CALIFORNIA COMPREHENSIVE OFFSHORE RESOURCE STUDY

CALIFORNIA STATE LANDS COMMISSION

STATE OF CALIFORNIA

PETE WILSON, *Governor*

STATE LANDS COMMISSION

LEO T. McCARTHY, *Lieutenant Governor*
GRAY DAVIS, *Controller*
THOMAS W. HAYES, *Director of Finance*

EXECUTIVE OFFICE
1807 - 13th Street
Sacramento, CA 95814

CHARLES WARREN
Executive Officer

November 1, 1991

Dear Friend:

We are pleased to provide you with a copy of the draft version of *The California Comprehensive Offshore Resource Study* (CCORS). This comprehensive inventory of California's coastal resources represents considerable time and effort by many persons.

As you have indicated your desire to review the draft document, you are invited to submit your written comments by January 1, 1992. Written comments should be mailed to Ms. Jane Smith, CCORS Document Coordinator, State Lands Commission, 1807 13th Street, Sacramento, California 95814. Written comments should include a specific reference to that portion of the document being discussed as well as personal contact information, should further clarification of the information you provide be required.

We hope you will focus your comments on correcting factual errors and adding critical data which have been inadvertently omitted in the draft document. Please provide reference citings for all information you provide so that material can be verified and added to the document's bibliography.

We appreciate your interest and willingness to help make CCORS the most useful document possible. We look forward to having your comments.

Sincerely,

Charles Warren
Executive Officer

Enclosure

CALIFORNIA COMPREHENSIVE OFFSHORE RESOURCE STUDY

CALIFORNIA STATE LANDS COMMISSION

D R A F T

Leo T. McCarthy
Lieutenant Governor

Thomas W. Hayes
Director of Finance

Gray Davis
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TABLE OF CONTENTS

INTRODUCTION i

EXECUTIVE SUMMARY iii

CHAPTER ONE: COASTAL USES

Navigation 1
- Commercial Shipping 1
- Fishing Industry 2
- Recreational Boating 2
- Effects 2

Fishing 3
- Ocean 3
- Inland 8
- Native American 10

Open Space, Recreation and Tourism 14
Protection of Biological Diversity 15
- Natural Areas 16
- Research and Education 19
- Habitat/Species Restoration 21

Population Trends 26
Residential 27
Oil and Gas 27
Mining/Sand and Gravel 28
Forestry/Timber 28
Farming/Agriculture 29
Range/Grazing 30
Mariculture 30
Aquaculture 33
Kelp and Sea Vegetable Harvesting 36
Desalination Plants 37
Salt Production 37
Power Production 39
Salvage 40
Outfalls 40
Ocean Dumping 41
Septic Tanks 43
Landfill 43
Mosquito Abatement 43
Groundwater Basins and Wells 44
Rural and Municipal Runoff 45
Surface Water 45
Shoreline Structures 47
Transportation 47
Military 48

CHAPTER TWO: STATEWIDE OVERVIEW OF ENVIRONMENTAL FEATURES AND CRITICAL CONCERNS

Geology 51
Physical Oceanography 53
Hydrology and Groundwater Quality 58
Air Quality 60
Marine Water Quality 61
Marine Biology 74
- Bottom Habitats 75
- Seabirds and Marine Mammals 82
- Rare, Threatened and Endangered Marine Species 89

Terrestrial, Wetland and Aquatic Biology 92
- Resource Inventory 93
- Development and Coastal Ecosystems 108
- Development and Wetland Ecosystems 114
- Development and Aquatic Ecosystems 115

Paleontology 119
Cultural Resources 120
Land Use 133
Visual 136
Noise 137
Socioeconomics 141
Transportation 143
Recreation and Tourism 155
Fishing 158

CHAPTER THREE: THE ASSESSMENT AND MITIGATION OF ENVIRONMENTAL IMPACTS

Legal Framework for Impact Assessment 175
Classification of Impacts 176
Probability and Risk Assessment 178
Mitigation of Impacts 186

CHAPTER FOUR: THE ADMINISTRATIVE AND REGULATORY PROCESS AFFECTING THE CALIFORNIA COASTAL ZONE

Federal Controls 212
- Significant Federal Statutory Controls 212
- Federal Agencies 225

State Controls 231
- Significant State Legislation/Principles 231
- State Agencies 237

Local Government Controls 254

CHAPTER FIVE: ECONOMICS OF OIL

Determining the Price of Oil 259
Oil and the Private Sector Economy 284
Oil and Public Money 288
Oil Development Economics 292

CHAPTER SIX: ENERGY PICTURE

Consumption 297
World Energy Production 302
Global Warming 308
California Petroleum 312
Moderating Variations in Oil Supply 320
Alternative to Oil Use 327

ACKNOWLEDGMENTS 355

GLOSSARY 361

REGULATORY AGENCIES 373

REFERENCES 375

INDEX 393

INTRODUCTION

The California Comprehensive Offshore Resource Study (CCORS) was initiated by the California State Lands Commission in 1987. At that time, the Commission was deliberating a development proposal to install up to three new oil platforms on five offshore oil exploration and development leases under its jurisdiction near Coal Oil Point in Santa Barbara County.

As the Commissioners evaluated this proposal, they became concerned that there was no centralized information source for all of California's coastal resources which could be used to measure the statewide implications of any new coastal development. The CCORS project was developed to address this concern.

CCORS has evolved into three distinct products: an informational report; a computerized Geographic Information System (GIS); and a coastal resources information library.

First, the informational report which is presented here, incorporates existing information on coastal resources, issues, and uses among other topics. The term 'Offshore' in the title is somewhat of a misnomer. Indeed the information in CCORS covers the entire California coastal zone—both onshore and offshore.

Second, through CCORS, the Commission has begun work on a statewide computerized Geographic Information System. Thus far, the Commission is working cooperatively with the California Coastal Commission, the National Oceanic and Atmospheric Administration, the Minerals Management Service and a variety of other state agencies through the Teale Data Center, to collect data and create common data gathering protocols.

The original outline for the CCORS document included detailed information about eight specific coastal segments. Due to budget and time constraints, however, this segment work will be included as data layers in the GIS data base.

The statewide GIS applications envisioned for the completed data base include an environmental evaluation model which is to be used to assess potential impacts of future projects, and an oil spill assessment model to assist in the preparation of responses to oil spills within the marine environment.

The GIS is scheduled to begin initial operations in mid-1991 with data layers covering bathymetry, seabirds, marine mammals and offshore facilities. Additional data layers will be added to the system as they are completed.

Third, CCORS has been the catalyst for the creation of an extensive coastal reference library. Throughout the development of the CCORS, the commission's staff has gathered and catalogued existing information resources. There are currently 1,661 different listings within the bibliographic reference for the CCORS library. More than 300 of these entries were used as direct references in preparing the CCORS document. The library is available as a research resource to the commission's staff as well as other governmental agencies and organizations with an interest in coastal information. The library is maintained at the commission's Sacramento office.

The creation of the CCORS document has involved a broad cross-section of the public in addition to commission staff and their consultants. Two public workshops which involved more than 100 participants were held to help determine the scope of topics to be studied. More than 300 members of the general public participated in a series of 13 public hearings held throughout the state to hear suggestions about the contents of the study. In addition, throughout the actual creation of the document, more than 200 individuals reviewed and commented on specific sections.

EXECUTIVE SUMMARY

THE CALIFORNIA COMPREHENSIVE OFFSHORE RESOURCE STUDY

The California coastal zone in 1991 is a classic illustration of problems that have been observed throughout the country and the world.

Overdevelopment due to pressure from increased population is the leading threat to America's—and California's—coastal zone.

More people, requiring more housing, roads, stores, office buildings, and waste treatment plants, creating more pollution of every type, are the greatest threat to the future of California's coast.

The California Comprehensive Offshore Resource Study (CCORS) has been designed to provide a centralized source of existing information about the state's coastal zone, including relevant onshore resources, stretching from Mexico to the Oregon border, and seaward to three-miles offshore.

CCORS creates a statewide context which can be used like a template to help guide future policy decisions about how best to reap the greatest benefit from coastal resources for the most people. CCORS is not a cumulative impact analysis or an environmental impact report prepared under the provisions of the California Environmental Quality Act (CEQA). Finally, the study neither discusses specific projects nor makes recommendations about the likely location or type of future projects which may be proposed within the coastal zone.

With the completion of CCORS, decision-makers have a new planning tool they can use to establish a balance between the need for resource restoration, preservation and protection and the pressures associated with development within the coastal zone.

While CCORS was primarily designed for use by the commission and its staff, the material contained in the informational document, library and the Geographic Information System should also be useful to members of the California Legislature, Congress, federal, state and local agencies, environmental groups, industry, citizen groups and anyone interested in coastal resource management.

In addition to assembling critical data about the uses of California's coastal zone and the key considerations that impact planning for manmade changes to the area, CCORS includes information about other important topics which should be considered whenever decisions are made about coastal resource management.

The issues covered by CCORS are complex. The collection of so much data about the coast has produced some definitive conclusions.

First, by examining the coastal zone as a whole it is clear there are certain coastal features which should be considered for protection during the critical evaluation of any proposed project. Such resources as the coast's remaining wetland areas, its fisheries and mammal breeding areas, unique recreation sites,

scenic areas of specific significance, active fault lines, areas where air and water quality standards are already regularly exceeded, and those portions of the region where the current infrastructure (e.g. water systems, roads, sewers etc.) is already at capacity, should be given special consideration in future review processes.

The detailed information in CCORS about the highly sensitive ecosystems in certain coastal regions raises strong concerns about future development of any type in these areas. Such places as the Channel Islands, Point Reyes and Bodega Bay, the Farallon Islands, Cordell Bank, Castle Rock in Del Norte County and Monterey Bay are among the more obvious areas that deserve this type of protection.

Second, consideration of infrastructure capacity, water and air quality, and geological stability should focus our attention on undeveloped areas within the coastal zone for special review during the evaluation of any proposed development.

If some development is inevitable, however, the information in CCORS supports further growth in areas with existing high industrialization where there is already a developed infrastructure in place and where the environmental impacts have already been mitigated as much as possible and negative economic impacts can be minimized. CCORS also points to the need to explore expanded activities in areas such as mariculture as viable alternatives to more intrusive uses of undeveloped areas within the coastal zone.

The information in CCORS also places in better perspective the relationship between the improvement of energy efficiency and conservation and future resource management decisions about projects the State Lands Commission may be asked to approve, which may be largely defended based on their energy production potential. As an "energy producer", the commission may wish to join other state agencies in promoting greater energy efficiency and conservation as part of its mandate to utilize the resources in its care for the broader good of the people of California. Promoting such things as energy efficient building designs, improved auto mileage, better transportation systems, and alternative energy sources seems intimately intertwined with the commission's responsibility to decide the fate of lands under its jurisdiction.

The detailed discussion about environmental mitigation contained in CCORS also makes it abundantly clear that, while there are many steps that can be taken to reduce the impacts or deterioration of resources as a result of development, "mitigations" are neither always successful nor a substitute for protection.

While such things as natural erosion and violent storms have been the historic enemies of the coastal zone, the information contained in CCORS points at other, manmade, enemies which pose a greater threat to coastal resources in the years ahead. According to Kristin Merriman, editor of "Outdoor America" magazine, "In 1990 . . . ecosystems must also battle a new threat, the year-round ravages of hundreds of millions of citizens who love the coast so much they are, paradoxically, wreaking havoc on its environment."

The evidence of this potentially devastating paradox is clearly visible within California's coastal zone. Consider these facts:

- According to preliminary figures gathered as part of the 1990 census, over 18

million people call the coastal region home—well over one-half of the state's entire population.

- These people have created a constantly growing market for residential, commercial and industrial real estate development.

- Along with more people and more places for them to live and work, have come a vast transportation system, sewage treatment and disposal facilities and other forms of infrastructure necessary to support human habitation along the coast.

- The offshore waters within the coastal zone have been industrialized by development of natural resources such as sand, gravel, and oil and gas.

- In 1986 (the last year in which complete figures were available), 86¢ out of every tourist dollar spent in California was spent within the coastal zone, a total of $32 billion.

- Commercial fishing in California's coastal waters in 1987 produced some $205 million in revenues. (Fig. ES-1)

- Forestry, farming and the production of power have all become critical uses of the coast and significant factors in California's economy.

- Air and water quality within the coastal zone have been severely damaged as a result of pollution from increased population and industrial development.

- More than 70% of the wetlands within the coastal zone have been lost to diking, draining, or filling.

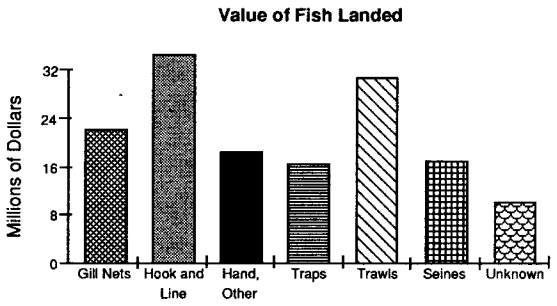


Figure ES - 1: Value of fish caught in California by each gear type in 1987. (California Department of Fish and Game, unpublished data.)

The conflicts which result from these competing uses of the state's coastal resources form the basis for one of government's greatest challenges: How to manage these resources in a way that balances the needs for environmental protection, economic stability, and preservation of the lifestyle qualities that have made California attractive to millions and millions of new residents. CCORS is a valuable tool in the quest to achieve this balance.

California isn't alone in its search for an answer to this dilemma. All of America's 95,000 miles of coastal territory are under comparable pressures.

Shellfish beds in California, similar to those found in Rhode Island's Narragansett Bay, which are closed to harvest 91% of the time due to water pollution, are threatened.

Contamination, similar to that which has made fish taken from Santa Monica Bay toxic and inedible, is responsible for polluting protected bays throughout the country.

Plastics, which have become a staple of today's modern way of life, are a death sentence for aquatic life and marine habitats. Every year,

tens of thousands of seabirds and marine animals mistake floating plastic debris for food and choke to death. Entanglement in plastic nets, packing straps and ropes has become a significant threat to seals, sea lions and whales.

During the summers of 1988 and 1989, medical waste and plastic debris washing up on several eastern beaches raised concerns about public health and safety, and had a dramatic negative impact on the economies of many seaside tourist communities.

Because of the lack of a comprehensive national energy policy during the last decade, we have failed to reduce our dependence on foreign oil resources or to create an emphasis on conservation and fuel efficiency. In fact, the absence of a policy in this area has resulted in accelerated oil and gas exploration in several offshore tracts throughout the United States, and pressure to develop offshore tracts in California.

Finally, the grounding of the Exxon Valdez on March 24, 1989 in Prince William Sound, Alaska and the American Trader accident in Huntington Beach the very next year, brought into sharp focus the prospect for environmental disaster as a result of inadequate safety regulation of the oil transportation industry.

The information contained in CCORS helps define the issues and concerns for California's policy makers. The first two chapters, "Coastal Uses" and "Statewide Overview of Environmental Features and Critical Concerns" detail the variety of competing uses for California's coastal zone and the concerns that must be addressed when considering further development of this sensitive region.

Chapter One: Coastal Uses, identifies 28 different activities which occur within the coastal zone. Some are obvious such as commercial fishing, residential development and offshore oil development. Others are less obvious such as the conduct of navigation, aquaculture and the production of electrical power. All depend, however, to some extent directly or indirectly on the ocean.

Chapter Two: Statewide Overview of Environmental Features and Critical Concerns provides an overview of the general considerations which govern the analysis of projects proposed for the California coast. It draws on the primary coastal uses discussed in Chapter One for its description of baseline conditions and potential effects.

This chapter provides general information only. Data about specific coastal segments will be included in the commission's Geographic Information System and will reflect the unique characteristics of each portion of the California coast.

Chapters One and Two bear out the fact that California's coastal zone—like other coastal areas throughout the nation—is not only a diverse, rich and productive environment; it is also extremely sensitive to the stress created by overdevelopment.

The four remaining chapters, Chapter Three: Mitigations, Chapter Four: The Regulatory Process, Chapter Five: The Economics of Oil, and Chapter Six: The Energy Picture, deal with practical elements of coastal management decisions faced by the California State Lands Commission and other public agencies.

Chapter Three: The Assessment and Mitigation of Environmental Impacts discusses some of the typical methods used to mitigate environmental impacts as well as the legal framework for evaluating these impacts, how

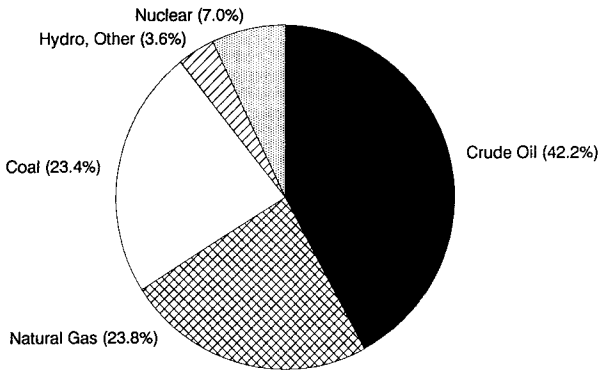
such impacts are classified, and the use of probability theory in assessing risk.

Chapter Four: The Administrative and Regulatory Process Affecting the California Coastal Zone presents a detailed and comprehensive overview of the primary agencies and regulations which control development within California's coastal zone.

Generally speaking, California has authority over offshore lands from the ordinary high water line out to three nautical miles from shore. This area is usually referred to as the "marginal" seas. The federal government has complete control beyond the three-mile boundary as well as authority over all territory within the United States with respect to matters delineated by the Constitution. Various local agencies have additional authority over both onshore and offshore development, specifically delegated to them by either the state or federal government.

To fully understand the complexity of the regulatory environment in which coastal planning takes place, it is important to note that there are 33 different federal agencies and more than 41 different state agencies with some form of jurisdiction within the coastal zone (Figs. ES-2 and ES-3). This chapter of CCORS places all of these agencies side-by-side, as a means of constructing a kind of road map which leads the way through the current regulatory maze.

Chapter Five: The Economics of Oil presents a broad picture of the various economic theories and conditions which help determine the value of petroleum products and therefore, the level of interest in further development of coastal petroleum resources. This chapter also includes a thorough discussion of both national and state energy consumption trends (Figs. ES-4 and ES-5).



Source: EIA, Monthly Energy Review

Figure ES - 4: U. S. energy consumption by fuel type, 1989.

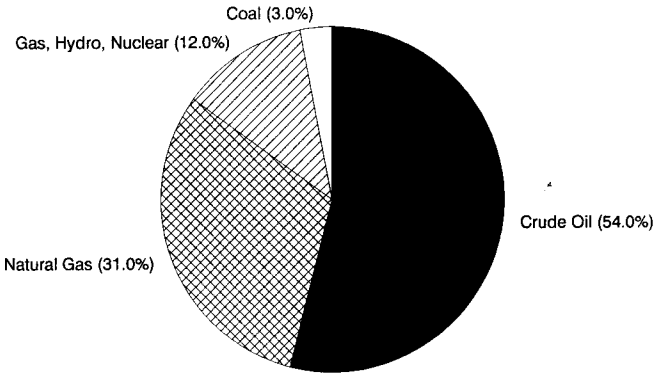


Figure ES - 5: California energy consumption by fuel type, 1988.

Chapter Six: The Energy Picture discusses energy in the economy and the environment. It defines the various sources and principal uses of energy (Fig. ES-6) and the role petroleum products play within the overall framework of our energy resources. It also considers our dependence on petroleum resources, the likely and available alternative sources of energy, and

efforts underway to moderate the effects of a possible interruption of oil supplies.

Since many of the industrial uses of the coastal zone involve petroleum development (Fig. ES-7), production and processing, this chapter creates a window on the future by anticipating demands for additional petroleum based energy supplies, while also identifying alternative opportunities which could relieve some of this pressure.

The information contained in these four chapters illustrates the complex issues and processes which govern decisions about future uses of undeveloped coastal areas, as well as changes in existing coastal uses.

The process of gathering and chronicling coastal information for CCORS has verified existing data gaps. Critical among these information gaps is the lack of credible data about economic impacts based on research techniques rather than anecdotal evidence.

CCORS also makes it clear that far too little is currently known about the offshore geology of the San Diego and mid-coastal regions to make informed policy decisions about these areas.

Another critical gap exists in the quality of information about Southern California ocean pollution. In an October 1990 report issued by the National Academy of Sciences, the academy's National Research Council was highly critical of ocean pollution monitoring capability currently in use along the Southern California Borderland (an area which stretches from Point Arguello north of Santa Barbara to Ensenada in Mexico). Calling monitoring efforts currently being used "fragmented," Charles A. Bookman, director of the council's Marine Board, said that "Only through . . . an integrated systemwide approach can environmental and human health objectives . . . be successfully attained, assuring that it is safe to swim in the ocean and eat local seafood."

Another less obvious gap exists in the quality and type of information available about project aesthetics and visual impacts. Because there is no statewide policy governing aesthetics or visual standards, it is difficult to make specific project determinations that reflect a full understanding of the potential impacts design elements could have on adjacent areas.

There is also a critical need for further information about the relationship between the California Delta and San Francisco Bay. The interdependence between these two vital ecosystems needs to be further explored. Before further irreversible degradation of the resource takes place, there is a need for a comprehensive strategy aimed at the restoration, protection and preservation of the Delta.

The information contained in CCORS—both what is known and what is not known—is an invaluable indicator of the challenge that lies ahead. While California is still attracting more new residents than any other state in the nation, the 1990 census provides irrefutable evidence that California's coast is becoming less desirable.

Ten years ago, 62.1% of the state's population lived in communities that touched the Pacific Ocean. In 1990, that figure has dropped to 59.8%. In Northern California, the Bay Area's share of the state's population dropped to 20.2% in 1990 compared to 21.8% in 1980. In Southern California, the inland shift is even more pronounced. A decade ago, Los Angeles County was home to 55.5% of the

region's people—a large proportion of them living in coastal communities. By 1990 that share had shrunk to 51.6%.

In order to better appreciate the significance of this population shift, each individual included in the count represents from $120 to $500 in federal funds for local programs.

The relationship between environmental concerns and economic realities is becoming an increasingly accepted argument for improved resource protection. According to former U.S. Senator Gaylord Nelson,

. . . The American people understand, even if some segments of our society do not, that the economy and the environment are inextricably intertwined: while you can have a country rich in natural resources with a poor economy, you cannot have a rich economy in a country poor in its resources or in its access to them. If we continue to degrade and destroy our resources, we will have created our own poverty. When it is asked, how much will it cost to protect the environment, one more question should be asked: How much will it cost if we do not?

FEDERAL REGULATORY MATRIX

STATUTE/ REGULATION/ AGENCY	RESOURCE / ACTIVITY											
	Mining	Oil and Gas Development, Leases, Sales	Coastal Zone Protection	Air Resources	Water Resources	Pollution	Wildlife/ Endangered Species	Fishing	Historic Preservation	Transportation	Communications	Pipeline Regulations
OCS LANDS ACT		◆		◆		◆						
NEPA	◆	◆	◆	◆	◆	◆	◆		◆			
CZMA			◆									
CLEAN AIR ACT			◆	◆								
CLEAN WATER ACT			◆		◆	◆						
REFUSE ACT			◆		◆	◆						
OCEAN DUMPING ACT			◆		◆	◆						
ENDANGERED SPECIES ACT			◆				◆					
MARINE MAMMAL PROTECT. ACT			◆				◆	◆				
MAGNUSON CONSERVATION ACT			◆				◆	◆				
HISTORIC PRESERVATION ACT	◆		◆						◆			
DEPARTMENT OF INTERIOR	◆	◆	◆				◆					
Minerals Management Service	◆	◆										
U.S. Fish & Wildlife Service			◆			◆	◆	◆				
National Park Service			◆				◆					
Bureau of Land Management			◆				◆		◆			
Bureau of Reclamation			◆		◆							
U.S. Geological Survey	◆	◆										
COMMERCE - NOAA - NMFS		◆	◆	◆		◆	◆	◆			◆	
ENVIRON. PROTECTION AGENCY			◆	◆	◆	◆	◆					
U.S. ARMY CORPS OF ENGINEERS		◆	◆		◆	◆	◆	◆	◆			
U.S. COAST GUARD		◆	◆		◆	◆		◆		◆		
FEDERAL AVIATION AGENCY										◆		
FED. COMMUNICATIONS COMM.											◆	
FED. ENERGY REG. COMM.										◆		◆
SURFACE MINING & RECLA. ACT	◆											
HARBORS & NAVIGATION CODE		◆	◆		◆	◆				◆		◆
FISH & WILDLIFE COORD. ACT					◆	◆	◆					
MIGRATORY BIRD TREATY ACT					◆		◆					
ARCHAEOL. RES. PROTECT. ACT									◆			
ANTIQUITIES ACT									◆			
RES. CONSERV. & RECOVERY ACT						◆						
COM. ENV. RES. COMP. & LIA. ACT						◆						

Figure ES - 2.

STATE REGULATORY MATRIX

STATUTE/ REGULATION/ AGENCY	RESOURCE / ACTIVITY														
	Public Access and Public Trust Uses	Leasing and Management	Coastal Zone Protection	Air Resources	Water Resources	Hazard Waste/ Toxics	Wildlife/ Endangered Species	Native American Interests	Oil & Gas Activities, Mining,Dredging, Geothermal	Geology and Land Resources	Energy Resources	Forestry and Fire Protection	Land Use Policy	Transportation	Utilities
PUBLIC TRUST DOCTRINE	◆	◆			◆		◆		◆					◆	
CEQA		◆	◆	◆	◆	◆	◆	◆	◆	◆					
MITIGATION MONITORING		◆	◆	◆	◆	◆	◆	◆	◆	◆		◆			
AB 884		◆			◆	◆			◆	◆	◆	◆	◆	◆	◆
CA COASTAL ACT	◆		◆						◆	◆	◆		◆	◆	
CLEAN AIR PROVISIONS			◆	◆					◆					◆	
CLEAN WATER PROVISIONS		◆	◆		◆	◆	◆		◆						
ENDANGERED SPECIES ACT	◆		◆		◆		◆		◆			◆	◆		
NATIVE AMERICAN REMAINS			◆					◆	◆						
SIGNIFICANT LANDS INVEN.		◆	◆				◆	◆	◆	◆					
STATE LANDS COMMISSION	◆	◆	◆		◆	◆	◆		◆	◆		◆	◆		
COASTAL COMMISSION	◆	◆	◆		◆	◆	◆		◆	◆	◆	◆	◆	◆	
FISH & GAME (Dept./Comm.)	◆		◆		◆	◆	◆		◆	◆		◆	◆		
SECTY. OF ENVR. AFFAIRS													◆		
Air Resources Board				◆					◆					◆	
State Water Res. Control Bd.					◆	◆			◆						
Reg.Water Qual. Control Bd.					◆	◆			◆						
Waste Management Bd.						◆			◆						
Offshore Development			◆						◆	◆					
Hazardous Substances						◆			◆						
Toxic Data Management						◆									
DEPT. OF WATER RES.					◆						◆				◆
DEPT. OF CONSERVATION			◆						◆	◆					
ENERGY COMMISSION									◆		◆				◆
BCDC	◆		◆			◆			◆	◆			◆		◆
COASTAL CONSERVANCY	◆		◆			◆	◆		◆	◆			◆		
DEPT. OF PARKS & REC.	◆	◆	◆			◆	◆	◆		◆					
Office of Historical Preserv.			◆					◆							
ANTIQUITIES ACT (Fed.)								◆							
ARCH. RES. PROT. ACT (Fed.)								◆							
DEPT. OF FORESTY	◆	◆					◆			◆		◆	◆		
DEPT. OF BOAT. & WTWYS.	◆													◆	
OFFICE OF PLANNING & RES													◆		
DEPT. OF TRANSPORTATION	◆								◆					◆	
PUBLIC UTILITIES COMM.									◆		◆			◆	◆
NATIVE AM. HERIT. COMM.			◆					◆	◆						
LOCAL GOVERNMENTS															
Local Coastal Programs	◆		◆			◆			◆				◆	◆	◆
APCD'S			◆	◆					◆					◆	
AM. INDIAN REL. ACTIV.-								◆							
Joint Resolution (Fed.)															

Figure ES - 3.

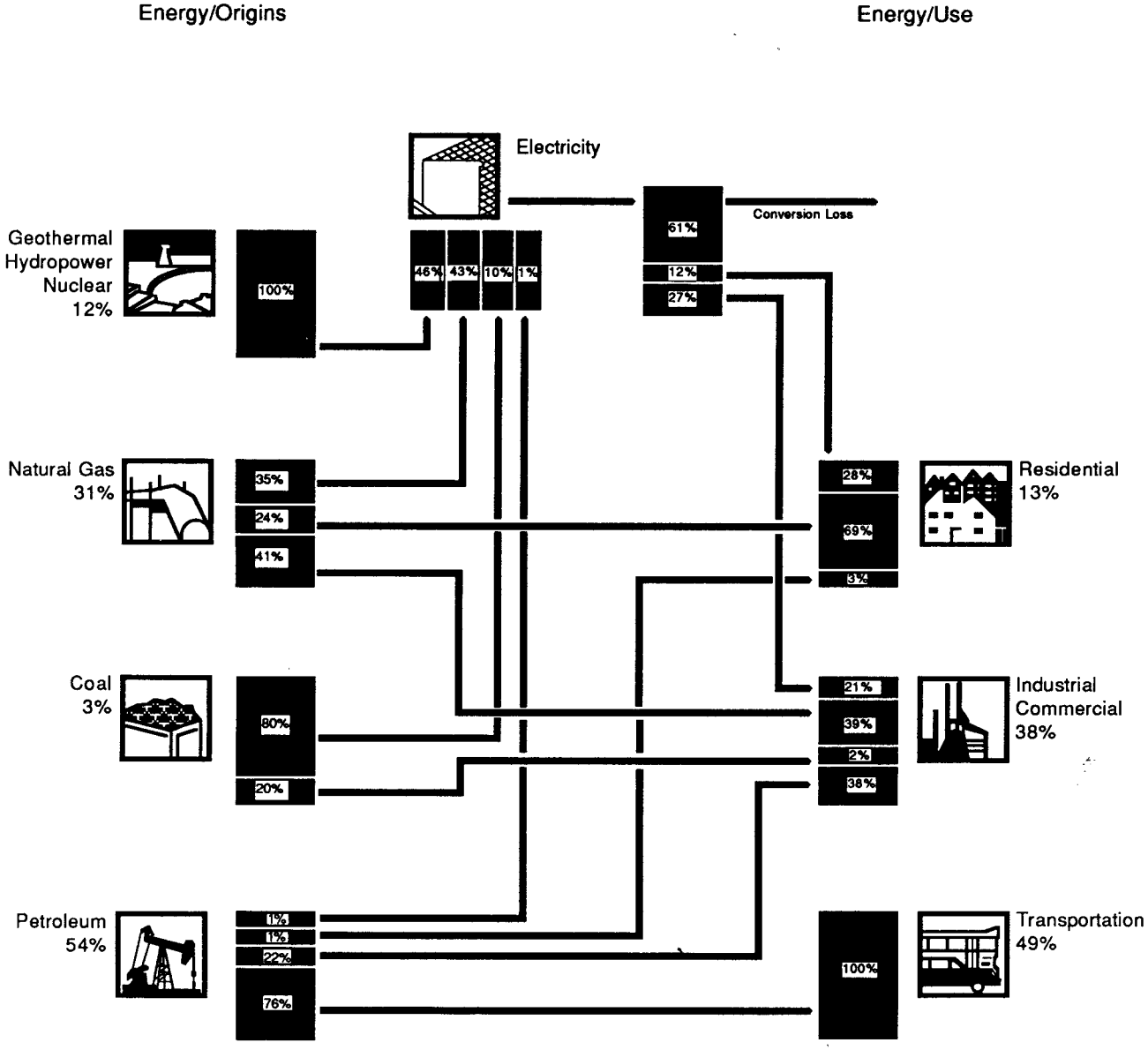


Figure ES - 6: California energy network, 1987.

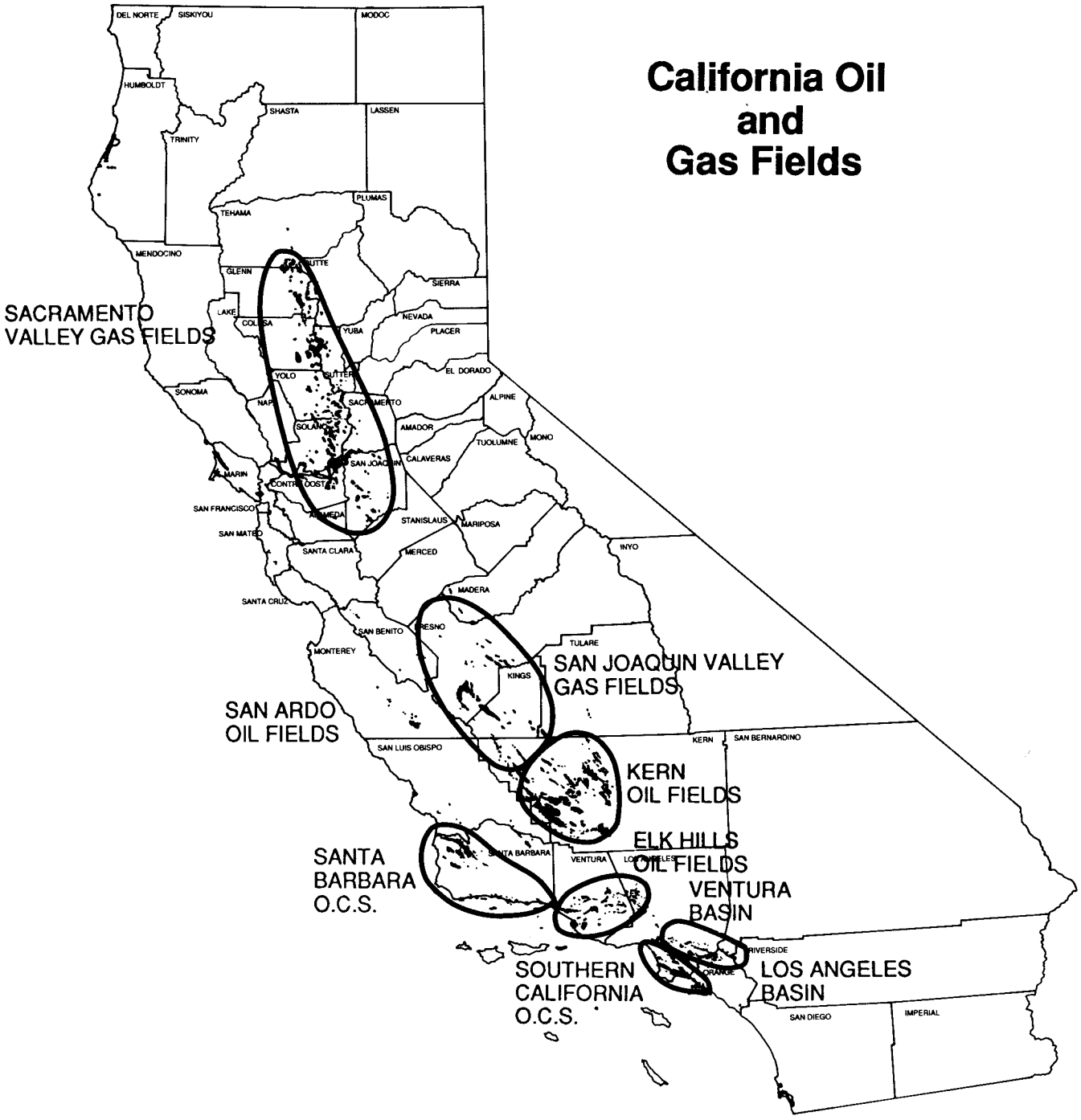


Figure ES - 7.

Source: California Division of Oil & Gas, 1988.

CHAPTER ONE

COASTAL USES

INTRODUCTION

The purpose of this chapter is to describe the major activities occurring in the coastal zone. Some are obvious uses such as commercial fishing and offshore oil development. Others, such as residential development, are less obvious but still depend on the ocean as both a recreational resource and a sewage disposal site.

