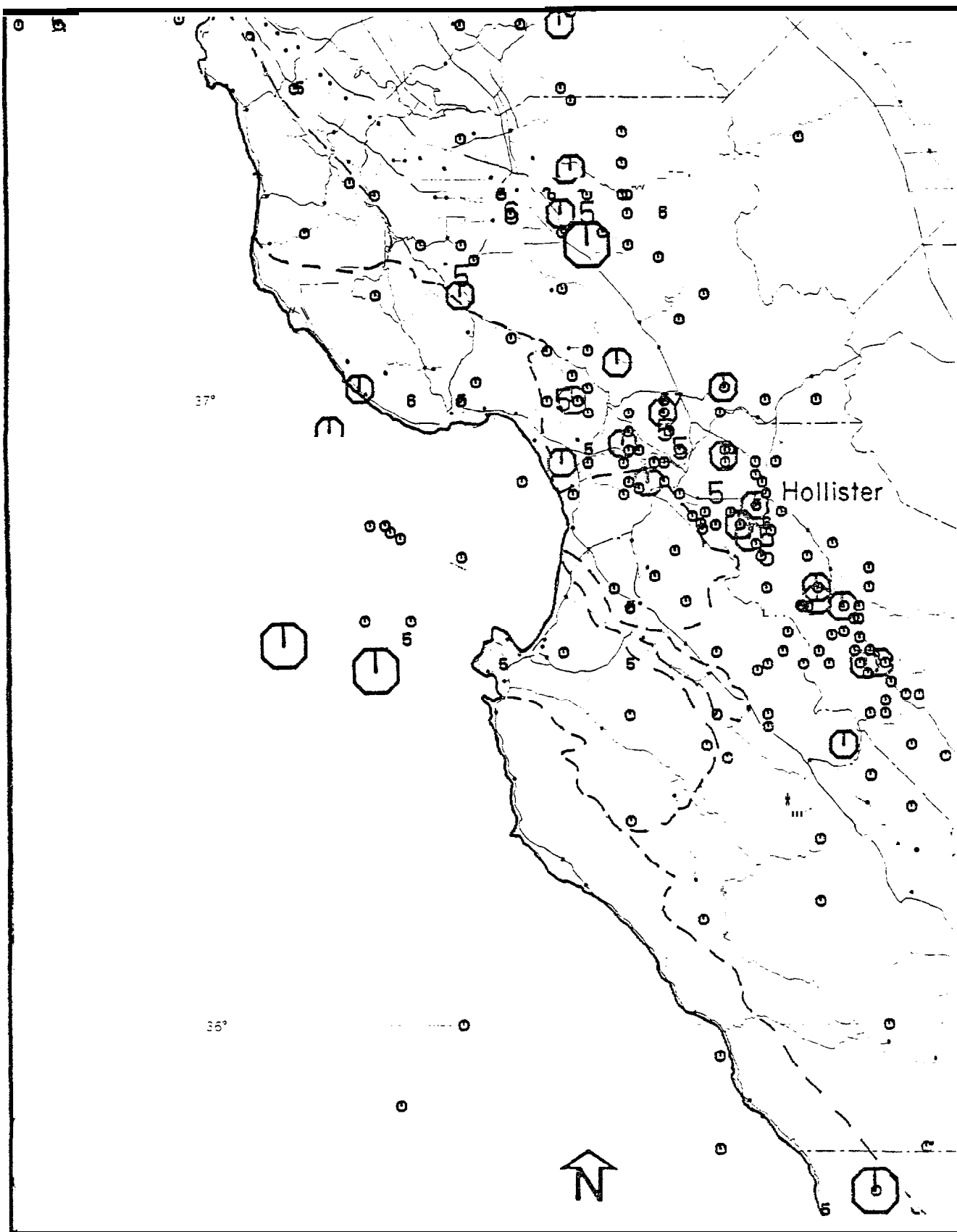


Figure 3-52. Historic Earthquake Epicenter Map. Sheet 3 of 4
(Real et al. , 1978)

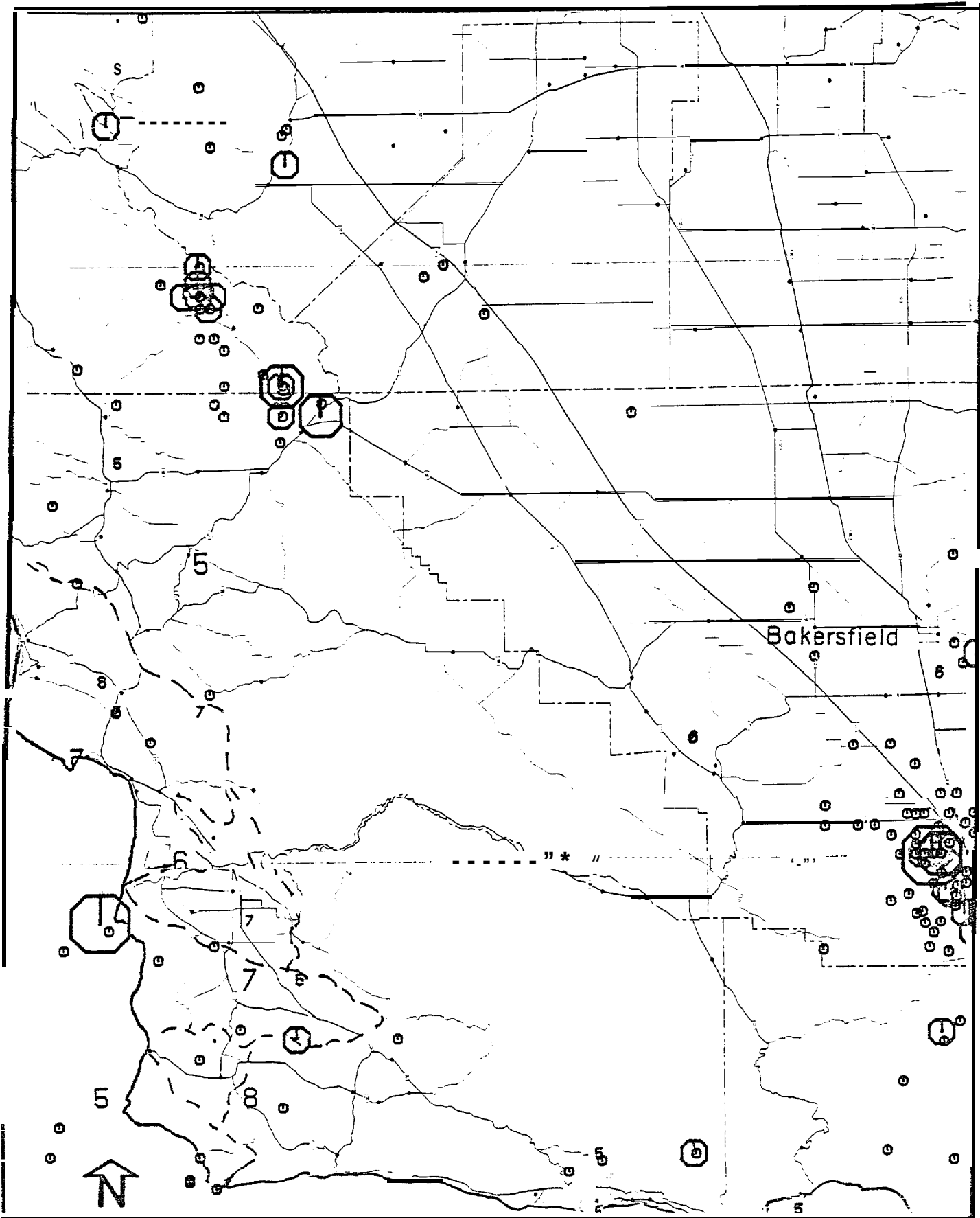


Figure 3-52. Historic Earthquake Epicenter Map. Sheet 4 of 4
(Real, et al., 1978)

Table 3-37. Earthquake Epicenters of Richter Magnitude 5 or Greater 1900 - 1979
(from Real et al., 1978; Coffman and Stover, 1977; 1978; 1979)

Latitude	Longitude	Date	Time/l/	Magnitude/2/
34.576	121.620	10/22/1969	22 51 29.0	5.4
34.609	121.435	11/ 5/1969	17 54 7.9	5.6
34.700	120.300	1/12/1915	4 31 0.0	5.5
34.700	120.300	7/31/1902	9 20 0.0	5.5
34.900	120.700	11/ 4/1927	13 50 53.0	7.5
35.730	121.200	11/22/1952	7 46 37.0	6.0
35.750	120.250	3/10/1922	11 21 20.0	6.5
35.750	120.330	8/18/1922	5 12 0.0	5.0
35.800	120.330	6/ 8/1934	4 47 0.0	6.0
35.800	120.330	6/ 8/1934	4 30 0.0	5.0
35.800	120.330	12/28/1939	12 15 38.0	5.0
35.800	120.330	6/ 5/1934	21 48 0.0	5.0
35.930	120.480	12/24/1934	16 26 0.0	5.0
35.950	120.470	11/16/1956	3 23 9.0	5.0
35.950	120.500	6/28/'1966	4 26 13.4	5.5
35.950	120.530	6/29/1966	19 53 25.9	5.0
35.970	120.500	6/28/1966	4 8 56.2	5.1
36.000	120.500	3/ 3/1901	7 45 0.0	5.5
36.000	120.920	11/ 2/1955	19 40 6.0	5.2
36.000	121.000	2/26/1932	16 58 0.0	5.0
36.230	120.650	2/ 5/1947	6 14 0.0	5.0
36.450	121.250	9/27/1938	12 23 0.0	5.04
36.570	122.170	10/22/1926	13 35 22.0	6.1
36.578	121.290	2/24/1972	15 56 51.0	5.1
36.580	121.180	7/29/1951	10 53 45.0	5.0
36.600	120.800	7/25/1925	17 57 49.0	5.0
36.610	122.350	10/22/1926	12 35 7.0	6.1
36.670	121.250	8/ 6/1916	19 38 0.0	5.5
36.680	121.300	4/ 9/1961	7 23 16.0	5.6
36.700	121.300	4/ 9/'1961	7 25 41.0	5.5
36.780	121.430	1/20/1960	3 25 53.0	5.0
36.800	121.450	6/24/1939	13 2 0.0	5.5
36.830	121.420	12/31/1910	12 11 0.0	5.0
36.870	121.630	9/14/1963	19 46 17.0	5.4
36.900	121.800	3/11/1910	6 52 0.0	5.5
36.910	121.480	11/28/1974	23 1 24.7	5.2
36.930	121.680	4/25/1954	20 33 28.0	5.3
36.950	122.260	2/15/1927	23 54 3.5	5.0
36.980	121.600	3/ 2/1959	23 27 17.0	5.3
37.000	121.780	12/18/1967	17 24 32.0	5.3
37.020	121.480	3/ 9/1949	12 28 39.0	5.2
37.020	122.200	10/24/1926	22 51 49.5	5.5
37.060	121.690	11/16/1964	2 46 41.7	5.0
37.170	122 000	11/ 9/1914	2 31 0.0	5.5
37.250	121.750	7/ 1/1911	22 0 0.0	6.6
37.300	121.800	8/ 3/1903	6 49 0.0	5.5
37.370	121.780	9/ 5/1955	2 1 18.0	5.5
37.600	121.800	6/11/1903	13 12 0.0	5.5
37.670	122,480	3/22/1957	19 44 21.0	5.3
37.700	122.500	4/18/1906	13 12 21.0	8.2
38.460	122.690	10/ 2/1969	6 19 57.1	5.7
38.470	122.690	10/ 2/1969	4 56 46.5	5.6
39.070	123.320	6/ 6/1962	17 50 6.2	5.2
39.450	123.260	11/22/1977	21 15 52.5	5.2
40.000	124.000	9/12/1938	6 10 0.0	5.5
40.000	124.000	12/20/1940	23 40 42.0	5.5
40.000	125.000	3/19/1910	0 11 0.0	6.0
40.000	125.000	3/10/1931	3 28 53.0	5.6

Latitude	Longitude	Date	Time/l/	Magnitude/2/
40.080	124.500	12/11/1930	9 0 0.0	5.0
40.130	125.080	9/13/1970	21 10 21.0	5.4
40.180	124.750	4/ 6/1961	4 4 45.0	5.1
40.200	124.420	9/22/1952	11 41 25.0	5.2
40.200	125.600	8/23/1931	18 1 35.0	5.3
40.230	124.270	6/26/1968	1 42 20.8	5.9
40.250	125.250	1/ 2/1935	22 40 58.0	5.8
40.270	124.830	2/27/1971	0 31 37.7	5.2
40.270	125.320	4/14/1962	7 53 14.7	5.4
40.270	125.630	11/25/1954	11 16 35.0	6.1
40.280	124.800	10/ 8/1951	4 10 35.0	5.8
40.300	124.900	1/12/1944	15 2 40.0	5.1
40.300	125.100	1/16/1944	2 20 29.0	5.1
40.300	125.420	12/ 5/1959	8 13 42.0	5.1
40.340	125.210	7/ 3/1974	5 0 58.4	5.1
40.400	124.700	5/27/1947	20 59 0.0	5.2
40.400	124.800	10/ 3/1941	16 13 8.0	6.4
40.400	125.000	10/ 6/1941	6 59 0.0	5.0
40.400	125.200	9/23/1947	13 52 55.0	5.3
40.430	125.520	7/14/1962	19 43 46.2	5.1
40.470	125.300	4/ 1/1951	19 21 8.0	5.0
40.500	124.200	10/29/1909	6 45 0.0	6.0
40.500	124.500	1/22/1923	9 4 18.0	7.2
40.500	124.700	12/10/1967	12 6 52.2	5.6
40.500	124.700	8/18/1948	19 11 57.0	5.0
40.500	125.250	2/ 7/1937	4 41 34.0	5.8
40.500	125.800	9/16/1965	4 10 8.0	5.0
40.570	124.140	6/ 7/1975	0 46 22.4	5.4
40.670	125.250	3/ 1/1972	9 28 42.0	5.2
40.670	125.770	10/11/1956	16 48 50.0	6.0
40.700	125.400	2/ 9/1941	9 44 42.0	6.4
40.750	124.500	6/ 6/1932	8 44 22.0	6.4
40.750	126.000	12/10/1926	8 38 53.0	6.0
40.780	123.870	12/21/1954	19 56 29.0	6.5
40.800	124.000	8/18/1908	10 59 0.0	5.0
40.800	125.000	9/ 9/1931	13 40 30.0	5.8
40.820	124.880	6/ 6/1960	1 17 48.0	5.7
40.830	124.170	9/23/1930	2 58 0.0	5.0
41.000	124.000	6/ 3/1935	17 8 0.0	5.0
41.000	124.000	7/ 1/1938	18 13 0.0	5.0
41.000	124.600	8/20/1927	20 5 44.0	5.0
41.000	125.000	7/15/1918	0 23 0.0	6.5
41.000	125.000	4/29/1923	2 31 29.0	5.0
41.000	125.000	10/10/1936	1 25 0.0	5.0
41.000	125.500	1/31/1922	13 17 22.0	7.3
41.000	126.000	12/31/1915	12 20 0.0	6.5
41.000	126.000	1/26/1922	9 31 20.0	6.0
41.130	125.300	7/24/1959	1 23 9.0	5.8
41.200	123.500	5/ 2/1945	19 47 54.0	5.0
41.250	125.710	11/26/1976	11 19 25.2	6.2
41.300	126.000	3/24/1949	20 56 56.0	5.9
41.500	125.000	6/ 4/1925	12 2 52.0	6.0
41.500	125.530	6/15/1973	19 18 47.5	5.0
41.520	125.050	12/17/1960	10 35 26.0	5.4
41.850	124.330	8/23/1962	19 29 13.1	5.6
42.000	120.500	1/11/1923	4 29 0.0	5.0

/1/ Greenwich Mean Time

/2/ Richter Magnitude Scale

Chapter 4

BIOLOGICAL ENVIRONMENT

The environment of the central and northern California coastal region supports an immense variety of plant and animal species. The occurrence and distribution of these species is the result of each organism's response to the physical conditions in the area. The study area extends over nearly eight degrees of latitude, with elevations ranging from the minus 1,000 meter depth contour in the ocean to over several thousand meters in the coastal mountains.

The physical conditions available in the study area potentially offer an endless array of possible sites or landscapes. To perceive some organization in this array requires a classification scheme that groups similar sites or landscapes. The aquatic areas were categorized using a modified version of Cowardin, et al. (1979), Classification of Wetlands and Deepwater Habitats of the United States. Terrestrial areas were categorized using a modified version of Cheatham and Hailer (1975), An Annotated List of California Habitat Types.

Cowardin, et al. (1979) identify five different systems at the highest level of a hierarchical classification scheme: marine, estuarine, riverine, lacustrine (lakes) and palustrine (ponds). With the addition of the terrestrial as the sixth system, the broadest organization can be placed on existing physical conditions. When the biological organisms that occur under these physical conditions are considered, the six systems can be considered as major kinds of ecological systems (i.e., ecosystems).

The biological environments of the study area are described in this chapter by characterizing each of the six kinds of ecosystems. The characterization for each system involves preparing a conceptual ecosystem model describing physical-chemical, biological and socio-economic components and their interrelationships.

Each of the ecosystems are subdivided into kinds of habitats and related to their particular coastal California conditions based on parameters such as substrate, inundation, salinity, exposure and dominant plants and animals. Some of the plants, animals and geographical areas found in each ecosystem have received special status under federal or state law.

MARINE ECOSYSTEM

Introduction

The marine ecosystem in the study area is composed of a number of subsystems, or zones and habitats, which are closely related by the exchange of materials and biological populations. In the region it is also necessary to recognize inputs and exports from adjacent systems such as the terrestrial environment and adjacent oceanic areas. In the strictest sense, the study region cannot be isolated as an "ecosystem" because of its openness and exchange with adjacent systems.

In the first part of this section, a conceptual model of the marine ecosystem is presented. The model is an idealized abstraction and facilitates a description of important components and processes which are part of the complex natural system. A regional characterization of the marine ecosystem follows the conceptual model.

In the study region, the marine ecosystem is complex and can be more conveniently presented as sub-models representing zones or habitat divisions of the environment. In addition, it is necessary to recognize inputs and exports with adjacent systems. The relationship between sub-models and adjacent systems is presented in Figure 4-1.

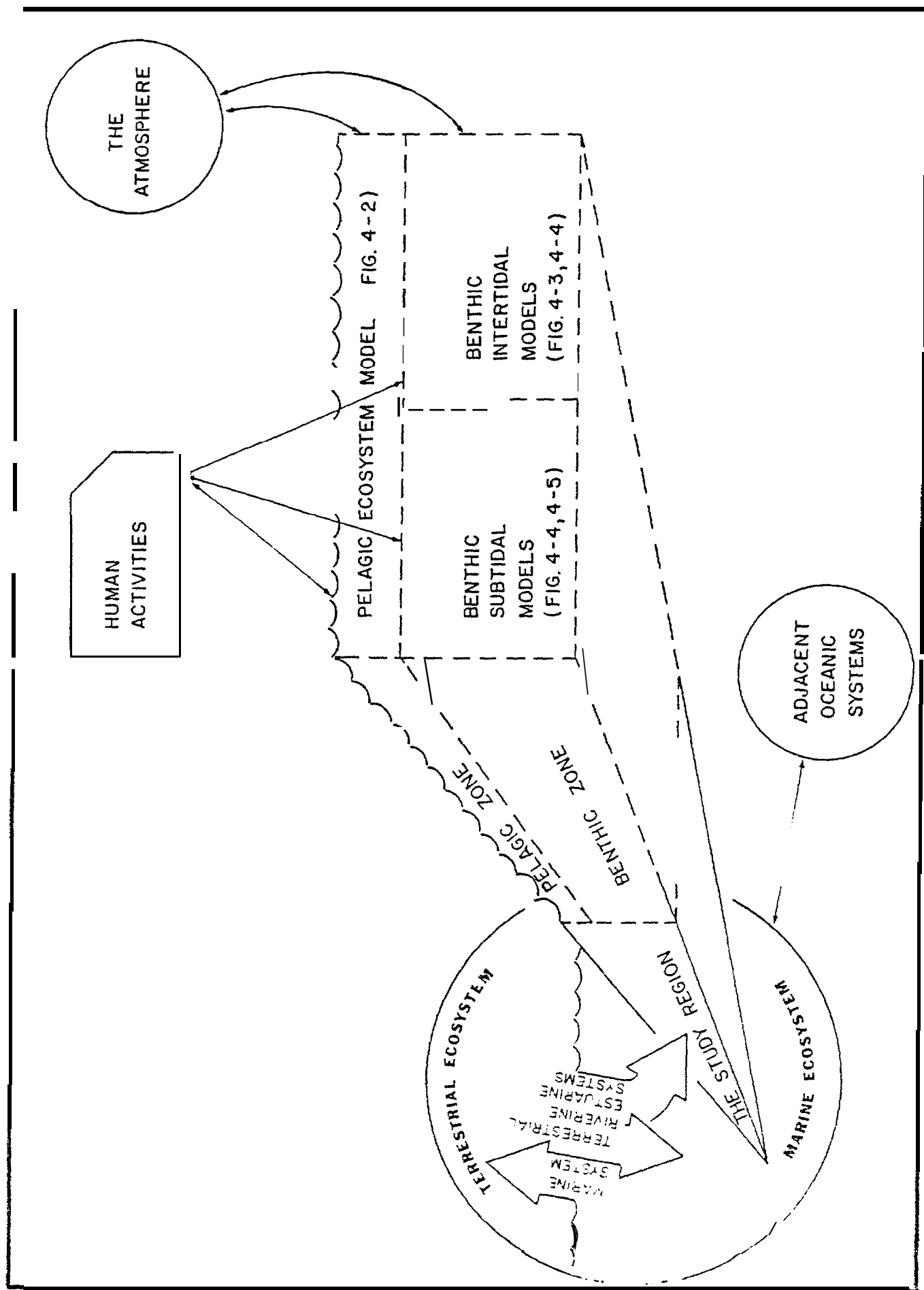


Figure 4-1. The Relationship of Habitat Models and Inputs to a Conceptual Model of The Marine Ecosystem

An ecosystem may be defined as being composed of living organisms (biotic elements) and their non-living environment (abiotic). For descriptive purposes, it is useful to consider that an ecosystem can be characterized by structural and functional components.

Conceptual Model

In the following discussion of the conceptual model, some of the ecosystem characteristics will be discussed as they relate to the model. Physical and chemical aspects of the environment have been presented in Volume II, Chapter 3, and will not be discussed here in depth. Detailed information for each habitat can also be found in Volume III, Chapter 3.

Freshwater, with its complement of dissolved and resuspended material, enters the marine environment directly as runoff as through riverine and estuarine systems. There may be considerable exchange of materials with estuarine systems, and estuaries may be important temporary habitats for several marine species (see Volume II, Chapter 4 - Estuarine Ecosystem).

Inputs from Adjacent Systems. The component models of the marine ecosystem conceptual model are presented in Figures 4-2 through 4-5. Inputs and exports to the region take place with adjacent oceanic regions, with the overlying atmosphere, and with adjacent estuary and terrestrial systems.

Heat, water, and dissolved gases are exchanged with the atmosphere at the sea-surface (see Figure 4-2). Material from terrestrial systems (e.g., pollutants) reach the marine environment by atmospheric transport. Winds (or advective processes in the atmosphere) are the major energy source for mixing and currents.

Exchange of water and populations with adjacent oceanic regions takes place as a result of major ocean currents. The primary movement and exchange is in the horizontal direction. Vertical transport, or vertical advection, is less pronounced (although as discussed later in terms of nutrient cycles, it is very important) and results from upwelling, downwelling, and mixing.

Abiotic Elements and Physical Processes.

Pelagic Habitat (Figure 4-2). The primary substratum that characterizes the pelagic habitat is seawater. The properties of seawater are largely the result of dissolved and suspended materials including dissolved inorganic ions (salinity), dissolved gases (O_2 , CO_2), nutrients (minor dissolved ions), sediments, and particulate detritus.

Large scale advective events such as ocean currents are important physical processes in the pelagic region. Salinity and temperature characteristics of seawater in the study region were determined in adjacent oceanic regions before advection into the region. In situ processes such as heating, mixing, dilution, and upwelling will alter the characteristics.

Physical processes are important in altering the distribution of chemical and physical properties as well as transporting biotic components. Physical processes that affect temperature, salinity, and dissolved gases are restricted to the sea surface. Temperature is a result of solar radiation at the surface and heat exchange with the atmosphere (including heat transferred as a result of evaporation and precipitation). Dissolved gas concentrations are determined by the equilibrium reached with the atmosphere. Salinity can be altered as a result of evaporation, precipitation, mixing with deeper water, or dilution by terrestrial freshwater inputs.

Mixing processes in the upper water column are important in determining the distribution of materials. Wave and wind mixing is strongest at the surface and decreases with depth. Mixing by currents may be relatively more important in shallow water than in deeper areas.

The density structure of the water column which is determined by temperature and salinity, affects the mixing or exchange of materials between surface and deeper layers. When there is a strong, stable density gradient, vertical transport is retarded. Changes in the density distribution are seasonal and related to solar radiation cycles.

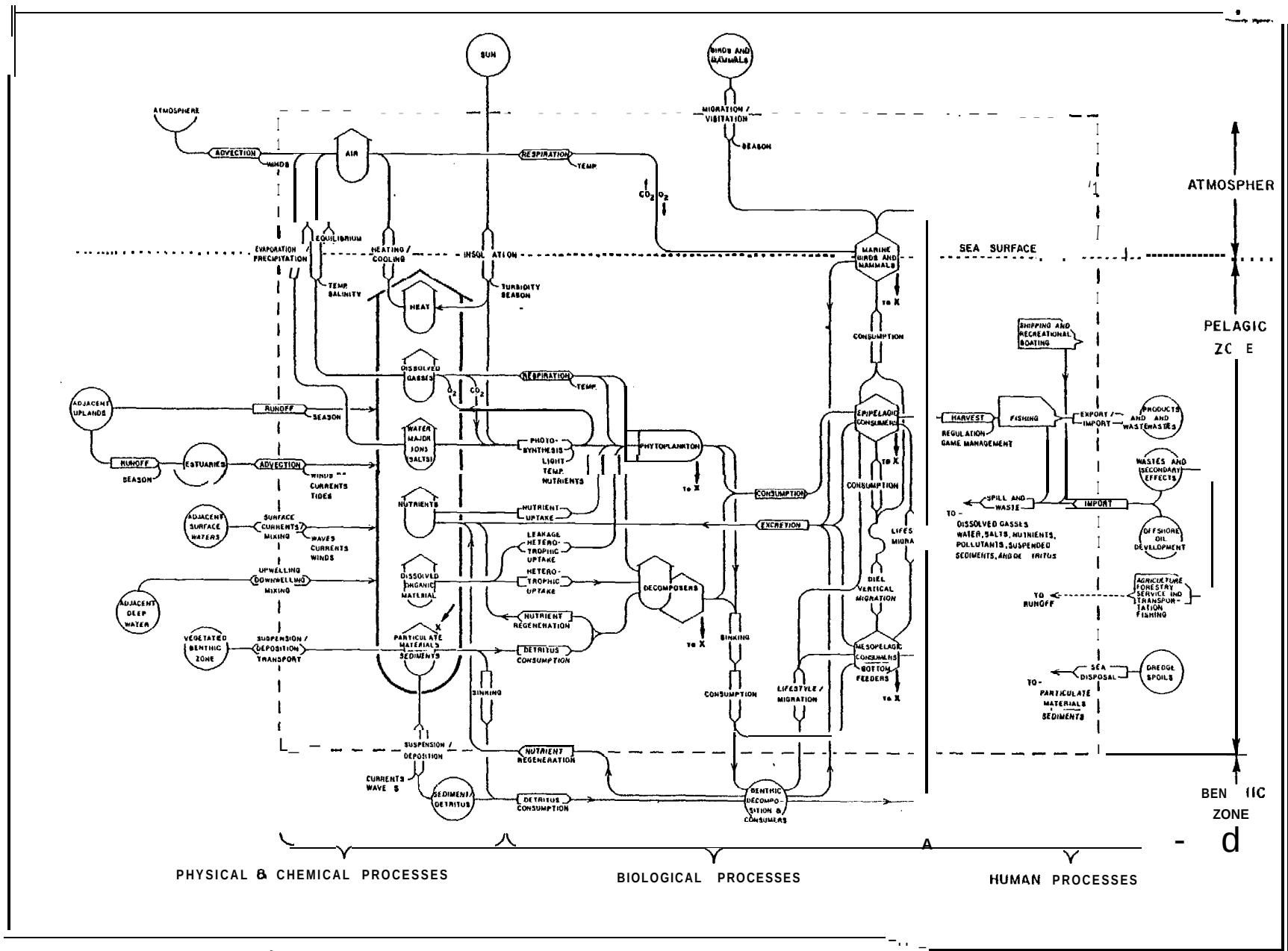


Figure 4-2. Pelagic Ecosystem Model

Figure 4-3. Intertidal Ecosystem Model

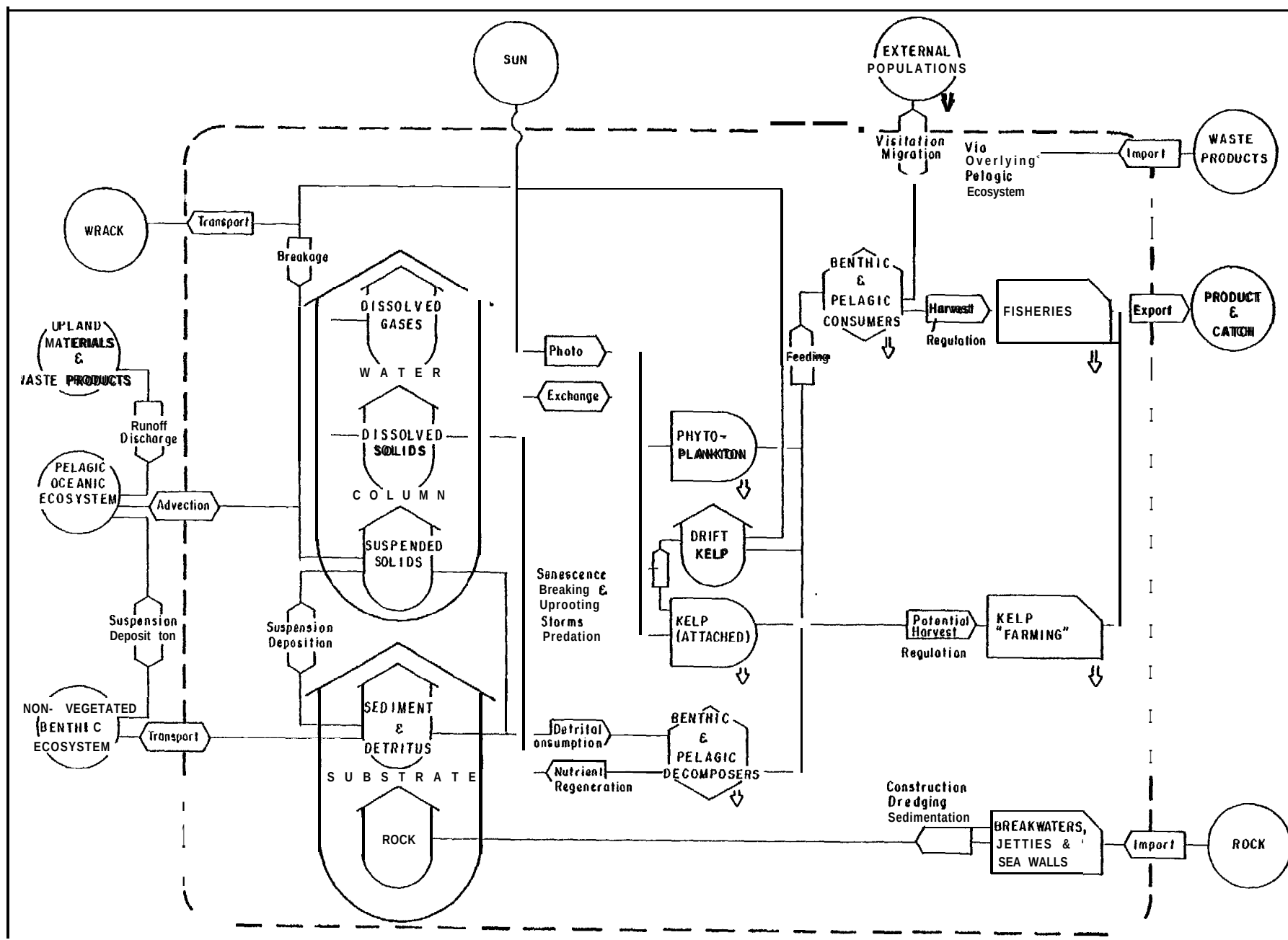


Figure 4-4. Aquatic Beds Ecosystem Model

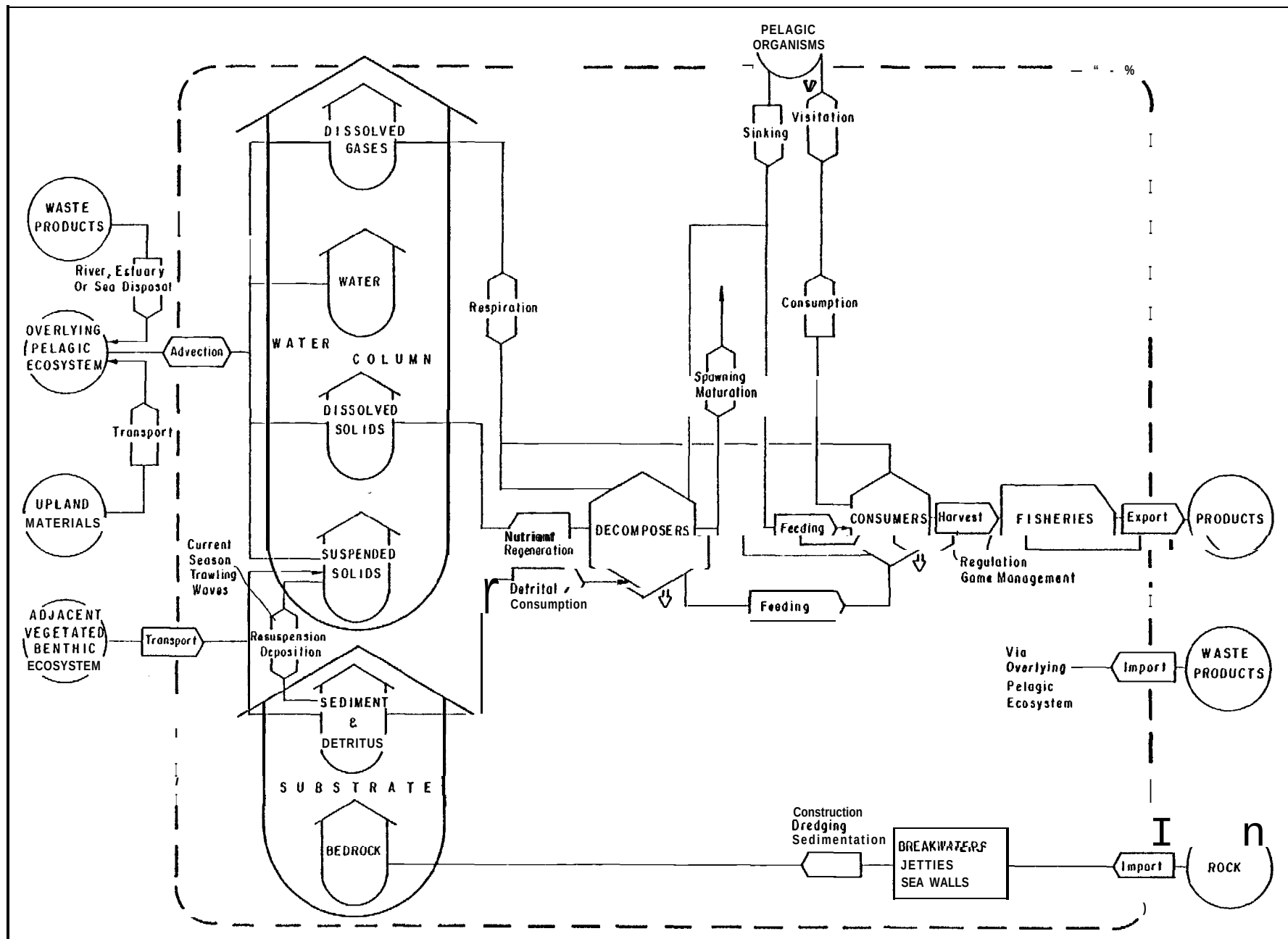


Figure 4-5. Consolidated and Unconsolidated Bottom Ecosystem Model

Upwelling and downwelling are wind-induced vertical mixing processes that result from the wind and current direction in relation to the coastline. Upwelling is one of the more important processes in the study region and is discussed in more detail in Volume II, Chapter 3.

Particulate materials (sediments and detritus) which are denser than seawater sink with a rate that depends on their density relative to water density and their size. The flux of particulate materials is not well understood and may be largely influenced by biological processes.

The distribution of physical properties cannot be entirely explained by physical processes. Biotic components exchange dissolved gases, nutrients, and particulate materials with the water column and markedly alter their distributions. Pelagic organisms themselves are dependent on support and transport by water.

Benthic Habitats (Figures 4-3, 4-4, 4-5). Benthic habitats are entirely or periodically covered by seawater, and there is an exchange of materials between the water column and benthic habitats. In addition to the physical and chemical characteristics of overlying seawater, the nature of the substratum is an important physical feature. Substrata range from rock bottoms to sand and mud sediments. The distribution and characteristics of substrata are dependent on geological processes such as erosion and sediment transport.

Exchange and redistribution of materials in benthic habitats depend on mixing and transport mechanisms in the overlying water column (as discussed above) and on the nature of the substratum. For example, water exchange with unconsolidated sediments depends on particle size. Some mixing processes generally decrease with depth; processes in shallow benthic regions are more complex and dynamic than in deeper benthic regions. The settling, resuspension, and transport of substratum, food materials, and reproductive products (including larvae) are also important physical processes that affect benthic habitats.

Biological Processes and Components. Biological processes such as respiration, excretion, consumption, photosynthesis, and the production of detritus, are common to all of the habitats and will be discussed later in terms of energy, materials, and nutrient cycles.

The nature of the biological components is different between the habitats and reflects the physical characteristics of the habitat as outlined below.

Pelagic Habitat (Figure 4-2). The pelagic habitat is primarily an open water environment, and organisms are supported and transported by water,

Biological populations in the pelagic environment consist of drifting plants and animals (plankton), larger, swimming animal populations (nekton), and surface associated populations, such as marine birds. Primary producers are microscopic floating algae (phytoplankton), consumer populations include herbivorous, omnivorous, and carnivorous zooplankton and fishes. Larger schooling pelagic fishes, marine mammals, and marine birds are exclusively active predators. Decomposers include protozoa, bacteria and fungi, although the latter group is poorly known in the pelagic environment. Biological components can be separated into surface populations (epipelagic forms, living in the upper 150 meters), midwater populations (mesopelagic forms, in the region between 150 and 500 meters), and deepwater forms (bathypelagic, forms living below 500 meters).

Benthic Habitats (Figures 4-3, 4-4, 4-5). Benthic habitats can be characterized as consolidated or unconsolidated bottom benthic habitats. Organisms living on consolidated bottoms are mostly restricted to the surface of the substratum (epifauna and epiflora). In unconsolidated bottom habitats, organisms can live on the surface or burrow into the sediment (infauna).

In the euphotic zone, benthic habitats support primary Producers. On consolidated bottoms primary producers are characterized by macroscopic algae (kelps and seaweeds) and sea grasses, e.g. surf grass (*Phyllospadix*). In unconsolidated bottom regions, primary producers may be limited to microscopic diatoms living at the sediment surface.

The predominant organisms are invertebrate consumers which are adapted to utilize particulate detritus. Feeding types of detrital consumers include suspension feeders (organisms which remove suspended particles from the water) and deposit-feeders (organisms which remove detritus from the sediment). Suspension feeders are relatively more important where there is water movement to suspend and transport particles, while

deposit feeders are characteristic forms in areas where there is deposition of materials.

Energy and Material Cycles. Energy and material cycles in ecosystems involve the transfer of energy rich compounds and structural material through food chains as food webs. Energy is initially fixed by primary producers and transferred to consumers. Each step in the transfer is known as a trophic level. Characteristically, energy is lost at each step. For example, only 10-30 percent of the energy fixed by primary producers may be actually transferred to primary consumers. Because of this energy loss at each step, the number of trophic levels is ultimately limited when there is insufficient energy to sustain a population of organisms at the next level. Energy flow is consequentially unidirectional; however, materials are recycled into the trophic structure at different levels.

Food webs in the marine ecosystem are complex; there are multiple pathways that energy and material flow can take. Two contrasting pathways that have been identified are grazing food webs and detrital food webs. In grazing food webs most of the primary production is directly consumed by grazers as primary consumers. Subsequent steps involve the consumption of grazers by higher consumers.

In detrital food chains, most of the primary production is transferred to consumers as dead or decomposing plant materials. In general, pelagic or oceanic food webs may be considered as grazing food webs, while intertidal, aquatic beds, and benthic food webs are primarily detrital food webs. For either of these food webs the ultimate fate of organic material is consumption by decomposers with the release of structural materials and nutrients back to the physical environment.

Primary Production. The primary energy source in the marine ecosystem is energy from solar radiation, which is trapped by primary producers through photosynthesis. Photosynthesis involves trapping solar energy and the incorporation (reduction) of inorganic carbon (CO_2 and/or HCO_3^-). Other elements, such as nitrogen and phosphorous, are required for plant tissue so that nutrient uptake is also part of the primary production process. Primary producers, as well as all biological organisms, remove oxygen from the water (as air in the case of mammals and birds) through respiration. Oxygen is used to oxidize organic material to meet an organism's energy needs. For primary producers, the relative rate of photosynthesis versus respiration will determine if (or how much) plant biomass accumulates.

In the pelagic environment there is sufficient light energy to sustain net photosynthesis (when photosynthesis is greater than respiration) only in the upper layer or euphotic zone. The amount of light penetration in the water column is dependent on turbidity (suspended and dissolved materials) of the water. Offshore waters are relatively clear and the euphotic zone may extend to greater than 100 meters, while in turbid coastal waters, the euphotic zone may be less than five meters.

Primary producers in the pelagic environment are unicellular drifting algae (phytoplankton) (Figure 4-2). In the intertidal region (Figure 4-3) and submerged aquatic beds (Figure 4-4), the characteristic primary producers are macrophytic algae (kelps and seaweeds) and vascular seagrasses, e.g. surfgrass (*Phyllospadix*). In benthic habitats within the euphotic zone (Figure 4-5), benthic diatoms at the sediment surface may be the only primary producers.

Food Webs. As previously discussed, primary productivity can be distributed by a number of pathways. In the pelagic habitat (Figure 4-2) phytoplankton population may be directly consumed by epipelagic consumers (primarily copepods and other herbivorous zooplankton). Epipelagic food webs include subsequent transfer to carnivorous zooplankton, small then larger schooling fishes, and eventually to birds and mammals. The production of detritus occurs at every step as the result of mortality and the production of fecal and other waste materials.

Since primary production in the pelagic habitat is restricted to the surface (epipelagic or euphotic), there must be energy transfer to the deeper regions (mesopelagic and bathypelagic) and benthic habitats. Some of this transfer is the result of sinking of phytoplankton and detrital material from the epipelagic region. Sinking of detrital material involves the colonization of sinking particulates by decomposers. The importance and complexities of this method of transfer are not well known. Another method of transport is the consumption of epipelagic copulations by mesopelagic consumers. Many mesopelagic consumers make diel (daily) vertical migrations into the epipelagic region to feed.

Some organic material produced in the pelagic habitat eventually reaches benthic regions, although the pathways are not clearly understood. In the shallow waters over the continental shelf there may be considerable settling of phytoplankton and detritus to benthic habitats.

Some of the problems presented in understanding pelagic food webs include the suggestion that much of the material fixed by phytoplankton may be leaked as dissolved organic material. This suggestion is not universally accepted but raises the possibility that transport via detrital food webs (as through decomposers) may be more important than initially anticipated.

Benthic food webs may be primarily characterized as detrital food chains, and consumer populations are largely composed of suspension and deposit feeders. The intertidal habitats (Figure 4-3), aquatic beds (Figure 4-4), and the euphotic region of benthic habitats (Figure 4-5) support primary producers; however, most of the primary production is consumed as detritus rather than directly as living plant material. Much of the production by macrophytic algae and seagrasses is annual, and a considerable amount of accumulated biomass is removed by storms and wave action and redistributed by currents. In shallow benthic habitats there is considerable exchange of materials and energy between benthic and pelagic habitats. For deeper benthic habitats (Figure 4-5), the classic picture suggests that food material settles from the surface regions as a rain of small detrital particles. To some extent this may be true, as the consumer populations are characterized by an abundance of deposit feeders. However, it has recently been discovered that there is an abundance of highly motile predators and scavengers, which suggests that occasional falls of large food items may be more important than initially appreciated.

Nutrient Cycles. Nutrient cycles are critical to renew inorganic nutrients (NO_3 , NH_4 , and PO_4), which are required by primary producers. Nutrient cycles, or nutrient regeneration processes, are intimately related to the transfer of materials through food webs and ultimately to decomposers. Some nutrients are directly released as the result of excretion by consumers; however, most of the nutrient regeneration is the result of decomposers.

In the pelagic habitat nutrients are removed in the surface waters by phytoplankton and regenerated in deeper waters by decomposers (Figure 4-2). Mixing events such as wind mixing and upwelling are important in renewing nutrient concentrations in the upper water column. For benthic habitats (Figure 4-3, 4-4, 4-5), nutrients are regenerated in sediments where detritus is deposited.

Community Composition. In natural biological systems there are often species assemblages persistently associated with a zone or habitat. If these assemblages are persistent over time and necessary roles such as primary production, consumption, and decomposition, are filled by species in the assemblage, then the assemblage may be considered an organized biological community. Ecosystems may be composed of one or several communities. In organized and persistent communities, species diversity, dominance structure, and distribution patterns may be characteristic of the community or ecosystem. The term "community", however, is often less rigorously applied to assemblages without implications of persistence or organization. Community composition, as it is used in the model, simply implies an assemblage, although assemblages, such as mesopelagic consumers, may be a community in the stricter sense.

Community composition is determined by the physical characteristics of zones and habitats and may change seasonally as a result of changes in the physical and biological environment. In the epipelagic region of the pelagic habitat (Figure 4-2), community composition undergoes seasonal changes as a result of succession and migration. There is less of a seasonal influence on mesopelagic regions and communities. In general, community composition in benthic communities is largely determined by substratum, and successional changes occur over longer time scales than seasonal events. The factors which influence community composition changes are complex and are more fully discussed in the habitat descriptions (Volume III, Chapter 3).

Limiting and Regulating Processes. Biological processes may be controlled or limited by a variety of factors. Individual processes such as photosynthesis may be limited by the availability of substratum, and solar radiation may limit the rate of photosynthesis. Populations or assemblages may be limited by the action of other populations (e.g. phytoplankton biomass development may be limited by consumption by herbivores). The number of trophic levels or steps in a food chain may ultimately be limited by the initial input of energy (primary productivity) and the rate of energy loss at each step.

Photosynthesis and primary production can be directly limited by the availability of light energy or nutrients. In the pelagic environment, phytoplankton populations are light limited during the winter when they are mixed below the euphotic zone, and nutrient limited during the summer when nutrients are depleted in surface waters. Benthic macrophytes may rarely be nutrient limited because of water movement in shallow areas and nutrient regeneration in shallow water sediments.

Primary producers can also be limited by loss of biomass as the result of consumption by consumers or through physical processes. In the pelagic habitat there may always be a loss of phytoplankton as the result of passive sink or downward mixing. Following the spring bloom, however, grazing populations of zooplankton may limit the development of phytoplankton populations by consumption.

Benthic algal populations can at times be controlled by grazing populations, as in the case of the red sea urchin (*S. franciscanus*) effect on kelp beds; and losses of biomass as the result of storms and wave action may be appreciable.

It is difficult to generalize about controlling factors in consumer populations. Major regulating effects may be the availability of food, loss to predators, loss as the result of mortality, and physical factors (water movement, salinity, availability of substratum, temperature, etc.).

Regional Description

Introduction. The marine environment considered in this report extends from Point Conception to the Oregon border, and from the extreme high water level of the intertidal to the 1,000 meter bathymetric contour. This includes all of the continental shelf adjacent to that part of the California coast, and the upper part of the continental slope.

In order to integrate information from various disciplines, and to more fully comprehend the nature of the physical, chemical, and biological environments and the processes and mechanisms which regulate them, a holistic "ecosystem" approach is applied. In reality, this areal environment does not comprise an ecosystem within the normally accepted definition of the term. Webster defines an ecosystem as "a complex of ecological community and environment forming a functional whole in nature." In this sense the California Current system, which is the main determinant of the physical and biological marine environment of this portion of the California coast, is not a "functional whole" or closed system, but is only one segment of the larger North Pacific circulation system. Biologically, this region does not support a definable community of indigenous species but is rather a mixture of subarctic, equatorial, central north Pacific, and locally indigenous forms. In this sense, it conforms more closely to the definition of an ecotone, i.e. a transition area between two adjacent ecological communities usually exhibiting competition between organisms common to both.

The following section will describe in very general terms, the biological structure, processes, and interrelationships which prevail within the study area, and will define the physical environment and mechanisms which regulate or affect them.

Physical Environment and Processes. In order to understand the functions and processes of the biota of an environment, a basic comprehension of the physical, chemical, and geological systems which determine and regulate that environment must be acquired. In the study area (the coastal California marine environment), the principal controlling factors are the complex structure and fluctuations of the current transport systems and the effects of coastal configuration, bathymetry, and substratum characteristics.

Horizontal Transport. The primary horizontal transport within this region is the California Current system and its associated subsystems. The California current is the eastern boundary flow of the anticyclonic (clockwise) North Pacific gyre. It originates at the divergence of the West Wind Drift (the major surface flow across the North Pacific) at a point about 300 km off the Oregon-Washington border. The major portion of the West Wind Drift diverges southward as the California Current; a lesser portion moves northward into the Gulf of Alaska. The California Current originates as water of relatively low salinity and low temperature, but becomes progressively warmer and more saline as it moves southward while mixing and entrains with waters of central

and equatorial Pacific origin. The width of this current varies from 600 to 1,000 km, thereby extending over all of the continental shelf and slope. It exerts transport influence to depths of between 100 and 500 meters. The south moving current is driven primarily by atmospheric pressure cells and associated surface wind systems. It is a sluggish current, with normal velocities ranging from a quarter of a knot to about half a knot. In general, both wind velocity and current velocity decrease from north to south. It is also a seasonally variable current with the flow most pronounced and persistent during the spring and summer months.

At Point Conception (the approximate southern geographical limit of this study), the coastal configuration and current direction diverge: to the south of Point Conception the coast angles abruptly to the southeast, while the California Current flow tends to the southwest. Point Conception, as will be discussed in more detail in the following biological section, also marks a major ecological boundary.

The south flowing California Current is underlaid by a persistent nearshore current of opposite directional flow, known as the California Countercurrent. This current is only 40 to 50 km wide and is even more sluggish than the California Current, with velocities ranging from less than a tenth of a knot to about a quarter of knot. The countercurrent has its core at about 200 meters depth, and continues to the bottom. Its temperature is generally somewhat higher than that of the overlying California Current, with greater density being maintained by higher salinity. It is also a seasonally variable current, having its strongest flow in summer. The countercurrent has eddies and local anomalies resulting from bathymetric features and coastal configuration. The driving force or forces behind this countercurrent are unknown.

The third major current within the overall California Current system is the Davidson Current, which is really a seasonal (November to February) surface manifestation of the California Countercurrent. This surface manifestation is primarily the result of winter wind reversals which weaken the southward flowing California Current and move it offshore, with a consequent inshore development of the northward flowing Davidson Current. The velocity of the Davidson Current, though variable, ranges from half of a knot to about three quarters of a knot (thereby being greater than either the California Current or Countercurrent). The Davidson Current is narrowest at Point Conception and widens with northward flow.

Vertical Stratification and Transport. The offshore water column adjacent to the California coast conforms generally to the normal three-layered structure of epipelagic, mesopelagic, and bathypelagic zones. The principal physical factors (aside from light penetration) which are used to delineate these different vertical zones are temperature and salinity, with temperature decreasing and salinity increasing with depth. In California offshore waters, the epipelagic zone (with comparatively low salinity and warmer temperatures relative to the deeper zones) extends from surface to between 100 and 150 meters depth. Within this surface layer, strong seasonal stratification normally develops during the summer as the result of increased insolation anti surface warming. The thermocline (or marked temperature gradient) separating this seasonal warm surface gradually moves downward through the summer and approaches the permanent pycnocline (or marked density gradient) which forms the lower limit of the epipelagic zone. This seasonal thermocline subsequently breaks down with vertical wave mixing associated with fall and winter storm surges (Figure 4-6).

Below the epipelagic zone lies the mesopelagic zone which has increased salinity, decreased temperature, and consequently greater density. With insufficient light for photosynthesis, this zone supports no plant life and consequently tends to possess higher and more constant values of dissolved nutrients, and lower values of dissolved oxygen, than does the epipelagic zone. Within the upper epipelagic zone, nutrient values are highly variable depending on seasonal stratification and primary productivity levels; these may become depleted to the point of limiting plant growth. The lower limit of the mesopelagic zone is normally considered to be about 1,000 meters; although off California this lower limit is assumed to lie at 500 meters (Figure 4-7).

The bathypelagic zone, extending from the lower limit of the mesopelagic zone to the ocean bottom, is a region of total darkness. It exhibits slightly decreased temperature, increased salinity, and increased density relative to the mesopelagic zone. Like the mesopelagic zone, it contains high levels of dissolved nutrients, and slightly lower levels of dissolved oxygen, as the result of faunal respiration (Figure 4-7).

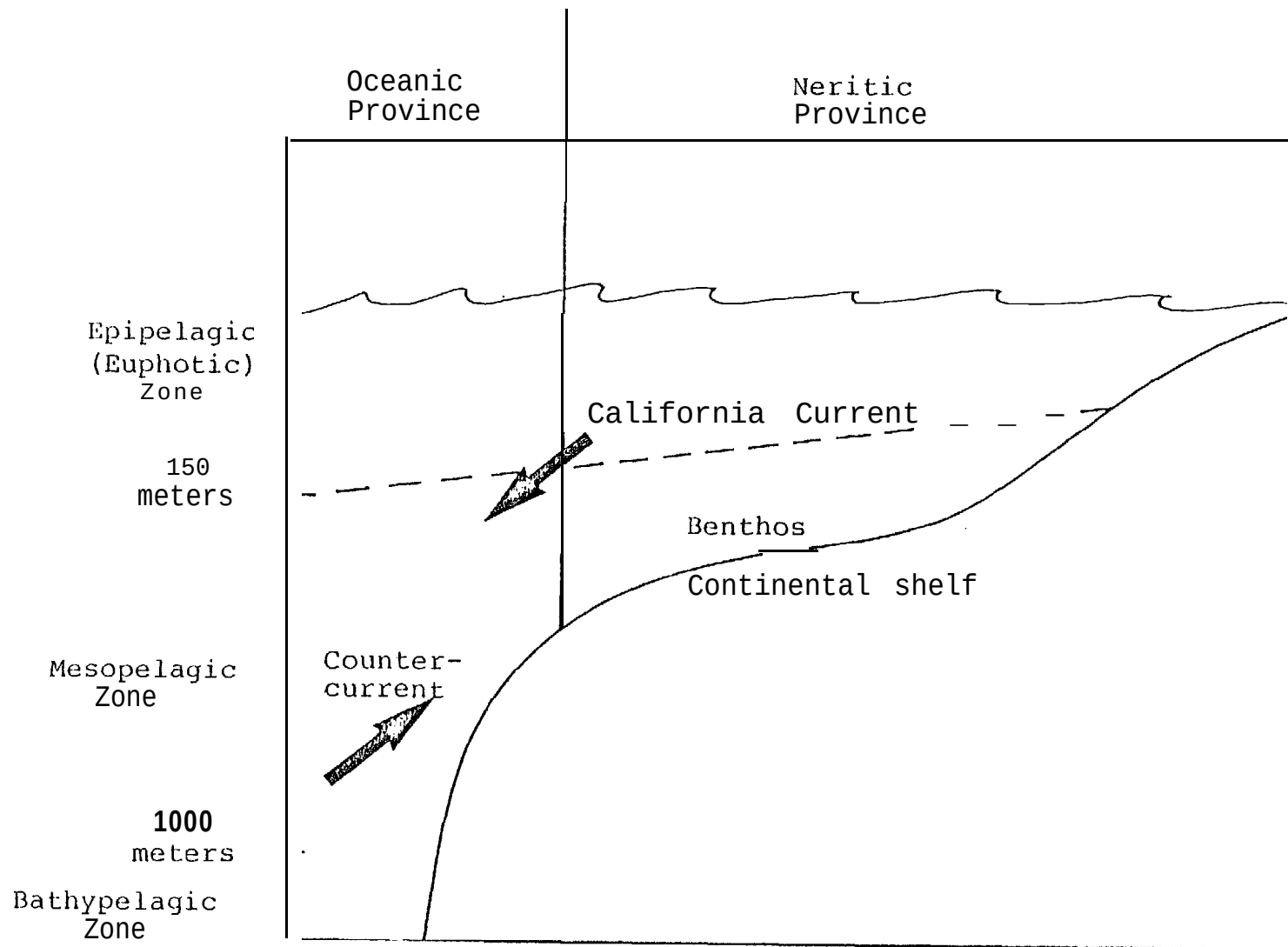


Figure 4-6. Vertical Stratification and Transport in the Pelagic Region of Central and Northern California (modified from Hedgpeth, 1957b)

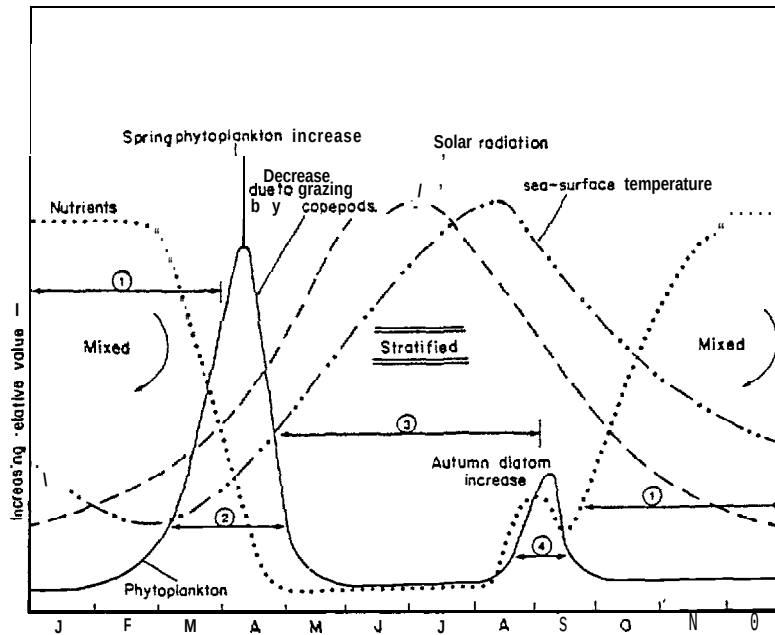


Figure 4-7. Seasonal Events in a Temperate Pelagic Region

Legend

- (1) Winter Minimum: Solar radiation and sea-surface temperatures are at their seasonal low during this part of the year. The water column is well-mixed by storms and wind. Nutrient levels are high in the upper layers as a result of deep mixing. Plant productivity and biomass are low because plants are carried out of the lighted surface zone by mixing.
- (2) Spring Bloom: Increasing solar radiation begins to warm the surface waters, and a stable density layer forms above the seasonal "thermocline" (the depth where temperature changes rapidly). Mixing by storms and winds are less prevalent at this time which allows the stability to persist. Since plants are retained in the lighted surface layer they increase rapidly. Plant growth (primary production = photosynthesis) is accompanied by uptake of dissolved nutrients. With an increase in plant biomass, nutrient levels in the water column decline. Grazing zooplankton begin to increase as a result of the available plant biomass as a food source. Phytoplankton populations reach their highest levels at this time and then begin to decline as a result of nutrient limitation and/or grazing pressure by zooplankton. Spring bloom conditions will be prolonged in regions of upwelling because of the upward transport of nutrients.
- (3) Summer Minimum: Sea surface temperatures reach their maximum for the year. The surface layer is strongly stratified above the "thermocline", and mixing between the upper warm layer and cold lower layers is minimal. Plant growth has depleted nutrients in the upper layers, and plant biomass has declined to a low level because of both nutrient limitation and ingestion by grazers.
- (4) Fall Bloom: Fall storms may result in some mixing of nutrients into the upper water column. Remineralization of nutrients and excretion of nutrients by zooplankton may also be significant sources. The increase in nutrients allows a moderate increase in phytoplankton populations, although grazing pressure may remain high during this period.

Mechanisms must exist for vertical transport and exchange of nutrients and materials within and between these levels; otherwise, nutrient depletion and starvation would ultimately ensue in the upper, photosynthetic (primary productivity) zone, and oxygen depletion would render the deeper layers uninhabitable. The main vertical transport mechanisms, aside from passive diffusion, are wave and tidal mixing and upwelling/downwelling.

The effects of wave and tidal mixing are limited essentially to the near-surface layer and are temporally variable in their magnitude. The tidal cycle along all of the California coast is semidiurnal, having two high tides and two low tides within each 24 hour period. These tides are generally unequal in magnitude and are temporally variable, depending on the relative positions of the sun and moon with respect to the earth. They are also geographically variable, depending on local coastal configuration and bathymetry. Horizontal currents and accompanying vigorous turbulence and vertical mixing may develop locally as the result of tidal movement. Locally, tidal currents may exert significant or even dominant influence. For example, tidal currents in excess of five knots are not uncommon at the entrance to San Francisco Bay. Overall, however, tidal transport mechanisms are relatively insignificant when compared to the more persistent and massive movements of water associated with long-term currents and upwelling systems.

Wind generated surface wave action can result in violent turbulent mixing of the ocean's upper layer. The magnitude of such wind/wave effects are temporally and spatially variable along the California coast. Stronger winds and waves are normally associated with the stormy fall and winter months. Storm frequency and magnitude, and resulting surface wave action, decrease from north to south. In addition to vertical mixing, wave action (usually in combination with tidal influence) commonly results in local, nearshore horizontal transport of considerable velocity.

Of greater importance than wave and tidal mixing to vertical exchange within the California offshore waters are the upwelling/downwelling processes resulting from prevailing wind and current patterns in conjunction with the earth's Coriolis effect. During periods of strong southward moving winds and nearshore currents, there is a net offshore transport of surface water with resultant coastal upwelling of cool, nutrient-rich deeper water to the surface. Such upwelling has a widespread influence over the physical-chemical and biological processes along the coast. There are few such upwelling coasts in the world. Aside from California, coastal upwelling occurs only along the shores of Morocco, southwest Africa, Peru, and along the Arabian peninsula in the northern Indian Ocean. These regions are notable for their extremely high primary and secondary productivity levels. They are some of the biologically richest areas, supporting some of the greatest fisheries in the world.

Upwelling off the California coast is extremely variable, both temporally and spatially. Generally it is strongest and most persistent during the spring and summer periods of prevailing north and northwest winds. Upwelling events are relatively continuous from Monterey Bay southward, and are more intense, although sporadic, along the northern coast.

Upwelling effects are strongly related to coastal configuration and local bathymetry. They are also variably influenced by winds and currents. Areas of strongest upwelling occur along the southern margins of projecting capes and headlands (such as Cape Mendocino) and at the heads of submarine canyons (as within Monterey Bay).

In contrast to upwelling, downwelling may be associated with the northward winter winds and northward-flowing Davidson coastal current. The Coriolis effect on this northward flow results in net onshore transport and "piling up" of surface water against the coast with resulting isostatic subsidence (downwelling) and replacement by surface water from farther offshore.

Coastal Configuration, Bathymetry, and Substratum. The California coast is relatively straight and uninterrupted. The only major projecting headlands are Cape Mendocino, Point Arena, Point Reyes, Point Sur, Point Buchon, and Point Conception; the only embayments of consequence are San Francisco Bay, Tomales Bay, Monterey Bay, Estero Bay, and San Luis Obispo Bay (Figure 4-8). As mentioned above, the projecting headlands exert a major influence with respect to the distribution of upwelling and the consequent biological productivity of the coastal zone.

The submerged continental shelf is rather narrow along the California coast, ranging from 15 to 80 km in width, and is traversed by several submarine canyons. Principal among these are the Monterey Canyon, Arguello Canyon, Lucia Canyon, Sur

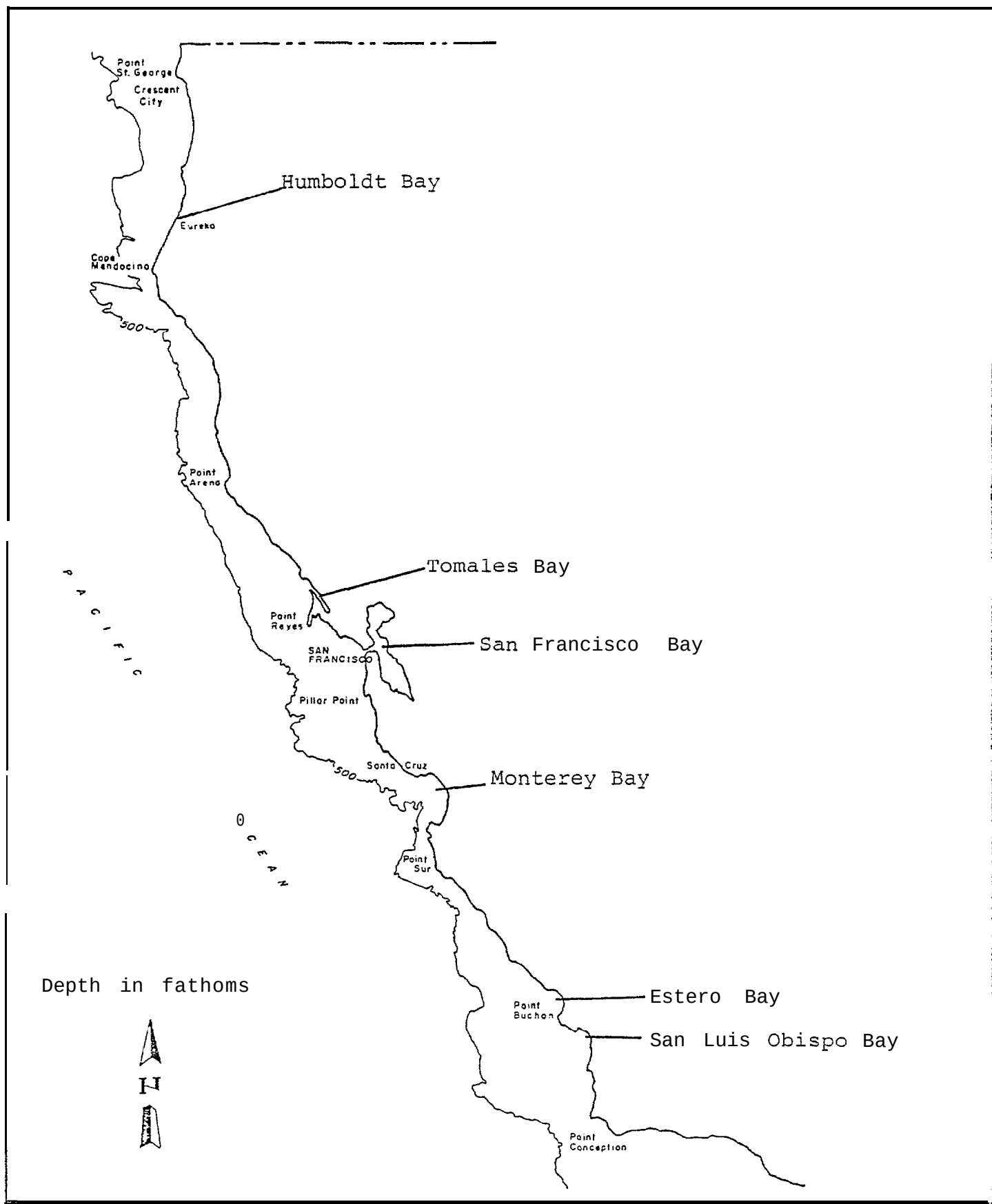


Figure 4-8. Coastal Headlands and Bays of Central and Northern California

Canyon, Ascension Canyon, Pioneer Canyon, Bodega Canyon, Noyo Canyon, Delgada Canyon, Mendocino Canyon, and Eel Canyon. These canyons are of some importance within the upwelling system, channeling the vertical flow of water from sub-shelf depths to the surface, creating localized areas of increased biological productivity. The continental shelf slopes gradually from shoreward down to the 300 to 1,200 meter contour, beyond which the bathymetry plunges down the continental slope to the Pacific Basin floor at nearly 4,000 meters. This shelf-break occurs at greater depths along this coast than is common for most continental shelves, and varies from north to south, with greater depths along the southern coast. The shelf width also varies latitudinally, broadening from north to south.

The geography of the shoreline and intertidal zone along the northern and central California coast is highly variable, ranging from rocky shorelines and steep seacliffs to low-relief sand beaches, with occasional bays and estuaries with finer, mudflat substrata. In general, rocky shorelines predominate along the northern coast, with sandy beaches being more frequent along the central and southern regions. Within any locale, however, the character of the shoreline can alter abruptly. Predictably, exposed capes and headlands are generally characterized by rocky substrata, and straight coastlines by coarse sand beaches.

Offshore, the subtidal benthic substratum generally varies with depth and distance from shore, grading from relatively coarse nearshore sediments (dominated by sand, gravel, cobble and rock) to finer silt and clay fractions with increasing depth and distance from shore. As with the intertidal region, these substratum distributions are highly dependent on local bathymetry and current conditions.

Coarser nearshore sediments are largely terrestrial in origin, resulting from degraded rock material. The finer sediments of the deeper, offshore areas tend to be largely biogenic in origin, consisting of nearly microscopic tests (shells) of planktonic diatoms, radiolarians, and foraminifera which have settled through the water column, sometimes to great depths, and slowly accreted. As will be discussed in more detail later, each substratum type (both intertidal and subtidal) supports its own distinctive faunal and, within the euphotic zone, floral communities.

The foregoing general description of the physical environment of the region is critical to an understanding of the biology of the California coastal region, and is applicable to the biological discussion to follow. As outlined in the preceding conceptual section, primary productivity and subsequent productivity levels, community structure, and trophic efficiency in the offshore waters are all highly regulated by vertical stratification and vertical and horizontal transport mechanisms within the pelagic habitat. Benthic faunal and floral species, and entire community distributions, are highly responsive to substratum type, wave activity and/or current velocity, and primary productivity levels of the overlying water column. Species are also responsive to characteristics of the near-bottom water (e.g. temperature, salinity, dissolved oxygen content, suspended organic matter, and suspended inorganic particles).

Biological Environment. The biotic marine environment could be subdivided in two different ways: (1) floral and faunal components, or (2) pelagic and benthic components. For purposes of this discussion, the primary distinctions will be the pelagic/benthic subdivision. Pelagic relates to the water column itself; benthic refers to that associated with the ocean floor, both intertidal and subtidal. As will be seen, the two basic components, pelagic and benthic, are closely interrelated.

Pelagic System. The pelagic community is composed of planktonic (floating) and nektonic (swimming) organisms. The plant portion of the plankton (phytoplankton) is functional only in the euphotic zone of the pelagic environment. The animal portion of the plankton (zooplankton) is composed of organisms which spend their entire lives as plankton (holoplankton) as well as temporary life stages (e.g. larval forms) of otherwise benthic or nektonic organisms (meroplankton). Zooplankton and nekton are found throughout the entire water column. Largest zooplankton biomass values occur within the upper layers of the water column in association with the basic food supply derived from phytoplankton productivity.

The distributions of organisms within the water column are described with respect to the zone determined by depth within which they most frequently occur (i.e. epipelagic, mesopelagic, and bathypelagic zones). Not all pelagic organisms are restricted to one zone, but may be temporary or periodic visitors to other zones. For example, the larvae of mesopelagic and bathypelagic fishes are primarily found in the food-rich epipelagic zone. Also, many adult mesopelagic fish and zooplankton species undertake extensive nightly vertical migrations into the epipelagic zone to feed on the abundant small zooplankton (including larval fishes) that occur there.

Photosynthetic primary productivity is the basis upon which all higher trophic levels (transcending from herbivorous grazers through top-level carnivores) are established. Primary productivity levels in the euphotic zone affect the productivity of the entire water column. The magnitude of the photosynthetic process is primarily determined by diurnal solar radiation (light) levels and nutrient availability.

Seasonal Variations. In temperate and high latitudes, physical-chemical environmental factors change seasonally with accompanying biological changes. Within the California Current system, these seasonal changes may be defined by three hydrographic periods: the period of upwelling, between mid-February and the end of July; the oceanic period, from the end of July to the middle of November; and the Davidson Current period, lasting from the middle of November to the middle of February. These hydrographic periods have associated seasonal biological periods.

1. Upwelling Period (mid February through July) - The upwelling period is associated with the two-peaked (spring and fall bloom) productivity cycle (Figure 4-7). Insolation during the early spring results in increased photosynthetic production. Additionally, it creates shallow thermal stratification and stabilization of the near-surface water, thus providing a mechanism for maintaining phytoplankton within the upper euphotic layer and preventing it from being carried down into the aphotic zone. Once this stratification sets in, primary productivity and phytoplankton standing stock levels increase rapidly with subsequent increases in zooplankton and nekton grazers and predators. This is a self-limiting system: the same stratification which promotes this initial productivity increase also limits nutrient exchange from the deeper zones. With a steady net loss of nutrients to the deeper zones through sinking organic and vertical zooplankton and nekton migrations, the stabilized surface layer rapidly becomes nutrient depleted. This nutrient depletion, augmented by increasing herbivore populations, results in a decrease of phytoplankton standing stock, which reduces food availability to higher trophic levels. Throughout the summer, the thermocline delineating the lower limit of the stratified surface layer deepens and approaches the permanent thermocline at the base of the epipelagic zone. This seasonal thermocline breaks down with stronger winds and wave mixing in the fall. If this breakdown occurs early enough, and if vertical mixing is sufficient to replenish the surface nutrient supply (yet not so turbid that phytoplankton populations cannot maintain themselves within the euphotic zone), a secondary, smaller primary productivity peak will occur in the early fall.

Throughout this cycle, there is a generally observable alteration of community structure known as species succession. In the early part of the cycle, the phytoplankton population is characterized by large forms, principally diatoms. Later on, these large forms tend to be replaced by smaller microplankton and nanoplankton species. This change may perhaps be in response to warmer temperatures, decreased nutrient levels, grazing pressure, biological conditioning of the water column, or a combination of these and other unknown factors. Changes in zooplankton species composition also occur throughout the cycle. Meroplankton (temporary planktonic forms) are more common during the early cycle, while holoplankton (totally planktonic forms) dominate later assemblages. There are also horizontal differences in species composition, particularly among the zooplankton. For example, fish larvae (ichthyoplankton) and benthic invertebrate larvae tend to be more abundant nearshore than offshore.

This typical productivity cycle is altered somewhat along the northern and central California coast, with productivity remaining at relatively high levels throughout the summer period in response to nutrient replenishment from upwelled waters. Additionally, the phytoplankton community within this coastal region maintains larger-sized species (characterized by diatoms) through the cycle. This results in a shortened food chain and increased standing stocks of higher trophic level organisms. As a result, the enriched high productivity coastal area supports the bulk of the commercial pelagic fishing industry.

Inshore primary productivity rates associated with upwelling along the coast (between 35°N and 50°N latitude) range between 6.62 and 61.65 milligrams carbon per cubic meter of water per hour ($\text{mgC}/\text{m}^3/\text{hr}$) during July and August. In contrast, productivity rates several hundred miles offshore, for this same period and latitudinal range, average less than $1.0 \text{ mgC}/\text{m}^3/\text{hr}$ (Winzler and Kelly, 1977a). Zooplankton standing stock values are also highest in the nearshore region during these summer months, although species diversity (number of species) is lower there than farther offshore. In general, the greatest biomass levels of both phytoplankton and zooplankton occur along the northern coast, particularly in the Cape Mendocino to San Francisco area. The end of the upwelling productivity cycles occurs in late summer with the onset of the oceanic period.

2. Oceanic Period (August through mid-November) - This period marks a transitional phase between the upwelling period and the Davidson Current period. At this time, primary and secondary productivity levels have decreased relative to those of the upwelling period. Onshore surface flow of oceanic waters occurs at this time and oceanic zooplankton species characteristic of the central Pacific water mass are more common.

3. Davidson Current Period (mid-November through mid-February) - During the fall and winter, the northward flowing Davidson current exists inshore and winter storms prevail. The strong storm wave action results in a thick (more than 100 meters) mixed layer. While nutrient levels in the surface waters are relatively high as a result of vertical mixing, the lower winter light levels and turbulent transport of phytoplankton cells out of the euphotic zone permit only relatively low levels of primary productivity. Zooplankton populations are also at lowered abundance levels during this period.

Pelagic Community Composition. The plants and animals that comprise pelagic communities include a wide variety of taxonomic categories. The most important elements of the phytoplankton are diatoms and dinoflagellates; other elements are coccolithophores and silicoflagellates. The zooplankton includes minute protozoans (e.g. tintinnids, radiolarians, and foraminifera), a large number of small crustaceans (e.g. copepods, ostracods, euphausiids, and amphipods), worms (chaetognaths and polychaetes), molluscs (pteropods and heteropods), jellyfishes and siphonophores (ctenophores), salps, larvaceans, and the egg and larval stages of most benthic and nektonic animals. The most abundant zooplankton elements are the protozoans, copepods, chaetognaths, euphausiids, salps, and larvaceans. Nektonic organisms include fishes, squids, and marine mammals.

Each oceanic water mass has its own individual physical characteristics and provides certain environmental qualities which permit the survival and reproduction of some species of organisms and not others. As a result, each water mass contains a unique, distinctive and identifiable community of phytoplankton, zooplankton and nekton species.

As has been mentioned, the California Current region is not an oceanic water mass with its own distinctive community structure. Instead, it is a highly complex current system, deriving its biological as well as physical characteristics from the subarctic, central and equatorial water masses.

Because the main California Current originates in the North Pacific West Wind Drift area, it starts its southward flow down the California coast with a distinct faunal dominance by subarctic and West Wind Drift zone (transition zone) species. As the California Current water moves southward, its physical characteristics are altered by mixing on its western boundary with central Pacific water and by the injection from the south of equatorial water from the deep countercurrent and surface Davidson Current. Some of the more broadly tolerant subarctic species persist and occur along with endemic species until the waters are thoroughly mixed with the equatorial and central waters.

Point Conception constitutes a major break in the physical and biological structure of the California Current system. South of this point, due to the coastal configuration, the main California Current flow is offshore and physical and biological characteristics derived from the central Pacific and equatorial water masses are of greater importance.

The California Current system can be broadly envisioned as a transition zone between subarctic and subtropical water masses and organisms, with a predominance of subarctic forms in the north, and of subtropical and equatorial forms in the south, with the greatest rate of change occurring in the Point Conception area. Unfortunately, this broad view is rather simplistic. The California Current system is highly complex. The seasonal inshore-offshore movements and fluctuations in the current velocities of the main Current flow, plus the seasonal appearance of the inshore Davidson Current, result in variations in southern and northern water and faunal input within the year. Also, long-term (e.g. from one up to five or ten years), large scale variations in current transport can occur, resulting in anomalously "warm water" or "cold water" periods depending on whether there is more subarctic or equatorial water influence along the entire coast. During these periods, species may be found in geographical locales far from their normal ranges (e.g. during "warm water" years, equatorial pelagic turtles are occasionally seen off of San Francisco and northern California). These variations are unpredictable, and their primary causes are not known.

The environmental ramifications of California Current flow variations may have profound effects. For example, a series of anomalous years providing poor conditions for the larval survival of commercially valuable fish species may greatly reduce the fishable stocks. If this occurs in conjunction with high fishing pressure, an entire fishery can collapse. Such is believed to be partially the explanation for the disappearance of the sardines in northern California.

Benthic Fauna and Flora. Subtidal benthic areas are subdivided either by euphotic/aphotic designations or by substratum type. The latter, which is more commonly applied, can be broken down into many small fractions depending on mean particle size and organic carbon content of the substratum material. In this report, the primary differentiation is based on substratum type, which is composed of two categories. Substratum type referred to as "consolidated" consist of bedrock outcrops and boulders larger than "stones". "Unconsolidated" substratum includes all size fractions, from cobbles and coarse gravel through gradations of sand and silt to fine clay fractions. Both of these substrata may exist within the euphotic and aphotic zones.

Certain substratum generalizations are relevant. Within the euphotic zone, the bulk of attached non-vascular macrophytes (algae and kelp) are associated with consolidated substrata (bedrock or boulder). Each of these floral assemblages is determined by depth, light intensity, nutrient availability, substratum type, and wave action; and each supports its own distinctive faunal assemblage.

Rooted marine vascular plants (seagrasses or eelgrasses) are associated with shallow water unconsolidated substrata within the study area, being limited to the upper reaches of bays such as Tomales Bay and San Francisco Bay and intertidal regions on the open coast. These vascular plants are the basis for a unique assemblage of associated algal and faunal components. These result in an identifiable "sea grass community."

Within the euphotic and aphotic zones, individual benthic species and resulting community compositions are strongly substratum related. The faunal/substratum relationship is not always one of direct cause and effect, however. A species may be present on a substratum because of direct needs supplied by that substratum. Frequently, however, both substratum and species distribution are also determined by other factors such as current strength and/or suspended particulate content of the overlying water.

Shallow water benthic communities associated with consolidated substrata are generally dominated by attached filter-feeding forms (e.g., mussels, rock scallops, tunicates, tube-building serpulid worms) which utilize the particulate content of the water column as a food source; and by grazers (e.g., limpets, sea urchins, abalones) which feed on attached micro- and macroalgae. Important mobile predators here are starfish and crabs. These communities generally are associated with fairly active water movement, which supplies them with the suspended particulate material upon which the filter feeders rely. Conversely, these organisms cannot tolerate water of high turbidity and suspended inorganic sediments.

Unconsolidated coarse substrata (e.g., gravel and sand) support mixed communities of attached and unattached filter feeders, selective detritus feeders (ingesting particulate organic matter on the sediment surface) and carnivore/scavengers. Although the species compositions of these communities are highly variable depending on factors such as substratum particle size, current strength, wave action, water depth, and particulate content of the water column, forms typically encountered are bivalve molluscs, gastropod molluscs, tunicates, sea stars, and basket stars (ophiurids), tubicolous amphipods, polychaete worms, sea cucumbers, sand dollars (echinoids) and crabs.

Finer unconsolidated substrata (silt to clay range) are also characterized by mixed faunal assemblages consisting of deposit feeders (ingesting the sediment directly for the organic matter it contains), selective detritus feeders, filter feeders, and carnivore/scavengers. The proportions of the different feeding types within these communities is variable depending on such factors as depth, substratum particle size, current velocity, particulate content of the water column, organic carbon content of the sediment, and salinity. In general, deposit feeders and selective detritus feeders tend to dominate within fine substrata communities.

Substratum types, particularly unconsolidated ones, and their associated floral and/or faunal assemblages are rarely distinct and clear-cut but tend to overlap and intergrade with one another, or to occur in locally patchy distributions. As a rule,

coarser sand and gravel substrata tend to occur at shallower depths inshore, and in regions of relatively intense bottom currents, while finer silt/clay substrata are found in areas of lower circulation associated with offshore depths, or protected enclosed bays, estuaries, or lagoons. Within the benthic communities, each of the basic feeding types typically includes species from several taxonomic categories; each benthic taxonomic category may be represented by several feeding types. For example, filter feeders include a wide variety of forms ranging from bivalve molluscs to tubiculous amphipods and polychaete worms. Various polychaete worms, conversely, may function as filter feeders, substratum feeders, selective detritus feeders, or carnivore/scavengers.

Although the benthic and pelagic communities have been discussed separately, they are intimately connected. The deep water benthic community is dependent upon the epipelagic community for its food supply. Food is supplied to the depths by a rain of particles (ranging from protozoans to whales in size and food content). Intermediary food links between the surface waters and depths are vertically migrating organisms. Many benthic and deep sea organisms rely on the food-rich surface layers for the early survival of their larval forms.

Shallow water benthic habitats are likewise intimately connected to the pelagic environment as a source of nutrients for algal growth, particulate food for filter feeders, etc. The early life stages of most shallow water benthic organisms, as with the deeper forms, are planktonic.

Human Effects on the Marine System. Acute or chronic disturbances of this physical/biological system may result from a number of sources, either man-caused or natural. Natural perturbations include uncommonly severe climatic fluctuations leading to droughts, severe storms, floods, or temperature extremes, nearshore or marine vulcanism and associated tidal waves or tsunamis.

Another natural event which sometimes occurs in subtropical or temperate regions is the phenomena known as "red tide". This results from rapidly increasing populations or "blooms" of very small dinoflagellate phytoplanktonic organisms, sufficient densities of which can impart an actual red tint to the surface waters. These organisms contain a complex neurotoxin which can have disastrous effects on fish and other organisms. While some forms, particularly bivalve molluscs, are immune to the toxin themselves, they tend to store it in their tissue, sometimes for long periods, and transmit it to higher trophic level predators which feed on them. Some of these higher predators, such as the sea otter, have evolved immunity systems; others, such as man, have not. Along the California coast certain bivalves, particularly mussels (*Mytilus*, sp.) are known to be toxic during the summer months.

Human-induced perturbations. Human-induced perturbations are myriad and often complex in both source and effect. A few of the many will be listed below.

Fisheries. Fisheries for human consumption tend to concentrate on the higher trophic levels, and are generally rather species selective. Frequently, these upper trophic level species are among the least productive in the ocean in terms of reproductive capacity, and consequently possess less recovery potential than do species lower on the trophic scale. In addition, commercial fisheries tend to concentrate their efforts on the larger and more reproductively viable size classes of these populations, augmenting the removal effect. This removal or reduction of a particular element of the trophic system can lead to overpopulation by species which would normally be cropped and kept within bounds by the removed consumer, sometimes resulting in long-term alterations of the trophic structure and nutrient exchange system. In some cases, these overfished populations will recover once fishing pressure is removed due to economic or legislative reasons. Sometimes, however, the overfished species do not recover but are replaced by other less desirable species occupying the same or similar trophic position.

An example of such overfishing is the case of the California sardine, which was subjected to such commercial pressure, probably combined with environmental changes, in the 1940's that its populations declined and failed, and was replaced by the less commercially desirable anchovy.

Chemical Pollution. Municipal and industrial effluents, which are frequently discharged into rivers leading to the sea or directly into the sea itself, commonly contain chemical compounds which have adverse toxic effects on one or more components of the trophic system. Effects can range, depending on the type of toxicity and magnitude of discharge, from complete disruption of trophic systems or even sterilization of local habitats to the rendering of commercial species unfit for human

(or other) consumption. The widespread use of the chemical pesticides which eventually find their way to the ocean is another major contributor to such chemical pollution.

Organic Pollution. Organic wastes, including municipal sewage discharge and effluent from industries such as pulp and paper mills, affect the marine environment in several ways. Organic effluents are generally unesthetic in nature. If the effluents are of sufficient magnitude relative to the local system into which they are introduced, and if they contain a high percentage of particulate matter, the increased turbidity of the water column may inhibit light penetration into the euphotic zone to such an extent that primary productivity is inhibited. This turbidity effect is probably exacerbated by the fact that most discharges are carried by fresh water, which remains on the surface due to its lower density. The introduction of these dissolved and particulate organics may result in heightened local nutrient availability and in some cases increased primary productivity, frequently with undesirable consequences. Another common result of organic pollution, particularly in enclosed waters of restricted circulation, is the increased oxygen demand resulting from the oxidation of these organics. In severe cases, this dissolved oxygen demand can render the water column, or parts of it, anoxic and uninhabitable.

Thermal Pollution. Discharges into the marine environment of heated effluents and coolant water from nuclear and fossil fuel power plants can have adverse effects on local habitats. These thermal effluents can raise or lower ambient water temperatures creating local disturbances and rendering natural habitats uninhabitable by normally endemic species and altering the species composition and trophic structure.

Radioactive Pollution. Little can be said about the long-term effects of radioactive wastes, the results of weaponry development, thermonuclear energy plants, and medical radiation, except that they are probably not beneficial. At a sufficiently intense level, radioactivity can result in the sickness and death of exposed organisms; at lower levels it may result in sterility or genetic mutations of unpredictable character. Bioaccumulation at chronic levels may often have a more long-lasting effect on the trophic structure (leading to man) than acute exposure.

Physical Disturbances. Direct physical perturbations of the nearshore marine habitat, such as channel and port dredging, construction of breakwaters, piers, and structures such as offshore oil platforms, result in obvious mechanical disturbances and transformations of the local habitat. Long-term alteration of current and circulation patterns may also occur as a result of nearshore construction. Such activities may also increase the turbidity of the water column, with the same detrimental results that apply to organic pollution. Agricultural practices, fires, and major construction projects on land also frequently result in increased erosion and sediment transport into the nearshore marine system. These sediments have a smothering effect on benthic organisms, inhibit primary productivity through increased water turbidity, and in some cases retard the pelagic larval development of certain species.

Another practice of this category which impacts the marine system is the filling of shallow bays and estuaries for housing or industrial development, thus effectively removing them from the marine system. Though rather insignificant in terms of relative area, these habitats are sometimes of critical importance as spawning and nursery grounds for numerous marine species, including anadromous fish. Anadromous fish populations may also be adversely affected by stream channelization, dam construction, and general degradation of water quality.

Oil Pollution. Of all types of man-caused pollution, marine oil spills probably receive the greatest media attention. Such spills may originate through catastrophic accidents such as shipwrecks and collisions, pipeline breaks, or wellhead "blowouts". Oil pollution may also be less dramatic but more chronic character, resulting from slow leakage of offshore well and transfer systems, industrial and municipal waste discharge, and flushing of ballast water by tankers at sea.

The effects of oil pollution are numerous. Some of them, such as the mortality inflicted on marine birds and intertidal organisms, are readily apparent, while others are less obvious. The toxicity of petroleum products, either crude or refined, depends to a considerable extent on its composition, with the lighter, more volatile fractions proving more toxic, though less physically obnoxious, than the heavier components. Irregardless of the nature of the spill, however, some chemical toxicity will probably ensue and can affect all levels and types of marine organisms from primary productivity to pelagic and benthic consumers. In the past, these toxicity effects have frequently been compounded by the use of dispersal agents, such as detergents, in cosmetic

attempts to "clean up" spills. Many organisms, primarily bacteria, will feed upon and degrade hydrocarbons such as oil if left to do so naturally. The rate at which such biological breakdown takes place depends to a large extent on the biotic environment, the temperature of the water column, and the composition of the oil. Oil also undergoes chemical decomposition and weathering.

Since oil floats, its heaviest impact is felt in the near surface layers and in the intertidal. In both cases oil exerts a smothering effect in addition to its toxic properties, interfering with animal respiration and gaseous air/sea interchange?, and inhibiting primary productivity through both toxicity and light occlusion.

Summary. Because of the upwelling within the California Current system, the nearshore marine environment of the California coast supports some of the richest biological communities, in terms of productivity and standing stock, in the world ocean. Estimates of primary productivity for the northern California nearshore system are much greater than those estimated for the Central Pacific. Other comparable systems, supporting primary productivity estimates similar to those of the California Current, are similar eastern boundary current/upwelling systems off the west coasts of South America and Africa.

This high level of sustained primary productivity supports increased copulations of heterotrophs at all levels of the food web within both the pelagic and benthic environments. It also results in a general shortening or short-circuiting of the food web, permitting the maintenance of larger standing stocks of predatory forms such as pelagic and demersal fish, large benthic invertebrates, and marine birds and mammals. Several of these species are of direct commercial interest to man, and support major fishing industries. Obviously, the disturbance of any level of the productivity system or food web will ultimately be reflected at these higher levels.

Features and Processes of Special Significance to Intertidal Habitats. At the interface of the land and sea, some of the physical-chemical processes and biological features identified in the marine ecosystem model become a more significant force in the operation of the ecosystem.

All the intertidal habitats can be understood as resulting from the interaction between the continental and oceanic forces of erosion and deposition with an additional and significant influence by the very active tectonic movements along the California coast. In general, the oceanic forces attempt, by eroding headlands and filling in embayments, to straighten the interface along which water and land meet, while the continental forces are constantly changing that interface with tectonic activity, erosion, and deposition. Any single feature along the coast can be understood, morphogenically, in these terms.

The tendency of wave and current action is to straighten and simplify the land-water interface. Consequently, wave force is concentrated by refraction onto seaward projecting points and reduced on the shores of less exposed areas (Figure 4-9).

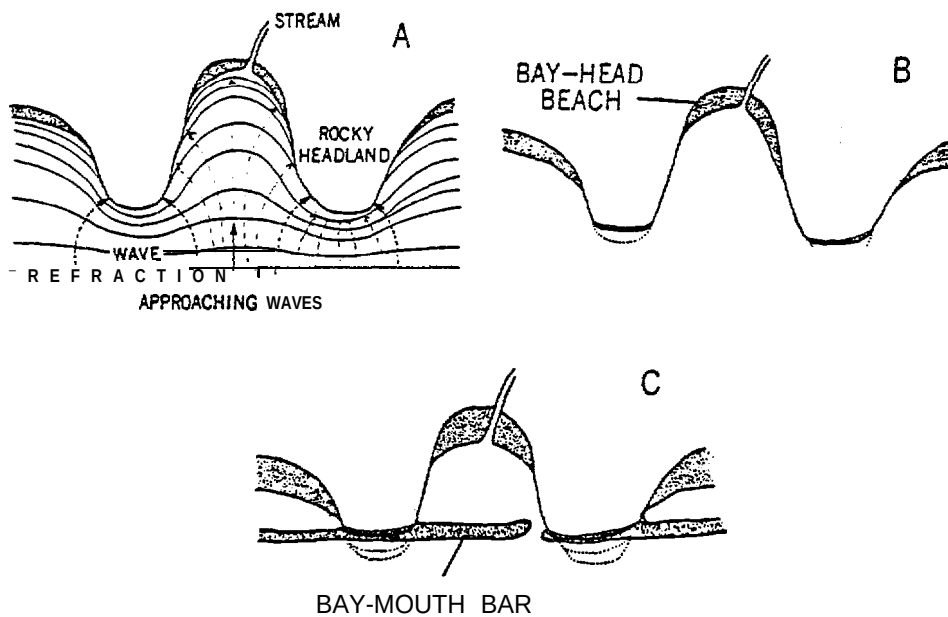


Figure 4-9. Rocky Promontories are Straightened by Wave Refraction.
 A. Deep-Water Waves Turn As They Approach Headlands, and Their Energy is Focused on the Projecting Points;
 B. Wearing Them Down and Creating Beaches;
 C. In Time, the Headlands Are Cut Back So Much That Extensive and Continuous Beaches Are Formed (modified from Bascom, 1964).

If these forces were the only ones to affect the coast, or if they were permitted to proceed uninterrupted for long periods, the results would be a smooth coast line. Due to refraction, the wave shock applied to coastal indentations is reduced to the point where deposition of both suspended and transported materials occurs, resulting in the common pocket beaches of the central California coast.

The erosional capabilities of wave action are applied by hydraulic and pneumatic pressure, abrasion, and corrosion. Resident organisms are adapted in various ways to these powerful forces. The strong wave action so characteristic of the coast is instrumental in developing another characteristic of these habitats that make them so organically abundant, the incorporation and availability of dissolved oxygen. Along the exposed intertidal habitats availability of oxygen is not a limiting factor for organisms except under the dessicating effects of long exposure.

Current activity exhibits its primary importance by supplying the general physical characteristics and wave generated longshore currents for the ocean waters of this region as discussed in Volume II, Part 1 of this report. The seasonal variations between the California Current (southward flowing surface current) and the Davidson Current (northward flowing surface current) are noted for their principle influences on the seasonal and endemic distribution and abundance of marine intertidal organisms.

Currents, while not having direct effect on the morphology of the coast are, however, the primary cause of another feature so important to the organisms in the intertidal habitats, the availability of dissolved nutrient minerals. Other than the recognizable and named current flows (Volume II, Part 1), the numerous density and temperature variations and eddy effects along the highly irregular coast result in abundant upwelling of nutrient-rich colder waters from depth. Temperatures are generally in colder ranges, permitting a higher percentage of dissolved nutrients and gasses than found in warm areas, again resulting in the biologic abundance so characteristic of the area.

The most characteristic feature of the intertidal habitats and the one prescribing the limiting factors for the organisms found here is its zonation. Zones have been designated in many ways; the designation used in this outline is that developed by Ricketts and Calvin (1968), (Figure 4-10).

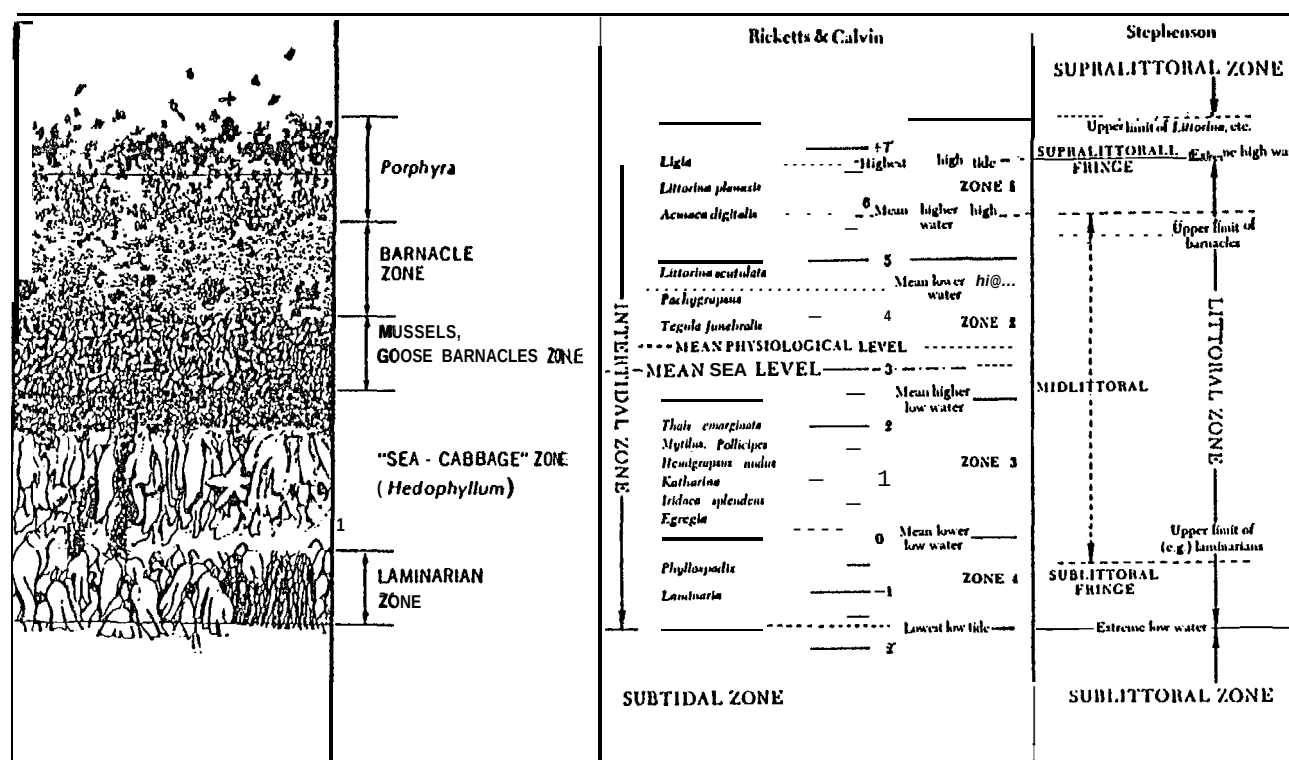
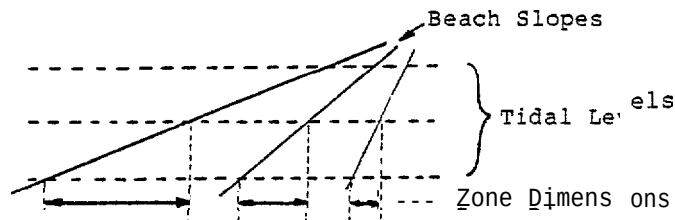


Figure 4-10. A Comparison Of Different Generalized Schemes of Intertidal Zonation. The Actual Heights Given Apply Only To the Ricketts and Calvin System; Other Systems Are Measured From the Points Shown (High-tide Average, Upper Limit of Barnacles, etc.) . (Adapted From Ricketts and Calvin, 1968; Carefoot, 1977)

The zones are determined at any one point by the interaction of the slope of the shore and the height of the tides. Shores of gentler slope will have relatively broader zonal boundaries than steeper slopes; greater tidal fluctuation will also result in broader zones.



The various zonal habitats are characterized foremost by differences in duration of exposure to air and degree of exposure to wave action. These and other environmental factors (Table 4-1), fluctuating as the tides ebb and flood in cyclic rhythm, are the limiting factors to which the life of the intertidal must adapt.

These tidal fluctuations will result in varying durations exposed to atmospheric conditions, possibly the most critical set of environmental parameters to which the organisms of these zones must adapt. This factor is well illustrated below (Figure 4-11).

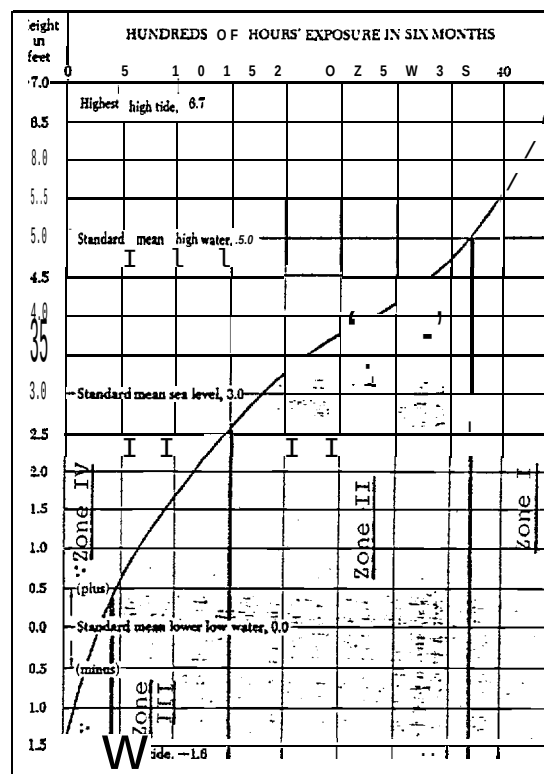


Figure 4-11. Hundreds of Hours' Exposure to the Atmosphere in Six Months (modified from Ricketts and Calvin, 1968)

Tides typical of the eastern border of the Pacific Ocean are noted to occur in a mixed, predominantly semidiurnal form. This means that the organisms of the intertidal region will experience two 'high and two low tides of fluctuating heights within a 24-hour period.

Table 4-1. Factors Affecting Intertidal Zonation
(modified from Dawson, 1966a)

- A. Physical factors
 - 1. light
 - a. intensity (varying with latitude, tidal exposure, solar exposure, cloud cover, biological overshadowing)
 - b. quality (varying with water depth, transparency, tidal amplitude)
 - c. periodicity (daily; seasonal)
 - 2. substrata
 - a. solidarity (bedrock, cobble, gravel, sand, mud)
 - b. texture (penetrability or suitability for attachment)
 - c. porosity (water-holding capacity)
 - a'. with regard to water availability (tidal flooding, wave wash, splash,
 - b'. with regard to wave shock or disturbance
 - c'. with regard to cobble scour
 - d'. with regard to retention of pollutants
 - d. volubility and/or erosibility
 - e. color (with regard to intertidal heat absorption, radiation and reflection)
 - f. chemical composition
 - 3. temperature
 - a. seawater temperature
 - a'. annual variation
 - b'. duration of maximum and minimum
 - c'. diurnal variation
 - d'. stratification; with respect to tides, mixing of nutrients, etc.
 - b. air temperature during intertidal exposure
 - a'. annual variation
 - b'. duration of maximum and minimum
 - c. direct heat of insolation (complete exposure; tidepool exposure)
 - 4. relative humidity (with respect to organisms subject to exposure)
 - a. seasonal variation in conjunction with exposure
 - b. duration of minimum coincident with maximum exposure temperature
 - 5. rain
 - a. seasonal extent coincident with tidal exposure
 - b. maximum duration
- B. Chemical factors
 - 1. salinity
 - a. annual variation from runoff
 - b. tidal fluctuation of the halocline
 - c. maximum concentration from evaporation during exposure
 - 2. availability of dissolved oxygen during dark-hour respiration
 - 3. availability of nitrogen, phosphorus and other essential metabolic substances
 - 4. availability of free carbon dioxide for photosynthesis
 - 5. pH (mainly significant in confined pools subject to marked increases during active photosynthesis)
 - 6. pollution
 - a. by natural marine organisms
 - b. by waste products of human activity
- C. Dynamic factors
 - 1. water movement
 - a. wave shock
 - b. ocean currents
 - c. tidal fluctuation and currents
 - d. maximum severity of annual storms or hurricanes
 - e. upwelling
 - f. extent of surface chop vs. calm
 - 2. tidal exposure (period and amplitude)
 - 3. tidal rhythm (with respect to release of reproductive bodies)
 - 4. wind (with respect to coincidence with exposure)

Table 4-1, (cent)

- D. Biological factors
 - 1. active predation and competition for available food
 - 2. grazing pressure on plant
 - 3. fungal and microbial activity
 - 4. competition for substrata
 - 5. protective cover against desiccation during exposure
 - 6. light restriction by overgrowth (either by macroscopic or microscopic forms)
 - 7. availability of host plants or animals for obligately eipphytic, endophytic, epizootic, endozootic, and parasitic organisms.

Zones are also affected by their orientation to the predominant wave direction (exposure). The diagram below (Figure 4-12) illustrates the broader nature of zones receiving the impact of waves due to the increased wetting and aeration under those conditions and the consequent broadening of ranges of the intertidal animals that "work" the zones.

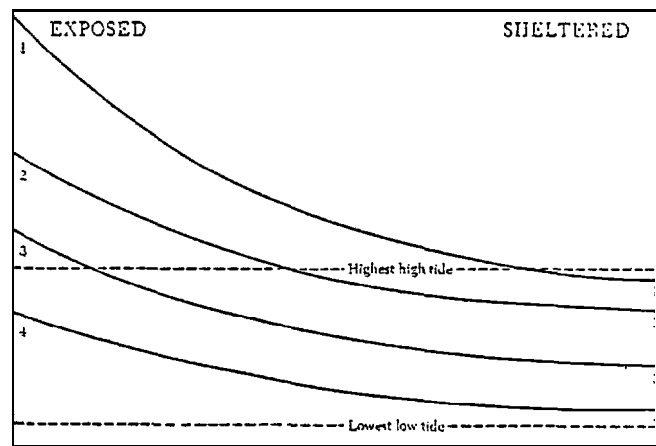


Figure 4-12. Intertidal Zones are Displaced Upward as One Proceeds Toward the More Exposed Part of the Coast: Such A Displacement Is Often Seen on Rocky Headlands (Ricketts and Calvin, 1968)

The flow of energy and material through the marine intertidal is presented diagrammatically in Figure 4-13. This illustration separates the primary producers and levels of consumers, while exhibiting its complexly interconnected constituents. Though this is only a general representation showing the possible interactions within the littoral region of the marine environment, a more specific breakdown of these trophic levels are discussed in the zonal descriptions of the Rocky Shore habitat. It should be noted, too, that the influence of any one of the factors discussed here depends on its interaction with and modification by other factors, and the importance of each of these factors varies in its impact on different intertidal species.

Hierarchical Classification of Subsystems

Cowardin et al (1979) devised a classification scheme for the deepwater and wet-land habitats of the United States. To better apply this system to northern and central coastal California, a few modifications were necessary in the marine ecosystem classification. A simple schematic of the classification system (Figure 4-14) shows the habitats of the subtidal benthic and intertidal are based on substratum type. Cowardin et al (1979), however, did not define the pelagic zone of the marine system. The pelagic zone as redefined here will be discussed as a subsystem, corresponding to subtidal and intertidal subsystems (which are based on substratum). The pelagic subsystem will not be refined to habitat level because of the difficulty in assigning specific depths to vertical and horizontal species distributions and biological processes.

Pelagic Habitat Type. The entire water column from the air-sea interface to the sea floor is considered to be in the pelagic realm. The pelagic habitat type is described in terms of ecological zones that vary with water transparency, temperature, and depth. Primary production occurs primarily in the aphotic (lighted) zones by phytoplankton (small planktonic (drifting) plants able to fix solar energy by photosynthesis). Characteristic phytoplankton include: Chaetoceros spp., Nitzschia spp., Ceratium spp., and Peridinium spp. Zooplankton (small planktonic animals) present in great numbers include: copepods, thaliaceans (salps), euphausiids (krill), and chaetognaths (arrow worms). Ichthyoplankton (planktonic fish larvae) are represented by juvenile rockfish (Sebastes spp.), Pacific hake (Merluccius productus), northern

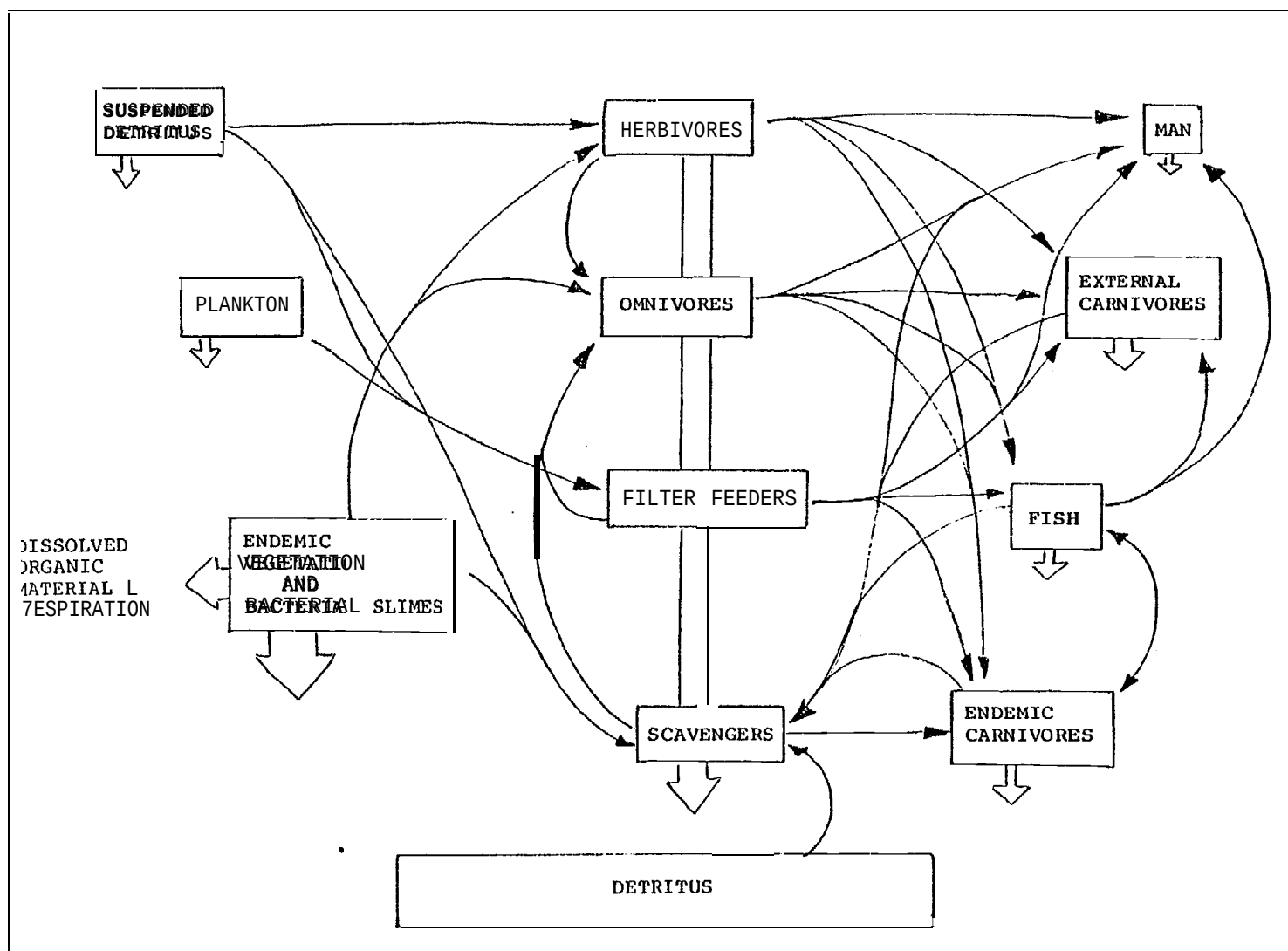


Figure 4-13. Flow of Energy and Materials Through the Marine Intertidal Zone

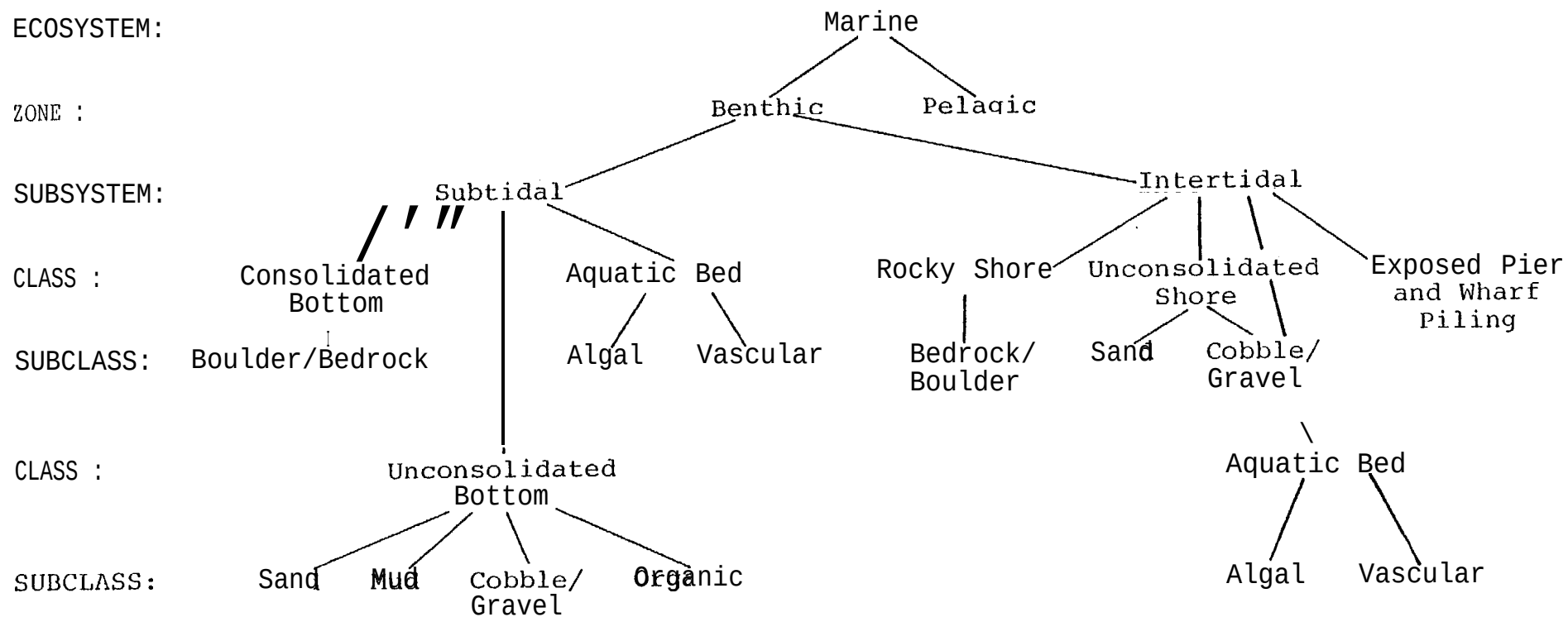


Figure 4-14. Hierarchical Classification of Marine Habitats
(Modified from Cowardin et al, 1979)

anchovy (Engraulis mordax), and sanddabs (Citharichthys spp.). The adults of these species (nekton-swimming forms, the term also includes squid and mammals) are important in the pelagic food web as well as having commercial importance. Sharks, albacore (Thunnus alalunga), Pacific sardine (Sardinops sagax) and salmon species (Oncorhynchus spp.) are also important components of the pelagic habitat. Squids (cephalopods) are important as predators and forage organisms. Marine mammals (except for baleen whales which filter feed zooplankton), feeding on fish and squid, have a direct impact on pelagic food webs when they are present in abundance. Humans have both a direct (a tertiary consumer utilization of the pelagic habitat for food source) and indirect (local alteration of pelagic habitat by construction, waste disposal and thermal effluent) impact on pelagic food webs.

The pelagic habitat, as it occurs off the coast of California is heavily influenced by the southward flowing California Current. This cooler subarctic water creates an ecotone of biological components from different biotic provinces, primarily cooler water species. Occasionally warm water species from the southern province are found in the region, but normally the species are similar to species found in Oregon and Washington.

Subtidal Habitat Types.

Submerged Algal Beds. Submerged algal beds occur below MLLW (mean-low-low-water line) grow attached to rock bottoms or other submerged hard substratum and are not often found on mud or sand substratum. They are extremely substratum-specific and are restricted by low light penetration at depths greater than 30 meters. Characteristic canopy species include giant kelp (Macrocystis pyrifera), and the bull kelp (Nereocystis luetkeana), and lower story species such as Laminaria spp. and coralline red algae. Common associated invertebrates include snails (Tegula spp.), crabs (Pugettia products), abalones (Haliotis spp.), and sea urchins (Strongylocentrotus spp.). Associated fish include: the kelp greenling (Hexagrammos decagrammus), lingcod (Ophiodon elongatus), kelp bass (Paralabrax clathratus), and rockfish (Sebastes spp.). The sea otter (Enhydra lutris) is commonly found near kelp beds within its range, consuming the benthic herbivores. The presence of the sea otter may affect the success of the community (reduced numbers of herbivores result in increased plant production). Submerged algal beds occur along the coast of central and northern California where suitable substratum, light penetration, and fewer benthic herbivores occur.

Submerged Vascular Plants. Three species of vascular plants are found along the coast of California. Zostera marina (eel grass) occurs in bays and estuaries and anchors itself in muddy substratum. Phyllospadix scouleri and P. torreyi (surf grasses) occur along the outer coast where they form extensive intertidal communities attached to rock or hard substratum at about the MLLW (0.0 foot) tidal level. There are no well-defined subtidal populations of these flowering plants along the outer coast of northern or central California (Turhollow, pers. comm.). Isolated subtidal individuals occur down to 10 meters depth, but not in dense enough numbers to describe as a habitat type. Subtidal populations of Phyllospadix do occur south of Point Conception and are important as nurseries for lobsters, sediment traps, and as sources of plant detritus. Refer to the intertidal and estuarine sections for the biology and distribution of marine angiosperms along northern and central California.

Unconsolidated Bottom - Sand. Sand habitats occur from the MLLW tidal datum to approximately 100 meters depth. Sand of varying particle size is the prevalent nearshore bottom type along the California coast. It is often interspersed with bedrock and boulder substratum. Dominant species are characteristically infauna (the polychaete tube-worms Diopatra ornata and Nothria elegans) with some epifaunal communities (e.g., sand dollars (Dendraster excentricus)). Infaunal species are directly associated with sediment type and grain size which determines compactness of the substratum. The Dungeness crab (Cancer magister), short-spined sea star (Pisaster brevispinus), and fish species including sanddabs (Citharichthys spp.), California halibut (Paralichthys californicus), the starry flounder (Platichthys stellatus), are commonly associated with sand substratum.

Unconsolidated Bottom - Mud. Mud habitats are found generally at depths greater than 100 meters along the shallow continental shelf but also occur in bays and estuaries. Input into the marine system is primarily via river mouths and deltas which can form terraces down to 100 meters. Characteristic fauna include infaunal communities: an echiurid worm (Listriolobus pelodes), acorn worms (Enteropneusts), and brittle stars (ophiuroids). Fish associated with the mud habitat are similar to those found in sand habitats: the dover sole (Microstomus pacificus), curlfin turbot (Pleuronichthys decurrens), petrale sole (Eopsetta jordani), and rockfish (Sebastes spp.). The Pacific haddock (Eptatretus stouti) is found only on mud bottoms. Mud habitats are characteristically at great depths (greater than 100 meters), creating difficulties in studying these communities.

Unconsolidated Bottom- Organic. Cowardin et al (1979) describe the subclass "organic" as unconsolidated material smaller than stones, predominantly composed of organic material. The subtidal benthic regions (excluding enclosed bays and estuaries) that have greater than 50 percent organic material occur outside of the present study area (below 1000 meters depth and/or outside of central and northern California). The subtidal organic material in the study area is a component of the substratum rather than a benthic habitat in itself.

Unconsolidated Bottom - Cobble/Gravel. The cobble/gravel habitat consists of unconsolidated substratum particle sizes from 2 mm to 25.4 cm. Cobble and gravel are normally associated with a mixture of sand and silt and are characteristic of high energy beaches or areas of river deposition (Komer, 1976; Shepard, 1963).

Cobble/gravel substrata are uncommon in the study area and generally contain few species or organisms. The particles are too large to provide habitat for infauna, and the species found in these areas are similar to boulder habitat species. Mechanical disturbance of the habitat often prevents establishment of stable or breeding populations. It is only when cobble/gravel substrata are intermixed with fine sediments that a habitat can be described, and this is infrequent along the central and northern California coast.

Consolidated Bottom - Bedrock/Boulder. Bedrock and boulder habitats contain essentially similar species and trophic relationships. Differences between these habitats are based on the degree of movement of the substratum. Bedrock is stationary, except when it gets broken up by heavy surge and wave action, then it becomes boulders. By virtue of its definition, this habitat is limited by light penetration and accumulation of unconsolidated substrata. In rocky areas of adequate light penetration the resultant algal cover defines submerged algal beds. Areas of greater than 25 percent unconsolidated sediments are defined as unconsolidated bottom.

The rock bottom along the central and northern California coast consists of granitic and sedimentary substrata. Except in areas of less than 30 percent algal cover, there are no primary producers on rock bottoms, and the community is dominated by encrusting suspension feeders. These suspension feeders rely on drifting phytoplankton and zooplankton and detritus as sources of energy. Water movement is an important physical parameter for rock bottom communities, as it serves not only to transport food and nutrients to the organisms and wastes away, but also, at its maximum extreme, may serve to abrade them with suspended sediments, or the case of boulder, may disturb the substratum to the extent that organisms may be destroyed.

Communities living on boulders can be heavily influenced by sand scouring, abrasion, and physical movement (proportional to size of boulder). Often boulders will be devoid of any organisms except for some encrusting coralline algae. In areas of little water movement (protected bays or coves), the boulders are stationary, and communities similar to bedrock communities are established. In other aspects, the boulder habitat is as described above for bedrock.

Intertidal Habitat Types

Unconsolidated; Sand. Intertidal sand habitats are characterized by few organic indications of zonal differentiation, the faunas being mostly burrowing forms, and few algae being able to secure attachment in the shifting substratum. Nonetheless, there are interstitial algae that provide some of the nutrient for the common burrowing polychaet Euzonus, the blood worm. The other most common inhabitant of this habitat is the mole crab (Emerita analoga) which varies its location with tidal fluctuation and feeds on suspended materials. Other species such as the Pismo clam (Tivela stultorum) may be locally abundant. Scavengers are also prevalent in the form of beach hoppers (Orchestoidea spp.). The ecology of the sand beaches depends on nutrient input from outside the habitat. Beaches are subject to loss or addition of materials depending on both natural and human factors and are in constant motion. Sand is classed as particles of from .07 millimeters to 5 millimeters in diameter and the coarseness of a particular beach is also dependent on several factors.

Unconsolidated; Cobble/Gravel. Just as sand coarseness is dependent on various factors, so, too, is the presence of particles of coarser nature. Gravel (5 millimeters to 76 millimeters) and cobbles (76 millimeters to 256 millimeters) are relatively uncommon constituents of California beaches and flats. This is because the particles of such size are subject to rapid erosion to sand size by the active oceanic forces. Also due to these active forces and the grinding of gravels and cobbles, there is little established biota on this type of beach. The only organisms to be found will probably be scavengers making use of the abundant flotsam and detritus deposited by wave and current action.

Rocky Shore; Boulder/Bedrock. Rocky shores are the other major constituent of California coasts along with sandy beaches. The stability of this habitat type provides substrata suitable for a diverse and prolific array of intertidal forms. Zonation is particularly marked in this habitat, various organisms adapted to the various physical parameters presented in the zones. Zones are a function of tidal cycles and represent various degrees of exposure to the numerous forces and effects of the land-sea interface. Algae become abundant from zone 2 and animals of wide variety make use of the hard, stable substrate. The commonest fauna includes Mytilus californianus, Balanus spp.; Pisaster spp., and numerous gastropod. However, representatives of all major and most minor phyla are also represented.

Exposed Pier and Wharf Pilings. Piers and wharfs of either wood or concrete are not common elements of exposed coasts, but where they do occur, they provide a substratum for typical intertidal organisms. In addition, because of the softer nature of the materials, boring organisms are added to the faunal lists. These would include Limnoria and Teredo in wood pilings and Adula and Penitella in concrete. When the typical intertidal biota attaches to the man-made structures they become "fouling organisms" and millions are spent in attempts to clear the structures or prevent settling with various types of protective coatings, none completely successful.

Major Marine Species

The species of concern selected for the marine habitats are identified in Tables 4-2 and 4-3. The reason for selection has been indicated. The criteria include legal protected status, commercial value, recreational value or ecological significance. A species account of each listed species as well as a more detailed account of the selection criteria are included in Volume II, Part 2 of this report.

Major Ecological Areas

Criteria for Selection. Twenty-six areas of ecological concern have been designated in northern and central California coastal intertidal habitats. They are listed in Table 4-4 in order of decreasing latitude between the California-Oregon border and Point Conception. Each area of ecological concern is included in one or more categories of special or protected values and uses, and all are under some degree of jurisdiction by government agencies. These relationships are also shown in Table 4-4.

Figure 4-15 shows the approximate locations of the areas of ecological concern along coastal northern and central California. Detailed locality maps accompany the individual descriptions of the areas of ecological concern.

Northern and central California coastal intertidal areas of ecological concern generally are in ecological reserves, fish and game refuges, marine life refuges, and areas of special biological significance established pursuant to statutes of the State of California. Redwood National Park, the King Range National Conservation Area, and the Point Reyes Headlands vicinity are federal preserves, but the nearshore waters and aquatic habitats are protected under a state program for areas of special biological significance. Similarly, the Farallon Islands Game Refuge, jointly administered by the California Department of Fish and Game and the U.S. Fish and Wildlife Service, is an area of special biological significance.

Ecological Reserves. The California Fish and Game Commission has established ecological reserves for the purpose of protecting rare and endangered species of wildlife or aquatic organisms or specialized habitat types. The California Fish and Game Code refers to ecological reserves as land and water areas preserved in a natural condition for the benefit of the general public to observe native flora and fauna and for scientific study. Special provisions for specific areas are cited in the individual accounts of areas of ecological concern contained within the basin reports of Volume IV. The taking of plant and animal life and disturbing geological formations in ecological reserves is generally prohibited. Sport angling from shore is allowed under state-wide fishing regulations.

Ecological reserves are administered by the California Department of Fish and Game in accordance with the California Fish and Game Code (Sections 1580-1584) and Title 14 of the California Administrative code (Chapters 3,11).

Legal descriptions of the boundaries of ecological reserves, maps, and other details are given in Smith and Johnson (1971).

Table 4-2. Status of Important (X) Pelagic and Subtidal Benthic Species

Common Name	Scientific Name	Habitat	Geographical Distribution	Rare, Threatened, Endangered, or Fully Protected	Commercial	Recreational	Ecological Interest
<u>Marine Mammals</u>							
Southern sea otter	<u>Enhydra lutris nereis</u>	Neritic	North Pacific and California coast (Monterey Bay south to Estero Bay)	X			X
Sperm whale	<u>Physeter catodon</u>	Pelagic	Cosmopolitan	X			
Gray whale	<u>Eschrichtius robustus</u>	Neritic	North Pacific	X			
Blue whale	<u>Balaenoptera musculus</u>	Pelagic	Worldwide	X			
Fin whale	<u>B. physalus</u>	Pelagic	Worldwide	X			
Sei whale	<u>B. borealis</u>	Pelagic	Cosmopolitan	X			
Humpback whale	<u>Megaptera novaeangliae</u>	Neritic	Cosmopolitan	X			
Right whale	<u>Balaena glacialis</u>	Pelagic	Cosmopolitan	X			
Northern elephant seal	<u>Mirounga angustirostris</u>	Neritic	Farallon Islands, California to San Benito Island, Mexico	X			
California sea lion	<u>Zalophus californianus</u>	Neritic	Southern British Columbia to Mexico				X
Guadalupe fur seal	<u>Arctocephalus townsendi</u>	Neritic	Farallon Islands, California to San Benito Island, Mexico	X			
Stellar sea lion	<u>Eumetopias jubata</u>	Neritic	Bering Sea to Southern California and Eastern Pacific to Sanriku				X

Table 4-2. Status of Important (X) Pelagic and Subtidal Benthic Species (continued)

Common Name	Scientific Name	Habitat	Geographical Distribution	Rare, Threatened, Endangered, or Fully Protected	Commercial	Recreational	Ecological Interest
<u>Pelagic/Nearshore Birds</u>							
Short-tailed albatross	<u>Diomedea albatrus</u>	Pelagic	Selected locations, eastern Pacific coast, Calif. coast	X			
Ashy storm-petrel	<u>Oceanodroma homochroa</u>	Pelagic	California and Northern Baja California				X
Sooty shearwater	<u>Puffinus griseus</u>	Pelagic	Worldwide				X
California brown pelican	<u>Pelecanus occidentals Californicus</u>	Nearshore, nests off-shore islands	Eastern and western coasts of North and South America	X			
Aleutian Canada goose	<u>Branta candensisleucopareia</u>	Offshore rocks, terrestrial	Aleutian Islands south to northern and central California	X			
<u>Fishes</u>							
Sablefish	<u>Anoplopoma fimbria</u>	Pelagic	Baja California to Bering Sea and Japan		X		
Sanddabs Pacific Speckled Longfin	<u>Citharichthys sordidus stigmaeus xantostigma</u>	Benthic	Baja California to SE Alaska; Longfin rare north of Point Conception		X	X	X
Northern anchovy	<u>Engraulis mordax</u>	Pelagic	From Baja California to British Columbia; most common from Magdalena Bay to San Francisco		X	X	

Table 4-2. Status of Important (X) Pelagic and Subtidal Benthic Species (continued)

Common Name	Scientific Name	Habitat	Geographical Distribution	Rare, Threatened, Endangered, or Fully Protected	Commercial	Recreational	Ecological Interest
<u>Fishes (continued)</u>							
Pacific halibut	<u>Hippoglossus stenolepis</u>	Benthic	Santa Rosa Island around North Pacific to Japan		X	X	
Pacific hake	<u>Merluccius productus</u>	Pelagic	From Baja California to Bering Sea		X		
Lingcod	<u>Ophiodon elongatus</u>	Neritic	Baja California to Alaska		X	X	
California halibut	<u>Paralichthys californicus</u>	Neritic	Magdalena Bay to British Columbia; common only south of Tomales Bay		X	X	
Dark-blotched rockfish	<u>Sebastes crameri</u>	Neritic	Santa Monica Bay to Bering Sea		X	X	X
Splitnose rockfish	<u>Sebastes diploproa</u>	Neritic	Baja California to Alaska		X	X	X
Widow rockfish	<u>Sebastes entomelas</u>	Neritic	Baja California to Alaska		X	X	X
Yellowtail rockfish	<u>Sebastes flavidus</u>	Neritic	San Diego to Kodiak Island, Alaska		X	X	X
Chilipepper	<u>Sebastes goodei</u>	Neritic	Magdalena Bay to British Columbia; most south of Eureka		X	X	X
Shortbelly rockfish	<u>Sebastes jordani</u>	Neritic	Baja California to Vancouver, British Columbia		X	X	X
Vermilion rockfish	<u>Sebastes miniatus</u>	Neritic	Baja California to Vancouver, British Columbia		X	X	

Table 4-2. Status of Important (X) Pelagic and Subtidal Benthic Species (continued)

Common Name	Scientific Name	Habitat	Geographical Distribution	Rare, Threatened, Endangered, or Fully Protected	Commercial	Recreational	Ecological Interest
<u>Fishes (continued)</u>							
Bocaccio	<u>Sebastes paucispinis</u>	Neritic	Baja California to Alaska		X	X	
Canary rockfish	<u>Sebastes pinniger</u>	Neritic	Baja California to SE Alaska		X	X	
Stripetail rockfish	<u>Sebastes saxicola</u>	Neritic	Baja California to SE Alaska		X		X
Albacore	<u>Thunnus alalunga</u>	Pelagic	Baja California to SE Alaska		X	X	X
Bluefin tuna	<u>Thunnus thynnus</u>	Epipelagic	Tropics to Gulf of Alaska; rare north of point Conception		X	X	
Swordfish	<u>Xiphias gladius</u>	Pelagic	Chile to Oregon		X		
<u>Plants</u>							
Giant kelp	<u>Macrocystis pyrifera</u>	Benthic consolidated	Madgalena Bay to Alaska		X	X	X
Bull kelp	<u>Nereocystis luetkeana</u>	Benthic	San Luis Obispo County to Alaska				X
<u>Coelenterates</u>							
Orange cup coral	<u>Balanophyllia elegans</u>	Benthic consolidated	Baja California to Puget Sound				X
Strawberry anemone	<u>Corynactis californica</u>	Benthic consolidated	San Diego to Salt Point				X

Table 4-2. Status of Important (X) Pelagic and Subtidal Benthic Species (continued)

Common Name	Scientific Name	Habitat	Geographical Distribution	Rare, Threatened, Endangered, or Fully Protected	Commercial	Recreational	Ecological Interest
<u>Coelenterates (continued)</u>							
Brown cup coral	<u>Paracyathus stearnsii</u>	Benthic consolidated	Baja California to British Columbia				X
<u>Marine Worms</u>							
Ornate tube worm	<u>Diopatra ornata</u>	Benthic unconsolidated	Baja California to Vancouver island, British Columbia				X
Sand tube worm	<u>Phragmatopoma californica</u>	Benthic consolidated	Baja California to Fort Bragg, California				X
Echiurid worm	<u>Listriolobus pelodes</u>	Benthic unconsolidated	South America to Monterey, California				X
<u>Molluscs</u>							
Red abalone	<u>Haliotis rufescens</u>	Benthic consolidated	Baja California to Sunset Bay, Oregon		X	X	
Black abalone	<u>Haliotis cracherodii</u>	Benthic consolidated	Baja California to Oregon		X	X	
Flat abalone	<u>Haliotis walallensis</u>	Benthic consolidated	La Jolla, California to British Columbia		X	X	
Pinto abalone	<u>Haliotis kamtschatkana</u>	Benthic consolidated	Point Conception to Sitka, Alaska		X	X	

Table 4-2. Status of Important (X) Pelagic and Subtidal Benthic Species (continued)

Common Name	Scientific Name	Habitat	Geographical Distribution	Rare, Threatened, Endangered, or Fully Protected	Commercial	Recreational	Ecological Interest
<u>Molluscs</u> (continued)							
Rock scallop	<u>Hinnites giganteus</u>	Benthic consolidated	Baja California to Aleutian Islands			X	
Market squid	<u>Loligo opalescent</u>	Pelagic	Central Baja California to Vancouver Island		X		X
<u>Crustaceans</u>							
Copepods	<u>Calanus</u> spp.	Pelagic	NE Pacific				X
Dungeness crab	<u>Cancer magister</u>	Benthic unconsolidated	Baja California to Aleutian Islands		X	X	
Euphausiids	<u>Euphausia pacifica</u> and	Pelagic nearshore	Trans-Pacific, from Sea of Japan, east to Baja California, north to Gulf of Alaska				X
	<u>Thysanoessa spinifera</u>		Mid-Baja California to Gulf of Alaska				X
Pink shrimp	<u>Pandalus jordani</u>	Benthic unconsolidated	San Diego, California to Unalaska in Aleutians		X		
Spot prawn	<u>Pandalus platyceros</u>	Benthic unconsolidated	San Diego, California to Unalaska in Aleutians		X		

Table 4-2. Status Of Important (X) Pelagic and Subtidal Benthic Species (continued)

Common Name	Scientific Name	Habitat	Geographical Distribution	Rare, Threatened, Endangered, or Fully Protected	Commercial	Recreational	Ecological Interest
<u>Crustaceans (continued)</u>							
California spiny lobster	<u>Panulirus interruptus</u>	Benthic consolidated	Baja California to San Luis Obispo County, California		X	X	
Peneid shrimp	<u>Sergestes similis</u>	Epipelagic	Gulf of California to Bering Sea, Alaska				X
<u>Echinoderms</u>							
Brittle star	<u>Amphioplus hexacanthus</u>	Benthic unconsolidated	Southern California to Monterey, California				X
Bat star	<u>Patiria miniata</u>	Benthic consolidated	Baja California to Alaska				X
Short-spined sea star	<u>Pisaster brevispinus</u>	Benthic unconsolidated	La Jolla, California to Alaska				X
Large-spined sea star	<u>Pisaster giganteus</u>	Benthic consolidated; Aquatic beds	Baja California to Vancouver Island				X
Giant red sea urchin	<u>Strongylocentrotus franciscanus</u>	Benthic consolidated; Aquatic beds	Baja California to Gulf of Alaska		X		X

Table 4-3. Intertidal Plant and Animal Species

Species Name	Common Name	Habitat	Distribution	Importance
<u>Fishes</u>				
<u>Amphistichus argenteus</u>	Barred surf-perch	Sandy intertidal to subtidal	Baja California to Bodega Bay	Sport and commercial
<u>Cebidichthys violaceus</u>	Monkeyface-eel	Rocky intertidal and subtidal to 24 m.	Baja California to Del Norte County	Sport
<u>Hexagrammos decagrammus</u>	Kelp greenling	Rocky intertidal	LaJolla to Aleutian Isls., Alaska	Sport and commercial
<u>Scorpaenichthys marmoratus</u>	Cabazon	Rocky intertidal to 40 fathoms	Baja California, to Sitka, AK	Sport and commercial
<u>Leuresthes tenuis</u>	California grunion	Intertidal and within a few Km of shore in 5-14 M.	Baja California, to Pt. Conception and seldom to Monterey	Sport
<u>Coelenterates</u>				
<u>Anthopleura xanthogrammica</u>	Giant green anemone	Low intertidal to 50 M.	Panama to Alaska	Ecological
<u>Marine worms</u>				
<u>Nereis vexillosa</u>	Mussel worm	Intertidal on rocks, pilings and gravel beaches	Santa Barbara to Alaska	Ecological
<u>Eudistylia</u> spp.	Fanworm	Rocky intertidal to subtidal	Pacific Grove to Alaska	Ecological
<u>Euzonus</u> spp.	Bloodworm	Sandy intertidal	Punta Banda, Mexico to Vancouver Island	Ecological
<u>Echinoderms</u>				
<u>Pisaster ochraceus</u>	Ochre star	Throughout the intertidal	Ensenada, Mexico to Sitka, AK	Ecological
<u>Molluscs</u>				
<u>Acmaea</u> spp.	True limpets	Throughout the rocky intertidal	Aleutian Islands, AK south to Pt. Conception	Ecological; scientific
<u>Adula falcata</u>	Falcate date mussel	Rocky intertidal	Coos Bay, OR south to Baja California	Sport

Table 4-3, cont.

Species Name	Common Name	Habitat	Distribution	Importance
<u>Littorina</u> spp.	Periwinkles	High rocky intertidal	Baja California to Puget Sound, WA	Zoological; scientific research
<u>Mytilus californianus</u>	California mussel	Exposed surf area with strong wave action	Socorro Is. Mexico to Aleutian isls. AK	Ecological; sport; commercial
<u>Penitella conradi</u>	Conrad's piddock	Abalone shells & soft substrate	Baja California to British Columbia	Sport
<u>Penitella penita</u>	Flat-tipped piddock	Non-biological substrates	Baja California to Bering Sea	Sport
<u>Siliqua patula</u>	Pacific razor clam	Sandy beaches	Monterey to Alaska	Sport; commercial
<u>Toredo navalis</u>	Shipworm	Wooden substrates (i.e., ship hulls & pilings)	Throughout all oceans	Negative economic impact
<u>Tivela stultorum</u>	Pismo clam	Exposed sandy beaches	Half Moon Bay to Baja	sport; commercial
<u>Crustaceans</u>				
<u>Balanus</u> spp.	Acorn barnacle	Intertidal on stable substrate	Throughout the California coast	Negative economic impact
<u>Emerita analoga</u>	Mole crab	Intertidal sandy beaches	Baja California to Kodiak Is., AK	Ecological
<u>Limnoria lignorum</u>	Gribble	Wooden substrates	San Francisco Bay, to Kodiak Is., AK	Negative economic impact
<u>Orchestoidea californiana</u>	Long-horned beach hopper	Supralittoral sandy beaches	Throughout California	Ecological; scientific research
<u>Pachygrapsus crassipes</u>	Lined shore crab	Rocky Intertidal and estuarine	Gulf of California to Yaquina Head, Washington	Ecological; scientific research
<u>Plants</u>				
<u>Enteromorpha</u> spp.		Rocky intertidal especially near freshwater input	Entire extent of California coast	Ecological
<u>Fucus</u> spp.	Rock weed	Rocky intertidal	Pt. Conception to northern WA	Ecological

Table 4-3, cont.

Species Name	Common Name	Habitat	Distribution	Importance
<u>Laminaria</u> spp.	Oarweed	Rocky intertidal to subtidal	Baja Calif-ornia to Bering Strait	Ecological; commercial
<u>Phyllospadix</u> spp.	Surf grass	Rocky intertidal	Baja Calif-ornia to British Columbia	Ecological
<u>Porphyra</u> spp.	Laver, Nori	Rocky intertidal	So. Calif-ornia to the Gulf of AK	Ecological; commercial
<u>Postelsia palmaeformis</u>	Sea palm	Rocky intertidal	Morro Bay to British Columbia	Ecological
<u>Ulva</u> spp.	Sea lettuce	Rocky intertidal to subtidal	Throughout all oceans	Ecological; commercial

Table 4-4. Ecological Areas in Northern and Central California Coastal Intertidal Habitats

Area Name	Type of Area ¹	Responsible Agency ²
Redwood National Park	NP, ASBS	NPS
Kelp Beds at Trinidad Head	ASBS	SWRCB
King Range National Conservation Area	NCA	BLM
Kelp Beds at Saunders Reef	ASBS	SWRCB
Del Mar Landing Ecological Reserve	ER, ASBS	DFG
Gerstle Cove Ecological Reserve	ER, ASBS	DFG
Bodega Marine Life Refuge	MLR, ASBS	DFG + UC
Bird Rock	ASBS	SWRCB
Double Point	ASBS	SWRCB
Point Reyes Headland Reserve and Extension	NP, ASBS	NPS
Duxbury Reef Reserve and Extension	ER, ASBS	DFG
Farallon Islands Game Refuge	GR, ASBS	DFG + FWS
James V. Fitzgerald Marine Reserve	MLR, ASBS	DFG
Año Nuevo Point and Island	ASBS	SWRCB
Pacific Grove Marine Gardens & Fish Refuge	FR, ASBS	DFG
Hopkins Marine Life Refuge	MLR, ASBS	DFG + SU
Carmel Bay	ER, ASBS	DFG
Point Lobos Ecological Reserve	ER, ASBS	DFG
Julia Pfeiffer Burns Underwater Park	SP, ASBS	DPR
Sea Otter Refuge	GR	DFG
Atascadero Beach	IP	DFG
Morro Beach	IP	DFG
Pismo-Oceano Beach	IP	DFG
Pismo Invertebrate Preserve	IP	DFG
Ocean Area Surrounding the Mouth of Salmon Creek	ASBS	SWRCB
Morro Rock Ecological Reserve	ER	DFG

¹ASBS = area of special biological significance

ER = ecological reserve

FR = fish reserve

GR = game refuge

IP = invertebrate preserve

MLR = marine life refuge

NCA = national conservation area

NP = national park

SP = state park.

²BLM = U.S. Bureau of Land Management

DFG = California Department of Fish and Game

DPR = California Department of Parks and Recreation

FWS = U.S. Fish and Wildlife Service

NPS = U.S. National Park Service

SWRCB = California State Water Resources Control Board

SU = Stanford University

UC = University of California.

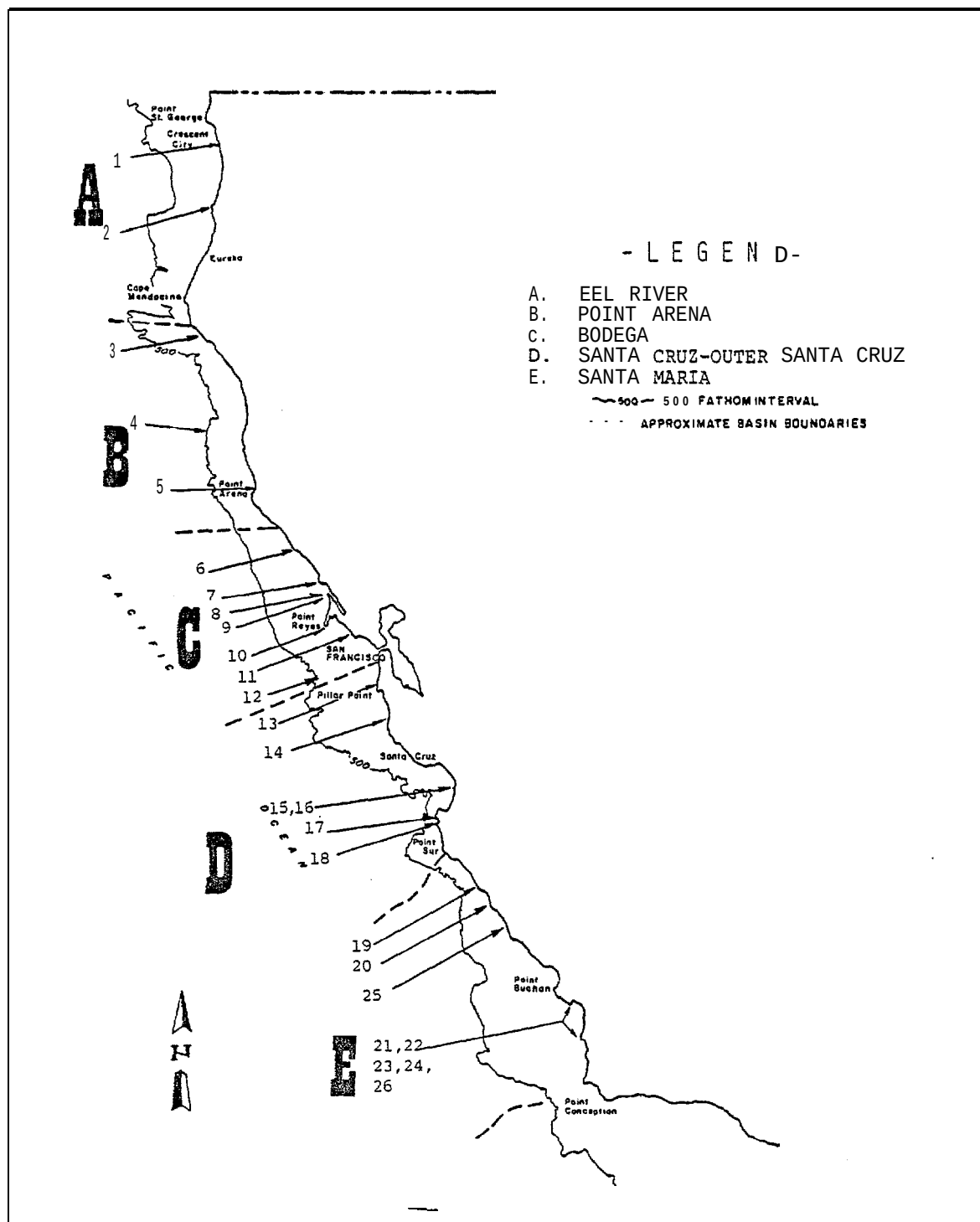


Figure 4-15. Location of Ecological Areas in Northern and Central California Coastal Intertidal Habitats (See Table 4-4 for area names)

Fish and Game and Marine Life Refuges. The California Legislature has established certain areas for the protection of most species of vertebrates (fish and game refuges) and plants and invertebrates (marine life refuges). In the intertidal portions of fish and game refuges, the taking of plant and animal life and disturbing geological formations is prohibited by regulation. Special provisions for given refuges are cited in the individual accounts. Refuges are controlled and managed in accordance with the California Fish and Game Code (Div. 7, Ch. 1, Art. 1,2) .

Legal descriptions of refuges are set forth in the California Fish and Game Code (Div. 7, Ch. 2 Art. 2,3,6). Additional details and maps are given in Smith and Johnson (1971) .

Areas of Special Biological Significance. The California State Water Resources Control Board (SWRCB) has designated 21 areas of special biological significance that lie within the coastal intertidal zone of northern and central California. Most of these coincide with refuges and ecological reserves discussed above.

Pursuant to the Porter-Cologne Water Quality Control Act (Division 7, California Water Code), the SWRCB adopted water quality control plans which required the designation of areas of special biological significance to afford protection for marine life in nearshore ocean waters by prohibiting waste discharges therein. By definition, "Areas of special biological significance are those...requiring protection of species or biological communities to the extent that alteration of natural water quality is undesirable" (SWRCB, 1976).

Legal descriptions, maps and administrative information pertaining to areas of special biological significance are given in SWRCB (1976).

Invertebrate Preserves. The California Department of Fish and Game has established several invertebrate preserves for the purpose of maintaining the stocks, primarily, of the Pismo clam. Taking of this intertidal clam is prohibited. It is further intended that these preserves be used to study the effects of California sea otter predation on the Pismo clam.

State of Knowledge of Major Ecological Areas. Despite official recognition of numerous areas of ecological concern, relatively little information has been published about them either as preserves or about their respective intertidal habitats, biotic communities, and general ecology. Consequently, biological knowledge of these areas largely must be abstracted and compiled from general and regional "works and from the scientific literature. The best source of basic biology of areas of ecological concern at this time are the habitat and community descriptions and the species accounts in other sections of this report.

Published reports on nearly all northern and central California intertidal areas of ecological concern should be available during 1980 and 1981. The reports will be published as part of the California State Water Resources Control Board's Water Quality Monitoring Report series. They will be prepared by marine scientists and will include a comprehensive overview of the physical, chemical, and biological characteristics of each areas surveyed.

Drafts of some of these reports have been made available to the writers of this report as they were preparing the individual areas of ecological concern accounts that follow in Volume IV. Credit is given to specific authors in individual area accounts. Formal publication of some of these reports may have occurred during completion of this text, thus some of the bibliographic notations may be outdated.

Major Human Influences

Human Activities Relative to the Marine Ecosystems. Man has always used the marine environment for numerous activities; commercial-industrial, recreational, aesthetic and scientific. His impacts on the marine ecosystems have been of long duration and sometimes they have been devastating. The potential for even more and greater negative impacts increases as man's use of this environment increases with time. possibly it is this area that deserves the most study by marine biologists and other concerned persons.

Because of the seeming vastness of the oceans, man has for a long time used the marine environment for disposal of wastes. Numerous areas are still receiving raw and/or slightly treated effluents from small communities. Such studies that have been done on such discharges indicate little effect on nearshore biota because of their small volume and the activity of the waves and currents. However, in no case had there been preexisting studies by which one could determine effects, and the fact that such discharges continue (and continue to be defended) indicate the way many think about this ecosystem.

Other types of pollution that have potentially great effect on marine ecosystems come from the many activities of man. Agricultural discharges that eventually reach the sea are rich in phosphates and nitrogen from commercial fertilizers, pesticides and their degradation products, and are often elevated in coliform bacteria from dairies and feed yards. Industrial discharges are often high in heavy metal concentrations and, in the form of coolant waters returned to the environment, heated waters. This thermal pollution also has potentially critical affect in the disturbance of the seasonal rhythms of spawning as well as the outright death of species whose critical temperature tolerances are exceeded. Thermal and heavy metal pollution by industry and utilities remain an ongoing concern for marine ecologists.

Closely allied with these forms of pollution in regards to origin and potential effects is the problem of radioactive pollution. Again, because of the oceans' size, it was thought to be an acceptable receptical for radioactive wastes. The radioactivity has been found, however, to enter the ecosystem and, reportedly, cause genetic disturbances. The long range effects of the relatively low level pollution to date remains to be ascertained; higher levels of radioactivity may be unacceptable.

A drainage effluent problem not often addressed is the storm drainage directly from streets, parking lots and driveways of our urban centers. These waters are highly elevated in heavy metals, suspended sediments, coliform bacteria, B.O.D. and hydrocarbon content. All are potentially devastating contributions of man to the marine biota. Hydrocarbons are also introduced at the numerous oil and gas loading docks along the coast and from the oil rigs proliferating offshore. There have been oil seeps along the coast since prehistoric times (Indians used asphaltum for inlays). Such pollution has been relatively benign. With the proliferation of shipping and loading facilities, however, hydrocarbon pollution is increasing in both amount and frequency with often dramatic and destructive impact on marine vertebrates, invertebrates and algae.

Recreational activities also have their impact on marine environments. While California Fish and Game laws adequately protect the sports fish from exploitation, there is little control on bait species. The recent use of "slurp-guns" to take the echiuroid worm Urechis in large numbers as bait for surf fish is cause for alarm among knowledgeable marine biologists. Urechis, the "fat innkeeper" of sandy bays, is not common and, in addition, forms the microfiche for several commensal forms. It is an interesting research organism and is slow to repopulate, so this use needs careful control. Another aspect of recreational collecting that has potential for ecologic alteration is the tendency of casual visitors to the shores to take souvenirs home as a reminder of their enjoyment. Unfortunately, these souvenirs are almost invariably the ochre star (Pisaster ochraceus) providing an example of seasonally intense selective predation on one species. That this species is also the top predator in the rocky intertidal habitats makes its removal as a family-room decoration even less environmentally sound. Studies indicate the strong controlling influence that Pisaster spp. have on the biota of the rocky shores, and these species, too, should fall among those that are closely watched by concerned personnel.

Other forms, too, fall under the category of exploited species. Even though Fish and Game limits apply to them, abalone (Haliotis spp.) and crabs (especially Cancer spp.) are intensely and selectively taken. Abalone, especially, has shown decline in populations; human predation, which is obviously important in certain areas, is usually discounted as a factor and the onus is attached to the normal predation by the sea otter.

Man also alters the marine environments, especially nearshore, with various structures designed to enhance the shore for his enjoyment. Jetties and groins, piers and pilings and breakwaters all affect the longshore movement of sand. As sand piles up against groins and jetties it deprives down-drift beaches of their supply of sand, thus resulting in severe erosion and expense to correct the problems. By altering wave patterns, breakwaters have sometimes unexpected effects on the adjacent shore. Very often, these man-made structures both fail to correct the problem attacked and create additional problems expensive to correct. Further, there are conditions outside the marine environment which have profound effects on these beaches. Damming of freshwater streams and rivers reduces the volume of sediments delivered to the ocean and thus available for beach formation. Consequently there are noticeable reductions in beach widths south of dammed waterways.

The marine environment, from the standpoint of the marine biologists, is extremely important. Many interesting and important research opportunities remain among the diverse and often unique faunas. New species continue to be described and the effects of various types of pollutants on marine organisms need careful study. Further, the numerous cases of introduced species (100 in San Francisco Bay, alone) both intentional and inadvertent, also need careful study. Some introductions, such as the striped bass, have been successful, others not. The impact on native populations of such introductions is hard to assess due to the lack of pre-introduction data but any such future transplantations should be carefully monitored. The field of aquiculture of commercially useable forms (lobsters, oysters, etc.) is in its infancy on this coast and remains an area of intense interest among biologists. **The biologists are concerned with the whole range of impacts, possibly least of all with the economic ones.**

Sensitivity of Marine Ecosystem to Human Impacts. Physically, the marine ecosystems are only locally impacted by human intervention. The aforementioned shore changes brought about by jetties, etc., are localized and correctable. Use of shore dunes by off-road vehicles has greater and longer lasting effects. Dune stabilizing plants are highly susceptible to damage and numerous instances exist of previously vegetated dunes being denuded by foot and vehicular traffic. The changes in wind patterns and, thus, beach erosion, caused by such changes cause problems for both sand dwelling organisms and humans wishing to enjoy the beach.

It is among the biological constituents of the marine environments that the most profound effects of human influence are to be found. Death, alteration of spawning cycles and times, and reduced vitality are some of the results of the various types of pollution presented. Organisms have different tolerances to various parameters, so it is impossible to make any general statements relative to such impacts. What can and must be said, however, is that careful and responsible studies should be undertaken to understand, as much as possible, the potential effects of proposed activities in the marine ecosystems.

ESTUARINE ECOSYSTEM

General Characteristics

Estuaries develop in partially enclosed bodies of marine water, including lagoons, river mouths, and protected bays. They could be considered as transitional zones (ecotones) between fresh water and marine habitats, characterized by the mixing of seawater with fresh water (from land drainage) by tidal exchange and diffusion.

Biotic zonation reflects the stressful physical conditions to which the organisms are subjected, and is especially related to salinity and elevation. Individuals must tolerate regularly changing physical conditions by specific adaptive mechanisms. High productivity in the estuary is maintained by "pulse-stabilization" or regular periodic fluctuations of physical conditions, especially water levels, salinities, nutrients, temperatures, and subsequently biological conditions (Odum, 1971).

Areal Extent. Estuaries are located in small, protected bays and river mouths, ~~drowned subsequent~~ to the post-glacial rise in sea level. Approximately 10 to 20% of the Pacific coast is comprised of estuarine habitats (Chapman, 1977). More extensive development is precluded by the tectonically active nature of land formation in coastal California. San Francisco Bay represents 88 to 89% of the total area covered by estuaries in California (MacDonald, 1977). Four to five percent occurs north of San Francisco Bay. Humboldt Bay is the major estuary of northern California. Seven percent of the estuarine acreage occurs between San Francisco Bay and the Mexican border, including Morro Bay and Elkhorn Slough.

Estuarine Ecosystem Model

Figure 4 - 16 is a model of estuarine ecosystem structure and function (a glossary of symbols used in the model has been included in Appendix A). Although this is a generalized model, it was designed to apply to California estuaries. Specific examples of estuarine processes have been drawn from available information pertaining to California estuaries where possible. Detailed information on estuaries within the study area is presented in Volume IV (Watersheds and Basins). The various habitats that comprise the estuarine ecosystem are discussed in Volume III, Part 1 (Habitats).

The physical-chemical processes of the water column and the substrate are defined. Dominant processes include temperature, light, wave action, sedimentation, and salinity. The influence of other ecosystems (oceanic and riverine) on these estuarine processes is delineated by the model.

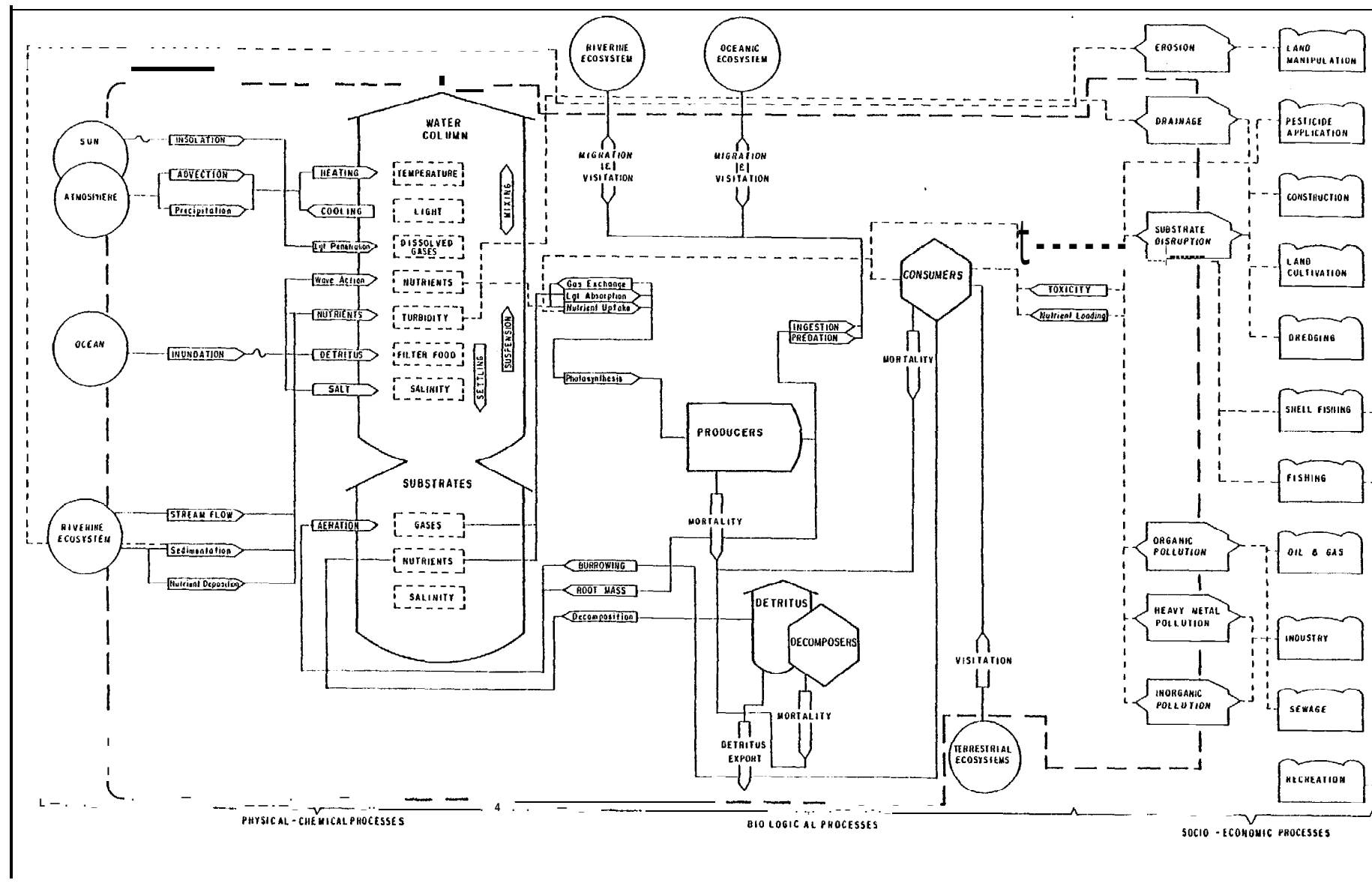


Figure 4-16. Ecosystem Model of an Estuary

The biological component stresses interaction with the physical and socioeconomic processes. The photosynthetic process is largely influenced by physical parameters. Biological processes, such as burrowing by animals, the growth of plant roots and the decomposition of organic matter, impacts the physical environment.

Human activities, which function as socioeconomic processes, can directly influence the biota by removal of individuals. It can also indirectly influence the biological component through altering the physical conditions which support the biota. The introduction of toxic substances to the water column or substrate, practices which increase sedimentation and removal of habitat by draining, dredging, or filling are examples.

Physical-Chemical Parameters. Physical conditions in the estuary are dominated by the type of substratum, water circulation, salinity, and temperature. These are discussed in the following sections for both the subtidal and intertidal zones. Other physical parameters, including dissolved oxygen, light penetration, and zonation, are reviewed in the habitat descriptions, Volume III, Part 1, Estuarine Ecosystems.

Substratum. Sedimentary estuarine deposits are derived from terrestrial sources that are transported by freshwater streams and rivers or from oceanic sources that are contributed by tidal inflow. Tidal velocities determine particle size distribution. The coarser sediments may be found near estuary mouths, with fine-grained muds being deposited on the deeper flat portions of the estuarine floors (Emery and Stevenson, 1957). Channel beds are dominated by large-grained particles, especially coarse sands. The finer sands are swept out of the channels by tidal currents. Shallower subtidal and intertidal zones are dominated by reworked, crossbedded, fine-grained silts and muds (Emery and Stevenson, 1957; Rubin and McCulloch, 1979).

Gravel, sand, silt, clays, nutrients, and pollutants may contribute to the dissolved or suspended stream load. Organic matter content in the estuary varies with the type of substrate. Sandy bottoms may contain negligible quantities of organic matter. In contrast, salt marshes may contain 13 to 16% organic matter (Macdonald, 1977).

Water Movement. Water circulation in the estuary is dominated by a two-layered circulation pattern, which results from the opposing freshwater flows and tidal inundation and wind stress. Density differences between fresh and seawater cause the fresh water to flow on top of the denser seawater. Turbulence causes mixing of the fresh and seawater layers (Lauff, 1967). The factors contributing to the degree of stratification within the estuary are considered under the discussion of salinity.

Tidal amplitude is a major driving force in estuarine circulation. The amplitude is greatest at the inlet to the estuary and diminishes to a minimum at the estuary head. The higher the amplitude, the greater the circulation force and flushing rate (Clark, 1974).

Coriolis force, the effect of the earth's rotation on motion at the earth's surface, substantially affects water circulation patterns in the estuary. In the northern hemisphere, fresh water flows seaward to the right of the estuary's center and a compensating up-estuary flow of higher salinity water occurs to the left of center (Lauff, 1967).

A third factor contributing to estuarine circulation patterns is the configuration of the estuary bottom. Decreased depth and increased width will contribute to greater vertical homogeneity of the water column and decreased turbulence. This influences the two-layered circulation pattern (Lauff, 1967; Conomos, 1979).

Salinity. Salinity distribution patterns within an estuary have been an important factor in classifying estuaries. The degree of stratification, determined by the quantity of fresh water versus salt water, has been used as the delineating criterion.

The categories include (1) highly stratified, salt wedge estuary, (3) partially mixed or moderately stratified estuary, and (4) completely mixed or vertically homogeneous estuary.

The intensity of stratification is influenced by the ratio of river to tidal flow, the strength of the tidal current, and the width and depth of the estuary. In general, vertical homogeneity increases with decreased river flow, increased tidal currents, decreased depth, and increased width (Lauff, 1967).

Salinity is dominated by the common salt, sodium chloride, and is derived from oceanic sources. Within the estuary there is a gradient in salt content ranging from a high value of 30 to 35 parts per thousand (ppt) near the inlet, dropping to near zero at a distance up the tributary tidal rivers. Salinities may be even higher in lagoons, which are subject to seasonal closure and concentration of salts resulting from evaporation. Table 4-5 indicates salinity zones within a typical estuary.

Table 4-5
Approximate Geographic Subdivisions, Salinity Ranges, and Zones of an Estuary

Divisions of Estuary	Salinity Ranges ¹	Zones
	$\frac{0.700}{1000}$ (parts/thousand)	
River	< 0.5	limnetic
Head	0.5-5	oligohaline
Upper reaches	5-18	mesohaline
Middle reaches	18-25	polyhaline
Lower reaches	25-30	polyhaline
Mouth	30-40	euhaline

¹ Modified from McLusky, 1971

The distribution of species in the estuary is influenced, in part, by the salinity distribution. Marine species select the higher salinities near the inlet, and freshwater species tend to occupy areas closer to tributary rivers. True estuarine species are tolerant of wide ranges of salinity. Their distribution is usually less limited than either marine or freshwater species.

Temperature. Temperature fluctuation is an important factor controlling migration, spawning, feeding efficiency, swimming speed, embryological development, and basic metabolic rates of aquatic animals in estuaries (Clark, 1974). Estuarine temperature variation arises from the mixing of two bodies of water of different temperatures (McLusky, 1971). Fresh water displays a wide range of temperatures and influences estuarine temperature distribution to a greater degree than does ocean water.

The high surface to volume ratio of estuaries subject the waters to the strong influences of land air temperatures and solar heating. As a result, seasonal and diel temperature ranges are increased.

Biological Features and Processes. The estuarine environment supports a diverse assemblage of organisms. The organisms may be conveniently divided into two major groups: the producers, including vascular plants, algae, and phytoplankton; and the consumers, represented by fish, birds, invertebrates, and zooplankton. Some of the factors which influence the occurrence and distribution of these organisms are discussed in the following sections. In addition successional changes of the biota, as related to physical processes, are discussed. A more detailed account of specific foodweb interrelationships is presented in the habitat descriptions (see Volume 111, Part 1).

Succession. The estuary is a transient phenomenon in relation to geologic time. The depositional budget for estuaries is generally positive, and is controlled by the physical characteristics of the area. It is impossible to determine the time required to completely fill an estuary, but it has been demonstrated that recent artificial modifications to San Francisco Bay caused by logging, dredging, filling, erection of structures, and over-grazing in the watershed of the area have severely accelerated natural rates of deposition (Akins and Jefferson, 1973; Krone, 1979).

Sedimentation rates for natural marshes in southern California have been measured by Stevenson and Emery (1958) and Warne (1971) at 0.5 cm/yr for a *Spartina* marsh and 0.1 to 0.3 cm/yr for *Salicornia virginica* marshes. Pestrong (1965) noted a sedimentation rate of 2 cm/yr for the urbanized San Francisco Bay marshlands.

Field studies in Oregon have indicated that habitats within an estuary reflect stages in the successive process of deposition. Soil cores taken by Jefferson (1974) on upper sections of salt marshes have shown at depths remains of plants that are associated with the lower marsh. This demonstrates a progression from low marsh to high marsh over time at the sample points.

Concomitant with physical changes are changes in the biological communities. The importance of animal-sediment relations has been demonstrated by many investigators (Aller and Dodge, 1974; Bloom et al., 1972; Rhoads and Young, 1970). One common change in marine benthic communities is the replacement of one community by another as a result of alterations in the substrate (Johnson, R.G., 1971). The succession of species occurs as a

consequence of differential growth, survival, and colonizing abilities of the specific organisms present (Odum, 1969). A physical change such as increased silt deposition may control patterns, rates of change, and limits of community development (Nichols, 1979).

The benthos or deep bottom community of the main channel in an estuary is an area characterized by clean sand and very little silt. The sand in the channel is uncompacted and allows the gastropod, Polinices lewisi (moon snail) and Olivella biplicata (purple olive snail), to move about freely beneath the top layer of sediment. The lack of silt allows the suspension feeders of the community (i.e., Clinocardium nuttalli (heart cockle) and Pecten circularis (thick scallop)) to feed without their siphons becoming clogged.

With increased sedimentation, difficulties with food acquisition, loss of attachment sites, and anaerobic conditions create stresses on the clean bottom inhabitants. An increased mortality ensues, which furnishes space for new colonizers, and a community which is dependent on greater amounts of silt and clay becomes established. Many of these invertebrates are deposit feeders (i.e., Macoma nasuta (bentnose clam), Mya arenaria (soft-shell clam), Axiiothella rubrocincta (joint worm, bamboo worm)). Their mode of feeding, ingesting and excreting mud, can modify the structure and composition of the substrate to such an extent that recolonization by the larvae of suspension feeders and sessile organisms is prevented (Rhoads and Young, 1970).

If disturbances such as turbidity and wave action are not too extreme, an eelgrass community may develop. This community habitat provides food, increased surface area, and refuge for many new organisms including Obelia sp. (hydroid), Crangon sp. (shrimp), Idotea sp. (isopod), and Caprella California-rellid). The matted root system of the eelgrass acts as a buffer to the effects of wind and currents, and can alleviate sediment erosion and shifting. The plant also offers diverse living accommodations for animals on its blades, about its base, and along its roots in the substrate. The stability provided by the eelgrass allows the development of a more complex, biologically controlled community, which is characterized by high diversity (Sanders, 1968). The eelgrass bed can also act as a trap for suspended sediment, and this continual deposition will elevate the beds until increased tidal exposure destroys them.

Studies conducted in Mission Bay, California indicate that when the level of intertidal mud reaches a certain level, species of Spartina (cordgrass) or Salicornia (pickleweed), which are tolerant to alternating periods of submergence and emergence, will become established. These species accelerate the rate of sediment deposition by reducing the rate of flow of tidal water, which allows more sediment to settle, and inhibits the export of detritus. As the salt marsh develops, the ebb tide creates high salinity levels. This may be due to both evaporation and the ability of the halophyte marsh plants to secrete excess salt (Phleger and Bradshaw, 1966). Few invertebrate species have tolerance limits broad enough to accommodate the variable conditions of the marsh. As a result, a community comprised of a small number of species with individuals possessing specific behavioral and/or physiological adaptations dominates the marshes (Krauter and Wolf, 1974).

As the elevation of the salt marsh increases, floral species requiring longer periods of aerial exposure for germination, such as Distichlis sp. (saltgrass), become established. The elevational zonation of marsh plants results from this process (Hinde, 1954). At the upper edge of the marsh, additional sedimentation causes the loss of wetland habitat and creates a transition to upland communities (see Atwater et al., 1979).

Producers. The producers in the estuary are photosynthetic green plants. Sunlight provides the energy necessary to convert carbon dioxide and water into carbohydrates. Nutrients essential to growth are obtained either from the soil or from the water column.

The producers provide food for consumers in one of two ways. Grazing organisms directly utilize the food stored in plant tissue. In contrast, detritus feeders consume dead plant remains that have been chemically altered by the action of decomposing microorganisms. This second food chain pathway has been shown to represent a greater flow of energy in some estuaries than does the more direct grazing food chain (Odum, 1971). Recent studies of the San Francisco Delta, however, indicate that detritus may not, at times, be as important an energy source as phytoplankton or even zooplankton. Although the potential energy from detritus is great, the overall nutritional values may be low. When phytoplankton are abundant (i.e., summer) they may be a significant trophic resource in parts of the estuary (Knight, pers. comm.).

Vascular Plants. The vascular plants in the estuary characteristically are vertically distributed in zones of mono-specific stands. Each species demonstrates adaptations to a narrow range of conditions found in localized regions of the estuary.

1. Tidal inundation. Elevation and tidal inundation are frequently considered to be the dominant controlling physical factors (Hinde, 1954; Vogl, 1966). Eelgrass, growing on gravelly-sand, sand, or mud in the subtidal and intertidal zones, occurs at the lowest elevations. In subtidal areas of turbid estuaries, eelgrass grows at depths of 1.8 to 3.6 meters. It may occur at depths greater than 30 meters in the less turbid offshore areas. The upper limit of growth is approximately +0.3 meters above mean lower low water (MLLW), but the majority of the growth occurs below MLLW (Keller and Harris, 1966).

Marsh grasses in the intertidal zone are also vertically distributed according to elevation and duration of submergence and emergence. California cordgrass (Spartina foliosa) is commonly located along the bayward fringes of the marsh. Typical elevations range from mean higher low water (MHLW) to mean high water (MHW). Pickleweed (Salicornia sp.) is typically found upland from cordgrass at elevations ranging from MHW to extreme high tide (Atwater et al., 1979).

2. Substratum. The underlying substrate may also have an effect on vascular plant distribution. Surfgrass (Phyllospadix sp.) characteristically grows at MLLW, but depends on a rocky substrate for a site of attachment and is most often found along coastline exposed to surf action. Marsh macrophytes prefer a fine-grained clayey substrate. The characteristically high cationic exchange capacity of the clay provides an abundant nutrient supply to the plants. Aeration and moisture content of marsh soils may also contribute to plant growth and maintenance.

3. Salinity. Salinity, as controlled by tidal inundation, rainfall, and evaporation, is also considered to be an important factor in the determination of plant distribution (Reed, 1947; Jackson, 1952). Pickleweed (Salicornia sp.) is frequently found growing in non-tidal areas or in shallow depressions or pans where salinity levels are high due to pending of tidal water and subsequent evaporation that concentrates salt.

4. Competition. Competition has been shown to be a determining factor of zonal patterns in plant growth. It has been demonstrated that Spartina alterniflora, an east coast cordgrass, is more productive under freshwater conditions than in saline areas. However, cordgrass typically inhabits areas of high salinity where other plants, more competitive under the less severe conditions, cannot grow (Adams, 1963; Barbour, 1970; Barbour and Davis, 1970).

Algae. The ecological factors that regulate marine algal distributions may be classified into three groups: chemical factors, physical factors, and biological factors (Prescott, 1968).

1. Physical factors. The most important physical factors determining algal distribution are tidal movements, wave action, and light. Wave action is generally not severe in the estuarine environment, but some provision must be made for attachment of the plants to the substrate. Tidal range partially influences the vertical zonation of algae. Algae are distributed in the intertidal or subtidal zones according to their ability to withstand exposure to air during low tides. Light penetration also determines vertical distribution. Green algae lack a pigment present in both red and brown algae, which allows the absorption of more light, permitting red and brown algae to dominate in lower zones.

2. Chemical factors. The most important chemical factors determining algal distribution in San Francisco Bay include nutrients, salts, and pH. Nutrients, especially nitrates and phosphates, are often in short supply in the surface waters of the estuary, limiting phytoplankton population growth. Salinity restricts the location of species with varying tolerances within the estuary (Silva, 1979). The effect of salinity on species composition is usually more evident for the phytoplankton community than for the benthic flora.

3. Biological factors. The biological factors affecting the distribution of algal species include competition and predation. Attachment sites for benthic algae are limited. Predation by grazers can be important in determining the zonation of benthic algae and the abundance of both benthic algae and phytoplankton.

Benthic algae are macroscopic forms that require an attachment site. They are normally found on rocky shores, mudflats, and on piers, jetties, and other hard artificial substrates. The dynamic nature of sandflat substrates usually excludes benthic macro-algae.

Phytoplankton inhabit the open water habitat. The phytoplankton association is dominated by diatoms, dinoflagellates, and silicoflagellates. Diatoms are primarily non-motile, while the dinoflagellates and silicoflagellates are motile. Diatoms also occur on the surface of mudflats and tidally-exposed creekbanks and can represent a substantial portion of total algal productivity (Zedler *et al.*, 1978).

Consumers. Estuarine primary consumers (herbivores) are represented by fish, birds, invertebrates, and zooplankton. They may obtain nourishment directly from live plants, algae, or phytoplankton. Detritivores feed on detritus and other available food found in the muds of the estuary. Secondary and primary consumers prey on other fish, birds, invertebrates, zooplankton, or insects.

Fish. The estuary supports a diverse fish fauna. Estuarine fish can be classified into four groups: marine species, estuarine species (endemic), freshwater species, and anadromous species. These groups have different patterns of abundance and use of the estuarine environment. In the Sacramento-San Joaquin estuary, marine species were most numerous (46 species), followed by freshwater species (26), estuarine species (15), and anadromous species (10) (Wang, pers. comm.).

Many coastal marine species occur in estuaries on a seasonal basis. Although estuarine dependence of west coast species has not been documented as thoroughly as on the east coast, many species of coastal marine fish are known to spawn in San Francisco Bay or use it as a nursery area during the fall and winter months (Wang, pers. comm.). Marine species, especially the adult stages, typically remain in the deeper portion of the estuary. Salinities in this zone are usually comparable to oceanic salinities, minimizing the need for physiological adaptations. Most of the marine species gradually return to the ocean during the spring and summer months. Coastal marine fish that commonly occur in estuaries include several species of sharks and rays, smelts, surfperch, rockfish, gobies, sculpins, and flatfish, as well as the northern anchovy and Pacific herring.

Estuarine fish are resident species, completing their entire life cycle within the estuary. Most of these species are euryhaline, with many of them tolerant of a range in salinity from seawater to completely fresh water. The most common estuarine fish include the plainfin midshipman, topsmelt, jacksmelt, bay pipefish, shiner surfperch, longjaw mudsucker, prickly sculpin, Pacific staghorn sculpin, and starry flounder. Also common in certain locations are the threadfin shad and delta smelt.

Several freshwater species also complete their entire life cycle within the estuary. These fish are characteristic of the freshwater tributaries that drain into the estuary, although many species are tolerant of low salinities and can be found in the upper portion of the estuary. The native freshwater fish include several species of minnows (Cyprinidae), the Sacramento sucker, the Sacramento perch, and the tule perch. Much of the freshwater fauna is represented by introduced species. All of the centrachids, including bass, crappiers, and sunfish (except the Sacramento perch), were introduced into California waters from other areas. Other introduced species include the carp, goldfish, white catfish, channel catfish, golden shiner, largescale logperch, and Mississippi silversides.

Anadromous fish may use the estuary on a seasonal basis or may complete their life cycle within the estuary. Anadromous species ascend to the upper drainages of the estuary to spawn in fresh water. The estuary serves as an acclimation zone, facilitating the physiological changes necessary to make the transition from salt water to fresh water. The adults of certain anadromous species die after spawning, while those of other species survive and return to salt water after spawning. The juveniles of anadromous species may remain in fresh water one or more years before returning to salt water. Anadromous species which are typically oceanic include the salmon, trout, and Pacific lamprey. These species generally pass through the estuary only during spawning migrations. Several other anadromous species may reside in the estuary during much of their life, including the sturgeon, the American shad, the longfin smelt, the threespined stickleback, and the striped bass.

Birds. A large variety of birds use the estuaries of California. They can be classified into six categories: shorebirds; gulls and terns; ducks (and other water-associated birds); raptors; wading birds; and song birds. These groups generally display different patterns of abundance and use of the estuarine environment.

1. Shorebirds. The heaviest use of the estuary by shorebirds in California comes during the spring and fall migrations, but many also remain during the winter. Most of these species favor intertidal habitats. As the tide goes out, shorebirds probe the exposed mudflats for invertebrates. At higher tides, they move to resting areas along the exposed marsh edges. The most common migratory shorebirds include the western sand-

piper, the marbled godwit, and the willet. Except for the killdeer, very few shorebirds remain year-round and breed in California estuaries.

2. Gulls and terns. Gulls and terns are conspicuous and important users of the estuary. Gulls are most numerous during the winter months, while terns are more commonly seen in summer months. Gulls feed on fish from open water or invertebrates found in the mudflats and also scavenge for food. The most common gulls in the estuary include western gulls, California gulls, herring gulls, and ring-billed gulls. Some, such as the western and ring-billed gulls, can be found on the coast throughout the year. Terns are predominantly fish-eaters. Common terns include Forster's tern and Caspian tern.

3. Ducks and other water-associated birds. Ducks and other water-associated birds are primarily winter visitors to the estuary. The surface-feeding ducks are usually found along the marsh edges and in shallow water over mudflats, feeding on vegetation and invertebrates. They include mallards, American wigeon, cinnamon and green-winged teal, and northern shovelers. The diving ducks are usually found in the deeper open water, where they dive for fish and mollusks. They include canvasbacks, greater and lesser scaup, ruddy ducks, and surfscoters. Other water-associated birds use the marsh edges and open water areas in much the same manner as the ducks. Common loons, western grebes, and double-crested cormorants dive for fish in the open water. American coots are normally found feeding on vegetation in the vicinity of the marsh. Pied-billed grebes feed on crustaceans, insects, and fish in the protected waters of marsh.

4. Raptors. Raptors, including hawks and owls, can be found over the marsh and open water. Species such as the osprey and southern bald eagle hunt for fish in the open water. The peregrine falcon hunts for ducks and shorebirds over open water, mudflats, and marsh. More common species such as the white-tailed kite, marsh hawk, and short-eared owl primarily search the marsh and adjacent fields looking for rodents or other small prey. Burrowing owls are typical residents of the levees that often border marshland areas.

5. Wading birds. Wading birds inhabit marsh areas, mudflats, and water edges. Larger birds, such as the herons and egrets, may be found in all three habitats. They include the great blue heron, black-crowned night heron, great egret, and snowy egret. Smaller waders, including the Virginia rail and the sora, are found almost exclusively in the marsh. They primarily feed on mice and invertebrates.

6. Songbirds. Songbirds also occur in the estuarine environment. They are generally associated with the emergent marshes, hunting for insects or foraging for seeds among the reeds and bushes of the high marsh. Common species include the marsh wren, song sparrow, house finch, and yellow-rumped warbler.

Invertebrates. Estuaries provide a habitat for enormous numbers of invertebrate species. The distribution of these species is controlled by complex interrelated factors which can be divided into two categories: physical factors and biological interactions.

1. Physical factors. The major physical factors affecting estuarine invertebrates include water movements, sedimentation, immersion, temperature, and salinity.

In many estuaries, the annual range of salinity at any location is one of the most important physical variables in determining the distribution of invertebrate species. The combination of tidal oscillations and freshwater discharges produces drastic changes in salinity, and only a limited number of organisms have the physiological adaptations for surviving these fluctuations. Bassindale (1943) demonstrated that the number of species decreased in the upper reaches toward freshwater source of the estuary, where salinity fluctuations might be greatest.

Substrate plays a secondary role in determining species distribution, as many organisms are dependent on a specific substrate. The nature of deposition of silt in estuaries can quickly alter a particular habitat.

The effects of wave action on species distribution is not significant in the estuarine environment, since wave action is generally reduced. Immersion and temperature are stresses typical of all intertidal areas, to which many organisms have evolved physiological and behavioral adaptations. (See habitat descriptions for further details).

2. Biological interactions. The physical variables can delineate the boundaries of distribution of an organism, but biological interactions are most important in determining the abundance within these boundaries. Dominant species often influence community structure within a particular habitat. It is possible for one species, such as the

starfish (Pisaster) which can control the structure of mussel communities, to dominate a community. More often, a group of organisms possessing similar modes of feeding (i.e., suspension feeders, deposit feeders) dominate a community. Rhoads and Young (1970) demonstrated that invertebrate deposit feeders have an inhibitory effect on populations of suspension feeders. Consequently, suspension feeders cannot colonize areas already inhabited by deposit feeders.

Competition between species and individuals for either food or space can influence the structure of communities. Woodin (1974) found that tubiculous polychaetes may occupy most of the available space in an area, excluding burrowing forms of polychaetes. Interactions between dense infaunal assemblages and settling larvae can produce the sharp boundaries characteristically observed between invertebrate communities. During feeding adults of the established community ingest settling juveniles, making colonization of the habitat by the young forms difficult (Woodin, 1976).

Many recent studies have examined the effects of predators on communities, concluding that predation can reduce the intensity of competition between prey species (Paine, 1963; Dodson, 1970; Stenson, 1976). With balanced predation, a more diverse faunal assemblage may develop due to the availability of more food and space.

Zooplankton. The estuary supports a diverse zooplankton community. The community includes species with established populations in the estuary and those introduced into the estuary by tides from the nearshore marine environment.

The zooplankton community is dominated by calanoid copepods. Dominant species in the middle portion of Humboldt Bay include Acartia tonsa and A. clausi, with the former most abundant in the summer and fall, and the latter most abundant during the winter and spring. In the upper estuary (near the freshwater source), Eurytemora affinis is most abundant. In the lower portion (near the outlet to the ocean) of the estuary, the dominant species reflect the marine influence. The most abundant species are copepods including Clausocalanus arcuicornis, Pseudocalanus sp., Paracalanus parvus, and Oithona similis (Gore, 1971).

An important component of the zooplankton community is the meroplankton, those organisms which are planktonic for only part of their life cycle. The meroplankton is dominated by barnacle nauplii, molluscan veligers, and polychaete larvae. Less abundant are crab, shrimp, and fish larvae.

Socioeconomic Processes in the Estuarine Ecosystem. Land manipulation, land cultivation and pesticide application are activities occurring in the watershed which impact the estuary through increasing sedimentation. The increased sedimentation rate can cause more rapid successional changes, especially from mudflat to emergent vegetation, and emergent vegetation to upland. The deposition of sediment can also smother individuals if it occurs at a sufficiently rapid rate.

The addition of pollutants to the estuary can occur in the watershed or can occur as direct addition to the estuary by pesticide application and through the activities of oil and gas development, sewage treatment plants, and other industry. Toxic substances can either kill individuals or accumulate in the tissues of lower trophic level organisms and be passed upward through the food chain. Biostimulation through the introduction of organic compounds can cause the depletion of nutrients or other resources.

Dredging and filling, often associated with shipchannel maintenance or construction, causes alteration or destruction of habitat. Increased turbulence may also result, limiting light penetration and smothering bottom-dwelling individuals.

Recreational activities such as shell-fishing and fishing can be detrimental to the ecosystem if individual populations become sufficiently depleted. An imbalance of the food chain can occur as a consequence. Other recreational activities, such as birdwatching and photography, will not substantially affect the ecosystem.

Classification of Subsystems of the Estuarine Ecosystem

The estuarine habitats chosen for discussion, and their characteristic dominants have been identified in Table 4-6. The U.S. Fish and Wildlife Service wetland classification system by Cowardin et al. (1979) was used as the basis for identifying these habitats and most closely relate to the "class" of the Cowardin system hierarchy.

Table 4-6. Habitat Types in an Estuarine Ecosystem in California

Habitat Type	Characteristic Dominant(s)
Unconsolidated Bottom	
Mudflat	Clams (e.g. <u>Tresus nuttalli</u>) Polychaete worms (e.g. <u>Capitella capitata</u>)
Sandflat	Sand dollar (<u>Dendraster excentricus</u>) Phoronid worm (<u>Phoronopsis viridis</u>)
Water Column	Phytoplankton (e.g. <u>Skeletonema</u>) Zooplankton (e.g. <u>Acartia</u> spp.)
Rocky Bottom	Bay mussel (<u>Mytilus edulis</u>) Acorn Barnacle (<u>Balanus glandula</u>)
Emergent Wetlands	
Marshes	Pickleweed (<u>Salicornia virginica</u>) California cordgrass (<u>Spartina foliosa</u>)
Eelgrass Beds	Eelgrass (<u>Zostera marina</u>)
Piers, Pilings	Bay mussel (<u>Mytilus edulis</u>) Acorn barnacle (<u>Balanus glandula</u>)

The differentiating criterion is the general appearance of the habitat, which may be in terms of the dominant life form of the vegetation (emergent vegetation and eelgrass or subtidal aquatic bed) or in terms of the physiography and composition of the substrate (unconsolidated bottom, rocky bottom, piers and pilings) . Derailed account of these habitats is provided in Volume III of this report.

Habitats of the Estuarine Ecosystem.

Water Column. The water column supports a unique community. Organisms found in this habitat are pelagic, able to exist without maintaining contact with a particular substrate. The water column environment is found in all bays and estuaries. In small or shallow bodies of water, the extent of open water may be greatly reduced at low tide.

The dominant organisms of the water column are the phytoplankton and zooplankton communities. The phytoplankton community is composed of microscopic plants, mostly diatoms and dinoflagellates, which convert sunlight into organic material. The zooplankton community contains permanent residents, such as copepods and temporary inhabitants, such as the larvae of crustaceans, mollusks, and fish. Zooplankton species feed on phytoplankton or other zooplankton. Many species of fish occur at different levels of the water column. Small schooling species usually feed on plankton. Other species may move to the bottom to feed, temporarily associating themselves with one of the other habitats. Many birds are associated with open water, either swimming on the surface of the water or flying above it. Most of these birds feed on fish.

Unconsolidated Bottom. Unconsolidated bottoms are the most common habitat type of the estuarine intertidal and subtidal zones. Sandflats are usually not extensive within the estuary. The weak currents of estuaries do not transport coarse sand particles very far. Sandflats are generally located near a source of sand, such as a dune. Mudflats are extensive in the estuary. They are composed of lighter particles, easily transported by low energy currents.

Mudflat. The lack of attachment sites in mudflats and the special adaptations required for respiration and feeding favor a particular type of organism. Most of the organisms living in the mudflat live in tubes or burrows, circulating water to obtain food and oxygen. The dominant organisms include clams, polychaete worms, echinurid worms and burrowing crustaceans. The surface of the mudflat supports diatoms, algae, snails and polychaete worms. Many fish move onto the mudflats at high tide to feed. Birds commonly feed on invertebrates in the mudflats during low tide.

Sandflat . The coarser substrate of sandflats supports a different community than mudflats. The shifting nature of the substrate virtually eliminates algae from this habitat. The organisms are dependent on food carried onto the sandflats by currents. The dominant organisms of the sandflat include the sand dollar, snails, polychaete

worms, and phoronoid worms. Certain crustaceans are also typical of sandflats. Many of the same species of fish and birds feeding over mudflats also feed over sandflats.

Rocky Bottom. Rocky bottom habitats occur in most estuaries and bays throughout the study area. Natural rocky bottoms are not prevalent in the estuary, normally occurring only near the entrance. Artificial rocky substrates, such as jetties and shoreline riprap may occur throughout the estuary, depending on the extent of human development.

The rocky bottom community is dominated by sedentary attached forms, including algae, barnacles, mussels and anemones. Other common invertebrates, capable of movement but also capable of firm attachment, are starfish, snails, and chitons. Many organisms hide under the rocks, including crabs and fish. Larger fish move into the rocky bottom habitat to feed during high tides, while several birds move in to feed during low tides.