NAVIGATION

California's Native Americans used the sea for travel. The Europeans "discovered" California by sea and ever since, the sea, the bays and the rivers of California have been used for the transportation of people and goods, for fishing and for pleasure.

California's marine navigation has three major components: commercial ocean transportation, commercial fishing and recreational boating. Each of these components uses both the state's coastal waters and some portion of the onshore coastal land and will be looked at broadly below.

COMMERCIAL SHIPPING

California transports approximately 143 million tons of cargo and three and one-quarter million passengers by vessel each year. This volume of maritime trade—one of the world's largest—is served by five major and several smaller ports.

The most important parts of California's maritime trade are:

- tanker traffic delivering crude oil from Alaska to California refineries (40 million tons/year), and petroleum products to Asia and eastern U.S. ports (51 million tons/year)

- container vessels and bulk cargo carriers on transpacific runs (27 million tons/year together), and

- passenger vessels (cruise ships) going primarily to Mexico or Alaska.

Vessels travel along two shipping lanes, running parallel to the coast, one northbound and one southbound. The majority of vessels are petroleum tankers, bound to and from refineries in the eastern portion of San Francisco Bay or the Los Angeles/Long Beach area. Most of California's passenger ship traffic travels the same routes, although they extend further south.

Crossing this traffic are east/west paths that converge on the Golden Gate and San Pedro Bay. Each of these destinations sends traffic streams on northerly routes to Japan and the Philippines, and southerly routes to Hawaii and the South Pacific. Finally, there is considerable military ship traffic from San Diego and San Francisco Bays, which travels in less predictable patterns.

The onshore element of the commercial shipping industry consists of navigation facilities, ports and shipyards. Navigational facilities, such as lighthouses and radio stations, typically take up less than five acres and rarely

compete with other coastal users or the environment. Ports and shipyards, on the other hand, occupy hundreds to thousands of acres and are often built on land or filled wetlands displacing other users and environmental sectors, and can include special purpose facilities such as container storage areas, tank farms, automobile yards or lumber sheds.

Commercial shipping is regulated by international law outside of U.S. territorial waters, and by the Coast Guard when within those limits. Insurance regulations, admiralty law, and several state and federal statutes also apply.

FISHING INDUSTRY

California has a large and varied fishing fleet, with over 4,000 active vessels in operation. This fleet uses the same port, shipbuilding and navigational elements described above, as well as smaller ports up and down the coast. In fact, every cove on the coast has served as a fishing anchorage or fishing ground at some point and will continue to in the future.

Most of California's fishing vessels work closer to shore than the commercial transport vessels discussed above, and conflicts are usually limited to the areas around entrances to major port facilities or in restricted waters, such as the Santa Barbara Channel. When operating, however, many fishing vessels are under severe mobility restrictions and find any traffic or stationary obstructions hazardous. While there is little competition for deep-draft port space since the fishing fleet can use shallower ports, there is competition with the shipping and transport industries for new port and processing facilities.

Deep-water fishing vessels are regulated by the Coast Guard and international maritime law, while fishing by the near shore fleet is regulated by the California Department of Fish and Game and the U.S. Fish and Wildlife Service.

RECREATIONAL BOATING

California has one of the world's largest pleasure boat fleets, with over 620,000 vessels registered with the Department of Motor Vehicles. From small skiffs to huge yachts powered by sail, prop and jet, this fleet can be found everywhere along the coast. It uses the same navigational aids as the commercial and fishing fleets, and shares some of the smaller fishing ports, but generally uses its own port facilities. There are many marinas, large and small, built for the exclusive use of pleasure boaters. Many launching ramps exist in these same locations as well as in areas where there are no permanent berthing facilities. Space for new marinas is at a premium, since the same coastal space is in demand for many other uses. In some restricted waters, especially San Francisco and San Pedro bays, recreational traffic co-exists with commercial shipping and fishing activities.

Recreational boating is regulated by the Coast Guard, the Department of Motor Vehicles and county governments. Marinas are under the jurisdiction of the State Lands Commission, the Department of Boating and Waterways, the U.S. Army Corps of Engineers and the local government.

EFFECTS OF NAVIGATIONAL USES

Use of the Coastal Zone by these three components generates huge revenues and payrolls. The shipping industry, fishing industry and support services for recreational boating are all major contributors to the public and private economic sectors.

However, despite extensive regulation, ships of all sizes can pollute our coastal waters. Garbage, bilge pumping and anti-fouling compounds are major pollutants resulting from all three components of navigation. The threat of major oil spills from tankers accidents is real, and increases with the volume of traffic. Finally, the expansion of existing and creation of new port facilities continues to use up scarce coastal land.

FISHING

OCEAN

In 1987, California commercial fishermen landed approximately 440 million pounds of fish and invertebrates worth over $205 million. More than 678,000 anglers fished from partyboats and uncounted others fished from small boats, piers, jetties, rocky headlands and beaches (California Department of Fish and Game, unpublished data).

Commercial Fishing

It is difficult to divide California's commercial fishing into discrete fisheries because many vessels are multipurpose; that is, they are used to target different species at different times, depending on fish availability and market conditions. One trawler might fish for bottom fish most of the year but switch to shrimp in the fall. Another might replace nets with crab pots and fish for Dungeness crabs.

In this section California fisheries are described in terms of gear type and target species. Information about regulation of commercial fishing, the location of commercial fishing grounds, seasonal distribution of fishing effort, and individual species or groups of species can be found in Chapter Two.

The most common gear types used in California are trawls, encircling nets, entangling nets, hook and lines, and pots and traps. Some fish and invertebrates are also taken by hand (Figure 1-1).

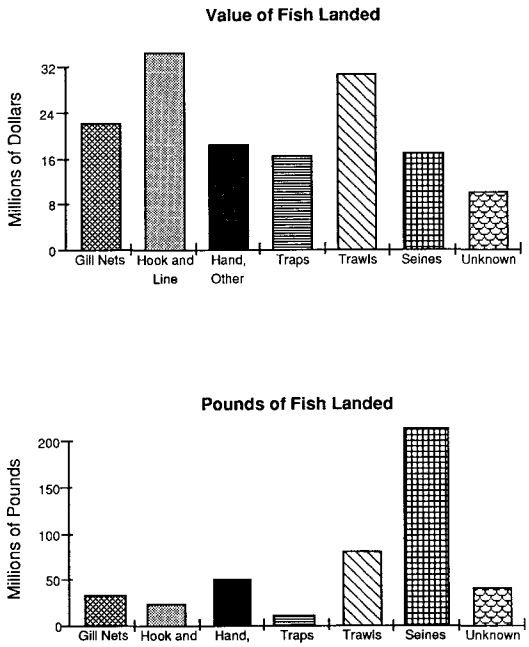


Figure 1 - 1: Value and pounds of fish caught in California by each gear type in 1987. (California Department of Fish and Game, unpublished data.)

Trawls

A trawl is a conical net pulled along the bottom or in midwater by a boat. Metal or wood doors keep the front of the net open (Figure 1-2). Some trawl nets used in rocky areas have rollers on the bottom that allow the net to skate over small rocks and reefs. Larger obstructions may snag the net.

Most trawling in California is bottom rather than midwater trawling. The primary target

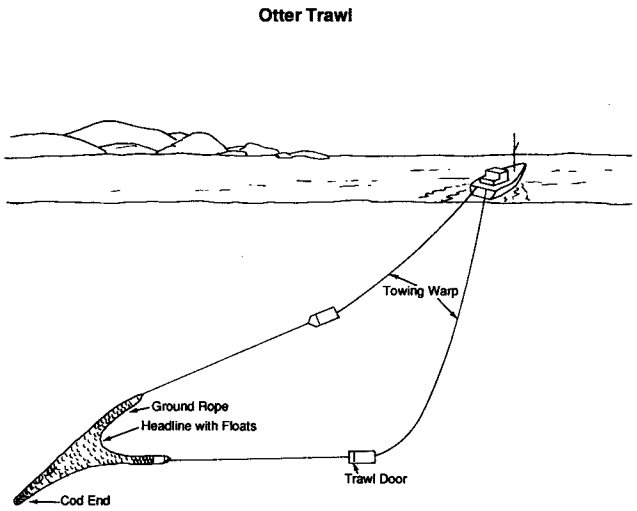


Figure 1 - 2: Schematic diagram of an otter trawl (from Centaur and Associates, 1981).

species are fish, particularly flatfish and rockfish, prawns and shrimp. Widow rockfish are targeted by midwater trawls.

Encircling Nets

Encircling nets are linear nets pulled around schools of surface or midwater fish by a boat or a skiff. A corkline holds the top of the net at the water surface. A leadline sinks the bottom of the net, keeping the net vertical in the water column. If a purse seine (Figure 1-3) is used, the bottom of the net is closed, or "pursed", after the fish have been encircled. If a lampara net is used, the bottom of the net remains open as the net is pulled into the boat.

The primary target species caught in encircling nets are squid, herring, anchovy and sardines, mackerel and bonito. Tuna will sometimes be targeted when available in California waters.

Entangling Nets

Entangling nets, including gill and trammel nets, are rectangular nets that ensnare fish

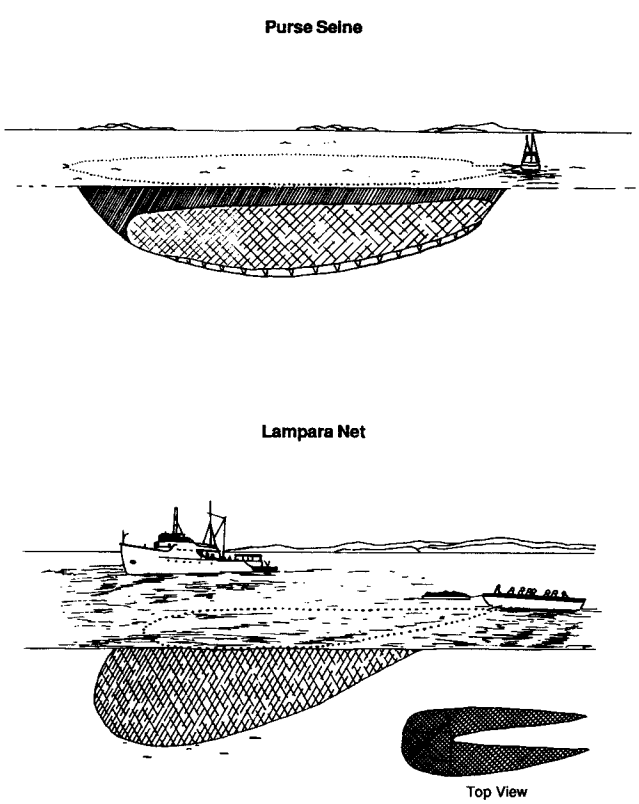


Figure 1 - 3: Schematic diagram of a purse seine and a lampara net (from Centaur and Associates, 1981).

attempting to swim through the net (Figure 1-4). A gill net is constructed with a single layer of netting. A trammel net is constructed of three layers, with the inner layer having smaller mesh than the outer layer.

Gill or trammel nets that are anchored in place are called set nets. They are marked with buoys and usually left to fish for one to two days before retrieval. Some nets are left to fish for more than two days (Hanan, et al., 1987). Primary target species for set nets are halibut, white croaker, rockfish, sea bass and several species of shark.

Some nets, called drift nets, are allowed to float with the current with one end attached to the boat. The primary species caught in drift

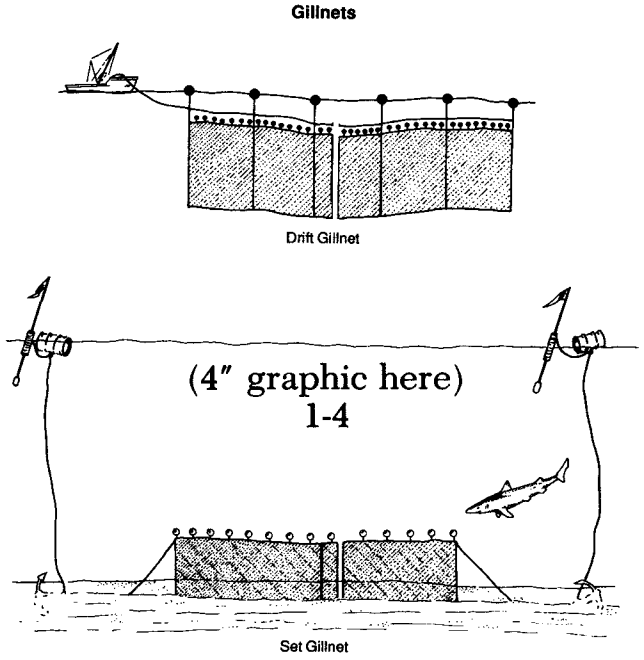


Figure 1 - 4: Schematic diagram of a drift and set gill net (from Centaur and Associates, 1981).

nets are thresher sharks, bonito (mako) sharks, and swordfish (Department of Fish and Game, 1985).

Hook and Line

Lines with hooks are fished in a variety of configurations. Handlines may be fished with or without poles and reels, with live or dead bait, or with lures. Where fish are aggregated, such as on the tops of rock outcrops, lines may be hung vertically from buoys and left to fish for an hour or two.

In other areas, lengths of lines called longlines are stretched horizontally between buoys. Shorter lines with hooks are attached to the main line. Longlines may be buoyed to fish in midwater or on the bottom; they may be anchored or left to drift with the current.

Hooks and lines may be trolled, that is, pulled through the water. One common method of trolling is to run one or more lines from booms that extend laterally from the boat. Leaders with hooks are attached to the lines approximately every six feet. Each line may have as many as 100 hooks.

Salmon and albacore are the principal species of fish caught by hook and line in California. Both species are trolled. Rockfish are caught by handlines and by lines suspended vertically from buoys in nearshore areas. Sablefish are caught with longlines set on the bottom in 600–1800 feet of water.

Pots and Traps

Pots and traps are cages designed in such a way that fish or invertebrates can enter but cannot not leave the cage. Bait is usually used as a lure.

Crabs and lobsters are the principal species caught by traps in California. Dungeness crabs (*Cancer magister*) are trapped on mud or sand bottoms from Morro Bay north to the Oregon border. South of Point Conception there is a fishery for the smaller rock crabs (*Cancer antennarius, anthonyi, and productus*). Spiny lobsters are trapped in rocky areas in the Southern California Borderland. Other species caught by traps include sablefish and spot prawns. There is a developing fishery for hagfish (slime eels).

Harvest by Hand

Harvesting by hand includes harpooning, dipnetting, and handpicking of fish and invertebrates.

To harpoon a fish, a person standing on a plank at the bow of the vessel throws or shoots a barbed shaft into a fish swimming at the surface. The shaft is attached to a length of line

and a buoy. The fish is followed until it tires and can be brought on board. Harpoons may be used to catch sharks, swordfish and bluefin tuna, although these species are more often caught with gill nets and purse seines.

Dip nets, sometimes called "brails," are hand-held nets attached to poles that are used to lift fish or invertebrates from the water. Dip nets are used to catch surf smelt in Northern California. They are used in Monterey Bay and some areas of Southern California to catch squid attracted to the stern of a boat by a night light.

Divers using scuba gear or surface supplied air harvest abalone and sea urchins in shallow (< 100 feet) rocky areas of California. The abalone fishery is one of the oldest fisheries in California while the urchin fishery is one of the newest.

Recreational Fishing

Recreational fishing includes angling with hook and line, clamming, crabbing and diving for lobster, abalone and fish.

Hook and line fishing is a popular activity throughout the state. In 1986, 2.6 million people made 8.9 million fishing trips and caught 46.6 million fish (Figure 1-5). Approximately two thirds of the fishing activity was in Southern California, which is not surprising since a majority of the state's population lives south of Point Conception.

Most fishing was from shore or from private or rental boats; 7–20% of the fishing trips were on party or charter boats. There was more fishing from party boats in Southern California than in Northern California, where most fish were caught onshore or from private boats. Compared to the number of trips, relatively more fish were caught from party/charter boats than from shore (Figure 1-6). Sixty percent of the fish were caught less than three miles from land (Figure 1-7). In Southern California there was more fishing in offshore areas than in bays and estuaries, whereas in Northern California the opposite was true.

The time of year that sport fishermen are most active varies with region. In 1986, fishermen in Northern California were most active in July/Aug (32%); although 36% of the fishing was between September and December. In Southern California, most fishing is done between May and August (40%) and September through December (40%). Due to the mild climate, fishing is enjoyed year round there.

Clamming is a popular activity, particularly in Northern California. Most clams are dug during low tide in bays or on sandy beaches. Clams are dug with a shovel or fork, although some are dug by hand. Razor and Pismo clams are taken on exposed sandy beaches. Gaper and Washington clams are dug in protected bays in Northern California. Chiones, Pismo and littleneck clams are dug in Southern California.

Crabs are caught with traps or baited hoop nets set from piers and jetties or outside the surfzone. Crab traps are not allowed south of Point Arguello. Dungeness crab (*Cancer magister*) are taken in winter and spring in Central and Northern California, mostly in bays and harbors. The sport take of Dungeness crabs is about 0.5% of commercial landings from Northern California (Hardy et. al, 1982). Rock crabs (*Cancer anthonyi, C. antennarius,* and *C. productus*) are taken throughout the year, mostly in Southern California.

Abalone, rock scallops and lobster are taken by hand from rocky areas. Abalone are pried

Number	Northern California	Southern California	Total
Fisherman	700,000	1,853,000	2,553,000
Trips	2,757,000	6,119,000	8,876,000
Fish Caught	35,334,000	11,227,000	45,561,000

Figure 1 - 5: Number of fishermen, fishing trips and fish caught in California in 1986 (from U.S. Department of Commerce,1987).

Percent Trips/Fish	Northern California		Southern California		Total	
	Trips	Fish	Trips	Fish	Trips	Fish
Shore	46.3	40.0	37.0	11.9	39.9	19.1
Party/charter boat	7.1	15.6	21.9	40.2	17.3	34.2
Private/rental boat	46.6	44.3	41.1	47.9	42.8	47.1

Figure 1 - 6: Percent fishing trips and fish caught from the shore, from party / charter or from private / rental boats in California in 1986 (from U.S. Department of Commerce, 1987). (Number of fish shown in millions.)

Percent Fish Caught	Northern California	Southern California	Total
<3 mi. from shore	50.9	65.2	61.7
>3 mi. from shore	11.7	24.8	21.7
Inland	36.3	8.8	15.4

Figure 1 - 7: Percent fish caught offshore (>3 mi.), nearshore (<3 mi.) or inland in 1986 (from U.S. Deparment of Commerce, 1987). Inland waters include bays, estuaries and tidal portions of rivers.

off rocks with an iron bar inserted under the foot of the animal. Rock scallops are pried off rocks with a knife or chisel. Some abalone and scallops are taken from intertidal areas, but most are taken subtidally. Lobsters are primarily taken south of Point Conception. Divers find lobsters under overhanging rocks or in crevices, grab them and wrestle them into a bag. Hooks, spear guns or other implements may not be used to take lobsters.

Divers with spearguns hunt rockfish, perch, kelp bass, halibut and other gamefish throughout California. Some divers use scuba gear, others snorkel. Spearguns may be simple

hand-held tridents or guns with a stock and reel and rubber-powered shafts attached to a long line.

INLAND

Fisheries in lakes, rivers, streams and bays have long played an important role for the people and animals of California. Native Americans fished as a means of subsistence long before the arrival of Europeans (see Native American Fisheries). Shortly after the Gold Rush, Europeans began numerous commercial fisheries utilizing California's abundant aquatic resources. In the 1800s a variety of fish were introduced to California waters. But before protective regulations were enacted and proper resource management existed, many of the food fish populations in the state were over-fished and today there is very little commercial fishing on inland waterways.

Fishing is a popular outdoor recreational activity—over 2.6 million fishing licenses were sold in 1987–1988 (California Department of Finance, 1988). In 1985 almost three million California residents and 131,000 non-residents fished in freshwater (U.S. Fish and Wildlife Service). Sport fishing contributes substantial money to the state economy. Expenditures for sport fishing (such as travel, food, lodging, gear, guides and rentals), contribute in excess of $2.2 billion to the state (Sport Fishing Institute, 1989). The yearly economic gain from salmon and steelhead recreational fishing on rivers is over $100 million, according to values used by Meyer (1988) in a report to the California Advisory Committee of Salmon and Steelhead.

The California Department of Fish and Game (CDFG) regulations on fishing include bag, possession and size limits, license requirements, gear restrictions, and season and area closures. These regulations help prevent over-fishing of declining populations (Barnhart, 1986).

Currently, the primary inland fisheries include anadromous fish (species which grow and mature in the ocean but migrate to freshwater to spawn), resident trout and warm water gamefish.

Anadromous fish are some of the most prized inland game species in the state, and by definition must spend at least part of their life-cycle in coastal waterways. Members of the salmon family, termed "salmonids" by resource managers, are perhaps the most significant species of the anadromous group. Anadromous salmonids in California include the steelhead (ocean-going rainbow trout), coastal cutthroat trout, and the king (chinook) and silver (coho) salmon . The king salmon, and to a lesser extent the coho, are also a major commercial fishery in their ocean-going stage of life (CDFG; 1969, 1979).

Another important anadromous game fish is the non-native striped bass, found primarily in the San Francisco Bay and the Sacramento San Joaquin River Delta/River system. Native sturgeon, also anadromous, share a similar distribution in the bay, Delta and Central Valley rivers (CDFG, 1979).

Historically, the anadromous fisheries—salmon, shad, sturgeon and striped bass—comprised the majority of the river fisheries. Italian immigrants began the first California commercial salmon fisheries along the Sacramento River around 1850. Canneries sprang up along the Sacramento and San Joaquin Rivers—processing more than 10

million pounds of salmon (primarily chinook) every year. But, by 1883 the salmon fisheries had collapsed as a result of over-fishing and habitat degradation from hydraulic gold mining (Allen and Hassler, 1986 and Skinner, 1962).

Today salmon and trout are extremely popular fish with most west coast anglers. In fact, 69% of the state's anglers trout fish (Grambsch, 1989). Both species are prized for their tremendous fighting qualities and excellent taste. Even though salmonids do not actively feed in freshwater, fishers use natural baits and artificial lures to catch them. Shrimp, night crawlers and fish eggs are some of the commonly used fresh baits; lures include spoons, spinners, diving plugs, flies and brightly colored bobbers. Fly-fishing, spinning, bait casting, drift fishing and plug pulling from drift or power boats and plunking from the banks are the leading methods used in salmon and trout fishing. Sport fishing for steelhead has become increasingly popular since the turn of the century. Since the 1940s declines in the natural steelhead populations of California have increased the need for hatchery produced fish. Advanced hatchery technology and widespread stocking have built up runs of steelhead making them available for anglers (Pauley, et al., 1986). The Klamath, Eel and Sacramento Rivers have the best remaining steelhead runs in the state (Barnhart, 1986). Steelhead fishers spend more per fish than other sport fishers, averaging $143.12 per fish (in 1983 dollars) (Meyer Resources Inc., 1985).

Cutthroat trout, coho and chinook salmon are also favorites. All are taken using the same basic fishing methods as those for steelhead. In fact, because of their similarities, cutthroat trout are often mistaken for steelhead (Moyle, 1976). Chinook are valued for their trophy size and coho for their aggressive nature (Beauchamp, et al., 1983). Other salmon—pink, chum and sockeye—may stray into California waters but are rarely taken. Salmon anglers also spend considerable amounts of money to catch their fish, averaging $48.35 to capture one fish (in 1983 dollars) (Meyer Resource Inc., 1985).

American shad were introduced into California in 1879 from the East Coast. Their introduction was so successful that a commercial shad fishery began just eight years later. American shad were never as popular on the West Coast as they were on the Atlantic Coast, so the shad fishery focused on roe which was shipped to the Orient (Skinner, 1962). In 1957, a ban on commercial shad fisheries was established in order to enhance the growing sport fishery (Moyle, 1976). The population of American shad is so large that when the fish migrate, sportsmen can be found on the banks of the Yuba and Feather Rivers, often standing shoulder to shoulder. American shad are commonly taken with flies, jigs and small spinners and give a spectacular fight on light tackle. A less conventional means of capturing shad is called "bumping." In "bumping," long-handled dipnets are hung off the stern of slow moving boats. When a ripe male is ensnared the net is quickly twisted and pulled aboard. The taste of shad is still not yet fully appreciated and many are caught for sport only and released (Moyle, 1976).

In 1879 and 1882 a total of 432 striped bass were planted in the San Francisco Bay Area. In six years a commercial fishery was created and within 10 years, the catch exceeded one million pounds annually. The commercial fishery existed until 1935 when the sale of striped bass was prohibited because of conflicts between sport and commercial anglers (Moyle, 1976).

Today striped bass (often referred to as stripers), support an extensive sport fishery in the Sacramento and San Joaquin Rivers. Angling for striped bass occurs year-round from boats, charters and shore. The fishery generates significant revenues for motel operators, restaurants, guides and so on. Meyer Resources, Inc. (1985) estimated that anglers spent about $71.56 (in 1983 dollars) to catch one striped bass. A serious decline in annual catch occurred 1980 to 1982 with an average of only 65,000 fish caught, down from the average of 266,000 in 1969 (Meyer Resource, Inc., 1985). By 1983, declines in the abundance of striped bass (from 1969 levels) resulted in an estimated $587 million loss in sales revenues to the state.

Sturgeon are valued not only for their meat, but also for their roe and isinglass (notochord). White sturgeon were considered to have a superior taste to green sturgeon, and a commercial fishery for white sturgeon in the Bay Area in the 1860s. Because of their large size and slow maturation, the sturgeon were quickly over-fished and unregulated commercial sturgeon fisheries nearly decimated the population in a short period of time. (Green sturgeon have not been as widely exploited because of their lesser value and fewer numbers.) A decrease in catches resulted in the possession of sturgeon being banned in 1901 (Moyle, 1976).

However, in 1954 white sturgeon fishing was reopened. Sportsmen found that the easiest way to catch the sturgeon was by snagging, but this was considered unsportsmanlike and was outlawed in 1956. The catch on hook and line declined dramatically until 1964 when bay shrimp were discovered to be an excellent bait for white sturgeon. Now the catch has increased and apparently stabilized at around 8,500 fish per year.

A small commercial fishery exists for Sacramento blackfish in Clear Lake. The catch is marketed in San Francisco's Asian markets. Although this fish is valued for its commercial use only, it merits further study because it is largely herbivorous and it plays a vital role in the food chain of its ecosystem. Splittail are thought to be one of the most primitive North American cyprinids. Sacramento splittail contribute to a small sport fishery important to the Chinese-Americans who catch them in the spring in flooded pools of the Sacramento and San Joaquin Rivers (Moyle, 1976).

Channel, white and blue catfish are the more popular sport fish of the seven species of catfish introduced to California. Because they have a nocturnal nature fishing for catfish is a nighttime activity. Catfish commonly are taken with live bait on the bottom. White catfish have traditionally been the most abundant and popular sport fish in the Sacramento and San Joaquin Rivers, but channel catfish—prized for their ease of catching and hatchery rearing—are increasing in popularity. Blue catfish were introduced for several reasons: their ability to reach trophy size, a range of tolerance to salinity in rearing situations, and their ability to control clam populations. Blue catfish are also increasing in popularity with anglers (Moyle, 1976).

NATIVE AMERICAN

Historically, the first inhabitants of Northern California were Native Americans (Figure 1-8). Several of these tribes lived in coastal areas; the Yurok owned land around the Klamath River, the Tolowa, and the Wiyot inhabited the area from the Little River to the Eel River including Humboldt Bay, the Mattole, and the Siskyone (Heizer, 1978).

Figure 1 - 8: Map of tribal territories in California (from Heizer, 1978).

Fishing provided much of the diet of coastal Native Americans. All these tribes were expert fishers and depended on the abundant ocean life. Each tribe utilized various fishing methods and specific gear for the variety of fishes taken. Tribes such as the Karuks, Chilula and Hupas who lived inland also took advantage of the rich sea life which they obtained either through trade with the coastal tribes or by capturing anadromous fishes in the rivers. Tribes traded food and materials often and amicably. Sea lion meat might be traded for such inland foodstuffs as acorns, pine nuts, and venison. Dentalium, a toothlike shell, was also used as money and was quite highly valued.

Many Native American ceremonies and legends concerned the ocean, its life, and conservation of its resources. Ceremonies, such as the First Eel Ceremony and the First Salmon Ceremony were performed to maintain the world supply and ensure ample harvests in the future. The Native Americans never overharvested and only took the fish they needed (Kroeber and Barrett, 1960). More than 2 million pounds of salmon were taken annually from the Klamath River alone (USFWS, 1987).

Estuarine and Riverine Fishing

Removable dams and weirs, pots, various nets and dugout canoes were all used to capture anadromous fishes and marine mammals in the rivers and estuaries (Figure 1-9). The anadromous fish taken included Pacific lamprey (eels); Chinook, coho, and sockeye salmon; steelhead trout; green and white sturgeon; and candlefish. Migrating salmon resting in backwater eddies fell prey to Native Americans who constructed scaffolding over the eddies and used dip nets to scoop up the fish.

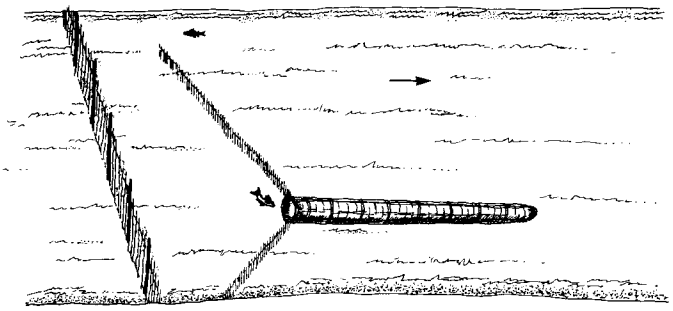


Figure 1 - 9: Tolowa double weir with a basket trap (from Kroeber and Barrett, 1960).

On the lower Klamath river, individual Yurok owned eddies but allowed others to fish them by permission. Weirs, brush barriers, and blockades, some with nets attached, slowed upstream migrations but had to be removed when so many salmon were present that the blockades might break (Kroeber and Barrett, 1960 and USFWS, 1981). Pots were used to catch migrating eels, and sturgeon were harvested using long nets. Swimmers would also dive into pools containing sturgeon or other fish. A swimmer would hold onto a sturgeon's neck and force its head up to the surface and then guide it to shore.

Other types of fish were grabbed by the tail or gills and brought to the surface. Candlefish migrated during January and February and were captured with dip nets. Fish not needed for immediate consumption were smoked or dried so they could be saved for winter, taken on hunting trips, traded, or even made into fish meal. Seals and sea lions were hunted from canoes and harpooned as they followed Pacific lamprey or salmon into the estuary.

Beach and Littoral Fishing

Native Americans seining in the surf captured smelt and surf fish with V-framed scoop nets (Figure 1-10). Stranded whales were eaten; but no one hunted live whales because it was too hazardous. During low tides, tribal members collected intertidal species such as

green sea anemones, abalone, crabs, limpets and sea weed. They also harvested razor clams, bent-nosed clams, cockles, other clams and Pacific flat oysters from the beaches and Humboldt Bay. Some shore birds, ducks and geese were also captured. At low tides, Native Americans rowed to offshore rocks in dugout canoes to collect mussels and barnacles. They not only ate the meats but also utilized the shells. Some shells were worn for ornamentation or ceremonial regalia, and some were made into tools. Abalone shells were sometimes strung for hanging around the ears and mussel shells were used for scoops, spoons and other tools (Kroeber and Barrett, 1960).

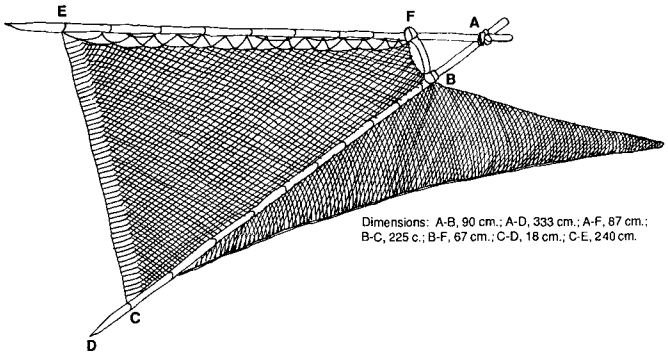


Figure 1 - 10: Yurok surf net or scoop net (from Kroeber and Barrett, 1960).

Ocean Fishing

The coastal Native Americans also angled for many ocean dwelling fishes. Rockfish, perch, lingcod, salmon and others were caught on hook and line using mussel meats, clams, smelt and perch as bait. They trolled for salmon from canoes, and fished for perch, rockfish, lingcod and other species from offshore rocks or from shore. Additionally, Native Americans collected sea gull eggs from some of the offshore rocks (Kroeber and Barrett, 1960).

European Influences

In the 1800s, Europeans began living on the north coast of California. They came for the gold, timber and agricultural lands. Hydraulic gold mining caused the rivers to become silted, which in turn suffocated fish eggs and larvae. Poor timber harvesting practices choked the rivers with sediment and large woody debris preventing anadromous fishes from migrating and reproducing. Many Native Americans starved because of the lack of fish. In addition, miners and settlers took away Native American lands and rights by force, relocating, displacing, and shooting the Native Indians.

In the late 1800s, Europeans started a commercial salmon fishery in the Klamath River estuary and employed Native Americans for most of the labor. There were processing plants for canning and the average catch from 1915–1928 was 52,000 salmon. The fishery was closed in 1933 (USFWS, 1981).

Current Fisheries

Today, north coast Native Americans still use many of the same species of fish and invertebrates (Sue Matsen, pesonal communication), and have retained important hunting and fishing rights.

In the 1970s a series of court decisions reestablished the rights of Native Americans to fish or use water without state regulation. Subsistence salmon fishing is permitted six days a week (excluding Mondays). In 1986, indian fishers took 26,091 salmon, 865 steelhead and 421 green sturgeon in gill nets and beach seines from the Klamath River Basin for subsistence (USFWS, 1987). Tribal members also harvest clams, rockfish, anemones, seaweed, surf fish, perch, lamprey, abalone and other animals for food.

In 1977 and 1978, Native Americans in the Klamath River sold the salmon they caught, but a moratorium in August, 1978 stopped

these sales because of low salmon returns (USFWS, 1981). The government lifted the moratorium in 1987.

Klamath River Basin Fisheries and Values

Three tribes, the Hoopas, Yuroks and Karuks, currently fish for anadromous fishes from the Klamath River Basin. Only the Hoopa and the Yurok have been allowed to sell their fall Chinook salmon catch. The 1987 and 1988 commercial gill net catches of the Hoopa and the Yurok were valued at around one million dollars with an average of 27,000 salmon caught. The Bureau of Indian Affairs (BIA) appoints one fish processor to buy salmon from the tribal members and the number of fish which may be caught (quota) is set by the Pacific Fisheries Management Council (PFMC). Recently, the Hoopa-Yurok Settlement Act divided the Hoopa Indian Reservation into two reservations. The Act reverted the lower forty miles of the Klamath River back to Yurok tribal domain. The Yuroks are allowed to fish exclusively from the mouth of the Klamath to the Highway 101 bridge. The Native Americans have a self-imposed regulation of gill netting only from the hours of 7:00 p.m. to 7:00 a.m. preventing interference with sport fishers during the day.

Even though a portion of the salmon catch is sold for profit, it is difficult to put a value on the fisheries. The Karuks, Yuroks and Hoopas use salmon and other fish for subsistence. In addition, salmon and other animals are an integral part of these tribes' cultural and religious heritage and for these reasons the fish are priceless to them (Sue Matsen, personal communication).

OPEN SPACE, RECREATION AND TOURISM

Recreation has been defined as "refreshment of one's mind or body after labor through diverting activity; play." People engage in such diverse leisure activities that no standard "recreational" area can be identified. Facilities can range from open spaces to multi-story resort hotels.

Tourism and recreation are closely related and are both big business in California. State Department of Commerce figures show $32 billion spent in 1986 on tourism in California, 86% of that in coastal counties. According to the Santa Monica Visitor and Convention Bureau, travelers from foreign countries spend an additional $4 billion, making tourism a bigger business in California than agriculture, manufacturing and aerospace. Figures from the California Department of Parks and Recreation and the National Park Service show that over 100 million visitors annually travel to parks in California's coastal regions. The Southern California Association of Governments has estimated some 64 million individuals travel to Los Angeles and Orange Counties for business or pleasure, of which one-third travel to beaches and coastal cities.