The degree of wave action and duration of tidal exposure help determine community composition and species zonation. Competition for space is also a key factor, as the organisms seek a site for attachment.

Emergent Vegetation. Emergent vegetation or marshes are distributed throughout the study area in estuaries, lagoons, and protected bays, but are best well-developed near Humboldt Bay, San Francisco Bay, and Morro Bay.

The dominant life forms of the habitat are the macrophytes. The vegetation is supported by a substrate composed of fine-grained well-sorted clays that are high in organic matter and moisture content. Invertebrates are prevalent in the soft muds and function as primary or secondary consumers.

Birds, mammals and fish typically consume plants or prey on invertebrates and may be primary, secondary, or tertiary consumers.

Physical conditions largely control biological zonation. The primary controlling factors are topography, tidal inundation, and salinity distribution.

Eelgrass - Subtidal Aquatic Bed. Eelgrass beds occur in estuaries and sheltered embayments throughout the study area. The most extensive beds are located in Humboldt Bay, Bodega Harbor, Tomales Bay, and Morro Bay.

The eelgrass plants are the dominant feature of this habitat. Eelgrass is rooted in the substrate, occurring on mud and sand bottoms. A variety of epiphytic organisms live on the eelgrass leaves, including diatoms, algae and invertebrates. Many invertebrates also inhabit the substrate of eelgrass beds. Birds and fish may reside in the eelgrass beds or visit them to feed.

The occurrence of eelgrass beds is largely governed by physical factors. Eelgrass beds occur primarily in the subtidal zone, since the plants are relatively intolerant to exposure to air. Light penetration determines the maximum depth of eelgrass beds.

Piers and Pilings. The occurrence of piers, pilings, and floats is determined by the extent of human activity. These structures are usually located in protected waters of bays and estuaries.

The community found on piers and pilings is similar to that found on rocky bottoms. The wooden substrate is fairly hard, favoring attached organisms. In addition to algae, barnacles, mussels, and anemones, the dominant attached forms include bryozoans, hydroids and tunicates. The reduction in wave action allows more delicate organisms to flourish. Many species of fish move into this habitat to feed. Wood softens after immersion in seawater, allowing boring organisms to attack piers and pilings.

Estuarine Species

The species of concern selected for the estuarine habitats are identified in Table 4-7. The reason for selection has been indicated in the columns following the common and scientific names. The criteria include legal protected status, commercial value, recreational value, or ecological importance. A species account of each listed species as well as a more detailed account of the selection criteria are included in Volume II, Part 2 of this report.

Table 4-7. Status of Major Estuarine Species

Common Name	Scientific Name	Status ¹	Commercial	Recreational	Biological Significance
Marine Mammals					
Harbor Seal	<u>Phoca vitulina</u>				X
Terrestrial Mammals					
Salt marsh harvest mouse	<u>Reithrodontomys raviventris</u>	E(US &CA)			
Birds					
California clapper rail	<u>Rallus longirostris obsoletus</u>	E(US &CA)			
Black brant	<u>Branta bernicla nigricans</u>			X	X
California black rail	<u>Laterallus jamaicensis coturniculus</u>	R(CA)			X
Salt marsh yellow throat	<u>Geothlypis trichas sinuosa</u>	FP (CA)			
Migrating and wintering waterfowl			X	X	
Western sandpiper	<u>Calidris mauri</u>				X
Marbled godwit	<u>Limosa fedoa</u>				X
White-tailed kite	<u>Elanus leucurus</u>	FP (CA)			
Osprey	<u>Pandion haliaetus</u>	FP (CA)			X
Peregrine falcon	<u>Falco peregrinus</u>	E(US & CA)			
Bald eagle	<u>Haliaeetus leucocephalus</u>	E(US &CA)			
Willet	<u>Catoptrophorus semipalmatus</u>				X
Brown pelican	<u>Pelecanus occidentalis</u>	E(US & CA)			
Fish					
Pacific herring	<u>Clupea harengus pallasii</u>		X		
Shiner surfperch	<u>Cymatogaster aggregata</u>			X	X
Pile surfperch	<u>Rhacochilus vacca</u>		X	X	
Topsmelt	<u>Atherinops affinis</u>		X	X	X
Longfin smelt	<u>Spirinchus thaleichthys</u>			X	X
Starry flounder	<u>Platichthys stellatus</u>		X	X	X
Pacific staghorn sculpin	<u>Leptocottus armatus</u>		X	X	X
Bay goby	<u>Lepidogobius lepidus</u>				X
Leopard shark	<u>Triakis semifasciata</u>			X	
Northern anchovy	<u>Engraulis mordax</u>		X		
Striped bass	<u>Morone saxatilis</u>			X	
Chinook salmon	<u>Oncorhynchus tshawytscha</u>		X	X	
Steelhead	<u>Salmo gairdneri</u>			X	
Rockfish	<u>Sebastes spp.</u>		X	X	X
Lingcod	<u>Ophiodon elongatus</u>		X	X	
Kelp greenling	<u>Hexagrammos decagrammus</u>			X	X
Cabezon	<u>Scorpaenichthys marmoratus</u>				X
Monkeyface-eel	<u>Cebidichthys violaceus</u>				X
Pacific lamprey	<u>Entosphenus tridentatus</u>				X
Green sturgeon	<u>Acipenser medirostris</u>			X	
White sturgeon	<u>Acipenser transmontanus</u>			X	
Threespine stickleback	<u>Gasterosteus aculeatus</u>				X
Sanddabs	<u>Citharichthys spp.</u>			X	X
Coho salmon	<u>Oncorhynchus kisutch</u>		X	X	
Invertebrates					
California brackish water snail	<u>Tryonia imitator</u>	E(US-prop)			
Newcomb's littorine snail	<u>Littorina subrotundata</u>	E(US-prop)			

¹E = endangered; R = rare; FP = fully protected; US = protected under federal law; CA = protected under California law; prop = proposed legal protection

Table 4-7. (continued)

num	Scientific	Status ¹	Commercial	Recreational	Biological Significance
Common Washington clam	<u>Saxidomus nuttalli</u>			X	
	<u>Macoma mulleriana</u>			X	
	<u>Mya arenaria</u>		X	X	X
	<u>Mytilus edulis</u>		X	X	X
	<u>Cancer antennarius</u>		X		
	<u>Hemigrapsus oregonensis</u>			X	
	<u>Neomysis mer</u>				X
	<u>Crangon franciscorum</u>		X		X
	<u>Acartia tonsa</u>				X
	<u>Cancer magister</u>		X		
	<u>Pisaster ochraceus</u>				X
	<u>Pisaster brevispinus</u>				X
	<u>Mytilus californianus</u>				X
	<u>Pachygrapsus crassipes</u>				X
	<u>Halictis rufescens</u>		X		
	<u>Acmaea spp.</u>			X	X
	<u>Limoria (limoria) lignorum</u>				X
	<u>Anthopleura xanthogrammica</u>				X
	<u>Balanus spp.</u>				X
Vascular Plants	<u>Zostera marina</u>				X
	<u>Salicornia virginica</u>				X
	<u>Spartina foliosa</u>				X
	<u>Phyllospadix spp.</u>				X
Nonvascular Plants	<u>Ulva spp.</u>				X
	<u>Enteromorpha spp.</u>				X
	Sea lettuce				
	Green algae				
Common Washington clam	<u>Mya arenaria</u>		X	X	X
	<u>Mytilus edulis</u>		X	X	X
	<u>Cancer antennarius</u>		X		
	<u>Hemigrapsus oregonensis</u>			X	
	<u>Neomysis mer</u>				X
	<u>Crangon franciscorum</u>		X		X
Common Washington clam	<u>Acartia tonsa</u>				X
	<u>Cancer magister</u>		X		
	<u>Pisaster ochraceus</u>				X
	<u>Pisaster brevispinus</u>				X
	<u>Mytilus californianus</u>				X
	<u>Pachygrapsus crassipes</u>				X
Common Washington clam	<u>Halictis rufescens</u>		X		
	<u>Acmaea spp.</u>			X	X
	<u>Limoria (limoria) lignorum</u>				X
	<u>Anthopleura xanthogrammica</u>				X
	<u>Balanus spp.</u>				X
	<u>Zostera marina</u>				X
Vascular Plants	<u>Salicornia virginica</u>				X
	<u>Spartina foliosa</u>				X
	<u>Phyllospadix spp.</u>				X
	<u>Ulva spp.</u>				X
Nonvascular Plants	<u>Enteromorpha spp.</u>				X
	Sea lettuce				
	Green algae				
	Green algae				

¹E = endangered; R = rare; FP = fully protected; US = protected under federal law;
CA = protected under California law; prop = proposed legal protection

Estuarine Areas of Ecological Concern

Specific estuarine areas within the watershed units have been selected as Areas of Ecological Concern. Several criteria were used in selecting these areas: 1) areas containing important migration routes, breeding or nursery habitat, or the distributional limits of a species; 2) areas especially sensitive to perturbation; and 3) areas given special legal or regulatory status, such as National Wildlife Refuges, Marine Life Refuges, Ecological Reserves. Each of these areas is described in the pertinent watershed chapter of Volume IV of this report.

The California State Legislature is authorized by U.S. Congress to acquire areas to be designated as National Wildlife Refuges (Ed Collins, pers. comm.). Management regulations pertaining to National Wildlife Refuges can be found in the Code of Federal Regulations, Title 50, Parts 25 - 35. Marine Life Refuges are established by the California State Legislature (Smith and Johnson, 1979). Regulations pertaining to all or specific Marine Life Refuges are listed in Smith and Johnson (1979). The Fish and Game Commission establishes Ecological Reserves (Smith and Johnson, 1979). General regulations pertaining to Ecological Reserves and development and management plans for specific reserves can be found in Schulenberg (1979) and Smith and Johnson (1979). Marine Areas of Ecological Concern are described under the ocean basin descriptions of Volume IV of this report.

Major Human Influences on Estuarine Ecosystems

An increasing population, and the ever-rising need for energy has accelerated the intrusion of human activity into coastal ecosystems. Deleterious man-induced changes in estuaries take several forms: disruption of land formations, diking or filling, alteration of water flows, and discharges of toxic substances. A common consequence of these perturbations is the disturbance of the area's wildlife (in the broadest sense of the word).

Diking and filling of estuaries have been common in the San Francisco Bay estuary and have, in part, been the cause of the dramatic loss of habitat. Approximately 60 to 85% of total marsh in California has been reclaimed to upland.

Recreational use of estuaries has increased in recent years. Hunting and fishing recreational uses are controlled by California Fish and Game laws. Although these recreational activities can adversely affect the ecosystem, their impact is probably less than that resulting from agriculture, industry, residential areas, oil exploration and drilling. Other forms of recreation, such as off-road vehicles, camping, and day use, are not regulated by the California Department of Fish and Game and can have much more serious effects on land resources than either hunting or fishing.

The alteration of landforms and vegetation for agriculture, commercial, residential, and industrial uses can have a devastating effect on coastal areas. Excavation and defoliation increases runoff, which not only causes more erosion, but also leads to increased transfer of toxic wastes contained in pesticides and fertilizers. Increased sedimentation from runoff can destroy salt marshes, eelgrass beds, tidal flats, and mudflats by raising the elevation of the substratum. Pollutants from industrial discharges can be directly lethal to organisms or can produce subtle changes in physiology and behavior which eventually lead to death. Chemicals can contaminate smaller organisms at the bottom of the food chain, adversely affecting predatory species and rendering organisms unfit for human consumption. Stormwater runoff from urbanized runoff can also contribute to the introduction of pollutants and to the increase in sedimentation. Such non-point source discharges may be a more substantial portion of total pollutants than originally estimated (ABAG, 1979).

Oil exploration and drilling has been responsible for much habitat destruction. The guidelines developed by Longley et al. (1978), if applied, hopefully will ameliorate the changes associated with oil exploration and development. The preliminary processes of oil exploration involves the clearing of large areas of habitat for access roads and for conducting detonations or vibrations to locate oil deposits. The introduction of heavy machinery in marsh areas produces high noise levels and creates large ruts which alter surface water flows. High levels of noise are generated from the machinery once the drilling begins. High noise levels tend to displace sensitive wildlife and waterfowl from an area. At this stage toxic or noxious substances which may be inadvertently released into the environment are produced. The installation of holding tanks and pipelines involves the clearing of more habitat, dredging operations and controlled low level pollution, whose affects are still unknown.

One of the greatest damages to an ecosystem can occur with large oil spills and the ensuing clean-up activities. Sessile organisms, and larval stages suffer the greatest damage from pollution (Evans and Rice, 1974). The consequences to the ecosystem vary from one locale to another.

RIVERINE ECOSYSTEMS

General Characteristics

The study area contains many relatively small streams draining the coastal mountain ranges. Also, two larger systems which drain relatively large inland areas flow through the study area before meeting the ocean: the Klamath River and the Sacramento-San Joaquin system (which drains into San Francisco Bay).

A model has been developed for coastal riverine ecosystems (Figure 4-17). The model is a graphic summary of important processes in the natural ecology of streams, and also of the important influences of human activities on those processes. The area of the model within the heavy-dashed line represents a hypothetical segment of a stream. Not every process and activity that occur in all stream ecosystems in the study area are shown in the model; the ones shown are only those that significantly determine habitat quality or species composition; or that affect, or are affected by, a human use of the ecosystem. Refer to Appendix A of this volume for explanations of the symbols used in the model.

The ecosystem model separates processes and activities into three major categories: physical-chemical, biological, and socio-economic. The following discussions summarize these categories.

Physical-Chemical Parameters. The left side of the riverine ecosystem model (Figure 4-17) summarizes important physical and chemical processes. Included in the physical-chemical realm are the substrates within which the biological processes occur: the water column and the stream bed. Important processes occurring between the sun-atmosphere and the water column are insolation (which drives heating and photosynthesis) and aeration (which exchanges dissolved gases including biologically important oxygen and carbon dioxide). Direct evaporation from the water surface and direct precipitation to the water surface, are much less important than precipitation and evapotranspiration in the watershed. Direct runoff from the watershed accumulates dissolved solids, and is also important in the transport of sediments from the watershed into the stream. Water that infiltrates into the soil may reach the stream via percolation through the stream bed.

In the model, "watershed" means the area of land, adjacent to the hypothetical segment, contributing direct runoff, tributary flow, and groundwater accretions to the hypothetical segment. Upstream watershed areas contribute water and other materials to the segment via upstream riverine ecosystems, not via "watershed". Materials are therefore transported to the hypothetical stream riverine ecosystem; materials are then transported from the hypothetical stream segment to the downstream riverine ecosystem.

Within the water column and stream bed, important processes are mixing, percolation of water between the water column and stream bed, suspension and settling of sediments and detritus, and erosion of stream bed sediments.

Biological Parameters. The central region of the riverine ecosystem model (Figure 4-17) summarizes biological processes. The riverine community is composed of producers, consumers, and decomposers. The materials exchange process between the riverine community and the substrate (water column and stream bed) are gas respiration, uptake and excretion of nutrients, and ingestion and defecation of particulate materials.

Biological exchanges with the riparian ecosystem are also important. In this mode 1, "riparian" means the vegetated strip bordering the hypothetical stream segment. Leaf litter <rep, insect drop, predation, and aquatic insect visitations occur between the riverine and riparian ecosystem. Riparian vegetation also provides shade, an important factor in stream temperature.

Socio-economic Activities. The right side of the riverine ecosystem model (Figure 4-17) divides socio-economic processes and activities into two general categories: general human activities occurring outside the ecosystem boundary and specific processes occurring on or near the ecosystem boundary. The general activities occurring outside the ecosystem boundary generally lead to the indicated specific processes on or near the boundary. For example, urbanization can lead to increased fishing, to stream channelization, to water diversion, to organic pollution, to impoundment, and to watershed disturbance and loss of vegetation.

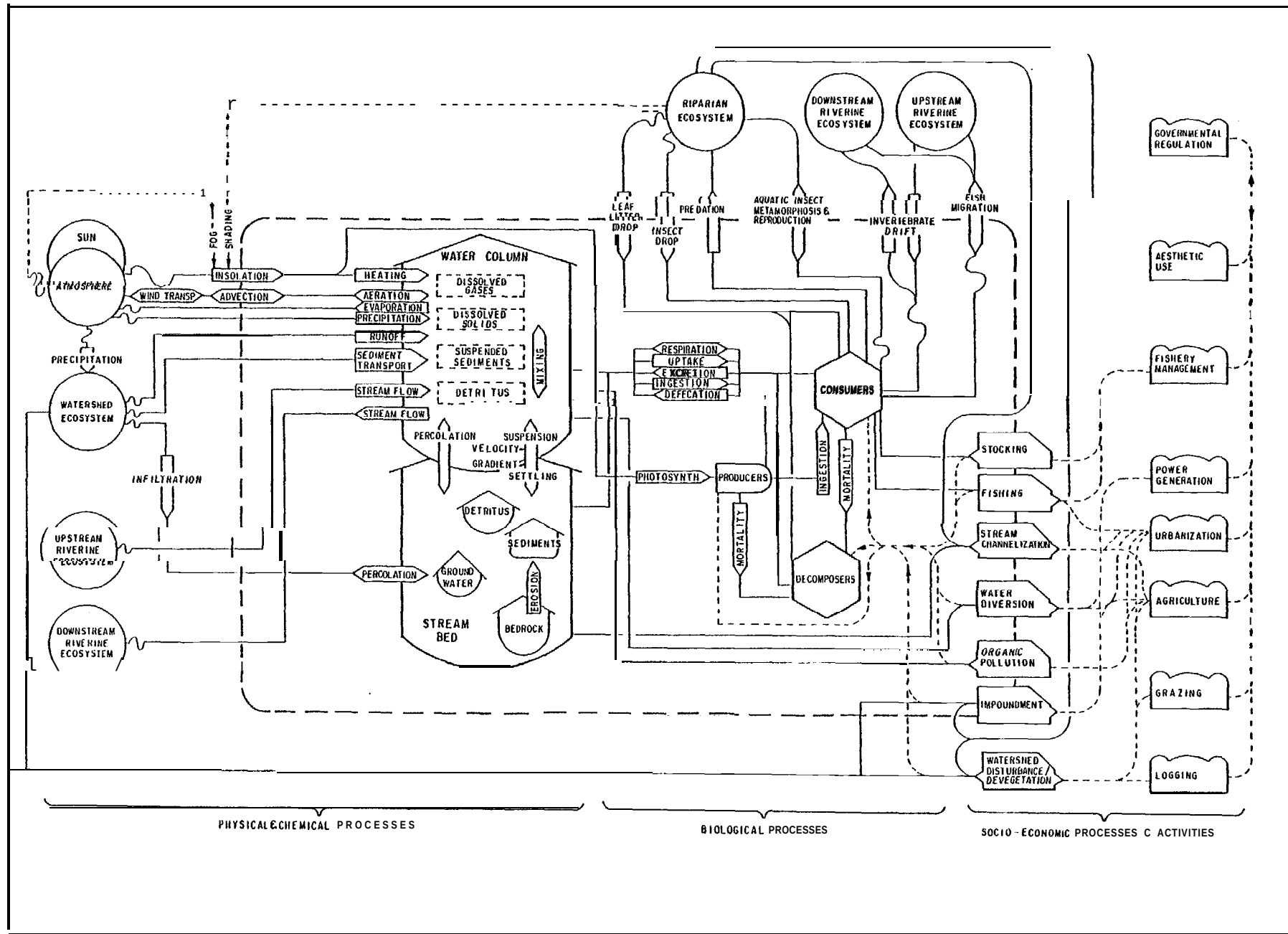


Figure 4-17. Ecosystem Model of Riverine Habitats

Hierarchical Classification of Subsystems

The habitat classification system of Cowardin, et al. (1979) is used for describing and characterizing riverine habitats in this report. The classification scheme divides the riverine system into four subsystems: tidal, lower perennial, upper perennial, and intermittent. Definitions of these subsystems are based mainly on salinity, flow velocity and regime and substrate type. Within each subsystem there are several hierarchies of categories based on substrate type or aquatic vegetation. The following discussions relate to general characteristics of the tidal, lower perennial, upper perennial, and intermittent subsystems. More detailed descriptions are given in Volume III, Part 1, Chapter 5.

Tidal. The lower end of the tidal riverine subsystem terminates where the concentration of ocean-derived salts exceeds 500 milligrams per liter (mg/l) during the period of average annual low flows. The upper end of the tidal subsystem is located where river current velocity ceases to fluctuate under tidal influence. Substrate type is usually mud or sand. Aquatic vascular plants may be found in backwater areas or other areas of low current velocity. Characteristic biota of tidal riverine habitats consist of planktonic forms (planktonic green algae, diatoms, and copepods) and forms associated with sand or mud bottoms (amphipods, midge fly larvae, freshwater clams). Emergent vegetation may grow along the banks.

Detritus imported from upstream areas is generally an important energy source for tidal riverine communities. Other locally important sources may be phytoplankton, attached algae, and vascular plants.

Tidal riverine habitats are best developed in streams with extensive floodplains and gentle gradients as they approach the ocean. These habitats are generally poorly developed in coastal streams of the study area because the coastal ranges rise abruptly from the coastline. The Sacramento-San Joaquin Delta is an example of a well developed tidal riverine habitat area, although habitat area and diversity there have been greatly decreased by stream channelization.

Lower Perennial. Lower perennial habitats are the lower reaches of a stream system that typically meander through a floodplain. These areas have relatively slow current velocities and year round (perennial) flows. The bottom is typically mud or sand. Characteristic biota consist of planktonic forms (planktonic green algae, diatoms, copepods) and forms associated with sand or mud bottoms (amphipod, midge fly larvae, freshwater clams). The biotic community is similar to the tidal riverine community, except there is less invasion by euryhaline (tolerant of fresh and salt water) marine and estuarine species (e.g., starry flounder).

Detritus is an important energy source. Phytoplankton, attached algae, and vascular plants may also be locally important energy sources.

Like tidal riverine habitats, lower perennial habitats are best developed in streams with a gentle gradient as they approach the ocean. Lower perennial habitats are generally poorly developed in the coastal streams of the study area because the coast ranges rise abruptly from the coastline.

Upper Perennial. Upper perennial habitats have higher gradients and faster current velocities than lower perennial habitats. Flow is perennial and the substrate is typically rock, cobbles, or gravel, with occasional patches of sand. Shallow, fast-flowing areas generally have gravel or boulder substrates and are called "riffles". Deep, slow-flowing areas have sand or mud substrates and are called "pools". The characteristic biota of upper perennial habitats consist of forms associated with the gravelly substrates of riffles (attached diatoms, mayflies, stoneflies, black flies). The characteristic biota composition of pools is similar to that of lower perennial habitats, due to similarities in substrate size and other physical habitat parameters.

Detritus and insect drop from the riparian zone are important energy sources in upper perennial habitats. Also important are attached algae.

Upper perennial habitats are probably the most extensive riverine habitats in the study area. They have diverse communities of algae, invertebrates, and fishes. Typical fish species found in upper perennial habitats are steelhead/rainbow trout (*Salmo gairdneri*) and sculpins (*Cottus* spp.). Some of the fish uses of upper perennial habitats are illustrated in Figure 4-18.

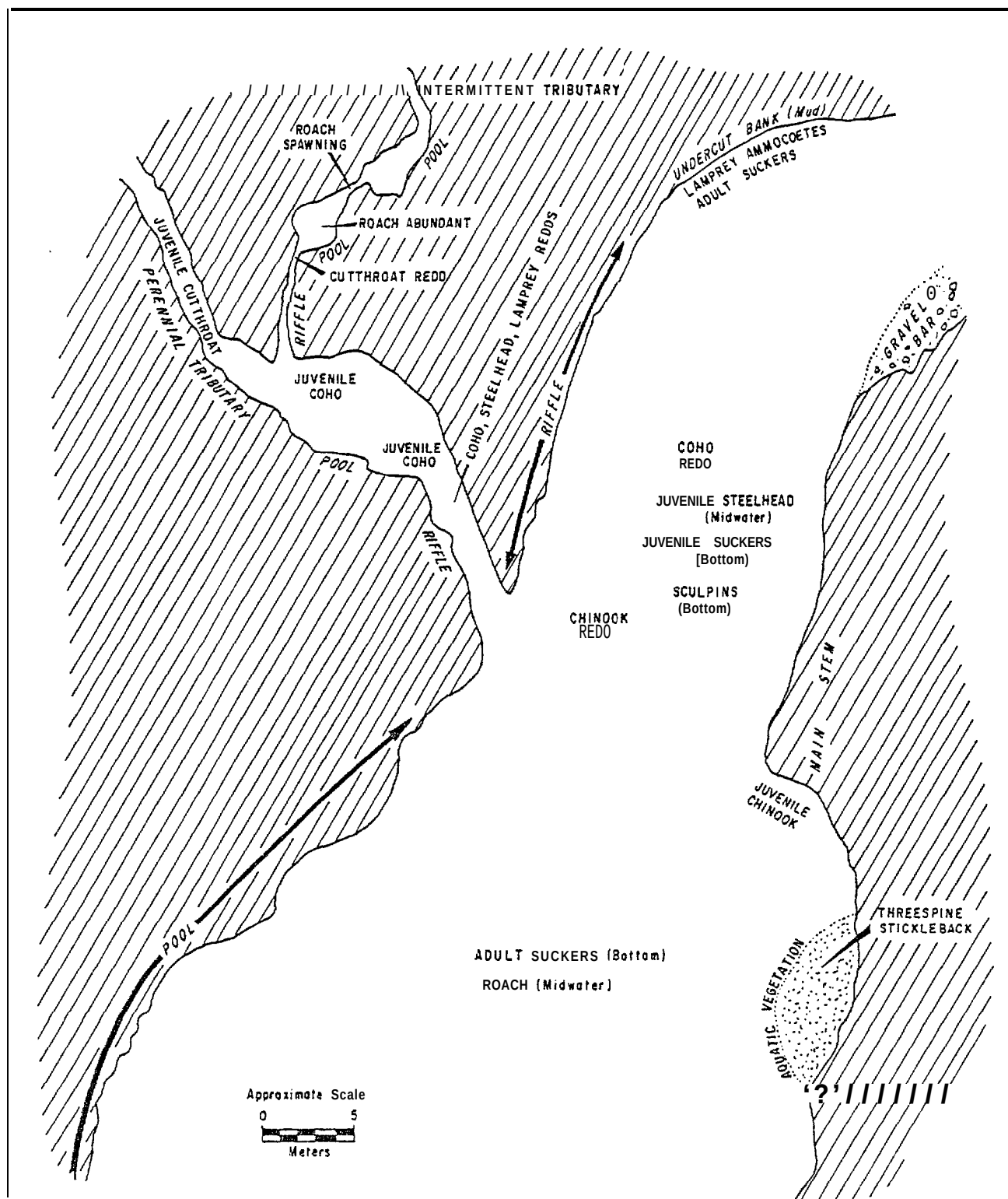


Figure 4-18. Location of Fish Forms in Upper Perennial Habitats (Generalized)

Intermittent. Intermittent riverine habitats contain flowing water for only part of the year. Flow may cease anytime from about late spring to early autumn, depending on the stream and the water year. Standing water may or may not remain in pools. Substrate type ranges from mud to bedrock; usually it is similar to that of upper perennial habitats. Characteristic biota are also generally similar to those in upper perennial habitats, but all the species must have ways to endure or avoid the dry periods.

Intermittent habitats typically occur upstream of upper perennial habitats; intermittence may also occur in the lower reaches of a stream.

Major Marine Species

The importance of fishes and aquatic invertebrates was based on their status as rare or endangered, recreational, commercial, or ecologically important species. The 15 species selected are listed in Table 4-8. Detailed discussions of the distribution, life history, and ecology of these species are given in Volume II, Part 2 (Species). Common and scientific names of fishes in this report are those designated by the American Fisheries Society (Bailey, et al., 1970).

Major Ecological Areas

Stream habitat areas selected as areas of ecological concern include Wild and Scenic Rivers, areas inhabited by rare or endangered species, and habitats used by anadromous salmonid fishes. These areas are mapped by watershed in Volume IV.

Wild and Scenic Rivers. Wild and scenic rivers in the study area are designated under the California Wild and Scenic Rivers Act, which created the California Wild and Scenic River System. There are no rivers in the study area in the federal Wild and Scenic River System. Rivers in the California Wild and Scenic Rivers System are given substantial protection against construction of major new dams and transbasin diversions. Temporary flood storage facilities and diversions for local water supply are permissible under the act. The act also directs the Secretary of the Resources Agency to prepare management plans to administer the rivers and their adjacent land areas. The plans must be approved by the California State Legislature. Thus far, the plans have been subject to much controversy and none has been approved. Rivers in the study area that are included in the California Wild and Scenic Rivers System are the Smith River and its tributaries, the mainstem Klamath, and the mainstem Eel.

Major Human Influences

The major human factors adversely affecting habitat quality in riverine ecosystems in the study area are stream channelization, water diversion, loss of streamside vegetation and disturbance of watersheds.

Stream Channelization. Channelization of streams is most prevalent in lower perennial and tidal stream reaches, especially where streams run through urban or agricultural lands. Principal instream effects of channelization are losses in habitat volume and diversity due to cutting off or filling in of backwater areas and marshy stream margin areas. Where riparian vegetation is removed, aquatic productivity may decrease due to decreased input of terrestrial detritus. Water temperatures may elevate when shade trees are removed to the point of excluding some formerly common species.

Water Diversion. Urbanization and agriculture are the main causes of water diversions. As one proceeds south along the California coast, natural water supply (precipitation and stream flow) decreases and human water demand increases. As a consequence, the effects of stream flow diversion are generally more severe in the southerly portions of the study area.

Watershed Alterations. Urbanization, logging (including road construction), and grazing are the main sources of watershed vegetation loss, disturbance or alteration in the study area. Urbanization is generally most significant between the Russian River and Monterey Bay. Logging is significant from Santa Cruz County north. Grazing is locally significant throughout the study area, but most significant from Monterey County south.

Table 4-8. Status of Major Freshwater Invertebrate and Fish Species

Common and Scientific Names	Status			
	Rare or Endangered	Commercial	Recreational	Ecological Interest
California freshwater shrimp (<u>Syncaris pacifica</u>)	X			
Pacific lamprey (<u>Entosphenus tridentatus</u>)				X
White sturgeon (<u>Acipenser transmontanus</u>)			X	
Green sturgeon (<u>A. medirostris</u>)			X	
American shad (<u>Alosa sapidissima</u>)			X	
Co'no salmon (<u>Oncorhynchus kisutch</u>)			X	
Chinook salmon (<u>O. tshawytscha</u>)			X	
Coastal cutthroat trout (<u>Salmo clarki clarki</u>)			X	
Steelhead rainbow trout (s. <u>gairdneri gairdneri</u>)			X	
Eulachon (<u>Thaleichthys pacificus</u>)			X	
California roach (<u>Hesperoleucus symmetricus</u>)				X
Sacramento sucker (<u>Catostomus occidentals</u>)				X
Threespine sticklebacks (<u>Gasterosteus aculeatus</u>)	X			X
Striped bass (<u>Morone saxatilis</u>)			X	
Prickly sculpin (<u>Cottus asper</u>)				X

The principal effects of watershed alterations on stream habitats are hydrologic alterations and increased sedimentation through disturbance of the entire watershed, and increased water temperatures and decreased leaf litter and insect drop through removal of riparian vegetation. Barriers to fish migration can also be created by accumulation of debris in streams (log jams) .

LACUSTRINE ECOSYSTEM

General Characteristics

The study area has few natural freshwater lakes. Lacustrine (lake) ecosystems in the study area consist mainly of small reservoirs (e.g., Kent Lake, Marin County) and some small lakes lying along coastal plains (e.g., Oso Flaco Lake, San Luis Obispo County).

An ecosystem model has been developed for lacustrine ecosystems (Figure 4-19) . The model is a graphic summary of important processes in the natural ecology of lakes, and also of the important influences of human activities on those processes. Not every process and activity that occurs in lakes is shown; the ones shown are generally those that significantly affect habitat quality or species composition, and that are significantly variable within the context of human activities and effects on the ecosystem. Refer to Appendix A for explanation of the symbols used in the model.

The model separates processes and activities into three categories: physical and chemical, biological and socio-economic. The following discussions summarize processes in these categories.

Physical-Chemical Parameters. The left side of the lacustrine ecosystem model (Figure 4-19) summarizes important physical and chemical processes. Included in the physical-chemical realm are the substrates within which the biological processes occur: the water column and the bottom substrate. Within the water column and bottom substrate are dissolved gases, dissolved solids, sediments, and detritus (nonliving particulate organic matter) .

The sun and atmosphere are important sources to lakes. Insolation drives heating, evaporation, and photosynthesis. Wind is important through wave-induced processes, in sediment suspension and the determination shoreline habitat types, "Other ecosystem" include the lake's watershed ecosystem, which contributes runoff, dissolved solids (including nutrients) , and sediments.

Biological Parameters. Biological processes of the lacustrine ecosystem are summarized in Figure 4-19. The lacustrine community is composed of producers, consumers, and decomposers.

Among the important biological processes in lakes are photosynthesis, uptake and excretion of nutrients (may determine algal standing crop levels) , and decomposition (releases nutrients).

Socio-economic Activities. The right side of the lacustrine ecosystem model (Figure 4-19) shows socio-economic activities and the effects of those activities on the ecosystem boundary. The general activities lead to the effects indicated on the ecosystem boundary.

Construction and filling adversely affect lake ecosystems by removing nearshore vegetation and decreasing lake habitat diversity. Fishing removes consumers. Boating may result in local shoreline disturbances (access points) , and in the introduction of litter and boat engine wastes into the system. Waste disposal, especially when it leads to eutrophication, can be a major human influence in lacustrine systems.

Hierarchical Classification of Subsystems

The lacustrine habitat classification system used for describing lakes habitats in the report is the lacustrine system of Cowardin, et al. (1979), except a pelagial (open water) subsystem has been added. Thus there are three subsystems: littoral, (nearshore) , limnetic (lake bottom) , and pelagial. Within the littoral and limnetic subsystems there are hierarchical categories based on substrate or aquatic vegetation type. The following discussions relate to general characteristics of the littoral, limnetic, and pelagial subsystems. Here detailed descriptions are given in Volume III, Part 1, Chapter 6.

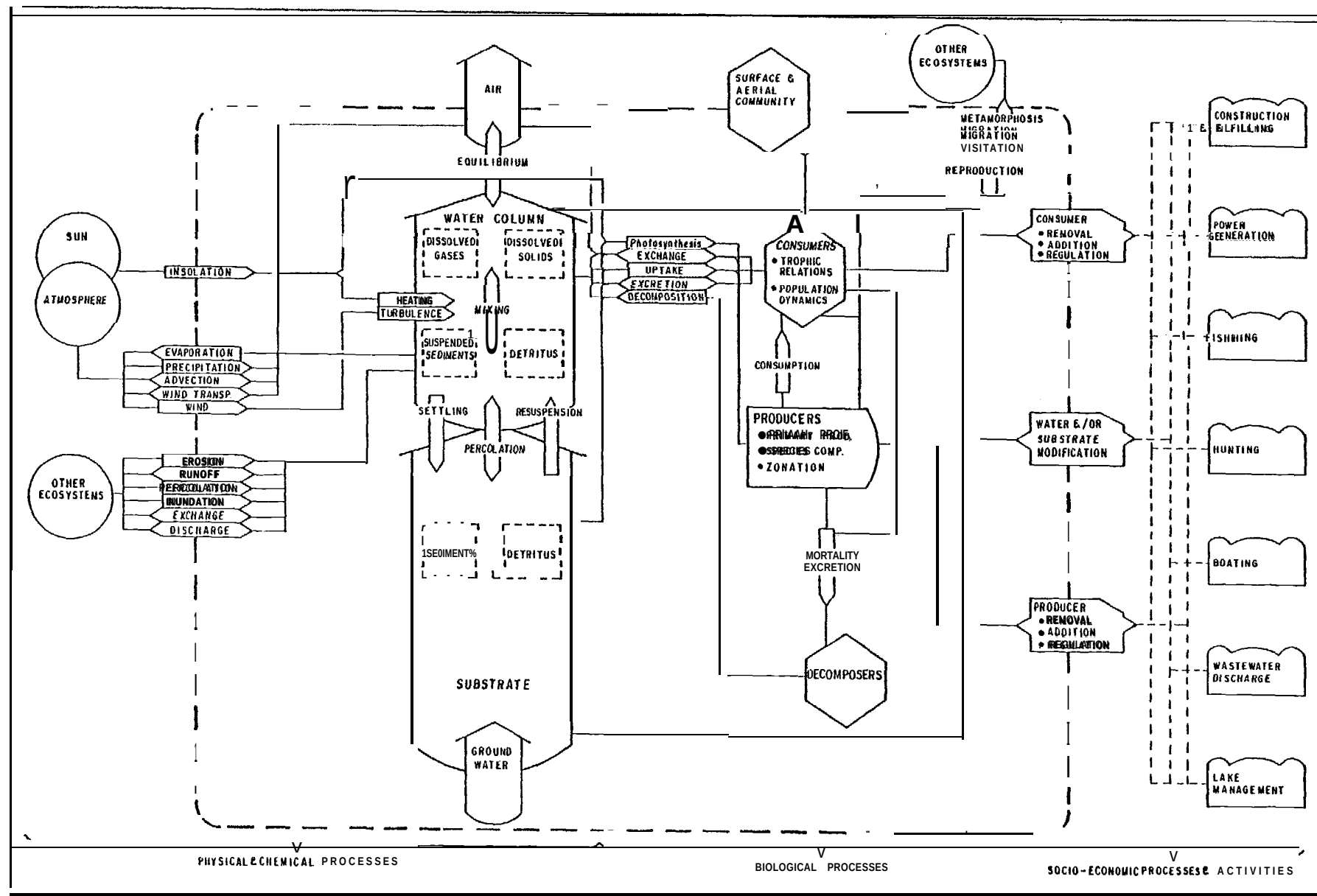


Figure 4-19. Ecosystem Model of Lacustrine Habitats

Littoral. The littoral subsystem is the nearshore area extending from the high water line to a depth of 2 meters (m) (6 feet) below low water or, if deeper, to the maximum depth of nonpersistent emergent vegetation. Bottom type can range from large boulders to mud, or be dominated by aquatic vegetation. Characteristic biota consist of forms associated with the particular substrate; common are rooted vascular plants, attached green algae and diatoms, aquatic snails, and caddisfly larvae.

Limnetic. The limnetic subsystem consists of bottom sediments extending from the edge of the littoral to the center (bottom) of the lake basin. Sediments are usually mud or organic. Characteristic biota include protozoans, oligochaete worms, and midge fly larvae.

Pelagial. The pelagial subsystem is the open water region extending from the edge of the littoral subsystem down to, but not including, the bottom sediments. Characteristic biota consist of planktonic (drifting) and nektonic (free-swimming) forms including green algae, diatoms, crustacea, and fishes.

Major Freshwater Species

Lakes are uncommon in the study area, and there are no designated species of concern and of ecological interest specifically associated with them, other than riverine species that might also be found in some lakes.

PALUSTRINE ECOSYSTEM

General Characteristics

Palustrine ecosystems in the study area consist of nontidal wetland areas dominated by emergent vegetation, of vernal pools, and of small bodies of water traditionally known as ponds. The palustrine habitat classification system used in this report is that of Cowardin, et al. (1979). The emergent wetland and vernal pool habitat categories are essentially identical to habitat categories described under Terrestrial Ecosystems (Volume II, Part 1, Chapter 4 and Volume III, Part 1, Chapter 8) and the reader is referred for descriptions of those habitats. The remaining palustrine habitat categories (pertaining to permanent open ponds) are similar to habitat categories under the littoral subsystem of the lacustrine system (immediately preceding section of this chapter and Volume III, Part 1, Chapter), and the reader is referred for discussion on those habitats.

TERRESTRIAL ECOSYSTEMS

An ecosystem is a geographic area in which biological components (i.e., organisms) interact with physical components (i.e., environment). Biological and physical processes relate organisms to environment in a system. Thus an ecological system (i.e., "ecosystem") is a conceptual tool which organizes thinking about the components and processes operating in a specific geographical place (also an "ecosystem"),

A terrestrial ecosystem can be defined as a structurally and functionally integrated concrete object composed of an organism or organisms (the biotic component) and a volume of soil and air (the abiotic environment of the biotic component) (Rowe, 1961). An ecosystem can be of any size, as long as it is a volumetric whole, containing at least one living organism. Ecosystem boundaries are defined by the purposes of the observer. Odum (1956) stressed the functional integration of ecosystems.

The "operational environment" of an individual organism has been defined by Mason and Langenheim (1957) as those physical, chemical, and biological phenomena that directly impinge on the organism during its life cycle. The source or origin of these operational factors is inconsequential to the organism. Its physiological responses are specific to the complex of direct environmental stimuli, the operational environment. Definition of an organism's "operational environment" focuses attention on the influence rather than on the origin of the stimuli. Waring, et al. (1972), discussed the use of the operational environment concept to develop plant response indices and thereby to predict ecosystem characteristics such as productivity, composition, biogeochemical cycling, and consumer population dynamics.

The terrestrial ecosystem model presented in Figure 4-20 synthesizes the concepts of "ecosystem" and "operational environment". The biotic component of a terrestrial ecosystem includes producer, consumer, and decompose organisms as well as their organic products (detritus and dissolved organic compounds). Operational environments of terrestrial organisms, and vascular plants in particular, consist of functionally related volumes of air (microclimate) and land (substrate).

Vascular plants are the dominant organisms in terrestrial ecosystems in the sense that their removal would cause the greatest alteration in both biotic (e.g., consumer forage) and abiotic (e.g., soil temperature) ecosystem properties (Daubenmire, 1968b). Biological processes link biotic components to their operational environments and to each other. In Figure 4-20, processes between producers and the microclimate-substrate complex are emphasized due to the dominant influence of producer organisms on both abiotic and biotic components. Biological processes also include transport of producer and decompose disseminules (i.e., seeds, spores, bulbs, and vegetative fragments of parent plants) across ecosystem boundaries, and consumer migration and visitation.

Physical-chemical processes operate both within ecosystem boundaries (e.g., between microclimate and substrate) and across ecosystem boundaries. For example, moisture may enter ecosystems through processes such as precipitation, wind transport, and condensation of fog, flooding, and subsurface flow. Physical processes may also act directly on organisms, as for example when fire, wind, or flooding cause physical damage to plants and animals.

Socioeconomic activities interact with the several ecosystem components. Socioeconomic processes may act directly by physically removing (whole or parts of) producer and consumer organisms. These processes may indirectly influence organisms by modifying conditions of their operational environments. For example, logging affects many wild-life species indirectly by removing vegetation necessary for shelter, cover, and forage.

In the following sections, components, processes, storage compartments, and external sources and sinks of the terrestrial ecosystem model (Figure 4-20) are described. Underlining indicates processes and compartments named in Figure 4-20. Appendix A of this volume consists of a glossary of symbols used in the model.

Physical-Chemical Components - Microclimate

Microclimate is a function of the vegetation or lack of vegetation on the site. It is also a function of the regional climate, topography (slope and aspect), and soil parent material (Major, 1951). Properties of microclimate that directly influence plant and animal physiological responses are described below. Although many of these properties do not act independently, they cannot completely substitute for each other.

Radiant Energy. The amount of radiant energy reaching photosynthetic surfaces influences biomass productivity of an ecosystem. Radiant energy may be optimum, adequate, excessive, or insufficient depending on plant genetic constitutions and on other properties of microclimate and substrate.

Air Temperature. Air temperature influences rates of physiological response in plant and animal organisms, as well as rates of many physical-chemical processes.

Vapor Pressure Deficit. Vapor pressure deficit (VPD) is the driving force for transpiration of moisture from plant leaves to the atmosphere. VPD indicates the difference in vapor pressure of water within the leaf and in the atmosphere beyond the boundary layer (i.e., the layer of still air along leaf surfaces). VPD is determined primarily by temperature and atmospheric humidity (Salisbury and Ross, 1978). High vapor pressure deficit causes rapid movement of moisture from plant tissues to the microclimate through both evaporation and transpiration (Daubenmire, 1974).

Gases and Aerosols. Gases such as ozone and aerosols such as salt spray may have important detrimental effects on plant tissues. Fog droplets, also considered aerosols, benefit many plants by lowering microclimate vapor pressure deficits and by condensing on plant leaf surfaces. This lowers evapotranspiration rates and may thus reduce plant moisture stress during rainless summer months.

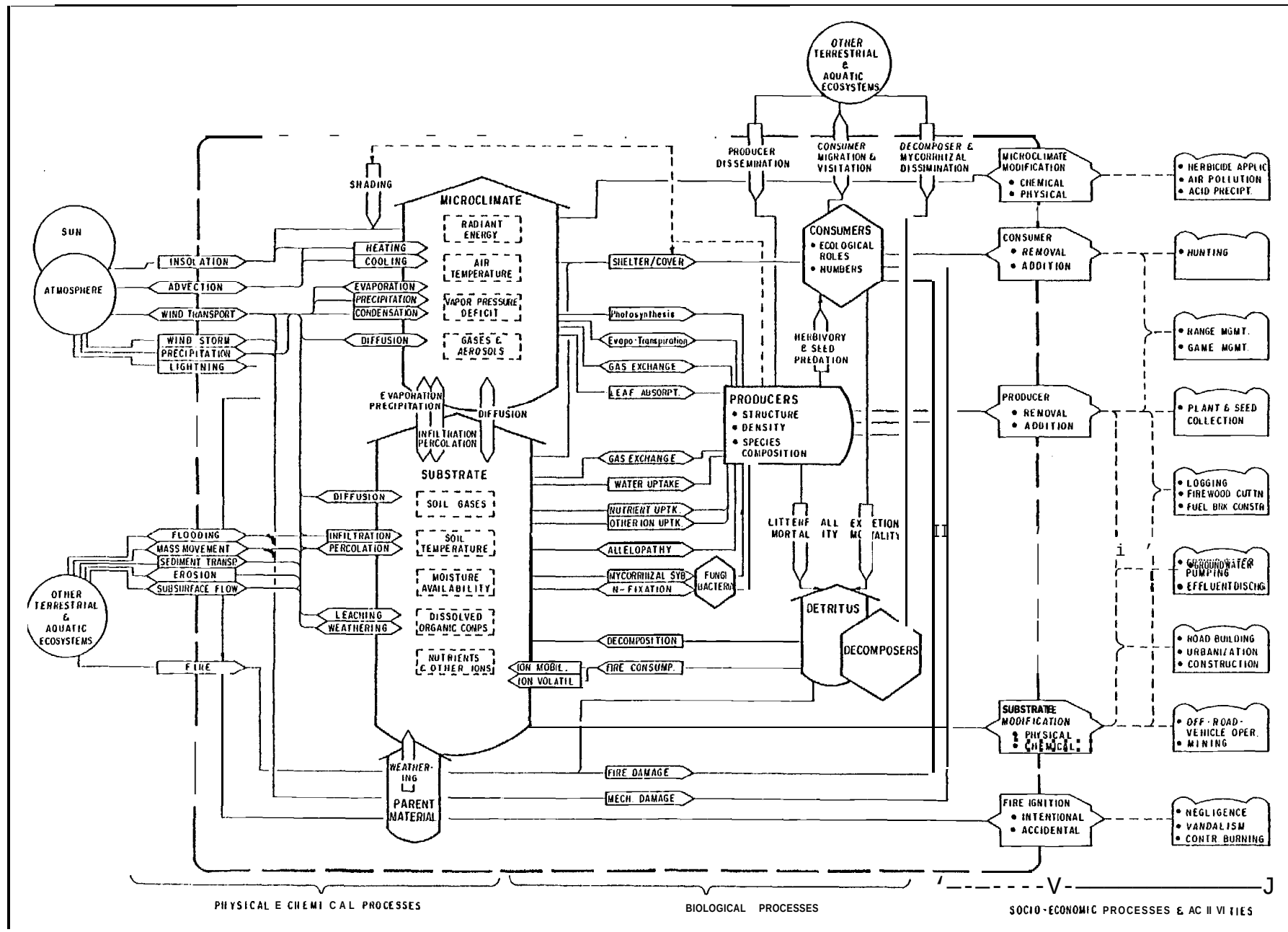


Figure 4-20. Ecosystem Model of Terrestrial Habitats

Physical-Chemical Components - Substrate

The substrate portion of terrestrial ecosystems encompasses the entire volume of mineral and/or dead organic matter occupied by plant roots. It includes living organisms (e.g., soil microflora and microfauna, fossorial mammals), water, and gases. Characteristics of soils such as texture, depth, and parent material are primarily important to plants through their influences on the following substrate features.

Soil Gases. In heavy soils or in soils saturated with water, oxygen deficiency and toxicity of excess carbon dioxide limit root respiration and therefore nutrient and water uptake. Soil micro-organisms (e.g., decomposers, nitrogen fixers) are also limited by low oxygen content in soils.

Soil Temperature. Temperature limits physiological responses of plant roots, seeds, and soil organisms. Soil texture affects soil temperature by determining air exchange between soil and microclimate. Rapid exchange favors conditions of temperature equilibrium. Therefore, coarse soils respond to warm air temperatures more rapidly in springtime.

Moisture Availability. This soil property indicates the amount of soil moisture available for plant uptake. Moisture availability is a function of soil storage capacity (primarily a function of soil texture); depletion of moisture by plants throughout the growing season; and replenishment of soil moisture by precipitation, subsurface flow or capillary rising from a deep water table (Waring and Major, 1964). Moisture availability limits both plant growth and activities of decompose organisms.

Dissolved Organic Compounds. Organic matter in mineral soils is primarily in the form of dissolved organic compounds. These compounds are decomposition products translocated from surface litter and humus layers (Bormann and Likens, 1979). Soil moisture depletion in study region soils causes precipitation of these compounds in lower soil horizons.

Nutrients and Other Ions. This soil property encompasses soil nutrients (derived from substrate parent material and from organic matter) ; soil acidity, alkalinity, or salinity; and toxic allelopathic ions (produced by plants and released from litter or from living cells) (Daubenmire, 1974) .

Parent Material and Weathering. Weathering of parent materials involves mechanical disintegration of rock particles and chemical decomposition of minerals (Brady, 1974). Climatic conditions, parent material physical and chemical properties, topography, vegetation, and soil microflora determine weathering rates and characteristics (e.g. , texture, fertility, toxic ions) of the resulting soil profile. Residual soils are weathered from bedrock parent materials. Other soils types are colluvial (weathered from gravity-transported material, e.g., landslides), alluvial (from water transported sediments) , and aeolian (from wind-transported materials) .

Physical and Chemical Processes

Processes Associated with Sun-Atmosphere Sources and Sinks. The sun-atmosphere complex supplies the energy (i.e. , sunlight) to drive ecosystem functions and several of the major compounds (i.e. , carbon, hydrogen, oxygen) used to build ecosystem structure. The amount of insolation (i.e. solar radiation received by plant leaves and the soil surface) is a function of regional climate (e.g., regional cloud cover patterns) and local topography (e.g., aspect and slope) . Advection is horizontal movement of air masses causing changes in temperature or other physical properties. For example, cold air drainage down mountain valleys may cause frost pockets and limit certain kinds of plants.

Wind transport brings fog, salt spray, pollutant chemicals, soil, sand, and plant seeds into and out of an ecosystem. Wind is directly important to plants in depleting atmospheric moisture and replenishing carbon dioxide at leaf surfaces (Daubenmire, 1974) . Wind storms disturb vegetation cover in some areas. Precipitation includes rain and snow as well as acid precipitation resulting from air pollution. Lightning strikes are the principal natural cause of fire ignitions in California ecosystems.

Processes Associated with Sources and Sinks in Other Terrestrial and Aquatic Ecosystems. Flooding involves sediment transport as well as transport of other materials (e.g. , dissolved nutrients, plant seeds, detritus) into and out of terrestrial ecosystems. Mechanical damage to plants and animals also results from flood events.

Mass movement indicates gravity-transport of soil and rock and often involves mechanical damage to existing vegetation. Sheet and channel erosion removes mineral and organic particulate matter from terrestrial ecosystems. Soil moisture moves by subsurface flow through water tables both into and out of ecosystem rooting zones. This may be crucial to deeply-rooted plants (e.g., chaparral shrubs) during the summer rainless season. Fire is a characteristic process in nearly all study region terrestrial ecosystems. It may be ignited by lightning or enter from other terrestrial ecosystems. Fire behavior is governed by ecosystem properties such as microclimate conditions, vegetation structure, and vegetation combustibility. A synthesis of available information on behavior, effects, and management of fire is provided by Mooney and Conrad (1977).

Processes Associated with Microclimate and Substrate. Microclimate heating and cooling is influenced by insolation, advection, and evaporation of moisture from plants and soil. Atmospheric and soil moisture moves between microclimate and substrate through processes of evaporation, precipitation, condensation (e.g., fog on tree foliage), infiltration (into the soil profile), and percolation (through the soil profile). Leaching occurs when percolating soil moisture moves nutrient ions and clay minerals between soil horizons or removes them from the ecosystem. Leaching of nutrient ions is partially responsible for nutrient-poor conditions in coarse-textured soils (e.g., pygmy conifer forest ecosystem). Weathering of flood sediments adds nutrients to alluvial flat ecosystems. Excessive weathering and leaching in areas of high precipitation, cool temperatures, vegetation-producing acid litter, and coarse soil textures often creates subsurface hardpans (Brady, 1974).

Biotic Components of Terrestrial Ecosystems

Producers. Producers use light energy to combine simple inorganic substances (e.g., carbon, hydrogen, oxygen, nutrient ions) into complex organic compounds. Producers are the foundation of ecosystem food webs and may be defined by biomass structure (i.e., height, spacing, and number of vegetation layers), density (i.e., number of plant individuals per unit area), and species composition. Cover types and habitat types exhibit characteristic values for these parameters.

Biological Processes between Producers and Microclimate-Substrate. Primary production by producer organisms is linked to microclimate by processes of photosynthesis, evapotranspiration (loss of water vapor through leaf stomates and cell walls), and gas exchange of carbon dioxide and oxygen through leaf stomates. Pollutant and toxic ions may enter producer organisms via gas exchange or by leaf absorption of liquid substances. Leaf absorption of condensed water vapor may help some plants maintain internal water balance.

Photosynthesis occurs only when water uptake by plant roots exceeds that lost through transpiration (Daubenmire, 1974). Many plant species typical of Mediterranean-type climates have evolved mechanisms for physiological and morphological control of transpiration and evaporation water loss (Rundel, 1977). Root uptake of water and nutrients is controlled by gas exchange rates of oxygen (for root respiration) and carbon dioxide (a toxic by-product of root respiration). Transpiration facilitates nutrient uptake by pulling internal plant water from absorbing surfaces (roots) to transpiring surfaces (leaves) (Daubenmire, 1974). Other ion uptake (e.g., toxic ions characteristic of serpentine soils) limits the occurrence and vigor of many plant species. Allelopathy occurs when compounds produced by certain plant species are toxic to other plant species or to their own seedlings (Hanes, 1977).

Nitrogen fixation results from symbiotic associations between certain bacteria and the roots of certain plant species (e.g., members of the pea family and members of the alder and Ceanothus genera) (Brady, 1974). Mycorrhizal symbiosis between fungi and plant roots (especially those of pines and members of the heath family) enables nutrient uptake under sterile soil conditions (Daubenmire, 1974).

Shading by plants is a major influence on ecosystem microclimate. Shading alters amounts of radiant energy, air and soil temperature, and vapor pressure deficits.

Consumers. Several trophic levels of organisms consume other living organisms or particulate organic matter. The consumer component can be described in terms of ecological roles (e.g., herbivores, carnivores, ant? detritivores), species composition, and numbers of individual organisms. Complex food webs exist within the consumer component, although all are based on producer organisms through herbivory and seed predation. Consumer shelter and cover requirements are met by microclimate conditions of temperature, humidity, and sunlight, all of which are influenced by plant shading.

Decomposers and Detritus. Excretion and mortality of consumer organisms, litterfall and mortality of producer organisms, and mortality of decomposers themselves comprises organic detritus. This material is subject to decomposition by fungi and bacteria to produce particulate organic matter and dissolved organic compounds in the soil profile. Fire consumption of detritus is responsible for ion mobilization of certain organic constituents and ion volatilization of others.

Dissemination of Producers and Decomposers, Visitation and Migration of Consumers. Other terrestrial and aquatic ecosystems are important sources of seed supply, decompose spores, and consumer herbivores and predators.

Socio-Economic Processes and Activities

Socio-economic activities such as logging or road construction interact with the various ecosystem components through socio-economic processes. As used in this section, a socio-economic process links a general activity to a specific modification within an ecosystem.

Microclimate Modification. Socio-economic activities may modify the gaseous and liquid nature of ecosystem microclimates. Herbicide sprays are absorbed through leaves of target species. Air pollutants are exchanged as gases through leaf stomates. Acid precipitation may have deleterious effects on both soils and plants.

Consumer Removal and Addition. Hunting and range management remove consumer organisms at several trophic levels. Hunting for predator control eliminates carnivores, while sport hunting typically removes herbivores. Range management and game management both add and remove consumers such as domestic cattle and managed game species.

Producer Removal and Addition. Plants are eliminated by many socio-economic activities. Logging, road construction and urbanization in general involve large-scale removal of vegetation cover. Where wildlands are managed for socio-economic purposes such as range management or timber management, producer organisms may be seeded or planted as well.

Substrate Modification. Socio-economic activities that disturb soil profiles may modify a number of substrate properties. Soil compaction alters soil aeration, soil temperature, and moisture availability. Nutrients and particulate matter are lost through erosion.

Fire Ignition. Since the settlement of California by European man, fire ignition patterns have been radically altered. Initially, ignitions were greatly increased by range clearing activities. In recent years, fire suppression policies have limited ignitions to those from negligence and vandalism, or from controlled burning programs.

Hierarchical Classification System

A hierarchical classification scheme modified from Cheatham and Hailer (1975) was used to categorize the terrestrial landscape of the central and northern coastal California region. The classification scheme is based on the concept that vegetation structure and composition are integrated expressions of the environmental factors operating at a particular site. The classification system contains 6 habitat classes, 15 cover types, and 46 habitat types.

At the most general level, a "habitat class" groups areas of similar dominant plant lifeform (or of similar substrate characteristics for wetland and dune ecosystems). The six habitat classes are grassland, shrubland, broad-leaved forests and woodlands, conifer forest, wetland and dunes. The habitat classes are subdivided into 15 cover types. A "cover type" is based on similarity of the external appearance of the vegetation (e.g., height, density, spacing, number of layers) and similarity of gross environmental characteristics (e.g., local climate, topography and substrate). At the most specific classification level, the cover types are subdivided into 46 habitat types based on a common dominant plant species or a common set of dominant plant species. Habitat types have similar biotic components and similar conditions of microclimate substrate, seed availability and disturbance history.

California's complex patterns of topography, soils, local climates and disturbance histories cause equally complex Distributional patterns among the terrestrial cover types. Eight of the 15 cover types exhibit azonal distribution patterns in the sense that they occur in small local sites throughout the study area due to unusual local climate, soil or moisture conditions.

Four cover types (i.e., meadows and seeps, riparian forests, perennial wetlands, and seasonal wetlands) typically occur in restricted local areas where plentiful soil moisture is available throughout much or all of the year. The three coastal strand cover types (i.e., supratidal beach, coastal foredune complex, and coastal dune scrub) are confined to immediate coastal sites where wind, salt spray, and sandy substrates are controlling environmental factors. The closed-cone conifer forest cover type occurs in local sites at scattered locations, typically near the coast, where unusual soil conditions and frequent fire favor closed-cone conifer tree species.

The other seven cover types are widespread with broader-scale distribution patterns. Broad-leaved evergreen forests are common throughout the study region, occurring inland in the north and near the coast in the south. Coastal conifer forest is the predominant cover type in the northern half of the study region, especially near the coast and at low elevations. It also occurs at some immediate coastal locations in the southern part of the study region. Predominant cover types in the southern half of the study region are coastal scrubland and chaparral. Both also occur north of San Francisco Bay but are more restricted in distribution in the north. Somewhat less common but widespread throughout the study region are grassland (inland, dry sites), oak woodland (also inland, dry sites), and lower montane conifer forest (high elevations).

Major Freshwater Species

A number of terrestrial species have been designated as species of concern and of ecological interest (Table 4-9). Species of concern are those taxa that have been granted special legal status because of the scarcity of their numbers (i.e., rare, endangered, threatened, or fully protected) or because they are commercial or recreation ("sport") species. Species of ecological interest are representative species that are important components or characterize the habitats of central and northern coastal California. Species accounts of each species are included in Volume II, Part 2 as well as a discussion of the criteria used in selecting the species.

Major Ecological Areas

Terrestrial areas of ecological concern in the study region fall into three categories. Some are areas of special biological importance to wildlife. Others are research natural areas established by various public and private agencies. The third category includes areas that have been identified by the Inventory of California Natural Areas (CNACC, 1975-). Certain sites fall into two or three of the above categories and may be listed several times.

Wildlife Areas. Areas of Ecological Concern for wildlife represent habitat recognized as important to particular wildlife species. Included are: 1) Critical Habitat of proposed or designated rare or endangered species, 2) habitat of either unique species or species of concern, 3) habitat supporting a significant variety of species and which is diminishing in supply in California (e.g., wetlands), and 4) key nesting areas of concentration areas for populations of species of concern. Many of these areas of ecological concern for wildlife have been identified as "areas of significant biological importance" for wildlife by the California Department of Fish and Game (1980). Additional areas of concern have also been identified in each watershed and are described in each watershed table.

Research areas. Research areas are defined as areas established and owned by public or private agencies specifically to preserve representative samples of ecological communities for scientific and educational purposes (Cheatham, et al., 1977). Preservation of these areas is justified by the following considerations: 1) research natural areas serve as baseline or control ecosystems against which effects of human activities on similar ecosystems can be measured, 2) natural ecosystems are vanishing rapidly under the pressure of expanding human developments and specific areas need to be set aside to ensure their protection, 3) ecological and economic stability depend on maintenance of large gene pools and genetic diversity among biological organism, and 4) research natural areas are required as training sites for future scientists and resource managers (Cheatham, et al., 1977).

Table 4-9. Status of Terrestrial Species

Common Name	Scientific Name	Status			
		Protective Status ¹	Commercial	Recreational	Ecological Interest
<u>Mamma 1.s</u>					
Brush rabbit	<u>Sylvilagus bachmani</u>			X	
Morro Bay kangaroo rat	<u>Dipodomys heermanni morrensis</u>	CA,US-E			
Deer mouse	<u>Peromyscus maniculatus</u>				X
California meadow mouse	<u>Microtus californicus</u>				X
Coyote	<u>Canis latrans</u>				X
Black bear	<u>Ursus americanus</u>			X	
Ringtail	<u>Bassariscus astutus</u>	CA-R			
Mountain lion	<u>Felis concolor</u>	CA-M			
Bobcat	<u>Lynx rufus</u>		X		
Roosevelt elk	<u>Cervus elaphus roosevelti</u>			X	
Black-tailed deer	<u>Odocoileus hemionus columbianus</u>			X	
<u>Birds</u>					
Turkey vulture	<u>Cathartes aura</u>				X
California condor	<u>Gymnogyps californianus</u>	CA,US-E			
Marsh hawk	<u>Circus cyaneus</u>				X
Red-tailed hawk	<u>Buteo jamaicensis</u>				X
Golden eagle	<u>Aquila chrysaetos</u>	CA-FP			
California quail	<u>Lophortyx californicus</u>			X	
Great blue heron	<u>Ardea herodias</u>				X
American coot	<u>Fulica americana</u>			X	
Snowy plover	<u>Charadrius alexandrinus</u>				X
California gull	<u>Larus californicus</u>				X
California least tern	<u>Sterna albifrons browni</u>	CA,US-E			
Band-tailed pigeon	<u>Columba fasciata</u>			X	
Mourning dove	<u>Zenaida macroura</u>			X	
Nuttall's woodpecker	<u>Dendrocopos nuttallii</u>				X
Chestnut-backed chickadee	<u>Parus rufescens</u>				X
Wilson's warbler	<u>Wilsonia pusilla</u>				

Chapter 5

THE SOCIOECONOMIC ENVIRONMENT

General Characteristics

The socioeconomic environment of the central and northern California coastal region is shaped by two major forces. The traditional force has been the utilization of natural resources of value for a wide range of human activities. In most of the region, these activities still dominate economic activities and settlement patterns. The second force is that of expanding and encroaching urban areas, particularly in the vicinity of the San Francisco Bay Area.

As discussed in Volume I, the Conceptual Model, the socioeconomic environment of the region shows considerable variation between its sub-regions, in terms of the particular resources that are dominant in each one and in terms of the degree to which urban influences have led to economic diversification. The northern sub-region (Del Norte, Humboldt, Mendocino and northern Sonoma counties) is strongly dependent on the forestry and forest products industry, which has traditionally been characterized by cyclically and seasonally fluctuating levels of activity. Agriculture, fisheries and recreation, which also show seasonal and cyclical fluctuations in level of activity, are also important sectors of the north-coast economy. These sectors are relatively more important in the north-central sub-region (southern Sonoma and Marin counties) and the south-central sub-region (San Mateo, Santa Cruz, Monterey, San Luis Obispo, and Santa Barbara counties). Fisheries and recreation are the primary resource-based activities in the central sub-region of San Francisco County, although these activities do not constitute as large a portion of that county's economy as they do through the rest of the region.

In all parts of the coastal region, growing immigration of retirees and seasonal residents (considered part of the recreation sector) and state and federal transfer payments and grants (discussed as part of the service sector) are important sources of imported income. The region is generally characterized by low population densities (compared with those of the highly developed San Francisco Bay Area), although relatively dense population occurs in the larger urban areas of Eureka, Santa Cruz and Monterey. Unemployment and seasonal employment are more widespread than in major urban areas and income levels are generally lower.

In addition to economic activities directly based on natural resources, government (mainly in the form of higher education and research institutions) and miscellaneous non-resource-based manufacturing, have become important basic (export) sectors of the economy in some coastal areas containing major urban centers. The economies of San Francisco County and the bay area, however, are comprised largely of non-basic, or service, activities such as commerce, finance, and manufacturing; consequently, they are different from the rest of the region.

Principal Natural Resources

The economically valuable natural resources of the region include very extensive forests, estuarine and marine finfish and shellfish, some extensive areas of agricultural land, limited mineral deposits, and a shoreline suitable at several points for ports or small harbors. The largely unspoiled natural recreation attractions of both coastal and inland areas, historical sites, and fish and wildlife constitute highly valuable resources. Other valuable resources include estuaries, dunes, and beaches. In the north coastal region, the overwhelming predominance of forests is diminishing as old growth on private lands is harvested. Reassessment of the value of forest resources has contributed to a shift in the way the region's natural resources are valued. A similar shift in public values may be occurring relative to the land, water, estuarine, and marine resources of the entire region as the importance of, and the interactions between the basic agricultural and fishery

activities in the coastal region become better understood. A fundamental change occurred with passage of the California Coastal Act in 1976. This legislation recognized the value of natural resources and unique coastal communities throughout the coastal zone.

Supply and Demand

Demand for all of the region's natural resources is increasing. At the same time, because of a growing understanding of the effects of over-exploitation and of conflicts between uses, limitations are being placed on resource extraction. Such limitations, and changes in policy regarding the manner in which resources should be used, lead to declining production levels and increasing unemployment both in the resource-dependent basic industry and in related service sectors, creating changes often referred to as economic dislocations. Adjustment to such dislocations tends to be difficult and costly due to the region's lack of diversification and its population's traditional ties with a few basic industries. For the same reason, the region is also strongly affected by cyclic and seasonal fluctuations in demand.

Capital, Labor, and Facilities

Much of the region is relatively isolated from major population and industrial centers. Transportation routes are limited; fuel and power are mainly imported from outside the region, and the population density is low. Major sources of capital have tended to be national forest industry firms or local processors strongly dependent on them. Much of the region's economic activity is carried out by self-employed individuals in the agriculture, fisheries, recreation, and mining industries who lack extensive capital resources. Participation in the labor force tends to be lower in the region than in the more urbanized areas of the state except where the recreation industry is dominant. This not only reflects the generally limited employment opportunities but also represents a potentially valuable human resource.

Major Basic Industries

As defined in Chapter 6 of Volume I, the Conceptual Model, basic industries are those which produce goods and services for export outside the local economy and result in the import of "new" money. Basic industries may involve the harvesting or other use of natural resources or may be more dependent on technology, manpower and secondary manufacture of raw materials. The former type generally characterizes the coastal region where, with the exception of sand, gravel, and rock for local construction use, each of the economically and culturally valuable resources is in demand by markets outside the study area. The traditionally dominant industries have been forestry and forest products, fisheries, agriculture, and recreation. The relative ranking of the forest industry, fisheries, agriculture, recreation, mineral industries, transportation involving external markets, and diversified manufacturing, varies among the watersheds. The overall ranking of these industries throughout the region is summarized below.

The volume of the forestry and forest products industry has been declining for a number of years and is expected to continue to decline. The long-term outlook for forestry is the subject of debate depending upon assumptions regarding management of the industry. The economic effect of efforts to diversify industrial activity in the northern California coastal region through increasing emphasis on recreation, aquaculture, and crop growing does not yet appear to be significant. Agriculture and recreation activities have, however, shown steady growth in most parts of the region. The fisheries industry, while traditionally experiencing cyclical, as well as seasonal, fluctuations, has not shown significant growth. Greater control over the resource through recent extension of the territorial limit may stimulate the investment necessary for industrial expansion. Mining has not been a significant generator of employment or income in the region. This may be changed, however, if significant development of offshore oil and gas resources occurs in the study area. Increased

demand for raw materials is stimulating reopening of some old mines and development of others as well as generating increased interest in offshore resources. Little success has been experienced by coastal communities attempting to diversify their economies through attraction of "footloose" industries, which are not directly dependent upon coastal resources. In a small number of watersheds, government activities, in the form of military installations, colleges (such as Humboldt University), and marine research institutions, contribute significantly to the coastal economy. Due to a combination of relatively high unemployment levels and relatively low income levels throughout the region, government transfer payments are an important external source of income.

Service Activities

The region supports a relatively well-developed service sector. The relationship between the basic and service sectors in terms of employment and income (the multiplier) is difficult to determine. (The concept of the multiplier is discussed in Chapter 6 of Volume 1.) This is largely because employment in agriculture, fisheries, and recreation, for several reasons discussed in later sections, can only be estimated. In addition, a portion of the production in these industries is locally consumed and some trade and service activities serve both the local population and tourists and so are partially basic. It would appear, however, that the typical regional employment multiplier is approximately 3.0, which means that for any job added in a basic industry, approximately two more are supported in activities that supply local goods and services.

The watersheds in close proximity to the major San Francisco Bay Area employment center, Lagunitas Creek in Marin County and San Gregorio in San Mateo County, are unusual. To some extent, local services are supported by the income of residents who commute from these watersheds to work. To some extent, also, these watersheds are dependent on support activities provided outside. This pattern also exists to a more limited extent in coastal communities in Mendocino, Sonoma, Santa Cruz, Monterey and San Luis Obispo Counties. The pattern makes reasonably accurate calculation of multipliers difficult and of less relevance than in more discrete economies.

Population, Employment, and Income

The Central and Northern California Coastal Region is relatively sparsely populated, with a concentration of urban centers along the coastal strip. In several watersheds, the population is made up of a relatively high proportion of elderly people. For this reason, and also due to limited employment opportunities, their participation in the labor force tends to be lower than the average for the state. Low labor force participation, high unemployment, and severe seasonal fluctuations in employment contribute to median family and per capita personal income levels significantly below state averages in many parts of the region.

Recent trends in coastal region population have been influenced by coastal zone development restrictions since passage of Proposition 20, which established a statewide coastal zone commission, and of the California Coastal Act in 1976 which passed responsibility for preparing detailed coastal planning programs to local governments in the coastal zone. Both the rate and the pattern of population growth have been affected by policies that have emphasized infilling existing communities and restricted development in intervening areas.

Data Presentation

As far as possible in this chapter, data related specifically to the study area are presented in a format that relates to the conceptual models found in Volume I, the Conceptual Model. Each sector of the coastal region economy is given in the following sections which are followed by a section on social, cultural, and land use conditions in the region. Wherever coastal region data are unavailable, data for the ten coastal counties (and, where relevant, also for the City and County of San Francisco) are used to demonstrate historical, current, and projected trends in socioeconomic conditions. The chapter ends with a discussion of the way in which other human activities interact with the subject, and the way in which the subject activity affects the natural environment.

Forestry and Forest Products

Lumber and forest products are the predominant basic industries in the Northern California Coastal region, and they are of lesser importance in the southern region.

Commercial production of lumber was heavy in the north coast region by the late 1850's and lumber exports were an economic mainstay of the area's counties. Sawmills and logging operations developed in other coastal counties in the mid-19th century, although because of overcutting and a lack of extensive timber stands, most forestry outside of the north coast region was short-lived. The rise of the national forests and a federal policy of conservation in the early 1900's led to the creation of sustained yield harvests on public lands, although reforestation practices were not generally used on private forest lands until a later date. While the economies have diversified considerably, the forest industry remains the most important source of basic industrial employment, income, and value, particularly in Del Norte and Humboldt Counties.

The following discussion will focus on forestry in that portion of the study area that lies within the north coast counties of Del Norte, Humboldt, Mendocino, and Sonoma Counties. It will be based on data provided at the county level. San Francisco County does not contain commercial forests. Other counties in the study area contain less extensive forest resources.

Forest Resources

Public and private commercial forests currently covers approximately 3,921,000 acres in the coastal counties. Humboldt, Del Norte, and Mendocino Counties account for 88% of that acreage. The acreage of commercial forest land in each of these counties accounts for well over one-half of its land area. Seventy-five percent of Del Norte County's commercial timber comes from public lands, although only a very small portion of the county's national forest land lies within the coastal region. Private lands are the principal timber sources in other counties, both within and outside the coastal region. Commercial timber stands also occur in Mendocino, Sonoma, and, to a lesser extent, in Santa Cruz, San Mateo and Monterey Counties (California Department of Finance, 1978; Oswald, 1968, 1972).

Species Range. The principal commercial species in the study area are Douglas fir, redwood, hemlock, true firs, ponderosa pine, and tanoak.

Douglas fir is the primary commercial species in Humboldt and Del Norte counties. It is also mixed with redwood in the study areas of Mendocino and Sonoma counties, and is the predominant coniferous type at higher elevations and drier exposures in both counties. Douglas fir was estimated to cover about 28% of Humboldt County's commercial acreage in 1965, although its current extent is believed to be more (Oswald, 1968). A 1965 survey of the Douglas fir acreage in Del Norte County showed that 55% of the commercial forest land in that county consisted of Douglas fir (Oswald and Walton, 1966). A survey of Mendocino and Sonoma counties' Douglas fir acreage showed that it covered only 18% of the combined commercial forestland of those counties. Redwood is the secondary species in Humboldt and Del Norte counties, although it is the principal species in the lower Eel River basin in central Humboldt County.

A break in the natural redwood range north of the Mendocino County line sets off the redwoods of Mendocino and Sonoma Counties from those to the north. Redwood, the principal commercial species of these two counties, accounts for 24% of their commercial timber acreage (Oswald, 1972). The commercial redwood range extends to a point south of the Russian River, generally extending inland about 15 miles. Like the Humboldt and Del Norte redwoods, the redwood type in this range is dependent on a cool coastal climate, although it is generally intolerant of direct exposure to ocean winds (Oswald, 1972).

When present in conifer stands, hardwoods have generally replaced conifers as second growth in those areas that have been heavily logged or burned. This is partially due to the sprouting ability of most hardwood species, together with the fact that when hardwoods are present in harvested conifer stands, they are often left standing as they have little commercial value (Oswald, 1972). Inventory data related to cutting history indicates that cutting has been a major factor affecting type

succession; i.e., where cutting has not been followed by prompt restocking of conifers, hardwoods are the most likely successors. In Humboldt County, hardwood forest types occupy 53% of the cutover commercial forest area, but only 28% of the area where no previous cutting has occurred (Oswald, 1968). Attempted conversion of timberland to grazing pasture has contributed to the extensive hardwood acreage in Mendocino and Sonoma Counties, where hardwoods account for 49% of commercial forest acreage (Oswald, 1972). Natural revegetation by redwoods appears to be more successful in those counties than is true for Douglas fir in Humboldt and Del Norte Counties,

Tanoak is the predominant species in hardwood forests. Pacific madrone, California black oak and Oregon white oak occur in smaller quantities. Because of their low commercial value, hardwoods are not cut in proportion to their acreage: they accounted for only 20% of sawtimber volume in Mendocino and Sonoma Counties in 1970 (Oswald, 1972). 97% of the hardwood acreage in those two counties is capable of growing merchantable stands of coniferous timber (Oswald, 1972). There is little present demand for hardwoods and the value of hardwoods will probably always be less than for softwoods. However, a pilot hardwood processing plant is under construction in Humboldt County in an attempt to determine and increase hardwood's potential commercial value (EDAW, Inc., 1979a). The abundance of hardwood types in the north coast region is a significant management problem in the area (Oswald, 1972).

Detailed maps of the range of forest species for California may be found in the Cal-Veg series (Parker and Matyas, 1978). A more readily usable but small-scale reference is Griffin and Critchfield (1976). For a discussion of forest species, listed by cover and habitat type, see Volume III, Habitats. For additional discussion of forest-related animals, see Part 2 of this volume.

Productivity. The Douglas fir is the most abundant and widespread species of conifer in Del Norte and Humboldt Counties and may be used as the index species for classifying the potential productivity of forest land in this area. The classification system shown in Table 5-1 uses the size of 100-year-old trees to distinguish five productivity classes which are measures of climate and soil favorability in a given location. In an area of dry soil, Douglas fir may grow only 30 meters or less in a century; in a good site, it may double that growth (Loy, et al., 1976).

Table 5-1. Volume Growth of Fir Trees of Different Heights in Different Site Classes (Loy, et al., 1976)

Height of Trees When 100 Years Old		Site Class	Wood Growth Per Year	
Meters (approx.)	Feet		ins/hectare	ft ³ /acre
Under 30	Under 100	V	Under 5.2	Under 75
30 - 40	100 - 130	IV	5.2 - 8.4	75 - 120
40 - 50	130 - 160	III	8.4 - 10.9	120 - 156
50 - 60	160 - 190	II	10.9 - 12.9	156 - 184
Over 60	Over 190	I	Over 12.9	Over 184

No similar site classification has been developed for redwoods. For Humboldt County, mature Douglas fir and redwoods are graded by three density (crown cover) and three size (height) classes. Second growth conifers under 100 feet in height, under 40 years old, or with a crown cover of less than 41% are classified as non-commercial on the County Assessor's maps. Brush or cutover areas are further subclassified as: logged in the past 10 years; logged in the past 20 years; or where one or more species have been removed, leaving one residual species. Similar classification and mapping have been undertaken in Del Norte County, but not in Mendocino County (EDAW, Inc., 1979c).

Table 5-2 shows the distribution of land in the study area counties by U.S. Forest Service land classification: productive-reserved, unproductive, and commercial forest lands, and non-forest lands.

The Forest Service, in Oswald (1972), defines these classifications as follows:

Forest Land: Land at least 10% stocked by forest trees of any size or formerly having had such tree cover and not currently developed for non-forest use;

Commercial Timberland: Forest land producing or capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation;

Productive-Reserved Forest Land: Productive public forest withdrawn from timber utilization through statute or administrative regulation (probably not applicable in the Coastal Region);

Unproductive Forest Land: Forest land incapable of yielding crops of industrial wood because of adverse site conditions. Includes sterile or poorly drained forest land, subalpine forests, and steep rocky areas where topographic conditions are likely to prevent management for timber production.

Coastal county totals (approximates) in Table 5-2 reflect inventories of forest land for different years (1965 and 1967). These totals should be treated as approximations.

Forest lands cover 64% of the counties comprising the California coastal region compared to only 33.2% of the U.S. as a whole. Of the coastal county forest land, 50% is classified as productive (either commercial or productive-reserved), while for the U.S. as a whole, 69% is productive forest land. Of productive land, 2.7% is listed as productive-reserved in the region and 4.0% for the U.S. These figures indicate that the region is a fairly heavily forested area; over one-half of the forest land is kept out of commercial usage.

The large portion of forest land that is removed from commercial harvesting indicates the value of the forest resource in California for other uses, including grazing and, more importantly, recreation. The increasing importance placed on recreational uses of forest land relative to harvests has been indicated by the recent withdrawal of timber stands from commercial production through expansion of the Redwood National Park and through the U.S. Forest Service RARE II wilderness evaluation process.

Table 5-2. Area (acres x 1,000) of Forest Lands in
California Coastal Counties, 1965-1967
(Winzler and Kelly, 1977b; California Department of Finance, 1978)

	Commercial Forest			Forest Land		Total Forest Land	Total Land Area	% Forest Land
	Public	Private	Total	Productive Reserved	Unproductive			
Del Norte	334	153	487	13	107	607	644	94
Humboldt	418	1,283	1,701	47	102	1,850	2,295	81
Mendocino	209	1,096	1,305		609	1,914	2,247	85
Sonoma	4	292	296	1	256	553	1,026	54
Marin				32	87	119	333	36
San Mateo	5	54	59	3	65	127	286	44
Santa Cruz	-	125	125	9	56	190	281	68
Monterey	12	5	17	4	1,107	1,128	2,127	53
San Luis Obispo		1	1	-	804	806	2,037	40
Santa Barbara	3		3	1	984	988	1,752	56
Region Totals	985	3,009	3,994	110	4,177	8,282	13,028	64

A Humboldt County Forest Resource inventory based on aerial photographs is available for 1975 (QRC Research Corporation, 1978). This survey, unfortunately, uses a different data presentation, preventing accurate qualitative comparisons over time with the 1967 Forest Service statistical data. However, the findings generally support projections by Oswald (1978) of an 89% decline in sawtimber output in the north coast between 1975 and 2000, based on historical harvest patterns. The differing views of this point are discussed later under Outlook and Effects.

While no recent comprehensive inventory data exist to define the extent of commercial, as opposed to productive-reserved or unproductive, forest land, analysis of current (1978) mapping by the Humboldt County Timber Assessor shows that only very small pockets of old growth conifers remain outside the state and national redwood parks (EDAW, Inc., 1979a). It is estimated from the same source that within the Humboldt County portion of the Eel River basin, only a very small percentage of forest land is in harvestable conifer stands. Within the Coastal Region portion of the Eel River basin, the percentage is even lower because of the extent of agricultural land in the river's flood plain. A new inventory of resources is urgently required together with a comprehensive study of regeneration success and potential, in order to arrive at a realistic evaluation of the future of the resources.

Ownership. The ownership of timber resources is an important factor in the "degree of commercial usage of forest lands. Management techniques and policies vary by owner, with small privately owned forest land generally more poorly managed than are the larger public and private holdings, as discussed under Use of the Resources. Consequently, the harvest volume is variable by area and changes over time as a result of management decisions by owners.

Table 5-3 lists areas of commercial timber land in the California coastal counties. The lack of currency of some of the data is a limitation that should be noted. Much of the data are based on surveys made prior to 1970, and considerable changes have taken place since those surveys were conducted. As noted in the previous section, new inventories have not taken place in a comparable form (see Oswald, 1978). Oswald estimates, however, that privately-owned acreage on the north coast declined 15% from 1965 to 1975.

Table 5-3. Area (acres x 1,000) of Commercial Forest Land
in Coastal Counties of California in 1965
(California Department of Finance, 1978)

	Public		Private			Total Commercial Acreage
	National Forest	Other	Forest Industry	Other	Total	
Del Norte	334 ¹		143	21	164	498
Humboldt	292 ¹	130	527	741	1,268	1,690
Mendocino	107 ²	98	468	628	1,096	1,301
Sonoma		1	60	199	259	260
Marin				7	7	7
San Mateo		1	8	35	43	44
Santa Cruz		6	2	127	129	135
Monterey		1		26	26	27
San Luis Obispo -				1	1	1
Santa Barbara						
Total	733	237	1,208	1,785	2,993	3,963
Percent of Commercial Acreage	19%	6%	31%	45%	76%	-
Region as Percent of State Acreage	9%	47%	45%	36%	39%	24%

¹ Oswald, 1968.

² Oswald, 1972.

In contrast with the State as a whole, the study region has a much higher percentage of commercial timber land in private ownership (roughly 47% in the State and 76% in the coastal counties). The forest industry owns less timber land than do other private landowners in the region, but the proportion of industry ownership on the coast is greater (31%) than that of its total ownership of commercial forest land in the state (16%). The importance of the miscellaneous small private holdings that, together with farmers, which comprise the "other private" category, is limited in the two northern counties. Only 22.3% of Humboldt County's commercial timberland was classified as

private holdings in 1967, and Del Norte County had only 4.8% in that category in 1965 (Oswald, 1968; Oswald and Walton, 1966). By contrast, the figure for Sonoma County has recently been estimated at 77% (Goldman, et al, 1977). However, Oswald points out that it is difficult to determine the interests of this category of owners (Oswald, 1972). Table 5-4 demonstrates the declining acreage of forest land owned by farmers in the coastal counties. These data are not directly comparable to those in Table 5-3 because they include non-commercial forest land. The table does indicate a general decline of 20% in forest land owned by farmers between 1968 and 1974, as well as a decline in value of forest products sold from farms.

Table 5-4. Acreage and Value (dollars x 1,000) of Woodland on Farms in California Coastal Counties, 1969 and 1974 (U.S. Department of Commerce, 1977)

county	Acreage ¹		Value ² (\$000)	
	1969	1974	1969	1974 ³
Del Norte	3,866	2,746	110	22
Humboldt	247,031	262,995	2,069	1,890
Mendocino	248,044	126,764	1,095	1,229
Sonoma	82,494	89,356	552	611
Marin	11,599	7,020	---	---
San Mateo	13,219	5,637	3	1
Santa Cruz	9,442	6,118	42	109
Monterey	60,420	39,438	25	24
San Luis Obispo	63,304	40,840	8	17
Santa Barbara	9,500	12,846	6	2
Region Total	748,919	593,760	3,910	3,905

1 Acreage includes woodlands with pasture.

2 Value includes sales of Christmas trees, firewood, and sawtimber.

3 Unadjusted for inflation.

Public lands provide the remaining one-fourth of the commercial timber in the coastal counties, primarily from Six Rivers and Mendocino National Forests (Oswald, 1978). The allowable harvest from "other public lands" has been reduced by approximately 30% in recent years. Output from commercial forest land is the subject of considerable debate concerning the rate of harvest of old-growth timber.

Use of the Resource. Lumber production is the primary use of commercial forest land in the north coast region. Recreational use occurs on commercial land in some public forests and on fewer private forest lands, but lumbering and recreation are basically incompatible resource uses. Grazing occurs on some harvested forest lands, particularly in Sonoma County (Oswald, 1972). However, Oswald states that attempts to convert forest land to pasture in Mendocino and Sonoma Counties have been highly unsuccessful, and have served to increase the amount of hardwood acreage in those counties. Forest land throughout the remainder of the coastal area is commonly used exclusively for recreation.

Public agencies such as the U. S. Forest Service, the Bureau of Land Management, and the California Department of Forestry have followed the principle of sustained yield in attempting to maintain existing forest resources. Sustained yield as defined by the Forest Service, is the long-term maintenance of a constant level of timber output without impairing the productivity of the land. The primary interest of private owners, who own three-fourths of the commercial timberland, is in harvesting a profitable volume of timber. Private owners are regulated to a certain degree by the State Department of Forestry through the mandatory filing of annual timber harvesting plans (THP's). However, the demands both of the THP review process and of monitoring the owners' compliance exceed the staff capacity (EDAW, Inc., 1979a; 1979c).

While public commercial lands are governed by "allowable cut" calculations in order to maintain sustainable yield, private lands are not. Private timber in the north coastal counties has historically been owned primarily by farmers and ranchers. The forest industry, during the post-war housing boom, began to purchase those private holdings and continues to do so to this date (Oswald, 1972). Private cutting has been

concentrated on densely stocked old growth. Douglas fir and redwood stands yield a high volume of sawtimber per acre. Such stands once accounted for nearly 45% of the total private harvest but are estimated to have declined in both volume of yield and acreage by over 50% since 1967 (Oswald, 1978). In order to maintain output, private cutting will have to concentrate increasingly on softwood sawtimber stands of younger growth and lower volume per acre in order to maintain substantial output.

Outlook and Effects. Future supply of timber resources in the California coastal region will depend on the success of regeneration efforts, management practices, relative yields of young growth vs. old growth timber, and the degree of intrusion of hardwood types into coniferous stands. In addition to biological volume growth, factors affecting productivity include improvements in timber utilization and timber accessibility, plus changes in the methods of measuring output (QRC Research Corporation, 1978). Policy decisions which have had or may have an effect on commercial timber output include the expansion of Redwood National Park, which reduced the amount of harvestable private timber in Humboldt County by an estimated 11%, and enforcement of Wild and Scenic River Management Plan recommendations (see EDAW, Inc., 1978; EDAW, Inc., 1979a). Additions to wilderness areas or maintenance of roadless areas through implementation of the RARE II (Roadless Area Review) recommendation for National Forest lands will have some effects on coastal county timber output although the study area is not affected. Timber preserve contracts, similar to contracts for agricultural land under the Williamson Act, have been made between owners and the California Timber Tax Board throughout the study area. These contracts establish timber preserve zones that have short-term benefits, in the form of tax breaks, for owners, but are not effective means of guaranteeing the long-term preservation of the timber lands.

Competing land uses are often critical factors in future timber availability. Depending upon the proximity of timberland to urban areas and access routes, sale of timber holdings for subdivision and development may be more profitable in some areas than maintaining a harvestable stand of timber. Although all private timber holdings are susceptible to such economic pressures, the smaller holdings of the "other private" category are more susceptible than those owned by the forest industry. Industry and public lands are more stable in terms of long-range plans for their management. Nevertheless, public lands are subject to fluctuating output due to policy decisions, while industry-owners, dominated by several large, often multinational, corporations have the capacity and mobility to reduce less profitable local operations in favor of other more profitable operations nationally or internationally. While the level of regional harvest may fluctuate due to these types of economic decisions, the level of industry investment in the timber resource itself is likely to increase (Financial World, 1 February 1979),

Projections of future timber supplies and harvest levels for the coastal region take into account many of those factors. A 1978 study of Humboldt County timber resources (EDAW, Inc., 1979a) has calculated annual cuts for the next thirty years based on three sets of assumptions: Case 1 assumes inventory replacements at the present rate; Case 2 assumes that all old growth timber will be used up before second growth; and Case 3 assumes that harvesting will occur simultaneously in stands for all trees above 60 years old. Annual cuts for these assumptions range from approximately 1,200 million board feet in Case 1 to 700 million board feet in Case Three (see QRC Research Corporation, 1978). These projections appear clearly to be unrealistic. Annual cuts in both Humboldt and Del Norte Counties combined between 1967 and 1974 averaged only 1,000 million board feet.

By contrast, Oswald (1978) estimates that output of softwood sawtimber from private timber lands in California's North Coast Region is likely to decline substantially in the next 10 to 15 years. There are insufficient sawtimber stocks with associated growth to maintain output until new stands, regenerated since the mid-1950's, reach merchantable sawtimber size. The major portion of the decline will occur in Humboldt and Del Norte Counties and will affect both Douglas fir and redwood output. Oswald states that "no reordering of cutting priorities by the timber industry among different types of stands will have a significant impact on the prospective decline." He further estimates that while output of sawtimber from public lands within and adjoining the region will become more important, this is unlikely to offset the private sector decline. Based on varying sets of assumptions, he estimates the combined sawtimber output from Humboldt, Del Norte, and neighboring Mendocino and Sonoma Counties to the year 2000. Under the assumption that historically high harvest rates continue, output will drop from 1,500 million board feet (the 1967-1974 average) to 354 million board feet by 2000. This projected sharp decline is subject to many variables, such as the regeneration potential of recently cut lands and the rate of

growth and sawtimber volume of previously restocked forest lands. However, it is clear that, given continued high levels of harvest, the conversion of forest land to other uses, intrusion of hardwood types on cutover coniferous land, and limited regeneration relative to the rate of harvest, the forest resource base will decline significantly in the future.

The socioeconomic consequences of lost timber resources and the resulting reduced harvest can be measured most readily in terms of direct employment and income losses. A number of studies have calculated expected reductions in employment and income associated with resource decline. Wall and Oswald (1975) estimated employment changes in the industry from 1970 to 2000, based on various assumptions concerning labor productivity, log exports, and an employment-wood consumption ratio in Western Washington and Western Oregon. Estimates have varied widely according to the assumptions employed. Under the basic assumption of continuation of present allowable cuts on public lands, a gradual decline on private commercial lands until a balance between growth and cut is achieved, and a gradual increase in harvest on other private lands, Wall projected a 56% decline in employment over the thirty-year period. Oswald (1978) has also noted that declines in output of sawtimber from private lands are likely to affect mills in the western areas of the coastal counties more than those in the eastern portion, which tend to draw their sawtimber from public lands. EDAW, Inc. (1979c) has projected a decline in average annual lumber and wood products employment in Del Norte County from 1550 to 450 from 1980 to 2000. The decline would accompany a decline in timber harvest over the period from 225 Mmbf to 65 Mmbf, a projection based on Oswald (1978), Del Norte County Assessor's Office projections, and a company-by-company survey.

Bell (1977) has discussed and compared several methods for relating fluctuations in harvest volume to employment in both forest industries and the dependent service sector. Given the traditionally strong dependence on the forest industry in Del Norte, Humboldt and Mendocino Counties, declines in the volume of available sawtimber will inevitably have a significant effect on the socioeconomic character of these counties. The cyclical and seasonal periods of unemployment in the industry are compensated to a certain extent by longer working hours and higher wages during the production season. Extended annual periods of unemployment have also been mitigated by transfer payments. Humboldt and Del Norte Counties are eligible, as areas with chronic and persistent unemployment, for unemployment benefits that extend past the normal thirteen-week period. The mechanisms of transfer payments and savings used to cope with seasonal patterns of unemployment are clearly incapable of handling the long-term decline in unemployment due to decreasing volumes of sawtimber.

The socioeconomic effects of declining timber output in the north coast region may be mitigated by the development of a diversified economic base, through expansion of manufacturing, service and recreational activities. There are numerous problems with economic diversification, however. Other activities, such as recreation, may also be seasonal and, since the area is so remote, demand may be unpredictable. Also, skills useful in the forest industry are generally not transferable to other occupations, and retraining may be necessary. Finally, there is a tendency in an area dependent on a declining industry to diversify quickly. Such an area is vulnerable both to "footloose" industries that are independent of local resources and thus may easily leave the area, and to resource-based industries that deal with non-renewable resources.

Forestry and Log Production

Timber Harvest Volume. The volume of timber harvest varies according to productivity, ownership and management practices, as described previously. Table 5-5 lists harvest volumes for the four main producing counties: Del Norte, Humboldt, Mendocino and Sonoma. These data are broken down by ownership class and species of timber. The inventories are outdated but more recent inventories have not been made on the same consistent basis. Oswald (1978) has updated his inventories to 1975 for the four counties (not recorded individually) based on county assessor's harvest information for 85% of the sample plots used in the original inventories. His findings show a 21% decline in private softwood sawtimber due to sawtimber harvest in excess of growth. In the redwood class with the highest basal area and volume, which accounted for 45% of total private harvests between 1967 and 1975, output declined by 50%.

Table 5-5. Volume of Sawtimber on Commercial Timberland by Ownership Class, Del Norte, Humboldt, Mendocino and Sonoma Counties, (in Millions of Board Feet -- $\frac{1}{4}$ -inch Rule)

	Public		Private		All Ownerships
	National Forest	Other Public	Forest Industry	Other Private	
<u>Del Norte</u> ¹					
Softwoods	9,002	---	3,560	180	12,742
Hardwoods	12	---	64	18	94
Total, All Species	9,014	---	3,624	198	12,836
<u>Humboldt</u> ²					
Softwoods	8,318	2,473	13,805	6,142	30,738
Douglas Fir	5,814	2,318	3,701	4,722	16,555
Redwood	---	2	9,320	995	10,317
Hardwoods	181	223	312	1,107	1,823
Tanoak	89	100	182	568	939
Pacific Madrone	42	65	47	252	406
Other	50	58	83	287	478
Total, All Species	8,499	2,696	14,117	7,249	32,561
<u>Mendocino and Sonoma</u> ³					
Softwoods	2,246	1,497	6,553	7,553	17,849
Douglas Fir	995	460	2,277	2,726	6,458
Redwood	---	1,026	4,114	4,433	9,573
Other	1,251	11	162	394	1,818
Hardwoods	11	151	534	592	1,288
Pacific Madrone	---	17	78	70	165
Tan Oak	---	73	330	228	631
Other	11	61	126	294	492
Total, All Species	2,257	1,648	7,078	8,145	19,137

1. Del Norte County, Oswald and Walton, 1966 (data not broken down by species).
2. Humboldt County, Oswald, 1968.
3. Mendocino and Sonoma Counties, Oswald, 1972.

The most significant factor that affects the volume of timber harvested in the California coastal region is the national demand for wood products, primarily by the home construction industry. Harvesting, particularly of softwoods other than redwood, on private forest lands is particularly influenced by demand fluctuations. According to a representative of the Pacific Lumber Company, active in Humboldt County, redwood harvests that are used as lumber and siding in commercial buildings and more expensive housing are not as susceptible as Douglas fir and other softwoods to general fluctuations in national housing construction (San Francisco Chronicle, 4 December 1979). Public forest lands harvested under sustained yield practices have maintained a fairly stable harvest volume. However, recent policy changes have called for increased harvest volumes.

Competition from other timber-producing regions also affects timber harvest in the study area. Timber production in the southern states is increasing and capturing a larger share of national lumber and plywood markets each year. In 1975, southern states accounted for 35.4% of total softwood and plywood production in the United States, up from 32.2% in 1970, 3.2% in 1965 and 0% in 1960. The South is also outgrowing the West Coast region in paper and allied products production. In addition, large amounts of timber are harvested by American companies in other countries. 30th

trends are likely to continue in the future because of lower labor costs, less expensive raw material supply, and the proximity of the South to the large eastern lumber markets (Lembke, 1976).

The other major factor affecting harvest volumes has been foreign demand for logs, particularly by Japan. Softwood log exports generally increased during the 1960's, but in 1968 they expanded to over four times the export volume in the previous year. Restrictive legislation passed in 1968 reduced exports considerably, but they remain at a fairly high level. Table 5-6 shows the annual trends in exported logs from the Northern California area. Plywood exports from the area have also been steadily increasing since 1971. The volume of log exports is related to several factors, including the lack of domestic timber supply in Japan and the demand for wood for housing construction in that country. Plywood exports may increase as Japanese construction measurements become more compatible with U.S. lumber measures (Lembke, 1976).

Nearly all of the exported logs were harvested on private lands, but, because of logs brought to port from outside of the region, the figures do not accurately reflect the portion of log exports that had been harvested on coastal county forest lands. Eureka is the only significant port for the export of logs in the study area (Bell, 1977).

Log exports have several significant socioeconomic impacts. The volume of unprocessed logs that are exported represents a diversion of a significant amount of sawtimber away from the regional mills. Using the ratio of employees per million board feet (in Bell, 1977) of 5.7, the 72,650,000 board feet of softwood logs exported from the Northern California area in 1978 represented an employment potential of 414 persons. Although this potential employment would be less for the study area, this multiplier serves to illustrate the relationship between log exports and employment. Another impact of log exports is that foreign bidding on domestic standing timber has often driven the price of the stumpage higher than many of the smaller mills in the region can afford.

Table 5-6. Volume (Board ft: Scribner Scale) of Logs Exported from Northern California Ports, 1961-1978 (Ruderman, 1979)

Year	Total Softwood	Douglas Fir	Hardwoods
1961	27,951	1,274	---
1962	37,469	412	---
1963	38,267	281	---
1964	13,367	40	7 1 3
1965	14,790	1,124	1,248
1966	21,888	1,363	1,640
1967	43,258	4,936	2,325
1968	212,163	26,186	4,973
1969	206,705	23,754	8,379
1970	192,083	32,531	2,353
1971	102,408	27,032	1,275
1972	77,459	18,337	1,320
1973	104,733	34,454	1,084
1974	77,735	35,146	560
1975	86,943	52,547	3,911
1976	109,812	73,924	659
1977	70,902	38,302	830
1978	72,650	49,024	1,772

Production Value. The value of the logs at the mill, prior to cutting, and the volume delivered to the mill is shown in Table 5-7. Judging from data for Mendocino County, the value of logs at the mill is about 29% above the value of the standing timber.

Table 5-7. Volume (Board ft. x 1,000) and Value (Dollars x 1,000) of the Timber Harvest in the California Counties in 1978 (California State Board Of Equalization, Timber Tax Division, 1979)

County	Board Feet	Value
Del Norte	344,081	\$ 91,673
Humboldt	566,577	123,876
Mendocino	439,768	92,323
Sonoma	25,633	4,575
Marin	---	1
San Mateo	5,722	1,362
Santa Cruz	14,499	3,059
Monterey	37	10
San Luis Obispo	---	4
Santa Barbara	---	1
REGION TOTAL	1,396,317	\$316,884
STATE TOTAL	4,343,726	\$682,051

The coastal counties contributed 32% of the board feet produced in the state, while they accounted for 46% of the total value of the state's timber harvest.

Forestry and Logging Employment. Employment in log production and forest product industries for the California coastal counties is listed in Table 5-8. Data are taken from County Business Patterns (U.S. Bureau of the Census, 1979). Because these data were gathered during March 1977, they are probably below the annual average for forestry and logging production due to the seasonality of the industry.

Forestry products and logging employment includes two standard Industrial Classification (S.I.C.) sectors, forestry (S.I.C. Code 08) and logging camps and contractors (S.I.C. Code 241). Where data were not directly available, figures based on reasonable estimates are provided. The logging and forest product employment figures correlate fairly well with logging harvests by county. Only 13% of the industry's employees work in forestry and logging (see Table 5-8).

Table 5-8. Estimated Logging and Forestry Employment in the California Coastal Counties, 1977 (U.S. Bureau of the Census, 1979)

county	Forestry Products (SIC 08)	Logging Camps and Contractors (SIC 241)	Total
Del Norte	10	616	626
Humboldt	105	603	708
Mendocino	5	500	505
Sonoma	15	54	69
Marin	---	---	---
San Mateo	3	56	59
Santa Cruz	3	75	78
Monterey	3	12	15
San Luis Obispo	3	8	11
Santa Barbara	---	8	8
REGION TOTAL	147	1,932	2,079

Data for Humboldt County show a decline in employment in the forest product industry from 12,804 employees in 1955 to 7,425 in 1976 - a 42% decrease (QRC Research Corporation, 1978). Although the annual rate of decline has slowed somewhat over that period, it is continuing, averaging 2.4% from 1972 to 1977 in Humboldt County (EDAW, Inc., 1979a).

Total employment levels in the forest industry depend on many factors including demand for the industry's products, changing product mix, increased utilization of forest products.

ducts, availability of raw material, level of capital expenditure, and skill and performance levels of labor (Wall and Oswald, 1975). The last factor, also known as productivity, can be measured by computing a ratio of raw materials (in thousands of board-feet of lumber or logs) to labor (number of employees). This parameter has two important uses. The first is as an indicator of trends in productivity in the industry. A labor-to-raw-material ratio can also be used in predicting future levels of employment based on the projected production and consumption of raw materials. This measure can be particularly valuable when dealing with the question of employment impacts of declining timber resources or of displacement of labor by technologic changes. This subject is reviewed by Bell (1977).

Figure 5-1 presents the trend in labor-to-raw-materials ratio, showing average annual employment in logging per million board-feet for coastal California, 1960-1971. This decline in employment relative to output is less marked for California than it is for Oregon and Washington, where much greater declines in employment have occurred over the same period. This is probably due to larger volume of production in those states, as well as a more extensive process of mill automation.

Seasonality is another significant characteristic of the logging industry in the coastal region. Figure 5-2 demonstrates the degree of seasonality in the coastal forest industry relative to the inland forest area. The annual fluctuation in overall employment in Humboldt and Mendocino Counties can be very high, and is strongly related to employment patterns in the forest industry. Unemployment in these counties in 1976 was more than 50% higher in January than the annual average rate. This compared to a 13% difference in the state for that year.

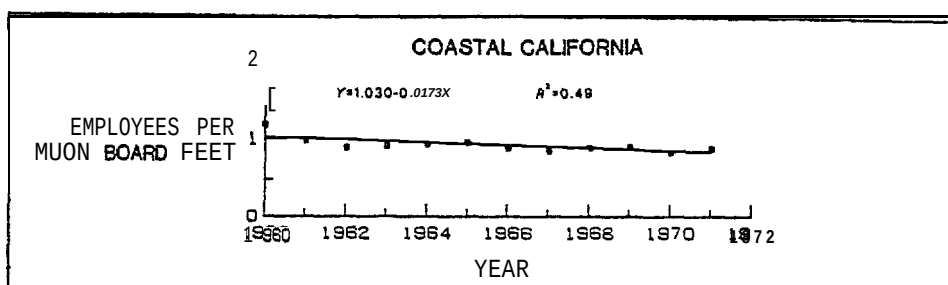


Figure 5-1. Average Annual Employment Trends in Logging, Coastal California, 1960-1971 (Wall and Oswald, 1975)

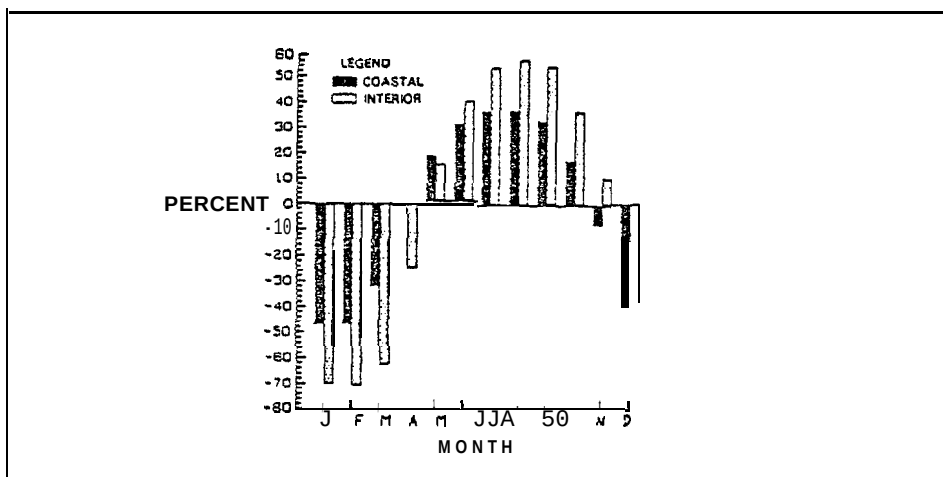


Figure 5-2. Monthly Deviations from Average Employment, California (Wall and Oswald, 1975)

Forest Products Processing

Processing Activities. Timber harvested within the Northern California coastal region is either processed within the study area or exported from coastal ports to other areas for processing. Processing activities are categorized as follows: lumber (saw mills); veneer and plywood; pulp and board; log export; shake and shingle; pole, post and piling.

Table 5-9 lists the number of mills by county and type for the coastal region. Mills are concentrated in the Eel River Basin and Eureka areas in Humboldt county, and the Fort Bragg and Willits areas in Mendocino County.

Table 5-9. Number and Type of Wood Product Mills by County, Coastal California, 1976 (Hiserote and Howard, 1978)

county	Saw-Mills	Veneer and Plywood	Pulp and Board	Shake and Shingle	Pole, Post and Piling	Export Operations	Total
Del Norte	6	3	1	---	---	---	10
Humboldt	28	7	3	3	---	6	47
Mendocino	12	1	2	4	---	---	19
Sonoma	6	---	---	---	---	---	6
Santa Cruz	4	---	---	---	---	---	4
Monterey	2	---	---	---	---	---	2
TOTALS	58	11	6	7	---	6	88

The flow of logs to the region's sawmills has been well documented by Hiserote and Howard (1978) and Howard (1972). Data were collected from a 100% canvass of all producers of primary forest products in the state during 1976 and 1972. Table 5-10 shows the volume of log flows to regional mills by source of original ownership. Public lands supply only 16% of the volume of logs processed in the region, while they supply 41% of the sawtimber in the state. Table 5-11 shows sawmills to be by far the largest volume users of logs in the region, relying on redwood for 55% of their supply. Veneer and plywood mills were heavily dependent upon Douglas fir.

Table 5-10. Public and Private Sawmill Production (Board ft. x 1,000) in Coastal Counties of California in 1976 (Hiserote and Howard, 1978)

Resource area and County	State	National Forest	Bureau of Land Management	Forest Industry				Farmer and Miscellaneous Private	TOTAL
				Other Public	Own Wood supply	Other Wood Supply			
North Coast									
Del Norte	---	21,163	---	---	86,249	30,429		5,685	143,526
Humboldt	---	144,583	400	18,025	481,138	172,725		103,847	920,718
Mendocino	37,501	33,632	---	757	187,838	33,052		102,540	395,320
Sonoma	---	---	---	---	47,290	4,100		45,299	96,689
Total	37,501	199,378	400	18,782	802,515	240,306		257,371	1,556,253
Central Coast									
Monterey and, Santa Cruz ¹	23,322	---	---	---	---	---		3,623	20,199

1. Combined to avoid disclosure.

Table 5-11. Public and Private Sawmill Production (Board ft. x 1000) by species in California (Hiserote and Howard, 1978)

Resource area and Industry	All Species	Douglas fir	Hemlock	True firs	Redwood	Ponderosa pine
North Coast						
Lumber	1,556,253	548,099	13,922	44,261	862,447	55,124
Veneer and plywood	293,919	241,523	6,758	6,775	32,771	2,617
Shake and shingle	3,455	---	---	---	---	---
Total	1,853,627	789,622	20,680	51,036	895,218	57,741
Central Coast						
Lumber	23,822	3,757	---	---	19,965	---
Pulp and board	2,700	1,755	945	---	---	---
Total	26,522	5,512	945	---	19,965	---

Resource area and industry	Sugar Pine	Incense-Cedar	Other Softwoods	Hardwooda
North Coast				
Lumber	3,668	4,505	22,624	1,603
Veneer and plywood	---	---	3,275	200
Shake and shingle	---	---	3,455	---
Total	3,668	4,505	29,354	1,803
Central Coast				
Lumber	---	---	50	50
Pulp and board	---	---	---	---
Total	---	---	50	50

As shown in Table 5-12, logs consumed in the region's mills were primarily from old growth timber in Humboldt and Del Norte Counties, while young growth timber predominates in counties to the south. This proportion of old growth sawtimber used in the north coast sawmills has declined slightly between 1972 and 1976. This corresponds to a trend in the logging sector towards increased harvest of young growth timber, as old growth stocks become depleted. There has been an overall decline of 16% in the number of the region's mills between 1972 and 1976. Most of the decline was due to the loss of nine sawmills in Humboldt County (Hiserote and Howard, 1975). There has also been a decline of 10% in the volume of logs consumed in the region's sawmills. However, the mill capacity of the region has declined only 5% in the same period, and maintained its 43% share of the total state mill capacity.

Table 5-12. Sawmill Production (Board ft. x 1,000) by
Timber Age Group and County in California in 1976
(Hiserote and Howard, 1978)

Resource Area and County	All Age Groups	Old Growth (100+ years)	Young Growth (less than 100 years)
North Coast			
Del Norte	143,526	111,765	31,761
Humboldt	920,718	687,539	233,179
Mendocino	395,320	140,241	255,079
Sonoma	96,689	23,680	73,009
Total	1,556,253	963,225	593,028
Central Coast			
Monterey and Santa Cruz ¹	23,822	2,184	21,638

1. Combined to avoid disclosure.

Using mill flow data, the percentage of logs consumed to logs produced was calculated for each county. The following figures represent consumption as a percentage of production in each north coast county: Del Norte, 88%; Humboldt, 121%; Mendocino, 78%; Sonoma, 193%.

Since the 1950's, economic pressures on small mills have resulted in a trend toward fewer but larger mills in the region. The regional capacity that is lost through the closure of small mills is somewhat balanced by the expansion of larger mills (Lembke, 1976). This process is partially responsible for the declining levels of employment relative to investment, as discussed previously (Figure 5-1).

California's plywood industry is concentrated in the north coast region, close to the Douglas fir resource. Pulp and board mills are dependent on the residue from other mills, and are thus also concentrated in that region (Hiserote and Howard, 1978). Much of the timber produced in the coastal counties' national forests, which lie mainly to the east of the study region, is processed by nearby mills, while coastal mills depend more heavily on private sources for their timber (Oswald, 1978).

Volume Produced. The volume of wood products produced in coastal counties is heavily dependent on logs harvested locally. Of all logs consumed by California coastal wood processors, 93.4% were harvested from regional forests in 1976. Fluctuation in timber supplies would therefore have a significant effect on coastal wood processing.

Other factors that contribute to variation in wood processing production are the demand factors for housing construction, manufacture of substitutes for wood products, alternative sources of lumber supply, and foreign demand for U. S. logs,

Employment. The numbers employed in the forest product industry in 1977 for the coastal counties is shown in Table 5-13. Included in forest products processing employment are sawmill and planing mill employment (S.I.C. 242); millwork, plywood and structural members employment (S.I.C. 243); wood containers employment (S.I.C. 244); and paper and allied products employment (S.I.C. 26). Processing employment (including paper and allied products industries) was about 87% of the total employment in the industry in 1977.

Table 3-13. Numbers of Employees in the Forest Industry in California Coastal Counties in 1977 (U.S. Bureau of the Census, 1979)

County	Logging	Forest Product Processing	Paper and Allied Products	Forest Industry Total
Del Norte	626	1,014	---	1,640
Humboldt	708	5,837	37.5(e)	6,920
Mendocino	505	2,819	---	3,324
Sonoma	69	1,471	---	1,540
Marin	---	79	---	79
San Mateo	59	214	947	1,220
Santa Cruz	78	405	---	483
Monterey	15	89	175(e)	279
San Luis Obispo	11	89	---	100
Santa Barbara	8	116	---	124
REGION TOTAL	2,079	12,133	1,497	15,709

Trends in total forest industry employment in Humboldt County, shown in Table 5-14, indicate a general decline in employment in this sector after 1959. Data for Del Norte County indicate a similar decline in employment from 1965-1978.

The decline in employment is related to the decreasing number of mills and the increasing ratio of capital investment to employment. This process has resulted in an increased dependency on a few large forest industries, a situation that is particularly acute in rural coastal areas where there are few other major employers. The highly seasonal nature of employment in the forest products processing industry (Figure 5-2) results in occasionally very high unemployment rates for those counties and communities that are heavily dependent upon the lumber industry. As discussed previously under Outlook and Effects, this has contributed to a way of life in which many people rely on transfer payments (particularly unemployment benefits), secondary sources of income, and savings from earnings during peak employment periods to get themselves through the periods of unemployment.

The numbers employed in forest products processing is also affected by decreases in the volume of timber harvested locally. The diversion of logs from the regional timber processing sector for foreign export also affects employment.

Table 5-14. Employment in Forest and Forest Products Processing, Humboldt County, 1950-1975 (QRC Research Corporation, 1978)

Year	Employees	Year	Employees
1950	9,406	1963	10,384
1951	10,415	1964	10,471
1952	11,887	1965	9,365
1953	12,001	1966	9,427
1954	11,879	1967	7,807
1955	12,804	1968	8,476
1956	12,274	1969	8,901
1957	11,100	1970	7,965
1958	10,907	1971	8,470
1959	12,200	1972	8,202
1960	11,429	1973	8,231
1961	9,949	1974	7,830
1962	10,425	1975	6,878

Data are second-quarter seasonally-adjusted figures.

Distribution and Secondary Activities

The logging, lumber, and wood product industries support other industries as well. Examples are transporting and marketing logs and finished products and the manufacture of equipment and machinery. Wood products are transported by water, land, and sea routes. Movement of lumber products dominates the transportation industry in Humboldt County. Lumber and wood products account for approximately 75% of the outbound commodities on highway carriers in Humboldt County, and comprised 52% of the total waterborne tonnage in Humboldt Bay in 1972 (EDAW, Inc., 1979a). Rail systems such as the Northwest Pacific Railroad carry large amounts of lumber and wood products out of the region, although a tunnel fire on that line has put it out of service since September 1978. The California Western Railroad in Mendocino County carries 5,000 carloads of lumber annually from Fort Bragg to Willits for export from the study area. This route is combined with a narrow-gauge passenger steam train, a popular recreational attraction.

Processed forest products are exported from the region throughout the nation. The export of logs from the region to Japan is discussed under the topic of Timber Harvest Volume. Distribution of wood products from the west coast to the east coast has been limited by the Jones Act, which requires that domestic shipping be done on U.S. ships, which usually are considerably less suited to lumber shipments than are foreign vessels.

Summary and Effects

Summary of Employment and Value Added. Declines in regional output of timber, together with productivity increases, have been primary reasons for declining employment in the regional forest industry. Timber resource management decisions, increased mechanization in the processing sector, and environmental interests are likely to play a large role in determining future levels of employment. Management practices that emphasize sustainable yields would conserve timber resources and could stabilize long-term forest-related employment; however, continued removal of timberland from commercial exploitation and for recreation and environmental protection may have an opposite effect. National forest lands have been recently evaluated under the roadless area review (RARE II) program to determine the suitability for and impacts of assigning wilderness or continued roadless status to certain areas (for maps and discussion, see U.S. Forest Service, 1978). Such withdrawals are not all likely to be from productive timberland, but some may be. A more significant action may be the implementation of management recommendations of the Wild and Scenic River Plans for the Smith, Salmon, Scott, and other rivers. Many recommendations could be met through the strict enforcement of the California Forest Practice Act (1973) and other existing regulations. The economic effects of such enforcement are currently under study.

To help offset declines in employment and production, restoration of watersheds affected by clearcutting has been proposed. The recently implemented California Forest Practices Act requires many new pre- and post-harvesting activities in conjunction with logging. Rehabilitation and reforestation of privately-owned commercial timberlands that are unstocked, poorly stocked, or stocked with hardwoods are proposed by the U.S.D.A. Forestry Incentives Program. The National Park Service has also suggested such a program for Humboldt County to help offset losses due to Redwood National Park expansion.

Multiplier Effects. To better gauge the effect of a decline in timber resources, calculations must be made that take into account losses in community employment as well as declines in forest industry employment. The relationship between the two may be expressed in terms of an employment multiplier. The general formula for computing the total employment impact of a decline in timber resources is as follows: $\text{employment/wood consumption ratio} \times \text{change in quantity of logs supplied} \times \text{employment multiplier} = \text{total employment change}$. Wood products employment multipliers have been calculated for Del Norte, Humboldt and Mendocino Counties at 2.76, 3.25 and 3.26, respectively (Bell, 1977).

Another measure of economic interdependence is a basic output multiplier, which would indicate the magnitude of impact in the rest of the economy occurring through a change in the forest products sector. As calculated by the Bureau of Economic Analysis for the north coast region (Del Norte, Humboldt and Trinity Counties), these multipliers are 1.869 for logging camps and contractors sector output, 2.365 for the wood products-processing sector output, and 2.563 for the wood container-producing sector. These are among the highest multiplier figures for the north coast region, reflecting the region's economic dependence on those sectors (U.S. Department of Commerce, 1977).

Natural systems Effects. Forestry and related activities have significant impacts on air and water quality, soils, and habitat conditions.

Particulate matter is the major air pollutant in the north coast air basin. Waste and wood fuel burning at lumber mills are predominant sources of particulate emissions in the north coast region. The lumber industry generates 64% of the average daily emission of particulate matter in Mendocino County in 1974 (California Department of Food and Agriculture, 1978). However, the level of particulate emissions generated by the lumber industry has declined considerably since 1970.

Herbicides, particularly 2, 4-D and 2, 4, 5-T, are regularly used in the north coast region as a means of controlling the growth of hardwoods on clear cut coniferous forest lands. The wind-drift of herbicides into inhabited areas has raised a considerable amount of concern regarding possible chemical contamination of humans through the use of herbicides. Government studies have shown strong evidence of linkages between those herbicides and birth deformities, hemorrhages, liver cancer and miscarriages. Herbicide 2, 4, 5-T has been under a temporary ban by the EPA as well as under local restrictions, and there is a strong chance both herbicides will be permanently banned either at the state or federal level. The Humboldt County agricultural commissioner reports some manual, rather than airborne, application of herbicides on small acreages (California Department of Food and Agriculture, 1978). Manual clearing of hardwood growth has been suggested as a means of avoiding the public dangers of herbicides while providing a new source of employment in the forest industry.

Logging has a marked effect on surface and groundwater systems. In particular, clearcutting has been found to increase runoff in certain areas (Hibbert, 1967), although increases in water yield from a clearcut harvest are also related to slope, soil composition, rate of revegetation, and amount of residual vegetation. Clear-cutting also increases the likelihood of landslides, stream blockage, and increased stream sedimentation. This effect is probably more limited in redwood forests than it is with other timber types because redwood root systems generally continue to support the soil mantle after cutting (Huffman, 1977). Harvesting also requires road building through watersheds, movement of heavy equipment (logging trucks and harvesting machinery), and hauling of logs across soils, all of which tend to encourage erosion. Most studies of logging-related erosion have concluded that road construction is a primary cause of erosion (Dodge, et al., 1976). The hydrologic effects of logging practices are highly controversial and may best be evaluated on a site-specific basis. The hydrologic effects of logging-induced or logging-accelerated erosion in the Eel River Basin were discussed by Cleveland, 1977b and EDAW, Inc., 1979a. A similar discussion for the Smith River system in Del Norte County may be found in EDAW, Inc., 1979c. Examples of hydrologic effects of forestry are discussed in the watershed descriptions pertaining to the northern watersheds.

Logging practices may also have impacts on fisheries in coastal streams. Examples are increased water temperatures and sedimentation, deposition of organic debris in streams, and turbidity. The stripping of vegetation along streams decreases shade and food supply and cover for fish, and increases exposure of the water to sunlight and heat. Other logging impacts include treater flow fluctuations, which result in higher peak flood flows, and lower summer flows with higher water temperatures (Rothacher, 1971). Water flow and temperature changes are likely to alter the occurrence of migration and smolting of steelhead and salmon (Brown and Heley, 1974; Lee and Baker, 1975). Adequate water flow through stream gravels and adequate dissolved oxygen are imperative for survival of chinook salmon embryos (Brown and Heley, 1974). Mortality is high when excessive erosion has deposited fine materials over the streambed which impedes oxygenation and fry emergence. Such sedimentation has increased enormously since widespread logging and harvest road construction in the upper Eel Basin began after World War II. In the Eel River basin, sediment discharge of unit areas after logging

increased 1,800% or more (Anderson, H. W., 1971) , compared with an acceleration of 200 to 400% for areas not poorly logged (Anderson, H. W., 1971) . Higher levels of turbidity caused by logging may result in gill damage to fish (Huffman, 1977) . An extensive discussion of erosion rates on California forest lands is found in Dodge, et al. (1976).

The potential effects of forest practices on water chemistry are reviewed by Newton and Norgren (1977). Effects include increased nutrient levels and pesticide and herbicide residues. Water quality impacts of associated pulp and paper wastes are reviewed by Gehm (1973) . Sawmills and pulp mills are a source of industrial wastewater discharge in several north coastal river systems. Discharge methods vary from mill to mill and include direct discharge from treatment facilities, non-point discharges on pasture, and tertiary treatment by percolation from settling ponds. Mill discharges are regulated by the State Water Resources Control Board.

The biological effects of forest practices are site-specific and management-specific. Review of this topic is provided by Gibbons and Salo (1973). Historical consequences have included impacts on faunal populations that are associated with old growth timber stands (e.g. , the osprey nesting areas in northern Mendocino County) .

Future Economic Importance of the Industry. The forest industry in the California coastal region is steadily declining. The decline is due largely to a decreasing resource base, as well as a decline in the number of mills. The decreasing availability of old-growth timber on private lands has been only partially offset by increases in the harvest of young growth stands. In addition, policy decisions concerning the relative value of the recreational and multiple use of timberland have reduced the amount of commercial timberland in the region, as has conversion of private timberland to more profitable uses such as suburban development or grazing. The withdrawal of public lands from commercial use will have less effect on the supply of sawtimber to the region's mills than will the conversion of private land to other uses (Oswald, 1978) .

There is a general economic trend in the forest industry towards more concentrated, capital-intensive operations. The closure of small mills, the expansion of other larger mills, and the declining rate of employment relative to investment indicate a greater reliance on large-scale production. There has been a recent interest on the part of the large forest industry corporations in acquisition of pulp and paper mills (Business Week, Feb. 19, 1979), which are relatively capital-intensive operations (Lembke, 1976). New technologies have been developed that may lessen the dependence of lumber companies on old growth timber, such as a process of milling undersized young growth timber into thick veneers, then combining the veneers into standard sizes of lumber.

Declines in timber production in the north coast region have been matched by increases in production in the southern states. Southern forest lands are generally flatter and more accessible, have less acreage in public trust, and are associated with generally lower labor costs than on the west coast (Forbes, 11 Dec. 1978); however, the density of Northwest timber is three times as great as that of southern forests (Forest Industries, September 1978).

Regional timberland is also considered to be generally undervalued, and is thus an attractive form of investment (Financial World, 1 February, 1979; Forest Industries, August, 1978). The Georgia Pacific Lumber Company is expanding its mill in Fort Bragg, indicating that timber processing, as well as timber ownership, is still profitable in the region.

External Factors Affecting the Industry. The forest industry is a major employer in the north coastal region only. The future of the industry there will be affected by a number of factors, including future yield from young growth timber stands, productivity increases in both harvesting and processing activities, competition from other regions in the U.S. and abroad, fluctuations in the domestic housing construction industry, removal of timber lands from commercial production, and foreign demand for regional timber.

Legislative actions that will affect the industry include the Wild and Scenic Rivers Act, the California Forest Practices Act and the RARE II Review. The Forest Practices Act requires submission of information about the proposed logging methods, erosion hazard rating, size of harvest area, and road construction, in addition to a map that shows area of operation and known features and hazards. Over 2,000 timber harvest plans were submitted to the California Department of Forestry (CDF) annually from 1975 to 1977. The plans are reviewed by an inter-agency board, and generally require a pre-harvest field inspection by a CDF inspector. If the Department takes no action on the plan in 15 days, the plan is automatically approved. The number of plans submitted and review staff limitations have made review and enforcement of the plans quite difficult. It is likely that the Forest Practices Act has succeeded in controlling only the most destructive harvesting activities, although it has also had the effect of opening private harvesting decisions to public review.

The federal Wild and Scenic Rivers act, Public Law 90-542, allows California to designate certain rivers and their immediate environments for preservation in a free-flowing state, with constraints on activities that would conflict with the goals of the act. The rivers that have been included in this Act by the State of California include portions of the Klamath, Eel, Trinity, and American River systems and the entire Smith River watershed located within the state. Management plans for most of those rivers are in the process of preparation and review. Timber harvesting activities have been identified by the resources secretary of California as having potentially significant impacts on those river systems, which could be counterproductive to the goals of the act. The secretary noted in March 1979, that "Timber harvesting activities should be controlled to protect the primitive values, to avoid creation of access or development inappropriate to the tentative classification of the stream, and to protect the streams from pollution". Management plans for these rivers generally recommend significant changes in timber harvesting practices within the river systems. Although implementing ^{legislation} has not yet been passed, it is probable that the Wild and Scenic Rivers Act will have a significant effect on timber harvesting activities within its jurisdiction.

The Roadless Area Review and Evaluation (RARE II) program currently under way is a study of 62 million acres nationwide either for possible inclusion in the nation's wilderness system or for designation as multiple-use land. Although a wilderness designation would preclude such land from commercial use, and thus have possible effect on the forest industry if that land had existing or potential use as a source of commercial timber, a multiple-use designation would allow for some harvesting, compatible with recreational use and resource protection. The President has recommended that 2.4 million acres in California be designated multiple use, that 975,000 acres be set aside as wilderness area, and that 2.6 million acres receive further study. As this is an ongoing program, the full effect of it on the forest industry is currently unknown. Impacts would depend, among other factors, upon the location, size and commercial productivity of land designated wilderness, and restrictions placed on land designated for multiple use. The program is also likely to have the effect of increasing recreational use and economic returns of forest lands.

FISHERIES

This section discusses both commercial and sport fisheries. The two fisheries are difficult to separate in many cases, because they often use the same port facilities and fishing grounds, and are dependent on many of the same species.

Resources

The water resources of the California coastal region are extensive: the Pacific Ocean is abundantly populated with important sport and commercial species. Numerous freshwater streams, creeks, rivers, and small lakes, from Monterey County north, contain many species of sport fish and provide spawning areas for anadromous species.

Species and Range. The principal species that are harvested in the California coastal region are coho and chinook salmon, albacore tuna, bottom fish such as sole, flounder and rockfish, and shellfish such as oysters, crabs, clams, abalone and shrimp. For a listing and discussion of species by habitat type, see Volume III. For discussion of fish species see Part 2 of this volume. For further discussion of commercial and sport fish species, condition and range, see Squire and Smith (1977), and Frey (1971).

An estimated 70% of chinook salmon found in California waters spawn in the Sacramento-San Joaquin River systems (Smith, et al., 1976); most of the other 30% is found north of San Francisco Bay. Coho salmon are not found in either system but spawn in coast streams north of or near Fort Bragg. (Frey, 1971). Dewitt and Welsh (in Winzler and Kelly, 1977b) describe at length the condition of spawning stocks of both species in California rivers, the declines that have occurred since 1960 due to dams and other types of habitat degradation, and the potential effects of the Peripheral Canal on chinook salmon in the Sacramento River system. Chinook and coho are the predominant salmon species in the region; pink salmon is a less common variety. Salmon make up a significant part of the local commercial and spare fishing industry from Monterey north.

Of the marine species, bottomfish, including rockfish, sole, perch, lingcod, sablefish, flounder, and hake, are fished extensively throughout the region. The bulk of the bottomfish catch is taken by commercial trawlers, but some sportfishing occurs in shallower waters. Bottomfish generally do not migrate along the coast, although tag data suggest that certain species (sablefish, petrale sole, and English sole) may migrate more than others (Frey, 1971). Offshore migration associated with spawning is characteristic of many species (NMFS, 1979).

Pacific hake spawn in the deep waters beyond the continental shelf, moving northward and onto the shelf in spring and summer. Hake has been harvested since the early 1960's by foreign trawlers, but there has been very little domestic demand for hake (Winzler and Kelly, 1977b). Although hake potentially is a valuable commercial species domestically, and investment in hake-fishing boats has recently been made in at least one coastal port (Jurick, Humboldt State Marine Extension Service, personal communication), there is evidence that the stock has declined considerably in recent years (NMFS, 1979).

Pacific Ocean perch stocks, at one time fairly abundant in coastal waters, now are scarce because of overfishing by Soviet and Japanese trawlers in the mid- and late 1960's. Recovery is expected to be a long process because of the characteristically slow growth rate of the species and inadvertent catch of perch by hake fishers (NMFS, 1979).

Anchovies have been an important species on the coast since the depletion of the sardine population in the 1940's and 1950's. Harvested mainly from Monterey Bay south, they are used for fish meal and are valuable as live bait for the sport fishing industry. Anchovies also are used as food by a wide range of marine predators.

The albacore tuna is a migratory pelagic species found along the U.S. west coast. Albacore runs originate mainly in Baja California, although their spawning ground has moved north along the coast as far as Oregon (Frey, 1971); consequently, the location of fishing grounds is highly variable from year to year. Albacore tend to migrate throughout the Pacific Ocean and are apparently responsive to temperature variations. The albacore tuna is usually harvested within 200 miles of the coast, although it is not normally associated with the continental shelf.

Another major commercial shellfish species is the Dungeness crab. The fishery extends from Point Conception to the Oregon border. The crab is generally found less than 10 miles offshore, in depths not over 300 feet, and has a preference for sandy bottoms (Frey, 1971). There has been a general decline in the crab population south of Cape Mendocino, but a considerable increase in abundance has been reported for the north (Winzler and Kelly, 1977b).

Shrimp fisheries are common throughout the study area. Ocean shrimp range from the Aleutian Islands to San Diego, but the harvest is mainly limited to areas north of Point Reyes in Marin County (Frey, 1971). The ocean shrimp beds are localized, with range from Alaska to San Diego, and are harvested in many areas along the coast. Ocean shrimp are important as a source of food for many species of commercially important marine predators such as rockfish and hake.

Oysters are cultivated and harvested under controlled conditions in several coastal bays and estuaries. Wild oysters comprise only a small portion of the fishery. Cultivation of the Pacific oyster, the primary sub-species, occurs in most coastal bays, limited primarily by the quality of the water (Frey, 1971). Seed for these oysters is mainly imported from Japan. Cultivation occurs mostly on state-owned tidelands.

Of the eight species of abalone found in California waters, only four (the red, black, flat, and pinto abalone) are found in the study area. While commercial harvest is restricted to deep waters, abalone gathering is a popular sport in certain coastal areas. Predation by sea otters and an increasing sport harvest has led to a decline in the abalone population from Monterey to Point Conception (Winzler and Kelly, 1977b).

Although over 125 species of fish and shellfish have been recorded in the regional sport catch, only about 20 are of significance (Miller and Gotshall, 1965). These include coho and chinook salmon, lingcod, halibut, rockfish, surfperch, cabezon, abalone, clams and crab. Razor clamming is conducted largely in Del Norte and Humboldt Counties; other species of clam are found throughout the coast. Principal species in the inland or estuarine sport catch include coho and chinook salmon, steelhead trout, and striped bass.

Steelhead trout, a popular sport fish, spawn in streams throughout the region and occupy much of the same habitat as that of salmon. Cutthroat and brown trout occur in some north coast rivers. Anadromous cutthroat populations occur in streams and rivers north of the Eel River, but brown trout occur as introduced species in the Trinity-Klamath River system. American shad and striped bass, species native to the Atlantic, were introduced in California waters in the 1880's (Winzler and Kelly, 1977b). Although both are harvested primarily in San Francisco Bay, populations occur in various rivers and estuaries along the coast where they have value as sport fish.

Littleneck, pismo, Washington, and razor clams are harvested for sport and food throughout the region although commercial harvest is highly limited. Clam digging is an important sport activity in many bays and estuaries, whereas razor clams, the favored species, are gathered mainly in Humboldt and Del Norte Counties.

Squid spawn and are harvested primarily in the Monterey Bay area, although they are also taken outside of San Francisco Bay and in Morro Bay. They are a significant commercial species in the region, although there is evidence that the resource may be underharvested (Winzler and Kelly, 1977b).

Supply and Demand Factors. Estimates of the regional supply of fish are usually expressed in pounds. The pounds available for harvest in a given location are dependent on ocean currents, temperature variations, long-term population fluctuations, overfishing, and human alteration of habitats, and other factors. The rate of removal directly affects the size and quantity of fish taken by regional fishermen. The supply of fish is dependent upon available biomass, season, and migration patterns, as well as on the capacity and range of vessels, competition from other domestic and foreign vessels, and other factors. Biomass and productivity are further discussed in Chapters 3 and 4 of Volume III.

The demand for commercial fish depends on consumer preferences, the availability and relative price of substitute products (such as crab for lobster or beef for fish), the worldwide demand for protein-rich foods, and the capacity of processing facilities. Demand also affects volume and value of landings and level of fishing effort. An example of the relationship between demand and volume and the value of eaten is proved by the tuna fishery. Although albacore has long been a popular sport fish, its commercial use was fairly limited until the development of processing and packaging technology, together with a strong marketing effort, generated a large demand for canned tuna. Tuna is now one of the largest and most profitable species of the California fishing industry (Gruen and Gruen, 1972). Squid, an underutilized species, is harvested in the region and canned for export. There is little demand for it in the US.

The overall demand for fish in the U.S. is strong, and increasing. There has been a long-term trend away from fresh, whole fish toward processed fish, particularly of the fish stick variety. Also, demand for more expensive fish products, such as salmon, halibut, lobster, crab and shrimp has been growing, while the market for low cost, high volume fish, such as most bottomfish, has been relatively weak. California, on the average, consumes 10% more fresh fish per capita than the rest of the country (Gruen and Gruen, 1972).

The demand for sport fishing, like the demand for other recreational activities, is a function of accessibility, income level, and climatic and aesthetic conditions. It is also affected by the probability of catch (success rate), the effort required, and the subjective and public values placed on the activity itself.

Seasonality, Control and Competition. The fishing industry has a number of unusual socioeconomic characteristics that set it off from other activities such as forestry and agriculture. Fisheries are a unique natural resource with respect to their "common property" attributes. Unlike land-based resources, neither water nor fish populations are owned to any significant extent, although state and federal authority is extended over certain ocean seas. Thus, fishery resources usually are available to all who have the means to obtain them. A potentially harmful effect of this "common property" characteristic is over-fishing and consequent resource depletion. An over-harvest of a species of fish or a fishing ground could affect the ability of the population to reproduce and result in a significant reduction or elimination of the resource. Despite this potentially adverse long-term effect, it serves the short-term economic interest of the fisherman to land as many fish as possible. Government intervention, in the form of catch quotas and exclusionary boundary limits, has been the main means of attempting to balance optimal ecological conditions and economic harvests. Human intervention to increase productivity through such means as salmon hatcheries and aquiculture operations has not been practiced on a large scale in the region, although aquiculture is likely to expand in the future.

Another unusual characteristic of the fishing industry is the high degree of physical mobility of its capital and labor resources. Fishing grounds are unstable, responding to ocean currents, bottom conditions, natural population cycles and human-initiated environmental alterations. The albacore tuna, for example, migrates throughout the Pacific Ocean, and has periodically shifted its breeding grounds up and down the California coast (Frey, 1971). Fishing fleets are also very mobile. Trawlers and trollers can travel long distances from coastal ports to reach productive fishing grounds. Consequently, the fishing industry is not entirely dependent on local conditions for economic success, as are other resource industries. Physical mobility also allows direct competition for resources to occur between fishermen who dock at different ports. The degree of competition between various parts of the region is determined by the supply of labor and amount of capital investment available to the fishing operations at their home ports, along with the capacity and quality of the onshore facilities.

Competition with fishing fleets from outside the region also occurs, although recent enactment of the Fishery Conservation and Management Act (P.L. 94-265) in 1976, extending national jurisdiction to 200 miles, has lessened competition with foreign fleets. This is probably the most significant regulatory decision of the recent past. Effective enforcement of the limit has sharply reduced foreign fishing harvest along the California coast.

Between 1965 and 1976, Russian, Japanese and Polish trawlers intensively fished California waters, capturing large volumes of hake, tuna, perch and salmon. Using larger factory ships, better equipment, and coordinated fleet operations, most foreign fleets had a considerable advantage over the relatively small ships and smaller-scale fleet operations of the regional fishing industry. Impacts on regional fisheries included pre-emption of fishing grounds and loss of fixed gear due to entanglement, but most significant was the over-harvest of the perch population, particularly by Soviet trawlers, which resulted in the near elimination of this fishery (NMFS, 1979).

The U.S. National Marine Fisheries Service (1977) has conducted a study of the trawl fishing resource as a result of P.L. 94-265. This study evaluated the status of the rockfish and bottomfish populations in Washington, Oregon and California waters, estimated a level of maximum sustainable yield per species, and recommended regulatory catch limits on both domestic and foreign trawl fishing operations. Regulatory measures in this management plan also require foreign vessels to obtain a permit from the Department of Commerce, and establishing geographic boundaries for foreign fleet activities. The findings of the study are summarized in Table 5-15.

The competitive position of the region's fisheries in the domestic and foreign fishing industry is partially determined by technological factors. Harvesting and processing methods used in the U.S. have not changed greatly in recent years. The region's trawl fishery is conducted by relatively small, aging vessels, taking trips of up to a week's duration and returning the fish for onshore processing (NMFS, 1977). This is in sharp contrast to the large vessels used in many foreign fleets, with the capacity to process and store the catch onboard. In addition, most U.S. trawlers operate independently without the advantage of fleet operations, although exceptions,

such as the Lazio fleet in Eureka, do exist. There has not been much domestic investment in the regional fishing industry, nor has there been extensive research on the fish resources and on the productivity and economic problems which have hindered development of the regional industry. Since the establishment of the 200-mile limit, there has been a marked increase in the level of foreign investment in the domestic fishing industry (Siegal, 1976). The extent to which this is occurring on the California coast is not well-documented, but there have been several reported instances of foreign investment in fishing companies in San Francisco (San Francisco Examiner, August 21, 1978).

Table 5-15. U.S. and Foreign Finfish Catch, Maximum Sustainable Yield, and Total Allowable Catch of the Pacific Trawl Fishery, in Metric Tons (NMFS, 1977)

Species	1974 Data Base	1974 U. S. Catch	1974 Foreign Catch	Est. MSY	Proposed 1977 TAC	Expected U.S. Catch	Total Allowable Level of Foreign Fishing
Pacific hake ¹	Fair	Trace	214,000	150,000-250,000	150,000 ²	6,800	143,200 ¹
Pacific Ocean Perch	Good	600	11,500	5,000-6,000	1,000	1,000	Incidental catch only, not to exceed 1.3% of hake catch
Other Rockfishes	Poor	9,600		18,000	18,000	18,000	
Flounders	Fair-Good	22,400	Trace	30,000-35,000	31,000	31,000	Incidental catch only, not to exceed 0.1% of hake catch
Sablefish	Fair	6,444	600	5,000-	7,000	7,000	Incidental catch only, not to exceed 0.2% of hake catch
Jack Mackerel	Poor	11,500	NA ³	210,000-450,000	55,000	51,000	4,000-from north of 39°N only
Others	Poor-Excel.	3,300	12,000	N/A ⁴	4,200	4,200	Incidental catch only, not to exceed 0.5% of hake catch

1. Includes that portion of the resource and fishery which occurs off British Columbia.
2. Provisional.
3. Mexican catch unknown.
4. Not applicable.

A particular technological constraint on the regional fishing industry is the lack of on-vessel refrigerated storage and processing facilities. This is a particular problem with regard to future development of hake fishery, as hake rapidly lose quality unless cleaned and frozen immediately after being caught. The fish storage capacity of the region's fishing vessels, and the processing capacity of onshore plants, are related constraints on the development of the domestic fishing industry (Prochaska, 1978; Orth, 1978). For these reasons, a portion of the United States catch of such species as pollock is being transferred to foreign ships for processing at sea (San Francisco Examiner, 21-22 August 1978).

A major investment was made recently in Eureka with the construction of three large hake fishing boats equipped for cleaning and freezing, an onshore refrigerated hake warehouse, and ten 84-foot trawlers, (Jurick, Humboldt State University Marine Advisory Extension Service, personal communication, 1980). The new boats are able to range much farther afield in search of fish and to stay at sea for prolonged periods. If this apparent trend towards larger, better equipped boats continues, the region's ability to compete with foreign boats beyond the 200-mile limit and to increase the volume of landings and local processing will be enhanced.

Another significant form of competition exists: that between the domestic sport and commercial fisheries. With certain species, such as salmon and halibut, there is direct competition for the resource and fishing grounds. Sport fishermen are also concerned with depletion of the anchovy population, a species that many sport fish depend upon for forage. Competing demands for the anchovy have necessitated constraints on commercial anchovy fishing (NMFS, 1978b).

Regulation is the primary means of control of fish harvests. Regulatory measures vary by species, and differentiate between commercial and sport fisheries. Commercial trawl fishing operations are restricted with regard to the mesh size of their nets, allowable catch limits, minimum fish size, and area and seasonal closures. Seasonal closures are generally set to protect egg-carrying females or immature fish. Catch quotas, seasonal closures, and net size and other equipment restrictions apply to the shrimp fishery. The abalone and Dungeness crab fisheries are also highly regulated due to the danger of overfishing.

The regulated seasonality of most commercial fisheries, the natural fluctuations in fish populations, and the sometimes unpredictable migratory patterns of certain species result in seasonal employment and income for fishermen.

Commercial Fish and Shellfish Harvest

Volume of Landings. Table 5-16 gives commercial landings by principal species, and by area, for 1975, the latest year for which complete data are available. In terms of poundage, bottomfish (primarily sole, lingcod, flounder, and sablefish) dominate the region's fisheries, with anchovies providing the greatest poundage in Monterey and Santa Barbara ports. It should be noted that this table gives poundage for only one year (1975). Fish landings can vary considerably between years, as is shown by the regional totals in Table 5-17.

Table 5-16 Commercial Fish and Shellfish Landings, by
Species and Area, Coastal Region, 1975, in Pounds
(California Department of Fish and Game, 1976-1977)

Species	Eureka Area	San Francisco Area	Monterey Area	Santa Barbara Area	Region Total	State Total
Dungeness Crab	3,495,505	322,040	1,638	115,480	3,934,663	3,934,663
Salmon	4,312,855	1,734,880	721,102	156,221	6,925,058	6,925,082
Albacore	2,329,298	928,722	2,602,850	1,498,800	7,359,670	15,412,778
Pacific Ocean Shrimp	3,746,298	1,189,671	---	62,400	4,998,369	4,998,369
Dover Sole	19,345,169	3,013,959	174,523	153,979	22,687,639	22,683,520
Anchovy	---	858,570	14,250,568	50,874,631	65,983,769	317,021,422
Sablefish	6,053,432	926,750	6,949,187	168,055	14,097,394	14,131,964
Abalone	---	53,007	848	1,412,345	1,466,200	2,138,474
Lingcod	1,223,076	940,493	523,765	502,643	3,189,977	3,190,195
Flounder	296,120	254,657	114,342	51,353	716,472	716,472
TOTAL, All Species	55,624,488	18,205,797	38,209,774	76,156,979	131,359,202	979,826,165

The poundage of fish harvested can be a valuable indicator of socio-economic repercussions of policies and activities affecting the marine and coastal environment. It is useful, however, to bear in mind the complexity of factors that may influence fluctuations in landings. Trends in harvest size may be related to a variety of occurrences, such as migration, weather conditions, hatchery production and stockings, level of fishing effort, and natural population cycles. A drop in hake landings after 1967, for example, was due to the combined effect of a termination of government subsidies to the hake fishery at the conclusion of fish protein concentrate studies, and a drop in the price of fish meal. Historic declines in perch landings have been more directly related to population depletion caused by overfishing (NMFS, 1977). Ports and Regions referred to in the following discussion are shown in Figure 5-3.

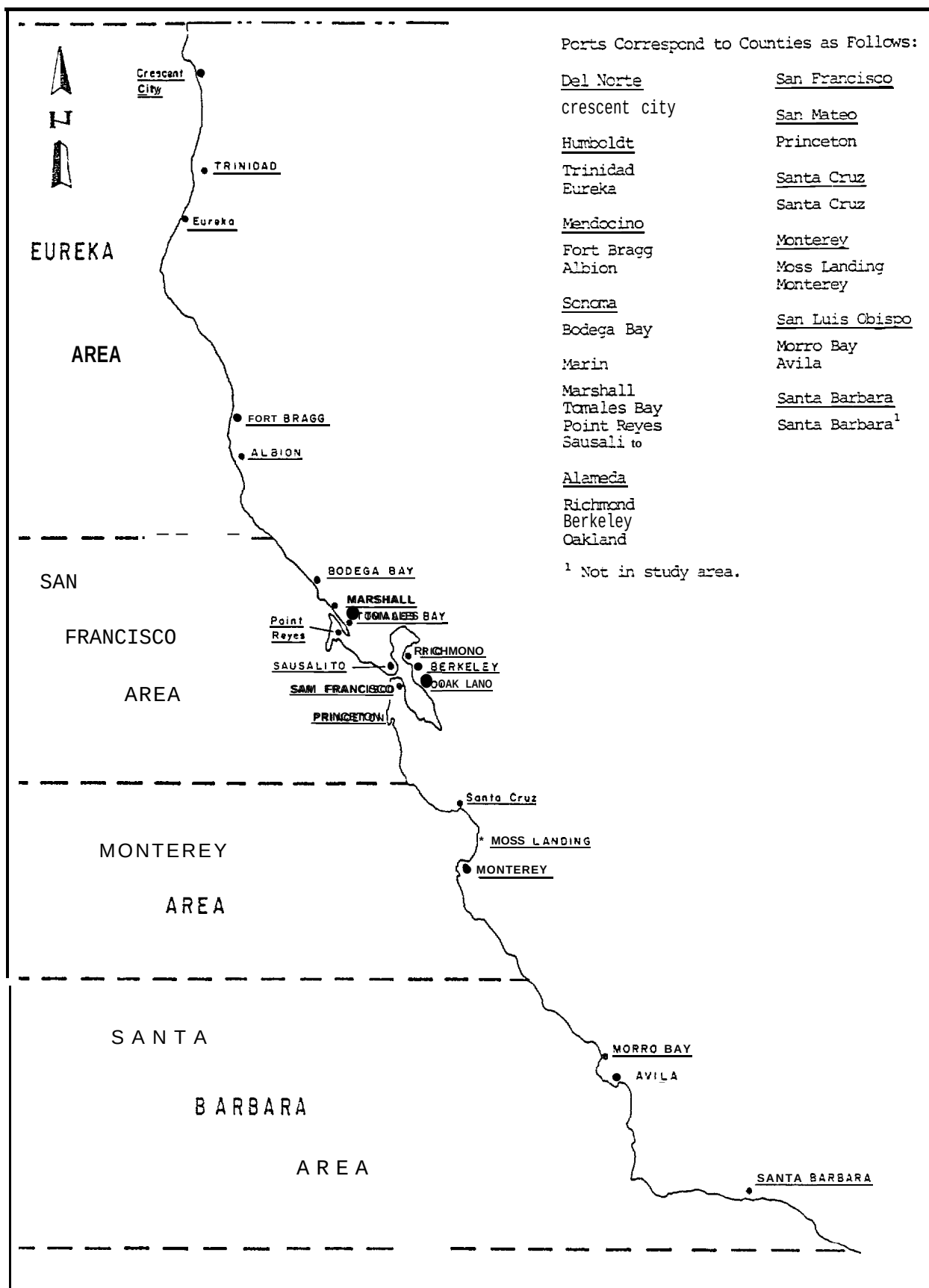


Figure 5-3. Commercial Fishing Ports and Areas in the Study Region (California Department of Fish and Game, 1977)

The commercial coho and chinook salmon fishery began in the San Francisco and Monterey Bays in the late 1800's. By 1916, ocean trolling moved north to Eureka and Crescent City. Landings reached 13 million pounds in 1919, although the fishery experienced a prolonged slump between 1928 and 1941, attributable to the combined effects of low levels of rainfall in the 1930's and dams and water diversion of spawning streams (Frey, 1971). Although landings increased to 9.8 million pounds in 1956, the state salmon catch declined sharply to 3.6 million pounds in 1968. Between 1963 and 1967, the fishery ranged between 7.4 and 9.7 million pounds annually. Prior to 1961, San Francisco Bay generally accounted for the greatest portion of annual catch. Through the 1960's, the ports of Eureka and Fort Bragg began to land larger shares of the state catch. By 1972, Eureka accounted for 17% of the state salmon catch, while Fort Bragg landed 24%. The port of Eureka's portion of the state catch had increased to 29% in 1975, or 2,018,051 pounds, while the salmon catch at Fort Bragg had declined to 19%. The actual volume of salmon landings and shipments at all Eureka area ports had increased to 5,125,901 in 1974, although this declined to 4,312,855 pounds in 1975, reflecting a statewide decline of salmon landings and shipments in that year.

Albacore tuna landings in the Eureka area (including Crescent City, Eureka, Fort Bragg, Trinidad and Albion) increased steadily to 7,067,951 pounds in 1970, declining by 86% by 1972, and rising to 2,329,298 pounds in 1975. San Francisco landings of Albacore totalled 6,995,840 pounds in 1971, brought in mainly at the ports of Sausalito and Oakland. This volume had declined to 378,804 pounds in 1973, but rose again to 928,722 pounds by 1975. An additional 124,862 pounds were landed from waters north of the state in 1975. Out-of-state landings are recorded annually between August and October in San Francisco. The Monterey area regularly records higher albacore catches than San Francisco, but catch fluctuations are similar to those in San Francisco.

Landings of bottomfish species, particularly sole, rockfish, sablefish and lingcod, generally have been increasing. The level of sablefish catch has grown in recent years due to the expanded domestic market.

Landings of Pacific herring in San Francisco and Marin Counties, at a fairly low level since reaching a high of eight million pounds in 1918, dropped to nearly zero from 1964 and 1972. The opening of a new market for herring roe in Japan caused an increase in the level of landings, which reached 4,356,231 pounds in 1976. The increased attractiveness of herring has brought more large boats into Tomales Bay, creating some conflicts with residents in the area (Eldridge and Kaill, 1973).

Anchovy landings occur mainly in Monterey and Moss Landing and have fluctuated over time in accordance with the availability of sardines, capacity of processing plants, and the size of the anchovy population (NMFS, 1978b).

Oyster landings depend largely on giant Pacific oyster cultivation in Humboldt, Tomales and Morro Bays. Landings in Eureka from Humboldt Bay oyster beds, the state's largest producing area, have declined slightly from a peak of 751,832 pounds in 1972. Oyster landings at Point Reyes and Tomales Bay declined to a low of 95,555 pounds in 1972, increasing to 253,667 pounds in 1975. Morro Bay production reached its peak in 1979, when 219,987 pounds of oysters were landed; 87,836 pounds were landed at Morro Bay in 1975.

The shrimp fishery first developed near Morro Bay, although landings at that port declined drastically after 1954. Bodega Bay has had wide fluctuations in shrimp landings, which increased steadily from 1957 to 1961, dropped to nothing by 1968, then rose from 525 pounds in 1971 to 1,189,671 pounds in 1975. Shrimp landings and shipments in the Eureka area have risen fairly steadily since 1952, to a high of 3,746,298 pounds in 1975. The drastic historical fluctuations in shrimp catch in Bodega and Morro Bays have been attributed to the inability of nearby shrimp beds to sustain a steady shrimp population (Dahlstrom, 1973).

While catch data are an important means of understanding resource conditions, they are not of great value in a discussion of the relative importance of various species to the coastal economy. Catch volume is not a reliable indicator of the abundance of a species, nor does it accurately reflect the capacity of the region's fishing vessels or port and processing facilities. It is also not indicative of the value of particular species. Volume data can, however, be valuable to a discussion of fluctuations in harvest of an individual species over time.

Table 5-17. Commercial Landings and Shipments by Principal Species and Total for All Species, Northern and Central California Coastal Region, 1965-1975, in pounds (California Department of Fish and Game, 1967 through 1977) .

Species	1965	1966	1967	1968	1969	1970
Dungeness Crab	4,803,906	12,376,390	11,716,488	16,015,581	7,938,396	15,413,589
Salmon	9,733,622	9,446,624	7,399,912	6,951,896	6,150,883	6,611,358
Albacore	8,477,529	7,613,319	10,397,928	7,957,099	7,488,202	21,090,321
Dover Sole	10,754,963	10,311,275	7,215,037	8,535,791	12,918,982	15,160,886
Pacific Ocean Shrimp	1,422,364	1,190,197	1,412,513	2,274,770	2,947,563	4,047,589
Anchovy	4,146,826	25,747,689	25,077,868	12,561,187	25,491,409	21,739,480
Sablefish	2,862,305	3,215,903	6,573,528	3,218,838	4,155,793	4,427,036
TOTAL, All Species	93,755,351	122,945,062	118,019,155	111,080,267	113,288,094	134,715,450

Species	1971	1972	1973	1974	1975
Dungeness crab	9,662,265	1,563,006	1,022,873	685,000	3,934,663
Salmon	8,116,878	6,423,248	9,667,886	8,749,000	6,925,058
Albacore	23,814,460	12,715,891	5,109,537	7,277,426	7,359,670
Dover sole	14,245,719	22,080,677	22,485,725	19,083,060	22,687,630
Pacific Ocean Shrimp	3,080,583	2,489,870	1,239,976	2,387,366	4,998,369
Anchovy	22,449,367	29,025,800	42,229,896	47,042,163	65,983,769
Sablefish	4,423,272	8,394,226	8,521,451	12,029,255	14,097,394
TOTAL, All Species	140,133,304	136,375,714	141,366,257	169,549,792	188,197,038

Value of Landings. Value of landings is the most useful indicator of the relative economic significance of a commercial species. As previously discussed, the price of fish depends on a large number of supply and demand factors. The level of catch can fluctuate enormously from year to year. As value is a function of both production and per-unit price, annual fluctuations in the value also can be large.

The ex-vessel value (price paid to the fisherman) for the major species of fish harvested in the coastal region is shown in Table 5-18.

The fisherman is generally in the position of being a "price-taker", having little control over the price being offered for the catch. For economic, institutional or geographic reasons, fishermen are often dependent on a particular processor-wholesaler, and have little ability to choose among prices. Fishermen generally earn a disproportionately low share of the proceeds of the fishing industry, while fish processing brings a fairly high return on investment (Gruen and Gruen, 1972). Another factor in the determination of the price of a given catch is the role of the broker, who regularly adjusts the price of fish according to market conditions, and speculates on future price changes.

The value of a species may vary by port. Dungeness crab, for example, brought an average of 68 cents per pound to fishermen in Eureka in 1975, while San Francisco fishermen received 97 cents per pound. Salmon was 88 cents per pound on the average

in Crescent City in the same year, whereas Fort Bragg salmon catch brought \$1. These differences are due to proximity to markets, and reflect the varying degrees of local dependence on processors and wholesalers.

Table 5-18. The 1975 Value of Finfish and Shellfish Landings for Principal Species by Area and Region, and Total for all Species in Dollars (California Department of Fish and Game, 1977) .

Species	Eureka Area	San Francisco Area	Monterey Area	Santa Barbara Area	Region Total
Dungeness crab	2,365,045	313,702	1,773	110,980	2,791,500
Salmon	\$,161,608	1,842,125	784,203	183,652	6,971,588
Albacore	732,835	293,736	826,672	476,738	2,329,981
Pacific Ocean shrimp	496,545	158,870	---	9,580	664,995
Dover sole	2,124,666	347,472	18,436	16,288	2,506,862
Anchovy	---	77,440	231,321	794,083	1,102,844
Sablefish	583,349	92,481	710,906	10,518	1,397,254
Abalone , Red	---	45,998	754	483,482	530,234
Lingcod	161,627	116,410	74,782	69,137	421,956
Flounder	33,094	28,717	17,269	7,336	86,416
TOTAL All Species	13,307,035	4,909,895	4,173,341	5,272,487	27,662,758

It is possible to compare the catches and value landed in each area in terms of percentages of state totals for 1975 as shown in Table 5-19. The relatively higher value of landings in the Eureka and San Francisco areas is likely due to the high per-pound value of salmon and crab.

Table 5-19. The Percentage Contribution of Pounds and Value (dollars) of Finfish and Shellfish to the State Totals in 1975 (see Tables 5-16 and 5-18)

Port	Pounds	Dollars
Eureka Area	6.5	10.4
San Francisco Area	2.1	3.9
Monterey	4.4	3.3
Santa Barbara	8.8	4.2
Region	21.8	21.8

Commercial fishing catch and value data are collected by California Department of Fish and Game (DFG) on the basis of port of landing and on the basis of the size and location of catch in the open ocean. DFG has divided the offshore area into a series of numbered statistical blocks. Commercial fishermen report their catch by weight of each species by statistical block. For any particular locale within DFG's reporting area, the weight of the catch of each fish species can be ascertained from the DFG records (with some limitations).

As part of this report, a ten-year record of the commercial catch for significant shellfish and finfish species was prepared (Table 5-20) from DFG records for each of the five blocks that comprise outer continental shelf (OCS) oil and gas lease sale no. 53 (northern and central California). The relationship between DFG statistical blocks and OCS lease blocks are as follows:

<u>OCS Lease Sale Blocks</u>	<u>DFG Statistical Blocks</u>
Eel River	203, 204, 211, 212
Point Arena	263, 264, 269, 270, 275, 276
Bodega Bay	432, 433
Santa Cruz	464, 465, 473, 474, 479, 480, 502, 503
Santa Maria	608, 615, 616, 624, 625, 632, 633, 634, 638, 639, 644, 645

The annual value for each species in Table 5-20 is calculated from annual DFG reports (see Table 5-20 for specific Fish Bulletin references) and is derived from the value of each species at the port closest to the catch area. The percentage of the total state catch is also calculated from annual totals given in each year's respective Fish Bulletin.

The significant species for each lease block were identified as follows:

Eel River Lease Block: Flatfish, rockfish, salmon.

point Arena Lease Block: Salmon, flatfish, albacore tuna, rockfish, lingcod, dungeness crab, Giant Pacific oyster, Pacific Ocean shrimp.

Bodega Bay Lease Block: Salmon, flatfish, Pacific herring, rockfish, albacore, tuna, Pacific Ocean shrimp, dungeness crab, Giant Pacific oyster.

Santa Cruz Lease Block: Salmon, albacore tuna, rockfish, flatfish, sablefish, northern anchovy, lingcod, Pacific herring, market squid, dungeness crab, red abalone, spot prawn.

Santa Maria Lease Block: Rockfish, albacore tuna, flatfish, salmon, lingcod, Giant Pacific oyster, dungeness crab, rock crab, red abalone, sea urchin.

The flatfish of the Pacific coast are: sole, arrowtooth flounder, rock sole, sand sole, English sole, rex sole, butter sole, petrale sole, clover sole, halibut, Pacific halibut, California halibut, sanddab, flounder, starry flounder, curlfin turbot, diamond turbot, honeyhead turbot, and turbot. Salmon includes chinook (king), echo (silver), sockeye, and pink.

The rockfish category includes the following members of the family scorpaenidae: whitebelly, canary, yelloweye, vermilion, black and yellow, black, greenspotted, and starry rockfish; striped, china, yellowtail, gopher, red, brown, rosy, widow, and splitnose rockfish; bocaccio; chilipepper; sculpin; and shortspine thornyhead.

The catch data have certain limitations that should be noted particularly with forecasting trends in level of catch, impact assessments and comparison among species and years. The data include commercial fishing catch but do not contain party boat and sport fishing data. The DFG catch by origin records are based on location of catch as reported by fishermen. In some cases fishermen do not specify exact location but do report pounds of each species. In such circumstances the catch is reported in a larger generalized block category on the basis of port of landing. The proportion of unspecified catch by locale in the records is greater for some species than for others. For some species such as salmon the numbers of fish reported in each DFG statistical area may be lower than the actual numbers caught. No information is available on the actual distribution of catch that is reported in the generalized block category and no attempt could realistically be made to compensate for the under-reporting of numbers recorded in Table 5-20. Annual fluctuations in catch are often severe as shown in Table 5-20, although such charges may simply mean the species was caught in a statistical block adjacent to the lease block and may not indicate a depletion of the fishery. Finally, only certain species are represented in the table, and not the total catch in a lease block area. The offshore catch data for particular species do not necessarily correspond with the pounds landed at nearby ports, as the mobility of certain fishing fleets often allows catch within a particular lease block to be landed at distant ports.

Relative to its size, catch data for the Eel River lease sale block in Table 5-20 show a consistently significant portion of the state flatfish catch being caught annually in the area, ranging from under 11% to over 18% of the total annual state catch. Data for the Point Arena lease sale block indicate that the area has been a fairly important salmon fishing area between 1972 and 1975. The percentage of the total state flatfish catch caught within the block also rose after 1979, and greater portions of the state lingcod catch were caught within the block between 1972 and 1975. The Bodega Bay lease sale block, including only two DFG statistical blocks, shows relatively large portions of the state catch of salmon in 1972, 1974 and 1975. Catch data for the Santa Cruz lease sale block indicate a decline in catch volume relative to the statistical totals for all species recorded in Table 5-20 in 1968, 1969 and 1970. No catches of pacific herring or market squid are recorded during the ten-year period. Generally high percentages of state catch for the red abalone are recorded in the Santa Maria lease sale block, which also includes periodically high percentages of the state catch for rockfish and lingcod.

Table 5-20. Finfish and Shellfish Landings (pounds and dollars) and the Percentage Contribution of Dollar Values to the State Total for Five OCS Lease Sale 53 Blocks in 1966 to 1975 (footnote descriptions on page 270)

EEL RIVER LEASE SALE BLOCK ²									
Species	1975			1974			1973		
	lbs.	\$	%	lbs.	\$	%	lbs.	\$	%
Flatfish	3,904,088	495,819	11.33	3,574,400	474,323	11.91	3,618,297	403,802	11.10
Rockfish	714,318	80,075	3.02	810,528	88,023	3.77	658,899	55,084	2.98
Salmon	27,312	26,354	0.39	142,509	120,933	1.63	1,292	1,103	0.01
Species	1972			1971			1970		
	lbs.	\$	%	lbs.	\$	%	lbs.	\$	%
Flatfish	4,278,652	369,248	13.04	2,593,990	248,504	11.11	3,645,838	342,344	14.55
Rockfish	877,452	61,158	5.34	558,824	35,821	5.00	580,425	35,754	5.43
Salmon	1,272	883	0.02	2,261	1,221	0.03	2,791	2,045	0.04
Species	1966			1968			1967		
	lbs.	\$	%	lbs.	\$	%	lbs.	\$	%
Flatfish	4,248,873	358,180	18.12	3,339,024	268,124	15.32	2,428,845	218,596	11.92
Rockfish	543,703	30,991	5.89	405,510	22,465	4.29	268,888	13,453	2.75
Salmon	335	198	0.01	689	371	0.01	319	159	0.00
Species	1969								
	lbs.	\$	%						
Flatfish	2,985,726	268,716	13.46						
Rockfish	336,010	16,800	3.34						
Salmon	1,025	504	0.01						

Table 5-20 (cont'd.)

POINT ARENA LEASE SALE BLOCK ³									
Species	1975			1974			1973		
	lbs.	\$	%	lbs.	\$	%	lbs.	\$	%
Albacore Tuna	77,242	24,300	0.05	523,286	180,220	4.43	148,700	58,067	1.72
Lingcod	213,283	26,175	6.69	308,307	42,331	8.06	165,997	18,260	4.66
Flatfish	2,894,347	368,161	8.39	2,632,490	349,331	8.77	2,713,387	314,753	8.32
Rockfish	1,812,540	203,186	7.61	1,513,553	164,372	7.04	846,968	70,807	3.84
Salmon	734,883	705,488	10.61	1,264,357	1,072,933	14.45	1,235,427	1,055,055	12.78
Giant Pacific Oyster	--	--	--	--	--	--	--	--	--
Dungeness Crab	34,230	23,156	0.87	3,038	2,675	0.44	12,787	9,969	1.25
Pacific Ocean Shrimp	361	47	0.00	--	--	--	--	--	--
Species	1972			1971			1970		
	lbs.	\$	%	lbs.	\$	%	lbs.	\$	%
Albacore Tuna	67,161	21,377	0.32	12,829	3,722	0.04	29,178	7,376	0.10
Lingcod	273,955	28,683	8.44	63,764	6,147	3.04	64,815	6,199	4.23
Flatfish	2,165,564	179,742	6.91	1,781,620	170,679	7.38	1,469,350	137,971	5.86
Rockfish	736,315	736,751	4.48	428,929	27,494	3.84	371,039	22,856	3.47
Salmon	1,023,146	714,227	16.02	29,702	16,039	0.37	584	428	0.01
Giant Pacific Oyster	--	--	--	--	--	--	--	--	--
Dungeness Crab	18,925	10,04	1.21	593	170	0.01	--	--	--
Pacific Ocean Shrimp	--	--	--	--	--	--	--	--	--
Species	1969			1968			1967		
	lbs.	\$	%	lbs.	\$	%	lbs.	\$	%
Albacore Tuna	87,468	17,503	0.59	24,158	4,531	0.16	128,194	24,357	0.72
Lingcod	42,856	3,916	3.85	60,259	4,812	5.51	62,201	4,976	0.63
Flatfish	1,186,493	100,021	5.06	908,527	72,682	4.17	888,438	79,959	4.36
Rockfish	376,925	21,485	4.08	336,610	18,648	3.56	316,118	18,967	3.23
Salmon	8,041	4,744	0.13	188,226	101,303	2.71	158,953	84,245	2.15
Giant Pacific Oyster	--	--	--	--	--	--	--	--	--
Dungeness Crab	--	--	--	--	--	--	3,769	603	0.03
Pacific Ocean Shrimp	--	--	--	--	--	--	--	--	--
Species	1966								
	lbs.	\$	%						
Albacore Tuna	2,330	396	0.01						
Lingcod	47,212	4,249	5.90						
Flatfish	965,578	86,902	4.35						
Rockfish	208,388	10,419	2.07						
Salmon	440,794	211,581	4.67						
Giant Pacific Oyster	--	--	--						
Dungeness Crab	--	--	--						
Pacific Ocean Shrimp	--	--	--						

Table 5-20 (cent'd.)

BODEGA BAY LEASE SALE BLOCK ⁴									
	1975			1974			1973		
Species	lbs .	\$	%	lbs .	\$	%	lbs .	\$	%
Albacore									
Tuna	138,026	43,658	0.90	26,408	9,203	0.22	---	---	---
Pacific									
Herring	---	---	---	---	---	---	---	---	---
Flatfish	257,124	42,503	0.74	269,090	46,122	0.90	136,609	17,049	0.42
Rockfish	25,289	3,540	0.11	37,135	4,738	0.17	43,308	4,158	0.20
Salmon	163,924	173,759	2.37	215,129	217,280	2.46	32,975	34,096	0.34
Giant Pacific									
Oyster	---	---	---	---	---	---	---	---	---
Dungeness									
Crab	1,339	1,298	0.03	---	---	---	8	8	0.00
Pacific Ocean									
Shrimp	866	112	0.02	---	---	---	---	---	---
	1972			1971			1970		
Species	lbs.	\$	%	lbs .	\$	%	lbs .	\$	%
Albacore									
Tuna	329,213	105,546	1.57	---	---	---	---	---	---
Pacific									
Herring	---	---	---	---	---	---	---	---	---
Flatfish	129,499	15,164	0.39	383,309	43,889	1.59	330,512	35,894	1.32
Rockfish	14,139	1,157	0.09	35,879	2,799	0.32	23,398	1,727	0.22
Salmon	229,003	185,492	3.57	295	203	0.00	3,803	3,080	0.06
Giant Pacific									
Oyster	---	---	---	---	---	---	---	---	---
Dungeness									
Crab	22	15	0.00	1,128	451	0.01	313	109	0.00
Pacific Ocean									
Shrimp	---	---	---	---	---	---	---	---	---
	1969			1968			1967		
Species	lbs .	\$	%	lbs .	\$	%	lbs .	\$	%
Albacore									
Tuna	---	---	---	---	---	---	---	---	---
Pacific									
Herring	---	---	---	---	---	---	---	---	---
Flatfish	302,315	29,687	1.29	227,068	22,287	1.04	336,679	30,301	1.65
Rockfish	13,093	1,011	0.14	6,833	605	0.07	36,545	2,924	0.37
Salmon	9,268	6,020	0.15	54	34	0.00	49	27	0.00
Giant Pacific									
Oyster	---	---	---	---	---	---	---	---	---
Dungeness									
Crab	47	18	0.00	205	70	0.00	555	161	0.00
Pacific Ocean									
Shrimp	---	---	---	---	---	---	---	---	---
	1966								
Species	lbs .	\$	%						
Albacore									
Tuna	---	---	---						
Pacific									
Herring	---	---	---						
Flatfish	272,372	24,513	1.23						
Rockfish	44,632	3,124	0.44						
Salmon	20	11	0.00						
Giant Pacific									
Oyster	---	---	---						
Dungeness									
Crab	---	---	---						
Pacific Ocean									
Shrimp	300	36	0.03						

Table 5-20 (cent' d.)

SANTA CRUZ LEASE SALE BLOCK ⁵									
Species	1975			1974			1973		
	lbs .	\$	%	lbs .	\$	%	lbs .	\$	%
Albacore Tuna	1,505	476	0.01	118,557	41,317	1.00	1,937	771	0.02
North. Anchovy	19,900	1,795	0.01	98,600	8,618	0.06	72,700	6,107	0.03
Pacific Herring	--	--	--	--	--	--	--	--	--
Sablefish	95,319	9,189	0.68	80,765	7,027	0.67	68,068	5,309	0.80
Lingcod	61,892	7,662	1.94	69,905	8,151	1.83	29,609	2,931	0.83
Flatfish	1,039,895	171,895	2.99	787,219	134,929	2.63	524,333	65,437	1.60
Rockfish	408,825	57,236	1.72	203,422	25,957	0.94	250,104	24,010	1.13
Salmon	214,017	226,858	3.09	651,997	658,517	7.45	525,877	543,757	5.47
Red Abalone	1,630	1,415	0.02	2,275	1,691	0.30	982	538	0.15
Market Squid	--	--	--	--	--	--	--	--	--
Dungeness Crab	28,574	27,717	0.73	60,995	56,115	8.90	81,356	77,939	7.95
Spot Prawn	--	--	--	--	--	--	--	--	--
Species	1972			1971			1970		
	lbs.	\$	%	lbs.	\$	%	lbs.	\$	%
Albacore Tuna	107,765	34,549	0.05	10,505	3,095	0.03	26,258	6,780	0.09
North. Anchovy	312,800	24,930	0.23	--	--	--	--	--	--
Pacific Herring	--	--	--	--	--	--	--	--	--
Sablefish	16,740	1,172	0.20	9,215	461	0.21	5,235	279	0.12
Lingcod	1,597	144	0.05	1,395	115	0.07	360	29	0.02
Flatfish	114,988	13,465	0.35	99,517	11,395	0.41	51,042	5,543	0.20
Rockfish	82,549	6,753	0.50	10,210	796	0.09	17,810	1,314	0.16
Salmon	42,477	34,406	0.66	19	13	0.00	813	659	0.01
Red Abalone	--	--	--	--	--	--	--	--	--
Market Squid	--	--	--	--	--	--	--	--	--
Dungeness Crab	--	--	--	70	28	0.00	--	--	--
Spot Prawn	--	--	--	--	--	--	--	--	--
Species	1969			1968			1967		
	lbs .	\$	%	lbs .	\$	%	lbs .	\$	%
Albacore Tuna	--	--	--	419	80	0.00	31,656	5,698	0.18
North. Anchovy	--	--	--	--	--	--	--	--	--
Pacific Herring	--	--	--	--	--	--	--	--	--
Sablefish	18,796	940	0.45	11,697	468	0.36	49,081	2,454	1.29
Lingcod	955	74	0.09	197	16	0.01	16,863	1,855	1.80
Flatfish	116,980	11,487	0.50	75,885	7,422	0.35	837,682	75,391	4.11
Rockfish	24,070	1,858	0.26	21,530	1,908	0.22	110,725	6,643	1.13
Salmon	23	15	0.00	1,079	673	0.07	8,387	4,529	0.11
Red Abalone	--	--	--	--	--	--	--	--	--
Market Squid	--	--	--	--	--	--	--	--	--
Dungeness Crab	--	--	--	--	--	--	5,600	2,128	0.05
Spot Prawn	--	--	--	--	--	--	--	--	--
Species	1966								
	lbs .	\$	%						
Albacore Tuna	--	--	--						
North. Anchovy	--	--	--						
Pacific Herring	--	--	--						
Sablefish	134,707	5,388	4.19						
Lingcod	9,725	972	1.22						
Flatfish	363,284	77,696	3.89						
Rockfish	442,215	26,533	4.39						
Salmon	63	37	0.00						
Red Abalone	750	135	0.02						
Market Squid	--	--	--						
Dungeness Crab	1,010	444	0.01						
Spot Prawn	--	--	--						

Table 5-20 (cont'd.)

SANTA MARIA LEASE SALE BLOCK ⁶									
Species	1975			1974			1973		
	lbs.	\$	%	lbs.	\$	%	lbs.	\$	%
Albacore Tuna	52,215	16,604	0.34	149,311	53,006	1.26	451,779	178,904	5.23
Lingcod	245,107	33,702	7.68	252,223	32,789	6.60	351,917	35,192	9.89
Flatfish	783,032	203,588	2.27	482,814	115,275	1.61	423,685	88,974	1.30
Rockfish	1,560,783	218,510	6.56	1,637,478	221,060	7.56	1,403,826	136,171	6.32
Salmon	40,387	47,455	0.58	12,799	12,223	0.15	94,183	105,485	0.97
Red Abalone	84,784	65,284	11.41	139,214	94,666	18.54	99,538	57,234	14.99
Giant Pacific Oyster	--	--	--	--	--	--	--	--	--
Sea Urchin	107,325	8,586	1.72	399,093	29,134	5.61	264,968	20,668	7.37
Dungeness Crab	11,799	11,327	0.30	15,587	15,431	2.27	22,695	20,652	2.22
Rock Crab	11,725	2 # 345	0.98	3,218	534	0.37	6,781	678	0.71
Species	1972			1971			1970		
	lbs.	\$	%	lbs.	\$	%	lbs.	\$	%
Albacore Tuna	472,950	151,344	2.25	42,241	12,461	0.12	676,679	175,937	2.26
Lingcod	218,746	21,875	6.74	82,553	8,255	3.93	40,699	3,582	2.66
Flatfish	486,547	81,983	1.50	445,694	62,397	1.85	316,301	41,129	1.26
Rockfish	1,151,332	102,008	6.95	648,291	51,863	5.73	1,023,343	71,634	9.43
Salmon	9,067	7,435	0.14	1,504	1,105	0.02	3,429	3,052	0.05
Red Abalone	207,657	105,905	18.80	271,446	97,721	9.22	225,318	76,608	7.77
Giant Pacific Oyster	2,329	2,026	0.27	--	--	--	--	--	--
Sea Urchin	69,861	3,807	91.37	--	--	--	--	--	--
Dungeness Crab	5,196	3,689	0.33	4	2	0.00	552	276	0.00
Rock Crab	2,991	318	0.35	147	13	0.03	282	23	0.05
Species	1969			1968			1967		
	lbs.	\$	%	lbs.	\$	%	lbs.	\$	%
Albacore Tuna	744,130	148,826	5.05	793,870	148,850	5.27	938,460	168,923	5.26
Lingcod	16,565	1,716	1.49	22,588	2,135	2.06	15,767	1,419	1.68
Flatfish	256,230	28,185	1.01	192,585	27,906	0.88	237,368	21,363	1.16
Rockfish	830,405	53,478	8.86	731,019	43,861	7.62	612,981	36,779	6.26
Salmon	3,052	2,289	0.05	1,655	1,076	0.02	2,944	1,472	0.04
Red Abalone	420,578	134,585	11.50	582,074	154,541	13.01	1,080,529	216,106	24.44
Giant Pacific Oyster	--	--	--	--	--	--	--	--	--
Sea Urchin	--	--	--	--	--	--	--	--	--
Dungeness Crab	--	--	--	159	65	0.00	3,470	1,388	0.03
Rock Crab	3,806	343	0.76	680	44	0.19	--	--	--
Species	1966								
	lbs.	\$	%						
Albacore Tuna	285,030	51,305	1.57						
Lingcod	13,819	1,244	1.73						
Flatfish	219,745	19,777	0.99						
Rockfish	443,070	26,584	4.40						
Salmon	8,081	4,768	0.09						
Red Abalone	798,285	151,674	16.08						
Giant Pacific Oyster	--	--	--						
Sea Urchin	--	--	--						
Dungeness Crab	2,656	1,169	0.02						
Rock Crab	--	--	--						

Footnotes to Table 5-20.

1. Dollar values and percentages of state catch are derived from the following numbers of the California Department of Fish and Game Fish Bulletin Series (California Department of Fish and Game, 1967-1977).
2. Eel River Lease Sale Block Contains D.F.G. Statistical Block numbers 203, 204, 211, 212.
3. Point Arena Lease Sale Block Contains D.F.G. Statistical Block numbers 263, 264, 269, 270, 275, 276.
4. Bodega Bay Lease Sale Block Contains D.F.G. Statistical Block numbers 432, 433.
5. Santa Cruz Lease Sale Block Contains D.F.G. Statistical Block numbers 464, 465, 473, 474, 479, 480, 502, 503.
- b. Santa Maria Lease Sale Block Contains D.F.G. Statistical Block numbers 608, 615, 616, 624, 625, 632, 633, 634, 638, 639, 644, 645.

Employment. Fishing equipment information is difficult to obtain from the usual data sources. Fisheries data are generally combined with agriculture and forestry employment data. Data collected by the California Employment Development Department for unemployment insurance records, although the most current source, cannot be considered an accurate count of fisheries employment. Partnerships, family business and self-employed persons are not required to contribute to state unemployment funds; as a result, many fishing operations are exempt.

Another method of gauging fishing employment is through use of licensing information. A major problem with this source is that it does not distinguish full-time fishermen from those who are engaged in fishing as a supplement to their regular source of income. There are no regional surveys that would serve to accurately distinguish between part- and full-time fishermen. Sport fishermen often purchase commercial licenses in order to increase their allowable catch, or to receive other advantages (Frey, 1971). Further, the California Department of Fish and Game lists license holders by area of residence, rather than by port of operation; however, licensing data may be used for a gross approximation of fishing employment.

Table 5-21 shows the number of licensed fishermen by area of residence. Because these figures vary yearly, a three-year average in 1974-1975 is included.

Table 5-21. Number of Licensed Commercial Fishermen, by Port Area
(California Department of Fish & Game, 1967-1977; NMFS, 1979)

Area	Years			
	1974-1975	1975-1976	1976-1977	Average
Eureka	2,200	2,261	2,689	2,383
San Francisco	3,069	2,821	2,936	2,942
Monterey	1,351	1,319	1,450	1,373
Santa Barbara	1,682	1,612	1,700	1,664

According to calculations by the U.S. Department of Commerce, about one-half of California's licensed fishermen spend more than 50% of their working time engaged in fishing. Applying that ratio to the coastal region, the number of full-time licensed fishermen is 4,181.

The number of workers in the fishing industry is expected to increase as a result of the 200-mile limit and efforts to establish an international export market; however, by 1985, the move towards larger, more efficient fishing ships is expected to curtail employment growth (California Employment Development Department, 1978).

The social characteristics of fishermen are relevant to an assessment of potential socioeconomic impacts. Regional fishermen may be characterized as generally older persons, often immigrants or descendants of immigrants, who frequently have strong ties to both the local community and the sea. The fishing skills that they have may not be easily transferable to other types of employment (Gruen and Gruen, 1972).

Economic distinctions may be drawn between types of fishing activities. Tuna fishermen tend to be relatively well-paid, having fairly large vessels and efficient equipment. The wetfish industry is a far more marginal activity, characterized by small boats, lower pay, and low catch-per-unit effort (Gruen and Gruen, 1972; Frey, 1971).

Sport Fishing

Although sport fishing incorporates elements of both commercial fishing and recreational activity, it is most useful for the purposes of this study to characterize sport fishing in conjunction with commercial fishing. Sport fishing is a resource-extractive activity, which competes at times with commercial fisheries for fishing grounds and species. It uses six basic methods: shore, pier, party boat, skiff, and skindive fishing, and surf netting. These methods vary considerably in time at sea and average catch per hour.

Sport fishing and commercial fishing activities have comparable impacts on the resource base and significant effects on each other. Statistical comparisons and distinctions between the two activities are usually difficult to make. Sport fishing activity is generally quantified in terms of "angler-days," or amount of human effort, while statistical records of commercial fisheries are kept in terms of pounds and dollar values of fish landings. Licensing data are another important source of information on sport fishing, although it is likely that many fishermen whose primary interest lies in sport fishing will purchase commercial licenses in order to increase their allowable catch for certain species, or in order to obtain certain tax advantages (Frey, 1971). In addition, sport licenses are not required for those who fish from public piers and jetties, although a significant number of angler days are spent on those activities.

Sport fishing is an important means of recreation in most of the region. It supports a large party boat industry in several ports, as well as generating income and employment, along with other recreational activities, in many coastal communities. Although it does not produce a saleable product, as does commercial fishing, it is an activity of intrinsic value to those engaged in it. Sport fishing also provides a source of food.

There is evidence of income differentials among those engaged in different types of sport fishing. Deep water ocean fishing, which requires boats and relatively costly equipment, is generally conducted by those with higher income levels, while land-based and shallow-water fishing are conducted more often by low-income fishermen (Gruen and Gruen, 1972).

A general distinction may be drawn between commercial and sport fishing in terms of onshore socioeconomic impact. Sport fishing generally has an effect on the coastal economy similar to that of other recreational activities. Sport fishermen are frequently drawn to the coast from outside the region. Their expenditures on equipment and boat rentals, lodging, food, drink, and gasoline within the region may be significant sources of imported dollars (NMFS, 1979; Gruen and Gruen, 1972). Because commercial fishermen generally reside near coastal ports, their expenditures do not represent a source of outside income.

Species and Volume of Catch. Sport fishing data are collected throughout the region by the Department of Fish and Game, but the type of data varies among species. Recreational ocean salmon fishing data are the most historically complete, although they are counted by number of fish rather than by weight. Reliable data for sport fishing on inland waterways have been gathered by the Department of Fish and Game since 1972. Catch data for most other species are not readily available. Comparisons of catch of sport species or comparisons between sport and commercial landings are therefore difficult to make.

The principal game fish sought by sport fishermen in the coastal area are salmon and trout (California Department of Fish and Game, 1976). San Francisco generally has the highest number of landings of coho and chinook salmon from party boats (California Department of Fish and Game, 1967-1977). According to recreational landing records kept by CDFG in 1975, San Francisco landed 72% of all the ocean salmon caught on party and private boats along the coast. San Luis Obispo County has the highest reported landings of all other sport species taken from inland waters in 1975 when 23,773 pounds of fish were landed, mainly blackfish caught in stocked lakes and reservoirs. Monterey and

Mendocino Counties also reported inland landings of shad. As a means of comparing ocean and river fishing in the coastal counties, Table 5-22 lists estimated angler-days spent on each activity in 1970. These data are the most recent data on angler days. A recent and detailed picture of sport fishing locations by species and fishing is described by Squire and Smith (1977).

Table 5-22. Ocean and River Angler-Days Spent by Sport Fishermen, in the Coastal Counties, 1979 (Smith, et al., 1976)

County	Ocean Angler-Days	River Angler-Days
Del Norte	24,340	214,600
Humboldt	124,170	83,850
Mendocino	104,495	26,900
Sonoma	111,700	91,900
Marin	57,700	6,600
San Francisco	238,400	(1)
San Mateo	240,800	6,200
Santa Cruz	309,000	37,200
Monterey	226,600	4,600
San Luis Obispo	242,700	7,500
Santa Barbara	187,500	--

1. These are inland waterways and therefore not included here.

Value. Estimates of the value of sport fishing are difficult to make. There are both direct and indirect forms of value associated with sport fishing. The direct value is the intrinsic recreational worth of the activity to the fisherman. Methods for determining that value include the fisherman's willingness to pay for the right to fish, evaluating the effect increased travel costs have on sport fishing, and conducting a survey of sport fishermen to determine what they consider the value of the recreational experience to be to them (Dwyer and Bowes, 1978). In all cases, the value is a subjective figure, depending heavily on qualitative factors.

The indirect value is that derived by an area (county, town, or port) from expenditures made locally by sport fishermen. Such expenditures typically include motel accommodations and the cost of a charter boat (Gruen and Gruen, 1972; NMFS, 1979). The salmon ocean fishery may be used as an example. Expenditures by salmon fishermen are estimated to be \$60 per angler trip, including the cost of chartering a boat and renting a motel room (NMFS, 1979). There was an annual average of 202,000 angler trips made in the region from 1972 to 1976 (Smith, et al., 1976). It is estimated that ocean salmon fishermen spend an annual average of \$12,200,000 in the region. The value of salmon fishing conducted on private or rented skiffs and along rivers probably would be somewhat lower due to different costs involved.

The Department of Fish and Game has calculated the estimated expenditures of all ocean and river fishermen in 1970. Those estimates, shown in Table 5-23, illustrate the variations among the counties and between the two sport fishing activities.

Sport fishing license data can be useful to indicate general trends in fishing intensity. As noted above, sport fishermen may obtain commercial licenses, and thus not be counted in sport license data. In the state as a whole, the number of licensed sport fishermen increased steadily until 1970, when the number of licensed fishermen began to rise and fall irregularly (NMFS, 1977). The fluctuations may be attributable to a number of factors, including increased transportation costs, weather, stream conditions, changes in fish populations, and a greater variety of other forms of recreation.

Table 5-23. Estimated Annual Expenditure by Anglers in 1970 in Dollars
(Smith, et al., 1976)

county	Location of Fishery	
	Ocean	River
Del Norte	297,700	2,408,000
Humboldt	1,518,800	1,444,000
Mendocino	2,678,500	464,000
Sonoma	1,366,390	1,471,000
Marin	1,412,200	115,000
San Francisco	2,915,300	(1)
San Mateo	2,945,700	107,800
Santa Cruz	3,779,900	659,000
Monterey	2,771,900	83,000
San Luis Obispo	2,968,400	135,000
Santa Barbara	2,294,000	---
TOTAL	24,948,790	6,886,800

1. These are inland waterways and therefore not included here.

Employment. Employment generated by sport fishing is difficult to measure. The types of employment are directly related activities (such as bait and ice stores, boat rental and launching facilities) and indirect employment, such as lodging places, restaurants, and gas stations; the latter is discussed in the section on recreation.

Fish Processing

Although various factors have tended to limit the growth of Commercial catch, fish processing has experienced fairly rapid growth since 1951 (Gruen and Gruen, 1972). Large corporations acquire processing operations and create a vertically integrated industry from fish processing through retail outlets in restaurants and supermarkets. A pattern of expansion is also apparent because Processors attempt to limit the degree of their dependence on particular species by marketing as many species as possible.

Although processing equipment may vary by species, horizontal expansion may have the advantage of reducing seasonal employment patterns when harvest periods vary among species. For a discussion of goals for such diversification in the Eureka area, see ARC Research Corporation (1978).

Pounds produced. The portion of catch that is used for processing is highly variable, depending on the species, the quality of the fish, and the relative prices of the fish markets. The type of processing varies by species and region. Relatively large amounts of anchovy, tuna, mackerel, and squid were canned in the region in 1976 (Oliphant, 1977). Filleting, boning, freezing, smoking, and curing are several types of processing that take in many different species, the most significant being salmon and hake. Anchovy reduction plants in Salinas and Monterey produce fish meal and fish oil.

The physical capacity for fish processing regulates somewhat the weight of fish harvested, particularly for those species that are processed rather than sold fresh (NMFS, 1978b). Regional processors are largely dependent on domestic supplies of fish, although they are increasingly forced to compete with importers of processed fish (Gruen and Gruen, 1972).

In 1976, there were ten canning and reduction plants operating in the region. Twenty plants were involved with the curing and manufacturing of fishery products; an additional five are located outside of the region in the San Francisco Bay area. With few exceptions, all of those operations are located within the study area boundary. Table 5-24 shows the volume of canned, cured, and manufactured fish products in the region in 1976.

Table 5-24. Pounds of Fish Species Processed in the Region and Their Percentage of the State Total in 1976 (Oliphant, 1977)

Process/Species	Pounds	Percentage
<u>Canned</u>		
Anchovy	33,456	100
Jack Mackerel	573,984	8
Salmon	48	<1
Squid	2,713,824	36
Albacore	44,880	<1
<u>Smoked, Cured</u>		
Albacore	1,588	4
Hake	37,418	100
Lingcod	96	8
Sablefish	19,590	4
Salmon	460,461	15
Herring	1,778	100
<u>Reduced</u>		
Fish Meal	911,000	2
Fish Oil (gallons)	90,981	6

Value and Employment. Data on the value of fish processing are spotty. The actual value of processed fish is dependent on price competition from imported processed fish products, and the cost of labor, fish and equipment.

Fish processing operations are concentrated in Eureka, Fort Bragg, and Crescent City, with others in Klamath, Trinidad, Requa, McKinleyville, Bodega Bay, Salinas, Moss Landing, and Morro Bay. Table 5-25 gives the range of employment in fish processing within the study area for 1977.

Estimated Numbers (range) of People Employed in Fish Processing by County in 1977 (U.S. Bureau of Census, 1979)

County	
Del Norte ¹	125
Humboldt	250 - 401
Mendocino ²	75 - 165
Sonoma	100 - 249
Monterey	40 - 98
San Luis Obispo	NA
Regional Total	590 - 913

1. From EDAW, Inc., 1979c.

2. From Mendocino County Chamber of Commerce, 1979.

Destination and Markets. Very little data exist on the proportion of fish products exported from the region. A 1974 study of Sonoma County estimated that 63.3% of the seafood processed in that county was for export, whereas 75% of the fresh salmon, crab and tuna was exported (Goldman, 1977).

The fishing industry supports a portion of the trucking industry. An estimated 25 to 30% of the local operators of logging trucks and tractors also have fish and fish products in Humboldt County (EDAW, Inc., 1979a).

Markets and methods of distribution vary among species. Certain fish for which the canned product is in great demand, such as albacore tuna, enter national markets (Fruen and Gruen, 1972). Canned squid is exported because there is no domestic demand for it. Canned anchovies were in fairly large demand in the 1950's, but demand and production dropped from 1,144,757 cases in 1953 to an annual average of about 500 cases in the 1970's (NMFS, 1978b). Anchovy reduced to fish meal is used as feed in the state's poultry industry.