Statewide recreation trends reveal a growing demand resulting from increased population. Recreational activities vary significantly depending on the age, sex, income level and ethnicity of the participants. As shifts take place in these demographic categories, demands for recreational activities change.

Land use decisions providing for tourism, recreation and open space uses are part of the local planning, zoning and permitting process. In the coastal zone, this is combined with the policies of the Coastal Act of 1976 which

recognize recreation and visitor-serving facilities as priority uses. On the waterside, agencies such as the U.S. Coast Guard, California Department of Fish and Game, Harbor Patrols and local police forces exercise some regulatory control over recreational activities.

Impacts from recreational activities are as wide ranging as the activities themselves. In addition to the human and economic benefits of recreation and leisure activities, a good parks and recreation system can benefit the economy by influencing business relocation decisions.

At its worst, recreation can result in overcrowding, trespass on private property, pollution of beaches and water, destruction of habitat and visual blight. Also, recreation/tourist uses draw people who over time may develop a resistance toward change. Such an attitude can limit or preclude other land uses.

Identifying alternatives to recreational uses of coastal areas is difficult. In large part, California's attraction for both people and business is based on the wide variety of recreational activities that can be enjoyed year-round.

PROTECTION OF BIOLOGICAL DIVERSITY

Protection of natural areas and the biological diversity they contain is important for a number of reasons. The plants and animals which produce our food, wood, cloth fiber, pharmaceuticals and other useful commodities are either wild stock or derived from wild stock. Natural areas are a source of genetic material that can provide new products for future generations. Natural areas afford opportunities for education and critical scientific research that cannot be duplicated in the laboratory or in man-made ecosystems. Natural areas also have inherent aesthetic, recreational and cultural worth. Many people highly value the opportunity to be in a natural setting undisturbed by man.

The coast of California, spanning nearly 10° latitude from north to south, encompasses two major marine biotic provinces and a wide variety of marine habitats. As a consequence, the state's coastal waters support abundant and varied marine life. Rocky intertidal and kelp forest habitats in California are among the richest in plant and animal species diversity to be found anywhere. The offshore islands support the most diverse pinniped (seals and sea lions), fauna in the world.

The California landscape lies over a broad range of climates, soils and topography, which has led to an exceptional diversity of terrestrial, freshwater and estuarine plants, animals and natural communities. California has over 5000 plant species, some 30% of which are endemic, or limited, to this state (Cochrane, 1985). There are about 680 native species of amphibians, reptiles, birds and mammals in California. Almost one-third of the state's amphibians are endemic species. Twenty-five of the 66 native species of freshwater fishes are endemic as well (Jones and Stokes, 1987).

There has been a significant loss of natural diversity statewide in the last 150 years, partly from commercial exploitation of natural resources and partly from human population growth and the development of society. In the recent past, 26 California plants have become extinct and another six have been eliminated from the state. Fourteen animals have become extinct and six have been eliminated from California, including the California state

mammal, the grizzly bear (Jones and Stokes, 1987). Currently, nearly 200 plant species and 80 animals are state or federally listed as threatened or endangered. Of the 380 terrestrial, freshwater and estuarine aquatic natural communities recognized by the California Natural Diversity Data Base of the Department of Fish and Game, 47% are considered rare and at risk of elimination.

Preserving natural areas is the most effective way to maintain biological diversity (U.S. Congress, Office of Technology Assessment, 1987). However, preservation of remaining natural areas is in itself not enough to ensure biological diversity. Species and community restoration of damaged ecosystems is also necessary for long-term protection of biodiversity.

Coastal uses which relate to biodiversity issues are: natural area protection, research and education, and habitat and species restoration.

NATURAL AREAS

Despite heavy urban and agricultural development, approximately 80% of the 23 million upland acres in the coastal counties is still in wildland vegetation (unpublished data from CDF, FRRAP data base). However, many of these forests, woodlands, shrublands and grasslands have been or will be subjected to uses such as logging, grazing, residential development or intensive outdoor recreational activities which alter them from their pristine condition. Fewer than 5% of the uplands in the coastal counties are officially protected from appropriative or otherwise damaging use (determined from unpublished data from CDF, 1988; Cochrane, 1986; California Coastal Commission, 1987).

Wetlands have been subjected to even more intensive development since statehood, with over 70% of the historic freshwater, brackish and salt marshes in the coastal region lost, including San Francisco Bay. However, approximately half the remaining wetlands acreages are in public ownership. (ESA/Madrone, 1982, 1984).

Marine environments are not subjected to the same level of physical disturbance as inland habitats, but there have been significant losses in natural communities in localized areas. Natural marine ecosystems along the entire coast have been significantly altered from their pristine condition by many types of water-borne pollution.

Numerous areas in the coastal region of California, both on and offshore, have been given official protection to preserve natural ecosystems, provide habitat for rare or endangered species, safeguard scenic areas, maintain open space or provide recreation in undeveloped areas. The extent of preserved natural areas in the coastal region is small and none of these sites can be completely protected from human disturbance; however, reserve status does provide some degree of protection.

One level of protection is based on the designation of an area as ecologically significant by one or more agencies. This provides a formal recognition of special values, but usually only informal protection. Management of such sites takes into consideration the special values present, but may allow a number of intensive uses. In some instances the designation prohibits certain harmful uses, as in the case of Areas of Special Biological Importance (ASBS) (which are protected from waste-water discharges), and the State Oil and Gas Sanctuaries (which prohibit oil and gas

development). Natural area designations in the coastal region include the following:

International

International Biosphere Reserves (UNESCO)

Federal

Wild and Scenic Rivers
National Marine Sanctuary (NOAA)
National Estuarine Research Reserve (formerly National Estuarine Sanctuary)
National Estuary Project (EPA)

State

Areas of Special Biological Significance (SWRCB)
California Significant Natural Areas (DFG)
Lands Possessing Significant Environmental Values (SLC)
California Oil and Gas Sanctuary (SLC)
Wild and Scenic Rivers

A higher level of protection is afforded in a managed natural area. Sites are managed by various public agencies and some private conservation organizations to preserve natural heritage values, often for scientific or educational purposes. Intensive uses, including recreation, are controlled. Often a natural area preserve is included within a larger, less protected land holding of the managing agency, such as a Research Natural Area within a National Park or National Forest. The major managed natural area programs in the California coastal region include the following:

Federal

Bureau of Land Management
- National Conservation Area
- Area of Critical Environmental Concern—Research Natural Area

National Park Service
- National Park
- National Seashore
- National Recreation Area
- National Monument

U.S. Forest Service (within National Forests)
- Research Natural Area
- Special Interest Area

U.S. Fish and Wildlife Service
- National Wildlife Refuge
- Wilderness Area

U.S. Navy
(Certain lands within Navy holdings are managed for ecological preservation)

State

Department of Fish and Game
- Ecological Reserve
- Marine Reserve
- Marine Life Refuge
  - Clam Refuge
  - Fish Refuge
  - Game Refuge
- Wildlife Area

Department of Parks and Recreation
- State Park
- State Reserve
- Underwater Park
- Natural Preserve (within a park or reserve)

University of California
- Natural Reserve

Private

The Nature Conservancy
- Nature Preserve

National Audubon Society
- Sanctuary

In addition to sites designated or preserved as natural areas under the formal programs and agencies named previously, numerous state beaches, regional, county and city parks, National and State Forests, hunting clubs and other privately-owned lands afford some protection for natural communities. The Nature

Conservancy has an active landowner notification program, working to further voluntary conservation for significant natural habitats on private lands.

Overview of Marine Natural Areas

Marine natural reserves are found throughout California; however, some regions possess greater concentrations than others. On the coast, rugged rocky shores with unique headlands, coves, reefs and islets, have more designations than long stretches of uniform sandy beaches with a low diversity of marine life. Five regions contain approximately two-thirds of all protected areas. In Northern California, scenic rocky shores from Ft. Bragg to the Sonoma Coast contain numerous state parks, underwater parks, and ASBS. The complex region from Bodega Head to San Francisco includes important headlands, reefs and islands which have multiple overlapping protected status. Another highly diverse rocky coastline with many designations ranges from the Monterey Peninsula south to Big Sur. In Southern California, the eight Channel Islands have special features that have been recognized by overlapping authorizations. A fifth region, from Newport Bay to Dana Point, contains diverse reefs along an otherwise sandy shore. Each of these reefs has received separate recognition.

Coastal areas with relatively few protected designations include: Trinidad Head to Ft. Bragg, San Francisco to Monterey Bay, Cape San Martin to Newport Bay, and Dana Point to La Jolla. Most of these areas consist of sandy shores. Some of the rocky sections probably have received little attention because of their inaccessibility (e.g., Cape Mendocino to Cape Viscaino, Point Sal to Gaviota).

Overview of Onshore Natural Areas

The level of protection for inland natural areas, including enclosed bays and estuaries, also varies throughout the coastal region. Protected areas inland are more concentrated in the far north (Del Norte, Humboldt and Mendocino counties) where there is little urbanization and the topography is rugged and unsuited for agriculture. Protected areas in this region include large tracts of land such as the King Range National Conservation Area (60,000 acres) and the North Coast Range Preserve (7,000 acres), that protect a wide range of habitats and wildlife. The three north coast counties have over one-third the state parks, over one-half the state reserves, and all of the designated Wild and Scenic Rivers found in the coastal counties.

Another area of concentrated protection is the urbanized San Francisco Bay Area. This area contains a significant portion of California's remaining wetlands and is an important wintering ground for millions of migratory birds. Protection includes large reserves such as the San Francisco and San Pablo Bay National Wildlife Refuges (29,000 acres), the Pt. Reyes National Seashore (71,000 acres), regional parks, numerous smaller marsh, slough and wetland ecological reserves, three large state parks, and privately protected areas.

Protection on the Central Coast is concentrated in the Monterey area, which has over 10,000 acres protected by state parks, and a National Estuarine Preserve. The central coast also contains the Ventana Wilderness Area which protects 164,000 acres of National Forest land including a wide range of habitats that support many rare and endemic species.

The largest protected area in Southern California is the Santa Monica Mountain

National Recreation Area (150,000 acres), in Los Angeles. Protection for coastal wetlands in the south is concentrated in San Diego and Orange Counties. The highest concentration of University of California Natural Reserves is found in the south.

In summary, in the coastal region protection for terrestrial habitats is generally provided by BLM holdings, National or State Parks and Reserves, or private holdings. The majority of coastal wetland protection is provided by California Department of Fish and Game Ecological or Wildlife Preserves, and U.S. Fish and Wildlife National Wildlife Refuges.

Until now, protection of aquatic habitats in reserves has not been done on any significant scale. Aquatic community preservation presents a difficult challenge. Activities on surrounding watersheds or in upstream reaches of water bodies have as much to do with the condition of a lake, pond, stream or estuary as uses onsite. Furthermore, larger waterways have traditionally been important for navigation and other commercial uses. For example, although the larger north coast rivers have been placed under protection in the state and federal Wild and Scenic River systems, many reaches of these rivers have been significantly impacted by the effects of logging, mining and other development activities.

RESEARCH AND EDUCATION

The ecologically diverse terrain of California, including mountains, deserts, marshes and beaches, makes it especially well-suited for research and education in biology. Primary and secondary schools routinely take field trips to the forests and seashores, public aquaria and natural history museums, marine laboratories and park visitor centers to learn about native plant and animal life. Many of the same sites and facilities—in addition to more isolated, less disturbed areas—are used by universities, government agencies, and non-profit organizations for research.

Marine Biology

The extent to which a particular coastal site is used for marine education and research is determined by the habitat type and its accessibility and location. Although sandy beaches support interesting marine communities, they are studied less frequently than rocky shores. Most of Northern California contains rocky habitats, but steep cliffs and private land limit their use to only a few places. In contrast, the coast of Southern California consists largely of sandy beach, and the few sites of rocky shore habitats are extensively used for education and research. Education and research facilities are most prevalent in urban rather than in rural settings. In Northern and Central California, for example, areas used for education and research are aggregated around the heavily populated San Francisco Bay and Monterey Peninsula.

California is home to many world-renowned marine research laboratories and public aquaria. Marine aquaria are extremely instrumental in educating the general public on the natural history of California's diverse marine life. Most of the larger aquaria have centers or institutes that fund basic research on a variety of topics in marine science. In addition, most research laboratories help to educate the general public through exhibits or by offering tours. Marine research laboratories and public aquaria require a continuous supply of unpolluted seawater to maintain marine organisms used for research and education.

Generally, the same sites and facilities used for education are used for research as well. Marine research topics range from studies on the molecular biology of marine organisms to the safety of offshore structures. The California Sea Grant program (which was established by legislation in 1966), provides funding for research projects carried out on the nine University of California campuses as well as through the California State University system and other institutions of higher learning. The program also awards scholarships, fellowships and graduate trainee support to those students interested in pursuing coastal issues.

Terrestrial, Freshwater and Estuarine Ecology

Most of the major forestry and range, park and wildlife management agencies have active education and research programs in ecological sciences. Research may take place in nurseries, greenhouses, laboratories, or manipulated field sites. Many of the areas set aside as natural reserves are used as living laboratories for education and research, where important baseline environmental studies can be made.

State and county parks and reserves offer interpretive and educational programs taking advantage of the diversity of coastal habitats. State-funded environmental education programs include on and off-site laboratory programs combining field research with classroom activities. Mini-grants are awarded for specific programs such as the Marsh Awareness with Resources for Slough Habitats (MARSH), which combines low-impact field studies and classroom activities for 224 classes throughout California. Similarly, The Aquatic Ecology Program run by the Eureka City School District is an example of a program using field experience and classroom studies to develop an environmental ethic in school age children. The district is hoping to disseminate the program throughout the state.

A network of outdoor programs run by public agencies, The Resident Outdoor Schools, serve 150,000 elementary school children per year. One third of these camps are in coastal counties. Programs to expose urban disadvantaged or "at risk" youth to outdoor experiences also include coastal programs and camps.

Universities, government agencies and non-profit organizations also extensively use the coast for education and research. The University of California Natural Reserve System protects for study a series of natural areas representing California's ecological diversity. Sixteen of the twenty-six reserves are found in coastal counties and are small samples of a wide variety of habitats including fresh and saltwater marsh, chaparral, redwoods, riparian habitat and interior coast ranges. The program began in response to developmental pressures on wild areas, and the reserves are managed specifically for academic uses.

The University of California Wildland Center similarly awards funding to research and education programs throughout California. The Wildland Center operates under the division of Agriculture and Natural Resources of the University of California and is a multi-campus organized research unit concerned with terrestrial renewable resources. In the coastal area, the Wildland Center operates the Bodega Marine Lab, conducts research on the University of California Natural Reserves, and enters into cooperative research agreements with local governments, the National Forest, or the Nature Conservancy.

Fishery restoration and enhancement programs (discussed in the following section), are also valuable for education. In cooperation with DFG, hatch-boxes or larval rearing tanks for steelhead are placed in many schools, giving grade and secondary school children a chance to learn about anadromous fish life cycles. Hatch-boxes are for hatching and rearing eggs of steelhead while the tanks are for larvae which are donated from a DFG hatchery and reared in the schools. Once fish reach fingerling size, they are released into streams close to the school. Each school only has about 100 fish, making the program's focus mainly educational, and not population enhancement (Larry Preston, personal communication).

On the collegiate level, College of the Redwoods (CR), Humboldt State University (HSU), and University of California, Davis (UCD) have anadromous fish hatcheries. At CR, coho and chinook salmon, steelhead, and rainbow and cutthroat trout are reared for use in the aquaculture program at the junior college. The Fisheries program at HSU also rears coho salmon, rainbow, steelhead, and coastal cutthrout trout. The hatchery manager has a contract to develop a broodstock of coastal cutthroat trout for DFG. In addition, the hatchery is used by aquaculture classes and by students and staff for research. Excess rainbow trout are sold to city of Arcata for public fishing in the marsh project (located near the aquaculture ponds) (Larry Preston, personal communication). UCD rears white sturgeon for education and for research on the undergraduate, graduate and professorial level.

HABITAT/SPECIES RESTORATION

There are many well-known practices which have been employed to repair damaged wildland resources, such as those employed in reforestation, range improvement, mining reclamation practices and fish and game restocking. Such efforts generally restore sites for commodity production or erosion control, but do not necessarily recreate the natural diversity which may have existed previous to disturbance. In recent years, efforts have been made to restore or recreate natural habitats that have been damaged or lost. Natural habitat restoration has been undertaken as mitigation for environmental impacts of new development projects, as well as the repair of older damage. Restoration techniques are often experimental and vary, depending on the organisms and environmental factors of the ecosystem involved. Restoration may involve replanting one or more dominant plant species, reintroducing animal species, removing exotic plants and animals, substituting artificial structures for natural features of the environment, increasing or reducing ecosystem influences such as fire, grazing or predation, and removing exogenous influences such as pollution or sedimentation.

Important restoration attempts in the coastal region include fisheries, riparian habitats, wetlands, oak woodlands, dunes, native perennial grasslands, and kelp, seagrass and eelgrass restoration in marine environments. The National Park Service, the State Departments of Parks and Recreation and Fish and Game, and the Nature Conservancy are among those groups carrying out large restoration programs.

Wetland Restoration

Major restoration activities are focusing on wetlands, which are now recognized as important habitats. Wetland restoration efforts attempt to reverse the direct loss of valuable habitat due to dredging and filling, as well as

more gradual degradation from excessive siltation, loss of buffers, and interruption of tidal or freshwater flows. Some wetland restoration projects may have multiple goals, including mosquito and flood control, aquaculture projects, research and education, or increasing public access. However, most projects are undertaken primarily to restore wildlife habitat or provide mitigation for development of wetlands.

Although remaining wetlands are now protected by law and policy to a much greater degree than in the past, limited development of wetland habitat is still permitted, but only with stringent requirements for mitigation. Mitigation can occur through restoration of degraded wetland habitat, or by the creation of new wetlands from uplands. For example, the California Coastal Act allows one-fourth of a degraded wetland to be destroyed if the remaining three-fourths is enhanced or restored.

The expectation of wetland restoration is that increased habitat quality will compensate for decreased quantity. However, restoration plans often cause environmental degradation themselves. First, mitigation for wetland development may result in a net loss of wetland acreage due to restoration failures. Second, mitigation sometimes involves changing one type of wetland habitat into another, instead of creating wetland habitat from upland habitat. Third, proposed projects are planned and reviewed on an individual basis rather than with a regional perspective. Thus, badly needed coordination of the projects is impossible due to lack of any regional authority. Finally, there is no single source of information on restoration projects and no comprehensive monitoring programs to assess changes in biodiversity (Zedler, 1988).

The objective of restoration should be to replace what has been lost, but it is often difficult to define precisely what has been lost. Coastal marshes for example have been subjected to much disturbance, and it is often difficult to determine specific restoration objectives. Restoration or enhancement projects usually involve partial to complete establishment of freshwater or tidal flows in an effort to stimulate growth and establish vegetation and associated wildlife habitat. Construction of channels or embayments, dike breaching, and the use of tidal gates and culverts are all methods used to increase these flows. Revegetation projects accompany all of these methods. However, the plantings are still considered experimental because of lack of experience with large scale restorations (Josselyn, 1982). Plantings have not always been successful, especially on dredge spoils which may have highly acidic soils.

Restoration can also involve protecting upland areas. The effects of a change in sediment load or freshwater flows in a river upstream can have severe impacts on the delicate balance of a downstream wetland. Revegetation of upland corridors, construction of temporary sedimentation detention structures, and replanting or recontouring of graded areas are all methods used in upland restoration.

Over 30 wetland projects have been completed in the California Coastal Zone and the San Francisco Bay Area with the majority of the projects in the San Francisco Bay (Josselyn 1982). Despite the great need for wetland restoration methods, the science and technology is still young and in some cases inadequate. In general, there is still a poor understanding of wetland processes.

Riparian Habitat Restoration

Riparian and stream restoration projects in the coastal region of California are undertaken for a variety of reasons, including streambank stabilization, fisheries improvement, or project mitigation. They may be carried out by local cities or counties, public interest groups, government agencies, or private developers.

According to the Riparian Revegetation Study Group—Society for Restoration and Ecological Management data base of riparian restoration (The Habitat Restoration Group, 1988), most riparian restoration projects are small, ranging from .5 to 4 acres. There are some large projects in San Diego County involving 150 acre sites.

The projects in Southern California are mostly for mitigation purposes, while the projects in the central and northern counties are undertaken for streambank stabilization and fisheries enhancement.

Seventy-three projects have been completed in Northern California. This total includes 30 small projects (less than an acre) in Humboldt County, and 10 in Mendocino County that were joint CCC/DFG streambank stabilization/riparian restoration projects. The remaining projects were undertaken for habitat enhancement for fish or waterfowl, revegetation, or urban creek restoration.

In Central California, 63 projects have been completed. Many of those in Santa Clara County are larger projects that are mitigation for flood control projects. In Monterey County, the majority of the projects were undertaken for streambank stabilization, with the remaining done for urban stream restoration, beautification, revegetation, or habitat enhancement.

In Southern California, 60 projects have been completed. The majority of the projects were done for mitigation purposes; the remainder for streambank stabilization, revegetation and habitat enhancement.

Fisheries Restoration and Enhancement

Habitat loss, overharvesting, pollution, stream impoundments and diversions, and other causes have resulted in declines in inland resident and anadromous fisheries populations. There is currently a variety of projects to help return fish populations to historic levels in California. Some are combined with ecosystem restoration projects and involve culturing fish to quickly but artificially increase populations.

Enhancement and habitat restoration projects are designed to return fish and wildlife populations to sustainable levels. Enhancement projects attempt to raise population levels by artificial propagation, habitat improvements and other means. Habitat restoration projects involve modifications to disturbed wilderness areas in an attempt to return them to a more natural and useable state. Modifications include placing structures in streams (rootwads, trees, etc.) to increase fish habitat and cover, removing migration barriers such as log jams, revegetation, and stabilizing landslides.

Decreased natural populations of fish and wildlife have become a national concern. Recently, Congress passed two laws requiring restoration of fish and wildlife habitat on the Trinity and Klamath Rivers in Northern California. The Trinity River Restoration Act is a 10-year project (beginning in 1986), costing $57 million and designed to bring fish and wildlife populations back to historical levels. In 1963, the construction of the Trinity and Lewiston Dams devastated fish and wildlife

populations. The Trinity River hatchery was built to mitigate the loss of fish and important habitat. However, in the early 1980s, it was estimated that there were 80% fewer chinook salmon and 70% fewer steelhead trout in the river than before the dam was built. In 1982, a 14-member task force was appointed to study the Trinity River. They determined the critical issues to be addressed for restoration including sedimentation; water quality; physical habitat; water flow problems for mainstream, tributary, and watershed of the Trinity River; and hatchery improvements. Additionally, the Restoration Act provides funds through Trinity County for individuals and organizations to perform other enhancement and restoration projects meeting the goals of the Act (Bill Brock and Mike Stempo, personal communication).

Another federal law, the Klamath River Restoration Act is a 20-year project costing $40 million and intended to bring fish runs back to historical values. Currently, the project is still in the planning and research stage. Baseline data is being collected on habitat types, anadromous fish populations, water flow, watershed problems, and harvesting practices and impacts.

Other similar projects are being carried out throughout the northern part of California with DFG either directing or approving a vast majority of these projects. Presently, money from three separate propositions designated for fish and wildlife is available through DFG. Propositions 19, 70, and 99 provide for funding of restoration and enhancement projects. Individuals, county and local governments, state agencies, commercial fishermen's associations, sport fishing groups, fish restoration organizations, non-profit agencies, Native American agencies, and other organizations participate in these programs.

The Fish and Wildlife Habitat Enhancement Act (Prop. 19) of 1984 created an $85 million bond for increasing the amount of and improving the quality of fish and wildlife habitat. The Wildlife Conservation Board (WCB), has designated $10 million for restoration and rehabilitation of waterways (excluding lakes and reservoirs) in order to improve fish habitat. To date 55 waterways projects have been approved for anadromous salmonid fishes (chinook and coho salmon and coastal cutthroat and steelhead trout) (Edon,1989). Proposition 70 requires a stamp be bought each year by all commercial salmon fishers. Money from the stamps is used for projects intended to increase salmon populations. Projects include migration barrier modification, watershed rehabilitation, fish culture, and similar work (Department of Fish and Game, 1989A and Larry Preston, personal communication). A small percentage of the money from Proposition 99 which taxes cigarettes is now being used for restoration of salmonid and warmwater fish habitat. Even though the proposition was approved only last year there are already 60 accepted enhancement and restoration projects costing over one million dollars (Department of Fish and Game, 1989A and Harvey Reading, personal communication).

Artificial propagation is utilized to boost natural populations quickly. Several American Indian tribes also rear salmon for enhancement of local populations. The Yurok have three pen rearing sites, the Hupa have a rearing facility and produce 80,000 chinook salmon, and the Karuk also rear salmon. The Humboldt Fish Action Council, the Mattole Watershed Salmon Support Group, the California Salmon,

Steelhead and Trout Restoration Federation, the Pacific Coast Fisherman's Federation Association and other organizations interested in restoration contract with DFG to enhance or restore salmonid fish populations. Many of these organizations have trapping facilities to capture mature salmon and steelhead traveling upstream to spawn. Typically, adults are spawned and the eggs held and reared in hatcheries until the larvae can be transferred to pens and ponds. Once they are of adequate size, the fish are released into creeks and streams. Fish reared in hatcheries, pens, or ponds not only have higher survival rates but tend to be larger at the same age than their wild counterparts. These facilities are capable of producing from 10,000 fish to over 200,000 fish each year and make a significant contribution to anadromous fish populations (Jud Ellinwood, Larry Preston, and Mike Stempo personal communication).

Some local governments such as the city of Arcata and the county of Humboldt rear anadromous fishes. The city of Arcata uses fish to help treat sewage (integrated reuse system), at the aquaculture ponds, for research and education, and for restoration and enhancement (Allen et al., 1982). Presently, they are culturing sturgeon, chinook and coho salmon, and rainbow and coastal cutthroat trout. Students from Humboldt State University do research for graduate theses and for class projects at these ponds. Salmon are released to a local creek (Jolly Giant Creek) for restoration of the population. The project has also restored valuable wetlands to the area. Only 10% of the original wetlands remain around Humboldt Bay. Marsh ponds were built to provide enhanced secondary treatment for waste water.

Prairie Creek Hatchery started rearing salmonid fish in 1961 and is the only county operated hatchery in the state. It rears about 35,000 chinook salmon, around 125,000 coho salmon and approximately 70,000 steelhead. Fish are released into Lost Man Creek (a tributary of Prairie Creek), for enhancement and restoration of native populations.

The Department of Fish and Game is the largest producer of anadromous fish for enhancement and mitigation. Of the 10 anadromous fish hatcheries run by the state, six are for mitigation due to power or water projects, and the other four are for enhancement of wild populations (Bruce Barngrover, personal communication). Many of the fish cultured are utilized by commercial and sport fishers thereby reducing the number of wild fish harvested. By far chinook salmon is the most cultured fish accounting for almost 90% of all fish produced by DFG. Steelhead and other salmon are also grown at state hatcheries. Striped bass are cultured at only one state-operated hatchery and more than three-fourths of all those planted for enhancement are purchased from private hatcheries by DFG (Mayo Associates, 1988).

Marine Restorations

Restoration techniques for giant kelp were developed in the early 1960s in order to reverse a decline in Southern California kelp beds (Wilson and McPeak, 1983). After the mid-1940s kelp beds in Southern California declined in size, particularly adjacent to large metropolitan areas (Harger 1983). The declines have been attributed to both human activities and natural factors. Restoration efforts from 1963 to 1980 focused on controlling grazing sea urchins and transplanting adult kelp plants. Restoration efforts, improved water quality from changes in dredging and waste-discharge practices, and commercial harvest of red sea

urchins are thought to have led to the dramatic recovery of the Point Loma and Palos Verdes kelp beds.

Huge storms during the 1982-1983 El Niño destroyed most of the kelp beds in California (see Chapter Two—Biology for more information). To replace kelp lost in 1982-1983, the Department of Fish and Game sponsored restoration programs in two major kelp bed areas, one in Orange County and one in Santa Barbara County. In Orange County from 1986 to 1988, kelp was restored to rocky habitats by collecting small juvenile and large adult plants from forested areas and transplanting them to nearby deforested sites. Competing algae and grazing sea urchins were also removed as necessary. In Santa Barbara, attempts were made to restore kelp to soft-bottom areas. Such restoration efforts require the provision of suitable substrate for kelp settlement and growth in an otherwise inhospitable, unconsolidated environment. In a mature sand-based kelp bed, large holdfasts of established plants serve as important substrates for the colonization of young kelp plants. Consequently, much of the effort in restoring kelp to the Santa Barbara area has involved deployment of "artificial growth centers" that mimic the holdfasts of established plants. Current techniques include transplanting young kelp plants to artificial growth centers constructed of chain link fencing attached to concrete mushroom anchors. In 1988 large storms again damaged kelp beds in California. The kelp beds in Orange County had recovered by summer of 1989. The beds in Santa Barbara County are presently being monitored to determine the success of transplantation efforts (K. Wilson, Department of Fish and Game, personal communication).

In late 1988, Exxon began a pilot program to develop techniques for restoration of surf grass (*Phyllospadix spp.*) that will be removed during installation of oil and gas pipelines near Las Flores Canyon in Santa Barbara County. They are testing techniques for attaching surfgrass to rock as well as techniques for stockpiling surfgrass for later reintroduction to the pipeline corridor.

POPULATION TRENDS

California's growth has far outstripped that of the United States as a whole over the last 10 years. According to preliminary figures from the 1990 Census, California added some 5.6 million people, raising the population of the state to 30 million, or almost 12% of the United States' total population.

New patterns of growth are reflected in this latest tabulation of who lives where. While it remains true that the northern part of the state grew more slowly than Southern California, traditional patterns have been broken. The City of Los Angeles actually lost percentage shares of the state's population, going from 18% of the total in 1980 down to 11.6% in 1990. The Central Valley, the Sierra foothills and the Southern desert were the magnets of the last decade. Growth rates of cities and towns like Folsom and Palmdale ranged from 167% upwards to 601%.

And in an important change, for the first time the coastal counties of California, from Del Norte to San Diego, lost a significant percentage share of the state's inhabitants. In 1980, these counties held 62.1% of our neighbors; now the share is only 59.8%. While this still means almost 18 million of us live on the shore side of California, the trend is clear.

Most analysts explain the shift on the high cost of housing, transportation gridlock, poor air and water quality and a gradual shift in jobs.

Trends shown in this census, if continued over the next decade, will lead to slower growth in the established urban centers of the Los Angeles basin and San Francisco Bay, while the agricultural valley and wilderness desert will be lost to near doubling of the current populations. The coastal counties will grow at a rate in between these areas, and will continue to concentrate the state's wealthier population.

RESIDENTIAL

In general, employment is the magnet that draws people to an area where they then seek housing. This pattern is modified in the coastal zone where people often settle for reasons associated with a particular lifestyle. Some 80% of California's 26 million people live within 30 miles of the coast, where housing costs often are the highest in the nation.

The coast of California exhibits a broad range of residential uses, from single homes tucked away on large acreages to 60+ unit per acre buildings.

Whatever the density, houses do not stand alone. They presuppose a vast network of services that also physically define the landscape. Roads, sewers, utilities, market areas and employment centers exist in conjunction with the residential uses.

City and county general plans and zoning ordinances govern the location of residential development. The Coastal Commission oversees most residential development within the area defined in the Coastal Act of 1976 as the coastal zone.

Residential development has a number of impacts. The beneficial impacts include shelter, home and hearth. The adverse impacts involve occupation of land, consumption of public services and generation of undesirable by-products.

Occupation of land by residential uses directly precludes other use options, such as industrial, commercial, agricultural, recreational and open space uses.

The occupation of land also consumes available public services including potable water, sewer, fire, police, roads, schools and utilities.

The by-products of residential development include traffic, air and water pollution, visual intrusion, solid waste, siltation caused by improper grading, increased urban run-off due to use of impervious surfaces, and sewage disposal through ocean outfalls.

Finally, much as with tourism, a very significant result of residential development can be the introduction of new people to the area, creating new attitudes about the subsequent use of adjacent or nearby property. These attitudes may limit other land uses. Evidence of this phenomenon is the number of slow growth/no growth initiatives appearing statewide.

OIL AND GAS EXTRACTION

There are 11 sedimentary basins that contain thick sections of ancient marine sediments and geologic structures favorable for the accumulation of oil and gas deposits within California's coastal zone. These basins are commonly known as the Southern California Shelf; the San Diego Offshore Area; the Los Angeles Basin; the Santa Barbara-Ventura Basin; the Santa Maria Basin; the Salinas Basin; the Santa Cruz Basin; the Bodega Basin; the Point Arena Basin (which does not include any state tidelands); the Eel River Basin and the

Bear-Mattole Offshore Area. Though all of the basins may contain oil and gas deposits, up until now only the Los Angeles, Santa Barbara-Ventura and Santa Maria Basins have produced oil and gas.

The first offshore drilling and development in the U.S. was from wooden piers that extended into state offshore tidelands from the Summerland shoreline in Santa Barbara County.

As new oil and gas deposits were discovered further from shore and at greater depths, new drilling and development methods had to be devised. Generally, these methods are classified as fixed and mobile drill-sites.

Fixed drill-sites include onshore locations (with wells drilled directionally to offshore deposits), piers, man-made islands, permanent platforms and remote control subsea well completions. Mobile drill-sites include semi-submersible drilling rigs, jack-up rigs and drillships. Both types of drill-sites can be used for exploratory drilling; however, fixed drill-sites are used mainly for developmental/production drilling.

Whether the drill-site is used for exploration or production, all aspects of drilling must undergo comprehensive reviews, approvals and constant monitoring to assure compliance with all federal, state and local agency rules, regulations and mitigation measures.

MINING/SAND AND GRAVEL

California is blessed with an abundance of mineral resources which are being developed to benefit global society. California produced an estimated $2.5 billion of non-fuel minerals in 1987 (up from $2.3 billion reported in 1986), leading all other states. California also led the nation in the production of boron minerals, Portland cement, diatomite, calcined gypsum, construction sand and gravel, rare-earth metal concentrates, tungsten ore and tungsten ore concentrates. It was second in the production of gold, natural calcium chloride, magnesium compounds from sea water, sodium compounds and wollastonite.

A wide range of minerals occur in California's coastal zone and waters. Present production includes sand and gravel for aggregate use; sand for filtration, glass making, abrasives and other specialty uses; shells as a source for lime; stone quarried for rip-rap and shore armor rock; magnesium compounds and other elements from seawater.

As urbanization encroaches on upland mineral production in the coastal zone and as local land use policies further constrain mineral development, demand by the public for construction aggregate, energy and fertilizer may force increased production from the offshore zone. Coastal mineral resources which will be available for development as markets open and certain technologies advance will be offshore gold and heavy mineral black sand deposits from rivers that have coursed through mineralized zones; phosphorite, an essential fertilizer material found offshore from Baja to San Francisco and in the Federal Extended Economic Zone (EEZ); and polymetallic sulphide nodules which may be produced by dredging.

FORESTRY/TIMBER

Forestry is defined as the management of forestlands for the production of renewable natural resources, including timber, firewood, recreation, wildlife habitat and watershed protection. Within the context of CCORS, the

discussion of forestry is limited to the commercial production of timber in the coastal region, extending inland over all the hills and mountains along western California, the Klamath-Siskiyou Range in the north, the Coast Ranges, and the Transverse and Peninsular Ranges of Southern California.

Forest practices on private lands in the state are regulated by the California Board of Forestry, with the agency support of the California Department of Forestry and Fire Protection (CDF). Information used in this section is from California's Forests and Rangelands: Growing Conflict over Changing Uses (CDF, 1988).

Of the total 16.5 million acres of potentially commercial timberland in California, about 3.9 million acres is located in the the coastal region. Most of this coastal forestland (2.9 million acres or 73%), is privately held. The U.S. Forest Service manages an additional .7 million acres, and the remaining .3 million acres is under various other public jurisdictions.

Almost 90% of coastal timberland is located in the three most northern coastal counties. North coast timberlands consist of redwood, Douglas fir, and other conifer forest types. One third of the state's annual timber harvest (over one billion board feet) comes from the productive forests of the north coast. Most of the timber harvested in the north coast is from privately owned lands, unlike the rest of the state which has harvest volumes split more evenly between the private sector and the Forest Service.

The economic value of the timber industry in California is difficult to assess because of the highly variable price of wood and wood products. Most California timber is used for lumber and the value of lumber produced each year in the north coast is about $600 million. The high economic value of the lumber from this region is due primarily to the large volume of redwood harvested.

Another important economic aspect of forestry in the north coast region is the high employment provided by the lumber and wood products industries. Over the last decade or so, forestry-related jobs have accounted for up to 51% of the total employment in the three north coastal counties. This is in sharp contrast to the state as a whole, where these types of jobs account for less than one percent of total employment.

FARMING/AGRICULTURE

For the past 39 years, California has been the leading agricultural state in the United States and agriculture has become a $14 billion dollar a year industry (CDFA, 1988a). Over 250 different types of crops and livestock commodities are produced throughout the state on over 79,000 farms and ranches. Livestock and dairy products generate the highest cash receipts at $3.5 billion a year, while fruits and nuts generate $3.3 billion a year, vegetables and melons $3.3 billion, field crops $2.5 billion, and nursery and foliage products $1.3 billion (Ibid).

Coastal counties generate 14% of these total values. These coastal counties grow a wide diversity of crops and also support one-third of the growing nursery industry. The diversity of California's coastal geography and climate is reflected in each county's agricultural production.

The northern counties are, in general, rugged in topography with cold rainy climates not conducive to agriculture. A few field crops

grow along river plains but logging is generally the main industry in northern coastal counties.

The southern and central coastal counties, however, have climates and geography highly conducive to agriculture and in some counties agriculture produces the highest gross revenue (UCD, 1982). Topography varies in the central and southern counties but generally a wide alluvial plain sloping from the coast provides fertile soil for croplands. The central counties grow mostly grapes, apples, pears, vegetables and nursery products while the southern counties grow vegetables, citrus, and nursery and specialty crops. In some of the counties the growing season is year-long with double and triple cropping practiced.

Monterey County ranks fourth in overall state agricultural production generating over one billion dollars a year, since many vegetables can be grown year round including high value specialty crops such as asparagus, artichokes, and mushrooms. San Diego and Ventura counties also have year long growing seasons with citrus and specialty crops such as avocados. Many of the coastal counties are able to grow flowers and foliage year round as well (UCD, 1982).

While California agriculture continues to thrive, the push to urbanization, especially in the coastal region, has led to the displacement of prime agricultural lands (League of Women Voters, 1981). One result of this displacement is a shift to more intensive agricultural practices and a conversion from cash crops to high value specialty crops. As intensification increases, the soil may become overworked and susceptible to erosion. In an attempt to raise productivity, the agricultural industry has been relying on increasing amounts of pesticides and fertilizers. (League of Women Voters, 1981). Although pesticide use is regulated to a certain extent by the California Department of Food and Agriculture, contamination of water, soils, and crops is often a serious problem. Pesticides used in agricultural practices even find their way into coastal bays and estuaries (CSWRCB, 1988).

RANGE/GRAZING

California's range and livestock industries consist primarily of beef cattle and sheep production. At least 41 million of 100 million acres in California are considered rangelands suitable for livestock forage production of some kind. Rangelands include grasslands, forest, woodlands, shrublands and desert.

The coastal counties contain about one-fifth of the state's total rangeland, most of which is grassland located in the central coastal region. Grazing occurs in all coastal counties except San Francisco.

The state's annual livestock production is currently valued at $454 million, including approximately $100 million from San Luis Obispo and Santa Barbara Counties. The north and south coast regions are a relatively small part of the grazing industry (California Department of Forestry and Fire Protection, 1988).

The economic value of the range industry has been steadily declining over the last 25 years, especially in lamb production. One of the main causes of this downward trend, which is predicted to continue into the future, is the loss of rangelands to urban and agricultural development.

MARICULTURE

Seafood is an important food source throughout the world. To supplement

production from natural populations, mariculture, or the farming of marine species, has become common practice worldwide. Only recently, however, has the United States begun to promote its mariculture industry. This increased interest in ocean farming is especially evident in California where there has been a doubling of the areas used for mariculture since the passage of the California Aquaculture Development Act in 1979.

Currently, there are at least 4872 acres leased for mariculture (primarily shellfish) in the state. The California Department of Fish and Game has leased 2675 acres. The others are private leases. The vast majority of leases are in the sheltered and relatively shallow waters of bays, estuaries, lagoons, and sloughs (Figure 1-11). Tomales Bay, Humboldt Bay and Elkhorn Slough are particularly active lease sites. Offshore leases along the open coast are less common and are largely restricted to protected sites in the Santa Barbara Channel.

Water quality poses the greatest problem for shellfish growers, and related concerns about the effects of pollutants on human health have curtailed the rapid development of the shellfish industry. Products such as oysters and mussels which filter water to obtain food, are of special concern because in the process of feeding they also pick up pollutants and concentrate them in their tissues. This poses a problem because these animals are usually eaten whole and often raw. In addition, certain dinoflagellates (a group of unicellular algae commonly ingested by many filter feeding animals), contain natural neurotoxins which, like pollutants, accumulate in the tissues of shellfish.

The consumption of shellfish contaminated with these toxins causes paralytic shellfish poisoning (PSP), a serious and often fatal condition. PSP is a much greater concern for shellfish growers in the northern part of the state since the species of dinoflagellates that are known to cause PSP are much more abundant there than in Southern California.

Wastewater discharges have been of primary concern with respect to water quality, and the implementation of the Clean Water Act has resulted in lower coliform bacteria counts in all the major growing areas. The California Department of Health Services, Environmental Health Division carefully monitors the effects of both point-source and nonpoint-source pollution. The latter is harder to control, and agricultural runoff is a potential problem in many estuaries (e.g, Elkhorn Slough, Arcata Bay, Tomales Bay, and Morro Bay), where mariculture operations are concentrated (Figure 1-11).

Physical characteristics that influence the biological components of water quality are also of concern in locating suitable lease sites for mariculture. Currents, nutrients, salinity and water clarity are all important in determining the quantity of phytoplankton or particulate organic matter that the animals use for food. Water motion from currents or wave action is usually beneficial because it provides a continual supply of food. Excessive water motion, however, makes it difficult to keep culture structures in place.

Although some leases are used for research or the provision of broodstock, the majority of mariculture leases grow a product to be sold as food. Product marketability depends on appearance as well as perceived quality. Buyers of whole animals prefer a uniform size and an attractive shell. California shellfish are relatively fast growing in comparison to those animals grown in other parts of the world. This

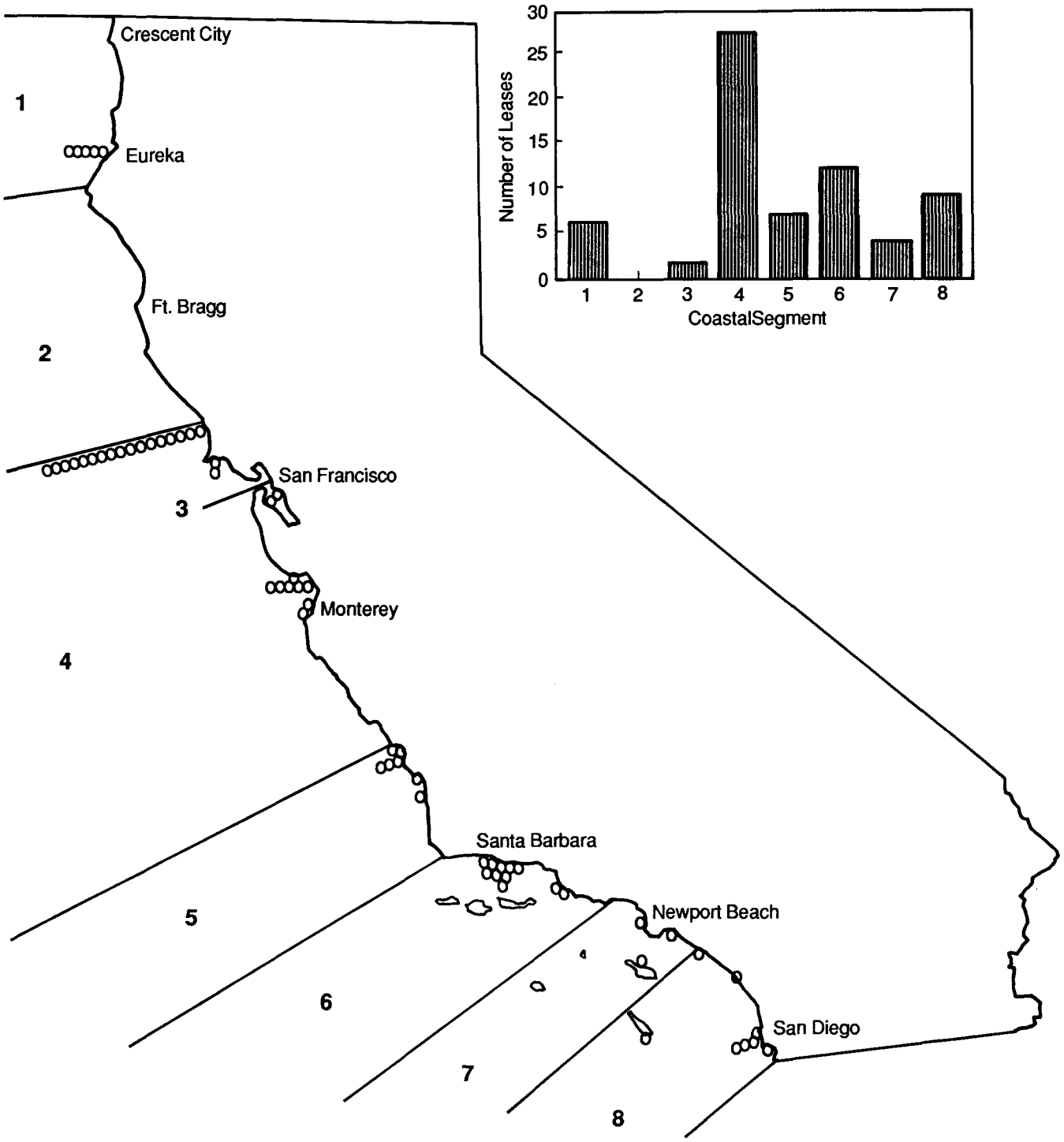


Figure 1 - 11: Mariculture lease sites in California. The histogram shows the number of leases in each coastal segment.

fast growth, however, results in shells that are thin and easily broken. The industry is currently seeking mechanical ways to ready the crop for market. But until a method is found, hand-cleaning techniques add to labor costs.

The three most common mariculture crops in California are oysters, mussels and abalone. Of these, oysters are the oldest, largest and most heavily regulated and are grown on the majority of leases in the state. Current production is approximately 3,850 tons per year, of which most is the Pacific oyster (*Crassostrea gigas*). Most oysters are grown in "beds" either directly on the bottom or in trays placed on the bottom. Beds are generally "seeded" using broodstock purchased from growers that specialize in this service. Off-bottom methods (suspended racks and bags) have recently been adapted from French techniques that are more expensive but reduce predator losses and contamination from polluted sediments.

There is a growing demand worldwide for mussels. Traditional European mussel beds have been contaminated, and California growers hope to exploit that export market. In the state, mussels (*Mytilus edulis* and *M. californianus*) are grown off-bottom using long-line techniques similar to those used in Italy. In shallow waters, the lines are suspended horizontally near the surface and can reach for more than fifty yards. In the open ocean, lines are suspended vertically from buoyed structures that are anchored to floats about thirty feet below the surface. Unlike oysters, mussel seed is obtained from natural spatfalls that attach to ropes and bags suspended in the water.

In contrast to oysters and mussels, leases for abalone (*Haliotis rufescens*) farms are almost entirely onshore where the animals are grown in tanks supplied with running seawater. Abalone are slow-growing grazers that begin life eating microscopic algae. They are weaned to feed on giant kelp (*Macrocystis pyrifera*) when they are approximately six months old. After this time, they are kept at specific densities and repositioned as little as possible to avoid mortality from handling. Because these animals are grown in environmentally controlled tanks and do not filter their food, public health concerns associated with coliform bacteria are less of a problem for abalone culture than for shallow water oyster and mussel cultivation. Nonetheless, the high overhead costs associated with feed and pumping seawater make abalone a much more costly crop to produce.

Mariculture in California waters is expanding. There is increased demand for shellfish and fin fish that can no longer be met from harvesting wild populations. More intensive leasing in protected bays and inlets along with increased interest in open ocean leasing can be expected in the future. In addition, the growing diversity of shellfish crops is expected to include sea urchins, rock scallops and shrimp. Meanwhile, there is ongoing research into the feasibility of enhancing fin fisheries such as halibut and white seabass by planting hatchery-reared fish (Anonymous in California Aquatic Farming, 1989).

AQUACULTURE

Aquaculture, the farming and husbandry of aquatic species such as fish and shrimp, is a growing industry worldwide and is expected to account for approximately 25% of all seafood consumed by the year 2000 (Ratafia and Purinton, 1989).

In California, there are over 260 aquaculture individuals and companies licensed to rear and

sell fish, invertebrates, algae and frogs. Seventy of these are registered to handle anadromous fishes. Some of these farms have a single species of fish, while others culture more than 20 various aquatic organisms (Department of Fish and Game, 1988).

A multitude of freshwater species are grown in the coastal counties of California. Rainbow trout, catfish, bluegill, Sacramento blackfish, sunfish and bass are reared at several facilities. Fee fishing for rainbow trout, catfish and bass is available at some facilities, while others sell their crop to the Department of Fish and Game (DFG) for stocking sport-fishing sites, or selling to restaurants or the public.

Striped bass (*Morone saxatilis*), white sturgeon (*Acipenser transmontanus*), salmon (*Oncorhyncus sp.*), and steelhead trout (*Oncorhyncus mykiss*) are the anadromous fish species cultured in California (Department of Fish and Game, 1988). Striped bass, introduced to California in the 1800s, is highly valued as a sport fish, but because of overfishing the commercial fishery for it was halted. Most private growers sell their bass to DFG for stocking programs. Striped bass and sturgeon account for practically all the anadromous fish-rearing facilities in Southern California (18 out of 21), although these farmers also rear freshwater species (Department of Fish and Game, 1988). In commercial production facilities, male striped bass are hybridized with female white bass to produce a hardier strain of fish. Typically, the hybrid reaches market size (one to two pounds) in a year and a half, and is worth less than $3.00 per pound at pond side. Aquatic Systems, Inc. (ASI) in San Diego has spent 15 years and $3 million on research and development of the first hybridized striped bass hatchery. In three years, ASI has produced more striped bass than have been landed by the entire commercial fishing fleet. Their success lies in their water source—geothermal wells—which allows them to produce a two and one-half pound bass in 18 months (Van Olst and Carlberg, 1990).

White sturgeon (revered as a delicacy not only for its meat but also for its roe), is grown in California to market size (8-12 pounds) in two to three years. Sturgeon need high dissolved oxygen levels to thrive, thus requiring these hatcheries to have good aeration systems. Poor water quality decreases production by reducing the carrying capacity of the facility and increasing susceptibility to disease. Sturgeon thrive on commercially available dry and semi-moist artificial feeds designed for salmonids (Hung, 1989).

Seven facilities in the state culture Atlantic salmon. Atlantic salmon are an East Coast species valued by growers for their good meat, fast growth rates, and non-aggressiveness. They grow to market size in less time (one to two years) than any species of Pacific salmon. Steelhead, coho (silver), chinook (king) and pink salmon are also reared in California. In hatcheries, salmon and trout are spawned artificially. When the fish are ready to spawn they are gently manipulated so that the sperm and eggs can be collected separately. The eggs and sperm are mixed later and the eggs reared in incubators. Once the eggs develop into young fish capable of feeding, they are placed in tanks or trough fed several times a day. From this point they are grown out in the hatchery or by "ocean ranching" or "pen-rearing."

Ocean ranching (extensive culture) and pen-rearing (intensive culture), are the two most common methods of rearing salmonid fish. In ocean ranching, salmon are reared in hatcheries only long enough to imprint on the

facility and then are released to grow out in the ocean along with wild fish. The salmon return to the facility to spawn and this is when they are marketed. Returns tend to be low with this method due to predation by animals and commercial and sport fishers.

These low yields are resulting in a switch to pen-rearing. In this method, juveniles are placed in wire mesh floating cages and held in bays, sounds and estuaries where they are fed artificial feeds. The cages must be cleaned of fouling organisms regularly to prevent the cage from becoming so clogged the fish suffocate. Due to the crowded conditions in the pens, disease is always a problem. Wasted feeds and excreta can also load a small waterway with excess nutrients possibly leading to eutrophication.

Crayfish (*Procambarus sp.*), tubifex worms and frogs are also raised in the coastal zone. Typically, these three native species are not the sole organism being cultured but are reared in the same ponds as fish and do not require much care. Crayfish and tubifex worms utilize excess fish food preventing it from being wasted and rotting in the ponds, thereby benefitting the farmer and resulting in another crop. Tubifex worms are excellent food for aquarium fish and can be purchased live and freeze-dried, while crayfish and frog's legs are considered a delicacy by many restaurant goers.

Mosquito fish (*Gambusia sp.*), *Tilapia sp.*, grass carp, goldfish, and koi (an ornamental fish) are warmwater fish introduced to the state and cultured in the coastal zone. *Gambusia sp.* are known to predate on the pesky mosquito, *Tilapia* are sold for food in ethnic markets, and goldfish and koi are utilized in the aquarium trade. Sterile grass carp (triploids) are aquatic mowers eating excess vegetation in aquaculture ponds. Baitfish (shiners and minnows), shad and bullheads are also popular freshwater fish for California culturists.

While some growers choose to rear one species exclusively (monoculture), others may rear two or more in the same ponds or systems (polyculture). Polyculture increases profits and maximizes production and efficiency with a minimal investment. Species which inhabit different trophic (feeding) levels such as shrimp (which are bottom feeders), and striped bass (which are surface feeders), can be successfully reared together without the two competing for food. Currently, research is being conducted on the polyculture of salmon and red seaweed at Oregon State University. The seaweed is used to treat hatchery effluent water in order to reduce eutrophication of surrounding waters. Not only does the algae benefit the environment and reduce costs of treating hatchery effluent, but also results in an additional marketable crop, algae (Levin and McNeil, 1989).

The growth of aquaculture as a profitable industry has led to new products and markets in chemicals, aeration systems, feeds and other areas. Aquacultural ponds and hatcheries require various machinery, equipment and products to keep them producing (similar to agricultural farms). Artificial feeds are formulated to meet the requirements of the cultured species. The feed industry alone is already worth over a billion dollars and is drawing producers of agricultural feeds into the market. These feeds are much like those used for domesticated animals and are designed to replace live foods (algae, rotifers, brine shrimp, etc.) (Ratafia and Puriton, 1989). Artificial diets yield efficient feed conversion ratios: one and one-half to two pounds of food ingested per

one pound of weight gained, whereas livestock generally take five pounds of feed to gain one pound of flesh.

In addition to feed companies, there are other California- based corporations which are involved either exclusively or partially in selling products to aquaculture facilities, ranging from nets to specific artificial feeds. San Francisco Bay Brine Shrimp is an example of a California based international corporation which produces aquaculture products. Their main product, the brine shrimp Artemia, is reared in salt production ponds at Leslie Salt Ponds in San Francisco and at Western Salt Ponds in San Diego. Brine shrimp are sold as cysts (a resting stage), live, frozen and freeze-dried. Their markets include the aquarium trade, researchers, and aquaculturists, both national and international. They also sell other foods such as dried krill and plankton. Other corporations are bringing satellite companies to California to import products such as artificial foods, live broodstock (animals used for spawning), chemicals and supplies.

A discussion of hatcheries used in research and education, and fishery restoration and enhancement is found in the Protection of Biological Diversity Section of this chapter.

KELP AND SEA VEGETABLE HARVESTING

Giant kelp (*Macrocystis pyrifera*) was first harvested in California in 1911. The kelp was used to produce acetone for the manufacture of explosives used in World War I (Department of the Interior, 1981). Now most of the kelp harvest is used for the extraction of algin, a product used as a binder, stabilizer, emulsifier, and molding material in pharmaceuticals, cosmetics and soaps, dental and food technology, and a wide variety of food and industrial products (Levring et al. 1969). There is also growing interest in harvesting kelp for abalone feed in mariculture facilities (see above).

For the purposes of harvesting, giant kelp beds are classified by the Department of Fish and Game into three types: 1) those that are leased, 2) those that are not leased but available, and 3) those that are reserved and cannot be leased. There are 74 such designated giant kelp beds in California (see Chapter Two—Biology). All three types of kelp beds can be harvested, though leased beds can only be harvested by the lessee. Non-leased (available) and reserved beds can be harvested by anyone providing that not more than 50% of the canopy be harvested during any three-month period. In all cases, only those portions of the plant within four feet of the surface can be removed. This reduces plant mortality and allows for rapid regrowth following harvesting.

Presently there are seven lessees in California waters. The biggest by far is the Kelco Division of Merck and Company, which is one of two lessees to harvest kelp for the extraction of algin. Four companies harvest kelp for abalone feed, while another leases kelp beds for research purposes.

Approximately 76,000 tons of kelp were harvested in 1988. Figures for the market value of the kelp harvest are not available, but the royalty to the state was over $156,000. Most of the kelp harvest comes from Southern California where the majority of giant kelp is found (Figure 1-12). Historically, the beds off San Diego, Santa Barbara and San Nicolas Island have been among the most productive areas for harvesting. Although annual kelp harvests have fluctuated over the last 50 years,

an unprecedented decline occurred in the early 1980s (Figure 1-12) due to the warm nutrient-poor waters and severe storms that were associated with the 1982–83 El Niño. Kelp harvests have yet to return to pre-El Niño levels. This is largely because the sand-based kelp beds off Santa Barbara, which account for a substantial portion of the total kelp in California (see Chapter Two—Biology), have been slow to recover (R. McPeak, Kelco Co., personal communication).

Most algae that grow in California are edible. While the Japanese have fully exploited native stocks and have extensive mariculture operations to grow algae, there has been little use of algae in California. However, three companies harvest approximately 20 tons of algae a year from intertidal areas in Mendocino County for sale in local health food stores (J. Lewallan, Mendocino Sea Vegetable Co., personal communication).

DESALINATION PLANTS

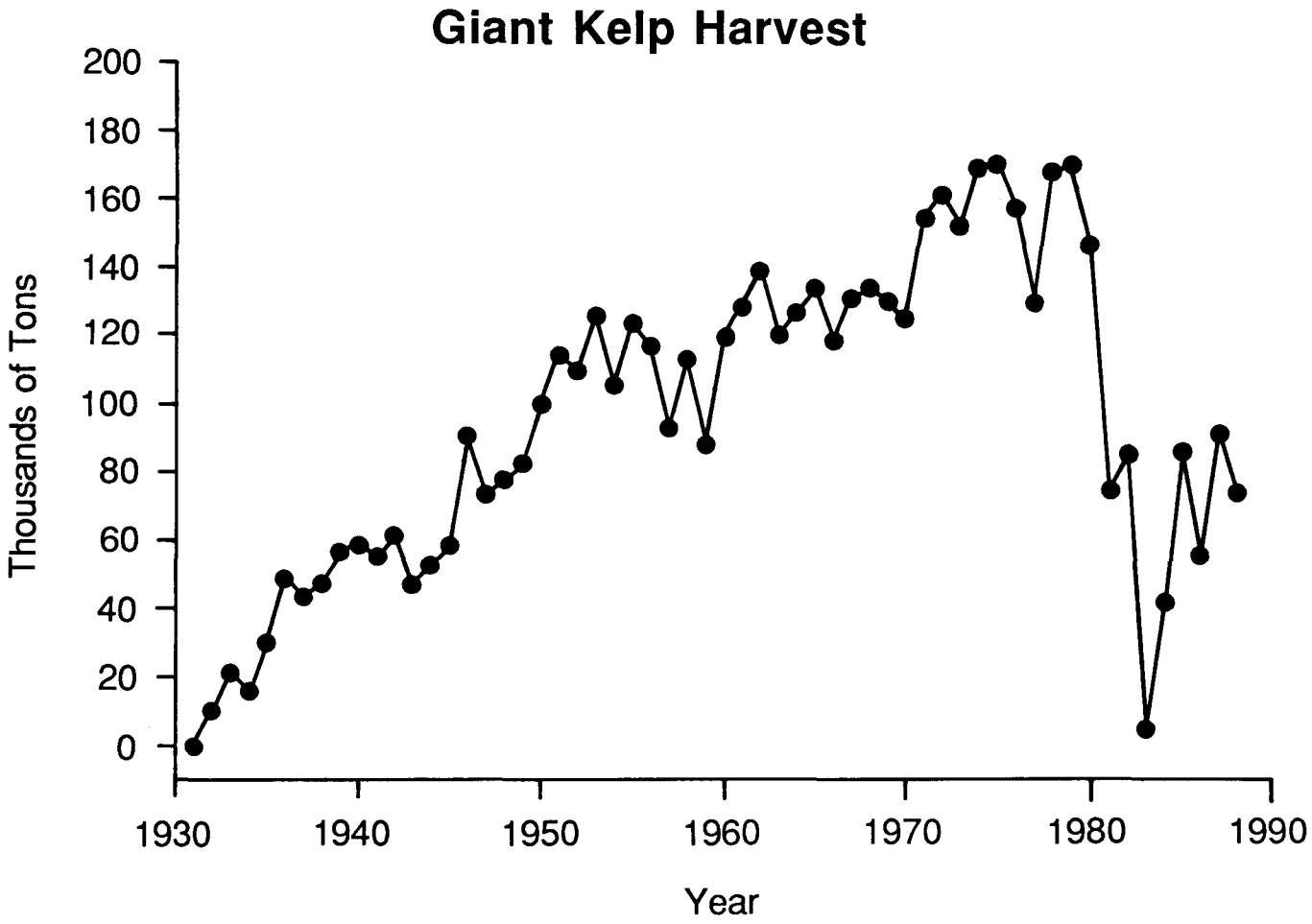
Desalination is a method by which pure water is extracted from saline water. In typical coastal facilities, sea water is pumped to a plant where it undergoes osmosis: water molecules pass through a screen or membrane too fine to admit salts or other molecules. There is limited use of the process in California because the materials which must be used in the corrosive saline waters are extraordinarily expensive. An oil processing plant in Santa Barbara County has the only major desalination plant on the West Coast.

SALT PRODUCTION

Salt (sodium chloride) production from solar evaporation of sea water is conducted in only a few places worldwide, where suitable conditions of climate, tides and large open areas exist. In this industry, sea water is brought into a system of evaporation ponds covering hundreds to thousands of acres each. The brine becomes more concentrated as it is moved from pond to pond over time. When a suitable concentration of salt is reached, the brine is crystallized and mechanically harvested (BCDC, 1969). Two areas of the California coast are sites of commercial salt production: San Diego Bay and San Francisco Bay.

The Western Salt Company, located at the south end of San Diego Bay, produces 40 to 80 thousand tons of salt annually from 1,300 acres of evaporation ponds. The company produces salt for industrial uses exclusively (G. Warner, personal communication, 1989). The Leslie Salt Company currently owns about 9,000 acres in San Pablo Bay and 28,000 acres in south San Francisco Bay (ESA/Madrone, 1982). Leslie's annual production is about 1.2 million tons, with most for commercial and industrial uses, and a small percentage sold as table salt (G. Morris, personal communication, 1989).

Historically, salt ponds replaced large areas of tidal marshes in San Francisco Bay and the central and south coast regions (ESA/Madrone, 1984). At the same time, however, the salt industry provided an environmental benefit by keeping large areas in open space which might otherwise have been lost to filling, reclamation, or dredging for industry, houses and agriculture. More importantly, evaporator ponds and the surrounding levees have high wildlife value. The salt pond systems sustain abundant populations of invertebrates such as brine shrimp and various fish species. These rich and sheltered feeding grounds, along with the nearby levee systems which provide high terrain for nesting or refuge, support thousands of



AREA	HARVEST (IN TONS) 1987	1988	REVENUE 1987	1988
Southern California	51,827	12,976	$96,519	$52,620
Channel Islands	38,469	42,619	53,952	71,404
Central California	2,963	20,030	14,331	32,166
Unknown	6	29	9	44
Total California	93,265	75,654	$164,811	$156,234

Figure 1 - 12: Total harvest and revenue of giant kelp in California.

migratory and resident shorebirds, waterfowl and wading birds. (See numerous studies cited in California Environmental Trust, 1987; Jones and Stokes, Associates, Inc., et al, 1979.)

In San Francisco Bay, the San Francisco Bay Conservation and Development Commission has primary state jurisdiction over the salt ponds. The Bay Plan (1969) recognizes the environmental values of the salt ponds, calling for maintenance of a viable salt industry to the maximum extent possible. The Corps of Engineers also has permit jurisdiction over salt ponds under Section 404 of the federal Clean Water Act.

POWER PRODUCTION

California uses electricity generated by almost every method known. Oil and gas fired plants, nuclear generators, hydroelectric dams, geothermal fields, wind generating fields and solar operations all exist within the state, and some power is also received from coal fired plants outside the state. These power facilities depend on geology, geography and climate, thus their geographical distribution is not uniform. For example, the 47 fossil fuel plants are concentrated in the southern half of the state, with only 13 north of the Tehachapi Mountains. On the other hand, the state's 68 hydroelectric plants are concentrated in the wetter northern and central parts of the state, with only seven in the dryer south. Geothermal plants are located in Lake, Sonoma and Imperial counties, while the majority of the state's wind power comes from just east of San Francisco Bay. There are currently five nuclear plants in the state, of which only three are operational (two plants are co-located at Diablo Canyon). Four are located at coastal sites in Humboldt, San Luis Obispo and San Diego counties.

This distribution is no accident. Each type of power production facility has special requirements, both for the power source and for the plants themselves. Fossil and nuclear plants are most efficiently located near bodies of water which can provide cooling, and need access to pipelines or road/rail networks to provide fuel for operation. Hydroelectric facilities need not only large flows of water over long periods of the year, but also need a height differential, either natural or man-made, to provide the driving energy. Geothermal power requires natural fields of either steam or hot water from within the earth. Wind generators need a constant source of winds at the right speed and direction. Solar power needs a certain numbers of clear days over the course of a year.

The California Energy Commission is responsible for monitoring the state's energy production. Its last comprehensive report, issued in 1986, shows the following (Figure 1-13):

California Power Production - 1987

Type	No. of Plants	% of Plants	Megawatts	% of Capacity
Oil and Gas	258	30.0	27305	55.0
Hydroelectric	309	36.0	11915	24.0
Nuclear	3	.3	5461	11.0
Geothermal	34	4.0	2482	5.0
Biomass	103	12.0	993	2.0
Wind	129	15.0	368	.7
Coal	6	.7	298	.6
Solar	17	2.0	199	.4
Total	859		49645	

Figure 1 - 13.

Counties discussed in this study account for about 24,000 megawatts of power production, or about 48% of the State's total. Of this coastal power, almost 83% comes from oil and gas fired plants. For example, 40% of oil and gas-generated electricity comes from San Diego, Los Angeles, Ventura, Monterey and Contra Costa counties. Just over 13% of the state's hydroelectric power comes from a coastal county, Los Angeles. Alameda and Contra Costa counties account for 22% of the state's

wind generation, while Los Angeles, Contra Costa and Humboldt provide 21% of the biomass electricity. Of the coastal counties, only Solano County generates an appreciable amount of solar energy, making up 13% of the state's total in that category.

SALVAGE

Marine salvage offshore California has two major aspects—immediate salvage of ships in danger of sinking or breaking up, and recovery of vessels or cargos from abandoned shipwrecks of an earlier age. When salvage is done immediately after the wreck, it is under the jurisdiction of admiralty law and the Coast Guard; historical salvage is under the jurisdiction of the State Lands Commission, with advice provided by the Office of Historical Preservation.

Ships have stranded on California's rocks and beaches since at least the 1500s; many have been completely or partially salvaged, but over 2000 identifiable shipwrecks remain on or just off the coast. Such salvage is a temporary "use" of the coastline, and usually does not affect other users or the environment. Depending on the weather and the condition of the stranded vessel, it will either be towed off after emergency repairs or left to break up after anything valuable that can be removed has been taken off. If the vessel is left in position, it will either eventually be buried in the sand or torn apart by the winter storms and scattered about the ocean bottom. Often only major components, such as engine blocks, are left visible after a few years. Recently, one or two major vessels and several smaller boats have come ashore each year.

The dangers to the environment from immediate salvage of vessels are primarily mechanical. Dragging large vessels over rocks and out to sea can damage rocky habitats, but the damage is usually over a restricted area and can be naturally repaired within a few seasons. Cargo spillage presents a larger risk, either during salvage or, if total salvage is not attempted, when the vessel is left to batter itself to pieces. Today, any major vessel not sunk in deep water is salvaged.

Ships lost in the past can be salvaged for archaeological or historical reasons, or for the recovery of treasure-real or imagined. As with immediate salvage, the operation is a temporary one and rarely affects other coastal users or the environment. An exception is treasure hunting which usually destroys a valuable cultural resource—the wreck itself—and prevents archaeologists from using that wreck to study the past.

There are usually one or two salvage attempts started each year, but there have been no successful salvages of entire vessels in California in modern times.

OUTFALLS

Liquid waste in coastal areas is often disposed of through a conduit leading from the point of waste generation directly to the ocean, or a channel, tributary, bay or estuary which enters the ocean. These conduits are commonly referred to as outfalls.

The types of liquid waste vary, ranging from rainwater which enters storm sewers to extensively treated industrial wastes. Common types of outfalls include those for sewage disposal, flood waters, cooling waters used in industrial plants, and processed industrial wastes. Pulp mills, fish farms, marine terminals, power plant cooling waters, sanitation district

outfalls (sewage and storm drain runoff), mineral processing plants, and oil production platforms all require outfalls.

Each outfall must comply with the State Water Resources Control Board "California Ocean Plan" which provides for quality control for ocean waters, and with the Federal Clean Water Act. In California, 332 facilities have current National Pollution Discharge Elimination System (NPDES) permits to discharge into the Pacific Ocean and its bays or estuaries. By far the largest permitted volumes are power plant cooling waters, followed by sewer outfalls.

Most outfalls consist of cement or steel piping which extends from the waste source to a location in the body of water which receives the waste. In rivers and streams the pipe normally terminates far enough into the bed to minimize the likelihood of erosion or channel scour. In bays and the ocean the pipe usually extends far enough offshore to ensure that the wastes are diffused and diluted before they are washed back onto the beach or other sensitive habitats. Both distance from shore and water depth are important. Outfalls may extend several hundred feet from the beach or as far as 7000 feet offshore. Oil and gas producing platforms offshore southern California normally dispose of produced waters (brines produced with crude oil) through an outfall which extends vertically several hundred feet below the ocean surface.

Outfalls provide environmental benefits because they promote the disposal of impure waters away from areas where human health and the human environment may be adversely affected. Environmentally adverse impacts of outfalls include those associated with pipeline construction and thermal, biological and chemical pollution of the ocean. On a statewide basis, the most serious pollution problems are those associated with sewage disposal in Southern California and toxics from paper mills in Northern California.

Other methods for liquid waste disposal include injection into underground reservoirs and recycling as grey waters, both of which may pose risks to human health and the environment.

OCEAN DUMPING

Dredged material composes more than 90% of the material disposed at ocean dump sites each year. There are 12 ocean sites (Figure 1-14) designated for the disposal of sediment dredged from harbors and marinas throughout the state, and three additional sites in San Francisco Bay.

Historically petroleum products, chemical waste, low-level radioactive wastes, munitions and other military waste were dumped at sea. However, in the early 1970's laws were passed to control ocean dumping and after 1975 chemicals, radioactive waste and munitions were no longer disposed of in the ocean. In 1988 Congress passed a law banning ocean disposal of industrial waste.