The party boat industry is heavily dependent on a supply of live bait, which consists mainly of anchovies caught by commercial fishermen. Anchovies are also processed in reduction plants for fish meal and oil. Fear that greater amounts of anchovies would, for economic and other reasons, be processed rather than sold as live bait to party boat operators has led to restrictions on the volume of anchovies that may be reduced to meal and oil (NMFS, 1978b).

Regional processors compete for domestic markets with fish processed overseas, particularly in South Korea and Japan. Cheaper labor costs for skinning and filleting of fish abroad has led domestic frozen fish stick producers to depend on foreign sources for much of their raw material (San Francisco Examiner, August 23, 1978). The fish that are processed overseas are often hake or pollock, caught in U.S. waters and processed by foreign vessels at sea.

Summary and Effects

Socioeconomic Effects and Interactions. In the coastal region, fishery-related employment makes up a significant portion of total employment. Both employment and production may be particularly important to local communities. Sport and commercial fisheries are estimated to be second in value to the forest industry in Humboldt county (QRC Research Corporation, 1978). Part-time fishing is also a significant source of employment and income and is a food source in parts of the region. Commercial and sport fisheries attract persons into the study area who spend money on goods and services within the area. These activities serve as export industries.

Commercial and sport fishing interact with other basic industries, as well as with each other. Conflicts between the two include competition over fishing grounds, catch, and harbor facilities. Commercial fishing may conflict with onshore uses, as evidenced by objections of residents to the presence of large herring boats in Tomales Bay. Sport fishing is strongly related to other recreation activities and is subject to similar variations in intensity depending on seasonal catches (Dwyer and Bowes, 1978).

As is true of other recreation, the popularity of sport fishing at a given locale depends heavily on the quality of the experience, the location of fishing areas with respect to users, and the availability of substitute opportunities (Dwyer and Bowes, 1978). Factors which influence the qualitative character of a sport fishing trip to a particular area include the degree of success (catch per unit effort) at that location, congestion of an area with other fishermen, services offered by charter boats, and weather and sea conditions. Sport fishermen are often attracted to a fishing area for other types of amenities as well as fishing (Gruen and Gruen, 1972). The availability of particular sport fish species in an area is an especially significant factor. Migration and spawning patterns, water quality, and access determine the availability of species to sport fishermen in a given area.

Many of the streams along the north coast have been altered by logging operations, erosion, sedimentation, stream blockage, deposits of organic debris, alteration of stream flow and changes in water temperature caused by removal of streamside vegetation, are occurrences related to logging and road construction activities that have reduced the capacity of many coastal streams to support salmon and steelhead runs. Further discussion of these problems with references to specific waterways may be found in Smith, et al. (1976). California Department of Water Resources (1974b) and in a publication by the California Water Resources Control Board (1975h). These impacts have, in many cases, lowered the number of available fish in a stream and lowered the general quality of sport fishing. A similar pattern occurs in upstream mining operations in certain streams (California Water Resources Control Board, 1975h).

Several coastal rivers, notably the Russian, are dammed during summer months to form swimming areas. These temporary dams tend to create irregular flows in the rivers during low flow. Construction of larger reservoirs and diversion of stream flow have major impacts on downstream habitats through reductions in waterflow and sediment deposition.

There are also interactions between fisheries and agriculture. Runoff from dairy feedlots has a high oxygen demand, which can be dangerous to fish populations (Baxter, et al., 1973). Effects of chemical contamination from cropland runoff are receiving increased attention. Estuarine habitats are particularly vulnerable because croplands lie principally in alluvial plains with fast draining soils (Zinn, in ASCE, 1978).

Removal of wetlands for marina development and harbor expansion and related dredging and dredge spoils disposal may be serious losses as demands for private boating and transportation expand. Offshore oil and gas extraction, tanker and freighter traffic, and channel dredging are potential sources of temporary or permanent degradation of habitat, or direct impact on marine and estuarine species.

Natural System Effects and Interactions. Commercial and sport fisheries have few direct effects on natural systems beyond the impacts of overfishing on some populations, although, as with sardine and perch, these impacts may be severe. Regional stock depletion through overfishing is discussed in Frey (1971). Localized pollution loads by fish processing plants may have harmful impacts in some locations.

There are some long-term food web and species interaction effects that are attributable to commercial fisheries. Removal of forage species (bait fish) will have potentially deleterious effects on dependent species, while removal of large numbers of predators can lead to increased populations of forage species. Anchovies, for example, are a common forage species in the southern half of the region for other fish and birds, and sport fishermen depend on them as a source of forage and live bait for sport fish. The interdependence of fish species in the ocean system is not well understood, nor are the relationships between fish populations and migration, thermal gradient, and ocean currents.

The industry increases the demands for marina and harbor development, and dredging and associated facilities. The effects of these and other activities in the region are particularly significant. These effects include increases in sedimentation, reduced circulation, changes in dissolved oxygen, disturbance of bottom materials, and blockage of fish runs. Anadromous and near-shore species are especially sensitive to human activities. There has been a great deal of documentation of such effects, ranging from the effects visiting school children have on tidepools to the effects of thermal discharges from power plants. Maintenance and restoration of watershed quality as well as controls on dredging and industrial waste dischargers are critical to the protection or enhancement of fish populations.

Outlook for the Industry. The fishing industry in the region has been in a state of stagnation for some time, although there are signs of its rejuvenation in some areas. The 200-mile limit has allowed domestic vessels considerably more access to fish populations. It has also resulted in a certain amount of investment by foreign investors in the fishing industry. Future expansion of the fishing industry is dependent on increased processing capacity, investment in vessels and equipment, attracting labor into the harvesting sector, size of fish populations, competition from abroad, and regulatory constraints on fish harvesting.

Aquiculture, mariculture and hatchery activities are potentially important areas for expansion. Through such operations in Humboldt County, "it is believed that the landings of finfish, shellfish, and other invertebrates could at least be doubled, as could the total value of the industries to the county" (QRC Research Corporation, 1978). This study proposes mussel, crab and seaweed farming; salmon ranching; improved processing facilities to eliminate most fish waste and refine it for sale at higher prices; exploratory fishing and facility improvement; stream rehabilitation; and improved salmon and steelhead culture facilities.

RECREATION

Resources

Facilities that augment recreational uses of the natural features, such as roadways, boat docks, and campsites, are also considered recreational resources. Recreational resources may also be wholly man-made. Within the study area, Hearst Castle in San Luis Obispo County is the best known example of this type of recreational resource, but museums, historic towns, amusement parks, and race tracks, all present within the coastal region, also belong in this category.

The recreational resources supplied by the natural features of the California coast are a source of international renown. As a consequence, use of 'natural' recreational resources receives the most attention in any review of recreational patterns and habits on the coast. However, the coast's extraordinary natural setting acts as a stimulus to man-made recreational activity; thus the man-made recreational facilities, however statistically neglected, may be highly significant.

Recreational Opportunities. Within the study area, almost all coastal recreational areas are generally accessible by auto. State Highway 1 traverses about three-quarters of the 380 miles of coast, running between Lompoc, in Santa Barbara County, to above Rockport, in northern Mendocino County. Highway 101 provides access to the coast north of this point, beginning at Eureka, in Humboldt County, and following the coast through Crescent City, in Del Norte County, to the Oregon border. However, not all sections of the coast are accessible from these roads and adjoining east-west lateral routes. The coastline adjacent to two military reservations, Vandenberg Air Force Base, occupying some 38 miles of coastline north of Point Conception, and Fort Ord, occupying 3 miles along Monterey Bay, is not accessible, even through connecting roads. Much of the area north of Rockport, in Mendocino County, and south of Mattole Point, in Humboldt County - an area called the Lost Coast - is also inaccessible.

Access to the water is made difficult by the topography of much of the coast, and by climatic conditions. Throughout some two-thirds of its length from the Oregon border to Morro Bay, the coast is lined by high bluffs and rugged, steep-sided hills running down to the water's edge. Within this stretch, the temperature of the water is too cold for swimming, at least without wetsuits. Water sports, with the exception of skin diving, tend to be concentrated inland along the coast in bays and rivers. Access to the water by boat is another matter. While the coast is without deep water ports, it is dotted with small bays and harbors suitable for small craft. Although there are a number of marinas within each county, there are long stretches of coast without small craft harbor facilities.

Recreational opportunities are severely restricted by the lack of access. Despite many public land holdings within the coastal area, most of the land is in private ownership [Figure 5-4]. Although the data includes counties other than the 11 counties within the coastal region, it is nonetheless an accurate representation of the public/private share of land in the coastal area. Although some public access onto private land is allowed, particularly onto company-owned timber lands in the northern counties, this accounts for a very small percentage of overall use.

Access development, incorporated into the policies of the California Coastal Commission, is one of the more controversial areas of public policy. Representative of the impact of private ownership, but an exception to the typical posture toward public access, is the Del Monte property between Monterey and Carmel. Here, public access on private property is permitted - by fee - for sightseeing along the spectacular 17-Mile Drive bordering the ocean.

Federal, state, and local agencies have sought to preserve access to unique or highly valuable recreational resources through land acquisitions. In the north coast area, state and federal agencies have acquired original stands of redwoods. Del Norte Coast Redwoods Park, Prairie Creek Redwoods, and Humboldt Redwoods are state parks. Redwood National Park was recently enlarged from 58,000 acres to 109,115 acres.

In the central coast area, 38,000 acres in western Marin County, and San Francisco County, have been placed in the Golden Gate National Recreation Area managed by the National Park Service. This large area, at the boundary of one of the larger urbanized areas in the country, adjoins the 64,000-acre Point Reyes National Seashore, part of which is reserved as a wilderness area, and includes the Marin headlands west

and north of the Golden Gate Bridge, and several ocean and bay front sites in San Francisco.

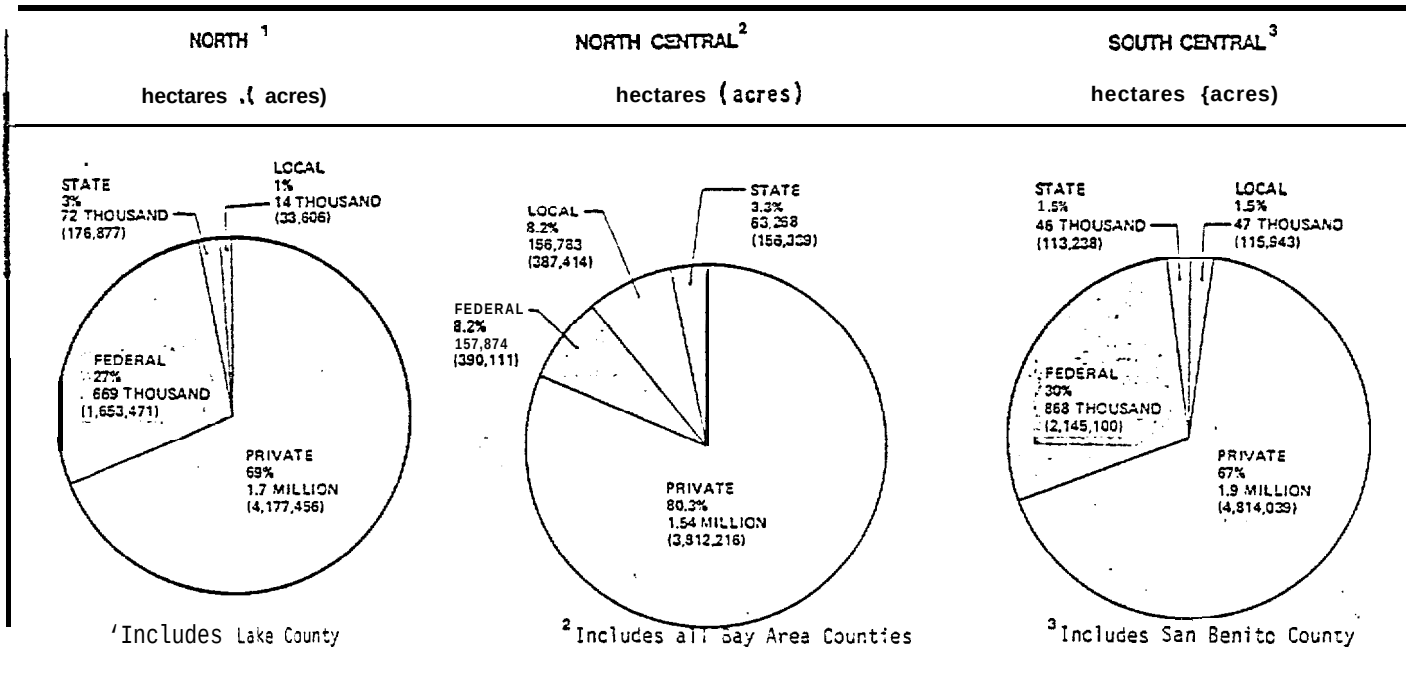


Figure 5-4. Land Ownership, California Coastal Counties (California Department of Parks and Recreation, 1979b)

In Santa Cruz and Monterey Counties, Point Lobos Beach (1,255 acres), just south of Carmel, and Pfeiffer-Big Sur Park (3,011 acres) are under state ownership. Preservation of, and access to, Elkhorn Slough at the estuary of the Salinas River have recently been attained by its designation as a National Estuarine Sanctuary.

In San Luis Obispo County, public access to Hearst Castle is assured through state ownership. In addition, various state holdings at Morro Bay, on the headlands of Point Buchon, and at Pismo Beach, exceed 10,000 acres.

The opportunities for sports fishing along the coast and its tributary streams are abundant owing to the size and variety of the fish population and the existence of small craft commercial fishing fleets that double as party boats. Access to fishing is also aided by the forbearing attitude of private land holders toward stream fishermen. For details of sport fishing see FIS. CRLES and the various watershed descriptions.

Hunting, although closely regulated, is sustained in the north coastal area primarily by the remoteness and ruggedness of the land areas extending inland from the coast. Bird hunting is a popular recreational activity. There are a number of major migratory fowl marshlands along the coast, many near main roads.

The discussion of recreation that follows is organized around three coastal groupings. The north coast includes Del Norte, Humboldt and Mendocino counties. The central coast is divided into the north central and south central areas. The north central area includes the San Francisco Bay Area counties of Sonoma, Marin, San Francisco, and San Mateo; and the south central area includes the counties of Santa Cruz, Monterey, San Luis Obispo, and Santa Barbara.

Redevelopments. Improvements to recreation resources include campsites, picnic areas, hiking trails, marinas and boat launching facilities. Services that support recreation activities are hotels and motels, restaurants and bars, and gasoline stations.

The prevailing public posture toward the use of recreational resources within the northern and central coastal area places a premium on maintaining the resources in a natural state; hence, developments tend to be tightly controlled. A current inventory of private and public recreational facilities is not available from any single source. The most complete inventory of park sites and facilities is published by the California Department of Parks and Recreation in a series called Recreation Outlook. The department has released the report for District 1 (north coast and Lake County) and expects soon to release Recreation Outlook District 4 (San Francisco Bay Area). Information in these series will be compiled as part of the California Outdoor Recreation Resources Plan now scheduled for publication in 1982 (Jack Bechtel, California Department of Parks and Recreation, personal communication, (1979).

Land resources and public and private recreational facilities in the north coast area are shown in Tables 5-26, 5-27, and 5-28. The sparsely developed nature of the area is demonstrated by the fact that there are fewer than 1,700 campsites within 2 million acres of recreational land.

The recreational importance of roadways, especially of Highway 101, within the north coast area is apparent from Table 5-29, which shows that traffic volumes on Highway 101, in Humboldt County, are 100% greater in August than in January.

Table 5-26. Area (acres) of Public and Private Lands Available for Recreation in Del Norte, Humboldt, and Mendocino Counties, 1979 (California Department of Parks and Recreation, 1979b)

	COUNTY			
Agency	Del Norte	Humboldt	Mendocino	Total
<u>FEDERAL</u>				
U.S. Forest Service	442,955	215,050	216,590	874,595
Bureau of Land Mgmt.	38	60,184	134,322	194,544
National Park Service	6,647	21,238	--	27,885
Other Federal	--	98,733	3,500	102,233
TOTAL FEDERAL	449,640	395,205	354,412	1,199,257
<u>STATE</u>				
Department of Forestry	--	--	51,225	51,225
Department of Fish & Game	--	--	--	--
Department of Parks & Rec.	15,789	60,345	10,472	86,606
Other State	7	23	36	66
TOTAL STATE	15,796	60,368	61,733	137,897
<u>LOCAL</u>				
Counties	52	566	538	1,156
Cities	2,024	2,282	23	4,329
Special Districts	--	--	529	529
TOTAL LOCAL	2,076	2,848	1,090	6,014
PUBLIC TOTAL	467,53.2	458,421	417,235	1,343,168
PRIVATE ENTERPRISE ACREAGE TOTAL	4,398	251,339	459,006	714,743
GRAND TOTAL	<u>471,910</u>	<u>709,760</u>	<u>876,241</u>	<u>2,057,911</u>

Table 5-27. Public Recreation Facilities¹ in Del Norte,
Humboldt and Mendocino Counties, 1979
(California Department of Parks and Recreation, 1979b).

No. of Areas	Campsites	Picnic Tables	Trails (Miles)
129	1,410	553	1,551
NA	<u>194</u>	<u>529</u>	<u>61</u>
	1,604	1,082	1,612

1. Excludes city facilities.

Table 5-28. Numbers (acres in parentheses) of Private
Recreation Facilities in Del Norte, Humboldt, and Mendocino Coun-
ties in 1979 (California Dept. of Parks and Recreation, 1979b)

Activity	Del Norte	Humboldt	Mendocino	TOTAL
Golf/Driving Ranges	3	7	2	12
Camping & Picnicking	25	21	33	79
Hunting:				
Upland Game	--	8	5	13
Waterfowl	4	--	--	4
Big Game	--	8	10	18
Fishing	--	--	4	4
Equestrian	--	2	4	6
Other	6	6	--	12
Total	38	52	11	101
	(4,398)	(251,339)	(459,006)	(817,927)

Table 5-29. Monthly Highway Traffic (automobile counts)
In Humboldt County, 1977 (QRC Research Corporation, 1978b)

Month	Percentage of the Annual Mean (100)		
	Location 1	Location 2	Location 3
January	55	65	65
February	69	75	81
March	79	85	77
April	79	95	100
May	92	101	97
June	133	120	120
July	166	145	131
August	174	165	137
September	119	109	128
October	94	91	111
November	75	76	80
December	66	73	73

Location 1: U.S. 101 at Humboldt and Mendocino County Line
Location 2: U.S. 101 at Humboldt and Del Norte County Line
Location 3: S.R. 299 at Humboldt and Trinity County Line

Without user survey data, it is not possible to know why people are coming to the area. The correlation of volumes among different stretches of Highway 101 suggests that most of the traffic is pass-through. However, peak month volumes are uniformly

greater on U.S. 101 in Humboldt County than on the same highway stretch in Del Norte County, suggesting that the main destination for many travelers are Humboldt Counties extensive redwood parks.

In the northern counties, the bays, rivers, and fishing opportunities, have made boating a leading recreational activity. In 1976, according to Williams-Kuebelbeck & Associates (1975?), there were 1,292 boat registrations in Del Norte County, 5,346 in Humboldt County, and 2,676 in Mendocino County.

Data shown in Table 5-30 on available boat berths (not necessarily occupied) suggests that the great majority of boats are trailerable and that most boating occurs in the bays and rivers. Generally, only a small proportion of boats are equipped or used for ocean travel (Williams-Kuebelbeck & Associates, 1974).

Plans for a near doubling of berths in Humboldt County demonstrate that the level of boating interest far exceeds facilities. In addition, peak day demand for launching facilities would far exceed the current capability of boat launching facilities (California Department of Parks and Recreation, 1979b).

Table 5-30. Existing and Proposed Small Craft Harbors and Boat Launch Ramps in the North Coast Region, 1976 (Winzler and Kelly, 1977b)

County/Harbor	Existing			Proposed	
	Total Berths and/or Moorings	Launching Ramp Lanes or Hoists	Charter or Party Fishing Boats	Berths	Launching Ramp Lanes or Hoists
<u>Del Norte County:</u>					
Crescent City Harbor	480	2	6		2
Sub Total	480	2	6		2
<u>Humboldt County:</u>					
Eureka	180	3	5		
Arcata		2			
Field's Landing, King Salmon	100	2	4		
Trinidad	200	1			
Fairhaven		2			
Woodley Island		—	—	300	1
Sub Total	480	10	9	300	1
<u>Mendocino County:</u>					
Noyo River (Ft. Bragg)	400	4	8		
Navarro River (Albion)	100	2	—	—	—
Sub Total	500	6	8		
TOTAL	1,460	18	23	300	3

Major federal and state recreation lands and facilities for the north central coast area are shown in Tables 5-31 and 5-32. These constitute approximately 80% of coastsides resources. With the exception of San Mateo County, city and county recreation lands lie primarily on the bayside and are intended to serve the local population. All facilities in the north central area, with the possible exception of those at the extreme north and south ends of the zone, are within one hour's driving time from Bay Area cities. The relatively small number of campsites in comparison with the level of visitor attendance reflects the high level of day use.

Table 5-31. Acres of Federal Recreation Lands in Marin and San Francisco Counties, 1980 (Doug Nadeau, National Park Service personal communication, 1980)

Park	Acreage Marin County	Acreage San Francisco
Golden Gate National Recreation ties (GGNRA)	33,900	4,186
Point Reyes National Seashore	64,000	--
Muir Woods National Monument	503	

Table 5-32. Length of Ocean Waterfronts in State Park Areas in the Central Coast of California (Department of Parks and Recreation, 1979b)

Unit ¹	Land Area ² Hectares (Acres)	Waterfront Meters (ft.)	Camp Units	Picnic Units	Trail Miles	Visitor (1977-78) Attendance
Mount Tamalpais SP	2,516.1 (6,217.45)	3,926 (12,875)0	17	29	40.7	626,765
Portola SP	704.2 (1,740.26)		58	81	13.5	45,888
Salt Point SP	1,742.4 (4,305.59)	8,340 (27,362)0	31	45	14.5	98,699
Samuel P. Taylor SP	1,065.7 (2,633.38)		92	92	37.3	122,924
Sugarloaf Ridge SP	830.3 (2,151.70)	-	51	17	25.0	108,143
Tomales Bay SP	412.0 (1,018.08)	3,901 (12,800)0		34	2.5	59,406
Austin Creek SRA	1,714.1 (4,235.59)		28	1	18.0	42,048
Fort Ross SHP	273.7 (676.29)	1,524 (5,000)0		35	1.3	122,040
Ano Nuevo SR	284.4 (702.68)	8,147 (26,730)0			2.0	91,100
Armstrong Redwoods SR	275.2 (680.00)			104	9.1	147,376
San Mateo Coast SB'S	339.4 (845.85)	14,210 (46,624)0	50	79	10.0	3,126,703
Sonoma Coast SB	1,205.9 (2,979.77)	20,437 (67,052)0	128	23	8.7	1,493,901

1. SP - State Park; SRA - State Recreation Area; SHP - State Historic Park; SB - State Beach; SR - State Reserve
2. Includes leased areas.

The north central coast area is traversed by Highway 1. Except for a short stretch through San Francisco, the highway is a two-lane road running close to the coast offering continuous vistas of the land and seascape. Except for San Francisco, the land area west of the coastal range is largely undeveloped. The presence of these visual resources and the closeness of the area to an urban region with a population approaching 5 million have made sightseeing the leading recreational use (De Leuw Cather, 1979). Highway 1 is thus a predominant recreational resource in itself, apart from its function as a provider of access to other recreational resources.

The San Francisco Bay Area is a center for boating. As shown in Table 5-33, which is an inventory of boating facilities, most of the activity is concentrated on the bay. There is, nonetheless, demand for more berths for ocean-going craft, as expansion plans at Bodega Bay, Port Sonoma and Pillar Point harbor demonstrate. The number of marina berthing facilities represents only a fraction of the boating interests. Boat registrations in 1976 in north central coastal counties totaled 37,500; registrations in all nine Bay Area counties totaled 133,700.

As elsewhere, federal and state landholdings in the south central coastal area (Santa Cruz County to Santa Barbara County) make up most of the recreational land holdings, and as Tables 5-34 and 5-35 show, they are extensive.

Table 5-33. Existing and Proposed Numbers of Small Craft Harbors and Launch Ramps in the Central Coast Region, 1976 (Winzler and Kelly, 1977b)

County/Harbor	Existing			Planned	
	Berths and/or Moorings	Ramp Lanes or Hoists	Charter or Party Fishing Boats	Berths	Ramp Lanes or Hoists
<u>Sonoma County:</u>					
Bodega Bay	280	4	12	250	-
Port Sonoma	40			400	2
Petaluma		<u>2</u>	—	250	<u>—</u>
Subtotal	320	6	12	900	2
<u>Marin County:</u>					
Tomales Bay	120	6	2		-
Fort Baker	50	.		-	-
Sausalito Yacht Harbor	425	2	4		-
Pelican Harbor	90				-
Clipper Yacht Harbor	700	2	6		-
Marinship Yacht Harbor	150	2		-	-
Kappas Marina	100	.	3	50	-
San Francisco Yacht Club	175	3			-
Corinthian Yacht Club	75	1			-
Paradise Cay	120	2	.		-
San Rafael Yacht Harbor	160	2	4		-
Lawries Yacht Harbor	110	.	2		-
Marin Yacht Club	100	1			-
Loch Lomand Marina	500	2	2		-
Private Slips	75				-
San Rafael Marina		—	—	550	<u>2</u>
Subtotal	2,950	23	23	600	2
<u>San Mateo County:</u>					
Redwood City Marina	210	3		200	-
Docktown	110	2			-
Pete's Harbor	200				-
Coyote Point Marina	476	2		730	-
Oyster Point Marina	280	2		300	-
Pillar Point Harbor	250	<u>2</u>	<u>8</u>	<u>1,680</u>	<u>2</u>
Subtotal	1,526	11	8	1,680	2
<u>San Francisco County:</u>					
China Basin	100	2		-	-
Fisherman's Wharf	157		12	400	-
San Francisco Marina	<u>723</u>	<u>3</u>	—	—	<u>—</u>
Subtotal	980	5	12	400	-

With the exception of the Monterey portion of Los Padres National Forest in Big Sur, federal land holdings lie inland in the coastal mountain ranges. By contrast, state holdings, although far less extensive, are concentrated along the coast. Almost all units of the state park system shown in Table 5-35 are coastal recreational resources.

Table 5-34. Federal Recreation Lands (acres) in
the South-Central Coast Region, 1978
(San Luis Obispo County, 1979)

County	{Los Padres National Forest}	BLM	NPS
Santa Cruz County			
Monterey County	302,782	72,558	1,073
San Luis Obispo	189,239	121,882	
Santa Barbara County	628,566		
	<u>1,120,587</u>	<u>194,440</u>	<u>1,073</u>

Table 5-35. State Park System Resources Sough Central Coastal Region, 1978
(California Department of Parks and Recreation, 1979b)

Unit ¹	Land Area*	Waterfront	Camp	Picnic	Trail	Visitor (1977-78)
	Hectares (acres)	Meters (ft.) Type 3	Units	Units	Miles	Attendance
Asilomar SB	42.27 (104.44)	1,859 (6,100)0				
Atascadero S0	30.38 (75.07)	3,033 (9,950)0	104			229,935
Avila SB	4.05 (10.01)	624 (2,046)0	-	27	-	
Carmel River SB	42.69 (105.50)	2,469 (8,100)0	-		-	231,557
Carpinteria SB	20.39 (50.39)	1,254 (4,115)0	261	103		365,373
Cayucos SB	6.33 (15.63)	503 (1,650)0		-		
El Capitan S0	53.76 (132.84)	2,871 (9,420)0	147	81	2.7	281,325
Manresa SB	27.63 (68.28)	2,896 (9,500)0				867,021
Monterey SB	5.49 (13.56)	744 (2,441)0				
Moro Strand SB	13.68 (33.81)	2,088 (6,850)0		5		152,532
Moss Landing SB	22.09 (54.58)	1,422 (4,730)0				701,415
Natural Bridges S0	22.09 (54.58)	1,524 (5,000)0		60	0.2	490,413
New Brighton SB	37.91 (93.67)	1,525 (5,000)0	115	37	1.0	227,292
Pismo SB/SVRA/NP	883.24 (2,183.52)	11,726 (38,470)0	505		-	3,281,837
Point Sal SB	19.80 (48.93)	1,463 (4,800)0				
Refugio SB	58.01 (143.34)	4,298 (14,100)0	85	48		176,148
Salinas River SB	99.53 (245.94)	4,724 (15,500)0				318,497
San Simeon S0	219.59 (541.38)	5,547 (18,200)0	134	25	-	267,927
Seacliff SB	34.59 (85.35)	2,134 (7,000)0	26	148	0.4	847,803
Sunset S0	128.59 (317.75)	6,096 (20,001)0	91	60	0.3	820,307
Twin Lakes SB	44.45 (109.85)	1,618 (5,308)0			0.7	554,527
		3,414 (11,200)L		-		
William Randolph						
Hearst Memorial SB	3.29 (8.14)	236 (773)0		45		150,612
Zmudowski SB	71.06 (175.60)	2,781 (9,124)0				266,158
Andrew Molera SB	871.69 (2,153.98)	4,286 (14,115)0	50		17.0	232,684
		5,486 (18,000)R				
Big Basin						
Redwoods SP	5,981.63 (14,780.89)	1,167 (3,828)0	229	175	57.0	637,602
Castle Rock SP	555.15 (1,371.81)	-	25	5	10.0	91,914
Forest of Nisene						
Marks SP	3,958.22 (9,780.94)	-	6	10	15.0	33,782
Gaviota SP	1,123.22 (2,775.52)	8,382 (27,500)0	59	22		187,088
Henry Cowell						
Redwoods S?	1,656.16 (4,092.45)		113	261	26.0	437,636
Julia Pfeiffer						
Burns SP	1,377.76 (3,404.50)	3,627 (11,900)0		12	3.5	123,261
Montana de						
Oro SP	2,815.19 (6,956.46)	5,852 (19,200)0	46	26	7.0	426,449
Morro Bay SP	797.78 (1,971.36)	12,044 (39,515)0	146	50	2.0	1,771,824
Pfeiffer Big						
Sur SP	332.53 (821.70)	4,298 (14,100)L	220	176	8.5	188,152
Wilder Ranch SP	1,276.35 (3,153.92)	7,315 (24,000)0				
Chumash Painted						
Cave SP	5.87 (14.50)				0.1	
Hearst San						
Simeon SHM	60.33 (149.08)					

Table 5-35 (continued)

Unit ¹	Land Area ² Hectares (acres)	Waterfront Meters (ft.) Type 3	Camp Units	Picnic Units	Trail Miles	Visitor (1977-78) Attendance
La Purisima						
Mission SHP	391.05	(966.31)	-	-	12.5	122,263
Monterey SHP	2.79	(6.89)	-	-	0.5	
Santa Cruz						
Mission SHP	0.47	(1.16)	-	-	-	-
John Little SR	8.50	(21.00)	640	(2,100)0	0.5	
Los Osos Oaks SR	34.44	(85.10)				11,148
Point Lobos SR	536.04	(1,326.58)	7,247	(23,777)0	6.0	276,307
Garcia Property Project	58.44	(144.41)				
Marina Beach Project	51.58	(127.32)	1,417	(4,650)0	-	-
Rincon Point Project	.08	(.20)				
Santa Cruz Trails Project	30.35	(75.00)	-	-	-	-
TOTAL	23,816.53	(58,830.45)	115,412	(378,763)0	2,362	1,407
			7,712	(25,300)1	170.90	14,770,769
			5,486	(18,000)R		

1. SB - State Beach; SP - State Park; SR - State Reserve; SVRA - State Vehicular Recreation Area; NP - Natural Preserve; SHM - State Historical Monument
2. Includes leased acres.
3. O-Ocean; L-Lake; R-River.

Within Planning District 7: (San Benito, Santa Cruz, Monterey, San Luis Obispo, and Santa Barbara Counties.)

4.2% of the land area in Planning District 7 is owned by the State Park System.

56.2% of the family campsites available in the region are provided by the State Park System.

32.3% of picnic facilities in Planning District 7 are within the State Park System.

60.2% of all hiking, biking, and riding trails within Planning District 7 are managed by the State Park System. (Does not include the 168.0 miles of off-highway vehicle trails in Hollister Hills SVRA.)

This coastal area has the greatest variety of public recreational resources. Resources include several historic Spanish missions at Santa Cruz, Monterey, and north of Lompoc (La Purisima), Hearst Castle at San Simeon, Pismo Beach Off-Road Vehicle Park, as well as a number of beaches and parks.

Private developments are also significant in the recreational inventory in this portion of the coast, in many cases not due to their size but because they are widely known and somewhat unique. Pebble Beach golf course is a famous location for golf tournaments. Laguna Seca Race Track, north of Monterey is one of the major tracks for auto and motorcycle racing in California.

Scenic roadways are a recreational resource of major importance. Two notable routes are the 17-Mile Drive, a privately-held road through the Del Monte property between Monterey and Carmel, and the section of Highway 1 between Carmel and San Simeon along the Big Sur coast.

The south central coast area includes a large number of registered boat owners. A total of 22,398 boats are registered in the south central counties. Boating facilities are shown in Table 5-35.

In contrast to other areas, this section of the coast has a number of large marinas. As there are few secluded bays along the coast between Santa Cruz and Point Conception, an unusually high percentage of craft may be used for ocean sailing. The need for development of additional ports-of-refuge has been recognized for many years.

Table 5-36. Numbers of Existing and Proposed Small Craft Harbors and Boat Launching Ramps in the South Central Coastal Region, 1976 (Winzler and Kelly, 1977b)

county/ Harbor	Existing			Flamed	
	Total Berths and/or ?100 rings	Launching Ramp Lanes or Hoists	Charter or Party Fishing Boats	Berths	Launching Ramp Lanes or Hoists
<u>Santa Cruz County</u>					
Santa Cruz Harbor	900	— 2		—	—
Subtotal	900	2			
<u>Monterey County</u>					
Moss Landing Harbor	465	3	3		
Monterey Marina	365	3	8		
Stillwater Cove	20	— 1	—	—	—
Subtotal	850	7	11		
<u>San Luis Obispo County</u>					
Morro Bay	570	— 4	— 6	800	— 2
Subtotal	570	4	6	800	2
<u>Santa Barbara County</u>					
Santa Barbara Marina	1,100	— 3	— 7	—	—
Subtotal	1,100	3	7		
TOTAL	3,420	10	24	800	2

Demand and Supply Factors. Recreational demand, particularly the use of private facilities, is difficult to quantify. Estimates are complicated by the complex of activities; e.g., sightseeing, hiking, picnicking, or birdwatching.

The starting point for estimating current demand for recreation is actual recreational activity. Of all recreational activities, park usage and the common activities associated with park attendance - camping, picnicking, hiking, and boating - are most closely monitored in California through two computer-based systems: PARIS (Parks and Recreation Information System), operated by the State Department of Parks and Recreation, and RIM (Recreation Information Management), operated by the U.S. Forest Service. Neither system supplies an accurate breakdown of use among several interrelated activities to eliminate double counting of recreationists. Demand figures based on use data thus tend to be inflated. The systems nonetheless offer a broad statistical basis for making judgments about recreational demand and can be used to infer the general level of recreational activity in any given area.

Long-range demand for recreational services depends on the amount of leisure time and personal income of the user. Overall trends in the United States reveal that personal income and leisure time are rising; hence, demand for recreational facilities and services should continue to increase. A comparison of attendance figures against population increases in California, shown in Figure 5-5, reveals dramatic increases in demand for state park facilities and seems to bear out the commonly held opinion that recreational demand is increasing 5% a year or more in the state.

It is certain that the coastal zone will receive a great share of the increased demand. A review of data generated by preference surveys of both state residents and out-of-state travelers in 1970 revealed that 80% of all recreational visits in California occur in the coastal zone of the current study (Gruen and Gruen Sedway-Cooke, 1971). Table 5-37 shows projected demand for the coastal region percentage of the statewide total, and facility deficiencies for 1990. Demand for state park facilities within the north and central coastal regions are projected to account for about 25% of total state demand (Table 5-37). The estimated deficiency of campsites alone is estimated to be 17.5% (California State Department of Parks and Recreation, 1979b).

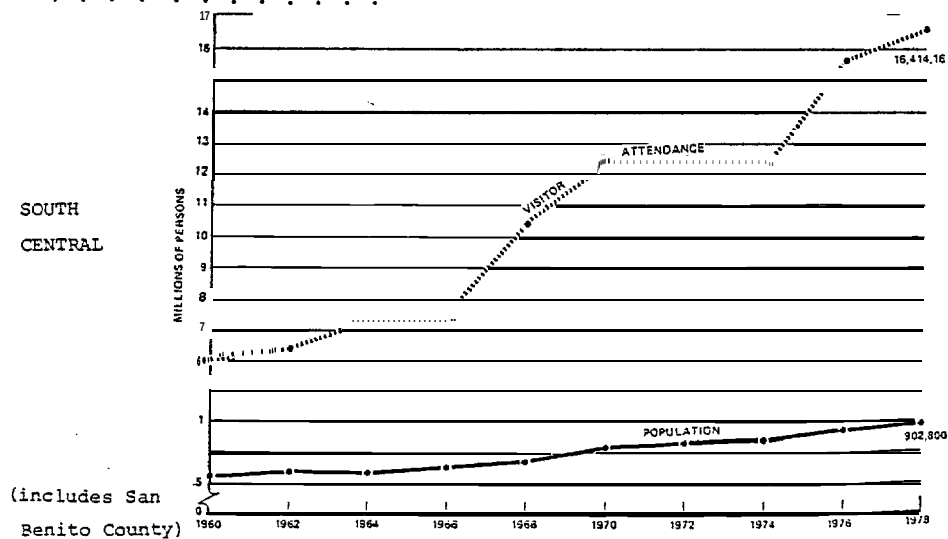
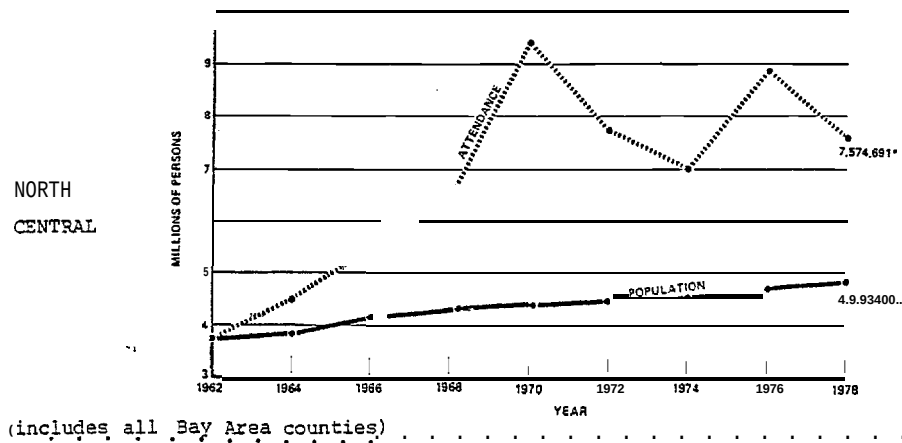
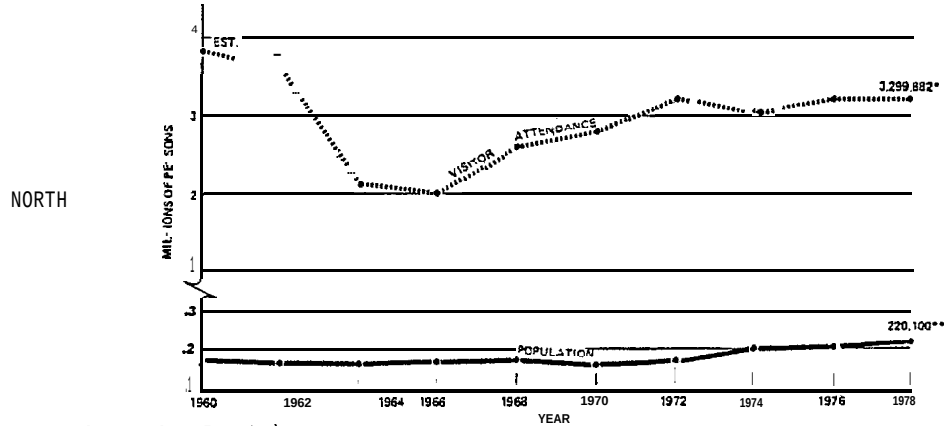


Figure 5-5. Numbers (millions) of persons using the State Park System and the Population (California Department of Parks and Recreation, 1979b)

Qualitative, as well as quantitative, changes in demand for recreation are taking place in the state. Increasing interest is seen in recreational activities which are in some way educational (Bradshaw, Institute for Governmental Studies, U. C. Berkeley, personal communication, 1979). Examples of such activities include birdwatching and other observational activities in connection with hiking and camping and visits to museums and historic places. At the same time, the rate of growth in demand for recreational vehicle travel and off-road vehicles (ORV's) may be dampened by high prices for such vehicles and the increasing costs of fuel. However, absolute growth in these activities will still occur with increased population.

Table 5-37. Projected Demand (man-days of recreation) for Recreational Facilities and Kinds and Numbers of Facilities Needed for the California Coast in 1990 (California State Department of Parks and Recreation, 1979b)

	Recreation Days x 1 Million		Facilities Needed		
	Total Demand (All Activities)	Composite Demand (Picnicking, camping, Hiking, Boating)	Campsites	Picnic Sites	Boat Access
<u>North Coast</u> ¹					
Planning District 1	91.2	15.7	2,341	4,503	407 ²
% of Statewide Total	1.8	3.7	2.2	3.7	
<u>North Central Coast</u> ³					
Planning District 4	773.4	48.8	10,312	10,073	2,463
% of Statewide Total	15.4	11.4	9.4	6.7	2.4
<u>South Central Coast</u> ⁴					
Planning District 7	373.3	35.1	6,450	12,843	11,085
% of Statewide Total	7.4	8.2	5.9	8.6	10.9
1. Includes Lake County					
2. Includes surplus					
3. Includes all Bay Area counties					
4. Includes San Benito County					

Because roads provide access to recreational opportunities, projections of traffic demand for key coastal routes indicate growth in recreation demand and the extent to which supply, or at least access, is likely to be constrained.

A study of traffic on Highway 1 by the California Coastal Commission shows the percentage increases in home construction that could occur along each segment of Highway 1 between Stinson Beach in Marin County, and Fort Bragg, in Mendocino County before service levels D and E and encountered (Table 5-38); service level D approaches congestion, level E represents extreme congestion. There will be little room for additional local traffic if service level D is to be maintained.

Table 5-38. Number of Single Family Homes and Projected Increases in 1980 to 1995 for Congested Levels (D) and for Extremely Congested Levels (E) Along Highway 1, Marin, Sonoma, Mendocino Counties (DeLeuw, Cather, 1979).

Reach	Single Family Homes	Percent Increase by Year					
		"D"			"E "		
		1980	1985	1995	1980	1985	1995
Stinson Beach	1,050						
Point Arena	160				100	60	40
Pt. Reyes	700				50		
Tomales	220	300	200	50	1,100	900	700
Bodega Bay	685			-	100	75	25
Gualala	475	80	20	-	220	200	125
Pt. Arena	935				375	325	200
Ft. Bragg	4,107				90	80	60

A study of Highway 1 through Big Sur conducted by Monterey County shows current and projected (1995) service levels at peak hours based on projected traffic volumes, high percentages of which are recreation-related (Table 5-39). The table shows that service will fall to unacceptable levels in almost all segments through 1995. Level E means congestion levels are unacceptable to most motorists; level F is extreme congestion.

Table 5-39. Peak Levels of Service in the Big Sur Area, Highway 1 Projected From 1970 to 1995¹ (Monterey County, 1979)

Highway 1 Section	Milepost	Level of Service	
		1978	1995
SLO Co. Line to Spruce Creek	0.0/9.4	E	F
Spruce Creek to Kirk Creek	9.4/18.9	E	E
Kirk Creek to Big Creek	18.9/28.1	E	E
Big Creek to Anderson Canyon	28.1/35.3	E	E
Anderson Canyon to Big Sur			
River Bridge	35.3/46.6	E	F
Big Sur River to Little Sur River	46.6/56.1	D	D
Little Sur River to Garrapata Creek	56.1/63.0	E	F
Garrapata Creek to Malpaso Creek	63.0/68.4	D	E

1. 1995 Level of Service based on projected traffic volumes.

Boating, because it represents a sizeable personal investment, is especially sensitive to economic fluctuations, particularly to changes in disposable income. The availability of launching facilities also has a push-pull effect on boating investments. Within the past five years, utility districts and water agencies have responded to boating demand by opening reservoirs for boating. The projections of demand for boat launching facilities in Table 5-40, although now somewhat dated, appear to be in line with the 1990 boat launching deficiency estimates supplied in Table 5-37 (note different regional organization of counties).

Regulations Controls and Composition. Controls over level of recreational use are expected through a variety of designations of public lands; e.g., wildlife areas, sanctuaries, preserves, and conservation areas. These designations usually dictate the number or facilities and type of access that will be provided and thus attempt to limit use to an appropriate carrying capacity determined by environmental characteristics and the public values assigned to those characteristics.

Table 3-40. Projected Demand and Net Excess Supply for Boat Launching Facilities on California Coastal Waters, 1975-1985
(Williams-Kuebelbeck and Associates, 1974)

Region/County	Demand, In-Season Weekend Day						supply	Net Excess Demand or Supply					
	1975		1980		1985			1975		1980		1985	
	Avg	Peak	Avg.	Peak	Avg.	Peak		Avg .	Peak	Avg	Peak	Avg.	Peak
North Coastal													
Del Norte	2	3	3	3	3	4	2	-	1	1	1	1	2
Humboldt	14	17	16	20	19	23	17	(3)		(1)	3	2	6
Mendocino	4	5	5	6	6	8	4	-	1	1	2	2	4
Subtotal	20	25	24	29	28	35	23	m	2	1	6	5	12
North Central													
Sonoma	7	8	9	11	12	15	7	-	1	2	4	5	8
Marin	6	8	7	8	7	9	10	(4)	(2)	(3)	(2)	(3)	(1)
San Francisco	0	0	0	0	0	0	0	-	-	-	-	-	-
Subtotal	13	16	16	19	19	24	17	(4)	(1)	(1)	2	2	7
Central Coastal													
San Mateo	6	7	7	8	8	10	1	5	6	6	7	7	9
Santa Cruz	9	11	12	15	16	20	10	(1)	1	2	5	6	10
Monterey	8	10	10	12	12	15	4	4	6	6	8	8	11
Subtotal	23	28	29	35	36	45	15	8	13	14	20	21	30
South Central Coast													
San Luis Obispo	7	8	8	10	10	12	6	1	2	2	4	4	6
Santa Barbara	11	14	13	16	15	18	15	(4)	(1)	(2)	1	0	3
Subtotal	18	22	21	26	25	30	21	(3)	1	0	5	4	9
TOTAL	74	91	90	109	108	134	76	(2)	15	14	33	32	58

Issuance of permits and licenses sometimes regulates access for fishing and hunting. This limits access by season and, in some cases, by site and limit take. Licensing of recreational vehicles, ORVs for example, is intended to limit access to approved public use areas (and to generate revenues for ORV parks).

Some control also is exercised over development of recreational facilities, hotels, restaurants and marinas. The California Coastal Zone Act of 1976 has a very far-reaching impact on recreation in the coastal zone, although the policies of the commission generally favor recreational development and access to the coast.

Local agencies also regulate development of recreational facilities. Some of the powers of the Coastal Commission will be transferred to local agencies following certification of local coastal plans. While the transfer will increase local control, it is also certain to lead to greater regulatory complexity, as local jurisdictions are certain to apply their local coastal plans differently.

One recreational activity of purportedly enormous growth is off-road vehicle (ORV) use. The extent of ORV demand is unknown because so much ORV activity occurs on private property. The State of California revised its initial projections sharply downward in 1974 after a new program of registering ORVs produced far fewer registrations than predicted. Many ORVs, particularly motorcycles, are registered for street use, and many owners of ORVs, such as dune buggies and snowmobiles, reportedly refuse to register out of protest (California Department of Parks and Recreation, 1975). The number of ORVs in Pismo Beach, the only public ORV park in the coastal zone, was by far the highest level of all state recreational facilities in the north and central coastal regions in 1977-78 (California Department of Parks and Recreation, 1979b). A 50% increase in use in the ORV portion of the park was registered in a three-year period between 1974 and 1977 (San Luis Obispo County, 1979).

Tourism

Tourism is probably the most difficult of basic industries to quantify because of the difficulty of separating the expenditures by visitors for lodging, food and drink, fuel, clothes, and recreation from expenditures made for the same things by local residents (lodging excluded) and commercial travelers. While relatively good data are available on the total value and employment associated with these services, almost no data exist, except through special studies, on the percentage of those services that result from tourism as opposed to local demand.

Tourist Volume, Activities and Origins. Precise estimates on the numbers of tourists visiting the north, central and south-central regions of the coast are not obtainable from existing statistical sources. About the only reliable way of obtaining accurate information about the levels of tourist visitation is to carry out a survey, which, because of expense, is an infrequently used means of data collection. An overall impression of the number of tourists entering each of the subregions of the coastal area under study may be gathered from Figure 5-6, which compares visitor attendance against population at state park facilities.

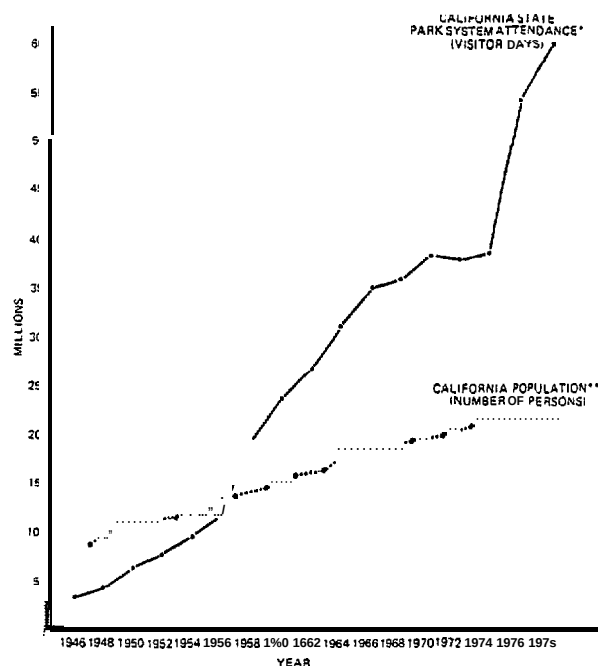


Figure 5-6. The Population of California and the Park Visitor Days in 1946 to 1975
(California Department of Parks and Recreation, 1979b)

Visitor figures are not entirely accurate, because both residents and nonresidents are treated as "visitors" in attendance records at state recreational facilities. Nor do visitor attendance statistics distinguish between single and repeat visits. It is theoretically possible, for example, for each local resident in the Bay Area, as shown in S-5 to have visited a state park facility twice during the year, thus accounting for all recorded visitor attendance at state park facilities within the region.

Data on visitor attendance would give a truer picture of nonresident "visitor" or tourist volume if they were compared with statistics on day use and overnight use, since this is the period of stay that separates residents from nonresidents. Raw data on day use and overnight use are collected by Jack Bechtel, State Department of Parks and Recreation (personal communication, November 1979), but have not been incorporated into visitor attendance statistics of the State park System Plan for 1980.

A number of surveys of visitor origins have been made that provide more insight into actual numbers of tourists visiting the coast.

A survey at Redwood National Park identified that 39.5% of the nonresident visitors were from out-of-state. A high percentage was from states west of the Mississippi, probably Oregon (23.9%). Sixty percent were from California, mostly from either the Bay Area or the Los Angeles area (Del Norte County Local Transportation Commission, 1977).

Surveys of visitor origins in the Bay Area - Sonoma County to San Mateo County - show a much different pattern. Seventy to eighty percent are local, i.e., from the San Francisco Bay area, and 20-30% come from other counties in California (DeLeuw Cather, 1979; McDonald and Smart, 1976).

Visitor origin studies at Pfeiffer-Big Sur State Park, Hearst Castle and Pismo Beach (California Department of Parks and Recreation, 1973; San Luis Obispo County 1979) reveal that 50% of visitors come from the Los Angeles metropolitan area, and 12-15% from out-of-state. Hearst Castle attracts 15-20% of its total visitor attendance from other countries. Four percent of visitors to Pismo Beach come from Kern and Fresno Counties to the east; 15% come from the Bay Area, perhaps reflecting the park's function as a specialty use area for ORVs. It appears that most of the visitor volume in the south central coast area originates from beyond the local area.

Tourist Accommodation and Expenditures. In many counties along the north and central coast area, recreation is reported as being a leading economic sector, and the anticipated growth rate of 5-10% per year underscores its importance as a growing industry. Estimates of total tourist expenditures demonstrate the economic significance of the industry. In Del Norte County in 1978, tourists are estimated to have spent 23 million dollars (EDAW, Inc., 1979c); in Mendocino County in 1975, 20 million dollars (Mendocino County, 1978); in Santa Cruz County in 1978, 82 million dollars (Recht/Hausrath, 1979b); and in San Luis Obispo County in 1976, 42 million dollars (San Luis Obispo SLO County, 1979). The San Francisco Chamber of Commerce announced on January 9, 1980 that tourism in San Francisco had become a \$1 billion industry during the previous year.

Such estimates of tourist expenditures are based on a number of statistical sources and special studies, none of which give an entirely accurate picture.

Data on revenues from lodgings, whether they are campsites, RV camps, hotels or motels, while not readily available, may be obtained at least in raw form. Revenue flow figures by campsite are available through the State Department of Parks and Recreation, although they are not presented in a published report (personal communication, Jack Bechtel, California Department of Parks and Recreation, 1979). Expenditures for lodging establishments may be estimated from overnight occupancy tax revenues reported by county. These are usually available through local chambers of commerce.

Estimates of total visitor expenditures in Del Norte County shown in Tables 5-41 and 5-42 were drawn from data in special studies of the impact of Redwood National Park expansion and related studies of unemployment in the northern counties. The level of expenditure in various categories may well be typical of visitors to the north county area, where recreation centers on camping and related inexpensive activities.

Table 5-41. Average Visitor-Day Expenditures for Del Norte County 1978 (EDAW, Inc., 1979c)

Services	Expenditures	% Total
Lodging and camping	\$ 2.80	20.6%
Restaurant meals	2.90	21.3
Gasoline, oil, auto repairs	3.20	23.5
Groceries and beverages	2.30	16.9
Other retail and services	<u>2.40</u>	<u>17.7</u>
Total	\$13.60	100.0%

Table 5-42. Total Expenditures by Recreational Visitors to Del Norte County, 1978 (EDAW, Inc., 1979c)

Services	Expenditures
Lodging and camping	\$ 4,760,000
Restaurant meals	4,930,000
Gasoline, oil, auto repairs	5,440,000
Groceries and beverages	3,910,000
Other retail and services	4,080,000
Total	\$23,120,000

Studies of visitor expenditures in Santa Cruz County and Monterey County, shown in Tables 5-43 and 5-44, reveal very different levels of expenditure, not only in comparison to Del Norte County but also between the two counties. Of interest are the very different patterns of expenditure of day visitors and overnight visitors, suggesting that nearness to a large metropolitan area provides a large and lucrative visitor market. Expenditures in Monterey County, much higher than in Santa Cruz County, appear to be generated primarily through lodging, i.e., convention facilities, which attracts a clientele capable of making unusually high levels of expenditure (Recht/Hausrath, 1979b). The expenditure pattern is atypical of the coast, but may well represent tourist expenditure patterns occurring in similar urban tourist centers such as San Francisco.

Table 5-43. Estimated Expenditures (millions of dollars) in Santa Cruz County, 1977-1978 (Recht/Hausrath and Associates, 1979b)

Category	Day Visitors	Overnight Visitors In Campgrounds	OVERNIGHT HOTEL/MOTEL VISITORS				Total
			Paying Less than \$30 Per Night Per Room	Paying \$30-\$44 Per Night Per Room	Paying \$45 or More Per Night Per Room	Total Hotel/Motel Visitors	
Lodging	..	1.1	3.8	7.0	1.5	12.3	13.4
Eating & Drinking Out	22.7	0.9	3.7	5.3	1.2	10.2	33.8
Groceries & Liquor Stores	2.6	1.9	0.5	0.5	0.2	1.2	5.7
Recreation/Entertainment/ Amusement	9.6	1.0	1.1	1.4	0.1	2.6	13.2
Auto-Related	4.3	0.9	0.7	0.6	0.1	1.4	6.6
Retail Goods	11.5	1.0	1.1	1.9	0.1	3.1	15.6
Total	50.7	6.8	10.9	16.7	3.2	30.8	88.3

1. The estimated total expenditures shown here were based on spending by day visitors and overnight visitors in campgrounds and hotels/motels. However, as discussed in the source material, totals appear to provide good estimates of total county spending by all visitors, including those not studied in detail (overnight visitors in condominiums, group quarters, rental houses, and staying with friends and relatives).

Table 5-44. Estimated Expenditures (millions of dollars) by Visitor Days in Monterey County in 1977-78 (Recht/Hausrath and Associates, 1979b)

Category	Day Visitors	Overnight Visitors In Campgrounds	OVERNIGHT HOTEL/MOTEL VISITORS			Total Hotel/Motel Visitors	Total
			Paying Less than \$30 Per Night Per Room	Paying \$30-\$44 Per Night Per Room	Paying \$45 or More Per Night Per Room		
Lodging	0	0.6	11.9	25.5	20.4	57.8	58.4
Eating & Drinking Out	30.0	0.5	16.6	33.4	19.6	69.6	100.1
Groceries & Liquor Stores	1.8	1.0	1.0	4.7	1.2	6.9	9.7
Recreation/Entertainment/ Amusement	3.2	0.5	1.0	2.8	1.5	5.3	9.0
Auto-Related	6.0	0.5	3.4	4.3	2.4	10.1	16.6
Retail Goods	19.5	0.6	12.0	35.2	16.8	64.0	84.1
Personal Services & Other	0	0	0.2	0.2	0.6	1.0	1.0
Total	60.5	3.7	46.1	106.1	62.5	214.7	278.9

Employment. Estimating employment in or related to the tourist industry depends on estimates of which sectors of the economy (and what percentage) serve the tourist industry and what percentage of employees in each sector serve tourist rather than resident demand.

The types of industries that serve tourists are typically gasoline service stations (SIC 554); eating and drinking places (SIC 58); hotels and other lodgings (SIC 70); food stores (SIC 54); apparel and accessory stores (SIC 56); and amusement and recreation services (SIC 79).

The next step requires estimating the percentage of revenues in each industry derived from visitor expenditures and preparing a cost structure that shows percentage of revenues paid out as wages and salaries. Both are highly judgemental exercises.

Projections of employment in recreation in Del Norte County are included in the figures on Table 5-45.

Table 5-45. Projected Employment (numbers) and Annual Average Income and Revenues for the Tourist and Recreation Industry in Del Norte County, 1980-2000 (EDAW, Inc., 1979c)

Years	Noncommercial Visitors	Employment	Income	Local ³ Government Revenues
Base Year (1978)	1,700,000	650	\$12,070,000	\$280,000
1981-1985	1,900,000	730	13,580,000	310,000
1986-1990	2,350,000	890	16,520,000	400,000
1991-1995	2,750,000	1,000	19,520,000	450,000
1996-2000	3,200,000	1,150	24,730,000	570,000

1. 24 hour visitor-days.
2. Full-time equivalent employment.
3. Assumes 1978 constant dollars.

The estimates in Table 5-45 deal with direct employment only and make no attempt to deal with the multiplier effect. The estimates prepared for Monterey and Santa Cruz County shown in Table 5-46 include the impact of indirect employment, that is, employment generated through supporting services for restaurants, service stations, and retail stores.

Table 5-46. Estimated Percentages of County Employment¹
Supported by Visitors in Santa Cruz
and Monterey Counties, 1979 (Recht/Hausrath & Associates, 1979b)

I t e m	Santa Cruz County	Monterey County
Percent of County's Service and Trade Employment Supported by Visitors	25%	44%
Percent of County's Total Employment Supported by Visitors	10%	15%
Estimated Percentage of Total Employment Supported by Visitors Which is Contributed By:		
Hotel/Motel	36%	Monterey Peninsula Hotel/Motel Visitors 74%
Day Use Visitors	46%	Monterey Peninsula Day Use Visitors 18%
Campers & Overnight Visitors in Condominiums, Rental Houses, Group Quarters, RV Parks, and with Friends and Relatives	18%	Campers, overnight Visitors to the Peninsula Staying in Other Facilities and all Visitors to County Areas Outside the Peninsula 8%

1. Includes direct, indirect, and induced income/employment effects of
visitor spending.

Boating represents a major segment of employment within the recreation industry
iii California, much of which is concentrated in the coastal region. Boating engages
all sectors of the economy: manufacturing, retail and wholesale sales, and services.

Table 5-47 shows estimates of the direct impact of boating on employment at marinas in
California. Some appreciation of the size of the industry can be gathered from Table
5-48, which gives the overall direct and indirect impact for California.

Table 5-47. Numbers Employed by Public and Private Marinas, California, 1975
(Williams-Kuebelbeck and Associates, 1974)

Ownership	Total Boat Slips	Employees Per 100 Slips ¹	Total Employment ²	Total Wages and Salaries	Average Annual Wages
Public Agencies ³	NA	NA	280	\$3,889,300	\$14,000
Lessees at Public Marinas	29,970	1.0	300	3,641,400	12,138
Private, Coast and Bays	8,910	1.5	133	842,000	6,330
Private, Delta	8,750	1.0	88	511,900	5,817
Private, Lakes and Rivers	9,630	.5	48	271,000	5,646
Total			849	\$9,155,600	\$10,783

1. Estimated employment for boat slip operations only.

2. Full-time equivalent.

3. Employment based on total wages and salaries divided by estimated
average annual wages.

Table 5-48. Total Direct and Indirect Income (millions of dollars) from the California Boating Industry in 1975 (Williams-Kuebelbeck and Associates, 1974)

Sector	Direct Income	Multiplier	Indirect Income	Total
Manufacturing	172.6	3.35	405.6	578.2
Retail & Wholesale	289.1	1.76	219.7	508.8
Services	116.0	1.75	87.0	203.0
Marinas	38.0	2.79	68.0	106.0
TOTAL	\$615.7	2.267 avg.	\$780.3	\$1,396.0

Another major recreational industry is the manufacturing, selling and servicing of ORVs. An analysis of the impact of this industry on employment would begin with a reliable estimate of the number of ORVs registered in California; such figures, however, do not exist.

Second Homes

Number and Location. The number of second homes in the northern and central coastal area of California is difficult to assess because only a small proportion of second homes constructed retain that status; most become primary residences (McDonald and Smart, 1976). Table 5-49 summarizes information concerning second home ownership.

Table 5-49. Second Home Development Projects and Units in Northern and Central Coastal California, 1976 (McDonald and Smart, 1976; California Coastal Zone Conservation Commission, 1975)

Name of Development	Project Size	Developer	Location	Number of Units	Number of Sales
Sea Ranch	. . .	Oceanic California	North Mendocino	5,200 lots	1,765 lots 350 units
Pajaro Dunes	150 acres 1.5 miles of coastline	Hare, Brewer Kelley	South Santa Cruz County Watsonville	143 lots	113 lots 43 units
Monterey Dunes Colony	120 acres	Trans-america Development Company	Moss Landing, Monterey Peninsula	32	4
Seadrift	120 acres	Seadrift Company	Stinson Beach, Marin County	346 lots	260 lots 121 homes
Boulder Creek Golf & Country	176 acres	Culligan Construc- tion Co.	San Lorenzo Valley, Santa Cruz County	31 lots	31 lots

In estimating the number of second homes, a distinction must be made between recreational lot sales and units actually built. In the northern three counties (Del Norte, Humboldt, and Mendocino) the number of recreational lots far exceeds the number of second home units. The numbers of lots and the number of second homes developed in Mendocino County, typifies conditions existing in the north region (Table 5-50). Sea Ranch, the largest second home development within the study area, has historically grown at 50 units a year [California Coastal Zone Conservation Commission, 1975].

The difference between the number of lots and number of units built underscores some of the main determinants of the second home market. Income characteristics required for lot purchase and construction of a house differ greatly. In the pre-1974 housing market, an annual income of \$15,000 or less was sufficient for lot purchase; second home construction, however, was estimated at that time to require an income of \$50,000 annually (McDonald and Smart, 1976). Within the ensuing half-decade, housing costs have doubled. It may be assumed that income differences for lot purchase and home construction have widened appreciably.

Table 5-50. The numbers of Undeveloped Lots and Developed Lots (homes) in Mendocino County, 1978 (Mendocino County, 1978)

Sonoma County Line Township	Lots	Number of Lots	Numbers Undeveloped	Numbers Developed	Percent Developed	Potential Population
1 Gualala area		1,813	1,282	531	29	3,846
2 Pt. Arena area		514	451	63	12	1,353
3 Manchester area		714	580	134	19	1,740
4		101	86	15	15	258
5 Elk area		361	244	117	32	732
6 Albion area		750	446	304	41	1,338
7		788	496	292	37	1,488
Mendocino		502	185	317	63	555
8 Fort Bragg area		1,435	620	815	57	1,860
9 Cleone area		459	263	196	43	789
10 Kibesillah area		128	105	23	18	315
11		141	133	8	6	399
Westport		99	58	41	41	174
12 RockPort area		23	20	3	13	60
13 Usal area		14	14	0	0	12
14 Bear Harbor area		43	43	0	0	129
15		7	6	1	14	18
Humboldt County Line		6,892	5,032	2,860	36	15,066

A major constraint upon the second home construction market is the lack of public services. The total number of lots in all three northern counties far exceeds present and projected public service capacities. Unless there is a relaxation of public standards, such lots may be considered, at best, long-term investments.

The pattern of second home development in the central coast subregion differs sharply from the north coast. Costs of land and public controls in the central coast have brought about a much closer correlation between lots sold and units built.

Employment. Employment resulting directly from second home construction and occupancy is difficult to quantify. In selected locations and for short periods of time, construction of second home subdivisions probably is responsible for maintaining the construction work force. If the conversion of second homes to first homes is as common as reported, however, the employment impact of the second home market probably should not be treated separately from the first home market.

Retirement

A large number of retired persons have reportedly made their homes in coastal communities during recent decades. Retired persons, through income support from retirement annuities (including Social Security, pensions, and life insurance annuities) bring income to the area and spend this income on goods and services. These expenditures have a multiplier effect on local business and income.

In addition to the normal government and private annuities, the elderly are often the object of special government support services for health, transportation, social centers, and social worker assistance. If the retirement population of the coastal region is large relative to that of other areas, it can attract a disproportionate share of this category of government income to the study area. However, if the elderly rely on services supported primarily by local revenue sources such as property tax, the services will be a source of income drain and will have a dampening effect on local business.

The impression that very large numbers of elderly persons live in the coastal zone relative to other areas in California is not altogether borne out by the population statistics for 1970 and projections to 1980 shown in Table 5-51. In 1975, the statewide percentage of population in the 65 and over age group was 9.7% (U.S. Department of Commerce, 1977). Of the coastal counties within the study area, the projected percentages of elderly population in three counties in 1980, Humboldt County in the north coastal area, Marin County at the center of the study area, and Monterey County in the south central area, are within one percentage point of the 1975 state average, and the percentages in seven counties are within three percent. Although the percentage of elderly has increased over the decade in all but two of the counties, the increase in most cases has been less than 2%. This does not indicate that net in-migration of elderly has been substantial. The increase results primarily from the aging of the local population.

Table 5-51. The percentage of the Population 65 Years of Age and Over in California Coastal Counties, 1970-1980
(Winzler and Kelly, 1977b; California Department of Finance, 1978)

County	1970		1980		Percentage Increase or Decrease
	Number	Percent	Number	Percent	
Del Norte	1,384	9.52	2,043	12.19	2.63
Humboldt	8,665	8.66	11,062	10.13	1.47
Mendocino	5,669	11.09	7,443	11.45	1.36
Sonoma	26,345	12.85	35,723	12.79	
Marin	15,184	7.36	21,289	9.32	1.96
San Francisco	99,738	13.93	102,227	15.80	1.87
San Mateo	42,579	7.65	63,808	10.66	3.01
Santa Cruz	20,590	16.63	24,581	13.10	(3.53)
Monterey	18,653	7.45	25,748	8.64	1.19
San Luis Obispo	13,011	12.31	19,070	13.06	.75
Santa Barbara	24,105	9.11	33,343	11.16	2.05

The impression that the elderly represent a significant factor in the recreation or retirement economy may result from their visibility, a frequent cause of which is, ironically, the inadequacy of government services existing in smaller coastal communities. Demographic information does not substantiate the claim, however, that they reside in the study area in disproportionate numbers or that "retirement" is a significant economic factor in the recreation industry.

Summary and Effects

Summary. The varied natural features of the north and central California coast, its temperate climate, its esthetic appeal, and its accessibility from large population centers, have produced an area that leads the state in recreational demand.

In concert with rising personal income and increased leisure time in the United States generally, recreational demand within the coastal region has risen sharply in all areas, averaging 5% a year. Increases have been at far higher rates in portions of the south central coast around Monterey, Carmel, Big Sur, and Pismo Beach in San Luis Obispo County.

In the central coast area, particularly, the supply of campsites and other accommodations and road access is now at capacity at peak periods in the summer months. To what extent limitations on supply act as a brake on demand is unknown. Increases in road capacity, campsites, and other facilities are fiercely resisted in some quarters as factors certain to reduce the aesthetic appeal of the coast.

Tourist expenditures are an important component of the local economy in all areas, but the level of expenditures varies greatly. Tourist expenditures are a dominant factor in the economies of Monterey and San Luis Obispo Counties, but are of questionable significance to the economies of Del Norte and Humboldt Counties. The level of expenditure seems highly dependent on time/distance relationships between recreational resources and major population centers.

The significance of employment based on recreation in the coastal counties as a whole is largely unknown. Recht/Hausrath and Associates (1979a) estimate that 15% of total employment and 45% of trade and service sector employment in Monterey County are directly supported by recreation and tourism. Nowhere else in the coastal region does recreation have such a significant employment effect. Moreover, because recreation-related trade and service employment is often part-time or seasonal and is generally low-paid, the benefits of employment potentially generated by recreation industry growth tend to be over-stated in many areas (QRC Research Corporation, 1978). The industry is, however, of great importance to unskilled workers and young people of school age seeking seasonal employment.

The range of expenditure levels for different types of recreation is an extremely wide one: sightseeing, except for fuel costs, involves virtually no expenditure; campsites typically cost \$2.00-\$3.00 per night. At the other extreme, second home prices in some areas start at \$100,000.

Multiplier Effects. A set of multipliers applicable to a highly active tourist area were developed for a study commissioned by AMBAG (Association of Monterey Bay Area Governments) and are shown below in Table 5-52. Leakage refers to revenues "lost" by the local economy.

Table 5-52. Waage Contribution to the Local Economy by Major Service Industries in Santa Cruz and Monterey Counties
(Recht/Hausrath and Associates, 1979a)

Consumption Category	Spending that Goes to Local Wages, Salaries		Part of \$1.00 Resident Spending that is Lost	
	Santa Cruz county	Monterey county	Santa Cruz County	Monterey County
Food	\$0.17	\$0.17	\$0.83	\$0.83
Clothing	0.18	0.20	0.82	0.80
Housing	0.40	0.40	0.60	0.60
Furnishings	0.18	0.20	0.82	0.80
Medical Care	0.70	0.70	0.30	0.30
Personal Care	0.90	0.90	0.10	0.10
Transportation	0.25	0.25	0.75	0.75
Recreation, Other	0.20	0.20	0.80	0.80

A very extensive study of multipliers in the boating industry was constructed as part of the Department of Navigation and Ocean Development study, Economic Impacts of the Boating Industry in California (Williams-Kuebelbeck and Associates, Inc., 1975?). Multipliers were developed for manufacturing ($m=3.35$); retail-wholesale ($m=1.76$); services ($m=1.75$); and marinas ($m=2.79$). This study contains an extensive section on the methodology used. The application of these multipliers was shown previously in Table 5-48.

Natural Systems Effects. Taken overall, the sustained rise in recreational demand occurring as one of the more significant social trends in United States society over the last two decades has had a beneficial effect on the preservation of natural systems. While it cannot be ignored that many recreational pursuits have effects

destructive to the environment, it is the pursuit of leisure that provides the broadest base of popular support behind the public protection of land and water resources renowned for their natural beauty and valued as habitats and sanctuaries for fish, wildlife, and vegetation.

By far the most important public action taken in pursuit of the protection of coastal resources in California within the last decade, quite possibly in the history of the state, was the California Coastal Zone Act of 1976, preceded by the popular initiative - Proposition 20 - of 1972. It is almost inconceivable that legislation so fiercely resisted by various industrial and commercial interests would have passed had the popular value of coastal recreational resources, its beaches and scenic character, not been so highly valued by residents of the state. Recreation interests also contributed importantly to the enactment of the Wild and Scenic Rivers Act in 1972 and passage of the California Recreational Trails Act of 1974.

Nonetheless, adverse effects on natural systems are produced by recreation. Loosely controlled second home construction often leads to greatly increased erodibility of the land, reduced water quality, and loss of aesthetic appeal. Furthermore, the correction of these problems through "catch-up" expansions of public services can induce another round of development that puts added pressure on resources valued for their aesthetic and recreational appeal.

ORVS, representing a major segment of the recreation industry, destroy soil, mantle and plants, causing increased erosion, and destroy food sources for wildlife. The impact of ORVS on coastal ecosystems, as Godfrey, et al., have described, was studied at Cape Cod National Seashore (ASCE, 1978). The study findings show that dune vegetation can be totally destroyed by even low levels of continuous ORV use, with consequent dune migration and damage from ocean waves to intertidal zones protected by barrier dunes. It is possible also that exhaust emissions from ORVS are toxic to plants and animals.

Even sightseeing and camping, considered usually as the most environmentally nonthreatening of activities, reach levels where popular sites take on a worn look, a sign of steady erosion of visual appeal and unique character. Primitive campsites, even in remote walk-in areas, may become eroded if in constant use. Relatively remote beaches may become similarly worn from cliff and dune erosion, clogging of streams with refuse, and campfire debris. There also has begun to be some general concern over the impact of large numbers of bird watchers on valuable avian habitats. For example, Godfrey et al. note that, apart from actual physical destruction of nests, ORVS appear to have a less significant effect on sitting birds than people on foot (ASCE, 1978). Walking on the beach, especially with free-running pets, can cause more harm to birds than ORVS obeying rules or controlled by fences on wide beaches (ASCE, 1978).

The growth in the popularity of boating has brought increased pressure to bear on public agencies for the enlargement of existing marinas and the construction of new ones. Marine habitats are frequently destroyed by the addition of new berths. Marina enlargement is usually accompanied by breakwater extension that affects littoral drift. Boating congestion brings pressure to bear for the enlargement of harbor entrances and existing channels; hence, dredging is a frequent impact of recreational boating. The major effect of boating, however, probably occurs as a result of incidental spillage of gasoline and diesel fuels, and the disposal of garbage and human wastes.

Socioeconomic Effects. The impacts of recreation discussed above also results in socioeconomic costs for public services and other wildlife management costs. There is, for example, considerable land-use competition between recreation and some economic activities. Recreational uses are often regarded as incompatible with mining and industrial development. Agriculture alters the natural setting and may restrict access to recreational areas. Logging operations, particularly clearcutting are generally not compatible with recreation and can diminish the attraction for tourists and hikers. An example of conflicts between the forest industry and recreation occurred recently (1977-79) with the expansion of the Redwood National Park in Humboldt County. The National Park Service requested the expansion to protect redwoods within the park from the effects of erosion caused by logging practices. The redwoods are one of the primary recreational resources along the Pacific Northwest Coast and one of the larger attractions of out-of-state tourists. The U.S. Congress authorized the expansion in early 1978.

Future Economic Importance. Recreational activity has increased steadily in California over the last four decades. In the last half of this decade, personal income gains among Californians, even when adjusted for inflation, were sustained at unprecedented levels. The number of persons reaching retirement age also increases yearly in the state.

Stable growth will not likely occur in all parts of the industry. The second home industry, in particular, may well be severely hurt by the cost increases in land and construction materials generally, the cost of money, and increasingly tight restrictions on development within the coastal zone. Increases in public land ownership along the coast can be expected to accompany strict control over private development. However, provision for mass recreation, in the form of trailer parks, hotels and motels, and road expansion, is unlikely to occur.

Much tighter restriction of ORV use can also be expected. Air pollution controls alone would require major adjustments in the manufacturing of these vehicles. Use regulations requiring that ORVs be transported to ORV parks away from urban areas can be expected to reduce demand.

External Factors Affecting the Industry. The price and supply of gasoline is undoubtedly the most important external factor affecting the industry. Fuel shortages during the oil embargo of 1974 were reflected in sharply decreased attendance at state parks, and the fuel shortage in California in June, July and August of 1978 apparently will have a substantial impact again on state park attendance levels (personal communication, Jack Bechtel, California Department of Parks and Recreation, October 1979). Cost may have a disproportionate impact in recreation-related industries. RV sales in 1978 fell well below even the depressed sales of autos. It is likely that increases in fuel costs will increase attendance at recreation sites near urban areas, and decrease attendance farther out. The impact on out-of-state tourism may also be substantial because of increases in air fares resulting from sharp rises in the cost of aviation fuels.

AGRICULTURE

The Resource

Since the 1940's, much of the prime agricultural land on the coast has been lost to urbanization. Economic factors and spatial limitations have played major roles in this ongoing process. The general trend has been toward land-intensive high-value crop production, such as floriculture and the cultivation of fruit crops such as grapes. Limiting factors to the expansion of agriculture are the availability of capital, labor, suitable land, and access to water (Barbe and Snow, 1973?).

Land Suitable for Agriculture. A combination of adequate soil, climate, and water supply produces good agricultural land. Although much of California's agricultural lands are inland from the coastal region, lands of the coastal region supply significant amounts of the state's agricultural production. In addition to containing some very fertile areas, the coast also has unique climatic conditions which make it particularly well suited for certain crops. The following discussion focuses on the coastal region, although it draws on information pertaining to the north and central California coastal counties. Only a limited amount of data is available for the coastal region itself.

The Soil Conservation Service of the U.S. Department of Agriculture has devised a general system of eight broad soil classes, known as the Land Capability Classification. The four classes suitable for crop production are:

Class I: Very good cultivable soils that can be cultivated very intensively. These are deep level soils with adequate water and few, if any, limitations for crop use.

Class 11: Good cultivable soils that can be cultivated intensively but have minor limitations that restrict their use for certain crops. Soils in Classes I and II are considered "Prime" under the California Land Conservation (Williamson) Act of 1965 (Government Code, Section 51200, et seq.).

Class III: Moderately good cultivable soils, possibly poorly drained and requiring careful management. Those soils are suited to fewer or to special crops.

Class IV: Fairly good cultivable soils, but with severe limitations, suitable for occasional cultivation only.

Soils in Classes V through VIII are generally not suitable for cultivation, although some soils in these classes may be capable of producing specialized crops such as grapes and apples and provide grazing for sheep or beef cattle. Since this classification system is extremely general, the process of soil formation is complex, the effect of human technology is often heavy, and the productive capacity of soils within a class can vary widely. Existing and potential prime agricultural lands in coastal counties are shown in Table 5-53, along with county land acreage. Potential prime agricultural lands are defined as "lands which have the capacity of being made prime through normal agricultural investment and practices" (California Office of Planning and Research, 1974)

Table 5-53 Acres of Existing and Potential Prime Agricultural Lands in the Coastal Counties
(California Office of Planning and Research, 1974,
California Department of Finance, 1978).

County	Potential Agricultural Land		Total	Percent of Total Land Area
	Existing	Potential		
Del Norte	10,200	3,000	10,500	1.6
Humboldt	53,600	22,000	75,600	3.3
Mendocino	43,000	106,000	149,000	6.6
Sonoma	108,900	172,000	230,900	27.0
Marin	34,200	12,000	46,200	14.0
San Mateo	8,700	16,000	24,700	8.6
Santa Cruz	25,000	--	25,000	8.8
Monterey	245,000	20,000	265,000	12.0
San Luis Obispo	149,300	363,300	512,600	25.0
Santa Barbara	183,400	155,500	338,900	19.0

Prime soils frequently occur in level areas such as alluvial plains and marine terraces, created through or overlain by sedimentary deposits. Such areas are also attractive for urban development, resulting in historic conflicts between agriculture and urban land uses. Table 5-54 illustrates this process, showing the projected encroachment of urban areas on existing and potential prime soils by 1985. It should be noted that information in this table represents the California Coastal counties, a larger area than the study region. (See Volume 3, Watersheds and Ocean Basins, for comparison.) As San Francisco County has no agricultural production or processing, it will be excluded from tables and discussion in this section.

Table 5-54. Acres of Prime Agricultural Land (acres) Within
The Projected 1985 Urban Development Zone,¹
Coastal Counties (in Acres)
(California Office of Planning and Research 1974)

County	Existing Prime Agricultural Land	Potential Prime Agricultural Land	Present Urban Area	Percentage at Existing and Potential Prime Land Within the Projected Develop- ment Zone	Percentage of Total Prime Land Within the Projected Develop- ment Zone
Del Norte	N/A	N/A	N/A	N/A	N/A
Humboldt	5,400	1,400	14,600	9.0	10.0
Mendocino	N/A	N/A	N/A	N/A	N/A
Sonoma	37,800	21,600	41,200	21.1	34.7
Marin	1,900	3,400	3,100	11.5	5.5
San Mateo	1,600	1,600	70,000	12.9	18.4
Santa Cruz	400	1,500	13,800	7.6	1.6
Monterey	3,700	6,300	6,900	3.8	1.5
San Luis Obispo	N/A	N/A	N/A	N/A	N/A
Santa Barbara	6,300	10,400	22,000	4.9	3.4

1. Lands adjacent to present urban areas of 50,000 or more population which are projected to be urbanized by 1985.

N/A Not Available.

The high percentage of prime lands subject to possible urbanization in the three counties bordering the San Francisco Bay reflect the development pressures exerted by that population center. Prime soils in Humboldt and Santa Cruz counties and some of those in San Mateo and Monterey Counties are also located on the coast, fairly close to developed areas, and are thus susceptible to urban pressure. The general encroachment of urban areas onto prime soils has encouraged the development of greenhouse and nursery production, activities which are not as dependent on productive soils. Construction of greenhouses has occurred on prime soils in some areas. (California Coastal Zone Conservation Commission, 1975). Urbanization of prime soils precludes their future use as agricultural resources, and is recognized as a significant problem on the coast and in the state as a whole.

Class I, II and III agricultural soils in the coastal area may be divided into two general categories:

Valley Land: Valley soils occur in two types. The river valleys in the higher rainfall areas of the coast have deep alluvial sand and flood plain soils, high in organic matter and slightly acidic. These soils originally produced some of the state's best redwood forests in Humboldt, Mendocino, Sonoma and Santa Cruz Counties. Cleared areas of those soils have produced high yields of intensive specialty crops such as bushberries, strawberries, vegetables, and flowers. The coastal valleys of intermediate rainfall from Monterey County south have similarly rich soils, but the inadequacy of rainfall for timber production has made agricultural production more feasible.

Terrace Land: The narrow benches of dark, slightly acidic soils bordering the coast have a high potential for grazing land and specialty crops that are dependent on coastal climates. (Barbe and Snow, 1973)

Although the specific climate of a locality is influenced by local topography, there are two main climate types in the coastal region. The North Coastal marine influence is a climate defined by the presence of fog through much of the summer and by cool, wet winters, which create a year-round cool climate with a limited amount of sunshine. The terrace areas are exposed to considerable amounts of wind and salt spray, limiting the variety of crops that may be grown there. The North Coastal thermal belt occurs in the river valleys, protected by dunes and ridges from the harsher terrace regime. These areas are exposed to less cloud cover and thus receive more sun and heat. The average temperature in the marine-influenced areas generally ranges from 30 degrees to 75 degrees F, while the thermal belt areas may range from 30 degrees to 100 degrees F. Coastal climatic conditions are an important characteristic that distinguishes the region from inland agricultural areas. Many crops are grown on the coast that are coastal dependent, in that they require climates available only on the coast.

The coastal region receives a considerable amount of precipitation, ranging from over 40 inches per year on the north coast to 13.74 inches in Salinas. Although this is generally higher than that received by agricultural areas inland, coastal agriculture requires additional irrigation, which is generally derived from local reservoirs and ground water basins. In the north coast, nearly all irrigation water is applied to field crops, mostly pasture. Applications in the San Francisco Bay counties are largely made on orchard and pasture land, while in the central coast irrigated water is mainly used for truck crops. Agricultural water demand varies greatly by county, accounting for an estimated 81% of total water demand in Sonoma County, whereas agriculture in Marin County accounts for only 9% of the water demand. When water supplies are limited, or their capacity is exceeded by demand, conflicts may result between municipal, industrial, and agricultural users of water.

Table 5-55 illustrates the changes in use of irrigated farmland in the coastal counties from 1969 to 1974. Although there was an overall decline in farm acreage in the counties, irrigated acreage showed an increase. Of the coastal counties' farmland, 5.4% was irrigated in 1969, increasing to 7.9% in 1974. Those rates of change were similar to those in the state as a whole. Statewide, however, a much greater percentage of farmland is irrigated - 23% in 1974 - due to the presence of the vast network of canals in the Central and Imperial Valleys.

Table 5-55 Acres of Irrigated Lands in Coastal
Counties, 1969-1974
(U.S. Department of Commerce, 1977)

County	1969		1974	
	Land in Farms	Irrigated Farmland	Land in Farms	Irrigated Farmland
Del Norte	34,512	3,476	17,924	4,435
Humboldt	740,220	19,175	771,157	16,317
Mendocino	946,259	16,069	674,907	15,877
Sonoma	667,158	22,397	588,077	32,350
Marin	175,038	500	140,748	761
San Mateo	84,514	7,107	78,699	6,830
Santa Cruz	60,960	16,007	53,948	13,344
Monterey	1,472,126	174,765	143,926	202,949
San Luis Obispo	1,553,126	41,484	1,624,526	35,734
Santa Barbara	951,637	62,635	966,803	71,501
Total	6,735,550	363,615	5,060,715	399,918
State Total	35,328,360	7,240,131	33,385,619	7,748,709

Farm Characteristics. Average farm size in both the U.S. and California has been increasing and the number of farms has been declining over the past decade. The general decline in the number of small farms is due largely to increasing economies. These trends are generally true for the coastal counties and to a slightly lesser extent for the state. There is considerable variation among coastal counties, as shown in Table 5-56. All counties from Monterey north lost farm acreage, but Mendocino County accounted for nearly 60% of that lost land, much of which was pasture land. This decline was offset slightly by increasing farm acreage in San Luis Obispo and Santa Barbara Counties, due to improved irrigation in those counties.

There have been several changes in the Socioeconomic characteristics of farm operators. In general, there has been a proportionate decline in the number of farm operators who live on their farm, and an increase in corporate ownership of farms. Although corporate ownership of farm acreage has increased more rapidly in the coastal counties than in the state as a whole, most other socioeconomic characteristics are comparable to those of the state, as shown in Table 5-57. Labor costs accounted for 21% of the region's farm production expenses, higher than the 17% figure for California. This difference is due to the fact that more crops which are grown in the region must be harvested by hand.

Table 5-56 Average Farm Sizes (in acres) in 1969 and 1974 for the Coastal Counties
(U.S. Bureau of Census, 1977; EDAW, 1979a, 1979c)

County	Number of Farms		Average Farm Size (in acres)		Loss of Farm Acreage 1969-1974
	1974	Percentage Change Since 1969	1974	Percentage Change Since 1969	
Del Norte	110	-10	163	-42	16,588
Humboldt	706	-22	1,092	+26	19,565
Mendocino	803	-20	840	-11	271,352
Sonoma	2,338	-17	252	+ 7	79,081
Marin	207	- 8	680	+ 2	34,290
San Mateo	30.5	-26	258	+26	5,815
Santa Cruz	661	+0.1	82	-11	7,012
Monterey	1,344	-17	1,271	+16	48,200
San Luis Obispo	1,292	-10	1,257	+16	+71,400
Santa Barbara	1,179	+ 8	820	- 6	+15,166
State Total	8,945	-11	671	+ 6	395,337
	67,674	-13	493	+ 9	

Table 5-57 Socioeconomic Characteristics of Farm Ownership in the Coastal Counties, 1974
(U.S. Bureau of Census, 1977; EDAW, Inc., 1979a; 1979c)

County	Farm Acreage	Acreages of Farms with Sales of Over \$2,500	Percentage of Farm Acreage Owned by Corporations (1)	Percentage of Operators with Farming as Principal Activity	Percentage of Operators Living on Farm Worked
Del Norte	17,924	14,219	9	39	64
Humboldt	771,157	727,112	4	57	70
Mendocino	674,907	611,252	2	48	66
Sonoma	588,077	546,481	6	51	66
Marin	140,748	133,200	3	65	65
San Mateo	78,699	73,258	27	57	38
Santa Cruz	53,948	46,201	10	60	55
Monterey	1,423,926	1,396,938	15	65	49
San Luis Obispo	1,624,526	1,587,768	28	51	60
Santa Barbara	966,803	908,807	20	50	50
Region Total	6,340,715	4,457,548	20	54	60
State Total	33,385,619	32,107,481	19	54	60

1. Farms with sales of over \$2,500.

In general, the coastal farms are slightly larger on the average than for the state, but a sizeable amount of farmland is used for unirrigated pastures.

The declining acreage in much of the region is due to sales of ranchland for non-agricultural uses, such as second home developments, or division into smaller parcels for investment.

Development Constraints. In the coastal counties, there are approximately 869,300 acres of soils in the coastal counties that could potentially become prime agricultural land, with only about 5% in areas of potential urbanization (Tables 5-52 and 5-53). There are many factors that limit the agricultural use of this land. One reason for non-conversion is the nature of the terrain. Many of those soils support ranchland, occurring on slopes or other areas where planting, irrigating, and harvesting would be difficult undertakings.

A more significant reason for non-conversion is economic. In several areas it has been found that owners of productive soils are not developing their land's potential for agricultural production because they are nearing retirement and hope to sell the land for development at a higher return than they would receive for the sale of any agricultural products they might otherwise produce (Baxter, et al., 1973; McDonald and Grefe, 1978). Although most of the potential prime soils do not occur in urban areas, they may be in good locations for conversion to rural subdivisions. In general, much of those lands have a higher value when sold for urban or rural development than they would have if the soils were used for agriculture. Land which has been subdivided is generally too small to utilize for commercial agriculture, although it may be usable for subsistence farming.

Another major economic constraint on further development of coastal agricultural land is competition with the more productive agricultural areas of the Central and Imperial valleys. Although this varies by product and by area, in general the scale of production that is necessary to compete economically with the Central Valley acts as an entry barrier to new agricultural production on the coast. This is mitigated by several factors, including lower transportation costs to Bay Area markets from certain coastal areas, and, more importantly, climatic differences between the two areas that put the coast at a competitive advantage in the production of certain crops, such as brussels sprouts and artichokes. In addition to market constraints, attempts to develop new areas of agricultural production, particularly on a small scale, are limited by a lack of access to venture capital and technologic assistance, the cost of various factors of production and diseases that flourish in the wet coastal climate (QRC Research Corporation, 1978).

A reason for the retention of ranchland in pasture rather than crop production is that the livestock industry in several areas is dependent on local grazing land. Although conversion of pastures to urban or rural development poses a greater threat, the development of crop cultivation on ranchland would force livestock owners to rely more heavily on feedlots. One of the factors that makes livestock production viable on the coast is the availability of relatively inexpensive grazing land (McDonald and Grefe, 1978).

Many of the presently and potentially productive soils along the north coast occur in areas that are subject to frequent flooding, such as the lower reaches of the Smith and Eel Rivers. Because of inundation by ocean tidal waters, flooding from rapid runoff, and poor drainage, many areas have never been developed for cropland. Many river terraces and bottomlands support rich dairy pasture in these north coast areas. Flooding and rain-softened ground require removal of cattle in winter in order to protect the pasture. Presumably because of the resulting increased cost of dairying, in addition to market considerations, beef cattle production is increasing in importance in those relatively flat areas (QRC Research Corporation, 1978).

An adequate supply of water for irrigation, together with irrigation problems posed by the topography of many areas, is another limiting factor to increased agricultural production. Competing demands for existing water from municipal and industrial users, occasional droughts and the lack of an irrigation network of the sort used in the Central Valley make it difficult for potential large-scale commercial agricultural producers to be assured of a constant and sufficient supply of water. By contrast, existing grazing operations on the coast generally do not require much irrigation above natural precipitation. Additional or alternative supplies of water are being developed in some areas. An extension of the California Aqueduct is being constructed into San Luis Obispo County from the Central Valley, while treated wastewater is being used for agriculture in some areas of Marin and Sonoma Counties (California Department of Food and Agriculture, 1978; Baxter, et al., 1973; McDonald and Grefe, 1978).

Social considerations may act as a general factor in increasing or decreasing agricultural productivity along the coast. In addition to the age of many farm owners (over 50 in most coastal counties) and economic considerations that inhibit further increases in productivity, an important influence is the cultural value placed on rural life by the owner (Baxter, et al., 1973). Younger people have migrated into rural coastal areas to get away from urban life and have developed small farms, which in most cases are geared to subsistence production and small amounts of local sales (Hancock, et al., 1977).

Political factors play a significant role in the development of coastal agriculture. Although policy at the state level is generally geared towards encouraging agriculture along the coast and discouraging non-compatible uses of productive land, efforts to pass legislation establishing a state-level commission to regulate use of prime agricultural land have so far been unsuccessful. Local policies are highly variable. Certain counties may not have zoning ordinances or planning guidelines that would encourage or protect agriculture, while others may have these but lack effective enforcement procedures. Some counties, such as Santa Cruz, have passed growth-control initiatives aimed at protecting agricultural land from development. Local policy decisions play a critical role, both in the conversion of land to agricultural use and the conversion of agricultural land to other uses. The Williamson Act, passed by the State of California in 1965, was created to enable counties to establish a lease-hold arrangement whereby owners of agricultural land could enter into a contractual arrangement with the county in return for making a commitment not to sell the land for non-agricultural development. The owner would receive considerable tax advantages. This has been generally ineffective as a means of increasing or maintaining land in agricultural use. Often, it has been used by developers as a tax shelter until it becomes politically or economically expedient to break the contract and develop the land. In other cases, lands that are held under the Act are in no danger of urban development, or the owners are unwilling or unable to continue or increase production on the land (Baxter, et al., 1973; McDonald and Grege, 1978; Hancock, et al., 1977).

Agricultural Production

Products. The coastal counties produce a wide range of agricultural products, including livestock and dairy products, vegetables, fruit, and flowers.

Livestock and livestock products are significant parts of the agricultural production of each county, with milk and cattle sales dominating farm receipts in all counties north of San Francisco. The dairy operations in these counties produce a significant amount of the state's milk production marketed mainly through cooperative creameries in Fernbridge, Petaluma, and San Francisco.

The livestock industry in those counties is heavily dependent on local grazing land. The 1,665,258 acres of pasture in those five counties represent about 25% of their total land area and nearly three-fourths of the land in farms. Hay grown and harvested for feed is a significant crop in terms of acreage, although not in value. Climatic changes, particularly droughts, affect both the carrying capacity of pasture and the volume of hay produced locally. Dairy operators, for whom food costs make up 80% of total costs, are particularly susceptible to changes in the local supply and price of food (McDonald and Grege, 1978). Although their costs fluctuate considerably, the price of milk is set by government policy.

South of San Francisco, brussels sprouts, nursery crops and artichoke production dominate the coastal terraces. Celery, cauliflower, broccoli, artichokes and brussels sprouts are all coastal dependent crops, grown most productively in the cool, moist climate found along those terraces. The coastal region is the primary national producing area for those crops, supplying 75% of the total U.S. brussels sprouts production in 1977 (California Department of Finance, 1978).

A much broader range of agricultural production occurs south of the Pajaro River. Monterey, San Luis Obispo, and Santa Barbara Counties derive less than one half of their agricultural sales from three crops, reflecting a more diversified agricultural base, while the seven counties to the north are heavily dependent on a few crops as shown in Table 5-62. This table also illustrates the relative production value earned in those three counties. Together, they accounted for 69% of the total value of agricultural production in the coastal counties. This percentage would be considerably lower in the coastal study area due to the exclusion of much of the central and all of the upper Salinas Valley, in Monterey County, and the Sonoma Valley area of Sonoma County. Agricultural production in most other coastal counties takes place within the study area boundary.