Until recently, garbage and trash from boats and ships has been routinely disposed overboard. In 1988, the U. S. Senate ratified Annex V of the MARPOL Convention, a treaty controlling ocean dumping. Annex V prohibits dumping of plastics and limits dumping of packing material to areas at least 25 miles from shore. Paper, glass, rags, food material and other garbage must be dumped at least 12 miles from shore, unless it is ground into fine pieces; then it must be dumped at least three miles

Designated Offshore Disposal Sites—Statewide
(Not including San Francisco Bay)

Figure 1 - 14.

from shore. Annex V applies to all ocean-going vessels, including recreational boats. Military and other government vessels have until 1994 to come into compliance with MARPOL Annex V. Annex V is enforced by the U.S. Coast Guard.

SEPTIC TANKS

Septic tanks are a method of disposing of wastes, principally domestic sewage, by containing sludge in a covered pit where it biodegrades. Fluids percolate through the soils until all biologic agents have degraded and oxidized to natural groundwater levels. In rural areas with sandy soils, sparse population and few public services, septic tanks provide an effective method for the disposal of sewage. In urbanized areas where volumes of sewage are greater, soils can become saturated so that septic tanks lose their efficiency. Soils can also become unstable and subject to slumping and other hazards.

Septic tanks are not widely used in the coastal zone and have no unique relationship to it. Where waste waters concentrate near the coastal bluffs, they may contribute to sliding; however, in areas suited to septic tanks—truly rural areas such as ranchland—housing is usually some distance from the ocean and bluff erosion is not exacerbated. Exceptions are areas such as Malibu where de facto urbanized communities have not built sewage systems and soils are at their limit to contain and treat sewage effectively.

LANDFILL

Over 75% of California's wetlands have been destroyed and converted to filled lands, either to reduce perceived threats of pestilence or to create developable acreage. Current state and federal policies discourage further filling of wetlands; however, some of California's most valuable real estate consists of such filled wetlands. Landfill is also used in certain circumstances to create developable lands in the ocean. Examples include the filled lands and islands of the Ports of Long Beach and Los Angeles and the drilling islands used for oil production off Seal Beach, Long Beach and Ventura.

MOSQUITO ABATEMENT

In California coastal counties where marshlands, estuaries, or restored wetlands cover a significant area, mosquitoes can become a pest problem. In general, good drainage and tidal flushing in coastal wetlands prevents the buildup of stagnant waters that support mosquitoes. However, with increased coastal development there has been a disruption of natural circulation patterns resulting in breeding areas (Josselyn, 1983).

There are various methods of mosquito control, depending on environmental circumstances and type of mosquito. California's coastal mosquito abatement practices include physical, biological, chemical, and preventative measures.

Physical controls include ditching, draining and levee work. Recirculation ditches dug by hand or lightweight vehicles, have been used in the San Francisco Bay Area since 1930 to increase tidal flushing. Although ditching eliminates some marsh intertidal pools and decreases arthropod species diversity, ditches create fewer environmental disturbances than insecticidal sprays (Resh and Balling, 1983).

Biological control using the predatory mosquito fish is often combined with physical

controls since recirculation ditches improve habitat for this fish. However, if stocking levels are too low, mosquito control may not be effective (1983, Resh and Balling). Another concern is that the mosquite fish may replace native fish populations.

When physical or biological controls are not feasible, chemical controls are used. The majority are mosquito larvicide oils that work by smothering larvae; however in some counties, organophosphates or "bio-rational" chemicals—those that are short-lived and target-specific—are used (California Mosquito and Vector Control Association, 1988). Since chemical controls can cause environmental degradation, recent emphasis has been on the combination of physical, biological, and preventative controls (Bradley, 1989).

Preventative methods include source reduction, especially in residential areas, public awareness programs, news releases, and correction of stagnant conditions.

In some counties, mosquito abatement is done by the County Department of Health, and in others by special districts. By state law, individual counties can transfer mosquito and vector control services to a mosquito abatement or vector control district. California Health and Safety Code Regulations set minimum standards for regulating mosquito breeding sites where they pose a "public nuisance" or a public health threat.

GROUNDWATER BASINS AND WELLS

In California, some onshore groundwater basins extend from onshore to the offshore. For example, this is characteristic of the Los Angeles basin, the Santa Maria basin, the Salinas River basin and the Eel River basin.

The extension of a groundwater basin from onshore to offshore presents an unusual potential problem. Normally a groundwater basin is fed by percolation of surface waters, and so the offshore portions of the basin contain saline waters, which are heavier than the fresh waters onshore. If the groundwater basin is heavily used and there is significant drawdown, sea water intrusion may occur: fresh water which is extracted faster than natural percolation can replenish it will be replaced by sea water which will flow onshore below the fresh water, toward the well(s) from which fresh water is extracted. Sea water intrusion can be a serious problem if saline waters intrude far enough to reach wells providing potable water to users.

Fresh water aquifers, whether onshore or offshore, can be polluted by drilling fluids when wells are drilled into or through those aquifers, or by foreign substances (such as oil or waste waters), flowing through the well bore. To prevent pollution of fresh water aquifers, drilling regulations require that all wells in potential fresh water aquifers be cemented and cased so that no fluid can escape from the well bore into the aquifer or from the aquifer into the well bore. These regulations are mandated by the Environmental Protection Agency, as well as the Division of Oil and Gas and the State Lands Commission.

Seepage of contaminated surface water is another source of pollution of freshwater aquifers. This contamination can occur in rural areas as a result of improperly controlled use of pesticides, and in urban or industrial areas from runoff containing residues and other toxic or hazardous wastes as well as from uncontrolled

industrial surface water runoff. Accidental discharges—which may be quite substantial—results in the greatest potential for contaminated industrial runoff entering the groundwater aquifers.

Pollution of freshwater aquifers by offshore oil or waste fluids has not been a problem.

RURAL AND MUNICIPAL RUNOFF

Large volumes of water—principally from rain, snow melt and irrigation—flow into the sea with minimal treatment. In urbanized areas, storm sewers may carry these waters into the storm drain systems and directly through a pipeline or conduit into the ocean, bay or tributary. In rural areas, these waters normally flow naturally into the ocean, bay or tributary.

Since this runoff contains any transportable materials in its path including chemicals or other particles, the quantity of pollutants entering the ocean via runoff is significant. Oil, chemicals off city streets and parking lots, chemicals used to treat agricultural lands, fecal material from domestic animals and dirt will all be washed into the ocean, bay or tributary. For instance, surface runoff is a significant source of pesticides, heavy metals and bacteria, and is second only to sewage discharges in contributing to the pollution of the Santa Monica Bay (SCAG, 1988).

Except in San Francisco, storm drain and sewage systems in Calfornia are separate; that is, there is separate piping for each system. Thus, in contrast to the situation on the eastern seaboard, sewer overflows caused by storm runoff are not a problem. The city of San Francisco has recently rebuilt its sewage system in order to improve treatment of storm water flows.

Water in storm drains is not currently treated. However, the 1987 version of the Clean Water Act mandated permits for urban storm drains. The Environmental Protection Agency is presently developing a permit program to fulfill the requirements of the Act. There is also some research underway in Santa Monica and San Francisco Bays to document the scope of the problem and develop treatment stategies.

SURFACE WATER DEVELOPMENT

Great spacial and temporal variation characterize California's water resources. Two-thirds of the total annual precipitation falls on the northern one third of the state. The north coast is similar to the humid Pacific Northwest, while the south coast is a semi-arid, near desert environment. Further, almost all of the precipitation in the coastal region and Central Valley falls as winter rain, with no significant amounts during the summer. The amount of rainfall, and thus the amount of runoff, differs from year to year, often by unpredictable extremes.

In this natural hydrologic setting there has been tremendous agricultural growth and a steady urbanization of the central and south coast regions. This has necessitated building a variety of water storage and conveyance structures as well as altering of many streams, rivers and flood plains, for water supply and flood protection.

Water supply and flood protection programs may be separate or combined; these projects are sometimes designed to provide power and

recreation benefits as well. Dams and their accompanying reservoirs are the heart of most water development projects. They allow the storage of seasonal rainfall which can be released later for irrigation, industrial, and domestic use and by trapping high flows, dams also serve an important flood control function. Water captured for human use can be conveyed by the natural waterways, or through artificial aqueducts or pipes.

In addition to relying on the dampening of peak flows provided by dams, flood protection projects usually involve modifications of downstream waterways and flood plains. These river modifications are designed to transport flood waters out of an area efficiently and to keep water off low-lying lands. Generally, flood control projects rely on a variety of engineering tactics which result in the destruction of natural streams, especially within urban areas. Such methods include removal of riparian vegetation, bank armoring, channelization, culverting and channel straightening. The concrete bed and banks of the Los Angeles River is an often-cited example of these methods. Other techniques are sometimes used which may or may not result in as great an impact to a waterway, including sediment or debris basins, levees, and bypass systems.

According to the California Water Atlas (OPR, 1979) there are hundreds of water development projects statewide, both small and large. Taken together, the water storage capacity in the large reservoirs in California is greater than that of any other state. Most of the numerous water supply and flood control projects which exist today were constructed decades ago, many in the nineteenth century. And they have been built by a diversity of entities, including private parties, and municipal, district, state and federal agencies. Over time, many smaller private projects have been transferred to government authorities. The larger water development agencies include the Federal Bureau of Reclamation and Army Corps of Engineers, and the California Department of Water Resources.

In the coastal region, most water supply and flood control development is concentrated in the central and south coast. In the north coast, there is ample water supply, the terrain is mostly steep, with little flood prone area, and the population is small. On the other hand, in the urbanized San Francisco Bay Area and south coast region, both water supply and flood control needs have led to numerous water projects, some quite massive.

The demand for water in the central and south coast regions far outstrips the available supply, and is met by large public systems originating out of the delivery areas. Examples include the Hetch-Hetchy system for San Francisco; the State Water Project, which supplies parts of the Bay Area, the Central Valley, and Southern California; and the Los Angeles Aqueduct and Colorado River Aqueduct, which provide water to much of urban Southern California.

Legal authority over water development in California is very complex. Laws, regulations and enabling statutes exist at all levels of government for both flood control and water supply management. Additionally, legal rights to use water—whether by diversion, storage, or riparian appropriation—are also quite complicated. Most decisions about water rights today are made by the State Water Resources Control Board. Water rights law is still in a state of active flux, with many recent and ongoing court cases causing its continuing evolution.

SHORELINE STRUCTURES

Ocean beaches are one of the most highly valued recreational features of the California coastal environment. But many beaches are being lost to erosion.

Beach sand is transported by wind, waves and wave currents in three kinds of movement—offshore, onshore and longshore. The sand movement along the shore occurs within relatively distinct sections of the coast called "littoral cells."

Though beach sand may come from cliff erosion, landslides, dunes or onshore transport, most of California's beach sands are delivered by coastal streams. Human activities such as dams, settling basins, flood control works, urbanization, etc. reduce stream flooding and thus affect beach sand supply.

Human activity has not only reduced the supply of sand—it has also increased the rate of loss, or changed the distribution, through improper design and placement of groins, jetties, breakwaters and dredged channel entrances in shoreline waters.

Constructed from large pieces of quarry rock, these structures create habitat in nearshore waters, yet drastically interfere with wave action and longshore currents, creating serious problems of sand deposition and erosion. Contemporary coastal engineering expertise is required to compensate for the alteration of habitat. Examples include Oceanside Harbor and parts of Long Beach where beaches protected by breakwaters are badly eroded seasonally and not replenished, yet excess sand deposition occurs up current of the structures.

In addition to their effect on shoreline sand movement, marine structures such as dikes, piers and jetties can impair productive habitat areas by interfering with water circulation. Properly designed structures may, however, provide positive benefits as havens for small fish, and as nesting and roosting sites. Marine and shoreline structures can also impair access to and along the shore and degrade the visual qualities of the coast.

TRANSPORTATION

California's coastal zone is used extensively by all modes of transportation. Air, land and sea routes and facilities are found linking every region of the coast with the inland portions of the state, with other parts of the coast and with the outside world. This network moves people, goods, and information in increasing volumes at increasingly higher speeds.

Both major and minor cities like to site airports near the ocean because it allows noisy, and occasionally dangerous, takeoffs and landings to take place over the water and away from people. Of California's largest and busiest airports, four are on the water: Los Angeles, San Diego, San Francisco and Oakland. The last three are built up at least partially on filled tidelands, while the first abuts the natural coast. Such facilities take up large quantities of scarce coastal lands, and make adjacent areas unsuitable for other uses, such as housing.

Land transportation consists primarily of highways, railroads, pipelines and electric transmission lines. These are all linear features; that is, they extend in relatively narrow paths for great distances. Pipelines and electrical transmission lines can be underground, but those that are not are considered visually disruptive. Highways are also considered visually unattractive, and add noise and air pollution to their list of disadvantages. Major

freeways use up extensive acreage and, because of this, have become prohibitively expensive in coastal urban areas. Railroads share many of the same disadvantages, but do not produce the same pollution, and the noise generated is more intermittent. Railroads also require station facilities, as well as the track rights-of-way, although very few railroad stations are located on the coast in California.

With sea-borne transportation systems, as with air transportation, the port facilities affect the coastal part of our state more than the transportation routes themselves. Ports become a focus for rail, pipeline and highway facilities so that goods can be transferred from one mode of transportation to another. In California, it is goods, rather than people, that are most often shipped by sea. Port facilities are extensive and use large amounts of coastal land.

Regardless of the cost, all elements of the transportation system are necessary for the continued health of California and its coastal zone. Much can and could be done to improve the system's efficiency—particularly reduced dependance on the private auto—that would lessen the unfavorable effects imposed on people; but it is unlikely that any single portion of the system could be discarded.

MILITARY

The military uses the land, sea, and air portions of California's coast for both operations and training.

The military is a major presence in almost every segment of the coast from San Francisco Bay to San Diego Bay, but there is very little of that presence north of San Francisco. While the Navy and Air Force are the major users, the Army has some facilities as well.

On land the military owns dozens of facilities, ranging from half acre radar sites to the sprawling complexes at Camp Pendelton and Vandenburg, each covering several thousands acres. This land is being used for airbases, artillery ranges, amphibious assault training, housing, ship repair facilities and basic training by all three service branches. Many of these coastal military installations are on land that would be of considerable value to developers if it were released from governmental use.

The ocean off California is used by the Navy for transit and training exercises. San Diego and Alameda are major naval anchorages, and San Diego is the West Coast's largest naval training facility. Surface ships, submarines and aircraft all use the ocean. San Clemente Island is reserved for naval use as a gunnery and missile target range, and for training underwater personnel.

Aircrew training by both the Navy and Air Force keeps the air over our coastline full of high performance aircraft at all altitudes. Good weather and availability of open space for flight operation and major facilities of all types will keep this area important for training in the foreseeable future.

At Point Magu and Vandenburg the Navy and Air Force conduct training and test launches of missiles ranging in size from five foot air–to–air missiles to intercontinental ballistic missiles. Vandenburg is also used for satellite launching, and was proposed as an alternate launch site for the Space Shuttle.

Effects

In many cases, the most important use of California's coast by the military is simply the use of the space itself. Camp Pendleton is an

example of a huge area that, according to many analysts, will be the only break in developed land between Los Angeles and the Mexican border (Sacramento Bee, 7/10/89). The Army's headquarters at the Presidio in San Francisco has been a developer's dream since the late 1940s, but has now been reserved for parkland, if and when it is released by the Army. This reservation for future protection, has also become an issue; the military has become increasingly good at protecting natural and cultural resources on its installations, and there is increasing pressure from environmental groups to keep territory under military control instead of releasing it to developers.

Uses of the ocean areas off the coast are, in many ways, similar to the shipping uses discussed under navigation. But there are two special cases that deserve mention. The first is submarine transit lanes. These are areas where submarines are making submerged high speed transits of an area. Operations with fishing nets are severely curtailed in such areas, for obvious reasons. The second case is the gunnery practice area off San Diego, especially at San Clemente Island. Non military vessels are forbidden where live-fire exercises are taking place.

Air operations generate complaints about noise, and can limit access to certain areas or altitudes to military aircraft only.

All military uses of the coastal area generate civilian employment in the local economies. In San Diego, San Luis Obispo and the Bay Area counties this economic impact is significant.

CHAPTER TWO

STATEWIDE OVERVIEW OF ENVIRONMENTAL FEATURES AND CRITICAL CONCERNS

INTRODUCTION

The purpose of this chapter is to provide an overview of the general considerations which govern the analysis of projects proposed for the California coast. This chapter will draw on the primary coastal uses discussed in Chapter One for its description of baseline conditions and potential effects.

GEOLOGY

DATA SOURCES

Because of California's great physical size, it possesses a broad diversity of geologic features which have prompted a volume of research writings. Information collected about the state's general geologic features has been extracted from a large core of material. Information pertaining to particular regional or zonal characteristics was gathered from a body of more "site specific" or local treatments.

Information of a statewide nature has been gathered from E.I.R.'s and special departmental reports including: Final Environmental Statement, Proposed Five-Year O.C.S. Oil and Gas Lease Sale Schedule (U.S. Bureau of Land Management, 1980), U.S. Department of the Interior Draft E.I.S., O.C.S. Sale No. 48 (B.L.M., 1979), Interpretation of the Gravity Map of California and Its Continental Margin, Bulletin No. 205 (Ca. Div. of Mines and Geology, 1980), California Soils; An Assessment (Ca. Dept. of Conservation, 1979), Hydrocarbon Potential of California Offshore Lands and San Pablo Bay (State Lands Commission, 1976), Erosion and Sediment in California Central Coast Watersheds (Smith, Shogren, Leifer, Shipman, 1979), Shell Pacific Summary Report 1982 (U.S. Dept. of the Interior B.L.M. Minerals Management Service).

A more complete listing of other general writings and more regional information will be found in the Bibliography.

GEOLOGIC OVERVIEW

California's upland geology has been subdivided into eleven areas, or geomorphic provinces. Each province is characterized by its own unique geologic features. (Baily 1966, p.7), Figure 2-1.

Four of these geomorphic provinces are within the scope of the California Comprehensive Offshore Resources Study (CCORS). The four provinces are: (1) the Peninsular Ranges, the southernmost province which is bounded on the north by the Los Angeles Basin and the California–Mexico Border on the south; (2) the Transverse Ranges, which frame the north margin of the Los Angeles Basin and trend east, to midway across the state. Their northernmost limit is defined by a line running east–west with Point Arguello on the coast; (3) the California Coast Ranges, which reach from the Sierra Madre Mountains east of Point Arguello north to the California–Oregon Border; and (4) the

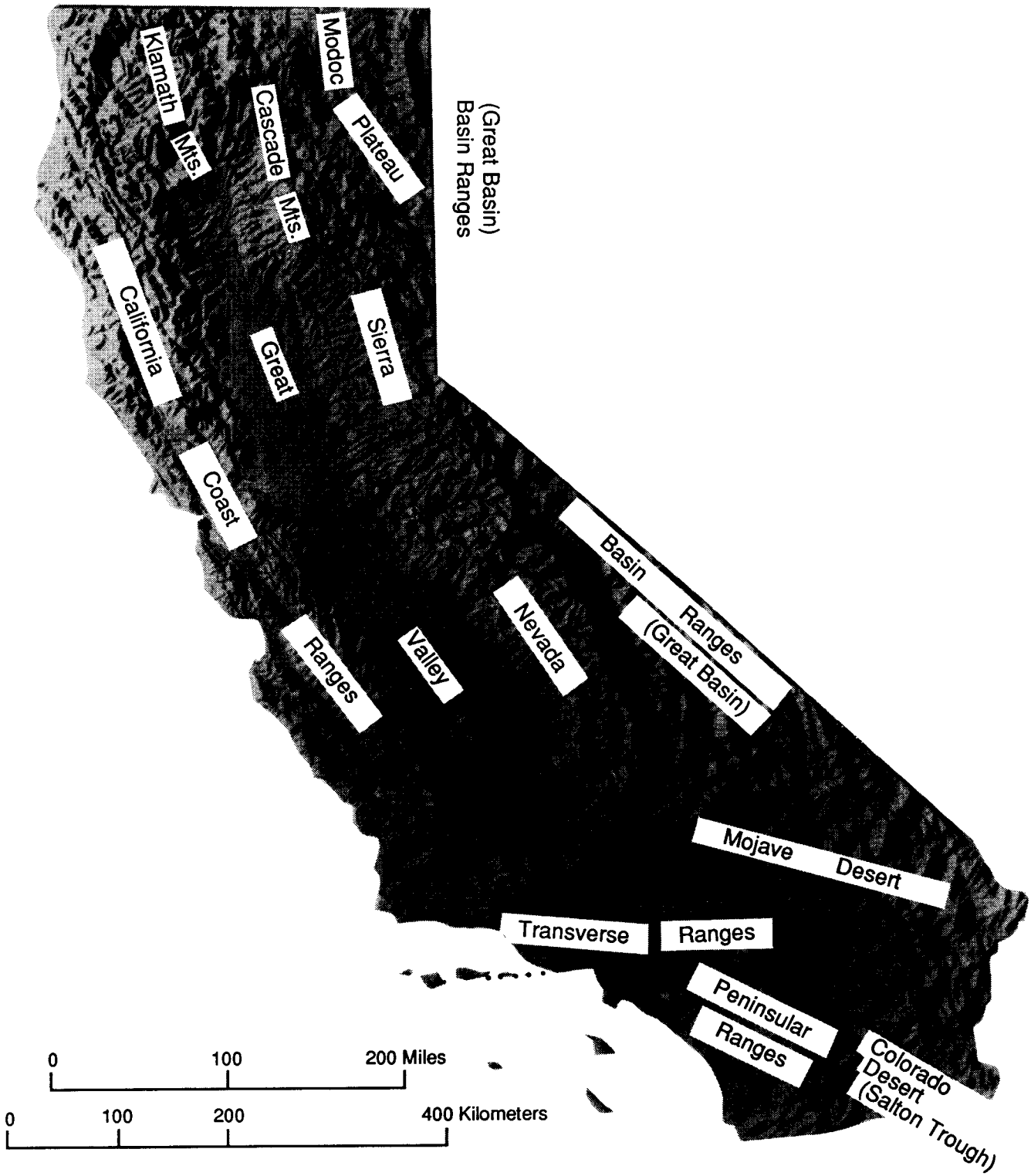


Figure 2 - 1: Relief map of California showing names and boundaries of physiographic provinces used in this report (from Bailey 1966, figure1).

Klamath Mountains, which extend from the northwest limit of the Great Valley north to the California–Oregon Border. The San Andreas Fault trace passes through three of these provinces, in a northwesterly direction, paralleling the coast and running from the Gulf of California, through the Coast Range province and San Francisco Bay west of the Golden Gate, out to sea at Point Arena. The fault sweeps north to Shelter Cove then cuts westerly ending at the Cape Mendocino Escarpment.

The geography of California's offshore is also characterized by separate regions or provinces. The offshore area between the continental uplands and the continental slope is differentiated into two zones: (1) the Continental Shelf, which runs south from Alaska past the Northern California border to a point off Point Conception; and (2) an area with its own distinguishing characteristics, including the continuation of the Continental Shelf southerly to Mexico and the sea floor south of Point Conception identified as the Continental Borderland (H.D. Palmer 1965, p.81; GSA Special Paper No. 31, 1941), (Figure 2-2).

Included within this Continental Borderland are eight Channel Islands: San Miguel, Santa Rosa, Santa Cruz and Anacapa (off Santa Barbara), and San Nicolas, Santa Barbara, Santa Catalina and San Clemente (southwest of the City of Los Angeles). The Continental Borderland has been interpreted as an offshore continuation of the California upland to the east (Emery, 1960; Parker, 1971), with its structural trends an extension of those onshore.

PHYSICAL OCEANOGRAPHY

This section describes patterns of water movement along the California coast. Currents, waves and other water movements transport marine organisms and pollutants and modify the environment of marine organisms by mixing waters having different physical characteristics. Waves constrain man's activities offshore and at the water's edge. This discussion of California oceanography is based on information in Hickey (1979), Williams, et al. (1980), and Science Applications International Corporation (1987).

CURRENTS

Prevailing winds that blow from west to east along 40o latitude (the "roaring forties") and from east to west along the equator (the Trade Winds) drive large-scale currents in the North Pacific Ocean. These winds and the rotation of the earth cause the clockwise movement of surface water called the North Pacific Gyre (Figure 2-3).

The eastern arm of the North Pacific Gyre has two currents: the California Current and the California Undercurrent. The California Current is a relatively wide current, 600–1000 km in width, that transports surface water south from subarctic regions towards the equator. Below the California Current, the California Undercurrent transports water from the equator towards the pole. The Undercurrent is a relatively narrow current (40–50 km in width) that flows along the contour of the continental slope.

South of Point Conception the California Current flows, for the most part, offshore of the Southern California Borderland. Within the Borderland there is a semi-permanent counterclockwise eddy known as the Southern California Countercurrent or Southern California Eddy. The northern Channel Islands split the Countercurrent into two branches (Figure 2-4).

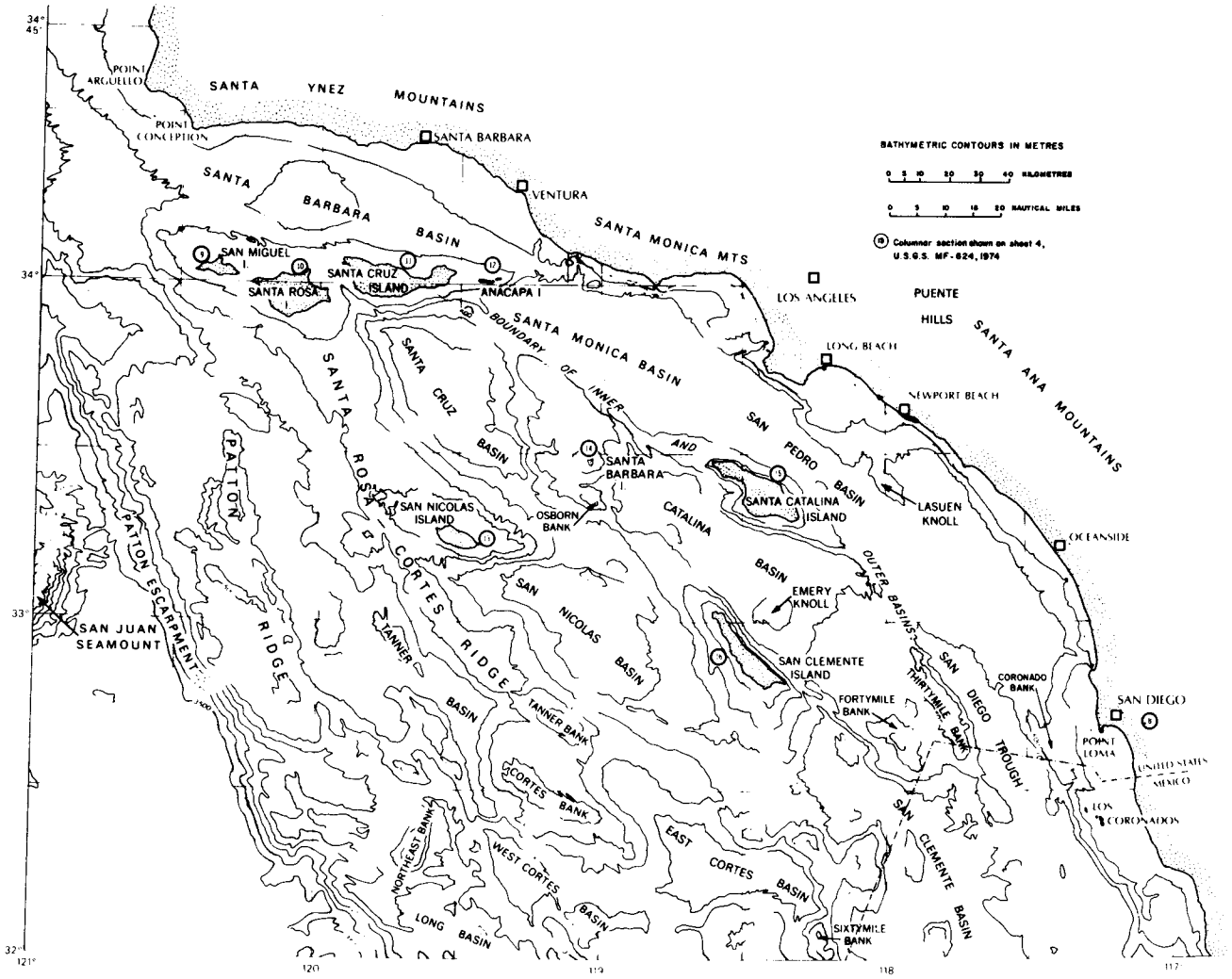


Figure 2 - 2: Index map of continental borderland of southern California showing inner and outer basin areas.

Bottom water within the Borderland generally meanders northward, following the contours of the basins. There is some southward transport south of Point Conception and at the offshore edge of the Borderland (Figure 2-5).

The California Current varies in strength and location seasonally. In spring strong southward winds strengthen the California Current. The current moves inshore, sometimes eliminating the Southern California Eddy. The winds may also induce upwelling, that is, the movement of cold nutrient-rich water from a depth of 100–200 m to the surface. Upwelling is an important source of nutrients for phytoplankton and thus helps maintain biological productivity in coastal waters.

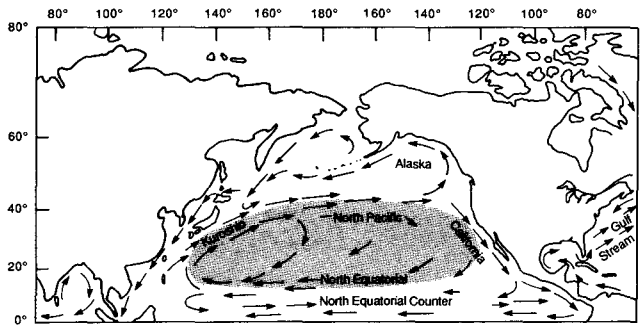


Figure 2 - 3: Pacific Ocean circulation. The North Pacific Gyre is highlighted.

In winter, north of Point Conception winds are northward; south of Point Conception winds are weakly southward (Strub, et al., 1987). The California Current moves offshore, and poleward flow develops north of Point Conception. This flow is called the Davidson Current and is thought to be a surface expression of the California Undercurrent. Upwelling is weak and sporadic in winter.

Each current carries water with distinct properties. The California Current brings subarctic water into California. This water is cool, relatively fresh, and rich in oxygen and nutrients. The California Undercurrent brings tropical water into California. This water is warm, relatively saline, and poor in oxygen and nutrients. At the western edge of the California Current, warm, nutrient-poor water from the central North Pacific mixes with subarctic water.

California has been described as a transition zone, because it is an area where subarctic water in the California Current, tropical water in the Undercurrent and central North Pacific water mix. There is proportionately more water of equatorial origin in the Southern California Borderland and more water of subarctic origin in Northern California.

During El Niño events, westward winds on the equator relax. Warm water from the western side of the Pacific moves eastward along the equator as a wave. Water temperature and sea level increase along the coast of North America. Upwelling is suppressed during El Niño events and biological productivity is low.

Flow within the California Current is not uniform. Slow moving water is interspersed with fast moving jets; meanders and eddies are common. Sometimes filaments of water move directly offshore between clockwise and counterclockwise eddies (Figure 2-6).

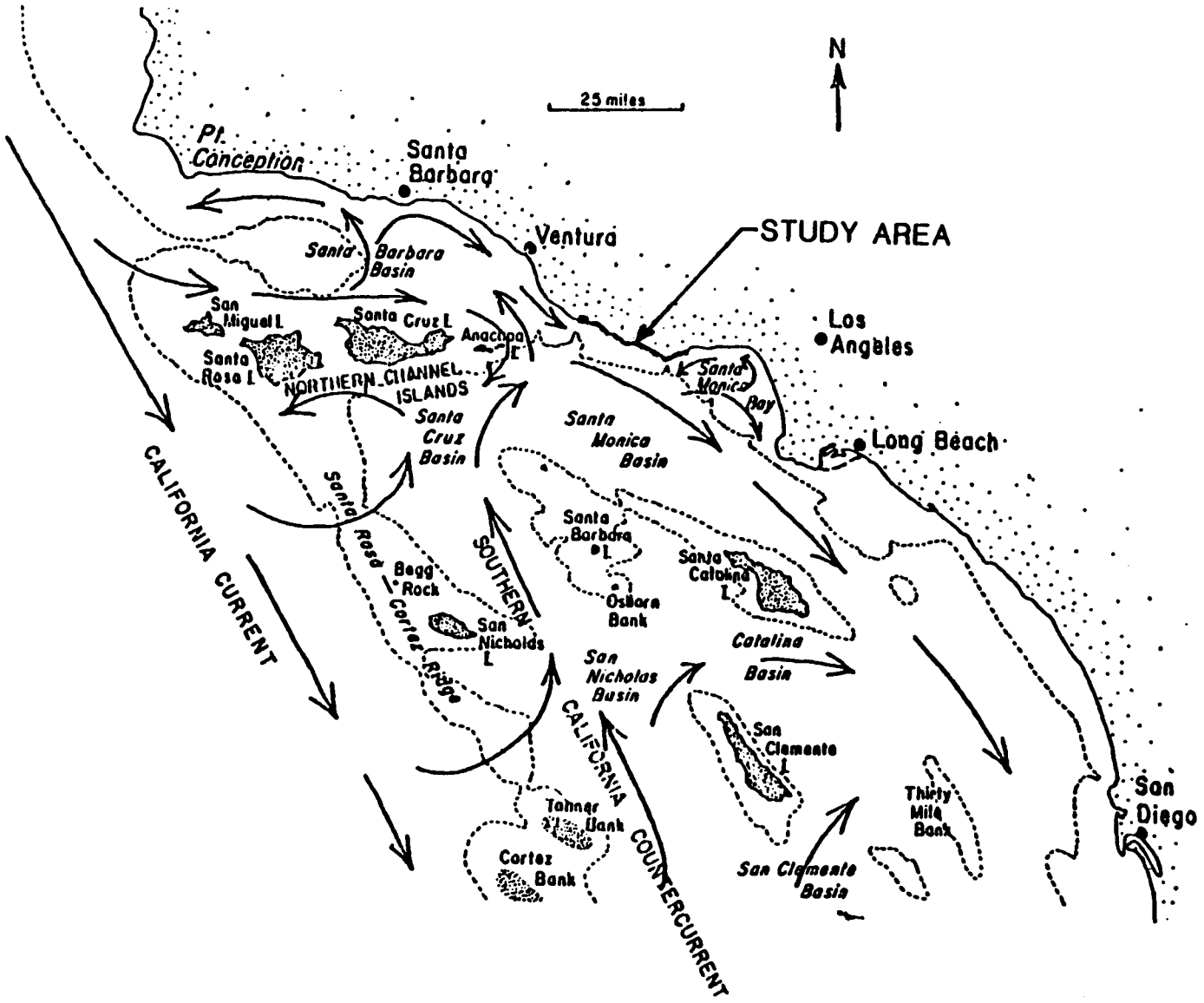
These filaments may transport coastal biota or pollutants discharged in the coastal zone 100 km or more offshore in a few days (Mooers and Robinson, 1984).

The California Current, the California Undercurrent and the Southern California Eddy describe large-scale, average patterns of water movement in offshore areas. Currents on the continental shelf are influenced by shoreline and bottom topography. Tidal currents may be important, particularly in constricted areas such as entrances of bays. Waves sometimes generate strong currents in the surf zone. Thus currents on the continental shelf are not as predictable nor as well known as offshore currents.

All these descriptions of currents are descriptions of average patterns. Since currents depend on wind and weather, tides and waves, water movement at a particular location at a particular point in time may differ considerably from the average patterns. As the wind shifts and weather patterns change, currents also change. Some variables—such tidal and seasonal fluctuations—are predictable; others are not.

WAVES

Many kinds of waves influence water transport and sea level height. These include



Dotted line indicates the 500 meter contour.

Figure 2 - 4: Surface currents south of Point Conception (from Chambers, 1988).

astronomical tides, wind waves and swells, internal waves and tsunamis.

In California there are two high tides and two low tides in each 25–hour period. One tidal excursion (one high tide and one low tide) is more extreme than the other. The highest high and and the lowest low tides in a year occur in the winter (November–December) and the summer (July–August). There are also 4.4 and 18.6 year cycles in extreme tides (Zetler and Flick, 1985). The amplitude of extreme high tides tends to decrease from north to south along the California coast, although San Diego has tides comparable to Crescent City (Williams, et al., 1980).

Wind waves are short period waves that are generated by local winds. Swells are long period waves that are generated by distant storms. These wave forms combine to produce the local wave climate. Extreme wave conditions occur most frequently during winter storms. Since the frequency and severity of storms decreases from north to south, average wave height and occurrence of extreme wave conditions decreases from north to south as well. The Southern California Borderland is less subject to extreme waves than offshore areas in Southern California because the Channel Islands intercept long period swells and reduce wind fetch. North of San Francisco large waves generally come from the south–southwest or,

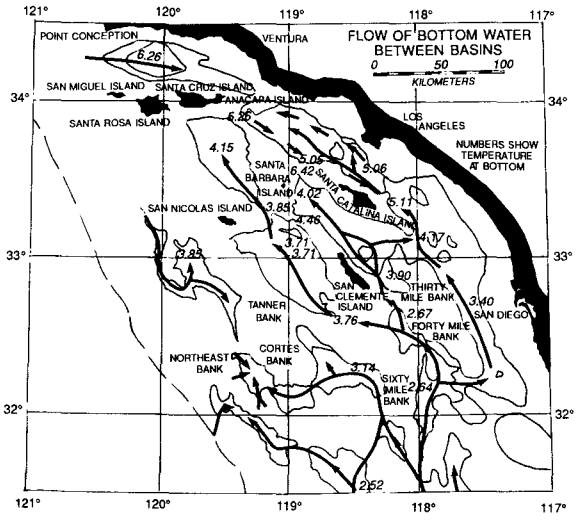


Figure 2 - 5: Paths followed by waters blowing from basin to basin in the Southern Continental Borderland as indicated by water properties. Width of lines is rough indicator of transport volume (from Hickey, 1990).

less frequently, from the northwest. South of San Francisco large waves are mainly from the northwest or west–northwest. In late summer, Southern California is sometimes exposed to large waves from the south that are generated by storms off Mexico or in the southern hemisphere.

Internal waves are waves that propagate along thermoclines and other density interfaces

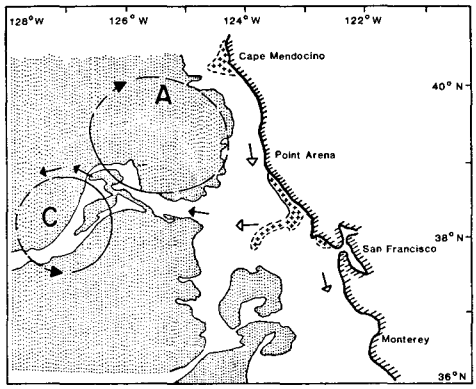


Figure 2 - 6: Schematized positions of a jet and eddies off of Point Arena (from Mooers and Robinson, 1984). Arrows indicate principal surface flow: solid arrows are definite and open arrows are inferential. Shading indicates a qualitative analysis of satellite infrared image: Gray shades for sea-surface temperatures on August 1, 1982. Coolest temperatures are indicated with crosses, warmest with dots.

below the surface of the ocean. Internal waves can cause turbulence around undersea banks and along the continental shelf break much as surface waves cause turbulence at the shore. It has been suggested that internal waves break the positive feedback cycle of an El Niño event (Graham and White, 1988). One expression of internal waves is the appearance of parallel rows of relatively calm water on the surface of the ocean. The passage of internal waves induces orbital motion of the water; that is, as the wave passes, a particle of water moves in a vertical circle (Figure 2-7). Naturally occurring oils collect in the zone of convergence between two vertical circles, calming the water. Buoyant material, such as plankton or plastics, tends to collect in zones of convergence. Zones of convergence may also be caused by orbital circulation caused by the wind. Other important zones of convergence form at fronts between water masses.

Tsunamis are very long period waves caused by underwater earthquakes. Most tsunamis that affect California are generated near the Aleutian or the Peru–Chile Trenches. The fault marked by the Mendocino Escarpment is capable of producing tsunamis; however, since these waves would propagate parallel to the

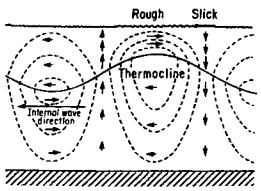


Figure 2 - 7: The pattern of currents and location of slicks over a set of linear internal waves. Flotsam and larvae transported by internal waves are trapped in slicks at the convergences. As the internal waves move onshore flotsam and larvae are carried shoreward by the converging currents at each slick (from Shanks and Wright, 1987).

coast of California, they should cause little damage here. In the deep ocean tsunamis are fast-moving, propagating at speeds of several hundred miles an hour. In shallow coastal water their speed is much reduced. In deep water tsunamis are only a few feet high and thus of little concern. However, in shallow water the wave drags bottom, causing the wave to increase in height and then to break. The effect of a tsunami depends on the direction and amplitude of the wave, the speed of propagation and the bottom and shoreline configuration. Tsunamis may cause extensive damage. In the great Alaska earthquake, run-up from a tsunami knocked down trees 1500 feet above sea level in some areas.

Extreme tides, waves and tsunamis are all relatively predictable phenomena. Wave data and models can forecast probable extreme events for the purposes of planning and coastal engineering. However it is difficult to plan for improbable events. Coastal damage in the winter of 1982–1983 was the result of high sea level joined to an unusually strong El Niño, extreme high tides and severe storms.

HYDROLOGY AND GROUNDWATER QUALITY

In nature, the quantity and quality of surface and groundwater resources are largely determined by that part of the hydrologic cycle that produces rain, and the runoff of rainwater along the surface and through the ground. Other significant factors in determining surface and groundwater hydrology are climate, geology and geomorphology. This includes the amount and annual distribution of rainfall, soil characteristics, topography and the earth's structure.

In California, especially in the coastal areas, man's use of the land has had a profound effect on surface and groundwater hydrology and, consequently, on onshore water quality. The type and extent of this effect has been as wide ranging as the state's coastal zone, and as diverse as the megalopolis of Southern California and the redwood forests of the North Coast.

Urbanization has required the importation of large quantities of water from far away sources. It has also required the storage of water in reservoirs behind large dams and in the aquifers (subsurface groundwater reservoirs). This has substantially altered the availability and allocation of water resources among competing uses, be they streamflow and habitat protection, the recharge of ground water aquifers, or supplying the needs of a major metropolitan area.

The beneficial uses of surface water include supplying streams and rivers with the fresh water necessary to support fish habitat, riparian vegetation and wetland environments. These in turn support a broad range of wildlife, including many threatened and endangered species. Surface water can also irrigate grazing and other agricultural lands and percolate through the ground to replenish the underground aquifers, an important source of water for many rural and urban communities.

Urban development has had a major impact on surface water, especially in coastal areas.

Grading natural landforms to accommodate residential subdivisions and commercial and industrial development, has led to the destruction of vegetation and habitat. It has accelerated soil erosion, and contributed to the pollution of coastal streams and the siltation of coastal wetlands. Urban runoff (containing engine oil residue and other domestic, commercial and industrial toxic wastes) has also contributed to the pollution of surface and groundwater and, in turn, coastal waters.

In recent years, local governments have taken increasingly effective measures to prevent and control these impacts by adopting increasingly stringent ordinances. These ordinances limit the timing of substantial grading to drier periods, require timely site restoration, and establish monitoring requirements during and after construction. However, these efforts have been rather uneven among the many local jurisdictions.

For certain categories of development, particularly industrial development, another potential source of onshore water pollution is accidents. Explosions, fires, or other accidental spills, can result in significant contamination of local surface and groundwater. If such an accident occurs near a significant habitat or a local water supply, its effects can be far reaching and long lasting.

In agricultural sectors of the California coast, the use of pesticides and herbicides has polluted surface runoff, some of which has reached groundwater basins, and has adversely affected fish and wildlife resources.

As mentioned above, groundwater is an extremely important water supply source. It is often the principal or sole source of water for entire communities or specific land uses in rural areas. These uses can range from an individual farm to an industrial plant such as an oil and gas processing facility. The demand for it can vary greatly from one area to another depending on the quantity and quality of the available reliable long-term supply. The amount of groundwater in a local area also determines the level of the water table, which can be important to the vitality of riparian watercourse and other significant vegetation, and some agricultural crops.

Overuse of groundwater, or overdrafting of groundwater aquifers, limits or eliminates the potential uses of groundwater. Overdevelopment that relies on groundwater can cause overdrafting of the resource. When such overdrafting occurs near the coast, it can result in seawater intrusion which may further pollute coastal groundwater aquifers and further limit their uses. Where seawater intrusion occurs in significant habitat areas, the type and quality of that habitat and the wildlife it supports may be substantially altered. Such alteration may be considered adverse, depending on the function of the affected habitat in the particular area in question.

Over the years, pollution of surface water and other discharges into the ground have polluted the groundwater in many parts of the state. Industrial discharges of hazardous wastes and leaking sanitary landfills have resulted in long-term contamination which, until recent years, has gone undetected. Such contamination of groundwater can severly limit the uses for which it may be suitable. And when the contamination of a community's water supply is discovered, it can profoundly affect the continued viability of pre-existing uses. Thus, the cumulative effects of man's use of surface and groundwater resources must be carefully evaluated. The regulatory system currently in

place can avert many development impacts on surface and groundwater resources, such as overdraft and contamination.

REGULATORY SETTING

The following local, state and federal regulations govern surface and groundwater use:

Surface Water

1. City and county General Plans and Local Coastal Plan policies, and non-coastal grading ordinances, including provisions for cut-and-fill operations and control of runoff and sedimentation.

2. Policies of the California Coastal Act of 1976, especially those which address the minimization of erosion and flood hazards and the maintenance of biological productivities of aquatic and terrestrial communities.

3. Requirements set forth by the Regional Water Quality Control Boards (RWQCB) with respect to discharges, rainfall runoff, injection of wastewater into groundwater aquifers, and the policies and objectives regarding the quality and beneficial uses of surface water. These include U.S. Environmental Protection Agency standards for issuance by the RWQCB's of the National Pollution Discharge Elimination System (NPDES) permits.

4. The requirement of the California Department of Fish and Game for the execution of a stream or lake Alteration Permit for any activity which will substantially alter the bed, bank, channel or flow of a lake or stream.

5. Primary and Secondary Drinking Water Standards promulgated by the U.S. Environmental Protection Agency.

Groundwater

1. City and county ordinances which address well drilling methods, well construction, well testing and water system construction.

2. Policies of the California Coastal Act of 1976 that require groundwater development not interfere with surface water flow or the biological productivity of streams.

3. The RWQCB's policies and objectives regarding the quality and beneficial uses of groundwater.

4. The California Department of Water Resources filing requirements for well drilling and construction logs.

5. The U.S. Environmental Protection Agency's Primary and Secondary Drinking Water Standards.

AIR QUALITY

METEOROLOGY AND CLIMATE

The lower atmosphere is the medium which carries air pollution from pollutant sources to surface-based receptors. In this medium, dispersion of air pollutants and the direction of pollution transport are dependent on the wind flow and vertical temperature. Meteorological factors which influence wind flow and vertical temperature distribution are macro-scale or hemispheric wind, diurnal effects, and topography.

Climatological data indicate that the potential for increased air pollution problems along the coastal areas of Central and Southern California resulting from emissions released over the offshore waters is great, especially during the summer when air pollution concentrations in coastal urban areas are

already high. This results from the predominant conditions in the region which generate a prevailing onshore moist airflow capped by a strong temperature inversion. These atmospheric conditions in conjunction with pollutant emissions are also conducive to the formation of acid cloud, ozone and sulfates. These pollutants are then transported toward the coast of Central and Southern California. Naturally, pollutants emitted very near the land reach the coast in more concentrated form than do pollutants emitted farther away. Nevertheless, the bulk of pollutants emitted over the Central and Southern California coastal waters impact air quality in the adjacent coastal plains in some form or another.

MARINE WATER QUALITY

Physical characteristics—such as temperature, salinity and nutrient concentrations—describe the ocean climate, much as temperature and rainfall patterns describe climate zones on land. The physical characteristics of the water are also an important factor in analyzing the effect of pollutants on the ocean; for instance, the addition of oxygen-demanding waste will have more effect on oxygen-poor environments than on oxygen-rich environments. This discussion of water quality is primarily based on information in Williams, et al. (1980).

TEMPERATURE, SALINITY AND DISSOLVED OXYGEN

As noted in the description of physical oceanography, subarctic water that predominates north of Point Conception is cooler and less saline than the equatorial water that predominates in the Southern California Borderland. This distribution of water masses, combined with latitudinal differences in precipitation and solar heating, produces a north to south gradient in surface water temperature, salinity and dissolved oxygen (Figures 2-8, 2-9 and 2-10).

Surface water is colder and less saline in Northern California. There is also a larger seasonal difference in temperature and salinity in Northern California than in Southern California. In nearshore areas, particularly south of points, upwelling in the spring and summer brings cold, saline, oxygen-poor bottom water to the surface, producing an onshore-offshore gradient in water properties. The seasonal range in temperatures is reduced in upwelling areas.

In nearshore areas, runoff can cause significant reductions in surface salinity. Outflow from the Columbia and Eel Rivers, and San Francisco Bay (Science Applications International, Inc., 1987) is sufficiently large to form somewhat persistent plumes, particularly in the winter and spring.

The properties of ocean water also change with depth. Surface water is warmer, less saline and contains more oxygen than bottom water. Water temperature and salinity are also more variable spatially and temporally at the surface than in deeper water.

At times there is an abrupt gradient in temperature (a thermocline) or density (a pycnocline) between deep cold water and warmer surface water. The gradient can form a barrier to mixing between the two water masses.

The depth of the thermocline varies geographically and seasonally. The thermocline is also generally deeper offshore than nearshore. In January and February there is a well-mixed surface layer with a well-developed thermocline, typically at 50 meters in nearshore areas and

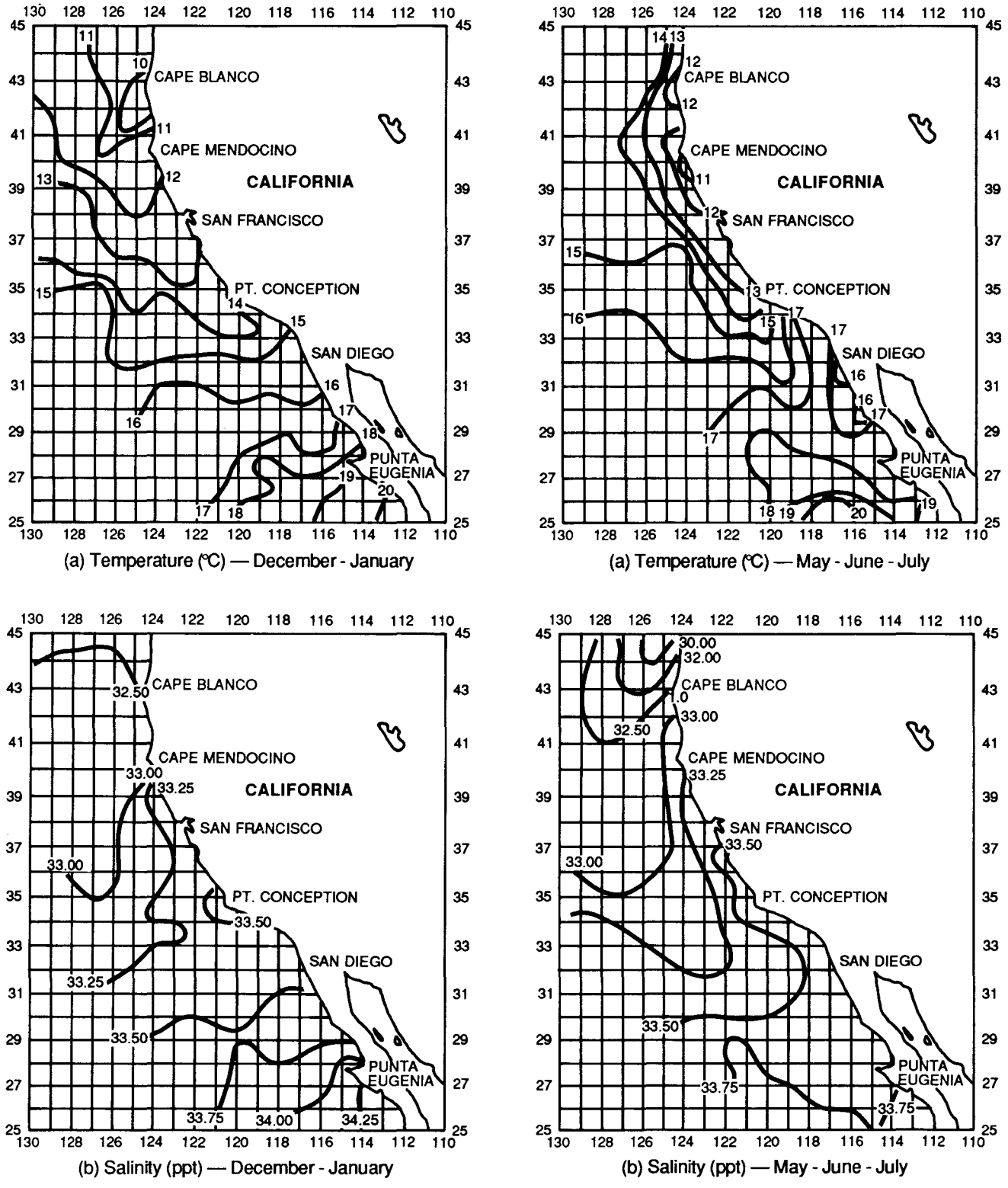


Figure 2 - 8: Surface water temperature and salinity in winter (non-upwelling) and spring (upwelling). (From Williams, et al., 1980.)

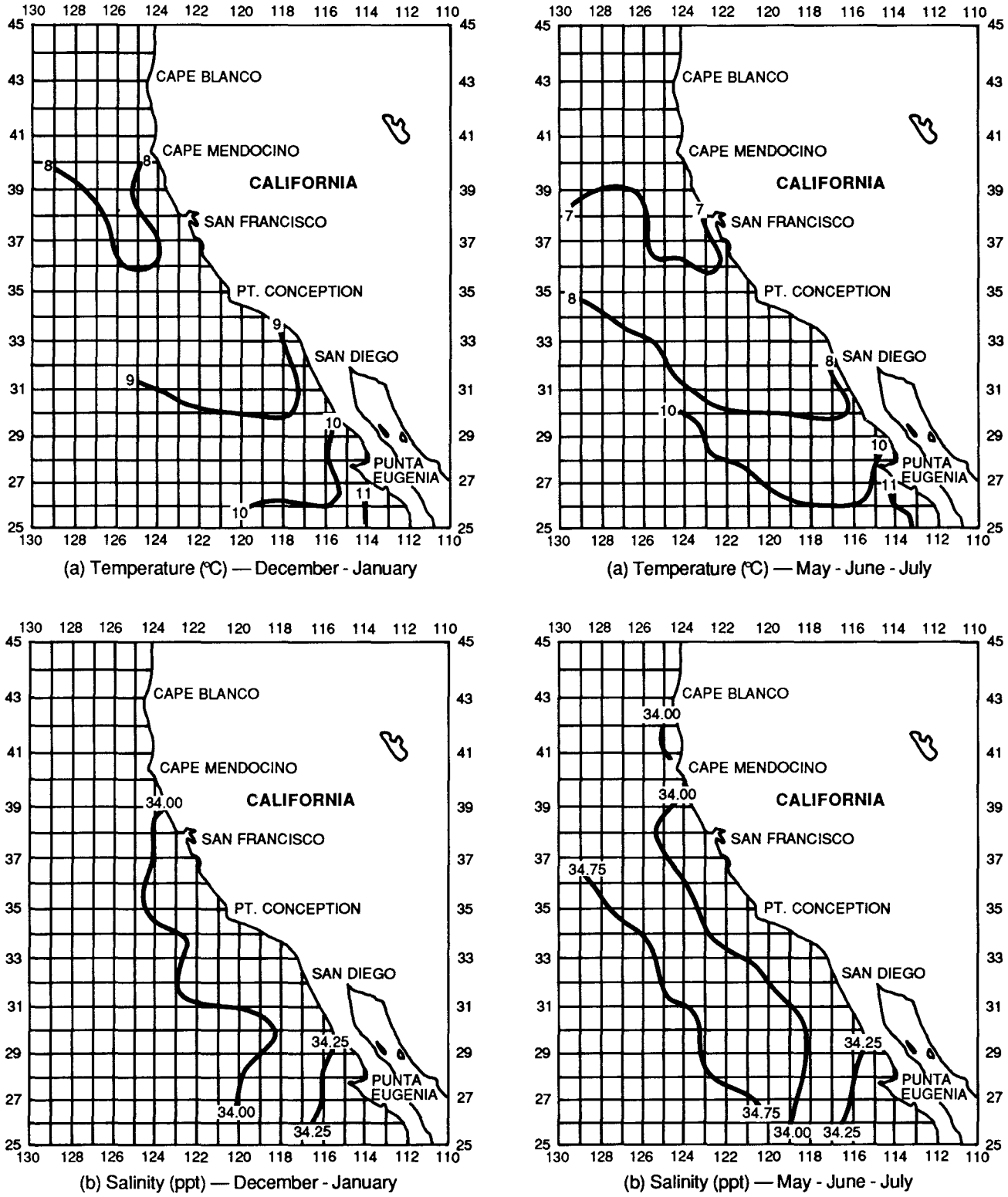


Figure 2 - 9: Water temperature and salinity at 200 m in winter (non-upwelling) and spring (upwelling). (From Williams, et al., 1980.)

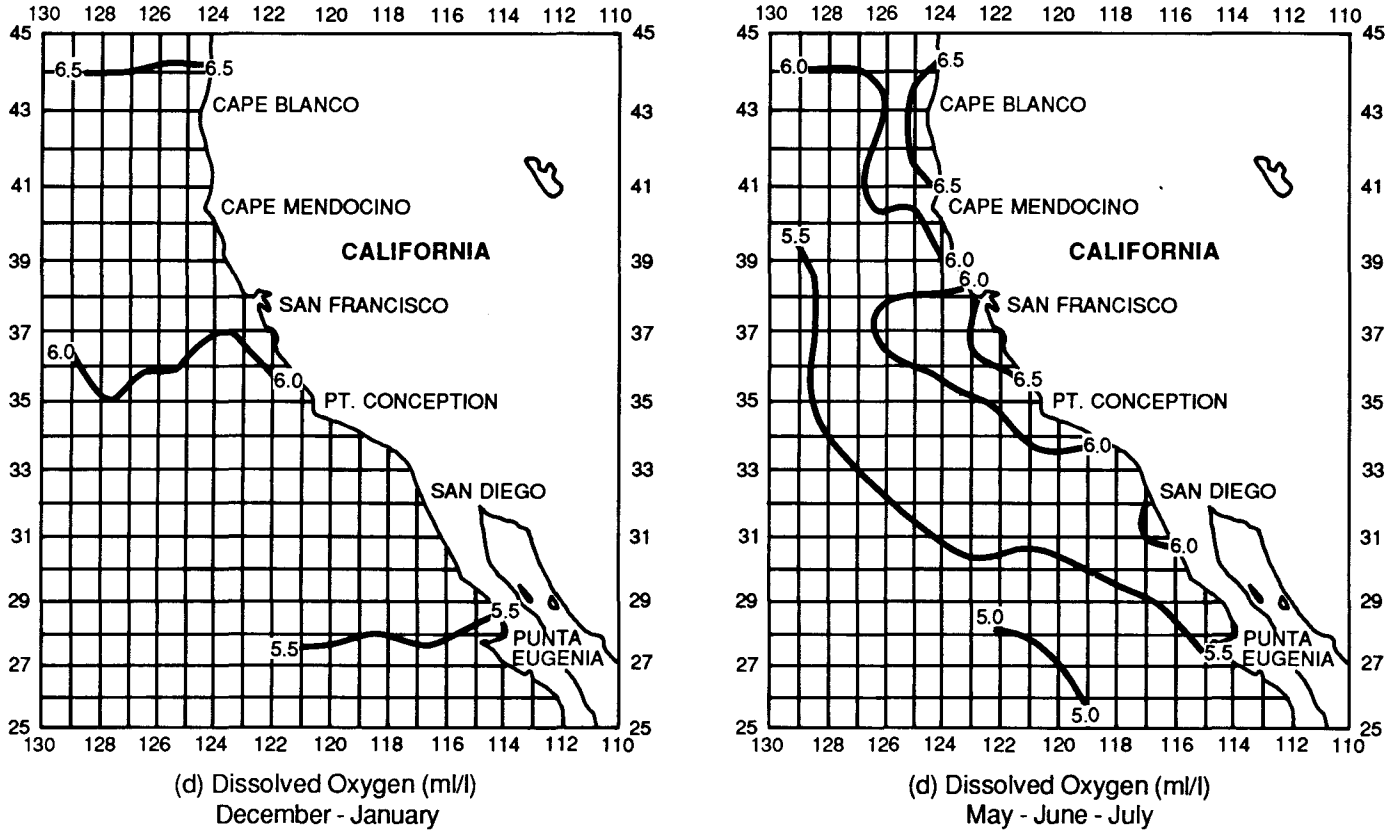


Figure 2 - 10: Dissolved oxygen concentrations at the surface in winter (non-upwelling) an spring (upwelling). (From Williams, et al., 1980.)

100 meters offshore. In spring, surface warming creates a secondary thermocline. This thermocline deepens as summer progresses until, in August, it reaches the depth of the primary thermocline.

The amount of dissolved oxygen in the water column decreases from saturation at the surface to a minimum value at a depth of approximately 700–1,000 meters (2,300–3,300 ft). Oxygen then gradually increases with depth. In late spring an oxygen maximum develops just above the thermocline. This oxygen maximum persists through the fall.

HYDROGEN ION CONCENTRATION (pH)

pH is a measure of the acidity/alkalinity of a liquid. pH is a unitless scale that ranges from 1 (most acidic) to 14 (most basic), with 7 being neutral.

Seawater is buffered, that is, it has the capacity to absorb acids and bases with little change in pH. The pH of seawater is largely controlled by the balance of carbon dioxide and forms of carbonate in the water.

Seawater is slightly basic. pH is usually highest at the surface and lowest in the oxygen

minimum zone. pH gradually increases with depth below the oxygen minimum layer. The pH for water on the continental shelf ranges from 7.5 to 8.6.

NUTRIENTS

Nutrients in the ocean, like fertilizer on cropland, provide the building blocks necessary for plant growth. Nitrogen, phosphorus and silicon are generally considered to be the most important nutrients in the ocean.

Nitrogen, rather than phosphorus, is believed to be the limiting nutrient for plant growth in the ocean (Rhyther and Dunstan, 1971). Phytoplankton preferentially absorb nitrogen as ammonium (NH_4^+); however, available ammonium is quickly absorbed so that free ammonium is often unavailable. Nitrate (NO_3) is the form of nitrogen most utilized by phytoplankton. Phosphorous is most often utilized as inorganic orthophosphate (PO_4), although some species of phytoplankton can break down organic phosphate. Silicon is important to diatoms and other organisms that use silicon to build exoskeletons and other structures.

In areas not influenced by upwelling, phytoplankton deplete nutrients in surface layers of the ocean. Continued cycling of nutrients and plant growth depends on upwelling as well as inputs of nutrients from land. In California, nutrient concentrations in surface water are low in fall and winter and high in the upwelling season (spring and summer). There is insufficient data at present to resolve the geographic distribution of nutrients. With the exception of nitrite (NO_2), nutrient concentrations increase with depth.

TURBIDITY

Turbidity is important as it is related to light transmission and therefore the depth of the water column that can support phytoplankton or algae. The bottom of the euphotic zone (the area available for plant growth) is considered to be the point at which light transmission is 1% of the incident light.

Turbidity depends on the amount of organic and inorganic particulate matter in the water. Plankton and marine snow (amorphous particulate material) are important components of organic material in the water, while sediment is an important component of the inorganic material in the water.

Turbidity is highest close to shore, where plankton productivity and sediment load is highest. Most sediment enters the coastal zone from streams and rivers and from the erosion of cliffs in the surf zone. Aperiodic large storms contribute most sediment to the ocean (Kolpack and Drake, 1985; Stow and Chang, 1987).

Waves produce turbidity by stirring bottom sediment and suspending fine particles in the water column. The size of particles that remain suspended depends on the kinetic energy of the water which, in turn, depends on wave size and water depth. Kinetic energy increases as wave size increases and water depth decreases. Thus larger sediment can be suspended into the water column in shallow water. In Southern California, bottom sediment in 30 meters of water is regularly subject to resuspension. Deeper sediment is usually undisturbed except during storms, when bottom sediment in 80 meters of water may be subject to resuspension (Drake, et al., 1985). When wave size decreases, heavier fractions settle back to the bottom. This periodic winnowing of bottom sediments produces a gradient in sediment grain size. Shallow, high-energy environments have coarser sediments than deeper, low-energy environments.

IMPACTS ON MARINE WATER QUALITY

Many human activities, such as ocean dumping and sewage disposal, impact marine water quality. This section provides an overview of the major types of marine pollution in California, their sources and relative magnitudes, the distribution of pollutants within marine ecosystems, and their ecological and human health impacts. Major sources of information include reports from the National Oceanic and Atmospheric Administration (Department of Commerce, 1988; 1989a, b), State Water Resources Control Board (1984; 1987; 1988a, b; 1990a, b), Southern California Coastal Water Research Project (SCCWRP 1973, Annual Reports 1977–89), Southern California Association of Governments 1988), Aquatic Habitat Institute (Phillips, 1987), Citizens for a Better Environment (1983), San Diego Interagency Water Quality Panel (1989) and Marine Review Committee (Murdoch et al., 1989). Much of this review is based on Southern California studies, because in this highly urbanized region the effects of human activities have been more thoroughly investigated than for any comparable area in the world.

Types of Marine Pollution

The types of materials affecting marine water quality can be broadly categorized as the following: debris, inputs changing common seawater characteristics, metals, non-metallic inorganics, organics, radioactive elements and biological pathogens. Debris consists of a variety of natural and man-made objects discarded into the ocean. It may include plant material (e.g., grass-clippings, wood), animal remains (e.g., shells, carcasses) or manufactured objects (e.g., paper, plastics, glass, metal). Whether floating or on the bottom, debris is often conspicuous and aesthetically displeasing. While debris may provide food or habitat for some marine organisms, it may harm or kill others after ingestion or entanglement.

Common seawater characteristics, such as color, odor, salinity, temperature and turbidity can be altered by human activities. Marine life may be stressed or die if exposed to changes in water quality (e.g., freshwater or hot water discharges) that are outside the ranges to which it is adapted. Increased turbidity due to releases of particulate matter may reduce the light available to plants, and clog the respiratory and feeding structures of animals. Falling particulates may smother benthic organisms and change seafloor habitats when they settle to the bottom. Metals occur naturally in seawater, sediments and living organisms, but pollution can greatly magnify these levels. Metals may be beneficial or toxic depending on the specific metal, its chemical form, its concentration and the particular organism. (Most animals have the capability of accumulating metals.) The toxicity of certain metals stems from their ability to poison critical enzyme systems. Some of the metallo-organic compounds, such as methylmercury and tributyltin, are among the most toxic substances known. The trace metals of greatest concern in the marine environment are mercury, tin, silver, copper, selenium, zinc, nickel, lead, cadmium, arsenic and chromium.

Non-metallic inorganic chemicals include many common constituents of seawater (e.g., chloride, sulfate, hydrogen ions (pH)), substances basic to plant and animal metabolism (e.g., oxygen, carbon dioxide), and growth-stimulating nutrients (e.g., ammonia, nitrate, phosphate). Some inorganic materials, such as cyanide, chlorine and sulfate can be toxic, and the lack of oxygen will kill most marine life.

Organic substances, that is, substances containing the elements carbon and hydrogen, include a host of natural and synthetic chemicals. Natural organic compounds are produced by living organisms and include body tissue, secretions and wastes. Petroleum and natural gas are hydrocarbons produced by heat and pressure acting on dead organisms. Decomposition of natural organic substances produces ecosystem-enriching nutrients, but also may deplete life-sustaining oxygen reserves. Man-made organic compounds are resistant to natural degradation. Many are toxic and remain so for a long time. They may be accumulated within living organisms, and reach increasingly magnified concentrations as contaminated prey are consumed by predators at each level of the food chain. Therefore, these synthetic pollutants are not only a serious long-term threat to natural resources, but also a potential human health risk. Synthetic organics of concern include industrial chemicals such as polychlorinated biphenyls (PCBs), chlorinated pesticides (e.g., DDTs, dieldrin, chlordane, endosulfan, toxaphene, pentachlorophenol, dacthal, endrin), polynuclear aromatic hydrocarbons (PAHs), phthalate esters, phenols, and dioxins.

Radioactive particles occur naturally and are produced by various human activities, including military, medical, and industrial endeavors. Some radioisotopes are long-lived and quite harmful to living systems.

Various biological pathogens are released to the ocean, especially via fecal wastes of infected individuals. Microorganisms of concern known to survive in seawater include viruses causing gastroenteritis and hepatitis, the disease-causing bacteria Staphylococcus, Salmonella, and Vibrio, and the pathogenic fungus *Candida albicans*. Indicators of potential human contamination in seawater include coliform, streptococcus, and enterococcus bacteria. Some human-derived and other pathogens may become concentrated in the tissue of filter-feeding clams and mussels.

Sources of Marine Pollution

Pollutants are released into California's marine waters from a multitude of sources. Some are obvious and well-documented, while others are poorly characterized. Pollutant origins typically are classified as point or nonpoint. Point sources discharge contaminants from a single location, usually via an outfall pipe. Major point sources are municipal wastewater treatment plants, industrial facilities and coastal power generating plants. Nonpoint sources include all other inputs, which generally enter the marine system from dispersed and uncontrolled origins. These diverse releases are much more difficult to isolate and quantify than point sources. Broad categories of nonpoint sources include river/storm water outflows (which carry wastes from many human activities), aerial fallout, vessel discharge, dredging and dumping activities, and offshore oil and gas operations.

Municipal wastewater discharges are the principal source of most marine pollutants in California. In Southern California, coastal outfalls are used to discharge effluent from 16 treatment plants. Municipal outfalls discharge wastes from residential, commercial and industrial sources. About 85% of the total flow is from residential sewage which contains a variety of household cleaners, oil, grease, food remains and human fecal wastes. Commercial and industrial sources discharge oils, greases and a variety of chemical wastes, including trace metals and synthetic organic compounds. Municipal wastes receive advanced primary

and/or secondary treatment which removes 50–90% of most particle-associated pollutants prior to disinfection and effluent discharge. In the past, some highly contaminated sewage sludge removed by treatment also was discharged to the ocean, but the last sludge discharge operation in Southern California was terminated in 1987.

Most industrial facilities currently discharge wastes into sewers connected to municipal waste treatment plants. Large industries discharging directly to marine waters are primarily limited to petroleum processing plants. Emissions from petroleum industries may contain process water (water associated with oil-bearing sediments) and refinery cooling and wastewater. Released pollutants include oil and grease, trace metals, and synthetic organics.

Coastal power generating stations use seawater to cool their generators, then discharge the waste heat in the same seawater that was withdrawn from the ocean. Some metals (from equipment decay), chlorine (added to control biofouling) and small amounts of liquid wastes may be found in the emissions. High volume intake flows draw in (entrain) and kill large quantities of planktonic organisms. In addition, turbulent discharge flows carry or resuspend particulate matter, resulting in plumes of turbid water at the outfall terminus.

The most important outlets for nonpoint source pollution are the 200–300 major streams and storm drains through which rainwater flows to the sea. In Central and Northern California, freshwater flow from rain and melting snow occurs year round. In dry Southern California, large flows occur only during major rainstorms. Freshwater runoff carries a wide spectrum of pollutants released directly or indirectly from numerous upstream human activities, including agriculture, forestry, mining, construction, industrial and urban endeavors. Water-borne pollutants may include suspended particulates, organic wastes, nutrients, herbicides, pesticides, hydrocarbons and a host of other chemicals. Except for urban storm drain systems connected to treatment facilities, these pollutants enter the ocean untreated. Untreated surface runoff in Los Angeles includes wastewater discharges from residential and industrial sources, accidental sewer overflows and operational spills. During storms this runoff becomes an important source of trace metals, toxic organic compounds and coliform bacteria to nearshore waters.