Horticulture and floriculture, particularly involving greenhouse production, have been increasing fairly rapidly in recent years in both volume and value along the coast, becoming a major source of agricultural income in several counties. It is a form of production well-suited to certain areas because of its low acreage requirements, minimal seasonal fluctuations in both value and employment, and relatively high sales value per unit of production (Hancock, et al., 1977). However, construction of green-houses has occurred in certain areas on otherwise useful prime agricultural land, precluding use of the soil for cultivation (California Coastal Zone Conservation Commissions, 1975).

Due to a continued high demand for California wines, production of wine grapes has become increasingly important throughout the region. Sonoma County has doubled its already considerable acreage of wine grapes in the past eight years. A large portion of the investment in Sonoma's crop has come from outside the county and has included some foreign investment (McDonald and Grefe, 1978; San Francisco Examiner, 16 November, 1979). Mendocino County grapes account for 30% of county farm sales. In Sonoma County, grapes, apples, and fruit CROPS account for the same share of sales. In both counties, apple orchards are being replaced by vineyards. Grape production also occurs south of Gonzales on the border of the coastal study region, in Monterey County.

Other major crops produced in the study area are berry crops, apples, and lettuce. Apple orchards, frequently located close to urban areas, are often subject to development pressures. Additionally, apples grown in Sonoma County are considered inferior in quality to Washington State apples, and tend not to bring as high a price (McDonald and Grefe, 1978). Watsonville in Santa Cruz County remains an important apple production area. Significant acreage in Sonoma and Mendocino Counties has been converted to other crops, such as pears and grapes.

Lettuce is the dominant crop from Santa Cruz south and is particularly important in the Salinas Valley in Monterey County. It is the dominant crop in that county, both in crop acreage and value. Coastal lettuce is harvested in spring and summer, while lettuce grown in the Central Valley is harvested mainly during fall and winter. The coastal region is, for part of the year, a primary source of the nation's lettuce.

Selling of timber on farmland is important to certain areas of the north coast, although environmental regulations restrict logging of woodlots to supplement farm income (QRC Research Corporation, 1978). Attempts to convert timberland on farms to grazing pastures have met with very little success in Mendocino and Sonoma Counties, often resulting in otherwise productive agricultural land being overgrown with low-value hardwoods (Oswald, 1972).

Volume and Value. The volume of agricultural goods produced is usually expressed in bushels, tons, head of livestock, or other measures unique to specific commodities. While the variety of measures of volume hinders comparison of total volume geographically or over time, such comparisons can be made for individual commodities or commodity types and may serve as an indicator of the well-being of a farm economy. The volume of production is affected by the land and water environment, soil quality, erosion, rainfall, drainage and other factors. It is also directly and indirectly related to economic factors, including technological improvements, the price and supply of labor, capital, land, and the national and international food supply situation. Frequently, in the south-central coastal counties more than one crop may be grown at different times on the same land. This practice, known as double-cropping, increases the volume produced on such land, and makes it necessary to distinguish between farm acreage or actual land area, and crop acreage or amount of harvested land. Table 5-58 gives a summary of volume and value of certain coastal crops as a proportion of state totals.

Table 5-59 indicates that crop acreage has declined in most counties north of Monterey since 1964, while increasing considerably in Monterey, San Luis Obispo and Santa Barbara Counties. This table also shows the crop acreage as a percent of total farm acreage.

Table 5-58. The Percentage Contribution (of Acreage and Value) of Non-grain Crops in Coastal Counties to the State Total in 1969 (Barbe and Snow, 1973?)

crop	Acres	Value
Artichokes	100	100
Asparagus	4	4
Beans, green lima	18	21
Beans, green snap	15	23
Broccoli	90	94
Brussel Sprouts	100	100
Cabbage	26	30
Carrots	26	34
Cauliflower	73	75
Celery	52	56
Cucumbers	3	4
Lettuce (head)	47	46
Green Peas	3	19
Bell Pepper	6	7
Potatoes	12	14
Spinach	41	39
Tomatoes (all)	4	11
Apples (all)	88	86
Avocados	11	12
Lemons (all)	11	12
Strawberries	45	41
Pasture - Irrigated	5	5
Pasture - Other	13	14
Cut flowers	---	34
Nursery products	---	18

Table 5-59. Croplands (.Acres). and Percentage Change from 1964 to 1974 in Coastal Counties (California Department of Finance, 1978)

County	Harvested Cropland (in acres)		Percentage Change	Percentage of Total Farm Acreage
	1964	1974		
Del Norte	3,879	3,292	-15	19
Humboldt	18,877	15,110	-20	2
Mendocino	25,808	24,161	- 6	3
Sonoma	83,771	79,321	- 5	13
Marin	5,523	4,359	-21	3
San Mateo	16,020	10,840	-32	14
Santa Cruz	27,080	16,793	-38	31
Monterey	234,857	261,514	+10	18
San Luis obispo	163,361	186,847	+13	11
Santa Barbara	90,010	90,702	+ 1	9
Region Total	669,126	692,939	+ 4	11
State Total	7,837,133	8,213,237	+ 5	24

Santa Cruz County has the highest percentage of harvested acreage in the coastal counties, indicating fairly intensive crop production in that county. The lower percentages for many counties indicate the relative importance of ranchland and unharvested pastureland. In general, the coastal counties have experienced the same increase in productivity of cropland as has occurred in the state as a whole, although most counties in the region have experienced a decline in harvested acreage. The region has a much lower proportion of its farmland in crop production, due to extensive use of the land for rangeland. The data in Table 5-59 indicate an increase in the volume of crops produced in the region, and that crop production is becoming concentrated in the southern counties. The volume of livestock has declined slightly in the region overall in terms of head of cattle, largely because of a large decline in livestock in Monterey County. This has occurred in conjunction with a significant decrease in pasture acreage in that county, due to conversion to cropland and urban use (Recht/Hausrath, 1978).

The value of agricultural commodities is a function of supply, demand and certain other factors. The selling price of a commodity grown in a particular area is dependent on the overall supply of and demand for that commodity, competition with similar crops grown in other areas, relative transportation costs and access to markets. The process whereby the actual price offered for a crop is determined is extremely complex, involving futures markets, brokers, processors and, as is the case with milk, government policy. The total value of agricultural production in the region's counties is shown in Table 5-60. The value figures supplied by farmers to the County Agricultural Commissioners are gross sales figures, and do not reflect the costs of production. Although it would be more useful to relate value figures to farm acreage, a value-per-acre figure for the region's counties would be deceptive. Cultivation of some of the crops with the highest sales, such as nursery and greenhouse products, takes place on minimal acreage, while the generally high-value livestock and dairy production takes place on extensive acreage. The gross dollar value of sales remains the most uniform and accessible data on the value of the region's agricultural production, and is therefore used here as the primary indicator of production trends.

Table 5-60. Value (in thousands of dollars)
of Agricultural Production, Coastal
Counties in 1969, 1974, and 1978

County	1969 ¹	1974 ²	1978 ²
Del Norte	3,606	7,675	11,299
Humboldt	15,982	22,153	33,553
Mendocino	13,181	25,891	36,275
Sonoma	68,782	123,407	154,778
Marin	13,898	22,643	29,245
San Mateo	20,171	44,098	73,675
Santa Cruz	70,467	66,561	109,956
Monterey	185,253	387,037	658,494
San Luis Obispo	54,220	84,951	165,457
Santa Barbara	82,423	151,426	208,076
Total	527,983	935,842	1,480,808

Source: 1. U.S. Department of Commerce, 1977;
2. County Agricultural Commissioners, 1967-1979.

The value of agricultural production occurring in the study area is approximately 25% of the coastal county total, as shown in Table 5-61. This low percentage is due to the high proportion of crop and livestock production that occurs in the inland valleys, and the relatively low production value of rangeland, which dominates the study area. Exceptions are Santa Cruz, San Mateo and Del Norte Counties, where nearly all of the agricultural county production occurs within the study area.

Table 5-51. Estimated Value (dollars x 1,000) of Agricultural Production in the Study Area and its Percentage Contribution to the Total for California (Barbe and Snow, 1973; EDAW, Inc., 1979a, 1979c)

county	Percentage in Coastal Area	Coastal Area Value, 1978 (in thousands)
Del Norte	100	11,299
Humboldt	51	17,045
Mendocino	8	2,757
Sonoma	8	12,382
Marin	8	2,340
San Mateo	98	72,201
Santa Cruz	100	109,956
Monterey	8	52,679
San Luis Obispo	26	43,019
Santa Barbara	20	41,615
REGION TOTAL		365,293

To varying degrees, coastal counties are dependent on only a few crops for most of their agricultural sales. Table 5-62 shows the percentage of total agricultural value accounted for by the three major crops in each county. The table also illustrates the greater diversity of agricultural production in Monterey, San Luis Obispo and Santa Barbara Counties, where each derives less than 50% of its total production value from three crops.

Vegetable crop production is the primary source of agricultural value in the coastal region as a whole. As shown in Table 5-63, the share of the coastal counties' total production value represented by vegetables has been increasing. The proportionate value of fruit crops, and cut flower and nursery production have also been increasing, while livestock and food crops have declined. Livestock, and poultry and related products accounted for 36% of agricultural sales in the state in 1974, while nursery and greenhouse production accounted for only 5%. Vegetable crops comprised 17% of the state's sales, and orchard crops 14%. Regional agricultural sales for all crops were 13% of total state farm sales in 1974.

Crops that do not appear in the previous tables are marijuana and timber. Marijuana is grown in many areas along the north coast, particularly in Humboldt and Mendocino Counties, and is generally cultivated close to the coast.

Growers operate with low overhead, harvesting the crop themselves. The risk involved is compensated by a high sales price which, together with the low overhead, makes it a very profitable crop to cultivate. Data on crop value are notoriously unreliable, 'out the value of Mendocino County's 1978 marijuana harvest was estimated to be between \$35 and \$413 million dollars (Randy Shilts, KRON News, November 1978). Marijuana sales have been a source of economic stimulus to several rural areas in this north coast region. As a result, cultivation has been tacitly tolerated by many authorities.

Sales of timber are considerably greater than agricultural sales in the north coast region. Total stumpage value in Mendocino County was \$93,750,000 in 1978, and the value of logs sold to mills totalled \$132,000,000. These figures compare to Mendocino County's total 1978 agricultural sales of \$36,257,000. Given the dominance of forest land along the north coast, these figures are particularly significant with respect to the study area.

In general, most of the production occurring in coastal counties is exported from the region. Exceptions include hay production, frequently used by local livestock production; subsistence farming which occurs in many areas along the north coast; and terrain products, such as grapes, which are processed in the region.

Table 5-62. The Three Major Crops in the Coastal Counties as a Percentage of the Value (dollars) of all Crops in 1978
(County Agricultural Comm., 1967-1979; EDAW, Inc., 1979a, 1979c)

County	Major Crops	Percent of Three Major Crops	
		Total Value	% Total Value
Del Norte	Nursery Products	6 0%	94%
	Cattle	17%	
	Milk	17%	
Humboldt	Milk	51%	69X
	Cattle and Calves	11%	
	Nursery Trees	7%	
Mendocino	Grapes	30%	53%
	Pears	15%	
	Cattle	8%	
Sonoma	Milk	30%	6 0%
	Wine Grapes	20%	
	Cattle and Calves	10%	
Marin	Milk	62X	85X
	Cattle	16%	
	Eggs	7%	
San Mateo	Potted Plants	42%	63%
	Cut Flowers	17%	
	Nursery Stock	4%	
Santa Cruz	Apples	23%	51%
	Strawberries	15%	
	Lettuce	13%	
Monterey	Grapes	7%	48%
	Broccoli	7%	
San Luis Obispo	Lettuce	24%	48%
	Cattle	16%	
	Celery	8%	
Santa Barbara	Lettuce	12%	30%
	Avocados	9%	
	Cattle	9%	

Employment. Agricultural employment in the region is concentrated in Santa Cruz, Monterey, San Luis Obispo and Santa Barbara Counties. Data on agricultural employment are limited. Varying estimates exist in current state reports due to the recent inclusion of agricultural services in California Employment Development Department wage and salary employment reports and other baseline revisions. Differences in data do not appear to have been reconciled. Table 5-63 gives estimates available for all ten counties. In addition, part-time employment and the lack of data on family workers, who are generally not counted, distort agricultural employment estimates.

Agricultural wage employment in the region is estimated at 36,592, or 6% of the region's work force (Table 5-63). If self-employed farmers were added to this figure, total agricultural employment would be approximately 46,228. The range among coastal counties is estimated to be from 15% of total employment in Monterey County to 1% in Marin and San Mateo Counties. Agricultural employment is somewhat higher on the coast in proportion to production than is the case in the state as a whole. Displacement of workers through mechanization of crop harvesting has generally occurred at a lesser rate on the coast than in the state as a whole. Table 5-64 shows the proportion of farm production expenditures spent on labor for coastal counties.

The lower percentages in Marin, Sonoma and Humboldt Counties reflect the lesser dependence of the dairy and livestock industries on hired labor. Field, orchard and greenhouse production tend to require greater amounts of labor.

Table 5-63. The value (dollars) of Major Agricultural Products and Their Contribution (percentage) to the Total Agricultural Value in Coastal Counties in 1974 and 1978 (County Agricultural Commissioners, 1967-1979; EDAW, 1979a, 1979c)

Product	1974		1978	
	Dollars	Percent of State Total	Dollars	Percent of State Total
Fruit and Nut Crops	130,258	14	255,406	17
Vegetable Crops	361,365	39	654,231	44
Field Crops	105,254	11	81,496	5
Cut Flowers	70,585	7	125,530	9
Seed Crops	10,968	1	8,365	1
Livestock, Poultry, Apiary	234,935	25	271,721	18
Nursery Products	22,672	2	38,476	3

Table 5-64. Estimated Agricultural Employment¹, in Coastal Counties, 1977 (California Employment Development Department, 1979b; EDAW, Inc. 1979a, 1979c)

county	Agricultural Employment	Percent of Total Employment
Del Norte	466	8
Humboldt	636	2
Mendocino	1,027	5
Sonoma	3,589	5
Marin	862	1
San Mateo	2,766	1
Santa Cruz	4,293	8
Monterey	15,551	15
San Luis Obispo	1,678	4
Santa Barbara	5,724	5
REGION TOTAL	36,592	6

1. Estimates for the northern counties are derived from employment data for agriculture, forestry, and fisheries combined.

Agricultural employment is highly seasonal, varying statewide by 25% from the yearly average. Within the coastal counties this varies considerably by county. Peak employment in Santa Cruz County was 49% above the annual average in 1978, similar to Monterey County (California Employment Development Department, 1979b). Employment in Mendocino County varied by 25% from the annual average. The peak period is generally from June to September, although crops with a late harvest, such as apples, may extend that period in certain areas.

Migrant farm workers are a primary source of labor for the harvesting of fruit and vegetable crops from San Mateo County south. Adequate housing for temporary and permanent farm workers has been a problem in Santa Cruz County (Santa Cruz County Low Income Housing Commission, 1969). Wage rates and contracts for farm workers are significant issues in this area, as they are in most agricultural regions in California.

Table 5-64a. Labor as a Percent of
Farm Production Costs in 1974
(U.S. Department of Commerce, 1977)

County	Percentages
Del Norte	30
Humboldt	10
Mendocino	22
Sonoma	14
Marin	8
San Mateo	35
Santa Cruz	33
Monterey	26
San Luis Obispo	16
Santa Barbara	17
STATE AVERAGE	17

Farms from Marin county north do not rely as heavily on migrant labor as do the southern counties. This is mostly due to the dominance of the dairy and livestock industries in those counties, which generally require a year-round work force. Working conditions in smaller dairies are often difficult, requiring split shifts and limited numbers of days off. This has made it difficult for smaller dairies to attract skilled and reliable labor (Baxter, et al., 1973).

The application of new technologies to agricultural production has had a marked effect on all aspects of farming, but has had a particular impact on employment. Mechanization of harvesting operations for certain crops, such as tomatoes, has resulted in a significant displacement of hired farm workers (Recht/Hausrath, 1978). While mechanization of the grape harvest has occurred in the Central Valley region, it has not been applied to north coast areas. Farm size, special planting methods needed for machine harvest, and growers' concerns with mechanical damages to vines and grapes have acted to prevent mechanization of the grape crop in this area (McDonald and Grefe, 1978). Mechanical lettuce harvesters have not been fully utilized in the Monterey area, apparently for technological reasons (Recht-Hausrath, 1978). Other types of agricultural technologies include pesticide use, fertilizer application and irrigation systems.

In general, technological innovations in agricultural production favor large farms. The financial resources necessary to adopt new technologies are not readily available to small-scale farm operations, while the volume of production necessary to make the application of certain new technologies cost-efficient tends to favor larger farms. The continuing trend toward more capital-intensive agriculture is causing some displacement of farm workers and is increasing the competitive advantages of crops produced on large farms, thus tending to reduce the economic viability of small farms (Recht/Hausrath, 1978; Moulton, 1974; Baxter, et al., 1973). Another consequence of the increasing economic advantages held by large-scale capital-intensive agricultural operations is a widening income gap between farm operators, so that the distribution of income in agriculture tends to become increasingly uneven (Moulton, 1974). These trends are generally true for coastal agriculture as it must compete with production from inland areas, where productivity increases due to technological changes are occurring more rapidly.

Agricultural Processing

Products, Value Added and Volume. Agricultural processing is an important activity throughout much of the region, although its significance varies by county and by season. The most important coastal food processing activities include wineries in Mendocino and Sonoma Counties, poultry products in Sonoma County, fresh and processed milk in Sonoma, Humboldt and Marin Counties, processed apples in Santa Cruz and Mendocino Counties, and miscellaneous fruit and vegetable processing in Santa Cruz, Monterey, San Luis Obispo and Santa Barbara Counties. Certain commodities, such as grapes, are almost entirely processed, while only a portion of other crops are sold for processing. That portion depends on, among other factors, the quality of the

harvested crop and the market value of the fresh produce relative to that of the processed product.

For the most part, value-added and volume-produced data for agricultural products processing are combined with similar data for fish products processing, bakery products, and other food and kindred products. Some gross estimates are available for various geographic areas (i.e., individual counties, the state and the United States), but no estimates with sufficient level of detail are available for the specific study region. Extensive, specific data relating to the portion of total "food and kindred products" that is the direct result of agricultural activities are available only on a limited basis.

Employment and Income. The significance of agricultural processing and processing employment is generally related to the type and productivity of local agriculture. For example, approximately one-third of Sonoma County's food processing employment and one-half of its payroll are in wine production, which depends on the local grape crop (McDonald and Greife, 1978). Livestock, wine, dairy and fruit processing, all of which are largely dependent on local production, accounted for 15% of the employment and payroll in Sonoma County's manufacturing sector in 1977 (U.S. Bureau of Census, 1979). Marin County's livestock and dairy production does not support much local processing activity, as much of that production is processed in Sonoma County and in the San Francisco-Oakland area (Baxter, et al., 1973).

County Business Pattern data give some indication of the importance of agricultural processing in the coastal counties. In many counties, actual counts are suppressed to avoid disclosure. However, a general range of employment may be derived, as shown in Table 5-65. The fact that the data are collected out of season (March 12) suggests that agricultural processing employment could reach 18,000 persons during the peak months, although the annual average is approximately 9,182-10,500. Comparison with data for the Monterey Bay region suggests that the upper figure in the range is the more accurate of the two (Recht/Hausrath, 1978). Data which are broken down for the study area itself are not available; however, Santa Cruz County's processing sector is located entirely within the study area. Vegetable and fruit processing in this county accounted for nearly one-third of total coastal processing employment.

While agricultural employment is likely to decline on the coast, food processing employment will expand in some areas. An overall increase in this sector of 24% has been projected in Santa Cruz and Monterey Counties, for the period 1976-1995 (Recht/Hausrath, 1978). This is primarily due to increased productivity in agriculture in the region, generating more food to be processed. This agrees with California Employment Development Department projections, although the Department also indicates working conditions in food processing plants in the Monterey area are poor.

Table 5-65. Numbers of Agricultural Establishments and Probable Numbers of Employees by Size Group in the Coastal Counties in 1977 (U.S. Bureau of Census, 1979)

County	Total Establishments	Number of Employees Per Size Group								Numbers Employed (Range)
		1-4	5-9	10-19	20-49	50-99	100-249	250-499	500-999	
Del Norte		.	-	-						
Humboldt	2		.	.	2	-	-			20-49
Mendocino	6	4	2		-	-	-			24-74
Sonoma	59	17	11	13	6	5	7			1,737
Marin	12	9	-	1	2	-	-			60
San Mateo	10		1	1	1	4	1	.		387-547
Santa Cruz	21	2	-	-	5	3	3	1	3	3,198-3,280
Monterey	11	2	1	2	-	1	3	2		1,506
San Luis Obispo	18	9	2	6	-	1	-		-	172
Santa Barbara	8	-	-	1	3	1		3		880-1,705
Total										7,984 -9, 130
Adjusted Average Annual Total										9,182-10,500

Distribution and Markets. Data on distribution and marketing of farm products and food processing products are not available at a regional level. A 1973 study of Santa Cruz County's economy estimated that 97% of the county's agricultural processing was sold out of the county (Goldman, et al., 1976). A similar study of Sonoma County shows a slightly lower proportion of processing sales to be exported, while only 33% of processed feed was sold out of the county, due to high demand for feed by the local livestock industry (Goldman, et al., 1977). Marin County showed only 60% of processing as being exported, while 92% of the production of the dairy industry was exported (Goldman, et al., 1973). Most of the dairy production in Marin and Sonoma Counties is marketed through cooperatives to processors and wholesalers in the San Francisco Bay area (Baxter, et al., 1973; McDonald & Grefe, 1978).

Summary and Effects

Summary. The previous discussion has indicated the relative importance of agriculture and agricultural processing as a basic industry in the region. Agriculture represents a significant land use in this region, and coastal agricultural production is highly valuable as a source of employment, income and sales, as well as a source of crops that may not be produced as efficiently in other areas. Agriculture is under a considerable amount of pressure in many areas as urban and rural development compete with it for suitable soils. Although this has resulted in an absolute decline in actual farm acreage, agricultural productivity is increasing overall, as technologic changes in irrigation and production methods make more intensive use of existing farmland possible. These changes, in turn, have caused decreases in employment in harvesting, have lessened the economic viability of small farms, and have had several environmental effects. Productivity increases, occurring in the four southern counties of the region, have generally resulted in a higher volume of crop production per acre.

Natural and Socioeconomic System Effects. Although the impacts of agricultural production can vary considerably by area and type of production, some general effects may be described.

Dairy production in several areas occurs on feedlots, especially during winter months. Rainfall runoff from these feedlots has an extremely high biological oxygen demand from 10 to 100 times that of untreated municipal sewage due to mixture with manure. The runoff entering streams and lakes can cause oxygen demand depletion and may result in fish kills and "long-term undesirable ecologic effects" (Wetherow, in Baxter, et al., 1973). In addition, disposal of feedlot manure on land can contribute significant amounts of salt to the groundwater through percolation. The cost of meeting requirements to reduce these types of pollution through new disposal techniques and construction of collecting ponds has been quite high for certain dairies, and, together with rising food costs, has forced several dairies to go out of business (McDonald and Grefe, 1978; Baxter, et al., 1973). Further reductions in pasture land through conversion to other uses would result in more widespread use of feedlots, further aggravating pollution problems in certain areas. Conflicts with residential areas through dust, flies and odors are other problems associated with dairy, livestock and poultry production.

Pesticides are widely used on crops in the region, although the most intensive use occurs in the southern counties. Pesticides can have long-term and often unknown effects on food chains, soils and water. In addition, pesticides may have harmful effects on persons who directly handle them, and on those exposed to their aerial application to crops. Pesticides transported through runoff have affected the water quality in certain areas, though they have generally not had as serious a contaminant effect as has industrial and municipal wastewater disposal. A discussion of pesticides and alternative means of pest control is found in Barbe and Snow (1973) and California Department of Food and Agriculture (1978).

The nutrients in the water runoff from fertilizers on agricultural land have an adverse effect on water quality that is similar to that of runoff from feedlot areas; i.e., high nutrient levels depleting the dissolved oxygen content of streams, leading to eutrophication.

The use of irrigation water has many natural and social system effects. The source of irrigation water varies among counties and locales. In some cases groundwater supplies much of the water, in others surface water is the dominant source. Currently, no water from the California Water Project is imported into the study area, although a proposal has been made to extend a portion of the San Felipe Water Project into the Salinas Valley. Extension of water to agricultural areas in Santa Barbara

and San Luis Obispo Counties is an issue in three areas. While increased irrigation demand is frequently used in support of arguments for new water projects, such water, once supplied, also tends to increase the potential for urban development in an area, with effects on agricultural land.

The increasing level of agricultural productivity has had several effects. Increases in productivity due to mechanization have resulted in a net displacement of hired farm labor as the demand for persons who harvest crops has declined, while the demand for those skilled in handling mechanical harvesters has increased slightly. Increasing levels of productivity due to greater irrigation places a heavier demand on existing water supplies, conflicting with water demand from municipal and industrial users, including agricultural processors. An economic effect of increasing productivity has been to orient farm production toward large-scale operations, making it increasingly difficult for newcomers and small operators to enter competitively into agricultural production.

An initial effect of agricultural production is the removal of natural vegetation and habitat. This has implications for a wide range of natural systems, particularly in sensitive areas such as the Watsonville slough. The extraction of groundwater for irrigation has led to overdrafting of the groundwater table in some areas, causing salt water intrusion. Diversion of surface water for irrigation reduces stream flow, changes sedimentation patterns and, through dam construction, increases turbidity, with consequences for downstream aquatic life. Having been used for irrigation, water returning to the hydrosphere may contain fertilizer and pesticide residue.

Agriculture plays an important role in the sociocultural makeup of many communities, providing an important lifestyle to many involved in it, and in certain locales may be the central source of employment and income. Agriculture also plays a significant qualitative role on the coast, being an important component of the visual environment. Coastal agricultural preservation is a general policy goal on the state level, although as discussed previously, its importance to local policies varies considerably.

Future Outlook. The reasons for the decline in agriculture as a land use in most of the region have been identified in earlier portions of this section. They include conversion of agricultural land to urban and rural development, declining economic viability of many types of farming activity, and low value of pasture land relative to other uses.

Coastal agriculture has generally tended towards forms of production which use land areas more intensively, including nursery and greenhouse production and farming methods such as double cropping (Barbe and Snow, 1973; Recht/Hausrath, 1978; QRC Research Corporation, 1978). Given the continued pattern of urban and rural development along the coast, this trend will likely continue. Several types of less intensive agricultural production have been recommended for the coastal area. These include an integrated wool-processing operation in Mendocino County which would take advantage of a local supply of crafts workers, and a combined grazing ranch and recreation operation, which would preserve grazing land while supplying income from fees charged for recreational use of the land. Other recommendations are discussed in Hancock, et al. (1977); McDonald and Grefe (1978); William W. Randolph and Associates (1977); and Baxter, et al. (1973).

Essential support for small-scale or extensive agricultural production are local planning and zoning programs that act to protect farmland from urban and rural development, as well as increased access to financing and necessary infrastructures for small farmers. This is in addition to state policies which may be effectively implemented and enforced on a local level.

EXTRACTION AND MINERAL INDUSTRIES (INCLUDING OFF SHORE OIL AND GAS DEVELOPMENT)

The extraction and mineral industry as explained in Volume 1, Conceptual Model, has been defined to include a variety of diverse activities that are combined for convenience because of frequently similar interactions with natural systems. Mineral resources in the Conceptual Model have been defined to include energy raw materials (oil, natural gas, geothermal steam) along with construction minerals (sand, stone, gravel), metallic minerals (gold, silver, copper) and other non-metallic raw materials (salt, feldspar, diatomite). Included under energy raw materials and receiving special attention in this section are offshore oil and gas resources, especially those of the outer continental shelf (OCS). Although there has been no OCS production to date off the central or northern California coast, recent exploration, leasing activity and trends in the nation's supply, demand and price of energy indicate a potentially significant role of OCS oil and gas in the future of the coastal economy.

Offshore oil was first extracted in 1897 in the United States, when 400 shallow wells were drilled from wooden piers, adjacent to a coastal oil field discovery near Santa Barbara. In the late 1930's and early 1940's, oil rigs set up in coastal marshlands of Louisiana followed oil-bearing geological formations out into the Gulf Coast (Oregon State University Sea-Grant College Program, 1978.) Eventually, exploratory wells and rigs were set up on the Gulf's outer continental shelf, more than three miles offshore.

Initial development of federal OCS lands in California began in 1963 with the issuance of 57 leases to allow for oil and gas development in six geological basins between Point Conception and the Oregon border. These leases were abandoned in 1967 after 21 exploratory wells could not find a commercially recoverable oil discovery (California Office of Planning and Research, 1977).

Attention then turned to Southern California where a history of successful onshore production indicated potentially abundant yields from offshore areas. Between 1966 and 1968, the federal government sold leases in the Santa Barbara Channel area. Exploration was successful with preliminary indications that hundreds of millions of barrels of oil lay under the Channel. Production began, but was abruptly halted following the catastrophic 1969 blow at the Union Oil Platform A, located in the Don Cuadros field near Santa Barbara. Until 1976, as a result of a moratorium, no offshore development plans were submitted to the federal government (California Office of Planning and Research, 1978).

Renewed interest in federal OCS oil and gas development in California began with the 1973 oil embargo and a national policy to reduce reliance on foreign oil imports by encouraging domestic oil and gas production. The United States Geological Survey began extensive OCS exploratory surveys and an accelerated OCS leasing program was enacted (San Luis Obispo County, 1979).

The initial lease sale of interest to the northern and central California coast is Lease Sale #53, scheduled for bidding in May, 1981. This proposed sale involves 243 nine-square-mile tracts (5,760 acres) within five subsea basins between Point Conception, in Santa Barbara County, and the Oregon border. Two additional lease sales, #73 and #80, are scheduled by the Department of Interior's Bureau of Land Management (BLM) for the California coastline in May, 1983 and June, 1984 respectively. Leasing tracts for sales #73 and #80 have not yet been identified and may include portions of the outer continental shelf off the northern and central California coast (Noah Tilghman, California Coastal Commission, personal communication, 9 December 1979).

Resources

Mineral deposits along the coast are shown in Figure S-7, Distribution of Mineral Resources in California.

Non-Energy Resources. Diatomite is presently the most significant non-fuel mineral resource found within the study area. Diatomite is a fine powdered earth used in industry as a filler, filtering agent, absorbent, clarifier and insulator. The Lompoc area of Santa Barbara County is the largest source of diatomite in the world. This area produced 379 short tons in 1977, valued at \$43 million, exceeding the total value of all other non-fuel minerals produced in the 10-county study area. The 1978 production of these mines provided a 58 percent share of all diatomite produced in the nation (U.S. Bureau of Mines, 1979). The two major operators in the Lompoc area are the Johns-Manville Company and Grefco, Inc.

Although not evident in Figure 5-7, production of sand, gravel and stone is sizable in all the counties of the study area. Due to the low value of construction materials, their weight, transportation costs, and relative abundance in other areas, they are normally consumed locally. However, consideration has been given to extraction of sand and gravel from bars near the mouth of the Eel River for barge transport to southern California. Such interbasin export awaits evaluation of the impact of extraction on the river and adjacent ocean beaches (EDAW, Inc., 1979a).

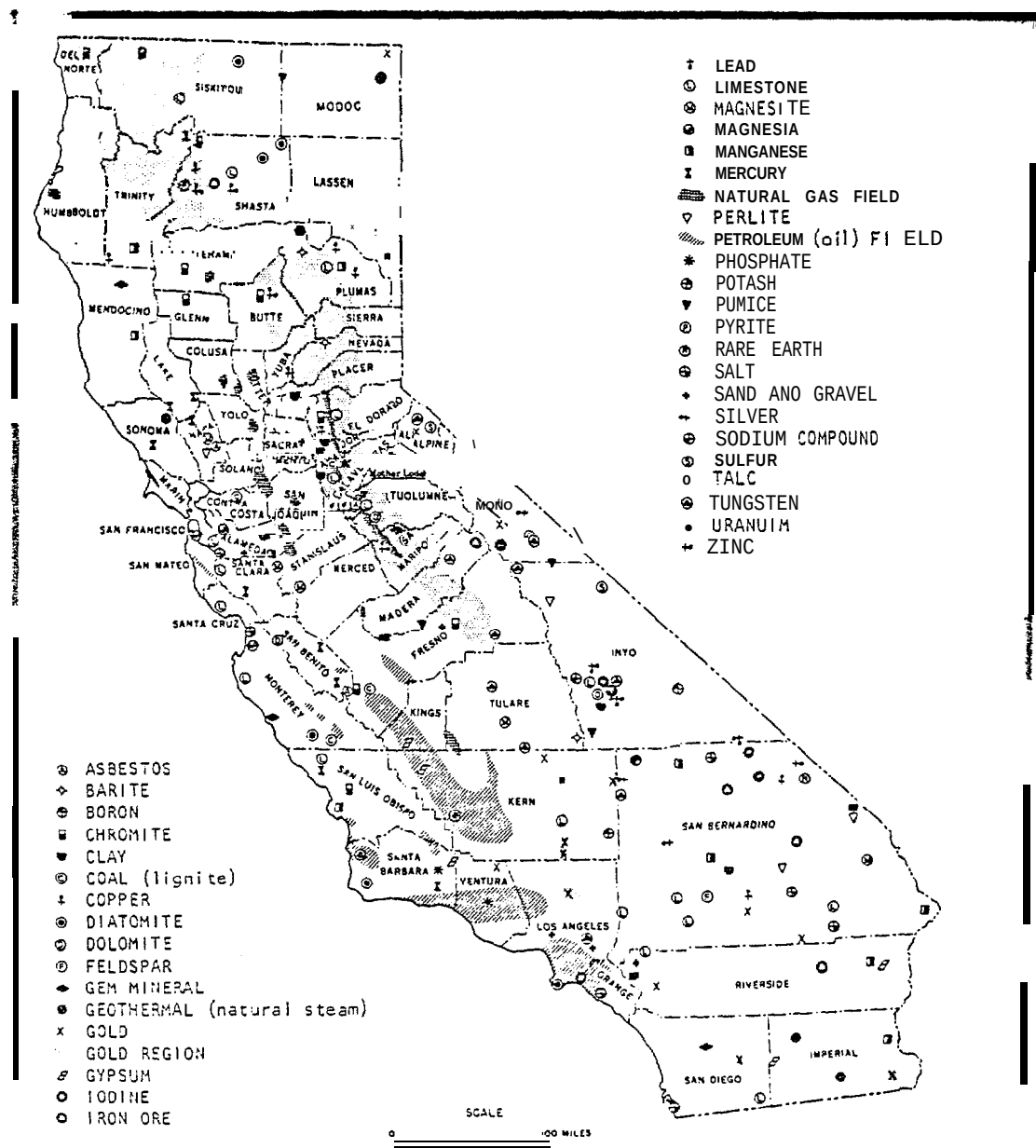


Figure 5-7. Distribution of Mineral Resources in California (California Division of Mines and Geology, 1966)

Few metallic minerals are found in the study area. In 1975, small amounts of gold and silver were recorded from a placer mine in Del Norte County (U.S. Bureau of Mines, 1976). Chromite and nickel also occur in Del Norte County. Deposits at Gasquet Mountain are being evaluated by the California Nickel Company for possible production (see Smith River Watershed Unit description in Volume IV).

Until recently, the mercury (or quicksilver) deposits of California have been the most productive in the United States and provided a significant proportion of the total value of the state's mineral production. California's deposits lie in a belt extending through the California Coastal Ranges from central Lake County southward to Santa Barbara County. In 1966 these ranges contained the nation's eight most productive mines. Within the 10-county study area, significant deposits have been found in San Luis Obispo, Santa Barbara, Sonoma and San Mateo Counties (California Division of Mines and Geology, 1966).

The price of mercury has dropped enormously, from \$700 per flask in 1965 to about \$120 per flask in 1976, leading to a similarly stunning drop in California production, from 10,291 (76-pound) flasks in 1964 to 196 flasks in 1976. The value of mercury production dropped from \$3,240,000 to \$36,000 between these years (California Division of Mines and Geology, 1966; Bureau of Mines, 1976).

Lime, feldspar, phosphates, salt, magnesium compounds and pumice are also found in various parts of the 10-county study area (see Figure 5-7 and Table 5-68, Mineral Production in North and Central Coastal Counties of California, 1977).

Energy Resources. Energy raw materials within the study area are also shown in Figure 5-7. Onshore oil and natural gas resources are not abundant within the 10-county region. Productive natural gas fields are located on the Humboldt and Mendocino County coasts and oil and gas is produced in significant amounts from fields in Santa Barbara, San Luis Obispo and Monterey Counties (see Table 5-66, Oil and Gas Production in North and Central Coastal Counties of California, 1977). As of December 31, 1977, the 10 coastal counties had 9,045 proved acres of oil or natural gas (excluding areas of Santa Barbara County outside the study area), just 2.1 percent of Californians total (California Division of Oil and Gas, 1978).

Geothermal resources are utilized to generate electricity at the Geysers Geothermal Resources Area in eastern Sonoma County. More units are being added to Pacific Gas and Electric Company's operation there. With the completion of Unit #16, scheduled for operation by September, 1981, commercial steam production will generate a net of 1,018 megawatts of electricity per day (U.S. Bureau of Mines, 1979).

According to the California Division of Oil and Gas, California's estimated recoverable oil reserves, as of 31 December 1978 totalled 4.2 billion barrels. California's recoverable gas reserves, as of 31 December 1976, are estimated at 4.4 trillion cubic feet (California Division of Oil and Gas, 1979).

Considering both estimated reserves and cumulative state oil production as of December 31, 1976, 78% of California's present recoverable oil resources has been extracted (U.S. Bureau of Mines, 1976).

The United States Geological Survey has listed definitions of resource terms that apply to oil, natural gas and natural gas liquids. The following definitions are schematically presented in Figure 5-8.

Resources. Concentrations of naturally occurring solid, liquid, or gaseous materials in or on the earth's crust in such form that economic extraction of a commodity is currently or potentially feasible.

Economic Resources. Those resources, both identified and undiscovered, which are estimated to be economically recoverable.

Subeconomic Resources. Identified and undiscovered resources that are not presently recoverable because of technological and economic factors but which may be recoverable in the future.

Identified Resources. Specific accumulations of economic resources whose location, quality, and quantity are estimated from geologic evidence supported in part by engineering measurements.

Identified subeconomic Resources. Known resources that may become recoverable as a result of changes in technological and economic conditions.

Undiscovered Resources. Quantities of resources estimated to exist outside of known fields on the basis of broad geologic knowledge and theory.

Undiscovered Recoverable Resources. Those economic resources, yet undiscovered, which are estimated to exist in favorable geologic settings.

Reserves. That portion of the identified resource which can be economically extracted.

Measured Reserves. That part of the identified resource which can be economically extracted using existing technology, and whose amount is estimated from geologic evidence supported directly by engineering measurements.

Indicated Reserves. Reserves that include additional recoveries in known reservoirs (in excess of the measured reserves) which engineering knowledge and judgment indicate will be economically available by application of fluid injection, whether or not such a program is currently installed.

Demonstrated Reserves. A collective term for the sum of measured and indicated reserves.

Inferred Reserves. Reserves in addition to demonstrated reserves eventually to be added to known fields through extensions, revisions, and new pays.

Cumulative Production. The sum of the production for the current year and the actual production for each of the prior years.

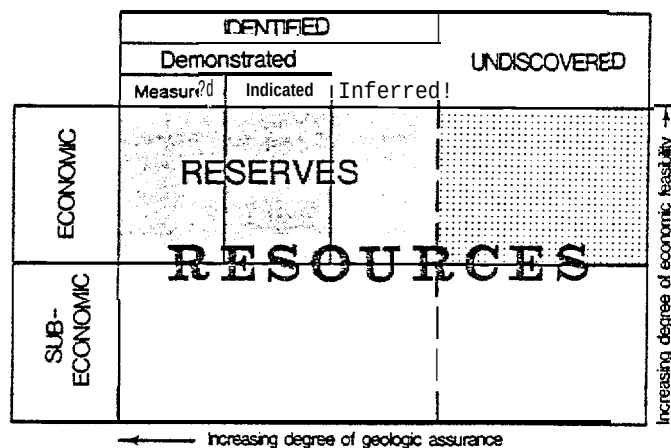


Figure 5-8. Petroleum Resource Classification by the U. S. Geological Survey and the U. S. Bureau of Mines (modified from McKelvey, 1973).

U.S.G.S. estimated offshore Pacific Coast oil and gas resources are listed in Table 5-67, along with resource estimates for the United States as a whole (both offshore and onshore). As of December 31, 1974, offshore Pacific Coast demonstrated or inferred reserves included 1.116 billion barrels of oil and 463 billion cubic feet of gas. These figures represent about three percent of the total U.S. demonstrated or inferred oil reserves and less than one percent of its demonstrated or inferred gas reserves (U.S.G.S., 1975a).

Undiscovered recoverable resources are expressed as an estimated probability range and as a statistical mean of that range. The offshore Pacific Coast is estimated to have between 2 and 5 billion barrels of undiscovered recoverable oil. The statistical mean of this range (3 billion barrels) represents 3.7 percent of the statistical mean of the estimated range of undiscovered recoverable resources in the nation as a whole.

The United States Geological Survey has also provided estimates of oil and gas resources in the five lease block areas proposed under Lease Sale #53. The areas

range seaward from 3 miles (the state territorial limit) to 27 miles and lie in waters from 162 to 2,437 feet in depth. Significant "shows" of oil and gas have been encountered in a stratigraphic test well 18 miles northwest of Point Conception (U.S. Bureau of Mines, 1979). Table 5-67 shows U.S.G.S. estimates of economically recoverable oil and gas resources for the five lease block areas shown in Figure 5-9.

The Santa Maria lease block area appears to have Lease Sale No. 53's largest reserve of economically recoverable oil and gas, according to the U.S.G.S. estimates. The onshore portion of this field had already produced 567 million barrels of oil as of April, 1978. Additionally, the State Resources Agency, which also conducts investigations for OCS oil and gas development, projects discoveries of 300 million barrels within the Santa Maria lease block areas, with only a 15 percent chance of not finding a commercially recoverable oil and gas resource, the lowest no-find percentage of all five basins within Lease Sale No. 53. The Draft San Luis Obispo County Local Coastal Program opines that "these resource estimates, combined with high oil industry interest in local offshore tracts and existing energy-related coastal facilities, including production, refining and transportation facilities along the San Luis Obispo coastline, support a conclusion that this region of OCS Lana Lease No. 53 will be the most likely site of near-future oil and gas production off Central and Northern California" (San Luis Obispo County Coastal Program, 1979).

Table 5-67. Production, Reserves and Undiscovered Recoverable Oil and GSS Reserves for the United States and the Offshore Pacific Coast, December 31, 1974 (United States Geological Survey, 1975a)

	Oil (billions of barrels)		Gas (trillion cubic-feet)	
	Pacific Coast Offshore	Total U.S. Off shore and Onshore	Pacific Coast Offshore	Total U.S. Offshore and Onshore
Cumulative Production	1.5	106.1	1.4	480.8
<u>Demonstrated Reserves</u>	1.2	38.9	0.5	237.1
Measured	0.9	34.2	0.5	237.1
Indicated	0.3	4.6	--	--
Inferred Reserves ¹	0.2	23.1	0.4	201.6
<u>Undiscovered Recoverable Resources</u>				
Statistical Mean	3	82	3	484
Estimated Range (95 %-5%) ²	2-5	50-127	2-6	322-655

1. Inferred reserves based on historical data.

2. The low value of the range is the quantity associated with a 95 percent probability (19 in 20 chance) that there is at least this amount. The high value is the quantity with a 5 percent probability (1 in 20 chance) that there is at least this amount.

Regulation, Controls and Competition

Onshore Resources. Mining on private lands is governed by the California Surface Mining and Reclamation Act of 1975, which is administered by the city or county in which the mining operation takes place. The law has provisions for various aspects of reclamation, and requires compliance with applicable regulations of the U.S. Environmental Protection Agency, Regional Water Quality Control Boards, the State Department of Fish and Game, and other agencies. An Environmental Impact Report may be required if it is determined that a potential for adverse impacts exists (U.S. Bureau of Mines, 1979).

On Public Domain land, mining is subject to the 1372 Public Domain Mining Law, and on U.S. Forest Service lands, it is subject to the Organic Administration Act of

1897. Under the authority of this latter act, the U.S. Forest Service has promulgated permit regulations that require the filing of an operations plan. If it is determined that the mining operation will have substantial impact, the operator is required to develop acceptable mitigation measures (U.S. Bureau of Mines, 1979).

The Federal Surface Mining Act of 1977 (P.L. 95-87) is the first attempt to define in advance the measures that must be taken to protect the environment from any impact. The law emphasized the regulation of the coal mining industry, but is flexible enough to lead to future regulations covering other surface mining activities in the study area (U.S. Bureau of Mines, 1979).

In 1977, the California State Mining and Geology Board adopted and published a policy statement for the guidance of local governments in the implementation of the Surface Mining and Reclamation Act of 1975 (SMRA). This act requires that the local governments (lead agencies) review and approved mining reclamation plans as a condition for issuing permits for surface mining within their jurisdiction. A major goal of SMRA is to protect significant mineral resources from land uses that would preclude mineral extraction at a later date. On June 30, 1978, the State Mining and Geology Board adopted Guidelines for the Classification and Designation of Mineral Lands to provide direction to the State Geologist in classifying the various areas of the State into Mineral Resources Zones according to whether they contain little or no mineral resources, significant resources, or require further study. These guidelines establish procedures whereby the Mining and Geology Board may designate mineral-bearing areas of statewide or regional significance to assure that they are available when needed. The Board also established priorities for a mineral land classification program to be implemented by the State Geologist and the California Division of Mines and Geology (CDMG). Emphasis will be placed on urban and urbanizing areas that are subject to urban expansion or other irreversible land uses. U.S.D.A. Forest Semite RARE II areas are also recognized for their mineral potential and the need to protect these resources from land uses incompatible with mining (U.S. Bureau of Mines, 1979).

Table 5-68. OCS Sale No. 53, Offshore Northern and Central California: Conditional Probability Estimates of Economically Recoverable Resources by Lease Block Area (United States Geological Survey, December, 1978)

Lease Block Area	OIL (Million Barrels) ¹			GAS (Billion Cubic Feet) ¹		
	95%	5%	Mean	95%	5%	Mean
Eel River	--	--	--	63	356	182
Point Arena	87	205	131	86	215	134
Bodega	8	50	23	8	51	22
Santa Cruz	16	273	123	16	277	123
Santa Maria	89	784	404	89	795	409

1. The low value of the range is the quantity associated with a 95 percent probability (19 in 20 chance) that there is at least this amount. The high value is the quantity with a 5 percent probability (1 in 20 chance) that there is at least this amount. The mean is a statistical mean of the two values.

The Board endorsed the position of the Attorney General of California that SMRA applies to all lands in California, including federal lands. Negotiations are underway to provide cooperation and coordination among the federal, state, and local government agencies having land management responsibilities (U.S. Bureau of Mines, 1979).

CDMG is actively involved in a broad range of mineral and earth science-related activities involving mined-land reclamation, land-use geology, and research on mineral resources for the future. The CDMG is responsible for providing technical assistance to lead agencies (cities and counties) in the evaluation of mined-land reclamation plans required by the Surface Mine Reclamation Act (SMRA) as a part of the permitting process. The CDMG is preparing plans for a workshop to provide local governments with background and guidance in fulfilling their responsibilities under SMRA. Of the 73 lead agencies (local agencies having prime responsibility) thus far identified (58 counties and 15 cities), only 42 have adopted ordinances implementing the provision of SMRA (U.S. Bureau of Mines, 1979).

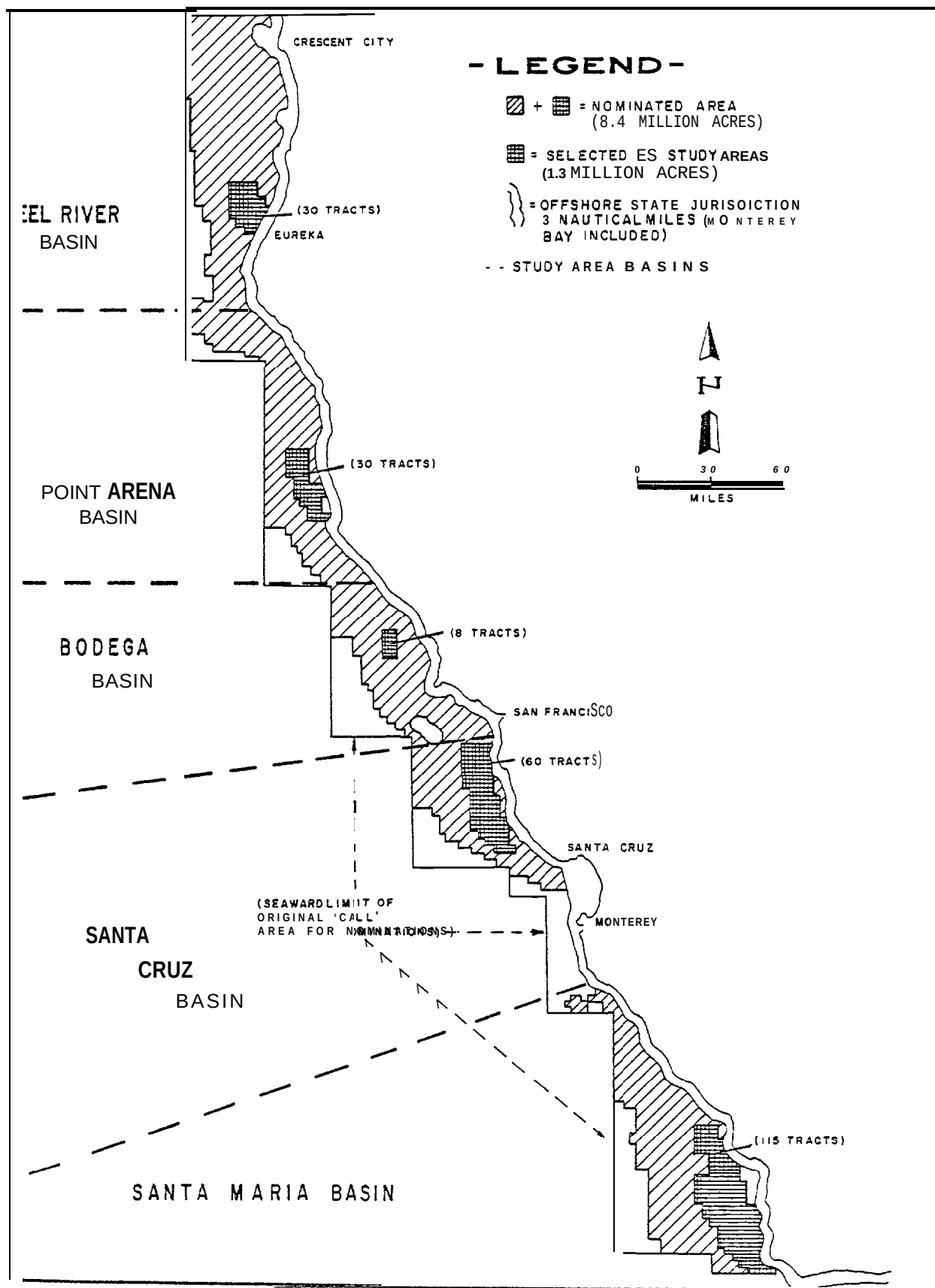


Figure 5-9. Proposed Bureau of Land Management O.C.S. Lease Sale Number 53 Central and Northern California

The first major revision of state water rights laws in 66 years has been proposed by the Governor's Committee to Review California Water Rights Law. Major proposals include creation of local groundwater management agencies with power to limit "over-draft" pumping from underground sources, and authority to condemn or purchase water rights to assure adequate streamflow for fish and recreational uses. The sand and gravel industry has a vital interest in the outcome. Groundwater aquifers are often in gravel, and actions taken to protect water resources could have serious consequences for the industry. Several gravel producers have challenged the proposals. In one case, a company was legally restrained from mining gravel on its own land because a nearby water district was storing water in an adjacent aquifer (U.S. Bureau of Mines, 1979).

The U.S. Bureau of Mines has provided to the lead agencies involved in developing California Coastal Zone Management (CZM) plans at the local level, lists of recorded mineral properties in the areas affected by CZM planning in order that these mineral resources receive consideration as the CZM plans are developed (U.S. Bureau of Mines, 1979).

Offshore Resources. Regulation of offshore oil and gas development is a complex and controversial issue involving many federal, regional, state, and local agencies.

The State of California is responsible for oil and gas activity within the state tidelands, an area defined by the U.S. Supreme Court in a 1965 ruling to be 3 miles off the mainland and around each island. California's State Lands Commission has been responsible since 1939 for leasing tidelands for oil and gas exploration and development. From 1939 to 1955, new tideland oil and gas exploration was allowed only where the state's submerged lands were being drained by wells on adjacent lands not owned by the state. With the passage of the Cunningham-Shell Act in 1955, state offshore lands were opened up for exploration and development where probable oil and gas drainage from state lands could be demonstrated. The Act restricted the issuance of new leases to the tidal and submerged lands lying between the city of Newport Beach, in Orange County, to a point 6 miles south of Oceano, in San Luis Obispo County (California Office of Planning and Research, 1977).

The coast north of Oceano to the Oregon border was placed in a petroleum reserve sanctuary, excluded from future development (San Luis Obispo County, 1979). The 1955 act enlarged previous state lease terms to permit "drilling from platform or other fixed or floating structures in, on, or over the tidal and submerged lands". The first such platform in state waters was installed by Chevron and Exxon in 1958 in the Summerland field of the Santa Barbara Channel (California Office of Planning and Research, 1977).

OCS development regulations and controls date back to a 1945 proclamation by President Truman which stated that "the Government of the United States regards the natural resources of the subsoil and seabed of the continental shelf beneath the high seas, but contiguous with the coasts of the United States as pertaining to the United States, subject to its jurisdiction and control." The proclamation, which survived a Supreme Court challenge in 1947 by coastal states and the oil industry, essentially arrested further development of offshore oil until a federal/state agreement could be reached (U.S.G.S., 1975a). Shortly thereafter, an Interim Agreement was negotiated between California and the United States to permit existing offshore operations to continue, pending further litigation and possible Congressional action (California Office of Planning and Research, 1977).

Congress passed the Submerged Lands Act in 1953, returning to the coastal states the 3 mile wide tidelands strip (with some exceptions) and preserving federal ownership and control over the subsoil and seabed of the submerged lands seaward of the belt granted to the coastal states. This area is termed the "outer continental shelf" (U.S.G.S., 1975a).

Later that year, Congress passed the Outer Continental Shelf Lands Act, which authorized the Secretary of Interior to grant mineral leases to OCS lands, and to prescribe regulations needed to carry out the act (U.S.G.S., 1975a).

[The seaward side of the Continental Shelf was delimited in an international agreement in 1958. The Geneva Convention on the Continental Shelf (ratified by the U.S. in 1961) defines the seaward limit of the Continental Shelf as out to a depth of 200 meters or beyond that limit, if exploitation of natural resources is possible (U.S.G.S., 1975a).]

The Secretary of Interior delegated the responsibility for leasing and managing offshore lands to two bureaus within the Interior Department, the Bureau of Land Management (B.L.M.) and the U.S. Geological Survey (U.S.G.S.). B.L.M. acts as a leasing agent and property manager. U.S.G.S. performs technical studies of the geology and mineral resources of federal lands and regulates the safety of oil and gas drilling operations (California Office of Planning and Research, 1977). A further discussion of federal laws and agencies affecting OCS development will be found later in this section and in Volume I, Conceptual Model.

State and local influence over OCS oil and gas activity appears to be limited. The California Office of Planning and Research revealed its frustration with California's limited role in OCS policy-making in the following excerpt from its 1977 report, Offshore Oil and Gas Development: Southern California:

"The current leasing system provides the state and local governments of California many opportunities to comment on proposed leasing and development activities but gives them little control over these activities. Although offshore oil and gas development will continue in state-controlled submerged lands, most new development will occur on federal OCS lands beyond the three-mile limit of California's jurisdiction. Federal policy determines the timing, size, and location of lease sales on the OCS; and federal agencies regulate industry exploration, development and production. OCS oil and gas development plans may include onshore facilities subject to state and local controls, but those facilities may also be built in federal waters offshore -- beyond state and local jurisdiction. Hydrocarbon emissions, oil spills, and economic and social impacts, however, do not recognize jurisdiction lines. The manner in which offshore development takes place will determine its effects on California, but the state and local governments of California can only comment on proposed leasing and development plans and hope that their concerns will be reflected in the decisions of federal officials."

Production and processing of federal OCS oil and gas generally require that state and local governments revise and approve some part of the operation. Typically, in California the facilities falling within this category include pipelines to shore (within the state's three mile jurisdictional limit), processing and storage facilities, and marine terminals with oil storage tanks and one or more additional pipelines across state-owned tidelands (California Office of Planning and Research, 1977).

California was one of the first of 30 coastal and Great Lakes states to have an approved Coastal Zone Management program under the Coastal Zone Management Act (CZMA) of 1972. California adopted its program by popular vote at the same time the federal Act was passed. Under the California program, nearly all coastal development is subject to review by one of six regional coastal commissions and by the State Coastal Commission. The coastal zone defined by the state act extends 3 miles seaward and from 1,000 yards to 5 miles inland (U.S. Bureau of Mines, 1979).

The California Coastal Act of 1976 requires that local governments develop Local Coastal Plans (LCP's), between 1978 and 1980, bringing their general plans and zoning ordinances into conformity with statewide coastal policies. After the state commission certifies them as adequate, coastal development permit authority will be returned to local governments (California Office of Planning and Research, 1977). Until then, state coastal development permits must be obtained in addition to any other permits required by state or local law.

Under the "consistency" provisions of the federal Coastal Zone Management Act, which requires that federal actions be consistent with the state plan insofar as possible, activities on the Outer Continental Shelf are subject to the CZM program if they affect land or water uses in the coastal zone. A recent (August 1978) federal court decision upheld the California CZM program and lifted a restraining order that had prevented the consistency provision from going into effect. Future applications for federal permits for offshore activities that may affect land or water of the coastal zone must be accompanied by a certification of consistency, which will be

reviewed by the State Coastal Commission (U.S. Bureau of Mines, 1979). The "consistency" provision [Section 307(c)(1)] of CZMA reads as follows:

"Each federal agency conducting or supporting activities directly affecting the coastal zone shall conduct or support those activities in a manner which is, to the maximum extent practicable, consistent with approved state management programs." (California Office of Planning and Research, 1977.)

A 1976 amendment to CZMA provided exceptions to the consistency provision of the 1972 Act that would allow OCS offshore oil and gas development even if consistency with state coastal management plans does not occur. Section 307(c)(3)(B), as amended in 1976, provides that any person submitting an OCS exploration or development plan to the Secretary of Interior must attach to it a certification of compliance with state management plans. Before licensing or permitting by the relevant federal agency may take place, either the state must concur in the certification of compliance, or, the Secretary of the Interior must find "... that each activity which is described in detail in such plan is consistent with the objectives of this title or is otherwise necessary in the interest of national security" (California Office of Planning and Research, 1977). Presumably, the secretary could override inconsistency with state coastal plans on grounds of national security interests. The consistency provision of CZMA is administered by the National Oceanic and Atmospheric Administration (NOAA), an agency of the U.S. Department of Commerce.

In addition to Local Coastal Programs and their relevance to the "consistency provisions" of CZMA, local governments in California have one further means of affecting offshore oil and gas development: the California Environmental Quality Act (CEQA). Although oil and gas operations occur beyond the state's jurisdiction, they may require onshore support facilities. Any development inside the three-mile limit, nearshore or onshore, must comply with all state and local permit requirements. The act stipulates that if a proposed project would have a significant effect on the environment, an Environmental Impact Report (EIR) must be prepared and that the draft be distributed or public comment before a final decision is made on a permit application. It further recommends, but does not mandate, that a public hearing on the draft take place to inform officials about public concerns (California Office of Planning and Research, 1978).

OCS lessees have considered the possibility of placing some processing facilities offshore anti beyond the three mile state limit in order to avoid state and local controls. Exxon is proposing to develop the Santa Ynez Unit in the Santa Barbara Channel with floating oil and gas processing units beyond the three-mile limit (California Office of Planning and Research, 1978). Floating processing units have been used successfully in North Sea oil and gas development (California Office of Planning and Research, 1977).

In 1976, the federal government enacted the Coastal Energy Impact Program (CEIP), a \$2.1 billion authorization, which provides through the Department of the Interior, financial assistance to state and local governments affected by OCS-related development, with the objective of balancing energy development and coastal resource protection with the coastal states' social, economic and environmental needs. The program set up two funds, the Coastal Energy Impact Fund, \$800 million through 1986 for planning grants, credit and repayment assistance and environmental and recreational loss grants, and OCS Formula Grants, \$400 million through 1985 (increased to \$1.3 million through 1988 by 1978 amendments to the OCS Lands Act) for financial assistance to prevent and minimize loss of valuable environmental or recreational resources (Mylroie, 1978). In California, CEIP is administered through the California Coastal Commission.

A 1978 amendment to the Outer Continental Shelf Lands Act of 1953 provides an increased role for coastal states in OCS leasing decisions. The amendments require the Department of the Interior to consult with local and development permit process, including tract nomination, referral studies, drilling and development process, product transportation and rule making (San Luis Obispo Coastal Program, 1979).

One of the principal motives for developing offshore oil and gas resources has been the governmental revenues that lease sales produce. OCS revenues are substantial, averaging about \$3.5 billion annually (as of 1974) and totalling over \$6.7 billion in fiscal year 1974 (California Office of Planning and Research, 1977). Nine-square-mile tracts included in Lease Sale #48 of June, 1979 (along the southern

California coast) were leased for a total of \$573 million, ranging between \$158 thousand for pre-sale Tract #112 and \$95 million for pre-sale Tract #11 (Noah Tilghman, California Coastal Commission, personal communication, November 15, 1979). The sale included a total of 148 tracts. States receive no revenues directly from OCS leasing but may receive rents or royalties from leases within the three-mile limit.

The lure of large lease revenues may create a kind of competition between the federal government and coastal states over exploitation of offshore oil and gas resources. Although the 1953 Submerged Lands Act and subsequent judicial proceedings have established the boundary between federal and state offshore resource control, submerged oil and gas reservoirs do not necessarily respect these boundaries. As a result, wells drilled on either side of the 3-mile limit may drain the same oil and gas reservoirs. A scenario may unfold in which the federal government authorizes the lease of OCS lands off the shore of a coastal state which opposes both OCS and State tideland development. But once the federal government begins leasing OCS tracts, the state may change its own policy and lease tideland tracts in order to share in the revenues.

In the private sector, offshore oil and gas development has resulted in cooperation among energy-producing companies. Because offshore development is both risky and expensive, oil companies often form consortiums to spread the risk and cost of exploration and development. Tracts in Lease Sale #48 were typically bid on by consortiums of two to four companies (Noah Tilghman, California Coastal Commission, personal communication, 26 November 1979).

Mineral production in California is taxed on an ad valorem basis at the county level. The state collects rents and royalties from mineral, oil and gas, and geothermal leases on state-owned lands and on lands for which the mineral rights are reserved in whole or part to the state. For the period ending June 30, 1979, mineral and dredging royalties to the state are estimated to be \$339,500, oil and gas royalties are estimated at \$87.2 million, and royalties from geothermal energy at \$4.3 million. The geothermal funds are placed in a trust fund pending the outcome of litigation to determine ownership of geothermal energy. At issue is the question of whether geothermal resources should be regarded as a mineral with ownership by the mineral-rights holder, or as water-owned by the holder of surface or water rights. At the federal level, it is regarded as a mineral (U.S. Bureau of Mines, 1979).

Production

Non-Energy Mineral Production. Mineral production (except oil and gas) along the coast in 1977 is listed by county and by mineral type in Table 5-68. Asterisked items refer to data withheld to avoid disclosure of individual company totals. Santa Cruz County leads coastal study area counties in production of sand, gravel and stone. Portland cement is also produced in Santa Cruz County at a plant in the city of Santa Cruz owned by Lone Star Industries. The company approved a program to improve and modernize their plant, to be completed in 1979 (U.S. Bureau of Mines, 1976).

Table 5-69. Mineral Production (in thousands of short tons) in North and Central Coastal Counties of California, 1977

	Del Norte	Humboldt	Mendocino	Sonoma	Y arin	San Mateo	Santa Cruz	Monterey	San Luis Obispo	Santa Barbara	10-COUL
											Tota
Cement	.	-					*		-		
Clays	.	-			*		*		12		
Liatomite		-			-	-	-	-		397	39
Geothermal Steam	-	-		NA	-	-	-	-			N.
Lime		-		-	-	-	-	*		*	
Magnesium Compounds-		-				*		*			
Phosphate Rock	-	-	-				*	-		*	
Pumice		-					*				
Salt		-				*					
Sand and Gravel	299	754	656		20	12	2,926	712	616	1,630	7,62
Stone	171	156	4	*		463	1,086	661	*	15	

NA - Not Available.

* Withheld to avoid disclosure of individual company figures.

Oil and Gas Production. Oil and gas production for 1978 in coastal study area counties is shown in Table 5-70. The 10-county area produced 29,770,000 million barrels of oil, or 3.9 percent of California's total that year. Natural gas production in 1977 in the 10 coastal counties was 15.7 billion cubic feet or 5.3 percent of the state total. Totals in this table do not include OCS production.

Table 5-70. Oil and Gas Production in North and Central Coastal California Counties, 1977 (California Division of Oil and Gas, 1978)

	Oil Production (Mbbbl)	Gas Production (MMcf)	Proved Acreage As of December 31, 1977
Del Norte			
Humboldt		1,620	1,310
Marin			
Mendocino			
Monterey	12,681		4,700
San Luis Obispo	1,780	650	2,750
San Mateo	37	2	205
Santa Barbara	15,275	13,840	27,935
Santa Cruz			
Sonoma			
10-county Total	29,773	16,112	36,900
California Total	335,215	304,772	440,976

Figure 5-10, and Figure 5-11 show trends in California oil and gas production from 1960-1978. Total gas production has been declining steadily since 1968. Oil production declined from a peak production of 374 million barrels in 1968 to about 310 million barrels in 1974. Production has decreased from 1974 to 1978 (see Figure 5-10).

Table 5-70 shows the breakdown of oil and gas production in the state by onshore and offshore activity and by state and federal (OCS) offshore activity. In 1977, 60.5 million barrels of oil were produced offshore in California or in federal waters, representing 17.3 percent of all oil produced in California. Of offshore production, 12.3 million barrels, or 20.3 percent was from the OCS.

Of 317.4 billion cubic feet of natural gas produced in the state in 1977, 19.7 billion cubic feet, or 6.2 percent, was produced offshore. OCS natural gas production was 5.4 billion cubic feet.

Most of the state's offshore oil and gas production has come from the Wellington and Huntington Beach fields near Los Angeles. All of the federal offshore production to date has come from the Carpinteria and Dos Cuadros fields in the Santa Barbara Channel, south of Point Conception (CDMG, 1979a).

Value of Production. The value of minerals (including energy-raw materials) produced along the coast in 1975 and 1976 is shown in Table 5-71. Santa Barbara County led the 10 coastal counties in value of mineral production in 1976, producing \$153 million. Monterey County was second in value with \$115 million. Petroleum was the most valuable mineral produced in both counties.

Excluding oil and gas, diatomite has been the most valuable mineral produced on the coast in the recent past, worth over \$43 million in 1977. All production is in Santa Barbara County.

Value Added. From Table 5-73, Number and Value (dollars) of mineral industries in California, value added per employee (VAPE) figures may be calculated by dividing total value added by the number of employees in the industry. Value added may be defined as the estimated market value added to a product at a particular stage of production, manufacture or distribution. VAPE figures are useful estimates for

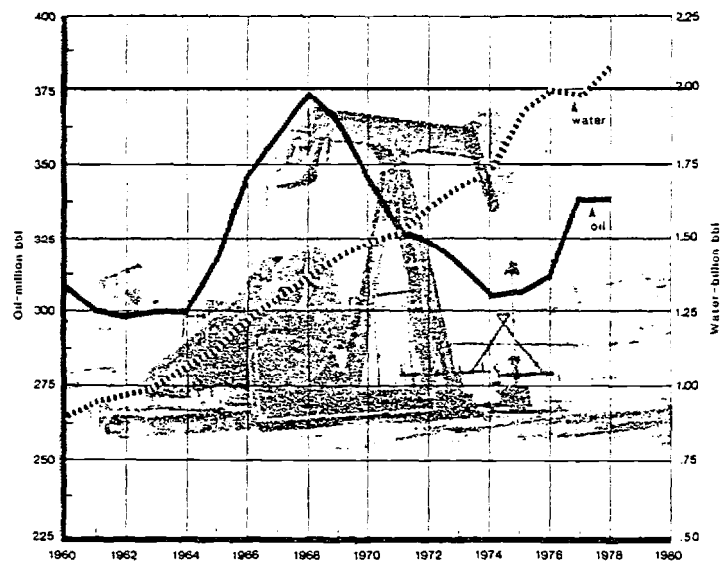


Figure 5-10. California Oil and Gas Production, 1960-1980
(California Division of Oil and Gas, 1979)

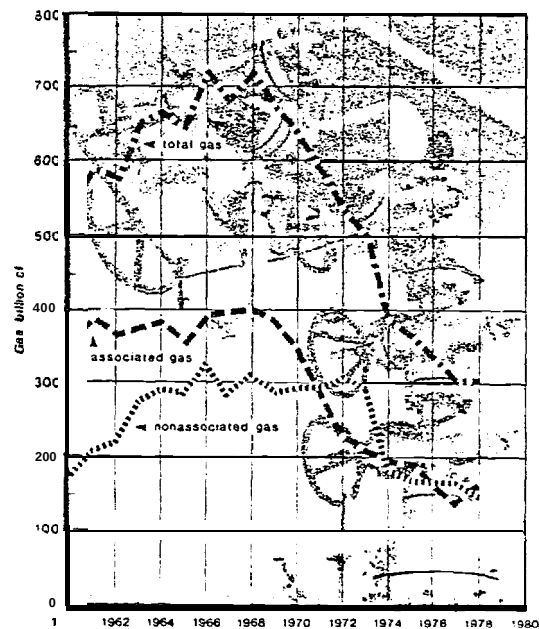


Figure 5-11. California Gas Production, 1960-1980
(California Division of Oil and Gas, 1979)

Table 5-70. Oil and Gas Production in California, 1977 and 1978
(California Division of Oil and Gas, 1979)

	1977	1978 ¹
Crude Oil:		
Onshore thousand 42-gallon barrels	288,965	289,000
Offshore:		
State do	48,196	45,000
Federal do	12,300	13,300
Total	349,461	347,300
Natural Gas:		
Onshore million cubic feet	297,767	292,700
Offshore:		
State do	14,237	13,300
Federal do	5,400	7,200
Total	317,404	313,200

¹preliminary estimate

Table 5-71. Value (in thousands of dollars) of Mineral Production in
California Coastal Counties, 1975 and 1976 (U.S. Bur. of Mines, 1976)

County	1975	1976	Minerals Produced in 1976 In Order Of Value
Del Norte	\$ 1,274	\$ 1,277	Stone, sand and gravel, gold.
Humboldt	3,527	2,484	Sand and gravel, stone.
Marin	w	w	Stone, clays.
Mendocino	562	998	Sand, and gravel, stone.
Monterey	118,271	114,629	Petroleum, magnesium compounds, lime, sand and gravel, stone, feldspar.
San Luis Obispo	11,568	w	Petroleum, sand and gravel, stone, clays.
San Mateo	9,141	10,791	Magnesium compounds, stone, salt, petroleum, sand and gravel.
Santa Barbara	156,212	153,254	Petroleum, diatomite, natural gas liquids, sand and gravel, lime, phosphate rock, stone.
Santa Cruz	w	w	Cement, sand and gravel, stone, clays.
Sonoma	5,915	w	Sand and gravel, stone, petroleum.

w - Withheld to avoid disclosing company proprietary data.

productivity of employees by industry. The data in this table are from the 1972 Census of Mineral Industries (California Department of Finance, 1979). In the absence of vocationally specific data, VAPE figures for the state as a whole may be used as last estimates.

Value added per employee in the mineral industry of California (including oil and gas) in 1972 was \$48,305. This compares to a VAPE estimate for all manufacturers in

California in 1972 of \$20,179. The higher VAPE estimate in the minerals industry is primarily accounted for by the oil and gas extraction sector which had a VAPE estimate of \$62,214. VAPE estimates for the other mineral industry subsectors in 1972 in California were \$27,179 for non-metallic mineral mining and \$13,333 in metal mining. No figures are available for offshore and OCS oil and gas production.

Table 5-73. Number and Value (dollars) of Selected Statistics on Mineral Industries in California in 1972 (California Department of Finance, 1979)

Item	Number or Value
Number of establishments	
Total	1,179
Metal Mining	25
Oil and Gas Extraction.	705
Nonmetallic Minerals Mining	378
Number of Employees	
Total.	29,000
Metal Mining.	W
Oil and Gas Extraction.	18,200
Nonmetallic Minerals Mining	9,000
Dollar Increase	
Total	\$1,400,900
Metal Mining	24,000
Oil and Gas Extraction.	1,132,300
Nonmetallic Minerals Mining	244,600
Capital Expenditures	
Total	\$ 247,200
Metal Mining	4,200
Oil and Gas Extraction.	203,800
Nonmetallic Minerals Mining	39,100

1. Totals include a small amount of mining activity not shown separately.

Employment. Very limited employment is typically supported by the mining industry. The most up-to-date available official government tabulations of employment by industry in counties of California (County Business Patterns and the California Employment Development Department's Wage and Salary Employment by Industry and California Employers' and Payrolls) all have significant shortcomings in their tabulation of mineral industry employment by county. County Business Patterns and California Employment and Payrolls do not provide data for counties with small mineral industry employment to avoid disclosure of individual company totals. Wage and Salary Employment by Industry groups mining and construction employment data for many counties. California Employment and Payrolls is probably the most accurate and useful source and is used in Table 5-73.

Table 5-73 shows that the coastal counties, excluding Del Norte, Humboldt and Mendocino, employed 1,924 persons in the mineral industry (including energy-raw materials). From County Business Patterns and other sources, it may be estimated that Del Norte, Humboldt and Mendocino Counties had between 20 and 33 mining employees in 1977, including 12 in Del Norte County, 6-13 in Humboldt County, and 2-8 in Mendocino County (U.S. Bureau of the Census, 1979, EDaw, Inc., 1979a; 1979c). San Francisco, not included in the study area, had 864 mineral industry employees in 1977, apparently all in administrative functions.

Santa Barbara County led coastal counties with 1,055 mineral industry employees in 1977. County Business Patterns indicates that about 35 percent of this total, or 370 workers were employed in oil and gas extraction (U.S. Bureau of the Census, 1979). No breakdown for offshore and OCS employment was available.

In no coastal county did the mineral extraction industry represent more than 1 percent of total wage and salary employment in 1977.

Data for the Santa Barbara-Santa Maria-Lompoc Metropolitan Area (Santa Barbara County) show an increase in mineral industry employment from 800 in 1972 to 1,100 in 1978 (California Employment Development Department, 1979e). Employment in this industry along the remainder of the coast appears to have been relatively stable during this period. Statewide mining employment grew from 29,200 to 37,000 between 1972 and 1978. Most of the growth has been in the oil and gas extraction subsector (California Department of Finance, 1979).

There has not been any offshore oil and gas activity along the study area coast to date. Presumably, no employment in the study area is attributable to tideland and OCS activity, other than perhaps some employment associated with private or public OCS administration. Santa Barbara County has had OCS and tideland development in recent years, but entirely south of the study area. Available published employment data sources do not break down data on oil and gas development to differentiate between onshore and offshore activity, making it difficult to estimate OCS and tideland related employment. Moreover, onshore and offshore development share a number of onshore facilities.

For a discussion of potential employment related to offshore oil and gas development, see Volume I, Conceptual Model.

Table 5-73. Number of Employees and Average Wages in the Coastal Counties of California in 1977¹ (California Employment Development Department, 1979e)

County	1977 Average Annual Mining Employment	1977 Annual Mining Wages	Average
Del Norte	NA	NA	NA
Humboldt	NA	NA	NA
Marin	49	NA	NA
Mendocino	NA	NA	NA
Monterey	658	12,596,000	\$19,100
San Luis Obispo	11.7	1,928,000	16,500
San Mateo	29	817,000	28,200
Santa Barbara	1,005	18,082,000	18,000
Santa Cruz	66	1,377,000	20,900
Sonoma	342	6,829,000	20,000
Coast Total	NA	NA	NA
California Total	35,628	\$687,714,000	\$19,300

1. Includes all wage and salary employment except self-employed persons, unpaid family workers. Wage data are rounded.

NA - Not available.

Income. Payroll data are also included in Table 5-74 for coastal counties of the study area in 1977. The mining industry contributed most significantly to Santa Barbara and Monterey Counties where payrolls were \$18.1 million and \$12.6 million respectively. (Note: County Business Patterns shows a 1977 mining payroll of \$23.2 million for Santa Barbara County, of which \$8.4 million was in oil and gas extraction.) In San Francisco, 864 mining industry employees earned \$25.8 million in 1977 (California Employment Development Department, 1979b).

Average wages in the industry are high. For California as a whole, mining and industry employees earned an average of \$19,300 in 1977. Employees in metals mining averaged \$17,600, oil and gas extraction, \$19,600, and non-metallic minerals (except fuels), \$18,700 in 1977. Average weekly earnings and hours, and average hourly earnings for this industry in California in 1977 are summarized in Table 5-75.

Annual salary estimates for OCS development have been provided by the Council on Environmental Quality (CEQ). Table 5-76 shows CEQ estimates of annual salaries of OCS

oil and gas workers broken down by phases of OCS operations in 1970 and updated to 1975 wages by the California Office of Planning and Research (1977) using an inflationary wage and salary index for oil and gas extraction.

Table 5-74. Weekly and Hourly Earnings in the Mineral Extraction Industry in California, 1977 (California Department of Finance, 1979)

Sector	Average Weekly Earnings	Average Weekly Hours	Average Hourly Earnings
Metal Mining	\$318.87	47.6	\$6.72
Bituminous Coal	330.77	39.9	8.29
Mining and oil, and Gas Extraction ¹			
Nonmetallic Metals (except fuels)	373.01	42.1	8.86

1. Bituminous coal mining activity in California is negligible.

Table 5-75. Estimated Average Annual Salary for OCS Employees in 1970 and 1975 (California Office of Planning and Research, 1977)

Type of Activity	1970	1975
Exploratory drilling	\$13,000	\$20,000
Platform fabrication	12,500	19,000
Development drilling	13,000	20,000
oil and gas production Operations	11,500	17,500
Support services	10,000	15,500
Onshore facility construction		14,000

Transportation, Processing and Distribution

Non-Energy Resources. Non-energy mineral resources generally undergo some processing at the mine, pit or quarry, or are shipped as raw materials to eventual industrial or agricultural users.

In the study area, a Portland cement plant at Santa Cruz requires input of raw materials including limestone, clay, shale, aluminum dress, silica, sand, quartz, iron ore, gypsum anhydrite and other miscellaneous materials. The cement produced is primarily sold to ready mix concrete companies outside the study area (U.S. Bureau of Mines, 1976).

Diatomite produced and refined in Lompoc in Santa Barbara County is sold primarily for filtration to industrial users. Feldspar, produced at an Owens-Illinois Company mine in Pacific Grove, Monterey County, is sold to glass makers and makers of enamelware. The Kaiser Aluminum and Chemical Corporation lime plant at Natividad in Monterey County sells its output to magnesia producers, sugar refineries, fertilize companies and other miscellaneous industrial users (U.S. Bureau of Mines, 1976).

Perlite, mined outside the study area, is expanded at a plant in Sonoma County. Expanded perlite is used as a filter aid, as a horticultural and agriculture aggregate, as a construction aggregate and for other miscellaneous purposes (U.S. Bureau of Mines, 1976).

Phosphate rock, mined in Santa Barbara County, has been used without treatment as a soil additive (U.S. Bureau of Mines, 1976).

Metals processing includes recovery of metals from scrap and, salvage; production of alloys from ingot; aluminum ore reduction; copper, lead, brass and bronze smelting; iron and steel milling; foundry of gray iron and steel; magnesium melting; and zinc processing (Winzler and Kelly, 1977b). No metals processing plants are found in the study area.

Energy Resources. The transportation, processing and distribution of oil and gas requires pipelines, tanker terminals, storage facilities and refineries.

Pipelines. Pipelines are used in the transportation of crude oil, reused oil, and natural gas from oil and gas fields (onshore and offshore) to processing facilities, and eventually to markets. Maps of major oil and gas pipelines within the study area can be found in A Summary of Knowledge of the Central and Northern California Coastal Zone and Offshore Areas; Volume III, Socioeconomic Conditions, Book 1, pp. II-50 to II-57 (Winzler and Kelly, 1977b).

Pipelines have been the primary mode of transmission for oil delivery from production areas to refineries in California. Pipelines accounted for 85 percent of crude oil delivered to refineries in the state in 1974. The remainder was carried by tankers or tank cars. California crude oil lines are for the most part a system of small, older lines, with only a small fraction of the total mileage consisting of pipes with a diameter of 20 inches or larger. The main trunk line systems relevant to the coastal study area include lines from the lower San Joaquin Valley (primarily Kern County oil fields) to San Francisco Bay area refineries and Los Angeles Basin resources. A set of lines from the Estero Bay area in San Luis Obispo County connect to the San Joaquin Valley trunk line (Winzler and Kelly, 1977b).

Offshore pipelines may carry produced fluids of crude oil, water and natural gas from offshore fields to onshore treatment and separation facilities and storage tanks. There are no pipelines of this sort in the coastal study area but they are a common mode of transportation of produced fluids from the Santa Barbara Channel to onshore facilities. Offshore pipelines are also used to transport crude oil and refined products between offshore tanker loading and unloading facilities onshore. Location of these facilities in the study is discussed in the following section on marine terminals.

Products pipelines carry refined oil among refineries, and between refineries and distribution points. A system of products pipelines exists among the San Francisco Bay Area refinery and petrochemical complexes (Winzler and Kelly, 1977b).

Natural gas lines carry produced natural gas from natural gas fields to gas transmission lines owned by public utilities. A line owned by Southern California Gas Company connects the Santa Maria field in northwestern Santa Barbara County to the Los Angeles market. Pacific Gas and Electric lines connect San Joaquin natural gas fields with major population centers of the remainder of the study area (Winzler and Kelly, 1977b).

Marine Terminals and Storage Facilities. Marine terminals along the coast serve the function of loading and unloading ocean-going tankers with crude oil, fuel oil, and other petroleum products and natural gas. The eventual destination of the oil and gas is storage facilities, refineries, electrical generating plants or consumer markets.

Within the coastal study area are six offshore marine terminals (see Figure 5-12). Five are located in San Luis Obispo County and the other is at Moss Landing, in Monterey County. Del Norte County has a small petroleum products receiving facility at Crescent City. Additionally, the San Francisco Bay area is a major petroleum marine terminal with facilities at San Francisco, Redwood City, Oakland, Richmond and other locations. South of Point Conception are five marine terminals located along the Santa Barbara County coast. Finally, the Los Angeles-Long Beach area is a major trans-shipment and refining center which stores and refines oil and gas shipped through marine terminals of the study area.

In San Luis Obispo County, the Port San Luis Marine Terminal is considered a trans-shipment and products terminal for loading crude oil onto tankers for shipment to refineries in Los Angeles Basin or San Francisco Bay area refineries. Crude oil is received by pipeline from Kern County wells, and is stored in adjacent tanks. The terminal's 3082-foot-long pier is presently used for loading operations on maximum 180,000 dead weight ton tankers. Maximum water depth at the facility is 31 feet 6 inches. The terminal is also used for unloading refined oil products for delivery to local markets (San Luis Obispo County Coastal Program, 1979).

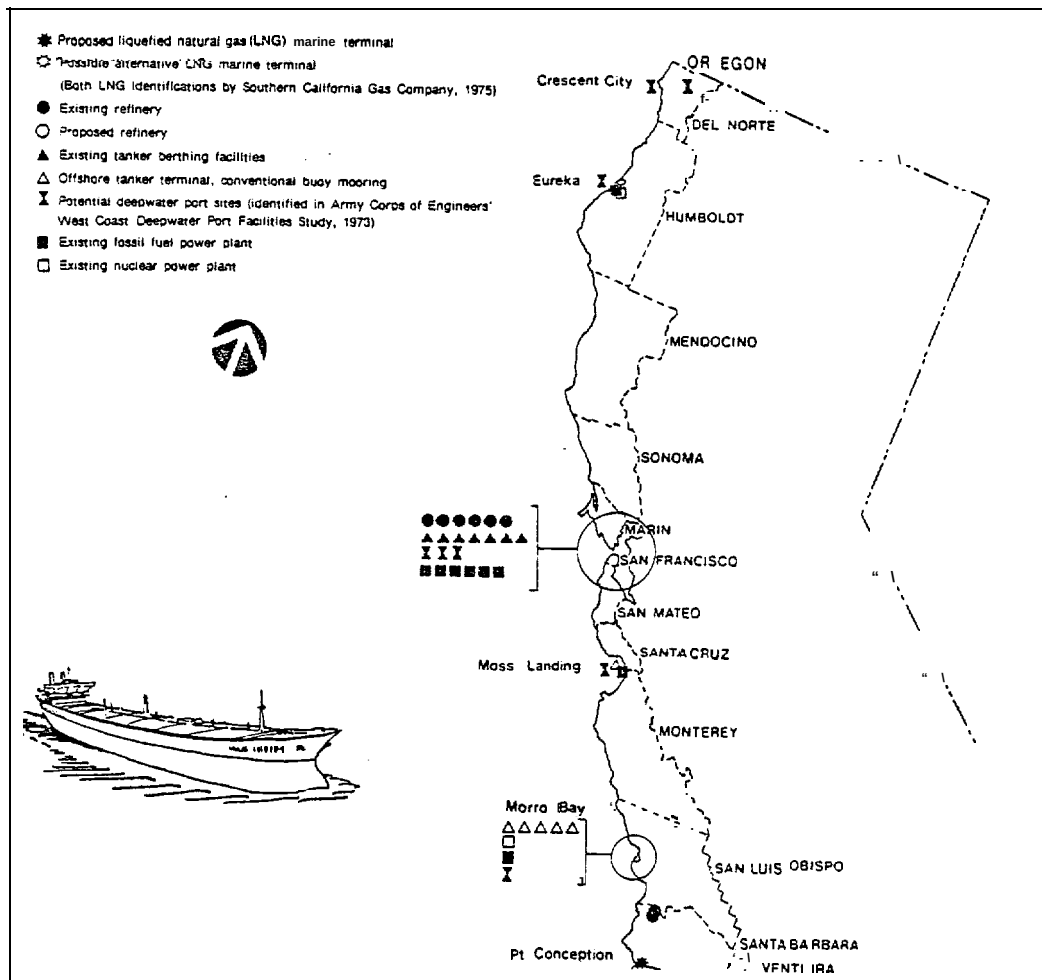


Figure 5-12. Existing, Proposed, and Potential Coastal Energy Facilities (California Coastal Zone Conservation Commission, 1975)

Four marine terminals are located in Estero Bay, in San Luis Obispo County. The Estero Marine Terminal, operated by Chevron, Inc., and located just north of the city of Morro Bay, is a crude oil offshore loading and wading facility which has a maximum water depth of 50 feet (Winzler and Kelly, 1977b). Sixty-six percent of the total crude oil shipped through the facility is provided by San Joaquin fields. Crude oil is shipped to ports in Los Angeles and San Francisco and to the state of Washington (San Luis Obispo Coastal Program, 1979.)

Pacific Gas and Electric Company maintains an offshore loading pipeline at Estero Bay used for loading crude oil and unloading fuel needed to operate the Morro Bay power plant. The facility has a maximum water depth of 50-70 feet and can handle tankers up to 50,000 dead weight tons.

Texaco operates an offshore petroleum products unloading facility at Estero Bay with a maximum water depth of 50 feet and capacity to serve tankers with a maximum of 20 thousand dead weight tons (Winzler and Kelly, 1977b).

The fourth Estero Bay facility is a U.S. Navy jet fuel mooring terminal and its associated storage tanks. Jet fuel is unloaded from vessels and stored in tanks and then shipped via pipeline to Lemoore Air Force Base (San Luis Obispo Coastal Program, 1979).

The Moss Landing facility, in Monterey County, is a crude petroleum and petroleum products offshore unloading facility operated by Pacific Gas and Electric. Fuels are unloaded for use at the Moss Landing power plant. The facility accommodates tankers of 50,000 dead weight tons in 55 feet of water (Winzler and Kelly, 1977b).

In 1975, Chevron proposed to add a deepwater berth and expanded onshore facilities at its existing marine terminal at Estero Bay. The new facilities would have permitted deep draft supertankers between 200,000 and 400,000 dead weight tons to berth at a single-point mooring approximately 2.5 miles offshore. Imported crude was to be transferred 277 miles to Chevron's Richmond refineries through a buried pipeline. Other potential deepwater sites were considered in both northern and southern California. As modern-sized tankers (over 160,000 dwt.) draw 60 to 80 feet of water, both the Los Angeles area harbors (50-60 ft. draft) and the terminals in the San Francisco Bay (35 feet draft) were considered too shallow. Other locations considered for deepwater terminals by Chevron were Crescent City, Humboldt Bay, Fort Bragg, Point Arena, Jenner, Moss Landing, Nipomo Dunes and Port Hueneme. Because of local opposition and escalator costs, Chevron scrapped its Estero Bay proposal and later announced that the Port of Long Beach would be its major West Coast supertanker terminal to handle oil from Alaska (San Luis Obispo Coastal Program, 1979).

In the mid-1970s, the U.S. Navy proposed the use of Chevron's Estero Bay terminal as a site to deliver crude oil from the Elk Hills Naval Reserve in the San Joaquin Valley. The Naval Petroleum Reserves Production Act of 1976 authorized the development of specified natural petroleum reserves. The act directs the Secretary of Navy to ship at least 350,000 barrels per day from Elk Hills to unspecified marketing locations. Three pipeline routes were considered: (1) to Port Hueneme in Ventura County, (2) via Coalinga to Estero Bay, and (3) to Avila Beach in San Luis Obispo County. Adverse problems of air quality resulting from loading of crude at marine terminals have eliminated these routes from further consideration (San Luis Obispo Coastal Program, 1979).

Siting of a liquefied natural gas terminal has been a major issue in the 1970s along the coast of California, directly affecting two sites within the study area. Four sites have been proposed for a \$600 million terminal that would receive 900 million cubic feet per day, 25 percent of present daily consumption, of gas from Indonesia and Alaska to bolster California's declining production and increased consumption. Strong local opposition has developed to each of the four sites proposed because of safety, cultural, environmental, and aesthetic reasons. The proposed sites are at Point Conception, in Santa Barbara County; Camp Pendleton, in San Diego County; Rattlesnake Canyon, in San Luis Obispo County; and Deer Creek, in Ventura County (U.S. Bureau of Mines, 1979).

Petroleum Processing Facilities. Petroleum treatment and separation facilities, either oil clearing facilities or natural gas processing plants, are used to ready produced reservoir fluids (oil, water and gas) for shipment to refineries, for reinjection or disposal, or for pipelining to consumers. Oil separation is usually done by gravity. Produced liquids are stored in tanks where lighter oil separates because of density differences. This process requires much storage capacity as an average of one barrel of oil is produced with ten barrels of water. Facilities are located as

near to the fields as possible. Offshore fields generally use a shore-based treatment facility, although Exxon has considered using a floating offshore facility for the Santa Ynez unit in the Santa Barbara Channel (Winzler and Kelly, 1977b). Floating facilities have been used successfully in North Sea oil fields (California Office of Planning and Research, 1977). Gas processing plants remove the natural gas liquid from "wet gas" leaving methane for input into the natural gas pipelines for distribution.

Only one treatment and separation facility is located in the study area, a natural gas processing plant in the Santa Maria Valley of Santa Barbara County. The facility has a gas capacity of 35,000 cubic feet per day (Winzler and Kelly, 1977b).

Refineries break up complex chemical structures of crude oil and natural gas liquids. The refined products may be further processed into petrochemicals, or consumed as fuels. In California, most petrochemical plants are integrated with a refinery into one unit (Winzler and Kelly, 1977b).

There are only two refineries in the coastal study area (excluding the San Francisco Bay area). Douglas Oil operates a refinery near Santa Maria, in northwestern Santa Barbara County. The plant had a capacity of 9,500 barrels per day in 1976 (Winzler and Kelly, 1977b). Union Oil operates a refinery and petrochemical plant. The plant has a maximum operating capacity of 41,000 barrels per day. Crude oil is transferred by pipeline from the nearby Guadalupecil field. The refinery is a partial processing facility. Raw crude oil is processed into gas, oil and pressure solvent which is shipped by pipeline to Union Oil's San Francisco refinery for final processing (San Luis Obispo Coastal Program, 1979).

The San Francisco Bay area is a major refinery center. Six refineries in the Bay Area had a combined refining capacity of 626,000 barrels per day in 1976, or 32 percent of the state's total capacity of 1,942,000 barrels that year. Los Angeles and Bakersfield are other important refinery centers in the state.

The ability of California's refineries to handle proposed OCS development will depend on a number of factors, including the volume and sulfur content of OCS production, future trends in state onshore production, and the volume of imported crude oil, especially from Alaska. A discussion of potential onshore facilities related to OCS development is contained in Volume 1, Conceptual Model.

Summary and Effects

Summary. The minerals industries, including energy resource extraction, have not been significant in terms of employment and income in counties along the coast study area representing less than one percent of total wage and salary employment in 1977. Employment in these industries has remained relatively stable over the last decade. Mild fluctuations have been related to increased demand for oil and gas, reduced demand for mercury, and development of new source energy resources, especially geothermal and OCS resources.

The overall importance of the minerals industry to the coast is not derived from its present size, but from the potential significance of the energy resources subsector, especially OCS development. The increasing return on domestic energy resource development, in relation to both private capital investment and to the national policy to reduce dependence on foreign energy sources, has made OCS oil and gas resources along the study area coast more attractive prospects for exploitation.

The Bureau of Land Management is doing initial studies in preparation for Lease Sale #53, a proposed lease that would grant oil and gas exploration rights to developers on 243 nine-square-mile tracts along the outer continental shelf between Point Conception and the Oregon border.

In terms of value added, the industry is somewhat more important but still not significant along the coast. Value added per employee (VAPE) figures for the minerals industry are more than twice as high as VAPE figures in manufacturing in California, yet as a percentage of total value added in coastal counties, mineral extraction industries still are in the 1-2 percent range.

Natural and Socioeconomic System Effects.

Non-Energy Resources. Extraction of sand and gravel from marine terraces and extraction of minerals from beach sands alter the substrate and habitats. Both mining and processing activities may have significant land alteration, water quality, erosion, air quality and visual impacts.

Air emissions from mineral-associated industries are primarily particulate, or sulfur dioxide from fuel combustion. Quantities of emissions from each industrial process are different. In general, relatively effective means of control are available for most mineral processes (Winzler and Kelly, 1977b).

There are a few chemical industries in the study area; the largest of these is the Kaiser refractory in Moss Landing, which produces magnesium oxide. This facility discharges 33 mgd of mixed processing and cooling waters to Elkhorn Slough. The effluent is calcium-rich water with magnesium oxide that escapes the settling pond (Winzler and Kelly, 1977b).

Energy Resources. For the purposes of discussing natural system effects, operations of the petroleum industry can be divided into production, refining, and market activities. (A discussion of natural system impacts of OCS oil and development is contained in Volume I, Conceptual Model.) Production includes locating and drilling oil wells, pumping and pretreating the crude oil, recovering gas condensate, and shipping these raw products to the refinery, or in the case of gas, to commercial sales outlets. Refining includes the conversion of crude oil to a finished saleable product, and manufacture of various chemicals derived from petroleum. Marketing involves the distribution of, and actual sales of, the finished product (Winzler and Kelly, 1977b).

During each of these operations, various air contaminants are produced and released. The major contaminants released during the production stage are hydrocarbons, nitrogen oxides and hydrogen sulfide. During the refining stage, hydrocarbons, nitrogen sulfide, sulfur oxides and carbon monoxide are released (Winzler and Kelly, 1977b).