Aerial fallout is another nonpoint source of contamination which has not been well-quantified. Fallout from smog, aerial sprayings and acid rain may be an important source of toxic chemicals such as lead, mercury, zinc, copper, DDTs and PCBs to marine waters. Aerial fallout to land eventually becomes part of freshwater runoff, while fallout at sea initially pollutes the sea surface microlayer which is an important habitat for planktonic organisms.

Marine vessel operations create important nonpoint source pollution. Ships release some oil and fuel products during normal engine operations and may discharge oily ballast or bilge water. Shipwrecks and other accidents at sea may release various toxic substances being transported. Overboard discharges of human fecal wastes in nearshore waters may be a source of bacterial contamination. Anticorrosion anodes and antifouling paints on ship bottoms release trace pollutants such as zinc, chromium, lead, copper, mercury, tin, arsenic and PCBs. Of most serious concern is the antifouling paint agent tributyltin (TBT).

Recently banned for most small vessels, this extremely toxic and persistent chemical is capable of severely impacting marine communities, especially in harbor and bay environments.

Ocean dumping, especially when poorly regulated, can be considered as a nonpoint source of various pollutants. Prior to 1972, largely unknown quantities of toxic chemicals, aerospace wastes, oil refinery refuse, military munitions, and radioactive wastes were dumped over designated deep-water sites. In addition, illegal "short-dumping" closer to shore likely was common. Since 1972, with few exceptions, dredged sediments are the only materials that may be dumped in large quantities offshore. Dredging ship channels in harbors and bays uncovers and resuspends contaminated sediments that typically occur in these poorly flushed collecting basins. Oceanic dumping of these contaminated dredge spoils transfers a mixture of harmful harbor pollutants to offshore ecosystems.

Offshore oil and gas operations affect water quality in numerous ways. Petroleum products may leak or spill during drilling operations, submerged pipeline ruptures, or tanker accidents. If a large oil spill occurs, chemical dispersants may be used to break up the surface slick. Natural seeps also release oil to the marine environment. Drilling fluids, cuttings and produced water contain various particulates, trace metals, and synthetic chemicals. Oil rigs and work boats may discharge treated domestic wastes, and heavy machinery releases combustion products and other substances.

Levels of Marine Pollution

Most marine pollution in California emanates from the major coastal population centers of Los Angeles, San Francisco and San Diego. However, within these urban complexes, levels of input from many pollution sources, especially nonpoint sources, are poorly known. In the Los Angeles area, monitoring studies conducted by the Southern California Coastal Water Research Project (SCCWRP) since 1971 provide the best available information on relative emission levels by various sources. SCCWRP's initial analyses identified municipal discharges, surface runoff, aerial fallout, vessel discharges and ocean dumping as important high level sources.

Municipal outfalls are the principal origins of most marine pollutants. In Southern California, 90% of the 1,310 million gallons per day of effluent in 1987 was discharged from four large plants. In comparison, Central and Northern California municipal outfall flow rates are only a few percent of those in southern California, except for the San Francisco Bay Area where discharges are approximately 50% of those in the south. During the past 18 years of outfall monitoring in southern California, municipal treatment plants have contributed higher levels (generally greater than 90%) of suspended solids, oil and grease, most trace metals, DDTs and PCBs than other known sources. However, despite major increases in population and in wastewater flow since 1971, emissions of suspended solids and other contaminants have decreased steadily due to source control (of industrial inputs), improved solids handling and increased treatment. From 1971 to 1988, emissions of suspended solids were reduced by 66%, oil and grease by 61%, combined trace metals by 89%, and synthetic organic DDTs and PCBs by more than 90%. Generally similar reductions in sewage contaminant emissions were achieved by other coastal municipal treatment plants in the state. Although DDT and PCB emissions now are negligible, sediment

concentrations remain high in areas where elevated discharges occurred in the past. Such is the case off Los Angeles, where huge quantities of DDTs were discharged to sewers or dumped offshore by the Montrose Chemical Company from 1947 to 1970.

Other point source industrial and power plant discharges generally represent only a small percentage of the chemical emission levels of municipal outfalls. Coastal petroleum-processing plants in Southern California have reduced oil and grease emissions by 95% from 1973 to 1987. Coastal power plants are the largest dischargers of waste heat and often create plumes of turbid water. In Southern California, heat output from seven power plants increased about 25% from 1973 to 1987.

Flows from rivers, streams and storm drains probably are the second largest contributor of contaminants to marine waters after municipal treatment plants; however, insufficient data exist for reliable runoff estimates. Flow contents differ throughout the state, with highly variable inputs of suspended solids, dissolved organics, toxic chemicals and bacteria, depending on upstream human activities. In urban areas, as pollutants from outfalls continue to decrease, runoff emissions may become a relatively more important source of marine inputs. Runoff may be especially important in bays and estuaries where most freshwater flows terminate and contaminants tend to accumulate. Significantly, about 40% of the land area of California drains into San Francisco Bay.

Limited data are available on aerial fallout levels of contaminants. Considering the large surface area of the ocean, collective inputs may be substantial, especially offshore from smoggy cities. In 1971, rainfall washout was estimated to be the predominant source of mercury, lead and manganese in the Southern California Borderland. Additional pollutants may be added via dry fallout. Aerial fallout of lead, derived mostly from vehicle exhaust, has declined as motorists switch to unleaded fuels.

The extent of contamination from marine vessels is unknown. Ship traffic has expanded in recent years, increasing the risks of major accidents and spills. On the other hand, improved regulations have restricted the dumping of vessel wastes. The use of antifouling paints clearly has released harmful levels of copper, tin and other trace metals, especially to marinas and bays. High levels of the toxin tributyltin have been discovered in all California waters harboring marine vessels.

Until the 1970s ocean dumping off large metropolitan areas released unknown quantities of numerous pollutants to deep water environments. Some chemicals (e.g., DDTs, PCBs) persist at high levels in offshore sediments and organisms. Currently, just dredge spoils may be dumped, and only if the material cannot be used onshore and meets certain sediment quality standards. Recent dredge inputs to the Southern California Borderland released approximately 20–50% of the arsenic, cadmium, chromium, copper, lead and zinc levels emitted by the combined municipal outfalls.

Offshore oil and gas activities along the California coast have increased in recent years, therefore the risk of accidental spills likely is higher despite additional safety procedures.

Distribution of Marine Pollution

Once introduced, the distribution of pollutants in the marine environment depends on complex interactions between the physiochemical properties of the contaminants

and a variety of physical, chemical and biological processes occurring in the ocean. Pollutants may float or sink, be dissolved in the water column, or attach to other particles. Their dispersal is affected by water turbulence, currents and sediment movements. Thus particle-borne contaminants discharged from point sources into calm water will accumulate on the bottom in the vicinity of the source, while dissolved chemicals released from diffuse nonpoint sources into current-swept areas will be broadly distributed. During or after ocean transport, pollutants may be degraded, transformed, or accumulated by living organisms.

Discharged pollutants may be distributed to four major ecosystem compartments: the sea–surface microlayer, the water column, bottom sediments and living species. Many dissolved or floating substances—including trace metals, chlorinated and petroleum hydrocarbons, and plastics—tend to accumulate in the sea surface microlayer. The few studies of this air/sea interface habitat suggest that elevated contaminant levels are highest near major sources of pollution such as harbors. Important pollutants in the water column include heat (from power plant discharges), suspended particulates (e.g., from wastewater and power plant outfalls), dissolved nutrients, and biological pathogens.

Many trace metals and toxic organics are associated with particles and eventually sink to the bottom. Sediments are the ultimate reservoir for most contaminants. Chemicals in sediments may be resuspended (by waves or currents) and redeposited several times before fresh material covers older deposits. Some organic wastes may be decomposed into nutrients and other inorganic chemicals (e.g., sulfides), depleting oxygen levels in the process. Synthetic contaminants, like DDTs and PCBs are highly resistant to degradation. They persist relatively unchanged within the sediments, or can be taken up by living organisms.

Pollutants may be bioaccumulated (taken up and retained) by organisms in complex ways, depending on the chemical form of the contaminant, its concentration and characteristics of the plant or animal species. Chemicals with a high potential for bioaccumulation include DDTs, PCBs and organo-metallic compounds such as methylmercury and tributyltin. Organisms with a high bioaccumulation potential generally have characteristics such as high fat content, live on or near the bottom (e.g., flatfishes), filter-feed (e.g., mussels), or deposit feed (e.g., worms) on organic particles, or are high on the food chain (e.g., seals). Within their bodies, organisms can store, degrade, or transform accumulated chemicals. Certain compounds (e.g., DDTs, PCBs, methylmercury, tributyltin), become increasingly concentrated or biomagnified as predatory animals consume contaminated prey at progressively higher levels of the food chain. As top carnivores, sea birds, marine mammals and humans eating contaminated fish and shellfish may acquire high concentrations of toxic chemicals, resulting in adverse health effects.

Ecological Impacts of Marine Pollution

A tremendous amount of research has been conducted to evaluate the various ways in which pollution can impact marine biota. Conclusive demonstration that certain contaminants are exerting detrimental effects on biological resources is an exceedingly difficult task, not only because of the bewildering array of pollutants now present (and probably interacting) in most discharge areas, but also

because marine ecosystems are perpetually in a state of flux as they respond in complex ways to "natural" environmental variables. Chronic, low-level pollution effects are the most difficult to distinguish from natural changes; however, where massive or highly toxic emissions occur, overall impacts can be quite obvious.

Pollution impacts may occur at any of the levels of biological organization, including molecular, cellular, whole organism, population, community and ecosystem. Usually the biological response levels are interactive. Thus, a toxic chemical that inhibits a biochemical process could reduce an animal's ability to feed so much that its population is eliminated by starvation; consequently the structure of the associated community changes. At each level of organization, impacts may be acute (lethal), thereby eliminating that biological unit (organism, population, community, or ecosystem), or chronic (sublethal), in which some pollution stress impairs the ability of the biological unit to function normally. Responses are generally graded in relation to the intensity of the stress agent; however, sometimes no effect is evident until a certain threshold pollutant level is reached, beyond which the biological unit collapses or dies.

At the level of the individual organism, pollution impacts might be physiological, behavioral or reproductive. They may affect any life history stage (e.g., egg, larva, juvenile, adult). At the population level, sensitive individuals will first show signs of stress. As pollution increases, more tolerant individuals also will be affected. At the community level, shifts in species composition and relative abundances occur as some populations become reduced or absent and others find conditions more favorable. Often there is a depression in the total number of species, while population levels of the remaining stress-tolerant species increase greatly.

Possible ecological impacts from major pollution sources in California are discussed below for three generalized marine habitat types—water column, soft-bottom and hard-bottom. The water column contains drifters (plankton) and swimmers (nekton). Production of phytoplankton (and secondarily of zooplankton) provides the fundamental basis of the food web that supports most other marine organisms. Therefore, impacts to plankton populations could seriously affect the abundance of many other species. However, since natural variation in plankton populations is high, human impacts are difficult to assess. Nutrient emissions from municipal outfalls and other sources apparently enrich plankton populations. In protected waters, blooms of toxic red tide organisms may result. Plankton, including invertebrate and fish eggs and larvae, are entrained and killed during passage through power plant cooling systems. In Southern California, such losses apparently have little effect on overall plankton abundance; however, some fish populations may be substantially impacted.

Much is known about pollution impacts on soft-bottom communities because most municipal outfalls discharge directly to these habitats. Small, relatively immobile invertebrates living in or on soft sediments are most affected by introduced contaminants. Many species directly ingest sediments contaminated with toxic chemicals, such as trace metals and synthetic organics. Worms, crustaceans, clams and other species suffer acute or chronic impacts, and larval recruitment to polluted sediments may be unsuccessful. Bottom-dwelling fishes (e.g.,

flatfish, white croaker) are affected primarily by the contaminated invertebrates they consume. In addition to direct mortality, sublethal impacts such as impaired reproduction and diseases (e.g., fin erosion, epidermal tumors), are evident in the vicinity of major municipal outfalls.

Soft-bottom communities have a typically generalized response to pollution, especially that caused by degradable organic wastes. Mildly polluted areas, enriched by added nutrients, support a higher diversity of species and total biomass than unpolluted areas. Moderately polluted regions have fewer species overall, but certain stress-tolerant forms (pollution indicator species) may be quite abundant. Grossly polluted areas, with high sulfide and low oxygen levels, contain little or no life. At each municipal outfall, some or all of these ecological impact gradations radiate outward from the discharge site. An impacted area of about 25 square miles was evident near the Hyperion outfall off Los Angeles in the late 1960's and 1970's. After reducing contaminant emissions, the impacted area has decreased to less than 12 square miles.

Most point-source outfalls no longer discharge into calm water habitats in bays, harbors or lagoons. However, soft-bottom communities here may still be impacted by past discharges of toxic materials which persist in poorly-flushed sediments. In addition, nonpoint sources such as freshwater runoff and vessel emissions create important, but poorly documented impacts. Highly toxic tributyltin leached from anti-fouling paints has impacted fish and shellfish populations in Marina del Rey (Los Angeles). Such adverse effects may be critical because shallow embayments serve as nursery grounds for many coastal fishes.

Municipal outfalls can affect hard-bottom habitats through increased turbidity, sedimentation and chemical toxicity. Elevated levels of suspended solids (turbidity), reduce the amount of light available for attached plants to carry out photosynthesis. Consequently, these plants and their associated animal assemblages can survive only in the shallowest depths. Increasing levels of falling particulates may clog the feeding and respiratory structures of filter-feeding invertebrates, bury encrusting species, or completely cover everything , transforming low rocky reefs into soft-bottoms. Other contaminant impacts on rocky habitat species, though less studied, apparently are similar to those described above for soft bottom benthos.

Giant kelp (*Macrocystis spp.*) is a keystone species whose extensive underwater forests support a multitude of algae, invertebrates and fishes. Catastrophic declines in kelp beds at Palos Verdes from 1940 to 1974 were associated with massive emissions from the Los Angeles County outfall. Since 1974, kelp beds have gradually recovered as particulate and toxin emissions declined. Heated water and particulates resulting from power plant outfalls similarly may impact kelp beds.

Most outfalls now are located well offshore of rocky intertidal habitats, however decreases in seashore plants have been associated with some outfalls. Other community impacts are difficult to distinguish from natural variation. Compared to subtidal habitats, intertidal shores are unique in being directly exposed to fallout from air pollution and to contaminants floating on the sea–surface microlayer, especially petroleum compounds. The complex effects of oil spills on intertidal life are well-documented.

Highly mobile marine mammals can occur in all the marine habitats discussed above, while

sea birds are limited to intertidal, shallow subtidal and sea surface areas. Because species in both groups generally are top carnivores, they have acquired high levels of biomagnifying toxins such as DDTs and PCBs. Reproductive failures of brown pelicans and other sea birds due to eggshell breakage have resulted from high concentrations of DDTs. Nearshore species of marine mammals washed ashore in Southern California often have elevated levels of DDTs and PCBs, but data are insufficient at present to show any cause-and-effect relationship. Sea otters and all sea birds are highly vulnerable to oil spills.

Human Health Impacts of Marine Pollution

Many pollutants released to marine waters have the potential to produce a variety of acute or chronic human health effects. Actual risks depend on pollutant characteristics and concentrations, as well as their potential availability to people. Generally, humans can be exposed to toxins, carcinogens, or pathogens either by eating contaminated seafood or by contacting or swallowing polluted water. DDTs, PCBs, chlordane and some metals (lead, silver, cadmium, chromium, mercury, tin) in fish and shellfish from contaminated areas are the greatest concerns. Eating relatively large amounts of fatty bottom fish caught near Los Angeles municipal outfalls may result in significant health risks, primarily due to the high levels of DDT and PCB contamination.

Water-contact activities (e.g., swimming, surfing, skin-diving) and consuming raw shellfish are the main ways infectious diseases could be acquired from the marine environment. Important pathogens (e.g., gastroenteritis and hepatitis viruses) are derived from human fecal waste discharged mostly from municipal outfalls, freshwater runoff and marine vessels. Of these, urban storm water runoff draining onto recreational beaches probably poses the greatest risk, especially if untreated sewage overflows into the same drainage system. Actual risks are not well known at this time.

MARINE BIOLOGY

The eastern Pacific has been divided into biological zones or provinces by a number of authors (see Valentine, 1966). Most authors identify five principal zones: Arctic, Alaskan, Oregonian, Californian and Panamanian (Figure 2-11). Point Conception is generally recognized as a major break between the cold-temperate biota of the Oregonian province and the warm-temperate biota of the Californian province. Some authors divide the Oregonian province into two subprovinces: from Point Conception to Monterey and from Monterey north. Valentine (1963) considers the area from Point Conception to Morro Bay an area of overlap between the Californian and Oregonian provinces.

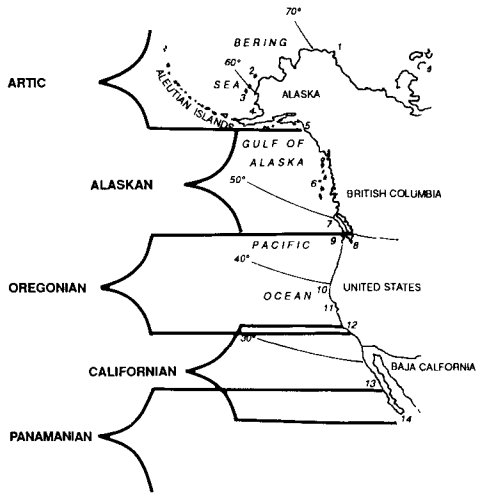


Figure 2 - 11: Principal biological provinces on the eastern Pacific (after Valentine 1963 & 1966).

These biotic provinces are consistent with the oceanography of the region. As described in

Physical Oceanography and Marine Water Quality, water in the Southern California Borderland is predominately subtropical in origin while water in northern California originates in the Gulf of Alaska. The two water masses meet at a front that is usually located off Point Conception. Depending on oceanographic conditions, the front may move south into the Borderland or north of Point Conception (Figure 2-12). The water mass in Southern California supports a biota with tropical affinities while the water mass in Northern California supports a biota with arctic affinities.

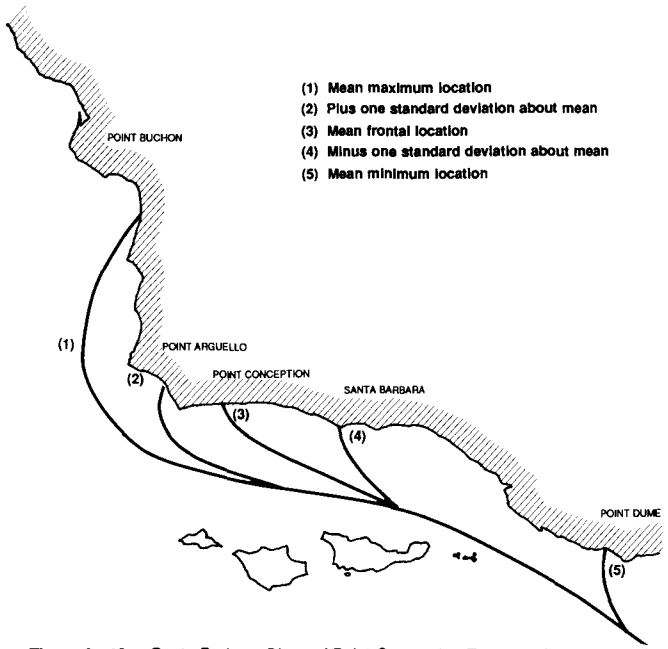


Figure 2 - 12: Santa Barbara Channel/Point Conception Front: estimated statistics on frontal location (from SAIC, 1987).

Species diversity is higher in Southern California than in Northern California (Horn and Allen, 1978; Newman, 1979). This is, in part, because tropical faunas have more species than subarctic fauna. Also there is greater habitat diversity in Southern California. North of Point Conception the continental shelf is relatively narrow. South of Point Conception the shelf is 45–90 miles wide and is divided into a complex series of ridges, basins, and islands known as the Continental Borderland. The greatest number of species is found near Point Conception, the area of overlap between the two provinces.

BOTTOM HABITATS

Substrate type (e.g., rock or sand) is one of the most important factors determining the kind of marine life on the bottom. Some organisms, such as kelp, sponges and barnacles, attach permanently to hard substrates and are only found on boulders and rocky reefs. Other organisms burrow like earthworms, eating organic material in the sediment. These organisms are found only in mud and fine sands. Each organism is adapted for a particular type of substrate and the types of organisms found in rocky and sandy areas are different. If oceanographic conditions change or sediment is introduced into an area (thus changing the bottom texture), biological communities will change as well.

Hard-Bottom Areas

For practical purposes, marine hard-bottom habitats in California can be divided into three depth categories: intertidal shores, shallow subtidal reefs ($<$ 200 ft), and deep offshore reefs ($>$ 200 ft).

In intertidal areas, the periodic fluctuations in water-cover caused by tides produce characteristic zonations of life. Only those species most resistant to desiccation and high temperatures can survive in the uppermost zone wetted only by wave splash. At the other extreme, organisms that cannot live long out of water are found in the lowest intertidal zone. In between are zones of life adapted to differing degrees of physiological stress and competition for space and food. In habitats with pits or

depressions, water collects to form tidepools containing "oases" of marine life. Large, deep pools provide unique opportunities for intertidal visitors to observe rich assemblages of species more typical of subtidal environments.

Exposure to wave shock and the type of bottom substrate are important factors determining the kinds of organisms present in rocky intertidal areas. Rocky shores partially protected from wave shock by a headland, island or offshore reef have a greater diversity of plants and animals than unprotected surf-swept shores, where only the hardiest organisms can survive. Beaches with smooth, low-lying, unstable rocks have less life than craggy, high-relief, bedrock shores that provide numerous microhabitats. Habitats with diverse substrate characteristics generally host the richest assemblages of marine species.

Predators, such as sea urchins and starfish, are also important in regulating distributions of intertidal organisms. Mussel beds are often limited to a well-defined band in the middle intertidal zone. The lower limit of the mussel beds is set by predation by starfish. Mussels that settle and grow below mid tide are eaten. Mussels in higher areas are protected because there is insufficient time between low tides for a starfish to consume a mussel. Sea urchins may eliminate algae from lower intertidal areas.

Overall, 45% of the California mainland coast is rocky (Figure 2-13). The northern and central California coasts have much higher proportions of rocky vs. sandy habitats than do those in Southern California (54% and 61% vs. 20%). The Channel Islands are predominantly rocky (77%), and contain over three times the rocky shoreline of the nearby Southern California mainland.

Rocky subtidal shores are very productive ecosystems, capable of supporting a wealth of marine life. Subtidal reefs are popular destinations for commercial and sport fishermen and scuba divers.

Plant-dominated communities thrive on shallow, well-lighted reefs of moderate to low wave exposure. Sunlight and nutrients stimulate lush plant growth, which in turn provides food for a variety of animals. In less than 40 feet of water, beds of surfgrass (*Phyllospadix spp.*) provide nursery areas for lobsters, fish and other organisms.

In deeper water or in areas with high wave exposure, sessile filter-feeding animals, such as gorgonians or bryozoans, predominate. Areas with excessive siltation or surge-generated sand scour, typically have few species. Nearshore mainland reefs tend to have more nutrients, higher turbidity, and greater sand influence than offshore island reefs, where terrestrial runoff is usually low.

In many places, forests of giant kelp add vertical complexity, increasing species diversity and providing food and shelter for a diverse assemblage of plants and animals, many of which are commercially important (Foster and Schiel 1985). Kelp itself is of great commercial value, with thousands of tons harvested annually (See Chapter One).

Kelp forests or "beds" are found on most hard-bottom substrates to depths of 100 feet; in the protected waters off Santa Barbara they also occur in soft-bottom habitats. Kelp forests in California can be classified into two types based on the species that forms the surface canopy. Bull kelp (*Nereocystis luetkeana*) forests range from Pecho Rock in San Luis Obispo County to the Aleutian Islands (Abbott

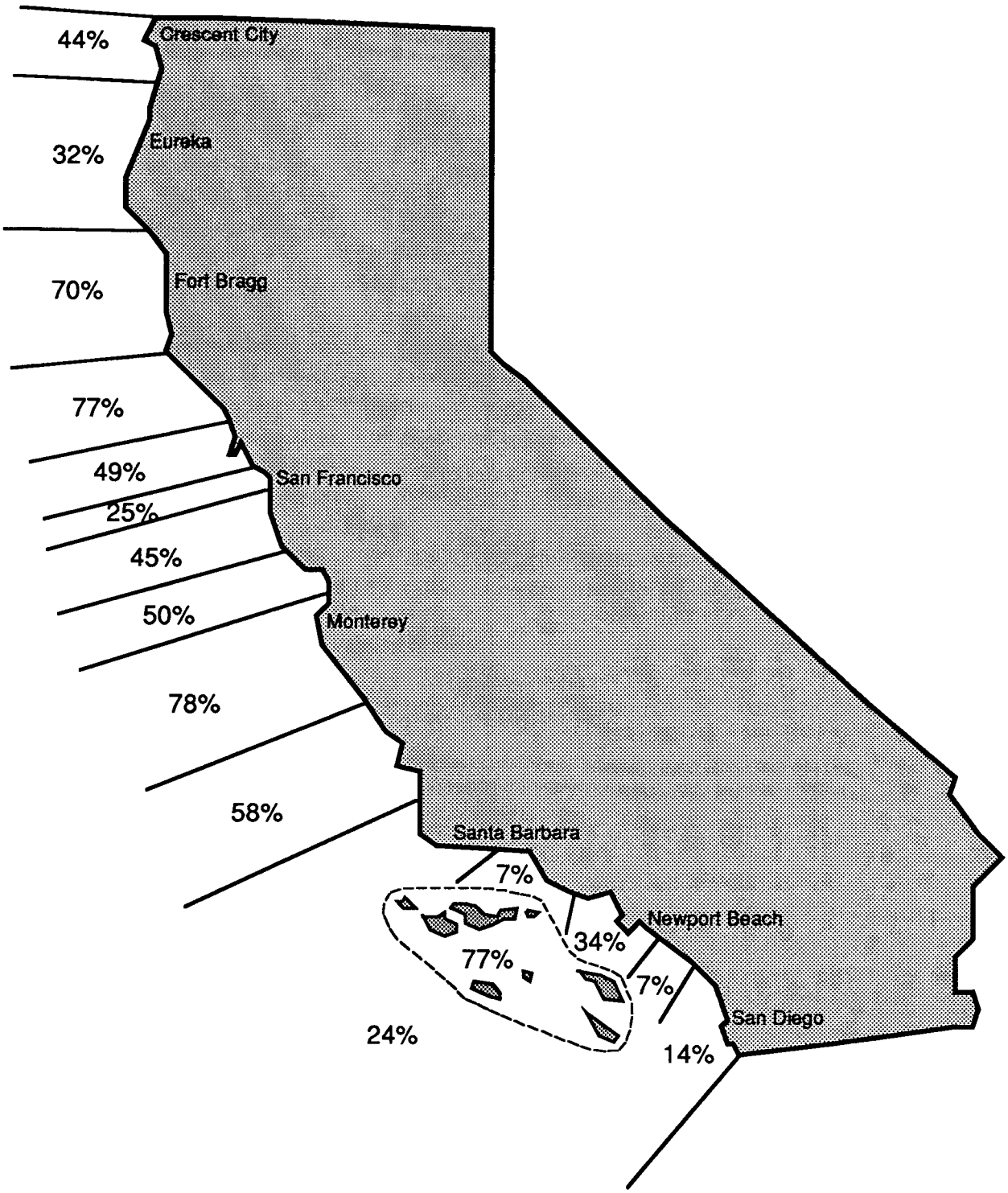


Figure 2 - 13: Overview map showing the percent of rocky shoreline for California coastal counties and Channel Islands. (Data are from Smith, et al.,1976).

and Hollenberg 1976, B. Van Waganen, ECOSCAN, personal communication). Giant kelp (*Macrocystis pyrifera*) forests occur from central Baja California to just south of San Francisco. In areas where their ranges overlap giant kelp and bull kelp often form mixed-species beds. The distribution of giant kelp in California is shown in Figure 2-14; bull kelp beds have not been mapped.

There is substantial seasonal and annual variation in the distribution and size of kelp forests in California. In general, productivity and biomass are greatest in the spring and early summer and lowest in the late fall and winter. The relative importance of the different factors that control kelp abundance varies along the coast. In Southern California, kelp decline is affected by several factors of which intrusions of warm nutrient-poor water, excessive grazing by sea urchins and episodic winter storms appear most important. Kelp can also be severely impacted by sea urchins in Northern California. Unlike southern forests, however, kelp beds growing in the cool waters of exposed northern coasts rarely suffer from warm nutrient-poor conditions but instead are subjected to more frequent and severe wave action associated with winter storms. Forests occurring off central California may fluctuate the least. As in the northern part of the state, waters are generally cool and nutrient-rich in this region; however, grazing by sea urchins is minimal because of the intense predation on them by sea otters, a key predator that is absent in northern and southern forests. Thus, seasonal and yearly fluctuations in kelp abundance in Central California appear to be controlled primarily by winter storms.

The distribution of shallow subtidal reefs is less well known than for the rocky intertidal. Large-scale studies have not been done, and the rigorous ocean conditions in many areas make scuba diving surveys difficult. Often nearshore reefs are found where rocky intertidal habitat occurs. Kelp beds generally are good indicators of subtidal reefs, except in the Santa Barbara Channel. Overall, numerous shallow reefs occur along rocky shores in both Northern and Central California, and around the Channel Islands. Relatively few subtidal reefs are found along the mainland in Southern California.

Deepwater hard-bottom areas (200–5,000 ft. in depth) are the least well known of California's rocky habitats. Most deepwater bottoms are muddy. Only recently have submersibles and remote-operated vehicles begun to explore the much less common and otherwise inaccessible deep rocky reefs. These surveys have been confined to areas of interest for offshore oil and gas operations. At greater depths there is insufficient light for plant growth and communities are dominated by animals. The physical environment (e.g. temperature, salinity, light) is fairly constant, and for a given depth, deepwater assemblages tend to be quite similar over broad geographic ranges. High-relief features such as those found at Cordell, Tanner, and Cortes Banks provide structural complexity resulting in highly diverse communities with abundant fishes and attached suspension-feeding invertebrates. Low-relief areas often are heavily silted, with greatly reduced species diversity. The amount of sediment cover is a major factor influencing biological assemblages on deep reefs. Increasing siltation smothers attached invertebrates, gradually changing the habitat to soft bottom.

Distribution records for deep hard-bottom areas are incomplete, based on scattered lead-line soundings, snags reported by fishermen, and geophysical (SONAR) surveys conducted by the U.S. Geological Survey and

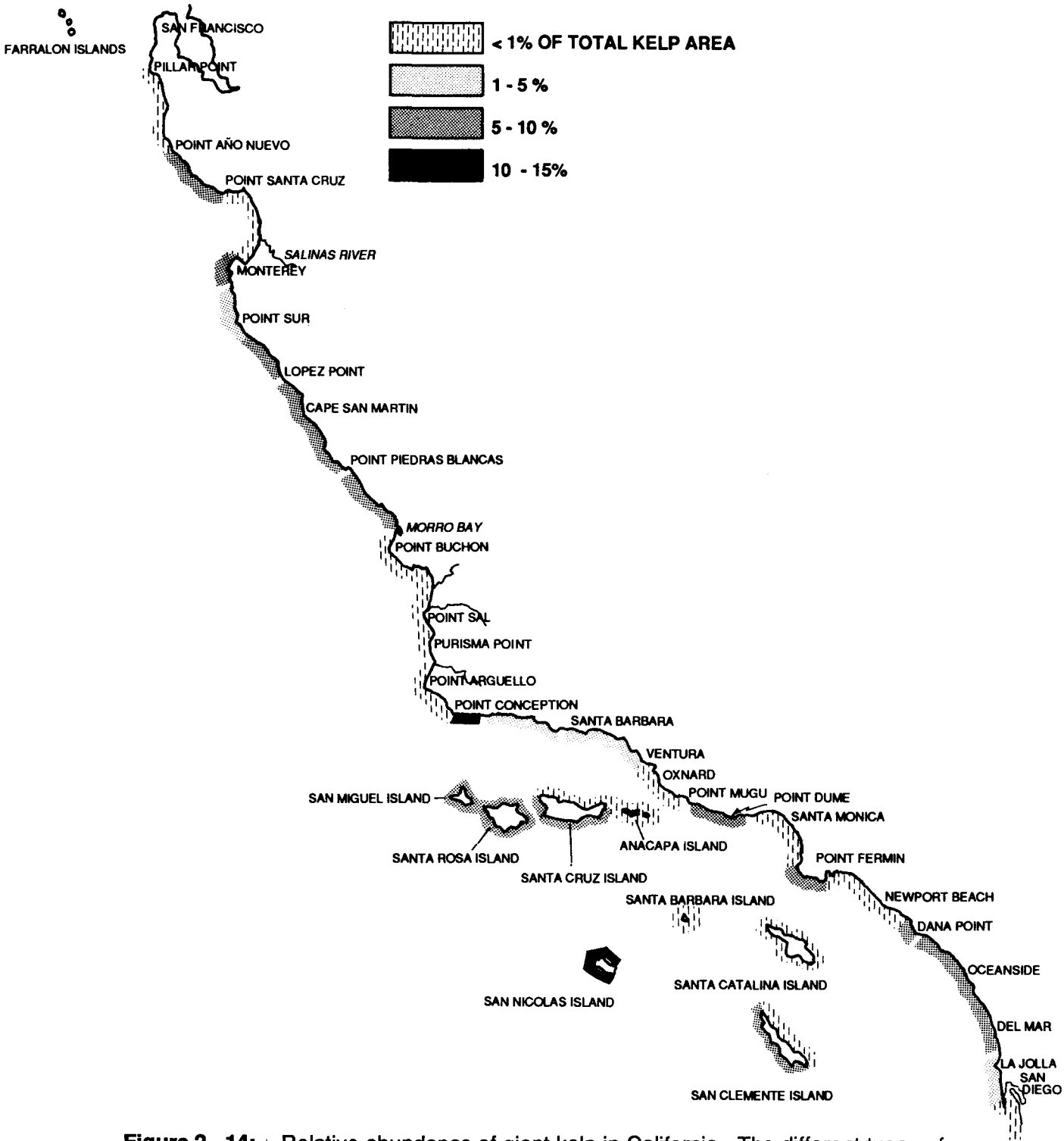


Figure 2 - 14: Relative abundance of giant kelp in California. The different types of shading represent the percent of the total kelp area in California that occurs in that shaded area. For example, the kelp beds around San Nicolas Island account for 10-15% of the total giant kelp area in California. Data from a survey done by the DFG in 1968.

by various oil companies. Recent direct observational evidence has shown that some previously reported hard-bottom areas are not exposed rock, but rather are rocky substrate covered by soft sediments. Deep rocky bottoms often are located offshore from major headlands and islands, and on the highest parts of undersea ridges, banks, and pinnacles. The latter features are most common in the Southern California Borderland.

Soft-Bottom Areas

In intertidal areas with unconsolidated substrate, organisms must cope with shifting sand as well as the rise and fall of the tide. Relatively few animals can withstand this rigorous environment; the diversity of life is lower on sandy beaches than on rocky shores. Some animals adapted to this environment, such as sand crabs, form dense aggregations that move with the shifting sand and tide; others burrow into the sand at low tide. In general, diversity is higher on fine sand beaches than on gravel and cobble beaches and higher in summer than in winter. Gravel and cobble are inhospitable environments where little organic material is retained, so food is deficient. Also organisms that colonize gravel and cobble beaches during quiet water are often crushed by sediment movement in storms. However, diversity may be high on protected cobble beaches where cobbles are not overturned during storm events. In this case, the undersides and interstices of the rocks become a haven for a variety of crustaceans and worms.