The only emissions released during the marketing stage are hydrocarbons lost through evaporation from storage tanks, transfers and spills. The emissions from the handling of gasoline are 100% hydrocarbons, of which two-thirds are highly reactive (smog producing). The quantities of emissions are dependent upon the operation and the type of control equipment in use (Winzler and Kelly, 1977b).

The production of oil and gas results in an associated production of highly saline wastewater, oily wastes, and other chemical wastes. The amount of wastewater generated by any one oil field varies with the character of the particular petroleum deposits. The majority of these wastes released in the study area are discharged in the coastal and nearshore areas around Santa Maria. The volumes of petroleum industry wastes are projected to decline in the future (Winzler and Kelly, 1977b).

Subsidence may result from withdrawal of ground fluids during oil and gas extraction and geothermal extraction operations. There have been indications of subsidence in the Geysers area of Sonoma County; however, existing information is not sufficient to evaluate the extent (EDAW, Inc., 1978).

Frequent oil and chemical spills are a major problem in the San Francisco Bay system. Spills occur most frequently during fuel transfer operations at dock facilities, but the most damaging incident occurred in January, 1971, when two tankers collided in the Bay and released 840,000 gallons of fuel. However, human error during refueling or fuel transfer is the most common cause (Winzler and Kelly, 1977b).

The potential for tanker collision and other tanker accidents is present all along the coast. Oil spills may adversely impact marine habitats and species. Impacts may be especially serious if spills affect wetlands or estuaries. Secondary impacts may also occur, affecting the commercial fishing industry, ocean sports fishing, and onshore recreational and tourist activities if oil slicks wash up on coastal beaches. The likelihood of ocean spills from tankers, pipelines and offshore rigs would increase if offshore oil and gas were developed in the study area. The Conceptual Model discusses natural and socioeconomic systems impacts of offshore oil and gas development activities.

Future Economic Importance of the Industry.

Non-Energy Resources. The extraction and mineral industries have historically been minor employers and personal income producers in the coastal economy, yet mineral resources may play an important role in the national economy when their input is necessary for an important industry and scarcity or unreliability of foreign sources characterize their supply.

The chromium deposits of the North Coast are a case in point. The United States relies primarily on imported chromite ore from Rhodesia, South Africa, the Philippines, and the U.S.S.R. Conversations with various mining and industry observers suggest that some industry officials are becoming nervous about the reliability of foreign supplies, and would be receptive to a proposal for a reliable supplement of domestic chromite ore at a price higher than for imported ore. One small mine in California reported production of chromite during 1976, the first recorded domestic production since 1961. The California-Nickel Company proposal to mine chromite at Gasquet Mountain in Del Norte County could have a significant impact on the economy and population of Del Norte County, where chromite mining has been dormant since the 1950's (EDAW, Inc., 1979c). California-Nickel suggests that the mine might employ 500 people at peak production (EDAW, Inc., 1979c).

Recently, the export of sand and gravel resources by water from Humboldt County to Southern California has been proposed. Barge transportation costs of such bulky materials would be substantially lower than shipment by rail or road. Shortages of concrete aggregate in Southern California could increase prices and consequently increase the feasibility of exporting local sand and gravel. Environmental objections could be strong and the effects of substantial gravel extraction would require much further examination (EDAW, Inc., 1979a).

In its editions of Projections of Employment by Industry and Occupation, 1980-85, the California Employment Development Department (1978) forecasts stability in non-energy resource mining employment in Humboldt, Del Norte, Sonoma and Santa Cruz counties through 1985. Mining employment in these counties is primarily dependent on sand, stone and gravel for construction aggregate.

Energy Resources. Future importance of extractive energy resources in the study area will depend primarily on the outcome of Lease Sale No. 53 and future OCS oil and gas development leases along the northern and central California coast. The draft Environmental Report for No. 53 is scheduled for completion in April 1980, and the sale itself is expected to occur in May 1981 (U.S. BLM, 1980b). The ever-increasing price of OPEC oil, and recent events in Iran, increase the likelihood that the sale will occur on schedule. Opposition to sale No. 53 has been officially expressed by every county within the study area. Lease Sales Nos. 73 and 80 have been scheduled by BLM for the California coast in May 1983 and June 1984, respectively. Lease block areas have not, as yet, been identified by BLM, and it is not known whether the northern and central California coast will be affected (Noah Tilghman, California Coastal Commission, personal communication, November 15, 1979).

Federal Statutes Relevant to Offshore Oil and Gas Development. Following is a list of federal statutes that may affect the OCS development process. A listing of agency responsibilities stemming from these statutes is contained in a subsequent section. The lists are adapted from the California Office of Planning and Research (1977).

Anadromous Fish Conservation Act (16 U.S.C. 757). This act authorizes the Secretary of the Interior to enter into cooperative agreements with states to conserve anadromous fishes. Federal monies are available to help reduce harm to the anadromous fishery resources of the coastal states from offshore development.

Clean Air Act Amendments of 1970 (42 U.S.C. 1857-1857f). The Clean Air Act sets general guidelines and minimal air quality standards on a nationwide basis. States are responsible for developing comprehensive plans for all regions within their boundaries. The requirements of the act and state programs apply to any OCS-related facility or activity onshore or within the three-mile-wide territorial sea, but it is unclear whether the Clean Air Act operates to regulate air quality offshore beyond three miles.

Coastal Energy Impact Program (CEIP) of 1976. The Department of Commerce's CEIP provides financial assistance to state and local governments affected by OCS-related development through a Coastal Energy Impact Fund which includes planning grants, audit and repayment assistance, and environmental and recreational loss grants, and OCS Formula Grants, for financial assistance to prevent or minimize the loss of valuable environmental or recreational resources.

Coastal Zone Management Act of 1972 (16 U.S.C. 1451-1464). The Coastal Zone Management Act (CZMA) provides federal funding to states to assist them in developing and administering their own coastal zone management programs. Amendments to the act enacted in 1976 created a program to compensate states for the onshore effects of the location of coastal-dependent energy facilities. Once a state has

devised a federally approved coastal zone management plan, the act requires federal agencies conducting or supporting activities directly affecting the state's coastal zone to do so in a manner consistent to the maximum extent practicable with the state's plan. Furthermore, activities requiring a federal license or permit affecting land or water use in the coastal zone must be consistent with an approved state plan or be otherwise necessary for the national security. Lastly, the CZMA authorizes federal grants to states of up to 50% of the cost of acquiring, developing and operating estuarine sanctuaries.

Commercial Fisheries Research and Development Act of 1964 (16 U.S.C. 779-779f). This act authorizes the Commerce Department to make federal funds available to states to research and develop commercial fisheries in areas affected by offshore development.

Department of Transportation Federal-Aid Highway Provisions (23 U.S.C. 138, 317). Under this act, the Secretary of Transportation must cooperate with various federal agencies and with the states in developing transportation plans and programs that include measures to maintain and enhance the natural beauty of the lands traversed. Roads servicing OCS-related onshore facilities that cross federal lands or were built with federal aid must comply with these provisions.

Federal Water Pollution Control Act Amendments of 1972 (FWPCA) (33 U.S.C. 1251, et seq.). The Federal Water Pollution Control Act Amendments (FWPCA) limit and control the discharge of oil or other hazardous substances into the sea. The FWPCA applies only to offshore facilities and vessels within 12 miles of shore. A permit from EPA is required if these activities result in discharges into the water.

Fish and Wildlife Act of 1956 (16 U.S.C. 742a-754). This act established the United States Fish and Wildlife Service in the Department of the Interior to study, protect, and manage fish resources. The Secretary of the Interior must investigate all changes or diminution in the number of food fishes of the coastal waters and report to the Congress his recommendations for actions to protect fish in these areas.

Fish and Wildlife Coordination Act (16 U.S.C. 661-6673). This act authorizes the Secretary of the Interior to assist government and non-government organizations in the protection of all species of wildlife and requires notification of the Department of Commerce if a particular offshore development harms wildlife.

Fish Restoration and Management Projects (16 U.S.C. 777-777k). Federal funds for the management and restoration of fisheries are available from the National Oceanic and Atmospheric Administration of the Commerce Department under the authority of this act.

Intervention on the High Seas Act (33 U.S.C. 1471-1487). The Intervention on the High Seas Act gives the Secretary of Transportation responsibility to take those measures necessary to protect the United States' marine resources, wildlife, coastal zone and estuaries, and shorelines and beaches against polluting oil discharges from ships on the high seas. The Secretary may coordinate all efforts to eliminate the threatened pollution and remove or destroy the ship and cargo creating the danger, if necessary. This act derives authority in international law from the Convention Relating Intervention on the High Seas in Cases of Oil Pollution Casualties, opened for signature November 29, 1969, T.I.A.S. 8068. The law pertains to all ships on the high seas except warships and other ships owned by foreign governments engaged in noncommercial service.

Marine Mammal Protection Act (16 U.S.C. 1361, 1362, 1371-1384). This act prohibits the taking of pinnipeds in offshore waters.

Marine Protection, Research, and Sanctuaries Act of 1972 ("Ocean Dumping Act") (33 U.S.C. 1401-1444). This act authorizes the designation of marine sanctuaries by the Secretary of Commerce with the approval of the President. Also under the act, the Environmental Protection Agency regulates the dumping of materials in the territorial sea, contiguous zone, or ocean waters.

National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321-4347). NEPA sets national policies to protect the environment and create and maintain conditions under which man and nature can exist in productive harmony. The act requires federal agencies to prepare and consider an environmental impact state-

ment before taking any major action that could significantly affect environmental quality, including offshore oil and gas leasing and development.

National Historic Preservation Act (16 U.S.C. 470, et seq.). The National Historic Preservation Act protects historical and cultural resources, including those on offshore lands. Mandatory procedures for protecting these resources appear in 36 C.F.R., Part 800, under the authority of Executive Order 11593 and this act.

Natural Gas Act (15 U.S.C. 717-717w). The Natural Gas Act authorizes the Federal Power Commission (FPC) to regulate natural gas pipelines engaged in interstate commerce, including those transporting gas produced from the OCS.

Natural Gas Pipeline Safety Act of 1968 (49 U.S.C. 1671-1684). The Department of Transportation sets and enforces standards for the design, installation, inspection, testing, construction and maintenance of natural gas pipelines, including those on the OCS, pursuant to this act.

Occupational Safety and Health Act of 1970 (OSHA) (29 U.S.C. 651-678). OSHA authorizes the Secretary of Labor to set and enforce mandatory occupational safety and health standards for work places. The act specifically applies to OCS activities.

Oil Pollution Act Amendments of 1973 (33 U.S.C. 1001-1015). This act prohibits the discharge of oil or oily mixtures from ships within 50 miles of land except in certain specific instances. The act outlines sections of the International Convention for the Prevention of the Pollution of the Sea by Oil (1954). Small discharges from ships en route to the coast are exempt.

Outer Continental Shelf Lands Act (43 U.S.C. 1331-1343). The OCS Lands Act of 1953 established the jurisdiction of the United States federal government over mineral resources of the Outer Continental Shelf beyond the three-mile territorial limit. State laws consistent with the act apply to the OCS. The act gives the Secretary of the Interior authority to lease OCS tracts by competitive bidding and provides general guidelines and directives for managing the exploration, development and production of the oil and gas resources. The Coast Guard regulates the safety of offshore activities and shares responsibility with the U.S. Army Corps of Engineers for insuring safe cavitation under the act. A 1978 amendment to the act requires the Secretary of the Interior to consult with local and state government at almost all stages of the OCS leasing and development process.

Ports and waterways Safety Act of 1972 (33 U.S.C. 1221-1227). This act authorizes the Department of Transportation to establish vessel traffic service and systems for ports, harbors and other waters subject to congested vessel traffic.

Submerged Lands Act (43 U.S.C. 1301-1315). The Submerged Lands Act grants coastal states exclusive rights to the resources of offshore lands up to three geographical miles from the shoreline. Federal rights and powers relating to navigation, commerce, national defense and international affairs within the three-mile territorial sea are retained by the federal government and not affected by this law.

Wildlife Restoration. (16 U.S.C. 669-669i). Through the Department of the Interior, federal funds are available to states under this act for wildlife restoration projects.

OCS Responsibilities of Federal Agencies.

Department of Commerce National Oceanic and Atmospheric Administration (NOAA). Several offices within the National Oceanic and Atmospheric Administration have OCS-related responsibilities: Office of Coastal Zone Management (marine sanctuaries and coastal zone management); National Marine Fisheries Service (commercial fisheries and other living marine resources); Environment Data Service (OCS marine environmental assessment data management); National Ocean Survey (tides, currents, and other environmental features affecting the design and location of offshore structures); National Sea Grant Program (marine research funds); Environmental Research Laboratory (assessment study of petroleum development on the Alaskan OCS); and, the National Weather Service (historic storm data, weather forecasts, and hurricane warnings). All federal agencies must notify the

Department of Commerce National Oceanic and Atmospheric Administration of any proposal to grant a license or permit that might affect marine life and habitats. NOAA provides meteorological, oceanographic, fisheries, and marine wildlife data to other agencies for assessments of environmental impacts and recommends mitigating conditions for protection of marine and coastal resources. In addition, NOAA assists the Department of Interior in the conduct of environmental baseline studies.

Department of Defense, Corps of Engineers. The U.S. Army Corps of Engineers has responsibility for preventing obstructions to navigation on the OCS. The Corps issues permits and sets and enforces regulations for fixed offshore structures, including platforms, artificial islands, pipelines and exploratory drilling vessels. In congested areas, the Corps of Engineers has authority to establish safety fairways within which the installation of permanent structures is prohibited.

Environmental Protection Agency (EPA). The Environmental Protection Agency has responsibilities for preventing and reducing air, water and noise pollution. EPA sets national ambient air quality standards for air pollutants and reviews state implementation plans designed to achieve those standards. EPA's air pollution controls apply to onshore facilities related to offshore petroleum development and could directly affect offshore operations. EPA issues permits for the discharge of pollutants into offshore waters and works with the Coast Guard to carry out a national oil spill prevention and cleanup program.

Executive Office of the President/Council on Environmental Quality (CEQ). CEQ advises the President on matters affecting the environment. CEQ establishes guidelines for the preparation of environmental impact statements under the National Environmental Policy Act and annually publishes substantive analyses of various environmental issues, including OCS oil and gas development.

Federal Power Commission (FPC). The FPC regulates the price and transportation of natural gas in interstate commerce, including all gas produced from the OCS. The Commission issues permits for the construction and operation of OCS and other interstate gas pipeline and storage facilities used with such pipelines, sets the wellhead price of OCS gas, and must assure the nondiscriminatory transportation and purchase of natural gas.

Interstate Commerce Commission (ICC). The ICC regulates rates and access to common carrier oil pipelines in interstate commerce, including oil pipelines from the OCS.

Department of the Interior/Bureau of Land Management (BLM). BLM has responsibility for leasing offshore lands and collecting lease bonuses and rents. In administering lease sales, BLM receives nominations and selects tracts for inclusion in the sale; prepares an environmental impact statement for each sale, makes economic, engineering, and geologic evaluations of tracts to be leased; and receives bonus bids and determines whether to award leases to the highest bidders on individual tracts. BLM also grants rights-of-way for oil and gas transmission lines from the OCS to shore.

Department of the Interior/Fish and Wildlife Service. The Fish and Wildlife Service provides biological assistance and recommendations for lease stipulations to BLM and U.S.G.S. for OCS leasing and development activities pursuant to Secretarial Order 2974 dated April 30, 1975.

Department of the Interior/United States Geological Survey (USGS). Before BLM leases offshore lands, the USGS makes broad area surveys to assess hydrocarbon potential, grants permits for the conduct of geophysical and geologic exploration, participates in the preparation of environmental impact statements on proposed lease sales, and advises BLM on the resource potential and dollar value of specific lease tracts. USGS has the primary responsibility for supervising exploration, development, and production activities on OCS leases. This post-lease supervision includes issuing and enforcing safety regulations, issuing geophysical and geologic exploration permits, reviewing exploration and development plans, issuing drilling permits, granting rights of use and easements for OCS pipelines on the OCS, and collecting royalties.

Department of Labor/Occupational Safety and Health Administration (OSHA). In conjunction with the Department of Health, Education and Welfare (HEW), OSHA sets safety and health standards for fixed structures on the OCS. OSHA conducts

inspections at the request of employers or workers and enforces the safety and health regulations.

Department of Transportation/Coast Guard. The Coast Guard has several responsibilities for safety and the prevention of pollution on the OCS. The Coast Guard establishes and enforces safety regulations for platforms and other fixed structures, insures proper marking of platforms to prevent collisions with vessels, and inspects floating drilling rigs. The Coast Guard enforces federal oil pollution laws in both federal and state waters offshore, shares responsibility with the Environmental Protection Agency for oil spill prevention and cleanup, and coordinates the National Oil and Hazardous Substance Pollution Contingency Plan. In congested waters, the Coast Guard may establish a voluntary Vessel Traffic Separation Scheme (VTSS) such as those established in the Santa Barbara Channel and Gulf of Santa Catalina, with traffic lanes separating vessels going in opposite directions. In establishing such a scheme, the Coast Guard has no authority over the drilling operations of floating drilling rigs or the placement of platforms. These facilities and operations fall under the U.S. Army Corps of Engineers' or U.S. Geological Survey's authority to regulate the location of fixed structures on the OCS.

Department of Transportation/Office of Pipeline Safety. The office of Pipeline Safety issues and enforces regulations applying to the design, installation, inspection, testing, construction, extension, operation, replacement and maintenance of natural gas and petroleum pipelines crossing state lines, including OCS pipelines. This jurisdiction includes transmission pipelines, offshore gathering lines and onshore gathering lines in non-rural areas.

TFWNSPORTATION AND ENERGY UTILITIES

Resources

Transportation resources fall into three broad categories: (1) the opportunities for development of transportation facilities provided by the geographic, topographic and meteorological character of a region; (2) the transportation facilities themselves, including docks and unloading areas, air fields, roadways, railway tracks and terminals, and their potential for adaption to changes in patterns of goods and people movement; and (3) the "rolling stock," including vessels, aircraft, railcars, trucks and automobiles.

The topography of the central and northern California coastal areas, marked by north-south trending mountain ranges rising steeply from the ocean, imposes major restrictions on the development of transportation systems: the major roadways and railways run inland of the coastal range, and there are few natural harbors suited to commercial development. There is, however, sufficient flat land in the alluvial plains at the mouths of rivers, in the narrow east-west trending valleys along the coast, and the interior valleys of the mountain ranges to allow development of airport facilities close to population centers. Climate does not, in itself, limit the development of transportation resources. In the north, however, heavy fogs frequently interrupt airport operations.

The ocean provides an easily accessible and virtually limitless supply of cooling water for electrical power generation. In addition, topography and climate produce swiftly flowing rivers (in northern California) which provide some potential for hydro-power generation. The forest resources of the northern region may also contribute to electrical power generation by means of (as yet experimental) power plants using wood by-products as fuel.

The rugged nature of the coastal mountains, on the other hand, represents a significant barrier to the construction of pipelines.

Land Transportation. Two highways run the length of the coastal region. State Highway 101 is a four-lane highway, which, except in the two northernmost counties, runs inland of the coastal range. State Highway 1 runs along the coast. For most of its length, it is a narrow, winding two-lane road; only in the stretch between San Luis Obispo and Cambria at the coast does it become four lanes. Access from the inland to the coast road is provided primarily by two-lane roads. The one exception is State Highway 17, a four-lane road that runs between Santa Clara County and Santa Cruz. The only other four-lane highway serving the coast is State Freeway 280, which runs just east of the coastal ridge in San Mateo County.

Highway 101 is the major freight-carrying route. Highway 1 is used primarily by recreational travelers. (See the section of this chapter on Recreation for a further discussion of roads as a recreational resource.)

Figure 5-13 is a map of the state highway system. An inventory of roads in the eleven northern and central coastal counties is given in Table 5-77.

Table 5-77. Mileage of Roads in Each Coastal County by Jurisdiction, 1977
(California Department of Finance, 1978)

County	All Roads Total	State Highways			County Roads	City Streets	State Roads Other Than State Highways	National Roads Not Overlapping State or Local Systems
		Total	Outside Cities	Inland Cities				
Del Norte	964	91	90	1	298	18	23	534
Humboldt	2,587	336	319	17	1,196	202	119	734
Marin	1,180	90	68	22	419	528	63	80
Mendocino	2,194	380	372	8	1,015	89	299	411
Monterey	2,305	289	264	25	1,292	525	27	172
San Francisco	886	34		34		845	2	5
San Luis Obispo	2,451	366	333	33	1,312	292	50	431
San Mateo	1,969	209	102	107	374	1,350	36	
Santa Barbara	2,253	317	276	41	886	471	34	545
Santa Cruz	1,058	124	106	18	593	254	87	
Sonoma	2,283	237	207	30	1,450	500	90	6

The figures shown in the table are countywide and do not give an entirely accurate indication of mileage serving the coastal region. In the three northernmost counties and the four southernmost counties, most of the highway mileage serves the coastal zone. In counties in the San Francisco Bay Area, however, most of the mileage shown is inland, serving the urbanized areas. For these counties (Sonoma, Marin, and San Mateo), the figures for county road mileage and state highway mileage outside cities give a closer approximation of mileage actually serving the coastal region.

Two Class I line-haul railroads serve the region: the Northwestern Pacific Railroad serves the area between San Francisco and Arcata; the Southern Pacific Railroad serves the area south of San Francisco as far as Santa Barbara County.

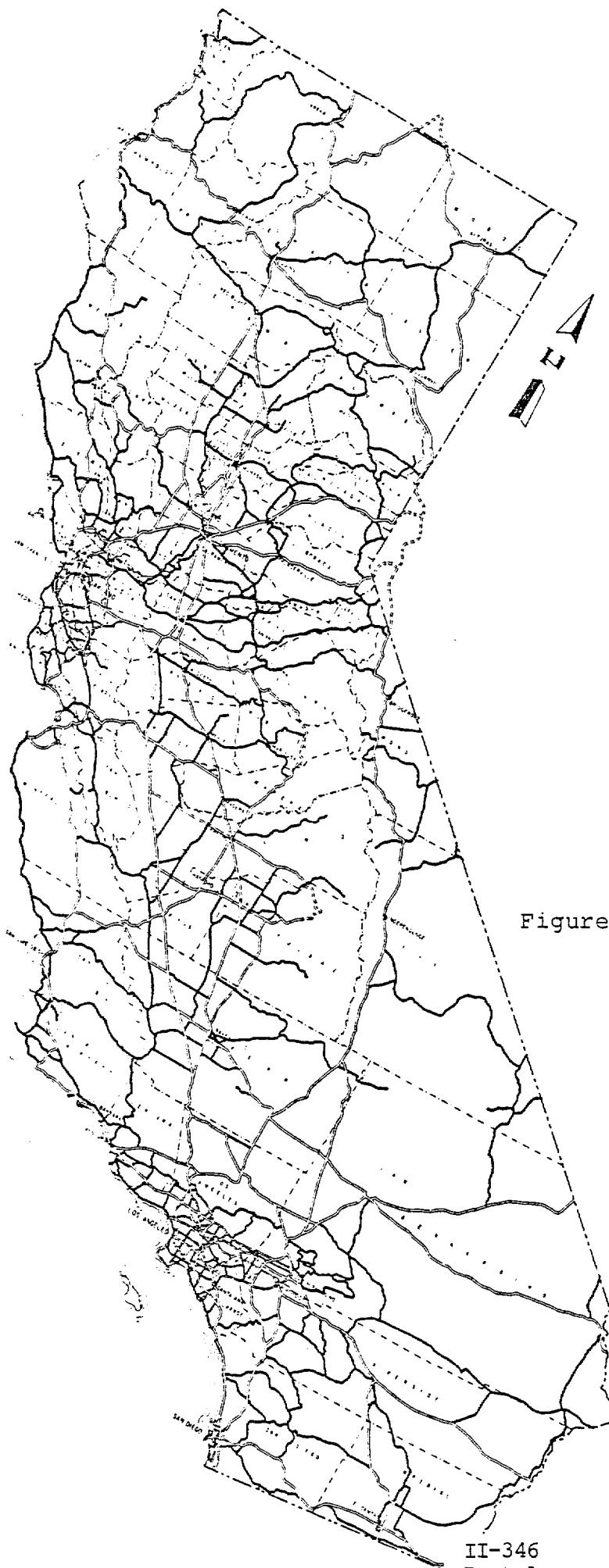
The Northwestern Pacific Railroad runs inland through Petaluma, Santa Rosa, Ukiah, and Willits, moves out to the coast at Scotia/Fortuna, and terminates just north of Arcata. Trackage of the Northwestern Pacific line is 314 miles.

The Southern Pacific line runs from Gilroy, south of San Jose, to Watsonville, where spur lines run north to Santa Cruz and southwest to Monterey. The main line turns southeast and runs down the Salinas Valley into the central valley of San Luis Obispo County. The line runs through Paso Robles, Atascadero, and San Luis Obispo, and then follows the coast through Guadalupe to Santa Barbara. A spur line serves Lompoc; a small railway, the Santa Maria Valley line, serves Santa Maria. The straight line trackage of the Southern Pacific line between San Francisco and Lompoc/Santa Maria is 346 miles, a small fraction of the 4,086 miles of the total Southern Pacific trackage in the state (Winzler and Kelly, 1977b).

Several smaller (Class II) railroads also operate in the region, serving as spur railroads to the main line. An inventory of these railroads is given in Table 5-78.

Table 5-78. Mileage of Class II Line
Haul Roads

Railroad	Mileage
Arcata and Mad River	8
California Western	40
Petaluma and Santa Rosa	37
Santa Maria Valley	18
Total	103



RESPONSIBILITIES		
	State Highway Routes	
	of Statewide Significance	of Regional Significance
DETERMINE DEMAND	COOPERATIVE	REGION
SET LEVEL OF SERVICE	COOPERATIVE	REGION
PRIORITY SETTING	STATE	REGION
DESIGN	STATE	STATE
CONSTRUCTION	STATE	STATE
OPERATIONS AND MAINTENANCE	STATE	STATE

LEGEND

- STATE HIGHWAYS OF REGIONAL SIGNIFICANCE
- == STATE HIGHWAYS OF STATEWIDE SIGNIFICANCE
- OTHER HIGHWAYS OF STATEWIDE SIGNIFICANCE

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Figure 5-13. State Highway System

Air Transportation. There are eight airports qualified to accept commercial traffic within the n-county coastal region. These are classified by the type of passenger service handled: San Francisco Airport (actually in San Mateo County) is the one international airport; the others are intrastate airports. Table 5-79 shows the relative volume of activity at each airport.

Table 5-79. Departures: Commercial Airports, Coastal Area-1974
(Winzler and Kelly, 1977b)

Airport	Departures
Eureka/Arcata	2,941
Crescent City	1,123
Ukiah	NA
Monterey	4,906
SFO International	109,611
Paso Robles	2,000
San Luis Obispo	8,000
Santa Maria	4,586
Study Area	133,167
California	361,217

Water Ports. Ports, which serve the movement of waterborne commerce, are distinguished from marinas, which serve small pleasure craft, although both functions frequently occur within the same harbor. Among commercial ports, it is useful to distinguish, first, between petroleum-unloading ports and commodity unloading ports and, secondly, between commodity-handling ports that can handle container vessels and those that cannot.

Excluding the ports in the San Francisco Bay, there are only four commercial ports in the coast region: at Morro Bay and Moss Landing south of San Francisco, and to the north, at Humboldt Bay and Crescent City. The activity of these ports is closely tied to the resource economy of the area. All are used for fish unloading. Humboldt Bay is also used for the export of lumber products. Although each of these ports has facilities for petroleum-unloading, both commodity-handling and petroleum-handling are concentrated within the San Francisco Bay area (see Table 5-86 under Resource Use). The only container-handling facilities along the coast are operated by ports located in San Francisco Bay. Other petroleum-unloading facilities in the region are at Avila, and there are offshore petroleum-loading facilities at Estero Bay, adjoining Morro Bay.

Energy Utilities. Electrical power plants are commonly classified by type, size and fuel type. There are five plant types: nuclear, coal (fossil fuel), steam, combined cycle and combustion turbine; three plant sizes: small (100Mw), medium (500-800 Mw) and large (1,000-1,300 Mw); and six fuel types: nuclear, coal oil, coal, gas, natural gas and methane. Within the study area power plants are located at Humboldt Bay, Moss Landing (Monterey County) and Morro Bay (San Luis Obispo County), as shown in Table 5-80.

Table 5-80. Existing Major Coastal Thermal
Electrical Generating Plants Over 50 Mw, 1979
(California Energy Resources and Development Commission, 1979b)

Name	Type	Installed Capacity
Humboldt Bay	Fossil Fuel	105 Mw
Humboldt Bay	Fossil Fuel	63 Mw
Moss Landing	Fossil Fuel	2,060 Mw
Morro Bay	Fossil Fuel	1,095 Mw

Pipelines, both onshore and offshore, carry crude oil between terminals, production fields, and refineries. Pipelines also carry refined petroleum products between refineries and distribution points. Most petroleum product lines are located in the Bay Area and run between the various refineries and major distributors such as the Southern Pacific Railway. Submarine pipelines (offshore) carry in offloading boiler crude or fuel oil from offshore marine terminals to power generation facilities. There are four offshore unloading facilities within the study area, at Moss Landing and Morro Bay (both operated by Pacific Gas & Electric) and two at Estero Bay just north of Morro Bay (one operated by Chevron USA, the other by Texaco) (Winzler and Kelly, 1977b).

Natural gas pipelines carry both natural gas produced in California and that from out-of-state sources. Natural gas pipelines within the study area terminate at Santa Maria, Morro Bay, Moss Landing and Eureka (Winzler and Kelly, 1977b).

Resource Use and Demand and Supply Factors

Transportation. The use of transportation resources (choice of mode) is dependent upon a host of market-related factors: price/cost as a function of bulk, speed of handling, origin-destination times and directness of route. The transportation market is highly-regulated; regulation affects price and, therefore, choice of mode. The object of regulation is to deploy capital investment in transportation services most efficiently. However, its effect frequently is to induce a monopolistic impact on prices, presumably in exchange for the retention of service to destinations that would otherwise be abandoned as unprofitable.

A choice of the three main modes of transport-road, rail, and air-exists along the coast at all major centers of population: Eureka/Arcata, Santa Cruz/Monterey, San Luis Obispo/Morro Bay, Santa Maria/Orcutt. Between these population centers, there are long stretches of coast, particularly north of San Francisco, where roads are the only means of access. Fort Bragg, at the center of this stretch, is served also by rail (the California Western line).

Transportation services in all modes are concentrated within the San Francisco Bay area. Major ports, airports, and highways in the Bay Area are shown in Table 5-8.

Table 5-31. Port and Transportation Facilities for Petroleum Companies in the San Francisco Bay Area, 1979

Location	Company	Commercial (l-c) Airports	Highways ¹ (4-lane) - state interstate
San Francisco	Chevron (Richmond)	San Francisco	Highway 280
Redwood City	Union-Oleum (Rodeo)	Oakland	Highway 680
Oakland	Pacific Refining	San Jose	Highway 17
Richmond	(Hercules)		Highway 80
Benicia	Exxon (Benicia)		Highway 580
Encinal Terminals	Lion-Amorco		Highway 37
	(Martinez)		Highway 101
	Shell (Martinez)		Highway 92

1. Routes serving coastal counties and connecting routes.

For transportation services, the demand/supply relationship is expressed as a function of capacity. Calculation of the capacity of a given transportation facility involves many variables, some quantifiable, some not. For example, a commuter using a segment of highway for travel from home to work is likely to have a different perception of when the roadway is at capacity, i.e., when mobility falls below some level of acceptability, than a sightseer on the same road.

The period of demand is one of the more important determinants of capacity. On roadways in particular, but also at airports and ports, demand is concentrated at some time periods, relaxed at others; hence, the concept of peak period capacity.

Peak load is also a critical factor in the supply of electrical power. The critical peak period of the day lies between 4 and 6 p.m. when a high level of residential demand and on-going commercial and industrial demand occur together. Energy conservation programs are aimed at reducing the peak demand requirements of electrical power generation.

Land Transportation. For roads, the relationship between demand and supply is frequently expressed as level of service. Table 5-82 shows levels of service for two-lane (rural) roads. For such roads, level C is often taken as the design standard.

Table 5-82. Explanation of Levels of Service
(DeLeuw, Cather, 1979)

Level of Service	Characteristics for a Two-Lane Highway
A	Unimpeded travel. Ideal traffic conditions. Passing only rarely necessary. Frequently, no other cars in view. Operating speed must be 60 mph or more.
B	Motorists free to choose own rate of travel, but periodic passing required for faster motorists to maintain rate of travel. Other cars often in view, greater proportion of driver's attention fixed on traffic. Operating speed is 50 mph or above. Increased level of congestion; short strings of traffic encountered making passing somewhat more difficult and less safe. When one group of cars is passed, another is soon encountered. Thus, trip time for faster motorists is somewhat reduced. Operating speed is 40 mph or above. Congested; long strings of traffic symptomatic. Passing generally unsafe, less frequent, never significantly gainful. Thus, rate of travel for all is dictated by the slowest motorists on the road. Air and noise pollution more noticeable, constant. Traffic conditions viewed as unpleasant by many drivers, although the more leisurely look at the scenery may be appreciated by the passengers. Steady flow means high volume of cars per hour, despite reduced median travel speed. Operating speed is 35 mph or above. Defined as at or near maximum capacity. Operating speeds range from 25 to 35 miles per hour, but momentary stoppages may occur. Traffic flow is unstable due to highly congested conditions. Noncommuter residents tend to avoid travel when possible. Recreational motorists not seriously deterred. Traffic is "bumper to bumper"; unstable flow is characteristic, both short and long stoppages not unusual. Resembles big city "rush hour" commuter conditions. Travel frustrating, unpleasant. Over-heating, mechanical breakdowns more frequent. High air pollution. Maximum number of cars on road, but volume per hour reduced by inefficient rates of flow. In the extreme, both speed and volume drop to zero. If a queue of stopped cars is observable at entry points, roadway may become self-regulating for those with a choice (i.e., nonresident recreational motorists), provided they are given a chance to turn about.

During peak periods (weekends) and peak months (summer months), Highway 1 is at service levels D and E throughout much of its length (De Leuw, Cather and Company, 1979; Monterey County Planning Department, 1979). As shown on Table 5-83 many east-west lateral routes providing access into the coastal area from Highway 101 have similar service levels. The service levels of these lateral routes are a less important factor in the two northern counties where the four-lane Highway 101 directly serves the coast, and south of San Luis Obispo where Highway 1 is a four-lane highway as far as Cambria above Morro Bay.

Highway 101 is the major transportation corridor for the region. Although it is a four-lane divided highway throughout its length, in many places its capacity is reduced because it is at expressway - not freeway - standards; that is to say, it is not a limited-access route throughout its length. Upgrading of Highway 101 to full freeway standards is likely to be a priority improvement in most coastal counties for several years to come.

Table 5-32. Summary of Service Levels Described in Table 5-81, on State Highways, 1979 (San Luis Obispo County, 1978; pers. communications: Greg BOYS, CALTRANS, 1980, Gene Cabaluna, Monterey County, 1979; Ron Marquez, Santa Cruz County, 1980; Joe Hoisting, Mendocino County, 1980)

County	Route ¹	Level of Service Peak	Level of Service Normal	Proposed Operational Improvements	Proposed Capacity Expansions ²
Mendocino	20	C	B		
	128	C	B		
Sonoma	116	C	B	X	X
San Mateo	92	E	D	X	
	84	E	D	X	
Santa Cruz	9	D	C	X	
	17	D	C	X	
	152	D	C	X	
	129	C	B	X	
Monterey	156	E	C	X	
	68	E	C	X	
San Luis Obispo	46	C	C		
	41	D	C	X	

1. Existing routes between Highway 101 and Highway 1.
2. An "X" indicates a proposed change.

Although the California Public Utilities Commission produces annual reports of the Class I rail carriers with right-of-way in the coastal study area, there are no statistics from which to make an estimate of rail capacity, specifically, within the coastal area. Therefore, coastal rail capacity must be inferred from statewide figures. The figures for freight traffic carried in California in Table 5-83 show that the railway share of commodity and petroleum traffic is following the downward national trend. Assuming that available rolling stock and loading facilities have not similarly declined, it can also be assumed that rail usage is far below capacity.

Air Transportation. Airfield capacity is the maximum number of aircraft takeoffs and landings that may be accommodated in a given period of time. The number accommodated is affected by ceiling and visibility, runway configurations and use, mix of aircraft types, the arrival/departure ratio, the availability and location of runway exits and a number of other factors. Typically, capacity is calculated as the hourly or annual number of takeoffs and landings.

Information on the capacity of commercial airports in the coastal area varies widely. In the San Francisco Bay area, the Association of Bay Area Governments (ABAG) and the Metropolitan Transportation Commission (MTC) conducted a two-year study of airports within the nine-county Bay Area. The Regional Airport Systems Study adopted in 1975, has been updated continuously since that time (ABAG/MTC, 1977a). Estimates of future demand for airport capacity are included elsewhere in the regional transportation plans prepared for each county, either by the counties themselves or by county-city planning organizations.

Ports. Port capacity is a function of the number of vessels that may be accommodated by the harbor system at any given time and the capability of the port's facilities to load and unload ships. Harbor capacity is dependent on channel geometry, meteorological and tidal characteristics, types of vessels, and traffic regulations.

Table 5-83. Freight Traffic and Petroleum/Natural Gas Commodities Carried within California on Class I Railroads, by Type of Movement for years 1965-1975 (Winzler & Kelly, 1977b)

Freight Commodity Group & Year	Freight Originating		Freight Terminating		Freight Traffic	
	Cars	Tons	Cars	Tons	Originating	Terminating
1975						
Crude Petroleum & Natural Gas (STCC 13) ¹	18	1,515	15,903	1,224,731	84.2	77
Refinery Products (STCC 29) ²	46,967	3,461,452	35,628	2,439,081	73.7	68.4
All Freight Classes	773,790	37,813,319	982,614	50,739,471	48.9	51.6
Petro/Gas Resources/Products as \$ of Total Freight Classes	6.0	9.2	5.2	7.2		
1965						
Crude Petroleum & Natural Gas (STCC 13) ¹	235	8,464	5,232	355,909	36.0	68.0
Refinery Products (STCC 29) ²	34,368	1,218,106	27,690	990,615	35.4	35.8
All Freight Classes	970,592	42,256,725	1,274,490	54,279,182	43.5	42.6
Petro/Gas Resources/Products as % of Total Freight Classes	3.6	2.9	2.6	2.6		
Change 1975-1965						
Crude Petroleum & Natural Gas (STCC 13)	-217	-6,949	10,671	868,882	48.2	9.0
Percent Change from 1965	-1205%	-459%	67%	244%		
Refinery Products (STCC 29)	12,599	2,243,346	7,938	1,448,466	38.3	32.6
Percent Change from 1964	37%	184%	29%	146%		
All Freight Classes	-196,802	4,443,406	291,875	3,539,711	5.4	9.0
Percent Change from 1965	-20%	-10%	-23%	-7%		

1. STCC Code 13 includes crude petroleum, natural gas, and natural gasoline.
2. STCC Code 29 includes products of petroleum and coal refining. STCC 291 would be more appropriate as this commodity group reflects products of petroleum refining only. However, 3-digit commodity classification was not performed.

The estimation of future demand for port capacity is difficult to quantify because it is highly dependent on world economic conditions and technological advances in the industry. The capacity of ports to meet future demand is contingent upon the number and type of off-loading and ancillary facilities existing onshore, the nature of the port's interface with land-based freight movement systems, and harbor channel capacity.

Depth of the harbor channel and refining capacity are the two major factors governing port capacity for petroleum movement. Oil tankers increasingly are vessels with drafts deeper than 45 feet, and this factor alone virtually eliminates ports along the coast from playing a future role as petroleum-handling facilities, except perhaps as offshore terminal points. Chevron gave extensive consideration to developing an offshore port at Morro Bay with a pipeline to its Richmond, California (San Francisco Bay area), refinery, but has not proceeded with the project because of cost.

Although they do not show potential for development as petroleum-handling facilities, the four coastal ports (Morro Bay, Moss Landing, Humboldt Bay, and Crescent city) will continue to handle commodities. Projections of future traffic, however, are not readily available. Historical statistics and tonnage volumes computed by the U.S. Corps of Engineers show wide swings in volume at Moss Landing and Crescent City between 1968 and 1977 and do not offer any basis for projecting future flows. At Morro Bay, the Corps reports 1977 volume only. (U.S. Army Corps of Engineers, 1977b)

The future of waterborne commerce at Humboldt Bay was studied by the Corps of Engineers in 1976 (U.S. Army Corps of Engineers, 1977b) and subsequently by Humboldt County as part of an overall economic development plan. Projections developed by the

Corps for forest products which account for most of the volume shipped, are given in Table 5-85. An important finding by the Corps at Humboldt Bay was that increases in channel depths (harbor capacity) would not substantially alter projections of commercial volume handled at the harbor (Humboldt County, 1979).

Table 5-85. Projections of Waterborne Shipments of Forest Products and Vessel Traffic at Humboldt Bay, 1970-2030 (EDAW, Inc., 1979a)

Year	Total Shipment		DeeP-Draft Dry Cargo
	(MM Bd. Ft.)	Tons	Vessel Trips in Humboldt Bay
1970	267	800,000	408
1980	270	807,000	387
1990	NA	804,000	382
2000	268	802,000	378
2010	NA	824,000	395
2020	293	844,000	411
2030	338	920,000	470

Nearly all waterborne commerce in commodities and petroleum is handled by ports of the San Francisco Bay area (identified previously in Table 5-81). Forecasts of waterborne commerce (excluding petroleum) have been prepared by the Metropolitan Transportation Commission and are shown under Table 5-86. The forecast provides a high and low estimate for each category of cargo; the spread between the high and low figures is indicative of the difficulty of estimating future volumes.

Table 5-86. Alternate Waterborne Commerce Forecasts, San Francisco Bay Area, by Type of Cargo in Million of Short Tons, 1977 (Metropolitan Transportation Commission, 1977)

Cargo Type	1980	1985	1990	1995	2000
Total Dry Cargo	13.5	16.8	20.8	25.6	31.0
	13.5	19.4	27.0	34.9	43.0
Container/LASH/RORO	6.1	8.6	11.4	15.0	18.9
	6.0	10.5	16.8	23.4	30.0
Break-bulk	3.5	3.5	3.7	4.0	4.0
	3.9	4.1	4.2	4.5	5.0
Dry bulk	3.9	4.7	5.6	6.6	8.1
	3.6	4.8	6.0	7.0	8.0
Non petroleum Liquid Bulk	0.5	0.7	0.9	1.2	1.4

Crude oil and petroleum products now account for 75% of total tonnage in San Francisco Bay, and the petroleum-refining capacity within the Bay Area is estimated to be 36% of the state total (San Francisco Bay Conservation and Development Commission, 1978).

As with commodities, future deliveries of petroleum and the capacities of Bay Area port facilities are difficult to determine. Future levels of consumption of petroleum products by industrial, commercial, and individual users are the major demand factor, and demand estimates based on even recent trends may be dramatically altered by steep price increases. A second major factor affecting the amounts of petroleum delivered by tankers is the source of petroleum supply. For example, according to the California Energy Commission, 99.6% of California refinery production in 1950 was supplied by California fields, and most of this was delivered by pipeline. By 1976, the supply from California fields had dropped to 49%. The remaining 51% was supplied by foreign fields or came from the Alaskan north slope, and nearly all of it was delivered by tanker. The volume of crude oil delivered by tanker to the Bay Area is estimated by the Corps of Engineers to reach 72,000 gallons per day by 1985 (San Francisco Bay Conservation and Development Commission, 1978).

Utilities. All areas within the northern and central coastal regions are supplied with electrical power. Pacific Gas and Electric (PG&E) is the major utility company supplying power, as shown in Figure 5-14, to all parts of the study area between Humboldt Bay and Point Conception. Del Norte County is served by the Pacific Power and Light Company through a 115 Kv line to its substation at Crescent City.

PG&E is also the main supplier of natural gas along the coast between Monterey Bay and the Oregon border. Few areas of the coast receive natural gas. PG&E gas pipelines serve the Eureka/Arcata area and communities around Monterey Bay. Pipelines of the Southern Counties Gas Company of California serve communities between Cambria, in San Luis Obispo County, to Lompoc, farther south in Santa Barbara County.

In spite of differences in forecasts of the amount of petroleum and natural gas that the state will require in the future, under all estimates, new and enlarged pipeline-carrying capacity from coastal terminal facilities will be required. The California Coastal Zone Act of 1976 limits the number of LNG terminals that may be constructed on the coast to one site. Point Conception, in Santa Barbara County, has been selected but has not received final approval. A number of new pipelines are likely to be built from existing petroleum port terminals in the Bay Area to new refineries constructed outside the area because of California air quality standards (Winzler and Kelly, 1977b; San Francisco Bay Conservation and Development Commission, 1978). Precise figures on the number, location and size of new pipelines are not yet available.

The coastal area is a choice location for new electrical generating plants because of access to cooling water and because there is greater prospect of achieving air quality emission standards on the coast, where the air quality is better, than at many inland sites. Seismic hazards and the permit criteria of the California Coastal Commission are a counterweight to the engineering advantages.

The northern and central coast areas are within the service area of the Pacific Gas and Electric Company. Its service area peak load is expected to increase by 5,600 MW by the year 2000, with about half the increase occurring before 1990 - an annual growth rate of about 1.6% (California Energy Resources and Development Commission, 1979a). All the existing coastal power plants - at Humboldt Bay, Moss Landing, Morro Bay, and the nuclear power plant at Diablo Canyon are being considered for expansion (California Energy Resources and Development Commission, 1979a).

Transmission line routes, generating plants and transmission substations are shown in Figure 5-15.

Regulation, Controls, and Competition. The volume, price, and availability of particular modes of transportation are greatly affected by government controls on carriers and traffic, and regulations affecting prices. The Interstate Commerce Commission of the federal government regulates trucking and rail transportation. The Civil Aeronautics Board regulates commercial air carrier traffic through restrictions on number of carriers, route availability and user rates. The United States Coast Guard regulates vessel traffic; the Federal Aviation Administration (FAA) regulates air traffic. Traffic regulation on land is a state and local responsibility, based on federal standards and guidelines. States affect volume and modal distribution of traffic through vehicular licensing requirements and costs, fuel taxes and load limits.

The impact of regulation on competition and thus on rates is a subject of much current interest, but there are few, if any, studies of the impact of tariff or traffic regulation on the coastal area.

Of clearer importance to characterization of the coastal transportation system is the regulation of transportation facilities by state and local governments. Planning for roads, transit systems, airports and ports (but not railways) is carried out cooperatively between the California Department of Transportation and the regional transportation planning agencies. In the northern three counties and in San Luis Obispo and Santa Barbara Counties, these agencies are the counties themselves. In Monterey and Santa Cruz Counties, the agency is the Association of Monterey Bay Area Governments (AMBAG), and for Sonoma, Marin, San Francisco, and San Mateo Counties, the regional planning agency is the Metropolitan Transportation Commission.

Within transportation plans, facilities are designated as regional or of state-wide significance. The designation indicates the level of government that has controlling (but rarely absolute) influence over particular facilities.

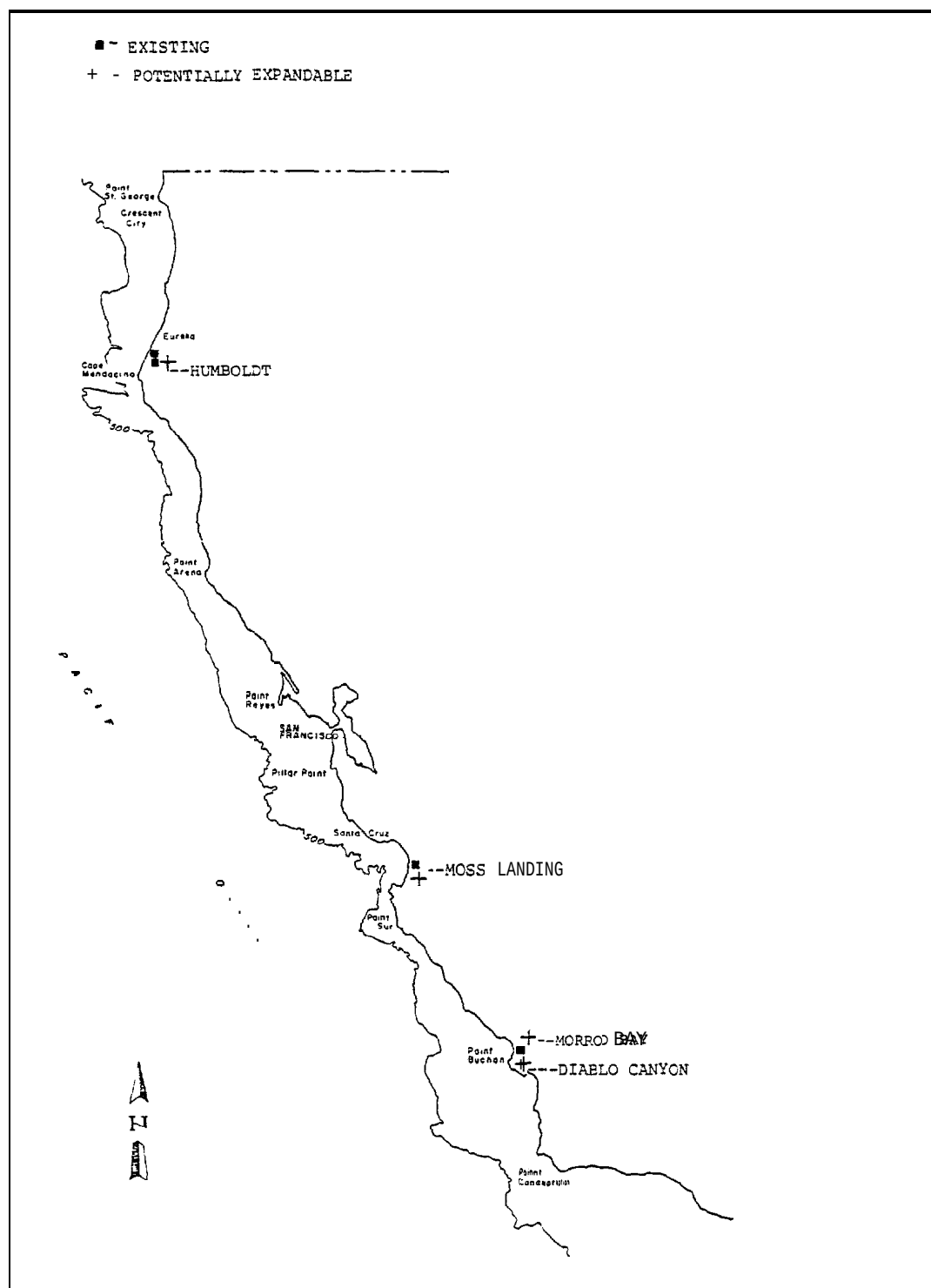


Figure 5-14. Existing and Potentially Expandable Thermal Electric Generating Plants, Coastal Counties, 1979. (California Energy Resources and Development Commission, 1979).

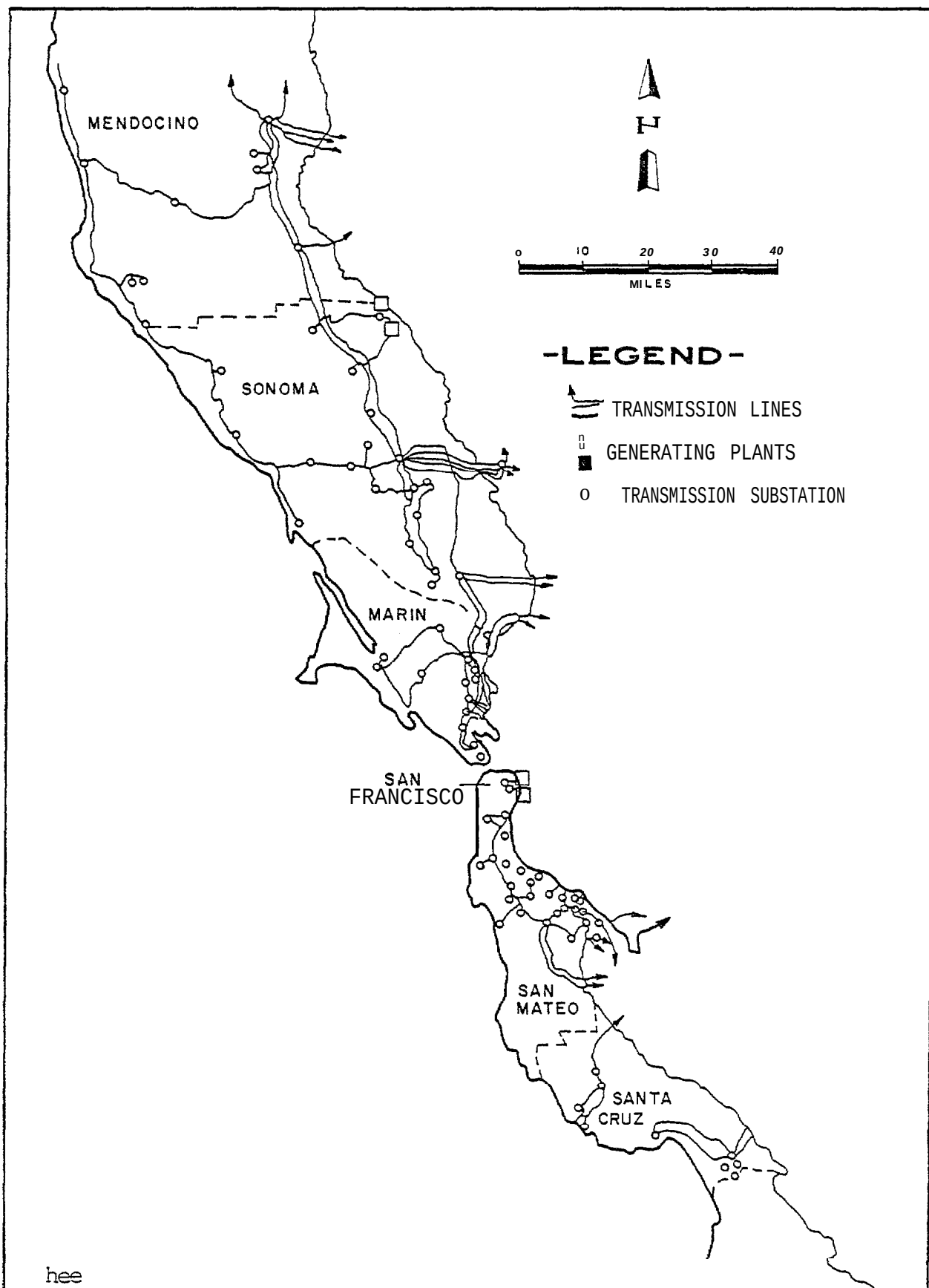


Figure 5-15. Transmission Lines in the Coastal Counties (California Public Utilities Commission)

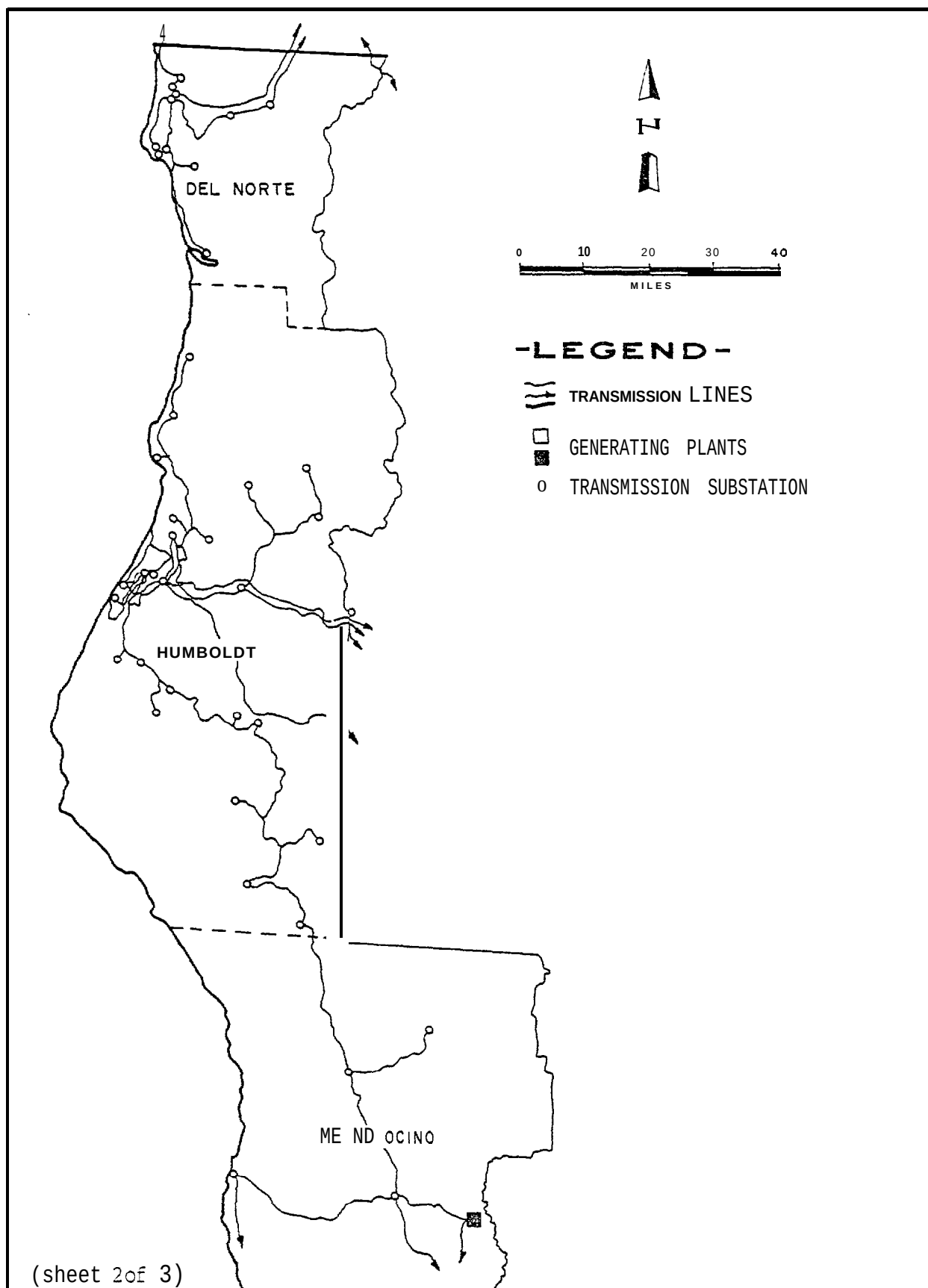


Figure 5-15. Transmission Lines in the Coastal Counties (California Public Utilities Commission)

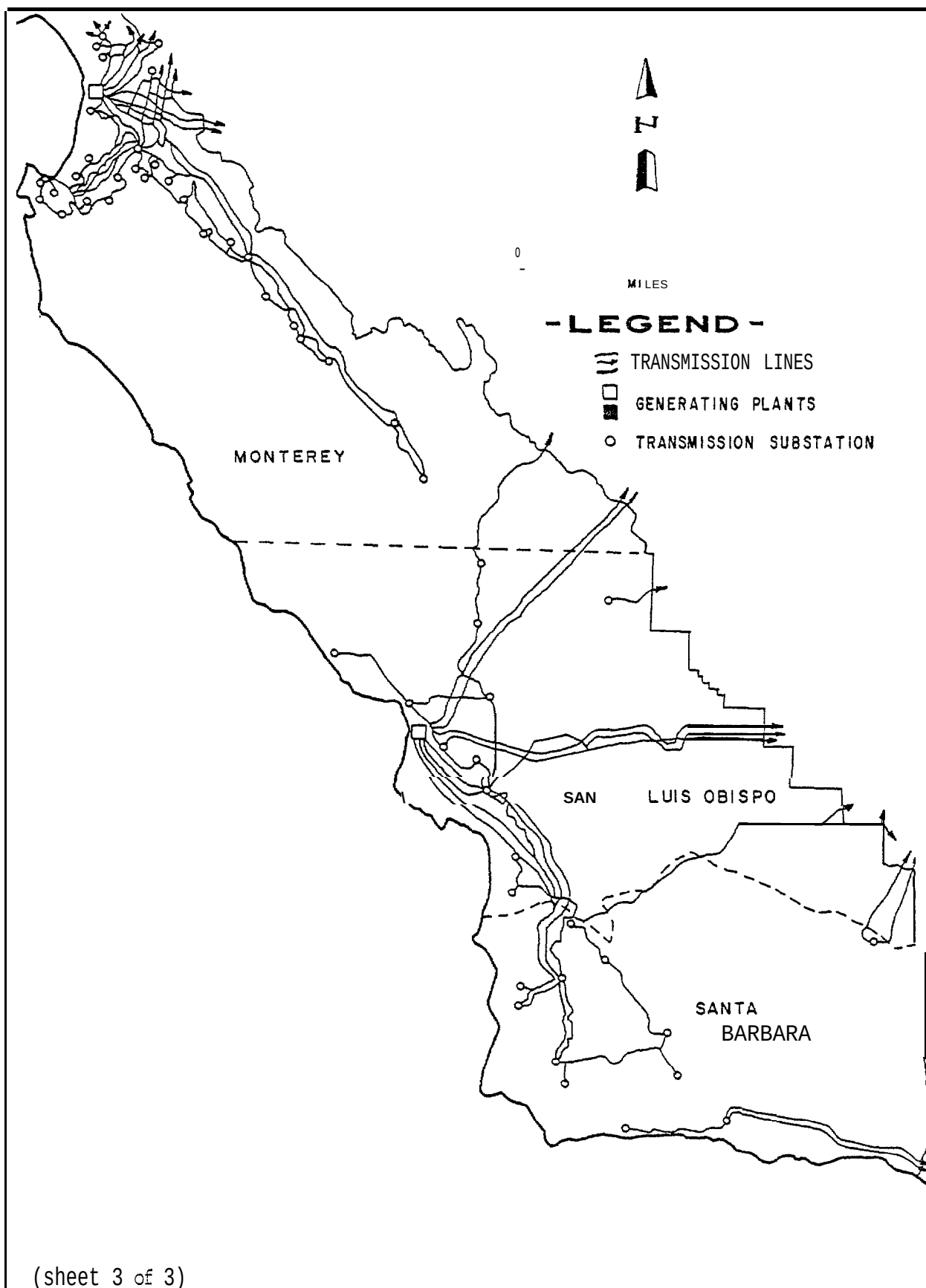


Figure 5-15. Transmission Lines in the Coastal Counties (California Public Utilities Commission)

Authority is often shared by two agencies. Control over roadway development is shared by the State Department of Transportation and the California Coastal Commission: the Department plans and develops roads consistent with Commission policies for coastal conservation and development. Coastal ports are under permit authority of the Coastal Commission, but port development in the San Francisco Bay Area is shared between the Metropolitan Transportation Commission (planning) and the Bay Conservation and Development Commission (permit). Airport development is directly dependent on federal authority over airspace (FAA) and local control over zoning, buildings, and, increasingly, noise standards.

The general regulatory posture - if one can be found among such a welter of authorities - is restrictive toward the expansion of transportation facilities within the coastal area. The state legislature has all but ruled out any capacity increases, i.e., lane increases, along Highway 1. Legislation defining the powers of the California Coastal Commission specifies that only one LNG site may be permitted along the California Coast. Airport expansion has been cautiously undertaken in the Bay Area. There is no evidence that these restrictions have hurt present trade or the economy of the coastal area, but restrictions on roadway development may be placing limitations on future population growth and residential development. (For discussion of the localized effect of restricted road development, Volume IV, see Watershed Units.)

Regulatory power over power plants and pipelines in the coastal zone is shared by the California Coastal Commission and the California Energy Commission. The Coastal Commission is required to designate specific locations within the coastal zone where the location of thermal electric power plants over 50 megawatts cannot be located. The provision exempts reasonable expansion of existing facilities.

The California Energy Commission cannot approve a new power plant site in a designated area without Coastal Commission approval. In nondesignated areas, the Energy Commission may allow power plants to be built without Coastal Commission approval, but it must provide the Coastal Commission with ample opportunity to protect valuable coastal resources that may exist within nondesignated areas.

The California Coastal Commission also shares permit power with the California Public Utilities Commission over pipelines having a terminus within the coastal zone.

Markets and Modal Split. Relatively current (1977) and very complete statistics on waterborne goods movement within northern or central coastal California are to be found in Waterborne Commerce of the United States, 1977, Part IV, U.S. Army Corps of Engineers 1977b. By contrast, little, if any, comprehensive data on tonnage moved by motor carriers exists for California, much less for the coastal county area. Table 5-86 below presents, possibly, the best and most recent "educated guess" of volumes by mode.

Table 5-87. Rough Indicators of the Scope of the California Freight Transportation Market, Interstate and Intrastate (Winzler and Kelly, 1977b)

Mode	Raw Estimate of Annual Tonnage	Percentage Share Of Market	Date Year
Air Freight	Less than 350,000	.08	1973
Motor Truck	153,870,000	34.20	
for-hire	(67,000,000)	(15.00)	1973
private	(60,120,000)	(13.00)	1973
agriculture	(25,750,000)	(6.00)	1973
Railroad	104,779,000	23.40	1973
Subtotal	257,999,000		
Foreign Trade	45,000,000	10.00	1972
Domestic Water Carrier	10,957,000	32.50	1969
Petroleum	132,800,000		1975
foreign crude			
(by tanker)	(27,691,333)		1974
pipelining of crude	(43,133,333)		1974
other	(61,975,334.)		1974
TOTAL	446,750,000		

Employment

Identifying transportation employment is a statistically difficult exercise, for in the Standard Industrial Classification (SIC) categories used to classify state employment data, transportation is grouped together with communication and utilities. A further difficulty encountered in drawing conclusions about transportation and employment within the coastal region stems from the use of Standard Metropolitan Statistical Areas (SMSA) as the subregional basis for employment data.

Table 5-88, which shows employment in transportation and utilities for 1973-1977, gives only the most general indication of employment trends. Employment growth has been extremely slow, especially considering increases in commodity flows noted earlier. It is likely that utilities employment is a stabilizing element in employment. Of interest are the employment figures for the central Bay Area, which dropped sharply in the recession years of 1974-1975 and have not risen since that time.

Table 5-88. Estimated Number of Wage & Salary Workers in Transportation & Utilities, 1973-1977, in thousands (California Employment Development Department, 1978)

SMSA	1973	1974	1975	1976	1977
Santa Rosa	3.3	3.2	3.4	3.5	3.8
San Francisco-Oakland	125.5	125.4	121.3	119.8	119.8
Salinas-Seaside-Monterey	4.3	4.5	4.4	4.5	4.7
Santa Barbara-Santa Maria-Lompoc	3.3	3.4	3.4	3.3	3.7

Employment in transportation manufacturing, shown in Table 5-89, is important in the San Francisco Bay area, although statistics almost certainly reflect auto manufacturing plants located in Alameda County. Employment figures for the Santa Barbara SMSA reflect the space shuttle program at Vandenberg Air Force Base.

Table 5-89. Estimated Number of Wage and Salaried Workers in Manufacturing-Transportation Equipment, 1973-1977, in thousands (California Employment Development Department, 1978)

SMSA	1973	1974	1975	1976	1977
Santa Rosa					
San Francisco-Oakland	13.8	13.5	10.1	12.6	14.7
Salinas-Seaside-Monterey					
Santa Barbara-Santa Maria-Lompoc	1.7	1.8	1.9	2.0	2.0

Value Added

Value added in the transportation industry is derived not only from actual carrying costs by the various modes, but also handling costs at ports, airfields, warehouses, and rail and truck terminals. These include activities such as loading, unloading and storage.

Summary and Effects

Economic Interactions. In the northern and central coastal regions, there is a major division between the transportation industry in the San Francisco Bay area and

the more northerly and southerly coastal counties. Within the Bay area, transportation is clearly a basic industry. Waterborne commerce, rail and truck commodity flows, air carrier passenger and freight traffic serve international and interstate markets.

Elsewhere, transportation is primarily a service industry responding to and circumscribed by the requirements of the local economy. The service it provides is, nonetheless an essential factor of the economic conditions within these areas. Resource industries are particularly sensitive to the behavior and costs of goods movement. Perishability of fish and agricultural products places a premium on reliable and speedy shipment. Owing to bulk, accessibility constraints and handling stages, changes in transportation costs can have a dramatic impact on the marketability of lumber products.

Economic relationships between transportation and the recreation industry are especially complex. Transportation serves the industry by supplying access to recreation areas. However, in so far as one of the major recreation activities - at least on the coast - is sightseeing, transportation behaves as a part of the recreation industry. The response of recreation to transportation services is ambivalent: some access is necessary if recreation is to be economically significant; too much access, on the other hand, might destroy the resource itself. For this reason, transportation along the coast is often found to be among the most controversial areas of public policy.

Natural Systems Effects. The effect of transportation on the natural environment is significant. Impacts may be separated into two categories: those resulting from facilities construction and maintenance, and those resulting from the movement of goods and people.

Waterborne Transportation. Some of the more significant impacts of waterborne transportation occur through displacement of habitats and wetlands by port construction, dredging and disposal of dredge spoils, and through spills, especially of pollutants (oil and toxins) resulting from discharge in vessel operations, careless handling in transshipment, and collisions between vessels or between vessels and other objects.

Impacts of dredging and spoil disposal may result from ongoing maintenance and operational measures necessary to sustain the waterborne commerce industry. The short-term and long-term effects of dredging are dependent partly upon the type of dredging, the type of disposal operations, and bottom materials. Changes due to channel maintenance dredging are similar to those resulting from widening and deepening of channels, but differ in intensity and scope (Ryckman, 1978). There are also differences in the degree of change between areas that have historically been dredged and those that have not.

The movement of material accompanying estuarine dredging operations has been shown to be small relative to natural movement. Similarly, changes in water movement and quality conditions have not been found to be significant. Increased stratification of salt and fresh water and increased upstream intrusion of salt water in estuaries and rivers, while not accompanied by a significant increase in total estuarine salt content, may produce changes in the biological community. Productivity is not necessarily decreased, however,

A principal adverse effect of dredging itself is increased turbidity and decreases in dissolved oxygen. Hopper dredging results in higher turbidity levels than pipeline dredging. Toxicants such as sulfides (although not pesticides and trace metals) tend to increase, and pH tends to be reduced in dredging plumes.

These effects of dredging, taken individually, are not usually significant, but especially in estuaries where water conditions are already degraded, the synergistic effects may be severe. Among the changes that may occur as a direct result of dredging are: stress on salmonids from reduced oxygen and clogging of gills by turbidity (Ryckman, 1978) avoidance of dredging plumes by adult salmonids, affecting migration and predation; severe stress on juveniles unable to avoid the dredged area; increased juvenile crab mortality and mutation (Krenkel, et al., in ASCE 1976).

Disposal sites are generally on land or in deep water rather than in estuarine waters. Deep water disposal would affect organisms in the coastal waters through smothering and may alter species composition if particle size or organic content are changed. Frequently, however, dredged sediments are swept away from disposal sites, creating effects similar to those of dredging. Unless sediments are swept seaward,

this could affect the productivity of oyster beds and other commercially or ecologically valuable habitats. The turbidity caused by dredging and disposal could also affect primary producers such as phytoplankton and eel grass.

Onshore disposal in wetlands could temporarily eliminate vegetation and alter elevation and soil composition, with long-term effects on species composition. The altered land may become suitable for other uses, although the wetland habitat would be lost. Water quality may also deteriorate as a result of sediment runoff from shore-line disposal areas unless the sites are properly located and diked to prevent such return.

Various natural and socioeconomic side effects of first time or maintenance dredging can be identified. Increased shipping and boating activities may bring economic benefit. Greater pollution hazards may result, however, from oil and gas spillage, discarded litter, and sanitary waste. Forest products activities will benefit from increased capacity through ease and lowered costs of transportation, which would permit expansion if adequate timber supplies are available. Varying effects on fisheries may be anticipated, depending upon local conditions. These include, on the positive side, increased productivity due to greater accessibility of ocean fishing grounds and increased berthing, and on the negative side, reduced estuarine fishery resources. Conflicts with some recreation and tourism values may occur due to aesthetic and ecological changes. Other recreation values may be enhanced by increased boating access and the secondary urban development stimulated by any increase in economic activity.

Land and Air Transportation. In the coastal zone, the development and operation of land and air transportation facilities would be affected by geologic hazards from earthquakes, landslides, and subsidence. The coast ranges of mountains are threaded throughout with active fault zones. Landslides close portions of existing highways yearly. Subsidence frequently also causes operational problems.

Climatic conditions along the coast increase the hazards of operating transportation services and occasionally cause disruptions in service, particularly at airports. Heavy fog, which covers much of the immediate coast for much of the year, is the major climatic impact, although high winds and rain during the winter months are also disruptive elements.

The development of land and air transportation facilities has the potential for a number of environmental impacts. Hydrology is often altered in a major way by road development. Cuts and grading increase surface flow, which in turn results in a deterioration of water quality, primarily through increased turbidity, but also because of less percolation down through the groundwater table. Increased rates of flow caused by road development often result in flooding, which causes damage and service disruption.

Loss of prime agricultural soils is a frequent consequence of road development along the coast. Prime soils are mostly located in narrow east-west trending valleys or within the alluvial plains near rivers. Nearly always, roadway alignments pursue the same low, relatively flat points of access.

Loss of soil mantle and a high level of sedimentation are also common and serious impacts of road development on steep coastal lands. Vegetation is lost both as a direct consequence of road construction and also as a result of increased erodibility of the land.

Air pollution results from both stationary and mobile sources. Air quality impacts resulting from the further development or use of transportation facilities along the northern and central coastal areas would be far less severe than those that occur in the Los Angeles basin or within the San Francisco Bay area. The prevalence of strong onshore winds and the lower level of automobile activity appear to be major reasons for the difference. Given higher levels of automobile use, however, air quality deterioration could occur rapidly in the summer months when southern climatic conditions prevail along much of the coast.

The consumption of petroleum resources is not a severe impact of transportation system usage within the coastal area. Travel within the coast is undoubtedly a fraction of annual mileage occurring in the state as a whole. Over the state, however, the impact is substantial; more than 33% of California's energy consumption is for transportation, almost all of which is petroleum-based (CALTRANS, 1975).

The potential for oil spills from greatly increased tanker traffic will be one of the certain results of California's rising demand for oil and is an impact treated at greater length in this volume, Chapter 5, Extraction and Mineral Industries. Within the study area, the danger of spill is concentrated within San Francisco Bay, where tanker traffic is most congested. Larger vessels do not reduce the risks. In fact, the opposite may be the case, for in San Francisco Bay larger vessels require unloading by lighter, which may greatly increase the possibility of a spill.

Other environmental impacts could occur as a consequence of socioeconomic activities their transportation services support. Chief among these secondary impacts along the coast are impacts on recreation and recreational resources, which include impacts on scenic quality. Roadway and airport construction may result in the removal of potential recreation sites, or intrude upon unspoiled views. More serious and more common impacts that occur as a consequence of the provision of transportation services include increased recreation access and overuse of sites, local population growth, and conversion of recreational land to urban use in the development of residential and commercial facilities. A less tangible, less quantifiable secondary impact, but one that nonetheless is often sensed, is the loss of the character and uniqueness that imparts much of the aesthetic value.

The main impact of transportation on fish and wildlife along the coast is also of a secondary nature. Transportation services are essential support for industrial and commercial development. The locations of roadways and airports are often the most significant influence upon the location of factories, plants, mills and other businesses.

In many areas, owing to the steepness of the coastal mountains and their closeness to the ocean, roads (and airports) have been built very close to the water. As a consequence, there has been an unusually high degree of wetland and habitat displacement by commerce and industry attempting to locate close to transportation services.

Utilities. Power plant construction can accelerate processes of erosion and sedimentation impacting streams and downstream wetland and estuarine systems. These added loadings may lead to a reduction in the life expectancy of partially enclosed water bodies such as lagoons, which have a limited capacity to dispose of deposited sediments.

All electrical power generating plants produce thermal waste regardless of whether they are fired by nuclear or fossil fuel. The discharge of heated water from power plants alters the marine environment and may be especially damaging to kelp beds and fish migrations in anadromous streams.

With the exception of the nuclear plant at Diablo Canyon which is not yet in operation, existing power plants in the coastal zone are fossil-fueled, using oil or gas as an energy source. The major pollutants from these types of plants are sulfur oxides from sulfur in the fuel and nitrogen oxides (NOx) due to high combustion temperatures in the gas turbine. Owing to the cost and availability of oil and gas, large power plants built in the coastal zone in the future are likely to be coal-fired steam generators using pulverized coal-fired and cyclone-fired furnaces. Flue gas from such power plants releases sulfur dioxide and particulate matter to the atmosphere. In addition, coal-fired power plants produce solid waste material as a by-product of coal combustion and flue gas desulfurization.

Elevated power transmission lines are damaging to natural vistas and may, in addition, displace significant amounts of timber. Pipelines may have the short-term impact of disturbing vegetation and are potentially destructive of archaeological and anthropological resources. In seismically active zones, which include much of the coast, spillage from rupture is always a potentially serious consequence of pipeline construction.

SERVICE ACTIVITIES

In addition to the basic industries discussed in previous sections, service activities play a fundamental role in the economy of the coastal region. In general, the service sector consists of those economic activities that provide goods and services essential to the basic industries and the populations of the coastal region. These include activities such as banking and insurance, grocery stores and gas stations, and local government. Service activities may be more specifically defined as those activities that do not draw money into the region from outside but rather circulate money within the coastal economy.

The allocation of activities to the service sector is somewhat problematic in an area as economically complex and dynamic as the California Coastal Region. A complicating factor in defining service activities is the importance of the recreational industry through much of the region. Recreational visitors bring money into the region and may spend it in service activities that also serve the resident population. A certain portion of service activities thus export goods and services outside of the region, and must be considered in economic terms as basic industries. The significance of service activities in the study area also varies geographically between the north and central subregions as Table 5-90 shows, and between eastern and western areas of the coastal counties. Given these economic complexities, it is useful to consider service activities in relation to the basic industries of the study region.

Table 5-90. Projected Service and Trade Sector Employment
in California Coastal Counties, 1980
(California Employment Development Department, 1979b)

	Wholesale Trade	Retail Trade	FIRE ¹	Semites	Government
Del Norte		1,125	175	775	1,525
Humboldt	1,125	5,757	1,350	8,025	9,975
Mendocino	700	4,500	700	3,975	4,450
Sonoma	3,400	20,100	5,800	40,000	4,900
Marin	2,600	16,600	6,100	19,200	13,400
San Francisco	39,100	68,400	83,500	140,300	87,600
San Mateo	24,100	45,000	14,700	48,600	33,700
Santa Cruz	1,775	14,575	2,375	12,000	11,650
Monterey	3,100	20,300	4,200	19,900	22,600
San Luis Obispo	1,300	11,000	1,800	9,000	12,900
Santa Barbara	4,400	28,900	5,000	33,000	24,700

1. Finance, Insurance and Real Estate.

Total Basic Employment Multiplier. The relationship between basic and service activities in the coastal economy may be expressed in terms of an employment multiplier. While there are difficulties in expressing complex and dynamic economic relationships in terms of static figures, multipliers are a useful means of illustrating the degree of dependence of the region's work force on its basic industries. Coastal counties will be the basis of the following analysis as county data are the most complete and readily available. In addition, many of the service activities on which the counties' basic industries depend are located in urban areas that are generally outside of the watershed boundaries. The San Francisco Bay area will be excluded from this analysis, although it plays important economic roles in the regional economy, because it is outside of the study area and since it is of a quite different socio-economic character from the coastal region. A discussion of the economy of the San Francisco Bay area, with input-output models, may be found in Goldman, and Nakazawa (1975).

Table 5-91 lists employment in the coastal region's basic industries, noting the resource-related basic industry to which each employment sector belongs. The table includes a calculation of employment for the basic industries and a computation of a basic employment multiplier for the ten counties in the study region.

The employment calculations are based on 1977 County Business Patterns data (U.S. Bureau of the Census, 1979) and 1977 California Employment Development Department (1979b) data. Both data sources organize employment information by Standard Industrial Classification (S.I.C.) codes, and both compile data from payroll tax forms. There are several reasons for referring to both sources. County Business Patterns data are collected for the week including March 12, 1977, under-representing employment in sea-

Table 5-91. Type Of Employment and Number of Employees for Coastal California in 1977 (U.S. Bureau of the Census, 1979; California Employment Development Department 1979b; EDAW, Inc. 1979a; 1979c)

(Code)	S.I.C. Sectors	Type of Employment ¹					Total Study Area Employment*
		For	Fish	Rec	Agri	Ext Trans	
(-)	Agriculture, Forestry, Fishing	x	x		x		45,741
(-)	Mining					x	2,322
(20)	Food and Kindred Products		x		x		17,532
(24)	Lumber and Wood Products	x					15,177
(25)	Furniture and Fixtures	x					1,833
(26)	Paper and Allied Products	x					1,497
(29)	Petroleum and Coal Products					x	246
(32)	Stone, Clay and Glass Products					x	3,021
(373)	Ship and Boat Building and Repairing						187
(42)	Trucking and Warehousing (50%					x	3,835
(44)	Water Transportation					x	365
(554)	Gasoline Service Stations (25%)			x			1,854
(58)	Eating and Drink: ng Places (25%)			x			12,293
(70)	Hotels and Other Lodging			x			13,819
(79)	Amusement and Recreation Service (50%)			x			4,852
(-)	Retail Trade (20%)			x			18,033
(-)	Other Manufacturing (80%)						56,270
(-)	Federal Government						19,864
(-)	State Government						24,376
Total Basic Employment							243,117
Total Employment (Basic and Non-Basic)							735,206
Basic Employment Multiplier							3.02

¹Forestry and Forest Products (For), Fisheries (Fish), Recreation (Rec), Agriculture (Agri), Extraction and Mineral Industries (Ext), Transportation (Trans).

²S.I.C. Codes 554, 58, 79 and retail trade calculated at 35% for Monterey County.

sonal activities, while California Employment Development Department figures represent annual average employment. California Employment Development Department data are not presented at the two and three digit S.I.C. level in every county as are County Business Patterns. However, unlike County Business Patterns, they do include government employment. One shortcoming common to both sources is that neither includes self-employed persons or family and other types of employment that need not be reported.

Allocating industry employment to basic and non-basic categories is a significant problem in studies of the composition of a regional economy. In Volume I of this study (the Conceptual Model), a basic industry was defined as "one that imports money from outside an area through the production of goods and services for export" (see Volume I, Conceptual Model). It is clear that portions of output of each basic industry are purchased and consumed locally. Those portions also change by area, by industry and over time. Judging from several representative local economic studies and from analyses done at the watershed level, the allocation of activities to basic and non-basic sectors made here is reasonably accurate for the region as a whole. Further refinement would require tracing industrial output to determine whether it is exported or consumed locally, a process that would be extremely costly for the entire coastal region. While such data are not currently available for the region, some local input-output and import-export studies do exist. Those conducted by the University of California's Cooperative Extension Program include Santa Cruz, San Mateo, Sonoma and Marin Counties (Goldman, et al., 1976; Goldman and Hart, 1977; Goldman and Nakazawa, 1975; Goldman, et al., 1973). For the limited purpose of calculating a basic employment multiplier, generalizations by second and third level S.I.C. classification are usually sufficient. Further discussion of multipliers and input-output calculations relevant to regional counties and industries is found in Goldman and Nakazawa, 1975; Bell, 1977; Harris, 1973; and Connaughton and McKillop, 1979. In this study, S.I.C. sectors, excepting transportation, other (non-resource-based) manufacturing, recreation and trade, are allocated wholly to basic or non-basic categories.

For transportation, only half of trucking employment is considered basic. A large share of carrying activity by this mode involves imports and does not bring money into the area. The limited amount of water transportation on the other hand, is nearly all export oriented (see the section on Transportation). For this reason, only 50% of "Trucking and Warehousing" employment is allocated to basic, whereas 100% of water transportation and "Ship Building and Repair" is considered basic.

Recreation has previously been defined as including tourism, second homes and retirement. The primary component is tourism, however, and this study has classified recreation in terms of tourist expenditures for fuel, food and lodging. An example of the distribution of tourist expenditures in those categories for Mendocino County is found in William A. Randolph & Associates, 1978. In Table 5-90, lodging is represented by "Hotels and Other Lodgings" (S.I.C. 70); basic employment in this classification is estimated at 100%. Food and fuel have been included in "Eating and Drinking Places" (S.I.C. 58) and "Gasoline Service Stations" (S-I-C. 554). An estimate of only 25% basic employment in each of these two classifications is used because employment in these classifications appears to depend largely on the local population, unlike "hotels and other lodgings," which is wholly oriented to the visitor sector. "Amusement and recreation services" (S.I.C. 78) have been estimated as only 50% basic industry, since many of these services (bowling alleys, movie houses) appear to serve the local population. This varies by area as well as time of year. The percentage is probably higher in counties such as Monterey and Santa Cruz, although a recent study showed a large portion of revenues "leak" outside of the region in Monterey County and thus do not provide income to local residents (Recht/Hausrath, 1979a). Also, many counties have annual county fairs, which provide additional employment in this sector for only a few weeks out of the year. On a regional and annual basis, however, the 50% figure is a reasonable estimate. Retail trade, exclusive of gasoline service station and eating and drinking establishment employment, is included here at 20% of its total, as it is partially supported by the visitor sector. Federal and state, but not local, government employment is wholly included here as employment supported by income that is largely imported. Finally, a large share of all durable goods manufacturing other than the separately listed wood and mineral products processing sectors must be included in the basic group.

Total employment in basic industries in the study area counties is calculated at 243,117 persons out of a total employment figure of 735,206. The basic employment multiplier of 3.02 indicates that for every person employed in a basic industry there are approximately two employed in service industries.

The basic employment multiplier can be used as a rough approximation of the effect of a change in basic employment on service employment. Analysis of a policy that results in an increase or reduction in employment in basic industries should take into account this service employment that depends on the basic sector.

It is important to note that, given the diversity of activities that occur in the region, the multiplier will vary considerably between counties or small divisions within the coastal region. The multiplier can be quite misleading when examined on a regional basis, particularly in a region as diverse as the central and northern California coast. The regionwide multiplier represents highly coastal resource-dependent economics, such as Del Norte and Humboldt Counties. It also represents counties whose economies are heavily dependent upon manufacturing and other activities typical of a highly developed urban economy. In San Mateo County, for example, 30,700 jobs, or 13.6% of the total employment is in "other manufacturing", which is not coastal-dependent.

Table 5-91 illustrates the range of basic employment multipliers among the ten counties in the study region for those basic activities that are strictly related to natural resources plus state and federal governments. A multiplier of 1.14 for Del Norte County indicates the dominant role played by basic industries in that county. At the other extreme, San Mateo, Marin, and, to a lesser extent, Sonoma Counties, all show high multipliers, which reflect the economic importance of the San Francisco Bay area, external to the study area. The highly developed service sector in each county depends on miscellaneous manufacturing and on income from residents and work outside of the county. The service sectors in these counties are thus more related to activities outside of the region than to basic industries within the region. If these three Bay Area counties were excluded from the calculation, the basic employment multiplier for the remaining regional counties would be 2.96,

Table 5-92. Basic Employment Multipliers for California Coastal Counties
(U.S. Department of Commerce, 1977; Employment
Development Department, 1979b; 1979d)

County	Multiplier
Del Norte	1.14
Humboldt	3.43
Mendocino	2.71
Sonoma	4.08
Marin	7.88
San Mateo	8.56
Santa Cruz	3.10
Monterey	2.26
San Luis Obispo	3.56
Santa Barbara	3.96

Although data are not available for the study area itself, the multipliers in Table 5-90 and 5-92 would be significantly different if their calculation were based on activities occurring solely within watershed rather than on activities in the coastal counties as a whole. Many of the basic industrial activities in Mendocino, Sonoma, Marin and San Mateo Counties occur in the coastal study area, while service activities are generally concentrated in the inland urban areas around U.S. 101. In these counties, the basic multiplier for the watershed itself would likely be considerably lower, reflecting a greater dependence within the watershed area on resource-based industries. Humboldt and Del Norte Counties would show little difference as they have not developed much of a service sector outside of the study area. Monterey, San Luis Obispo and Santa Barbara Counties, having urban areas within the study area boundaries as well as outside would likely maintain their relatively high multipliers. Santa Cruz County is located entirely within the study area, and its multiplier would remain the same. Thus, if the economic activity within the regional boundary as a whole were considered, there would likely be a significantly greater degree of dependence on basic industries shown, reflected in a lower employment multiplier than was developed in Table 5-91.

Employment Activities by Service Group

Wholesale and Retail Trade. The retail and wholesale trade sector is generally non-basic, providing goods and services to the coastal population for local consump-

tion. This varies geographically and by industry. San Mateo County, for example, shows almost one-half of its trade output to be exported to the bay area (Goldman and Hart, 1977). Fish wholesalers, particularly in Eureka, are likely to be involved in export markets. A certain amount of regional retail sales are made to visitors from outside of the region; this is accounted for by allocating 20% of retail employment to the basic sector in Tables 5-90 and 5-91. With the general exception of goods and services sold to tourists, this sector on the whole generates little income for the coastal economy. Wholesale and retail trade activity is dependent on income-producing sectors for its existence. Basic activities generate income and attract a population whose consumption demands support the trade sector.

An assessment of the relative local importance of the wholesale and retail trade sector is provided by the business multiplier (the change in sales of a dependent sector activity caused by a one dollar change in sales in another sector). For this sector, in general, larger multipliers indicate a greater interaction with local sectors and a greater proportion of purchases made locally (Goldman and Hart, 1977). The wholesale and retail trade multiplier was estimated at 3.3 for the central coastal region, including the Bay Area, and at 2.3 for the North Coast area). In both areas the multipliers were among the highest of all industries, indicating a relatively greater interdependence with the local economy than is true for most other sectors. This is borne out by several local studies, which found the trade sectors of Sonoma, Marin and Santa Cruz to have multipliers of 2.8, 2.0 and 2.5, respectively. In each case, the trade sector had one of the highest business multipliers in the county and also made less than one-quarter of its sales outside the county (Goldman and Hart, 1977; Goldman, et al., 1973; Goldman, et al., 1976). The studies also show the trade sector to be highly reactive to changes in sales in other sectors, particularly those in basic industries. In Sonoma County for instance, a 100% increase in sales of salmon, crab or tuna generates a 16% increase in overall retail and wholesale sales. The retail and wholesale trade sector is generally one of the service activities that is most dependent on regional basic industries.

Government Employment. The classification of government employment as basic or non-basic is open to debate. In line with our definition of basic industries, government becomes a basic activity when the amount of government expenditures and employment in the region exceeds the total taxes collected, so that there is a net flow of money into the regional economy. State employment figures show that government employment has increased in the region at a rate greater than that of most other sectors, although Proposition 13 will increasingly affect levels of local government employment.

The significance of the federal government to this study area varies by location. Federal government as a percentage of total employment ranged from 1% to 2% for most coastal counties in 1977, with the exception of Monterey County and Santa Barbara Counties. Federal Government employment accounted for 7% of Monterey County's total. This mainly comprised military and non-military personnel at Fort Ord, and, to a lesser degree, at Camp Roberts and Hunter Liggett Reservation outside the study area. In Santa Barbara County 3.2% of total employment is in the federal government sector, mainly at Vandenberg Air Force Base. The share is 4.0% if missiles and space equipment manufacturing is included. By comparison, federal employment represented 3.6% of Californians total employment and 4.7% of its total income in 1977 (California Employment Development, 1979b). It would appear from these data that the federal government is not a particularly significant source of earned income or employment for the study area. Since the federal government employment that does exist in the study area is generally supported by income from outside of the area, it is here considered as a basic activity.

Another measure of the federal government's significance to this area is the level of federal per capita expenditures, particularly transfer payments. These include social security payments, Medicaid, aid to families with dependent children, veterans benefits, and food stamps. To the extent that these payments support people over and above what they pay out in taxes, transfer payments constitute another source of basic income in the federal government sector. Another type of federal expenditure includes federally-funded construction activity, such as road building and harbor improvement, and grants for economic adjustment and development, such as grants in mitigation of national park expansion. The net flow of income into the region from these sources may be considered basic, although, on the whole, the benefits, and in some cases the impacts, are reflected in other local basic industries.

The state and local government sector is a much more significant employer than the federal government, in the coastal counties as well as in the state as a whole. Most of the employees in this category are employed in local government and education. Statewide, 82% of all government employment was in state and local government in 1977, over one-half being in public education. There is an annual fluctuation in employment

in this sector, due to summer layoff of school employees. The state government employed 3% of the total state workforce in 1977, while local government employed 13% (California Employment Development Department, 1979). State government employment is considered to be a basic activity in the region, while local government is allocated to the non-basic sector.

State employment in San Mateo County comprises less than 1% of County employment, while in San Luis Obispo County the state accounts for 12%. Variations are due to the presence of state schools, hospitals and correctional institutions. Local government is more consistently important throughout the region, employing between 15% and 20% of the work force.

While state and local governments had increased their employment and expenditures in the early 1970's, the passage of Proposition 13, a state freeze on hiring and the possibility of a new ballot initiative limiting government budgets have all acted to ^slow the expansion of, and in some cases reduce or stop, certain activities of the state and local governments although this has been mitigated to a certain extent by supplementary sources of funds. This has had considerable impact on employment in, and expenditures of, governmental bodies within the coastal region, although long-term effects on the level of service activities provided by state and local government are difficult to determine.

Local governmental expenditures vary by county, according to the local tax base, revenue receipts from other government bodies and the like. Services provided by local governments and boards of education primarily serve the local population and are therefore considered non-basic activities. Local fiscal decisions play a significant role in the economic health of basic activities, however, and basic industries provide local governments with a significant tax base. Local expenditures on parks, sewage lines and water supply may enhance recreation by attracting more visitors or second home owners to an area. They may, however, have significant growth-inducing effects which generate unmanageable service demands and environmental changes that affect the prosperity of local basic industries. Local zoning and tax policy decisions can have considerable effect on all basic industries.

Proposition 13, which limited increases in property taxes, has reduced the general availability of funds for local government expenditures on public services and on support activities for basic industries. The effects will become more severe when surplus state funds available to "bail out" local communities are exhausted. Local budgets will become increasingly dependent on state and federal grants, revenue sharing monies, and public-private funding partnerships.

Other Non-Basic Employment. Also included in the non-basic sector are non-basic manufacturing, construction, utilities, communications, local transportation, and business and professional services.

Although it varies by location, construction is generally one of the larger components of the non-basic sector. It is also the most volatile component, being an accurate reflection of changing national economic conditions as well as functioning as indicator of expansion or decline in the basic economy of the coastal communities. Change in the level of construction activity is the result of many factors, including changes in interest rates, demographic changes, the attractiveness of an area for second home development, a community's proximity to population and employment centers, and environmental regulations. Construction activity in second home developments and federally-funded construction projects may be considered as basic industries insofar as they support activities that import dollars from outside the region. Generally, however, construction activity is a regional, population-serving activity, and as such it is considered a non-basic activity in the study area. Construction employment averages between 3% and 5% of total employment in the ten coastal counties, roughly the same proportion as in the state as a whole (California Employment Development Department, 1979b). The counties that are located close to the Bay Area had the highest rates of construction employment and income in the study area, due to immigration and urban expansion.

Non-basic manufacturing, including such activities as local printers, machinery building and repair, support the local population and basic industries. Approximately 62% of manufacturing in the region is non-basic, although this varies from 83% in San Mateo County to 10% in Humboldt County. The remaining share of other non-basic employment is in local transportation and utilities.

Summary and Effects

The economies of the northern and central California coastal region show considerable differences with regard to their dependence on the local natural resources. The north coastal counties - Del Norte, Humboldt and Mendocino - show the greatest dependencies on basic industries, and are thus the most strongly tied to export markets and the availability and quality of natural resources. This is due to the combined effects of historical fluctuations between prosperity and decline, distance from population centers, and limited development of infrastructure service activities. One result of this specialization is a production-consumption imbalance that forces those counties to import the majority of goods they consume. Such imports represent massive leakages of spending power and potential employment out of the economy.

Connaughton and McKillop (1979) have calculated the percent of the economic base of sixteen northern California counties that was attributable to employment for export in the lumber and wood products sector in 1970. Humboldt, Del Norte and Mendocino counties showed the highest dependency indicators, 66.3%, 63.6%, and 55.9%, respectively. Each showed a significant decline in dependency from the 1960 rates of 86.9%, 83.6% and 69.9% but remained at over twice the average, 27.3% for the sixteen counties.

The counties of Sonoma, Marin, San Mateo, and Santa Barbara are considerably less dependent on local resource-based activity. The central reason for this is that relatively large segments of the resident population are employed outside of the region, bringing money back in and spending it in the non-basic sectors. Santa Cruz, Monterey and San Luis Obispo are mixed, with large agricultural and recreational sectors as well as high proportions of employment in government and the non-basic trade, services and manufacturing sectors.

The service sector in the central coastal region is highly dependent on income derived from employment outside the region. In some areas, the local service sector must compete with services, particularly retail trades, outside of this region. Residents of Marin employed in San Francisco, for example, spend a certain portion of their income on goods and services near their place of employment. External employment also tends to reduce the number of employees available locally for both service and basic activities (SWA Group, 1975). Urban expansion has put economic pressures on land-based resource activities in areas throughout the region. Urban expansion and rural subdivision of otherwise productive lands preclude most future resources activities on those lands (William A. Randolph & Associates, 1978).

The outlook for basic industries varies by industry and region. In general, the California Coastal Plan places a priority on maintaining resource-based activities, except where they conflict with natural systems and certain human activities, particularly recreation.

As discussed in previous sections, several activities that could be encouraged to bolster employment and income in traditional regional industries have been recommended in economic plans in the area. For agriculture, these have included combining ranching operations with recreational use of the rangeland; developing a cottage-industry form of wool production; and processing cull, or waste, fruit. Improving harbor facilities, developing more commercial aquaculture and mariculture operations, and processing fish waste and trash fish for by-products and to eliminate polluting wastes, have all been mentioned as means of enhancing local fishing activity. Employment and income in forest industries could be bolstered through more extensive utilization of hardwood species. Tanoak, the most common, can be used for furniture, particle board, pulp and charcoal; other hardwoods may be chipped or cut into shore lengths for parquet flooring as well as being used for fuelwood. Improving access to certain areas has been proposed to increase recreational activities, as has developing parks and facilities and recreational use with other resource activities such as forestry and ranching. Other, more general, recommendations have included local zoning changes, tax incentives and increasing the availability of loans for working capital to those active in basic industries. These are discussed more concretely in the previous basic industry sections.

Social and Cultural Systems

Social and Demographic Character

Overall Employment Patterns. Employment patterns within the three northern counties are relatively clearly defined; they reflect the resource-based economy that dominates the subregion. Finding general patterns within the central coastal subregion is another matter. Labor statistics and employment trends and projections prepared by the State of California Employment Development Department are organized on the basis of Standard Metropolitan Statistical Areas (SMSAs). Sonoma County comprises the Santa Rosa SMSA; Marin, San Francisco, and San Mateo fall within the Oakland-San Francisco SMSA; and the remaining counties (Monterey, San Luis Obispo, and Santa Barbara) each fall within separate SMSA'S. The related coastal sectors are, in each case, part of much larger economic units.

In the northern subregion, as Table 5-92 illustrates, the important employment sectors are forestry and forest products, fishing, agriculture, and services, here reflecting the importance of the recreation industry as well as high wage levels in the forest industry. Unemployment in the subregion is high. The annual average was 13% in Humboldt county over the last three years (1978-1980), 12.3% in Del Norte County and 9.2% in Mendocino County. By contrast, the state annual average is about 6% (California Employment Development Department, 1979a).

The high unemployment of the three northern counties is partly due to declines in the forestry and forest products industry. Unemployment in the industry may increase in 1980 owing to a general decline in construction activity following the tight money policy instituted in October 1979 by the U.S. Federal Reserve Board. State employment projections for the three northern counties, shown in Table 5-92, represent anticipated increases in employment in the service sector from increased recreation activity. Fuel shortages in 1979 and steep increases in price of gasoline may affect the accuracy of these projections, however.

Table 5-93. Projected Number of Wage and Salaried Workers for
the North Coast Wage and Salary Employment Average, 1980
(California Employment Development Department, 1979a)

Source of Employment	Del Norte	Humboldt	Mendocino
Agricultural, Wage & Salary	550	675	1,325
Nonagricultural, Wg. & Salary	5,625	39,800	21,350
Construction and Mining	100	1,375	750
Manufacturing	1,625	7,650	5,225
Lumber & Wood Prod.	1,425	5,750	3,500
Food & Kindred Prod.	---	925	---
Other Manufacturing	200	975	1,725
Total, All Industries	6,175	40,475	22,675
Transportation and Public			
Utilities	300	2,300	1,050
Wholesale Trade	---	1,550	700
Retail Trade	1,125	5,757	4,500
Finance, Insurance			
and Real Estate	175	1,350	700
Services	775	8,025	3,975
Government	1,525	9,975	4,450

The north coast counties have always experienced higher than normal unemployment rates, even when the lumber industry was at its peak in the early 1960s. The high unemployment rates are primarily due to the seasonality of employment in the resource-based industries of the north coast. Many employees in the tourist industry, lumber industry, commercial fishing industry and agriculture work perhaps eight months of the year and are unemployed the remaining four months. However, at least in the forest industry, workers earn a satisfactory income for the entire year. As a result, average annual unemployment rates are high, but their significance in a seasonal resource-based economy may be overstated.

Other factors contributing to high unemployment rates along the north coast are the large number of transient residents, alternative-culture farmers, and Indians on reservations. These groups have traditionally had high unemployment rates.

Employment patterns in Sonoma, Marin, San Francisco, and San Mateo Counties as shown in Table 5-93 reflect the economy of a large (and growing) metropolitan area. Wholesale and retail trade, services and manufacturing, particularly of electronics instruments, are recent and growing sectors. Unemployment has subsided from a high in 1975 of around 7%, to 6.7% where it is expected to remain for the next two to three years.

In the four southern counties, Santa Cruz, Monterey, San Luis Obispo, and Santa Barbara, the high percentage of total employment in the government sector has been a stabilizing influence over the years. Government is the single largest employment sector in two of the four counties (Monterey and San Luis Obispo), and the third largest in the other two (Santa Barbara and Santa Cruz). The bulk of government employment originates from educational institutions and civilian personnel employed at military installations. The University of California at Santa Cruz and California Polytechnic Institute in San Luis Obispo County are both large universities. Fort Ord Army Base outside Monterey, and Vandenberg Air Force Base, in Santa Barbara County, both sustain large civilian work forces.

In each of these counties, services is the fastest growing economic sector and has registered the largest employment gains. A high level of in-migration into these counties is one factor stimulating employment in services. The other is the expansion of hotels, motels, restaurants and other facilities, in response to steady increases in tourist expenditures.

Table 5-94. Projected Number of Central Coast County Wage and Salary Employment, Annual Average, 1980 (California Employment Development Department, 1979a)

Source of Employment	Sonoma	Marin	San Francisco	San Mateo	Santa Cruz	Monterey	San Luis Obispo	Santa Barbara
Agricultural, wage & salary	5,600	500	400	2,500	5,425	21,400	2,100	6,700
Nonagricultural wage & salary	92,500	67,500	537,600	243,000	57,050	90,400	46,500	122,600
Construction & Mining	6,800	3,400	22,400	10,800	2,525	4,600	3,450	6,600
Manufacturing	12,300	3,900	47,600	33,300	10,050	10,500	3,700	15,700
Lumber & wood products								
Food & kindred products								
Other manufacturing								
Total, all industries	98,100	68,000	538,000	245,500	62,475	111,800	48,600	129,300
Transportation & public utilities	5,000	2,300	48,700	32,800	2,125	5,200	3,250	4,300
Wholesale trade	3,400	2,600	39,100	24,100	1,775	3,100	1,300	4,400
Retail trade	20,100	16,600	68,400	45,000	14,575	20,300	11,000	28,900
Finance, insurance, & real estate	5,800	6,100	83,500	14,700	2,375	4,200	1,800	5,000
Services	40,000	19,200	140,300	44,600	12,000	19,900	9,000	33,000
Government	4,900	13,400	87,600	33,700	11,650	22,600	12,900	24,700

Employment and Income. Personal income reflects levels of pay and skill in local industries, unemployment patterns, and participation of residents in the labor force.

The per capita income statistics shown in Table 5-95, however, do not reflect the effect of the recession in 1974-1975 nor do the median income statistics from 1976 reflect the growth in personal income that occurred in California from 1977 to 1979; in 1977, average personal income in California increased almost 14%. It is nonetheless unlikely that the rankings have changed significantly, if at all.

The median income statistics reflect real differences in personal income among the coastal counties. Median incomes in Marin and San Mateo Counties are the highest in the state, and reflect the health of the financial, electronics and tourist industries, trade, government and professional services in this area.

In Santa Cruz County and in San Luis Obispo County, there is a wide difference between general median income and joint (that is, family) median income. The difference may reflect the number of college students and college-age population engaged in seasonal and part-time employment.

Table 5-95 . Median Per Capita Income, 1974, and
Median Reported Income, 1976, by Coastal County
(California Department of Finance, 1978; U.S. Bureau of Census, 1977)

Per Capita Income 1974			Personal Income By Tax Return			
County	Total	Average Annual % Change 1969-74	All Returns		Joint Returns	
			Median	Rank ¹	Median	Rank
Del Norte	\$4,169	7.8	\$ 9,962	22	\$14,015	36
Humboldt	4,411	7.6	10,341	18	15,469	19
Mendocino	4,142	7.1	9,657	37	14,028	35
Sonoma	4,501	7.6	10,491	15	16,192	17
Marin	7,150	8.0	15,508	2	23,051	1
San Francisco	4,142	7.1	9,562	39	16,549	12
San Mateo	6,621	7.5	13,368	3	29,951	2
Santa Cruz	4,641	7.6	8,920	51	15,465	21
Monterey	4,688	8.0	9,875	25	15,165	24
San Luis Obispo	4,163	7.5	9,217	45	14,615	27
Santa Barbara	4,756	7.0	9,774	31	16,528	13

1. Rank among all California Counties.

Table 5-95 illustrates the dependence in the three northern counties on wages and salaries. The relatively high percentage of income from transfer payments in Humboldt County probably reflects the high unemployment there. Moving south, the relatively higher incomes from property and businesses reflect the investment opportunities associated with high income levels.

Table 5-96. Personal Income (thousands of dollars) for Coastal
Counties in 1976 (California Department of Finance, 1979)

County	Wages and Salaries	Other Labor Income	Proprietors' Income	Property Income	Less Con- tributions for		Social Insurance	Residence Adjustment	Personal Income
					Transfer Payments				
Del Norte	147,696	10,724	25,384	45,949	63,305		10,808	82,535	364,785
Humboldt	389,922	30,493	61,238	80,385	109,430		26,978	-2,554	641,396
Mendocino	204,744	15,673	36,317	52,297	65,789		14,254	-1,304	359,262
Sonoma	721,768	55,012	118,328	294,763	298,836		51,084	155,803	1,593,426
Marin	595,015	40,706	178,883	357,288	205,418		46,226	679,048	2,010,162
San Francisco	6,684,086	524,657	390,971	1,311,364	1,016,037		409,138	-3,072,562	6,445,415
San Mateo	2,781,476	242,125	343,373	851,051	509,806		186,043	756,485	5,298,273
Santa Cruz	423,309	33,633	78,577	186,703	183,937		30,395	80,898	958,662
San Luis Obispo	373,578	25,534	61,615	124,793	147,343		26,114	16,332	723,081
Santa Barbara	1,111,198	76,164	152,273	432,758	281,805		72,824	-1,802	1,979,572
Monterey	1,135,927	66,320	213,639	316,691	258,577		67,584	-5,927	1,917,643

Poverty levels, not apparent in personal income statistics, are an important aspect of the coastal economy and its employment pattern. Table 5-97 shows the number of family heads with incomes below the poverty level projected for 1980. In the northern counties, the number of households below the poverty line again suggests that unemployment is unusually high. Elsewhere, it is evident that minorities suffer poverty conditions in disproportionate numbers. In Monterey, Santa Barbara, and probably also San Mateo and Santa Cruz Counties, those below the poverty level are predominantly farm workers.

Table 5-97. The Projected Numbers of White, Black, and Spanish-American Families with Below Poverty Level Incomes for California Coastal Counties in 1980
(California Employment Development Department, 1979a)

County	Total	White	Black	Other	Spanish American
Del Norte	490	420		70	30
Humboldt	3,010	2,860		150	130
Mendocino	1,970	1,810	160		80
Sonoma	790	320	230	240	820
Marin	650	360	200	90	170
San Francisco	15,620	6,640	4,920	4,060	2,660
San Mateo	7,210	5,050	1,590	570	880
Santa Cruz	5,270	5,040	50	180	740
Monterey	6,510	5,400	620	490	2,740
San Luis Obispo	3,977	3,754	95	128	583
Santa Barbara	6,002	5,696	268	98	1,285

Population. Nowhere are the differences between the northern and central subregions more strikingly apparent than in their different population growth characteristics. The northern three counties have been, historically, sparsely populated and slow growing, although that pattern has recently and abruptly changed in Mendocino. With the exception of San Francisco, the counties in the central subregion have been part of California's explosive population growth over the last two decades. Table 5-97 illustrates the pattern of change.

Table 5-98. The 1969-1978 Populations and Changes for Coastal Counties of California (California Department of Finance, 1978).

Counties	Population 1960-1978						Components of Change 1970-1978		
	1960	1970	% Change	1978	Net Change	% Change	Births	Deaths	Net Migration
California	15,717,204	19,955,134	27.0	22,297,000	2,326,300	11.7	2,690,200	1,434,000	1,040,100
Del Norte	17,771	14,580	-18.0	17,100	2,500	17.3	2,300	1,300	1,500
Humboldt	104,892	99,692	5.0	107,600	7,700	7.7	13,100	7,300	1,900
Mendocino	51,059	51,101	0.1	63,900	12,800	25.0	7,700	4,500	9,600
Sonoma	147,375	204,885	39.0	271,600	66,700	32.6	28,200	19,500	58,000
Marin	146,820	206,038	40.3	222,900	14,200	8.2	19,400	12,500	7,300
San Fran.	740,316	715,674	-3.3	658,700	-57,000	-8.0	69,700	67,400	-59,300
San Mateo	444,307	556,234	25.2	585,100	27,700	5.2	58,900	33,600	2,400
Santa Cruz	84,219	123,790	47.0	173,900	50,100	40.5	17,800	13,200	45,500
Monterey	198,351	250,071	26.1	275,000	27,600	10.0	40,400	14,800	2,000
San Luis Obispo	81,044	105,690	30.4	140,000	34,300	32.5	12,700	9,100	30,700
Santa Barbara	168,692	264,324	56.4	292,500	28,200	10.7	31,300	17,300	14,200

Within the central subregion, however, redistribution of population has occurred in the 1970-1980 period as readily developable land had been used up and as some counties, in response to the very rapid development of the previous decade, have moved to apply growth controls. The impact of policies regulating or limiting growth is clearly evident in the difference in percentage increases in population between Marin and Sonoma Counties, between San Mateo and Santa Cruz Counties, and between San Luis Obispo and Santa Barbara Counties and as shown in Table 5-97.

In Marin, San Mateo, and Santa Barbara Counties, growth has been slowed because limitations have been placed on service expansions for the essential components of the urban infrastructure: roads, water supply and wastewater collection, and treatment systems. New development in Marin and San Mateo Counties has been, for the most part, contained within bayside land areas. In Santa Barbara County, new development along the coast has been restricted through zoning and subdivision controls backed by a building moratorium in turn made necessary by shortages in water supply.

The statistics of existing and projected population shown in Tables 5-97 and 5-98 give a distorted picture of population within the coastal region. Most of the population in the three northern counties and in Santa Cruz and counties to the south live within the coastal area. However, as shown in the first column of Table 5-98 in Sonoma, Marin and San Mateo Counties, most of the population is located inland around the Bay in keeping with the general pattern of development of the San Francisco Bay area.

Table 5-99. Population Projections for the Coastal Counties, 1980, 1990, 2000
(California Department of Finance, 1978; EDAW, Inc., 1979a; 1979c)

county	1975 (Coastal) Region	Average Annual Growth Rate				
		1980	1990	2000	1980-1990	1990-2000
Del Norte		16,700	19,100	21,700	1.4	1.3
Humboldt		109,200	118,100	125,600	0.8	0.6
Mendocino		65,000	80,800	96,300	2.2	1.8
Sonoma	(3,990)	279,200	354,800	427,700	2.4	1.9
Marin	(8,660)	228,300	259,300	285,800	1.3	1.0
San Francisco		646,600	630,100	632,400	-0.3	--
San Mateo	(127,830)	598,300	641,400	662,400	0.7	0.3
Santa Cruz		186,900	248,300	309,700	2.9	2.2
Monterey		294,600	356,400	409,300	1.9	1.4
San Luis Obispo		146,000	181,800	216,100	2.2	1.7
Santa Barbara		298,500	339,400	372,900	1.3	0.9

The population projections appearing in Table 5-98 are taken from the California Department of Finance E-150 series which assumes a national birthrate of 2.1 children per woman and a net in-migration to California of 150,000 people per year.

These projections, which are derived from national and statewide trends, should be treated with caution when they are applied to different regions or individual counties and cities within the state. It cannot be assumed, for example, that in-migration into different parts of the state will reflect the statewide pattern. For that matter, in-migration to the state itself has varied widely over the last decade. In fiscal year 1963, in-migration was 320,000; in fiscal year 1970, it was 73,000. The average in-migration rate for that decade was 150,000. Within the state, the distribution of in-migration is highly dependent on economic factors. For example, as shown in Table 5-97, Components of Population Change, out-migration from Del Norte and Humboldt Counties occurred in the 1960-1970 period primarily because of a recession in the forest industry. Elsewhere along the coast, as also shown in Table 5-97, population growth rates on the order of 30, 40 and 50% obviously occur because of new arrivals to those counties in numbers that reflect the attracting influence of a buoyant and growing local economy.

Age Composition. Table 5-100 summarizes projected age characteristics by county. The projections are derived from the cohort survival model of the "E-150" Series. Projections of age composition would look much different under a higher or lower fertility rate, but it is in-migration and the age of the incoming population that could alter the projections in a major way.

The average median age in the three northern counties is below the state average but is projected to approach the state average in 1985 as the population of these counties ages. The number of young people below 18 years of age suggests that much of the population is composed of relatively large families. Elderly persons do not make up a disproportionately large part of the population.

In the San Francisco Bay area, age characteristics suggest that average household size is much smaller and that the proportion of elderly to the rest of the population is much higher than in the north.

Table 5-100. Median Age, California Coastal
Counties, 1980 and 1990, Projected
(California Department of Finance, 1978)

county	1980	1990
Del Norte	32.20	35.52
Humboldt	29.15	32.13
Mendocino	30.75	32.49
Sonoma	32.24	35.36
Marin	34.06	37.99
San Francisco	35.30	37.27
San Mateo	35.83	39.71
Santa Cruz	30.51	34.52
Monterey	28.16	31.35
San Luis Obispo	31.21	35.45
Santa Barbara	30.35	34.39

In the southern four counties (Santa Cruz, Monterey, San, Luis Obispo, Santa Barbara) the median age is much below the state average - surprising because with the exception of San Luis Obispo County, the elderly are thought to constitute a very high percentage of the population. In Santa Cruz, San Luis Obispo and Santa Barbara Counties the percentage of large student populations at college age would reduce the median age sharply.

Racial Composition. The racial composition of the coastal counties is shown (as a projection for 1980) in Table 5-101. The coastal counties are predominantly white, but the Spanish-American population is a significant minority group. The notable exception, again, is San Francisco, where blacks, Chinese, and Spanish-Americans are major minority groups and together represent over 40% of the population.

In the northern counties, minorities represent a very small proportion of the population. The pattern is reversed in the southern-most three counties, where the importance of agriculture and its linkage to Spanish-American, Japanese, and Chinese farming employment is apparent.

Table 5-101. California Coastal Counties
Total Population by Race, 1980, Projected
(California Employment Development Department, 1979a)

County	Total	White	Black	Other	Spanish American
Del Norte	17,600	16,370	60	1,180	1,310
Humboldt	109,030	103,570	580	4,880	6,050
Mendocino	63,600	60,600	370	2,620	4,100
Sonoma	128,600	23,500	1,510	3,590	8,450
Marin	227,500	217,640	5,610	4,210	12,620
San Francisco	649,700	372,270	106,130	171,320	98,480
San Mateo	593,700	500,660	48,700	44,330	69,860
Santa Cruz	186,000	177,650	1,510	6,810	20,390
Monterey	286,900	246,450	17,300	23,170	80,810
San Luis Obispo	147,300	139,090	3,180	4,980	17,760
Santa Barbara	299,200	277,020	10,220	11,980	47,630

Housing Characteristics and Demand. The high rate of migration into the coastal counties and the rapidly increasing level of personal income, particularly in the latter part of the 1970's, has kept the demand for housing high.

In the central coast subregion, the ability of the home building industry to respond to growing demand has depended upon the availability of serviced land. The number of units added over the last eight years, as shown in Table 5-102, reveal a rather extraordinary level of construction activity, with increases in the housing stock typically exceeding 15% over the decade. In San Luis Obispo, one-third of the

county's housing stock was added in the last eight years! Mobile home construction has typically increased by 40% to 50%. The demand for mobile homes may reflect the impact of growing numbers of home buyers priced out of the regular housing market. In the five northern counties, where incomes are on the average lower and where growth in personal income has been slower than elsewhere in the coastal region, mobile home construction approaches or exceeds 50%.

Table 5-102. California Coastal County Housing Construction, 1970-1978 (U.S. Bureau of Census, 1978)

County	Existing Housing Units 1970				Existing Housing Units 1978				Total Units Added	
	Single House Units	Multi- Family Units	Total Units	Mobile Homes	Single House Units	Multi- Family Units	Total Units ¹	Mobile Homes	Homes & MF	Mobile Homes
North										
Del Norte	4,206	591	4,797	544	4,526	660	5,186	1,673	389	1,129
Humboldt	27,594	5,341	32,925	2,297	30,001	6,890	36,891	4,621	3,966	2,324
Mendocino	15,673	1,819	17,492	1,422	18,573	2,855	21,433	3,714	3,941	2,519
Central										
Sonoma	63,715	10,265	73,980	4,080	81,695	19,519	101,214	9,357	27,234	5,277
Marin	52,091	19,148	72,239	721	60,246	17,270	85,770	1,727	14,540	1,006
San Francisco	104,595	205,465	310,060	342	105,688	213,553	319,241	342	9,181	--
San Mateo	134,337	53,333	188,170	2,313	150,135	71,959	222,094	2,974	33,924	661
Santa Cruz	40,180	8,847	49,027	3,071	51,796	15,455	67,251	5,898	18,224	2,827
Monterey	57,355	15,117	72,472	2,404	64,888	25,046	89,934	6,417	15,462	3,013
San Luis Obispo	29,179	6,060	35,239	2,373	38,821	11,375	50,196	6,478	14,957	4,105
Santa Barbara	59,907	25,214	85,121	3,685	66,565	35,857	102,422	5,788	17,301	2,103

1. Excluding Mobile Homes.

The housing construction figures say little about the steep rise in prices over the past three or four years, particularly in the counties of the central coastal subregion. Apart from normal inflationary factors, price increases seem to reflect shortages of serviced land. The rate of delivery of new units in Marin, San Mateo, Santa Cruz, Monterey, and Santa Barbara Counties constitute an outright housing shortage. In these areas, high prices and shortages in supply may be expected to characterize the housing market throughout the next decade.

The combined effects of price rises and housing shortages will probably remove low-income households from the home ownership market and, possibly, from the rental market as well. Even those with moderate incomes living on the coast will be hard-pressed to find housing. In Santa Maria, for example, the cost of housing is rising twice as fast as personal income. Few households would be able to afford new homes in Half Moon Bay in the San Mateo County mid-coastside area, where in 1976 new homes cost between \$90,000 and \$300,000 (McDonald and Smart, 1976). Local coastal plans, now in various stages of preparation, confirm that the disparity between housing prices and local income constitutes a severe problem requiring urgent attention.

One source of housing supply may be through housing rehabilitation. Possibly owing to the remoteness of many coastal communities from large centers of population, possibly owing to the difficulty of supplying public service and regulating and monitoring building practices, many housing units within the coastal area are in substandard condition. Within Del Norte County, Marin County, and San Mateo County coastal areas, for example, substandard units have recently been estimated to be 12%, 13% and 10% of the stock (Del Norte County Chamber of Commerce, 1977; Marin County, 1979; San Mateo County, 1979). A thorough appreciation of the condition of the stock is made difficult by the dated nature and narrow interpretation of "substandard" in census information. Local coastal programs usually lack the resources necessary to conduct housing surveys.

Land Use Patterns

Existing Land Use. Resource-based land uses still predominate throughout the entire coastal region. This is particularly the case in the three northern counties where 70% of the land in Del Norte County (Del Norte County, 1976) and 80% in Humboldt

County (California Department of Food and Agriculture, 1978) is forest land- In Mendocino County, an estimated 40% of land is forest land and another 47.6% of land in the county is in farms (Mendocino County, 1967). Within this area, most of the population is concentrated in small villages and towns along the coast. Eureka, with an incorporated area population of 24,500, is the largest urban center on the coast between the Oregon border and San Francisco.

The coast keeps its rural character southward through Sonoma, Marin, and San Mateo Counties, where sweeping marine terraces lying west of the coastal mountains are used for cattle grazing, dairy farming and the production of vegetable crops. Unlike the northern three counties, however, the undeveloped lands within the coastal zone lie virtually at the doorstep of one of the larger urban areas in the United States - the San Francisco Bay Area. In stark contrast to coastal land areas to the north and south is the City of San Francisco which is almost wholly developed.

South of the Bay Area, a different development pattern is apparent. Within the wide, broad plain lying behind Monterey Bay are the sizable cities of Santa Cruz and Monterey, acting as the north and south poles of a scattering of small communities strung out between them along the coast. Overall, these communities represent a large urban concentration: their combined population exceeds 350,000. Within the triangle between the apexes of Santa Cruz, Monterey, and Salinas to the east, is the most productive agricultural area in coastal California. The viability of the agricultural industry here has undoubtedly helped maintain a pattern of development within the area which so far has proven resistant to urban sprawl.

Located near the center of a predominantly agricultural county, the city of San Luis Obispo and its environs is currently the most rapidly growing area within the northern or central coastal regions. Development is extending westward from the city toward the coast along the east-west trending valleys into the Los Osos-Bayview area south of Morro Bay and southward from the city, along Highway 101 towards Avila Beach, and, beyond that, around the city of Arroyo Grande. Nonetheless, despite the pace of development, urban and developed rural land constitute but 3.8% of the county's total land area; agriculture and open space account for 74% (California Department of Food and Agriculture, 1978).

In Santa Barbara County, the northern communities of Santa Maria/Orcutt comprise another center of rapid urban development. The conversion of agricultural lands to urban uses appears to be occurring primarily in the area in between the two towns. Agriculture nonetheless remains the predominant use of land in this part of the coast where throughout the decade substantial increases in the amount of irrigated farmland have taken place west of Santa Maria/Orcutt around the small town of Guadalupe.

Beyond a very general descriptive overview of land use within the coastal zone, characterization of land use patterns become much more elusive. A major difficulty in generalizing about land uses occurs because of the diversity of land use classifications and statistical sources.

No one source gives land use statistics by the same categories or the same data for all counties. Further, what appears to be a simplified classification of use, such as appears for San Luis Obispo county in Table 5-103, is often misleading because there are no standard definitions of land use. It is not uncommon for several different independent surveys of the same area to find no agreement whatsoever on the percentages of land in different categories (Winzler and Kelly, 1977b).

Table 5-103. San Luis Obispo County Land Use, 1977
(San Luis Obispo County, 1979)

Land Use Category	Number of Acres	Percent of Total
Urban	40,406	1.9%
Rural Residential	15,854	0.8%
Rural Commercial	35,014	0.2%
Rural Industrial	18,803	0.9%
Agricultural	1,223,868	57.7%
Open Space	348,047	16.4%
Public	23,400	1.1%
Miscellaneous	447,851	21.0%
Total County	2,122,240 acres	99.9%

Because public lands are a very important factor in the protection of resources, both at the coast and inland, it is useful to examine public land ownership patterns within the northern and central coastal regions as identified statistically in Table 5-103 below and by Figure 5-16 which follows it.

Table 5-104. Summary of Public Land Ownership, California Coastal Counties, 1977, in Acres
(California State Lands Commission, 1977)

county	Federal	State	county	Cities	School Districts	Jr. College Districts	Special Districts	Total Publicly Owned Land	Total Land Area ¹
Del Norte	461,287.76	19,546.51	2,675.99	272.37	150.50	0.00	94.82	484,029	641,920
Humboldt	506,142.84	67,926.71	7,926.38	4,637.07	678.40	0.00	253.74	587,564	2,286,720
Mendocino	308,255.80	77,362.04	5,793.51	2,665.95	403.30	0.00	2,113.26	396,593	2,244,480
Sonoma	26,858.44	29,196.76	4,708.22	5,132.95	874.40	77.00	90.30	66,937	1,010,560
Marin	84,678.48	14,162.94	4,183.05	4,104.18	882.40	63.50	19,542.17	217,615	332,800
San Francisco	6,113.24	1,508.65	12,296.59	0.00	316.50	58.00	3.34	20,294	28,800
San Mateo	638.97	9,601.67	43,782.77	9,560.62	2,316.90	59.00	2,375.59	68,337	290,560
Santa Cruz	406.38	36,250.02	3,206.90	6,462.29	418.00	134.00	2,435.44	49,312	280,960
Monterey	865,631.25	19,921.12	31,746.88	5,526.43	1,155.30	136.00	1,118.31	925,234	2,127,360
San Luis Obispo	318,047.16	30,428.71	30,251.22	3,531.81	662.03	0.00	237.18	383,150	3,122,240
Santa Barbara	753,757.75	15,960.85	6,261.63						

1. Figures may not agree with those in Table 5-108 due to inclusion of tidelands and other differences.

The very large public acreages in the northern three counties and in the southern three counties are accounted for by three large national forests: Six Rivers, Mendocino, and Los Padres. Nonetheless, as a percent of total land area, public ownership is an important factor in the mid-coast counties. In Marin County, for example, almost all land west of the eastern urban corridor is owned either by Marin Municipal Water District or by the federal government.

The relative amount of land in public ownership is not the point of main importance, however; it is the effectiveness of resource protection offered by such ownership. The impact of public land ownership is discussed elsewhere (see the Recreation section of this chapter, and Volume IV, Watershed Units). One of the main purposes of public ownership within coastal counties is to protect public access to the coast. The table summarizing the number of miles of coastline in public ownership appearing in Table 5-105, is useful in forming a relative measure of access throughout the study area. It does not accurately represent miles in public ownership, however. It excludes, for example, the 32 miles of coastline within Vandenberg Air Force Base, most of which is not accessible to the public.

Two categories of land resources are obviously of overwhelming importance to the coastal economy: timberland, and agricultural lands. With these, as with other land resources, it is necessary to distinguish between the extent of the resource and the location, type and intensity of use, if any useful appreciation of the character of land use is to be gathered. Table 5-105 below categorizes land use in a way that allows an accurate idea of the extent of the resources (lands in farms) and type of use. Irrigated land which is not cropland, for example, is probably almost entirely pasture land. "cropland harvested" gives a good measure of farmland actually in production as distinguished from land left fallow.

Table 5-106 shows productive timber land acreages throughout the study area, but omits the very significant commercial forest lands in National Forests. Extensive portions of three of these forests are within the study area. Much of the commercial forest land within them (as shown in Table 5-107) should be added to the inventory shown in Table 5-105.

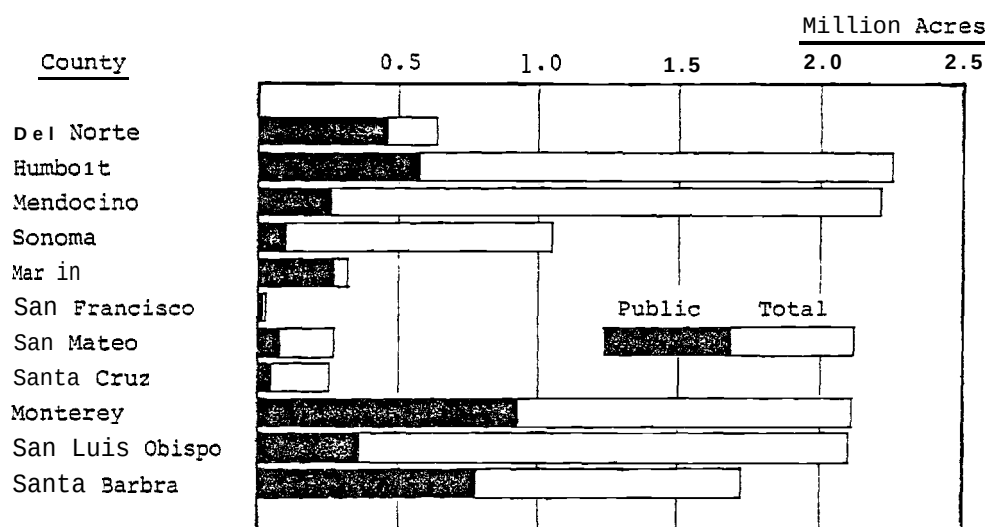


Figure 5-16. Number of Acres of Land in California Coastal Counties and Number of Acres in Public Ownership, 1975

Table 5-105. Summary of Coastline in Public Ownership, 1976 (E.S.R.I., 1980).

county	Miles	Miles Available To Public	Percent Available To Public
Del Norte	45.5	23.6	51.0
Humboldt	121.3	79.5	65.5
Mendocino	120.0	12.6	10.0
Sonoma	62.0	21.1	34.0
Marin	70.2	54.0	77.0
San Francisco	8.4	7.7	91.0
San Mateo	56.0	18.0	32.0
Santa Cruz	42.0	17.0	40.0
Monterey County	111.0	44.0	40.0
San Luis Obispo	93.0	21.0	22.0
Santa Barbara Co.	109.0	16.8	15.0

Table 5-106. Number of Farms, Total Land Area (acres) , and Land in Farms, by Coastal County, 1974 (California Department of Finance, 1978)

Counties	Number of Farms	Total Land Area (In acres)	Total In Farms (In acres)	Cropland Harvested (In acres)	Irrigated Land In Farms (In acres)
Del Norte	122	644,352	16,954	3,292	4,318
Humboldt	800	2,295,232	793,417	15,110	16,463
Mendocino	878	2,246,976	702,836	24,161	15,639
Marin	250	332,928	148,893	4,359	786
Sonoma	2,652	1,026,240	600,706	79,321	28,572
San Francisco	NA				
San Mateo	366	286,080	78,795	10,840	6,849
Santa Cruz	690	281,472	54,603	16,793	13,090
Monterey	1,228	2,127,296	1,439,538	261,514	206,041
San Luis Obispo	1,383	2,037,120	1,619,091	186,847	34,834
Santa Barbara	1,267	1,751,680	967,484	90,702	67,021

Table 5-107. Acres of Commercial Forest Land Outside National Forests by County and Ownership, California, 1975, in Thousands of Acres (California Department of Finance, 1978)

county	Public-Other than National Forest	Forest Industry	Other Timber	Private Growers	Farmer and Miscellaneous Private	Total Private	Total All Ownerships Outside National Forests
Del Norte		143			21	164	164
Humboldt	130	527			741	1,268	1,398
Mendocino	98	468			628	1,096	1,194
Sonoma	1	60			199	259	260
Marin					7	7	7
San Francisco							
San Mateo	1	8			35	43	44
Santa Cruz	6	2		17	110	129	135
Monterey	1				26	26	27
San Luis Obispo	-				1	1	1
Santa Barbara	-						

Table 5-108. Total Area and Commercial Forest Land Managed by the U.S. Forest Service in Coastal Counties¹, 1975 (California Department of Finance, 1978)

National Forest	Total Land Area	Commercial Forest Land
Los Padres	1,750,000	80,000
Mendocino	876,000	350,000
Six Rivers	969,000	775,000

1. Omits Klamath National Forest, a small section of which is in Del Norte County.

For a more extensive discussion of agricultural and timber land resources, see the sections of this chapter on Forestry and Agriculture.

There are three broad categories for built-up or developed land uses in the study area. Roads, ports, and power plants are uses categorized as "transportation and utilities" and are described in the section on Transportation. "Urban land" and

"developed rural land" are the two other Categories. The urban land classification is usually applied to residential, commercial and industrial lands within incorporated areas and the classification "developed rural land" to the same uses outside municipalities.

The distinction between urban and rural developed land is important in the coastal zone where much of the existing development, and pressure for new development, occurs outside incorporated areas. Rural developed land is taken in most cases to mean lands in residential and commercial use but not serviced, i.e., not connected to municipal water supply services or to a sewerage collection and treatment system. In some places, the designation may also apply to approved buildable lots; i.e., lots which have accrued all necessary development approvals short of a building permit.

Water and Sewer Services. Almost all communities within the coastal region rely on groundwater as the source of municipal and agricultural water supply. Basins in large clusters are found in the Santa Ynez and Santa Maria River valleys in northern Santa Barbara County; along the Salinas River Valley and (in a broad band) throughout the Monterey County coastal plain; and within the Eel River estuary and the alluvial plain surrounding Humboldt Bay. Elsewhere, narrow, elongated groundwater basins are to be found along the many small creeks and streams that typify the coast south of the Eel River. A detailed inventory of groundwater resources may be found in the California Department of Food and Agriculture reports on pesticide use (California Department of Food and Agriculture, 1978), which in turn rely heavily on the various water quality Basin plans prepared for the north, central and south central coast regions by the State Water Resources Control Board.

Typically, groundwater supplies are supplemented by water from various reservoirs constructed in the nearby coastal mountains. Moving from south to north, major resources (also used as sources of groundwater renewal) are Lake Cachuma (Santa Barbara County), Twitchell, Lopez and Nacimiento Reservoirs (San Luis Obispo County), Lake San Antonio (Monterey County), Crystal Springs Reservoir (San Mateo County) and Nicasio Reservoir (Marin County). Northward of Marin County supplemental water is taken from the Russian River for the Sonoma and Mendocino County coastal areas, and from the Mad River for the Eureka/Arcata area.

A reading of the watershed descriptions will demonstrate that in almost every locality along the coast shortages of water exist and overdrafts of the groundwater table are occurring. Problems are particularly acute in the agricultural areas of the Salinas River basin in Monterey County and the Santa Maria and Santa Ynez River valleys where irrigation requirements of high yield crop production represent the major cause of escalating water demands.

It appears that water supply has been kept in a delicate balance with demands made by various types of users through impoundments of the various creeks and streams found in all parts of the coast. Although impoundments are recognized as having a damaging effect on fish and riparian habitats, they have been loosely regulated. The seriousness of the practice is now receiving greater attention from public agencies, notably the California Coastal Commission.

For wastewater treatment, many of the smaller communities and most rural settlements rely on septic tank systems. Even well established, larger urban areas, such as McKinleyville in Humboldt County, may not have a municipal wastewater collection or treatment plant. Where they do exist, wastewater treatment systems typically have quite localized service areas, usually treating flows from single communities and frequently excluding developed unincorporated areas close by. Consolidated and area-wide systems are being constructed within the Arcata/Eureka area, among the communities of the San Mateo mid-coast, and between communities around Monterey Bay. Further information concerning these service systems is provided in the appropriate watershed descriptions in Volume IV.

Wastewater treatment plants serving communities along the coast usually provide primary treatment of wastewater followed by discharge to the ocean. Wet weather flows receive little or no treatment because few plants have retaining ponds. The location of discharge is a frequently encountered problem. Many plants discharge to sloughs, estuaries, lagoons, or near wetlands and marshes rather than to areas where ocean currents and tidal action swiftly diffuse pollutant concentrations. Effluent quality requirements are established through the State Water Quality Control Board's Ocean Plan. Since 1972 the Board has pursued a policy of removing discharge locations from areas of special biological significance. Point source discharges into the Pacific Ocean are located and identified in Figure 5-17.

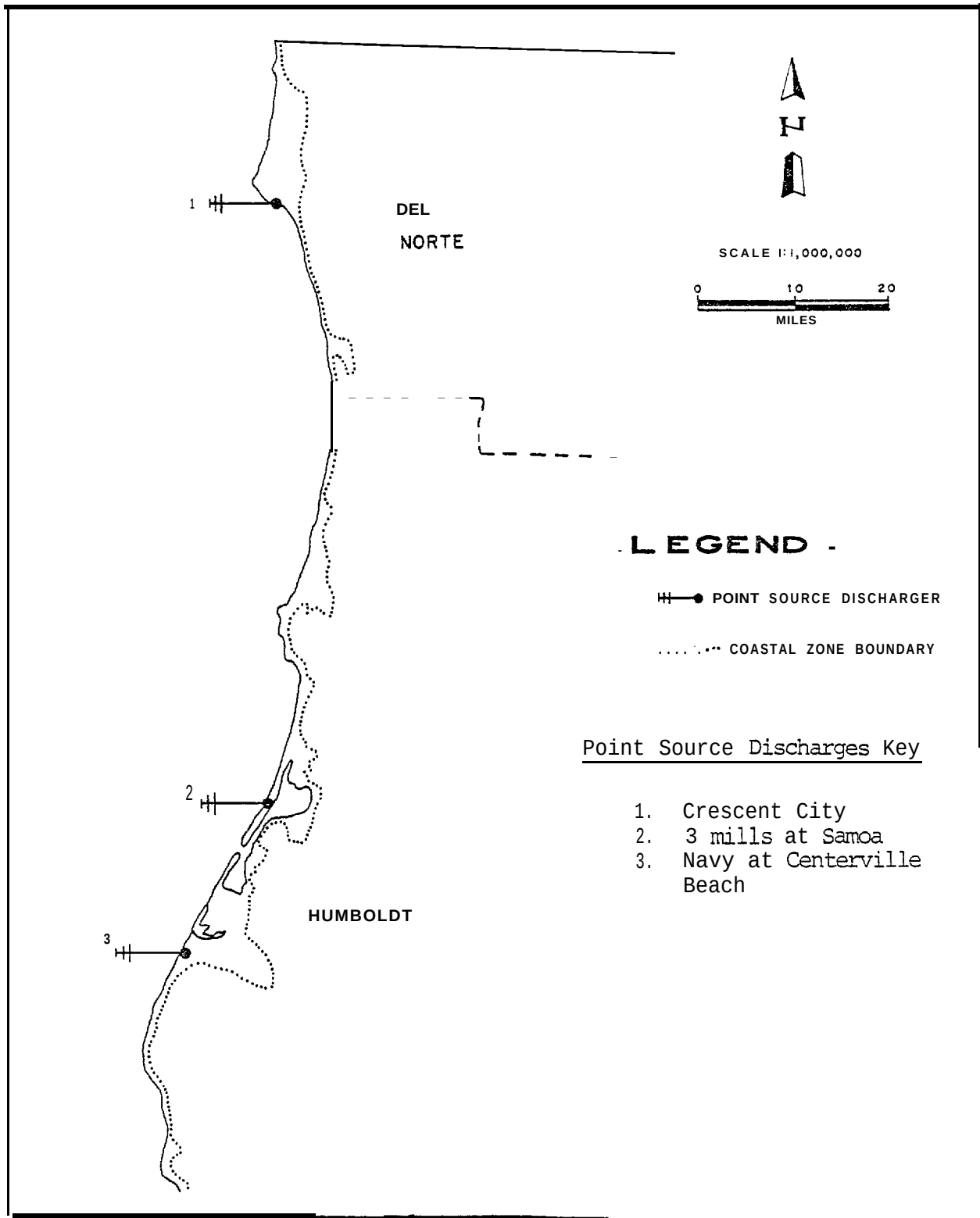


Figure 5-17. Coastal Zone Boundary (California Coastal Commission 1979 Coastal Zone Boundary Map), and Major Point Source Discharges (Regional Water Quality Control Boards) into the Pacific Ocean (Sheet 1 of 4)

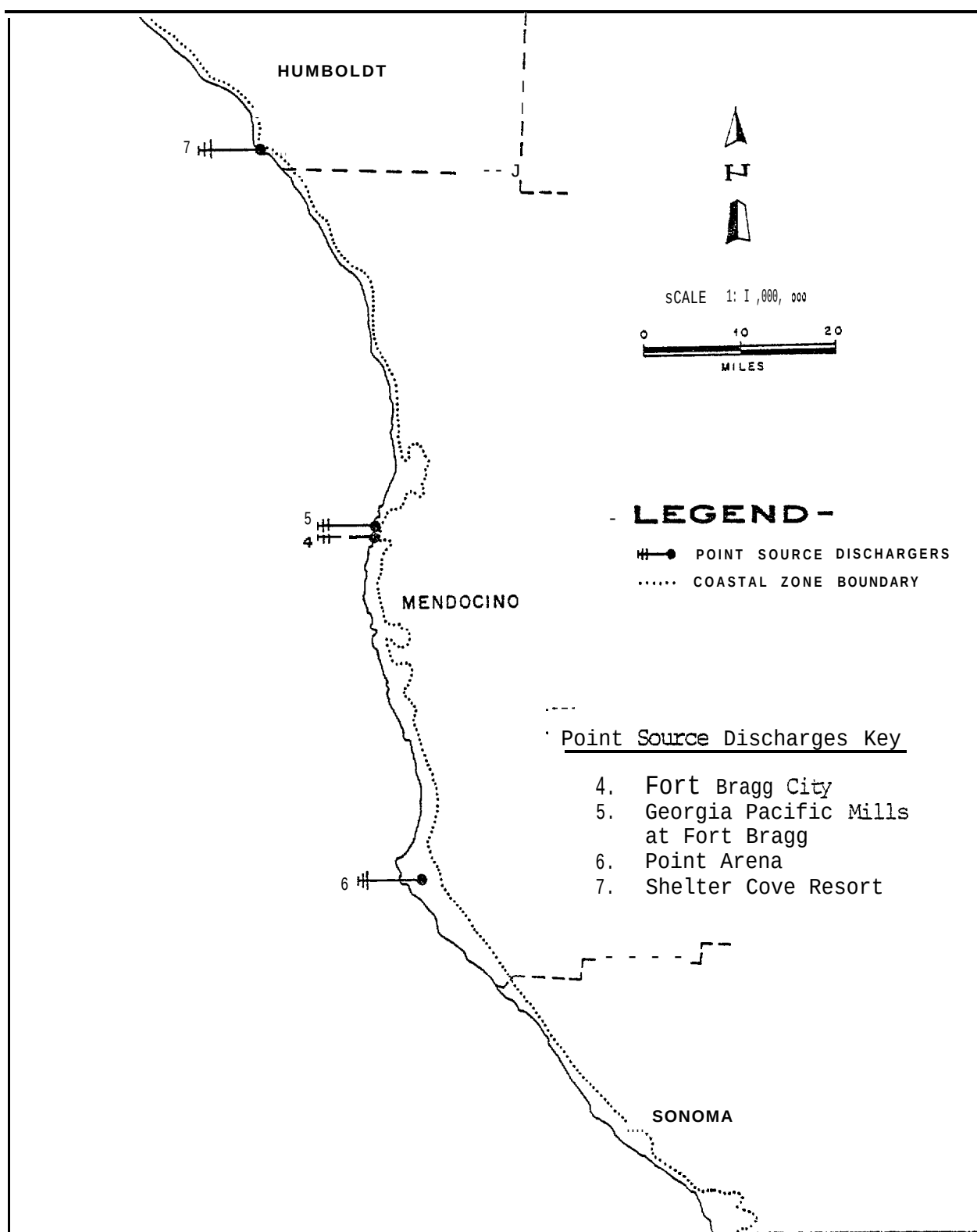


Figure 5-17. Coastal Zone County (California Coastal Commission 1979 Coastal Zone Boundary Map), and Major Point Source Discharges (Regional Water Quality Control Boards) into the Pacific Ocean (Sheet 2 of 4)

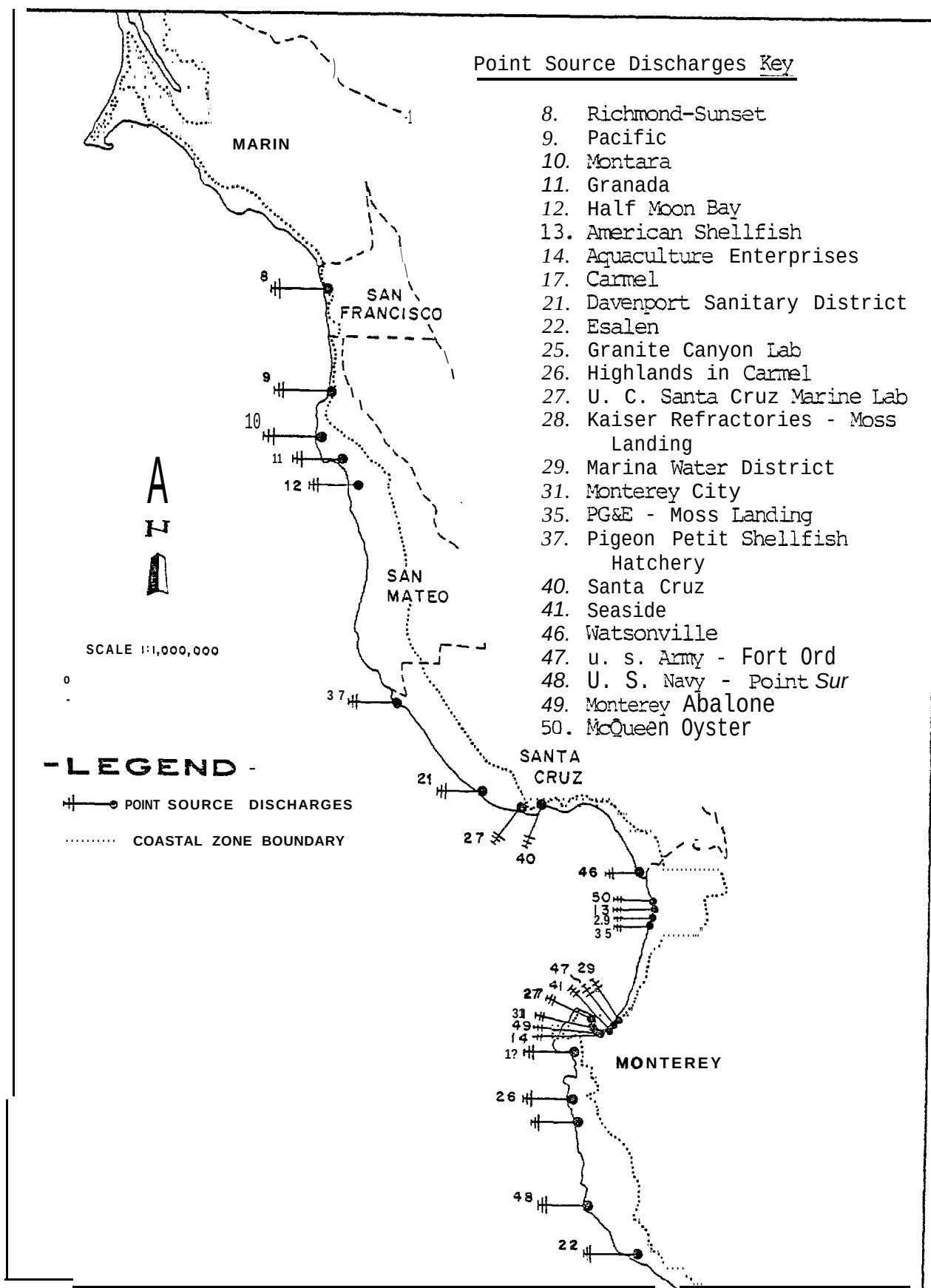


Figure 5-17. Coastal Zone Boundary (California Coastal Commission 1979 Coastal Zone Boundary Map) and Major Point Source Discharges (Regional Water Quality Control Boards) into the Pacific Ocean (Sheet 3 of 4)

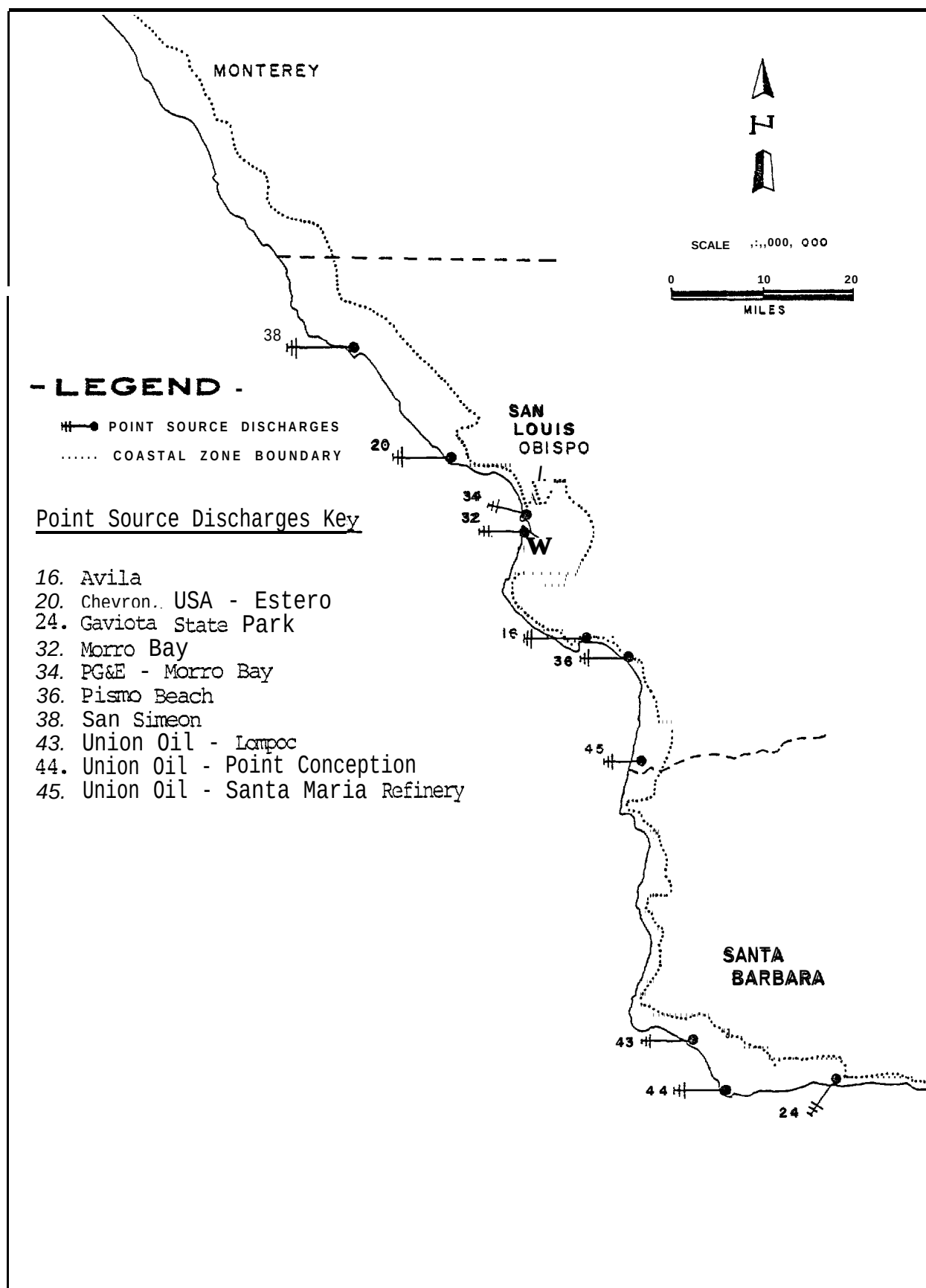


Figure 5-17. Coastal Zone Boundary (California Coastal Commission 1979 Coastal Zone Boundary Map) and Point Source Discharges (Regional Water Quality Control Boards) into the Pacific Ocean (Sheet 4 of 4)

New development within coastal areas over the decade has brought many wastewater treatment plants close to capacity. The replacement of such plants through the construction of larger consolidated systems has progressed slowly, often because many people within the communities affected have resisted the increased potential for urban development such plants would provide.

Types of pollutants that receive special attention in the coastal zone are organisms of the coliform group, the presence of which may prevent shellfish and processed fish products from meeting public health standards, toxic substances, and other deleterious substances that may cause unpalatable taste and odors in sea food. Treatment standards for wastewater also specify permissible dissolved oxygen and pH levels as necessary to maintain fish habitats.

Land Use Trends. What is of importance in assessing the character of urban land development within a given area is knowledge of the extent of "rural" land approved for development and the service capacity of roads, water supply and sewage treatment systems. The two together will give an accurate reading of the development potential of any given area, although not necessarily of the timing of development.

The relationship between "buildable lots" and service constraints represents the most commonly found source of tension within public bodies responsible for land development on the coast. It is over the question of service supply that most preservation and development issues fall into clearest relief. It is important to note again that almost all areas of the coast are near capacity in water supply and sewage treatment, and in many cases face congestion of local roads. For a more extensive discussion of the problem, the reader is referred to the sections of this chapter on Recreation, and Transportation, and further, to the various watershed descriptions in Volume IV. In addition, Local Coastal Plans now in various stages of preparation by cities and counties along the coast can be relied on to give extensive attention to services capacities and to the constraints service limitations place on the extent and location of new development.

The inventorying of land (and water) resources within the coastal zone, that is, along the coast and immediately inland of it, has received concerted attention throughout the decade, both before and after control and protection of those resources was institutionalized through passage of the California Coastal Act of 1976.

Prior to passage of the act, the U.S. Army Corps of Engineers surveyed the coast in the late 1960's as part of a national shoreline study (U.S. Army Corps of Engineers, 1971). The Corps findings, presented in map form, concentrate on the erosion characteristics of the coastline. A subsequent study, also presented in the form of very detailed maps of the coastline, was conducted by the California Department of Navigation and Ocean Development (1977a). These two studies give detailed information on the character of the coastal shoreline.

A parcel-by-parcel inventory of land uses within the coastal zone - keyed to maps - is available through the California Department of Water Resources publication Land Uses Within the California Coastal Zone (California Department of Water Resources, 1978c). Parcel information, updated to 1976, is statistically tabulated by computer and is available as a printout through regional offices of the Department. As previously noted, this inventory uses only one of many classification systems in use and, like any large area inventory, may represent varying interpretations of each class by survey personnel.

Creation of the California Coastal Commission in 1972 and passage of the Coastal Zone Act of 1976 dramatically altered the influence of market forces on the use of coastal zone land resources. The jurisdictional boundary of the Commission was reduced by the act and has been further amended since then. Jurisdiction was also "decentralized" through the provision for approval of certain types of use in certain areas by local jurisdictions upon certification of a Local Coastal Plan. Although the boundary is subject to change, its general delineation is shown in Figure 5-17.

As a consequence, even a clearly-defined general pattern of public policy constraints on the uses of coastal zone resources must await the coastal Commission's certification of at least a majority of local coastal plans. As of this date, no more than 10% of these plans have been certified and it seems virtually certain that the June 30, 1981 deadline specified for completion of the process will have to be extended.

In the interim, the California Coastal Plan of 1975 serves as a useful reference on the nature of the coast and of the linkage between various planning objectives of the Commission and the protection of coastal resources. The Commission follows the objectives and policies embodied in the California Coastal Zone Act of 1972, however, and these, in many cases, differ substantially in their application from those represented in the 1975 plan.

A recent inventory of coastal resources considered to be of special significance by the Coastal Commission may be found in its recent statement designating areas in the coastal zone from which power plants would be excluded (California Coastal Commission, 1979). This report is also useful as a source of information on further land acquisitions likely to be undertaken by various public agencies. In addition, the Summary of Knowledge of the Coastal Zone and Offshore Areas (Winzler and Kelly, 1977b) provides a detailed listing of properties the California Coastal Commission recommends (1976) for public acquisition.

Natural Systems Effects of Settlement. The settlements within the coastal region sprang up in response to the economic stimulus provided by the forest, agricultural and fishing industries. Coastal communities act as sites for the various processing and distributional functions of a resource economy. Urbanization nonetheless creates natural systems effects that may be distinguished from those occurring because of the activities of resource industries. There are two major categories of impact of urbanization: existing resources are displaced by the "improvements" of street construction and the building of homes, shops and other buildings; and natural systems are impaired, altered or destroyed through pollution caused by concentrated human activity. A classification of coastal land use activity zones and their typical impacts may be found in Volume III.

Displacement Impacts. Within the coastal region the resources affected in a major way by displacement are prime agricultural soils, marine and wildlife habitats supported by wetlands, and scenic and recreational resources. The impact by displacement on these and other resources is given specific attention in the various watershed descriptions. Generally speaking, the loss of agricultural lands is a serious impact of urban expansion around Humboldt Bay, around Half Moon Bay in San Mateo County, and in the vicinity of Morro Bay in San Luis Obispo County. The displacement of marshland by urban uses has been greatly reduced since passage of the California Coastal Zone Act but impacts on wetlands owing to the secondary effects of nearby urbanization continue to be pervasive. Recreational and scenic resources are threatened by the scattered nature of development along the coast in several locations. The Mendocino County coast may be the most severely affected.

Another type of displacement effect results from water supply services. Many coastal communities rely on groundwater as the source of their municipal water. Overdrafting of the groundwater table occurs frequently and salt water intrusion into the table, among other effects, is occurring, or threatening to occur, in many places along the coast. Water supply is also commonly provided by the damming of coastal streams. The displacement of normal flows from these rivers is damaging to riparian vegetation and to fish and wildlife habitat.

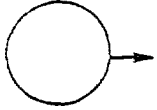
Pollution. Water pollution is a significant impact of urbanization within the coastal zone. Owing to the scattered and rural nature of development in many areas, septic tank systems are frequently relied upon as the method of wastewater treatment, even in much more densely developed "rural" subdivisions. Many municipal systems provide only primary treatment and discharge to sloughs and wetlands where the cleansing of tidal action is largely absent. Urban runoff that may be frequent and heavily sediment-laden in coastal communities, because of the coast's hilly nature as well as heavy seasonal rains, is a source of pollution largely unstudied and difficult to treat.

Resources frequently identified as requiring protection from reduced water quality are shellfish beds, marine life refuges, ecological reserves and designated Areas of Special Biological Significance, various vegetative habitats required for the maintenance of wildlife, and migratory waterways for fish and spawning areas.

Air pollution is a continuing impact of urban activity. Weather conditions along the San Luis Obispo and Santa Barbara coast produce persistent subsidence inversions. In counties within the Monterey and San Francisco Bay areas, radiation, subsidence and frontal inversion are common (California Department Of Food and Agriculture, 1978). These climatic conditions greatly increase the severity of air pollution, but the impact is offset by the relatively low levels of population and industrial development typical of the northern and central coastal regions.

II-388
Part 1

Appendix A
GLOSSARY OF SYMBOLS



Source of energy or matter external to the system or portion of a system being modeled. This symbol, and many of the others here, are based on H. T. Odum (1971) .



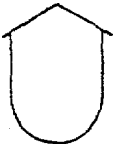
Atmospheric source of energy and matter, including solar radiation and various atmospheric disturbances.

D

Produce-r: plant or plant community.

O

Converter: animal, microbe, or community of animals or microbes; can be consumers of decomposes or both.



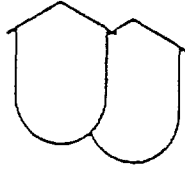
Storage compartment or substrate. Note : Symbol for storage compartment or substrate may be used within a larger storage compartment for discrete materials that are not dispersed throughout the compartment.



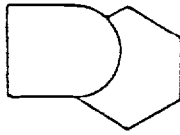
Effects of socio-economic activities on specific ecosystem components.



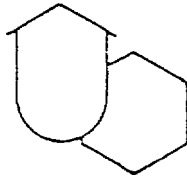
Socio-economic activity. Used to represent the conventionally named human activities (e.g., logging, road construction) .



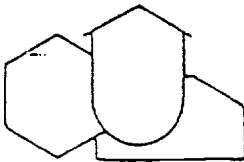
Multi-compartment storage.



Biological community: producers and converters. The boundary between the compartments may be omitted and their relative positions may vary.



Substrate-converted combination, such as the detritus-decomposer union, where the distinction between the two is not essential for the system being modeled.



Composite human community and activity: a combination of conversion, storage, and socio-economic functions.

u

'To detritus. Indicates a flow of material and energy to the nonliving compartment. Combines mortality and flow to detritus, thus simplifying models.



Boundary for the specific ecological unit being modeled.



Flow path for energy or matter or dollars.



Flow path for regulating influence or effect
(i.e., not flow of energy, matter, or dollars) .



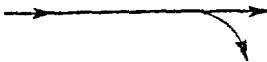
Materials in storage compartments that are
distributed homogeneously.



Directional flows.



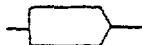
Converging or combining flows.



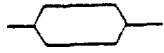
Diverging or branching flows.



Switch. Incoming flow is divided into two or
more different paths by a primary regulating
process, or goes one way or another depending
on the regulating factors.



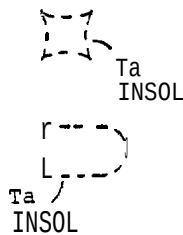
One-way valve. Flow in one direction along a
single path occurs through and is controlled
by a primary regulating process, and depends
on its secondary regulating factor.



Two-way valve. Flow in two directions along a single path occurs through and is controlled by a primary regulating process and its secondary regulating factors. Flow can go either or both directions, e.g., materials in and out. This symbol often represents a complex group of interacting processes.



Sequential valve. Flow occurs through and is regulated by a series of primary regulating processes acting in sequence with little or no interaction. (Previous two valves are used for nonsequential or complex interacting processes.)



Secondary regulating factor. The controlling factors that regulate a primary regulating process (represented by either a switch or a valve, as above). Examples illustrated here represent the regulating factors air temperature (Ta) and insolation (INSOL).



Cyclical or periodic flow from source, such as tides, daily and seasonal cycles of the sun, etc.



Boundary between ecosystem model areas (physical-chemical, biological, socio-economic). Locate at bottom of the page.



Emphasizes important processes.

Appendix B - Glossary of Geologic Terms

alluvial fan	A cone-shaped deposit of alluvium made by a stream where it runs out onto a level plain or meets a slower stream. The fans generally form where streams issue from mountains upon the lowland.
alluvium	A general term for all detrital deposits resulting from the depositions of modern rivers, thus including the sediments laid down in river beds, flood plains, lakes, fans at the foot of mountain slopes, and estuaries.
andesite	A volcanic rock.
aphanitic	A term pertaining to the texture of rocks in which the crystalline constituents are too small to be distinguished with the unaided eye.
arenite	Consolidated rock of the texture of sand irrespective of composition. Syn: psammite.
argillaceous	A term applied to all rocks or substances composed of clay, or having a notable proportion of clay in their composition.
argillite	A rock derived either from siltstone, claystone, or shale, that has undergone a somewhat higher degree of induration than is present in those rocks.
basalt	An extrusive volcanic rock composed primarily of calcic plagioclase and pyroxene, with or without olivine. More generally, any fine-grained dark-colored igneous rock.
bedrock	The solid rock underlying unconsolidated material, or exposed at the surface.
bentonite	Clay formed from the decomposition of volcanic ash.
biotite	A ferro-magnesium mineral; see Vol. I, Chapter 3, Table 3-1
breccia	A rock made up of highly angular, coarse fragments. May be sedimentary or formed in place by crushing or grinding along faults.
Cenozoic	An era of geologic time; see Vol. I, Chapter 3, Table 3-2, Geologic Time Scale.
chert	A compact, siliceous rock formed of silica.
chlorite	A ferro-magnesium mineral; see Vol. II, Chapter 3, Table 3-32.
clast	An individual constituent of detrital sediment or sedimentary rock.
elastic	A property of rocks by which they consist of fragments of rock or organic material that have been moved from their place of origin.
clay	Sediment particles in the smallest size category. See Sediment: Sizes.
claystone	A rock composed of clay-sized particles, See Sedimentary Rocks.
conglomerate	A cemented elastic rock containing rounded fragments, pebble or gravel sized.
Cretaceous	Period of geologic time. See Vol. I, Chapter 3, Table 3-2, Geologic Time Scale.
dacite	An igneous rock type which is the extrusive equivalent of quartz diorite.
detritus	Material produced by the disintegration and weathering of rocks.

diapir	A piercing fold.
dolomite	1. A mineral, $\text{CaMg}(\text{CO}_3)_2$, commonly with some Fe replacing Mg. 2. Rocks that approximate the mineral dolomite in composition.
dunite	A rock mineral like peridotite but consisting almost wholly of olivine and containing accessory pyroxene and chromite.
eclogite	A granular rock composed essentially of garnet and pyroxene.
en echelon	Parallel structural features (such as faults) that are offset like the edges of shingles on a roof when viewed from the side.
euzeosyncline	A geosyncline with volcanic rocks.
extrusive	Igneous rock derived from magma poured out or ejected at the earth's surface.
feldspar	A group of abundant rock forming minerals. See Vol. I, Chapter 3, Table 3-1.
feldspathic	A term applied to rocks containing feldspar as a principal ingredient.
fissility	A property of rocks by which they split easily along closely spaced parallel planes.
flew rock	A rock formed from the solidification of a lava flow.
fold	A bend in rock strata or any planar structure.
foliation	The laminated structure of rocks resulting from segregation of different minerals into layers parallel to the schistosity.
geosyncline	A large, generally linear, trough that subsided deeply throughout a long period of time in which a thick succession of stratified sediments and possibly extrusive volcanic rocks commonly accumulated.
gneiss	A coarse-grained metamorphic rock in which bands rich in granular minerals alternate with bands in which schistose minerals predominate; generally derived from granitic rock.
granite	A plutonic rock consisting essentially of alkalic feldspar and quartz.
granodiorite	An intrusive igneous rock composed of quartz and orthoclase with mafic minerals.
granulite	A metamorphic rock composed of even-sized interlocking granular minerals.
gravel	See Sediments: sizes.
graywacke	A type of sandstone characterized by: (1) large detrital quartz and feldspars (phenocrysts) set in a (2) prominent to dominant "clay" matrix, (3) a dark color, (4) generally tough and well indurated, (5) extreme angularity of the detrital components, (6) presence, in smaller or larger quantities, of rock fragments, (7) certain macroscopic structures (graded bedding, intraformational conglomerates of shale or slate chips, slip bedding, etc.) and (8) certain rock associations.
grus	Gritty, sandy detritus formed by the weathering of granitic rocks.
heavy mineral	A mineral with density greater than 2.9, the density of bromoform.
hematite	A ferro-magnesium mineral. See Vol. I, Chapter 3, Table 3-1.
hornblende	A ferro-magnesium mineral. See Vol. II, Chapter 3, Table 3-32.

igneous rocks	Rock formed by solidification of hot mobile material termed magma.
illite	Name for a group of clay minerals abundant in argillaceous sediments. They are intermediate in composition between muscovite and montmorillonite; many are made up of interlayered mica and montmorillonite.
indurate	Hardened rock; hardened by pressure, heat, cementation or other causes.
intrusive	Igneous rock that consolidated from magma beneath the earth's surface.
Jurassic	A period of geologic time, see Vol. I, Chapter 3, Table 3-2, Geologic Time Scale.
limestone	A bedded sedimentary rock consisting chiefly of calcium carbonate (CaCO_3) which yields lime when burned.
lithology	A term referring to the physical character of a rock; the rock type or composite of rock types in an area.
mafic	A term pertaining to rocks composed dominantly of the magnesian (MgO) rock-forming silicates; subsilicic; basic.
magma	Naturally occurring mobile, liquid rock material.
marble	A metamorphic rock composed essentially of calcite and/or dolomite.
Mesozoic	An era of geologic time. See Vol. I, Chapter 3, Table 3-2, Geologic Time Scale.
metamorphism	Process by which consolidated rocks are altered in composition, texture, or internal structure by conditions and forces of pressure, heat, and the introduction of new chemical substances.
metamorphic rock	A general term for all those rocks which have formed in the solid state in response to pronounced changes of temperature, pressure, and chemical environment.
metasedimentary	Sedimentary rocks which have been partially metamorphosed.
metavolcanics	Partly metamorphosed volcanic rocks.
mica	A ferro-magnesian mineral. See Vol. I, Chapter 3, Table 3-1.
miogeosyncline	A geosyncline without volcanic rocks.
Miocene	An epoch of geologic time. See Vol. I, Chapter 3, Table 3-2, Geologic Time Scale.
monzonite	See quartz monzonite.
Oligocene	An epoch of geologic time; see Vol. I, Chapter 3, Table 3-2, Geologic Time Scale.
orthoclase	A feldspar mineral. See Vol. I, Chapter 3, Table 3-1.
outcrop	The exposure of bedrock or strata projecting through the overlying cover of detritus and soil.
oxide	A compound of oxygen with one other more positive element or radical.
paleontology; palaeontology	The science that deals with the life of past geological ages. It is based on the study of the fossil remains of organisms.
Paleozoic	An era of geologic time, see Vol. I, Chapter 3, Table 3-2, Geologic Time Scale.

peridotite	A general term for essentially nonfeldspathic plutonic rocks consisting of olivine, with or without other mafic minerals.
phanerite	A general term applied to wholly crystalline rocks, the mineral constituents of which may be distinguished with the unaided eye.
phyllite	An argillaceous rock intermediate in metamorphic grade between slate and schist.
pillow lavas	A general term for lavas that exhibit pillow structure.
plagioclase	A feldspar mineral. See Vol. I, Chapter 3, .
Pleistocene	An epoch of geologic time. See Vol. I, Chapter 3, Table 3-2.
Pliocene	An epoch of geologic time. See Vol. I, Chapter 3, Table 3-2.
pluton	A body of igneous rock that has formed beneath the surface of the earth by consolidation from magma.
porcelanite	A light-colored porcelaneous rock resulting from the contact metamorphism of calcareous clay.
pyroclastic	A general term applied to detrital volcanic materials that have been explosively or aerially ejected from a volcanic vent. Also, a general term for the class of rocks made up of these materials.
quartz	A silicate mineral. See Vol. I, Chapter 3, Table 3-1.
quartz diorite	An igneous rock containing major plagioclase, quartz, and hornblende or biotite, or both.
quartzite	A granulose metamorphic rock consisting essentially of quartz.
quartz monzonite	A phaneritic rock containing major plagioclase, orthoclase, and quartz, with minor biotite and hornblende, and accessory apatite, zircon, and opaque oxides.
Quaternary	A period or system of geologic time. See Vol. I, Chapter 3, Table 3-2, Geologic Time Scale.
Recent	An epoch of geologic time. See Vol. I, Chapter 3, Table 3-2, Geologic Time Scale.
rhyolite	The aphanitic equivalent of a granite.
sand	See Sediment: size.
sandstone	A rock composed of cemented sand grains. See Sedimentary rock.
schist	A medium or coarse-grained highly altered metamorphic rock.
schistosity	The variety of foliation in coarser-grained metamorphic rocks.
sediment	Material derived from disintegrated rock that has been or is being transported from its origin.
sediment: size	Sediment is classified by size as follows:

<u>Sediment</u>	<u>Size (Millimeters)</u>	<u>Size (Approx. inches)</u>
Pebble	4-64	0.16-2.5
Gravel	2-4	0.08 - 0.16
Sand	1/16-2	0.0025-0.08
Silt	1/256-1/16	0.00015-0.0025
Clay	less than 1/256	less than 0.00015

sedimentary rock	Rock composed of sediment which has been cemented or precipitated. Sedimentary rocks are generally classified by the size of the sediment making up the rock. That is, sandstone is made up of sand, siltstone of silt, and claystone and mudstone of clay.
serpentinite	A rock consisting almost wholly of serpentine minerals derived from the alteration of previously existing olivine and pyroxene.
shale	Fi ssile or laminated claystone and siltstone
shear	The application of forces which subject a rock body to shear stress, similar to the displacement of the cards in a pack relative to one another.
shear zone	A zone in a rock mass in which shearing has occurred on a large scale so that the rock is crushed and brecciated.
sphene	A silicate mineral. See Vol. II, Chapter 3, Table 3-32.
Tertiary	A period of geologic time. See Vol. I, Chapter 3, Table 3-2, Geologic Time Scale
tuff	A rock formed of compacted volcanic fragments, generally smaller than 4 mm (0.16 in) in diameter.
ultrabasic	Some igneous rocks and most varieties of meteorites containing less than 45 percent silica; containing virtually no quartz or feldspar and composed essentially of ferromagnesian silicates, metallic oxides and sulfides, and native metals, or of all three.

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PERSONAL COMMUNICATIONS

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BIBLIOGRAPHY

Introduction

The annotated bibliography which follows was prepared with the assistance of automated data processing. Information on how it was produced is presented in Volume V of this report, Data Source Appendix.

User's Aids to the Bibliography

No personal communications are included in the bibliography; they are listed in the preceding section entitled "Personal Communications".

"See references" are provided within the bibliography from abbreviated forms of corporate authors to the full form used in the citation. For example, a text reference may be (ABAG, 1979). Looking in the bibliography for "ABAG" one would locate the following "see reference": ABAG SEE ASSOCIATION OF BAY AREA GOVERNMENTS. One would locate the full citation by looking for "ASSOCIATION OF BAY AREA GOVERNMENTS" in the bibliography.

The abbreviation "CA." appearing before numbers of pages in many citations stands for "circa". This indicates that the number following is approximate because the document being cited was either unnumbered or in various pagings.

In addition to the standard bibliographic information, most citations also have watershed unit/offshore basin abbreviations, descriptors, an annotation, and a note on the document's availability.

- a) Expansions for the three-or-four character watershed unit/offshore basin abbreviations are listed below in order of geographical position (north to south) with offshore basins following watersheds.

<u>Watershed Unit/Offshore Basin</u>	<u>Abbreviation</u>
Smith River Watershed	SMI
Klamath River Watershed	KLA
Mad River Watershed	MAD
Eel River Watershed	EEL
Mattole River Watershed	MAT
Noyo River Watershed	NOY
Gualala River Watershed	GUA
Russian River Watershed	RUS
Salmon Creek Watershed	SMN
Lagunitas Creek Watershed	LAG
San Francisco Bay Watershed	FRA
San Gregorio Creek Watershed	GRE
San Lorenzo Creek Watershed	LO R
Pajaro Watershed	PAJ
Elkhorn Slough Watershed	ELK
Salinas River Watershed	SIS
Carmel River Watershed	CAR
Morro Bay Watershed ,	MOR
Santa Maria River Watershed	MAR
San Antonio Creek Watershed	ANT

<u>Watershed Unit/Offshore Basin</u>	<u>Abbreviation</u>
Cent'd.	
Santa Ynez River Watershed	YNZ
Point Arguello Watershed	ARG
Eel River Basin	OEEL
Point Arena Basin	OARE
Bodega Basin	OBOD
Santa Cruz-Outer Santa Cruz Basin	OCRZ
Santa Maria Basin	OMAR

- b) Among the descriptors are habitat names, some of which have terms abbreviated. The following is a list of abbreviated habitat name terms along with the full terms.

AQUAT	Aquatic
COBBLE	Cobble/gravel
COBBLE/G	Cobble/gravel
COBBLE/GR	Cobble/gravel
COBBLE/GRA	Cobble/gravel
COBBLE/GRAV	Cobble/gravel
EM	Emergent
FLOATING	Floating vegetation
FRESHWA	Freshwater
MAR	Mars h
MOIS	Moisture
MOS	Moss
NONPERS	Nonpersistent
NONPERSIS	Nonpersistent
NONURB	Nonurban
PAL	Palustrine
PER	Perennial
PEREN	Perennial
PERS	Persistent
PERSIS	Persistent
SEAS	Seasonal
UNCON	Unconsolidated
VA	Vascular plants
VAS	Vascular plants
VASC	Vascular plants
VEG	Vegetated
WE	Wetland
WET	Wetland

- c) The note in parentheses () at the end of many of the citations gives one or more locations where the document being cited was obtained. When an academic institution is named within the parentheses, the document often is available in a library at that institution, even though the term "LIBRARY" may be omitted. For example, "H. C. BERKELEY - BIOLOGY" refers to the Biology Library at the University of California at Berkeley.

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57. CALIFORNIA DEPT. OF NAVIGATION AND OCEAN DEVELOPMENT. 1977B. CALIFORNIA COASTAL ENGINEERING DATA NETWORK, SECOND ANNUAL REPORT, JANUARY 1977 THROUGH DECEMBER 1977. PREPARED BY SEYMOUR, R. J. IN COOPERATION WITH SCRIPPS INSTITUTION OF OCEANOGRAPHY, UNIVERSITY OF CALIFORNIA, HIGGINS, A. L.; WALD, S. L.; WOODS, A. E. SACRAMENTO, CA. CALIF. DEPT. OF NAVIGATION AND OCEAN DEVELOPMENT. 123 P. ORZ WAVES (OCEAN), MARINE. NEARSHORE WAVE MONITORING DATA-SANTA CRUZ HARBOR. (UC BERKELEY - WATER RESOURCES CENTER ARCHIVES.)
58. CALIFORNIA DEPT. OF PARKS AND RECREATION. 1973. A STUDY OF VISITOR USE IN SELECTED INLAND UNITS OF THE CALIFORNIA STATE PARK SYSTEM. 50 P. RECREATION.
59. CALIFORNIA DEPT. OF PARKS AND RECREATION. 1975. THE OFF-ROAD VEHICLE: A STUDY REPORT. 65 P. MCP RECREATION. DESCRIPTIVE OVERVIEW OF OFF ROAD VEHICLE RECREATION IN CALIFORNIA.
60. CALIFORNIA DEPT. OF PARKS AND RECREATION. 1979B. RECREATION OUTLOOK IN PLANNING DISTRICT ONE. 69 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS RECREATION, PARKS/BEACHES. SURVEY OF PARK ACREAGE AND FACILITIES, PUBLIC AND PRIVATE. DEMAND STATISTICS FROM DEPT. COMPUTERIZED INFORMATION SYSTEM (PARIS).
61. CALIFORNIA DEPT. OF TRANSPORTATION. 1975. CALIFORNIA TRANSPORTATION PLAN JULY 1975, ENVIRONMENTAL IMPACT REPORT - VOLUME 3 - DRAFT. 642 P. TRANSPORTATION, ENVIRONMENTAL ASSESSMENT METHODS. CONTAINS OVERVIEW OF CALIFORNIA ENVIRONMENTAL SETTING, CALIFORNIA TRANS. PLAN. DESCRIBES ANALYTICAL PROCESS. SUMMARIZES ENVIRON. IMPACTS BY DIFFERENT PLAN ALTERNATIVES.

62. CALIFORNIA DEPT. OF WATER RESOURCES. 1974B. WATER MANAGEMENT FOR FISHERY ENHANCEMENT ON NORTH COASTAL STREAMS. PREPARED BY NORTHERN III STRICT. 68 P. MAT WATER QUALITY, WATERSHED MANAGEMENT, STREAM FLOW, SEDIMENTATION, LOGGING. AERIAL PHOTOGRAPHY, MAPS.
43. CALIFORNIA DEPT. OF WATER RESOURCES. 1978A. CLIMATE SUMMARIES OF CALIFORNIA AIRPORTS. COMPILED BY GOODRIDGE, J.C. 85 P. CLIMATOLOGY, PRECIPITATION, TEMPERATURE--AIR, HUMIDITY. (CALIF. DEPT. OF WATER RESOURCES, SACRAMENTO, CA.)
64. CALIFORNIA DEPT. OF WATER RESOURCES. 1978B. INDEX TO SOURCES OF HYDROLOGIC DATA. CALIF. DEPT. OF WATER RESOURCES BULL. 231-73. 315 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG SURFACE AND GROUND WATER MEASUREMENT STATIONS. (CALIF. DEPT. OF WATER RESOURCES.)
65. CALIFORNIA DEPT. OF WATER RESOURCES. 1978C. LAND USE WITHIN THE CALIFORNIA COASTAL ZONE. CA. 350 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG COASTAL PLANNING, LAND USE. COMPILATION, IN MAP ATLAS FORM, OF LAND USE INFORMATION FOR THE CALIFORNIA COAST.
66. CALIFORNIA DEPT. OF WATER RESOURCES. 1978D. WIND IN CALIFORNIA. CALIF. DEPT. OF WATER RESOURCES BULL. NO. 185. 207 P. CLIMATOLOGY, WIND. (CALIF. DEPT. OF WATER RESOURCES, SACRAMENTO, CA.)
67. CALIFORNIA DEPT. OF WATER RESOURCES. 19790. WIND STORMS IN CALIFORNIA, DRAFT. PREPARED BY DIVISION OF PLANNING. 34 P. CLIMATOLOGY, WIND. (CALIF. DEPT. OF WATER RESOURCES, SACRAMENTO, CA.)
68. CALIFORNIA DIVISION OF MINES AND GEOLOGY. 1966. MINERAL RESOURCES OF CALIFORNIA. BULLETIN 191, CALIFORNIA DIVISION OF MINES AND GEOLOGY. 450 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG MINERAL RESOURCES. DESCRIBES THE MINERAL RESOURCES OF CALIFORNIA, THEIR USE, MANNER OF OCCURRENCE, DISTRIBUTION. STATISTICS ON THE PRODUCTION OF THE COMMODITIES ARE SUMMARIZED.
69. CALIFORNIA DIVISION OF MINES AND GEOLOGY. 1971. PRELIMINARY MAP OF MAXIMUM EXPECTABLE EARTHQUAKE INTENSITY IN CALIFORNIA. 1 MAP SHEET. SEISMOLOGY. (CALIF. DIV. OF MINES + GEOLOGY--SAN FRANCISCO.)
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71. CALIFORNIA DIVISION OF MINES AND GEOLOGY. 1973B. STATE OF CALIFORNIA PRELIMINARY FAULT AND GEOLOGIC MAP. SACRAMENTO. CALIF. DIVISION OF MINES AND GEOLOGY. 2 MAP SHEETS. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG, DEEL, OARE, ORCD, OCRZ, OMAR GEOLOGY, SEISMOLOGY. CALIF. DIVISION OF MINES AND GEOLOGY PRELIMINARY REPORT 13. (CALIF. DIV. OF MINES + GEOLOGY--SACRAMENTO, CALIF. DIV. OF MINES + GEOLOGY--SAN FRANCISCO.)
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75. CALIFORNIA EMPLOYMENT DEVELOPMENT DEPT. 1979A. ANNUAL PLANNING INFORMATION. CA. 130P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, (LAR, MOR, MAR, ANT, YNZ, ARG EMPLOYMENT. ANALYSIS OF RECENT CHANGES IN THE LABOR MARKET, AND OUTLOOK THROUGH 1990. SEPARATE REPORT FOR EACH METROPOLITAN STATISTICAL AREA.
76. CALIFORNIA EMPLOYMENT DEVELOPMENT DEPT. 1979B. CALIFORNIA EMPLOYMENT AND PAYROLLS; OCTOBER - DECEMBER 1977. CA. 125 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG EMPLOYMENT, COMMERCE AND INDUSTRY. DETAILED RECORD OF EMPLOYMENT AND EARNINGS IN CALIFORNIA. DATA ARE CLASSIFIED BY INDUSTRY AND PRESENTED ON A COUNTY, AREA, AND STATEWIDE BASIS.
77. CALIFORNIA ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION. 1979A. CALIFORNIA ENERGY DEMAND 1978 - 2000; DRAFT. 107 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG UTILITIES, FCSIL FUELS. GIVES MAJOR TRENDS IN ENERGY GROWTH. GIVES FORECASTS OF ENERGY GROWTH PREPARED BY ENERGY COMMISSION AND COMPARES WITH FORECASTS OF UTILITIES. GIVES FORECAST METHODOLOGY.
78. CALIFORNIA ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMMISSION. 1979B. MAPS OF THERMAL ELECTRIC POWER PLANT SITES IN CALIFORNIA. 29 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG POWER RESOURCES, UTILITIES. GIVES VITAL STATISTICS OF EXISTING PLANTS AND OF POTENTIAL EXPANSION.
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80. CALIFORNIA NORTH COAST AIR BASIN AIR POLLUTION CONTROL COUNCIL. 1977. AIR POLLUTION CONTROL PLAN FOR THE CALIFORNIA NORTH COAST AIR BASIN. SUBMITTED TO THE CALIF. AIR RESOURCES BOARD. CA. 40 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN AIR QUALITY, EMISSIONS, PARTICULATES (AIR). (HUMBOLDT COUNTY AIR POLLUTION CONTROL DISTRICT.)
81. CALIFORNIA OFFICE OF PLANNING AND RESEARCH. 1974* PRIME AGRICULTURAL LANDS REPORT. 15 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG AGRICULTURE, LAND USE. POTENTIAL AND PRIME AGRICULTURAL LAND BY COUNTY, TABLE.
82. CALIFORNIA OFFICE OF PLANNING AND RESEARCH. 1977. OFFSHORE OIL AND GAS DEVELOPMENT; SOUTHERN CALIFORNIA, VOLUMES 1 AND 2. 879 P. OIL DRILLING. DESCRIBES SPECIFIC EFFECTS OF OCS DEVELOPMENT IN SOUTHERN CALIFORNIA. BUILDS ON MATERIAL PUBLISHED IN AN EARLIER STUDY BY THE SAME NAME.
83. CALIFORNIA OFFICE OF PLANNING AND RESEARCH; FOX, G. 1978. OUTER CONTINENTAL SHELF OIL AND GAS; THE ROLE OF STATE AND LOCAL GOVERNMENT. GPR 1(2): 3-11. CEEL, OARE, OBOO, OCRZ, OMAR OIL DRILLING, GOVERNMENTAL ORGANIZATION, COASTAL PLANNING. SUMMARY OF FEDERAL AND LOCAL INPUT REQUIRED FOR OIL AND GAS DEVELOPMENT IN CALIFORNIA. THE NEED FOR COMMUNICATION BETWEEN FEDERAL AND LOCAL AGENCIES IS EMPHASIZED.
84. CALIFORNIA REGION FRAMEWORK STUDY COMMITTEE. 1971. COMPREHENSIVE FRAMEWORK STUDY, CALIFORNIA REGION, APPENDIX XV: WATER QUALITY, POLLUTION AND HEALTH FACTORS. PREPARED FOR PACIFIC SOUTHWEST INTER-AGENCY COMMITTEE, WATER RESOURCES COUNCIL. 230 P. WATER QUALITY, STANDARDS. (UC BERKELEY - WATER RESOURCES CENTER ARCHIVES.)
85. CALIFORNIA STATE BOARD OF EQUALIZATION, TIMBER TAX DIVISION. 1979. CALIFORNIA TIMBER HARVEST BY COUNTY, JANUARY 1, 1978 TO DECEMBER 31, 1978. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG VOLUME OF TIMBER HARVESTED EACH YEAR, BY COUNTY, IN BOARD FEET. UNPUBLISHED.
86. CALIFORNIA STATE LANDS COMMISSION. 1977. PUBLIC LAND OWNERSHIP IN CALIFORNIA 1977. 222 P. SMI, KLA, MAD, EEL,

MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LCR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ LAND USE.

87. CALIFORNIA STATE WATER RESOURCES CONTROL BOARD. 1975A. ABSTRACT REPORT ON WATER QUALITY CONTROL PLAN FOR KLAMATH RIVER CONTROL PLAN I-A. PREPARED BY REGIONAL WATER QUALITY CONTROL BOARD, NORTH COAST REGION. 56 P. SMI, KLA WATER QUALITY, STANDARDS. KEY ELEMENTS AND SUMMARIZES WATER QUALITY CONTROL PLAN. (REGIONAL WATER QUALITY CONTROL BOARD, NORTH COAST REGION, SANTA ROSA, CA.)
88. CALIFORNIA STATE WATER RESOURCES CONTROL BOARD. 1975B. PROGRAM FOR WATER QUALITY SURVEILLANCE AND MONITORING IN CALIFORNIA. PREPARED BY DIVISION OF PLANNING AND RESEARCH, SURVEILLANCE AND MONITORING SECTION. 136 P. SMI, KLA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LCR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG, CEEL, DARE, OBOD, OCRZ, OMAR WATER QUALITY, HEAVY METALS, TRACE METALS, CHLORINATED HYDROCARBONS. (CALIF. STATE LIBRARY WATER RESOURCES CONTROL BOARD.)
89. CALIFORNIA STATE WATER RESOURCES CONTROL BOARD. 1975C. WATER QUALITY CONTROL PLAN, CENTRAL COASTAL BASIN, ABSTRACT. PREPARED BY REGIONAL WATER QUALITY CONTROL BOARD, CENTRAL COAST REGION. 54 P. LCR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG WATER QUALITY, STANDARDS. (ELEM ELEMENTS AND SUMMARIZES WATER QUALITY CONTROL PLAN. (REGIONAL WATER QUALITY CONTROL BOARD, CENTRAL COAST REGION.)
90. CALIFORNIA STATE WATER RESOURCES CONTROL BOARD. 1975D. WATER QUALITY CONTROL PLAN, NORTH COASTAL BASIN I, ABSTRACT. PREPARED BY REGIONAL WATER QUALITY CONTROL BOARD, NORTH COAST REGION. 35 P. MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG WATER QUALITY, STANDARDS. KEY ELEMENTS AND SUMMARIZES WATER QUALITY CONTROL PLAN. (REGIONAL WATER QUALITY CONTROL BOARD, NORTH COAST REGION, SANTA ROSA, CA.)
91. CALIFORNIA STATE WATER RESOURCES CONTROL BOARD. 1975E. WATER QUALITY CONTROL PLAN REPORT, CENTRAL COASTAL BASIN (3). PREPARED BY REGIONAL WATER QUALITY CONTROL BOARD, CENTRAL COAST REGION. CA. 425 P. LCR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG WATER QUALITY, STANDARDS. (REGIONAL WATER QUALITY CONTROL BOARD, CENTRAL COAST REGION.)
92. CALIFORNIA STATE WATER RESOURCES CONTROL BOARD. 1975F. WATER QUALITY CONTROL PLAN REPORT, SAN FRANCISCO BAY BASIN (2), PART 1. PREPARED BY REGIONAL WATER QUALITY CONTROL BOARD, SAN FRANCISCO BAY REGION. CA. 185 P. LAG, FRA, GRE WATER QUALITY, STANDARDS. (REGIONAL WATER QUALITY CONTROL BOARD, SAN FRANCISCO BAY REGION.)
93. CALIFORNIA STATE WATER RESOURCES CONTROL BOARD. 1975G. WATER QUALITY CONTROL PLAN REPORT, SAN FRANCISCO BAY BASIN (2), PART 11. PREPARED BY REGIONAL WATER QUALITY CONTROL BOARD, SAN FRANCISCO BAY REGION. CA. 470 P. LAG, FRA, GRE WATER QUALITY, STANDARDS. (REGIONAL WATER QUALITY CONTROL BOARD, SAN FRANCISCO BAY REGION.)
94. CALIFORNIA STATE WATER RESOURCES CONTROL BOARD. 1975H. WATER QUALITY CONTROL PLAN REPORT. PREPARED BY REGIONAL WATER QUALITY CONTROL BOARD, NORTH COAST REGION. CA. 550 P. MAD, EEL, MAT, NOY, GUA, RUS WATER QUALITY, WATER SUPPLY, WASTEWATER, WATERSHED MANAGEMENT, LAND USE. PLANS, SOCIOECONOMIC DATA, TABLES.
95. CALIFORNIA STATE WATER RESOURCES CONTROL BOARD. 1976. AREAS OF SPECIAL BIOLOGICAL SIGNIFICANCE. 55 P. CEEL, DARE, OBOD, OCRZ, OMAR LEGISLATION, MANAGEMENT RECOMMENDATIONS, REGULATIONS, BIOLOGICAL RESERVES, MARINE-PELAGIC-MERITIC, MARINE-INTERTIDAL-AJ (JA TICBED, MARINE-INTERTIDAL-REEF (NONBIOLOGICAL), MARINE-INTERTIDAL-ROCKY SHORE, MARINE-INTERTIDAL-UNCONSOLIDATED SHORE. Delineates by legal descriptions and maps areas of special biological significance in nearshore waters of California.
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KL, LA, MAD, EEL, MAT, NOY, GUA, RUS, SMN, LAG, FRA, GRE, LOR, PAJ, ELK, SLS, CAR, MOR, MAR, ANT, YNZ, ARG, CEEL, OARE, OBOD, OCRZ, OMAK WATER QUALITY, TRACE METALS, HEAVY METALS, CHLORINATED HYDROCARBONS. (CALIF. STATE WATER RESOURCES CONTROL BOARD.)

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99. CALTRANS SEE CALIFORNIA DEPT. OF TRANSPORTATION
100. CARB SEE CALIFORNIA AIR RESOURCES BOARD.
- 101* COMG SEE CALIFORNIA DIVISION OF MINES AND GEOLOGY
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108. CNACC SEE CALIFORNIA NATURAL AREAS COORDINATING COUNCIL
109. CNCRAPCC SEE CALIFORNIA NORTH COAST AIR BASIN AIR POLLUTION CONTROL BOARD.

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