The kinds of animals found in subtidal soft-bottom areas depend predominantly on water depth and sediment texture. These two factors are, in part, related. Sediment texture tends to get finer with depth because in shallow water waves stir the bottom, suspending sediment particles in the water column. The more vigorous the water motion, the larger the particle that will remain suspended. Since waves create the greatest water motion in shallow water, sand and gravel are found in shallow surgy areas and mud is found in quiet water areas such as enclosed bays or in deep water. Moving water also carries food. In shallow, exposed areas sediment is coarse and water movement high. These conditions favor organisms that build permanent burrows or live on top of the sediment and feed by filtering or by catching particles as the water moves by. In deep or protected areas, fine sediment and slow water movement favor organisms that burrow, feeding on particles in the sediment.

Surveys done to date (Hartman, 1966; Fauchald and Jones, 1977, 1978a, 1978b, 1979; Thompson and Jones, 1987; and Department of Interior, 1989) suggest that soft-bottom biota can be divided into continental shelf, upper slope, lower slope and basin assemblages. In general, species diversity is higher on the shelf than on the slopes or in the basins. Some of the basins are oxygen-depleted and support very few individuals and species.

At present there is insufficient data to rigorously define biological communities in California or to map individual species of interest. The mainland continental shelf of Southern California has been extensively sampled, but deeper areas in Southern California and much of Northern California are not well known. For this report, maps showing the location of hard substrate or potential hard substrate are provided for each segment. These maps show the location of hard-substrate communities as far as is known at the present time. Kelp beds and artificial reefs are also shown.

Open-Water Habitats

Satellite images taken during active upwelling effectively show the open-water environment. Swirling eddies of cold, nutrient-rich water line the Northern California coast and intrude into the northern Channel Islands; warmer water fills the Southern California Borderland. Offshore, west of the upwelling zone and the Santa Rosa-Cortez Ridge, is relatively uniform, clear oceanic water. The coastal zone is more turbid because surf and streams bring sediment into the water, and because the nutrient-rich water supports abundant plankton populations. The most productive water is found immediately adjacent to the shore. Fish and seabirds thrive in nearshore waters.

As discussed at the beginning of this section, oceanographic conditions and the distribution of water masses control the distribution of marine organisms. This is particularly true of open water species, some of which float passively with the currents and some of which actively seek specific water conditions. Each water mass (oceanic, equatorial and subarctic) supports a particular suite of species. As water masses shift, the distributions of the species change as well.

Species distributions change with water depth. Deep water is dark, fairly uniformly cold in temperature, and slow moving. Surface water is sunlit and relatively warm. It is mixed by waves and moved more or less rapidly by currents. Physical conditions, such as temperature and salinity, are more variable in surface water than in deeper water.

Surface water supports phytoplankton, microscopic plants that fuel the food chain. In clear offshore water, phytoplankton may grow as deep as 300 feet; in turbid coastal water, phytoplankton may be restricted to the top ten or fifteen feet. Upwelling in spring and early summer brings nutrients into sunlit surface water, allowing for growth of phytoplankton and the rest of the food chain. As summer progresses, a thermocline develops, isolating warm surface water from deeper cool water. Phytoplankton deplete nutrients in the surface water and growth slows. Often a phytoplankton layer develops near the thermocline, where there is sufficient light for growth as well as some transport of nutrients from deeper water. This phytoplankton layer is dispersed when falling temperatures and winter storms break down the thermocline. The food chain in the deep ocean is supported by a rain of organic matter from the surface.

Productivity in the ocean is closely tied to the currents and upwelling. When the California Current is well-developed and southward transport and upwelling is strong, phytoplankton and zooplankton are abundant (Smith and Eppley, 1982; Chelton, et al., 1982), and productivity of food chain organisms is high. When southward transport and upwelling is weak, such as during El Niño events, nutrients in surface water are depleted and phytoplankton populations decrease (Fiedler, 1984). Some food chain species decline in abundance; others move out of the area. The scarcity of food can cause reproductive failure in seabirds and marine mammals (Ainley and Boekelheide, 1990; Barber and Chavez, 1983). In the 1982–83 El Niño, there was reduced survival of immature California Sea Lions and Northern Elephant Seals. Many species of seabirds abandoned their nests.

Concentrations of plankton, birds, fish and mammals are often found at fronts where different water masses converge (Briggs, et al., 1984 & 1987; Smith, et al., 1986). One notable

front (described above), runs perpendicular to the coast off Point Conception. There is an another front perpendicular to the coast off San Diego. This front defines the edge of the California Current as it moves inshore near the Mexican Border (Palaez and McGowen, 1986). Parallel to the coastline approximately 100 to 300 miles offshore there is a front between clear oceanic water and turbid coastal water. Albacore are known to feed preferentially on the offshore edge of this front (Laurs, et al., 1984). During upwelling the edge of the front is broken by eddies and filaments of cold water, particularly from Cape Mendocino to Point Conception and off Cape Blanco and Point St. George. Species congregate at convergences between cold upwelled water and warmer surface water. The freshwater plume from San Francisco Bay forms another front, particularly from late winter to early spring when the plume may extend 20 miles from shore.

Areas with steep gradients in bottom topography, such as seamounts, canyons and escarpments, are also areas of high productivity. Smaller scale upwelling and eddies occur along these features enhancing primary productively. For example, Cordell Bank, a sea mount off Bodega Head, has been recognized as a National Marine Sanctuary because of the number and diversity of marine animals recorded there. In Southern California, the Santa Rosa–Cortez Ridge, including Tanner and Cortes Banks, is a significant marine feature.

SEABIRDS AND MARINE MAMMALS

The abundance and diversity of seabirds and marine mammals that occur along California are remarkable. More than a third of the world's species of cetaceans (whales and dolphins) occur off California; populations of some species of birds are among the largest in western North America south of the Aleutians. In the fall an estimated seven million seabirds in 103 species occur off California (Briggs et al., 1987). Several hundred thousand marine mammals are residents or common migrants in California, including 25 species of cetaceans, six species of seals and seal lions, and the Southern Sea Otter (Figures 2-15 and 2-16). The number and distribution of species vary with year, season and habitat requirements.

Migratory Species

Migratory marine birds and mammals account for most of the biomass of California marine vertebrates. Animals migrate south from breeding grounds in the northern Pacific, north from Mexico and Central America, and north from breeding grounds in the southern hemisphere. Cetaceans also make onshore–offshore migrations.

Gray Whales have the most clearly defined migratory route. In Northern California, Gray Whales often stay within a mile of shore, bypassing bays and other indentations in the coastline (Figure 2-17).

The migratory route through the northern half of the Southern California Borderland is not known; however, in the southern part of the Borderland, the whales use five primary paths for the southbound migration and three for the northbound (Schulberg, et al., 1989; Figure 2-18).

During the northward migration females with calves often stay near the surf zone, even within 100 feet of the surfline. A few Gray Whales may summer in California around islands of the Southern California Borderland, the Farallon Islands, Big Lagoon, Klamath River and St. George Reef.

SPECIES	MIGRANT	RESIDENT	OCCASIONAL	RARE	NORTH	SOUTH
Blue Whale	*				*	*
Fin Whate	*				*	*
Sei Whale			*		*	*
Bryde's Whale			*			*
Humpback Whale	*	*			*	*
Minke Whale	*	*			*	*
Gray Whale	*	*			*	*
Right Whale				*	*	*
Sperm Whale	*				*	*
Baird's Beaked Whale			*		*	*
Cuvier's Beaked Whale			*		*	*
Mesoplodon spp				*	*	*
Killer Whale	*	*			*	*
False Killer				*		*
Pilot Whale	*	*				*
Risso's Dolphin	*	*			*	*
Pygmy Sperm Whale				*	*	*
Dwarf Sperm Whale				*	*	
Striped Dolphin				*		*
White-sided Dolphin		*			*	*
Common Dolphin		*				*
Bottlenose Dolphin		*			*	*
Dall's Porpoise		*			*	
Harbor Porpoise		*			*	
Right-whale Dolphin	*	*			*	*
Spotted Dolphin				*		*
Spinner Dolphin				*		*
Frasers Dolphin				*		*
N. Fur Seal	*	*			*	*
N. Elephant Seal	*	*			*	*
Harbor Seal	*	*			*	*
N. Sea Lion	*	*			*	*
Cal. Sea Lion	*	*			*	*
Guadal. Sea Lion			*			*
Sea Otter		*			*	*
Sea Turtles	*					*

Figure 2 - 15: Marine mammal and reptile species of California.

Many large baleen and toothed whales migrate south in winter and north in summer in California, but the migratory routes are less well defined than for Gray Whales. While many large whales migrate through California to northern Alaskan feeding grounds, some stay in California. Fin, Humpback and Sei whales use the Southern California Borderland as part of their winter feeding grounds, while Fin, Humpback and Blue whales use Northern California as part of their summer feeding grounds. Some Fin and Minke whales may

Primary Seabirds of California (from Briggs, et al 1987)

SPECIES NORTH	SP/ FALL MIGRANT	BREEDING RESIDENT	WINTER RESIDENT	SUMMER VISITOR	YR-ROUND RESIDENT	SOUTH	NORTH
Loon spp							
Red-throated	*		*			*	*
Pacific	*		*			*	*
Common	*		*			*	*
Grebe spp							
Eared/horned	*		*			*	*
Western	*		*			*	*
Albatross							
Black-footed				*	*	*	*
Laysan			*			*	
N. Fulmar	*		*			*	*
Gadfly Petrels				*		*	
Shearwater spp							
Pink-footed				*		*	*
Buller's				*		*	
Sooty	*			*	*	*	*
Short-tailed	*		*			*	
Black-vented			*	*		*	*
Storm-Petrel spp							
Fork-tailed		*			*		*
Leachs		*		*	*	*	*
Ashy		*			*	*	*
Black		*		*	*		*
Least				*			*
Red-billed Tropic Bird				*			*
Brown Pelican		*		*	*	*	*
Cormorant species							
Double-crested		*			*	*	*
Brandts		*	*		*	*	*
Pelagic		*			*	*	
Brant	*		*			*	*
Scoter spp							
Surf/white-wing			*		*	*	*
Black			*			*	*
Red/Red-necked Phalarope	*					*	*
South Polar Skua				*			*
Jaeger spp							
Pomarine	*		*			*	*
Parasitic	*					*	*
Long-Tailed	*					*	*
Gull spp							
Bonaparts	*		*			*	*
Heermans				*		*	*
Mew			*			*	*
Ring-billed					*	*	*
California			*			*	*
Herring	*		*		*	*	*
Thayers			*			*	*
Western		*	*		*	*	*

Figure 2 - 16A.

SPECIES	SP/ FALL MIGRANT	BREEDING RESIDENT	WINTER RESIDENT	SUMMER VISITOR	YR-ROUND RESIDENT	SOUTH	NORTH
Glaucous-winged			*		*	*	*
Sabines	*					*	*
Black-legged Kittiwake	*		*			*	*
Tern spp							
Royal					*	*	
Elegant				*	*	*	*
Common/Artic	*					*	*
Forsters		*			*	*	*
Least		*			*	*	*
Common Murre		*	*		*	*	*
Pigeon Guillemot		*				*	*
Murrelet spp							
Marbled		*			*		*
Xantus'		*	*			*	*
Craveri's			*			*	
Auklet spp							
Cassin's	*	*			*	*	*
Rhinoceros	*	*			*	*	*
Puffin spp							
Tufted	*	*				*	*
Horned	*		*			*	*
Black Oystercatcher		*			*	*	*

Figure 2 - 16B: Primary Seabirds of California (from Briggs, et al 1987).

reside year round in the Southern California Borderland, and Minke and Humpback Whales have been documented year round in parts of Northern and Central California.

There are certain regions in California where cetaceans concentrate. The Gulf of the Farallones appears to be significant for several species of baleen whale, particularly Humpback and Blue whales, during late summer and fall. During winter surveys by Dohl, et al. (1978, 1983), harbor porpoise were abundant around Trinidad Head and Cape Mendocino in Northern California, Risso's Dolphin around Points Pinos, Sur and Conception in Central California, Pilot Whales around Santa Catalina Island, and Right Whale Dolphins in patches from Point Reyes to Point Conception. Dohl, et al. (1983) noted that Gray Whales stacked up at Point St. George during the southward migration until some critical level is reached; then they continue on their route.

For species of toothed whales that are mostly pelagic in their habits such as the beaked whales, very little is known about their movements or behavior. These species are rarely seen nearshore or at sea.

Large numbers of pinnipeds also migrate through California waters. An estimated 200,000 Northern Fur Seals, primarily adult females, migrate each winter from Alaskan rookeries to feed in offshore areas of California. Tens of thousands of California Sea Lions and Northern Elephant Seals migrate into California

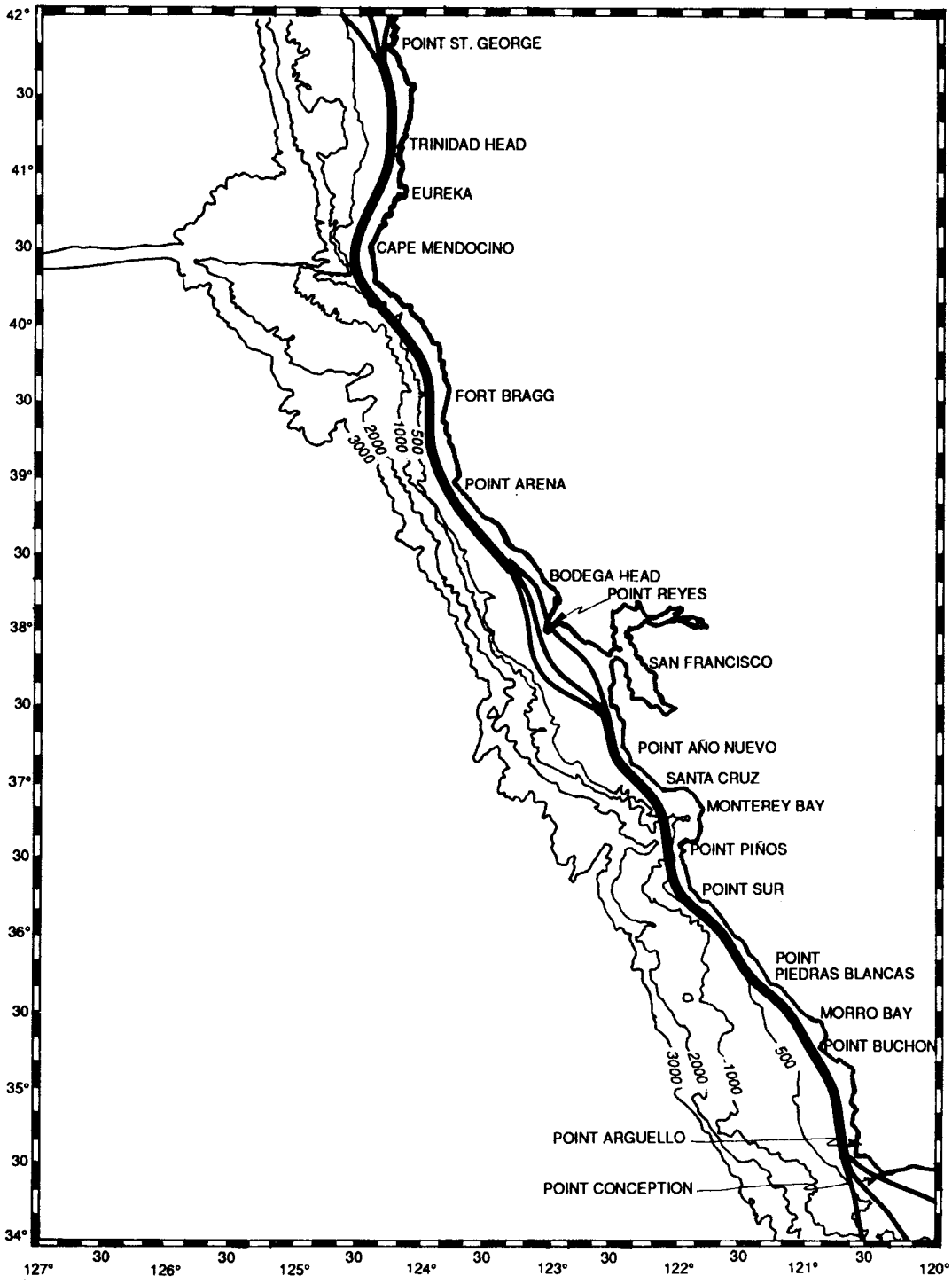
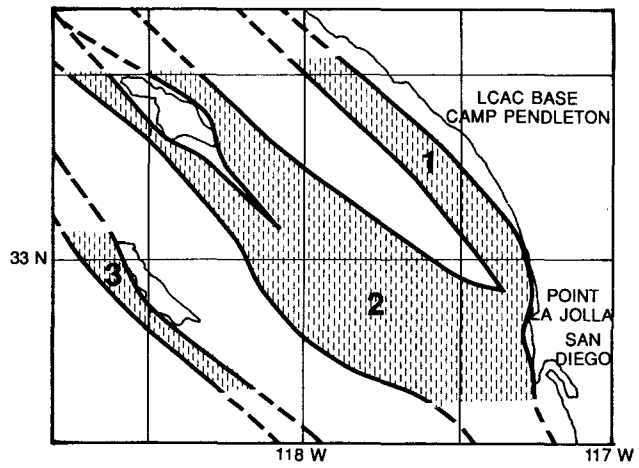


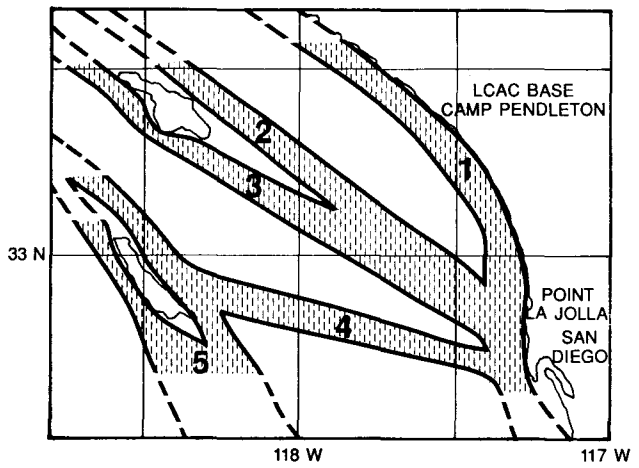
Figure 2 - 17: Gray whale migratory pathway in Northern California.

Source: University of California - Santa Cruz, Center for Coastal Marine Studies.

from Mexican breeding areas on the offshore islands of Baja California and the Sea of Cortez.



Northbound Gray Whale Migratory Corridors.



Southbound Gray Whale Migratory Corridors.

Figure 2 - 18 Source: From Shulberg, et al, 1989.

Several million seabirds migrate into and through California in the spring and fall; a few species account for most of this influx (Figure 2-16). From May through August, there is a migratory wave from the southern hemisphere across the equator to California. Sooty Shearwaters are particularly abundant, numbering from three to five million birds (Briggs, et al., 1987). Pink-footed Shearwaters are also common. In the fall approximately 75,000 Brown Pelicans, along with Heermann's Gulls and Craveri's Murrelets, migrate north into California from Baja California nesting sites. Other species migrate to California from northern breeding sites in the region from Alaska to Oregon. Of particular note are Northern Fulmars, Rhinoceros Auklets, scoters, grebes, gulls and phalaropes. Briggs, et al. (1987) determined that birds concentrated in shelf areas regardless of latitude and identified five primary areas: Crescent City to Trinidad, Point Reyes to Monterey, Morro Bay to Point Arguello, Santa Barbara Channel, and Santa Rosa–Cortes Ridge. Densities of seabirds in these areas averaged 50/km^2 and on occasion could exceed 1000 birds/km^2. In general, Briggs, et al. (1987) determined that densities of birds averaged highest over the continental shelf (111 birds/km^2), compared to the slope (28 birds per km^2) or water deeper than 2000 meters (8 birds per km^2).

Shorebirds migrate through and to the outer coast of California from fall to spring. Few species, though, breed in California. The state is a significant segment of the Pacific Flyway utilized by millions of shorebirds that migrate annually to and from northern breeding grounds to wetlands extending from Southern California to as far south as Peru. Along the route, birds stop to feed and rest at numerous locations in California. Examples of coastal areas of particular importance include outer coastal beaches in Monterey County, Pajaro and Salinas river mouths, and Año Nuevo Beaches and Point Reyes. Coastal lagoons and river mouths along Southern California are important to species such as Snowy Plovers, Least Terns and Sanderlings. In a survey of Central and Northern California, Page, et al.

(1989) reported that Sanderlings were the dominant coastal species followed by Black Turnstones, Ruddy Turnstones and Surfbirds. (Most shorebirds, however, congregate in bays and estuaries which will be covered in another section of this report.)

Resident Species

Principal mammal residents in California include Killer and Pilot Whales, Common, Pacific White-sided, Bottlenose, Risso's and Right-Whale Dolphins, Dall's and Harbor Porpoise, and Northern Elephant and Harbor Seals, Northern and California Sea Lions, Northern Fur Seals, and Sea Otters. Many of these species, such as Northern Fur Seals, Northern and California Sea Lions and Pilot Whales, may be resident and migratory. Most whales, porpoises and dolphins range over large areas, often many miles from shore. However, whales, Harbor Porpoise, Harbor Seals, sea lions and sea otters may feed close to shore, sometimes in the surf zone.

Common resident seabirds include Common Murres, Brown Pelicans, Ashy and Leach's Storm-Petrels, Brandt's Cormorants, Western Gulls, and Cassin's and Rhinoceros Auklets (Briggs, et al. 1987). Pelicans, cormorants, surf scoters and gulls generally feed close to shore, whereas shearwaters, storm-petrels and auklets often feed over the shelf break. Populations of most resident species are depleted from historical levels due to competition with humans for breeding sites and for food, incidental take in fisheries and from pollution (Ainley, personal communication).

Terrestrial Breeding and Haul-Out Sites

Both seabirds and pinnipeds require terrestrial habitat for resting, breeding and raising their young. There are 23 nesting species of seabirds in California, around 0.85 million birds (Briggs, et al.1987). Primary breeding species are Common Murres (53%), Cassin's Auklet (19%), Western Gulls (8%), cormorant spp. (11%), and Leach's Storm-Petrel (3%; Sowls et al. 1980). For seabirds, the most important terrestrial site in California is the Farallon Islands. The Farallones support 35% of all California breeding seabirds and are the largest seabird breeding area in the continental United States. Ainley, et al.(1987) estimate that a minimum of 400,000 seabirds reside in the Gulf of the Farallones from mid-March to mid-August. Almost the entire world population of Ashy Storm-Petrel nests in Central California, 77% of which (5–10,000 birds) nests on the Farallon Islands. The Farallones are important because they support a large diversity of species and significant percentages of the state's and the world's seabirds.

Another 40% of California breeding seabirds occur along a stretch of coastline from the California/Oregon border south to Cape Mendocino. All of the state's population of Fork-tailed Storm-Petrels, 91% of Leach's Storm-Petrels, and 60% of all Rhinoceros Auklets breed in this region. Castle Rock, located near Point St. George, is the second most important breeding area in California and supports around 140,000 seabirds including 11 species.

The Channel Islands are also a significant breeding site for seabirds. The entire state breeding populations of Black Storm-Petrel, Brown Pelican, and Xantus' Murrelet occur there. San Miguel and adjacent islands support around 29,000 nesting seabirds; Anacapa and Santa Barbara Islands support the only California breeding colony of Brown Pelicans;

and Santa Barbara Island and adjacent Sutil Island support the only Black Storm-Petrel colonies.

The largest concentrations and greatest diversity of breeding marine mammals also occur around the Channel Islands. Approximately 20% of the state's Harbor Seals, 100% of Northern Fur Seals, 100% of California Sea Lions, and 85% of Northern Elephant Seals breed on the Channel Islands. San Miguel Island is a zoogeographical boundary island where species of sea lions of north and south come together (DeLong, NMFS, pers. commun.).

Other significant breeding areas along California include Año Nuevo Island—where 68% of the state's population of northern sea lions and around 12% of northern elephant seals breed—and the Farallon Islands (Bonnell, et al., 1983). Northern Sea Lions also breed along mainland California at Cape Mendocino (26% of the total) and Point Saint George (5%). Point Saint George is the northern-most breeding colony of Northern Elephant Seals (Bonnell 1983). Harbor Seals breed on mainland sites throughout the state, but areas of highest concentration include the Point Reyes Peninsula (17% of total), remote coves in Mendocino County (14%), and around Humboldt Bay (13%) (Hanan, et al., 1989).

Pinnipeds also congregate onshore to molt their fur and to rest. Many of these sites are breeding sites; however, during their annual northward migration, California Sea Lions congregate on a number of island and mainland sites that are not used for breeding. California Sea Lions, for example, only incidentally breed on the Farallon Islands, but over 5,000 rest there during migration. More recently, hundreds of male sea lions have congregated on boat docks in San Francisco Bay in winter during the Pacific Herring spawn. Offshore islands around Point St. George and Trinidad Head are also important resting areas for sea lions.

RARE/THREATENED/ENDANGERED MARINE SPECIES

Rare, threatened and endangered species that occur offshore of California are shown in Figure 2-19. Whales, fur seals and sea otters were hunted almost to extinction in the late 1800s and early 1900s. Since hunting was curtailed, most mammals have slowly increased in abundance, but none have reached pre-exploitation population levels.

Cetaceans / Pinnipeds / Fissipeds

Blue Whale
Fin Whale
Gray Whale
Humpback Whale
Right Whale
Sei Whale
Sperm Whale
Southern Sea Otter
Guadalupe Fur Seal

Reptiles

Green Sea Turtle
Leatherback Turtle
Loggerhead Sea Turtle
Pacific Ridley Sea Turtle

Birds

California Brown Pelican
Least Tern
Short-tailed Albatross

Figure 2 - 19: Rare / Threatened / Endangered Species offshore of California.

Gray, Blue, Fin, and Humpback Whales are regularly seen in California. The distribution of these species in California is discussed above. Sei and Sperm Whales occur throughout California, generally in oceanic waters well offshore or in deep water at the continental shelf break. The Right Whale, however, is the world's most endangered large whale and has rarely been seen in California in this century. For the most part, this species is found only in

the Bering Sea. Unlike other whales, the Right Whale population does not seem to be increasing.

Historically, the Guadalupe Fur Seal ranged from Point Conception and the Channel Islands south into Mexico (Antonelis and Fiscus, 1980). Now they are a rare visitor to the southern Channel Islands and the total world population numbers less than 2,000. The Southern Sea Otter feeds, rests and breeds in kelp beds from Año Nuevo Island to Pismo Beach. Occasionally otters are spotted as far north as Cape Mendocino and as far south as Point Conception. The current population in California is around 1800 otters. The population appears to be increasing at a very slow rate. (Van Blaricom, personal communication).

In 1982 the Southern Sea Otter Recovery Plan was instituted with two directives: to translocate sea otters to other areas in California in order to reduce vulnerability of the population to oil spills; and to protect recreational and commercial fisheries from sea otters at sites outside of their current range. The Southern California Borderland, except for San Nicolas Island and Begg Rock, is a "no otter" management zone; that is, otters that move into the area are captured and returned to the current range.

Between 1987 and 1989, 135 otters were transplanted to San Nicolas Island in order to establish a second colony site (Marine Mammal Commission Annual Report 1990). Most of the animals dispersed from San Nicolas. Twenty-nine otters returned to Monterey Bay; 77 are unaccounted for. As of March 1990, 15 sea otters remained around the island (G. Van Blaricom, USFWS, personal communication).

Sea turtles are tropical species that seasonally visit the Southern California Borderland. There are four species of sea turtle that occur in California including the Green (*Chelonia mydas*), Leatherback (*Dermochelys coriacea*), Loggerhead (*Caretta caretta*), and Pacific Ridley (*Lepidochelys olivacea*). Turtles are occasionally seen in Southern California but are most often seen in summer. The summer range of the Leatherback extends up to Alaska, whereas the other three are confined to south of Point Conception.

No sea turtles are known to lay eggs in California; however, a group of around 25 Green Sea Turtles annually over-winters in the southern end of San Diego Bay near the warm water effluent channel of the San Diego Gas and Electric Company facility (Stinson 1984). Historically, turtles laid eggs on sandy beaches on the Pacific coast of Central and South America and Baja California. Presently, though, populations are decreasing rapidly from hunting and destruction of breeding habitat.

The Least Tern nests on sandy beaches, usually near a lagoon or estuary that is used for feeding. Breeding has been negatively affected by human intrusion, loss of breeding sites to shoreline development, and predation by dogs, cats and predatory birds. Least Terns are migratory, arriving in late April and leaving in August. Breeding sites are documented from San Francisco south to Scammon's Lagoon in Baja California. Specific breeding sites in California are shown on the individual segment maps. The current population numbers less than 2,000 birds.

The California Brown Pelican was declared an endangered species in 1970 after failing to reproduce at nesting sites in California. Nesting by pelicans in Southern California declined

90% over 20 years because of pesticide contamination. The pesticide DDT and its byproduct DDE passed through the food chain and concentrated in the tissues of the top predator, the pelican. This pesticide caused a hormonal imbalance which in turn caused pelicans to lay eggs with thin shells which easily broke during incubation. Since DDT was banned, the concentration of DDT in the food chain has decreased and pelicans are now breeding on Anacapa Island and Santa Barbara Island. Historically, Brown Pelicans bred at Prince Island near San Miguel Island. They also nested at Point Lobos, but after the collapse of sardine populations, this colony was abandoned. The current California breeding population numbers 2500–3000 (Briggs, et al., 1987). In the winter Brown Pelicans roost at various locations in California. These roosting areas are required for resting and for drying their feathers after foraging in nearshore areas (Jaques and Anderson, 1988).

The Short-Tailed Albatross historically bred on islands in the western Pacific and ranged southward from Alaska to Baja California. Populations on the breeding islands were decimated by feather traders in the late 1800s to the early 1930s. As of the 1980s, there are only a few hundred birds extant. In the last century, there have been only a few sightings of Short-Tailed Albatross in California.

The Northern Sea Lion has recently been declared a threatened species under the Federal Endangered Species Act. The Northern Sea Lion is declining throughout its range due to multiple factors including food availability, disease and pollutants, and other unknown factors. In California, the breeding range has been reduced so that the Northern Sea Lion no longer breeds in the Channel Islands. The southernmost extent of breeding is now Año Nuevo. A high percentage of premature births occur on the Farallon Islands. Pollutants and disease-causing agents have been found in the tissues of fetuses there.

Marine species for which there may be sufficient information to support listing as rare, threatened or endangered and that are currently being considered include Marbled Murrelet and Western Snowy Plover. The Snowy Plover and Marbled Murrelet populations are declining because of breeding habitat degradation; Marbled Murrelets nest in coastal old growth forests which are being heavily logged. Snowy Plovers nest on sandy beaches which are popular recreational areas throughout California.

Additionally, the Northern Fur Seal is a species of special concern whose numbers are declining on Alaskan breeding grounds. Since 1974 the population has declined at an annual rate of 5–8% per year (Gentry and Kooyman 1986), in part, due to entanglement of seals in lost and discarded fishing gear and incidental capture in commercial fisheries (Marine Mammal Commission Annual Report, 1988). This decline will result in a significant reduction in the number of fur seals wintering in California waters.

In addition to federally listed species, the California Department of Fish and Game lists several seabirds and waterbirds as species of special concern. Included are seabirds that once nested throughout California such as the White Pelican, White Ibis, and Common Loon. Species whose numbers are declining are Fork-tailed Storm-Petrel, Double-Crested Cormorant, Gull-Billed Tern, and Tufted Puffin. Other species of concern include Black Storm-Petrel, Ashy Storm-Petrel, Harlequin

Duck, California Gull, Rhinoceros Auklet, Elegant Tern and Black Skimmer (Remsen 1978).

TERRESTRIAL, WETLAND AND AQUATIC BIOLOGY

This section describes the terrestrial, wetland, freshwater and estuarine aquatic biological resources of California from the border of the ocean shores up to approximately 30 kilometers inland. Vegetation, wildlife and fisheries, together with the physical environment, will be discussed in the context of ecosystems. An ecosystem is "a geographic area in which the component biological and physical elements and processes exhibit significant interrelationships" (Jones and Stokes, 1980). The California coastline offers a wide range of natural ecosystems, from redwood forest to salt marshes. Information in this section is from Bakker, 1971; Barbour and Major, 1977; Holland and Kiel, 1986; Kuchler, 1977; and Mayer and Laudenslayer, 1988.

A description of each coastal ecosystem follows in the Resource Inventory section below. Also included in this section is a description of the areas developed by people along the coast, such as eucalyptus plantations and agricultural land, which provide wildlife habitat or other ecological functions. The inventory concludes with a discussion of rare, threatened and endangered plant and animal species. The last part of the overview, entitled Effects of Development, explains the impacts on terrestrial, wetland and aquatic biological resources by human development, both onshore and offshore.

From the Oregon border to the Mexican border, the coastline exhibits significant variation in climate and vegetation. The annual rainfall of 200 centimeters in the north supports dense stands of coniferous forest, while the low precipitation of 30 centimeters or less along the south coast supports oak woodlands, chaparral and grassland. Topographically, the entire coast is mountainous, giving rise to the physical attributes of slope, slope aspect, and elevation; these attributes then influence what plant species will thrive in a given location. The soils of the coast vary greatly, from the rich, alluvial soil in which redwoods grow to the salty, sandy soil beneath dune scrub.

Salt marshes punctuate the entire shoreline. The San Francisco Bay-Delta region harbors the largest tidal marsh area on the Pacific Coast. Salt marshes occur in estuaries where shallow water is protected from wave action and salinity is maintained by an input of freshwater from adjacent watersheds.

Rivers and streams which originate in or traverse the coastal region add to the landscape diversity. The habitats provided by streams and their adjacent riparian zones are essential for many aquatic organisms, including valuable fisheries. River and stream environments also provide for many riparian-dependent plants and animals.

Biological systems are valuable for the production of many commodities, for providing "ecological services," and for aesthetics and recreation. Livestock grazing on rangelands, timber production and fisheries are the main commodities derived from natural biological systems. Discussions of these topics are found elsewhere in this document.

Natural ecosystems provide "ecological services" to modern society which cannot be readily replaced by technological innovation. For example, one ecological service provided by

plants is the control of soil erosion. Also, vegetation serves to moderate the climate for people and animals, not only on a global scale, but also locally by providing wind breaks, shade and shelter.

Control of pest populations is another ecological service provided by natural ecosystems. Rodent populations are stabilized by the predation of larger mammals, snakes and owls. Rodents must also compete for food and habitat opportunities, thus their numbers are kept at a steady state. Many species of insects perform the ecological service of wildcrop pollination. Maintaining habitat for these pollinators supports wild crops such as berries and vector-pollinated trees.

Marshes perform valuable services by filtering out sediments before they reach the open waters of coastal bays. Loss of coastal wetlands has led to decreased water quality in many bays and estuaries.

The coastal biological resources offer a setting for various types of recreation. Scenic vistas of vegetation, ocean and waterways have great value. Demand for recreation is increasing steadily, at least commensurate with the state's increasing population, if not faster. California's current population of 30 millon people is expected to reach 35 million by the year 2000. This 17% increase will likely bring with it a comparable increase in demand for recreation.

RESOURCE INVENTORY

Terrestrial

Redwood Forests

Redwood forests occur as tall, dense stands of trees and may be pure coast redwood or mixed with Douglas-fir. Found along the coast from Monterey County to the Oregon border, these forests grow on floodplains, alluvial flats, slopes and canyons from sea level up to 1000 meters elevation. Redwoods require moderate temperatures and year-round moisture availability. The central and northern California coast provides this necessary environment, characterized by moderate to high rainfall, cooling summer coastal fog, and moist soil in canyon bottoms. Redwood trees have adapted to periodic flooding and fires and, in fact, these events are integral to their ecosystem. One hundred ninety-three wildlife species use the redwood ecosystem for food, cover, or special habitat requirements. A number of rare and sensitive species inhabit redwood forests, including two mammals, ringtail and fisher; two amphibians, red-legged frog and ensatina; and three birds, osprey, marbled murrelet, and the spotted owl.

Only 10% of the original old-growth redwood forests remain today. Second– and even third–growth redwood forests now occur over much of the original range. Redwoods are very resilient, and can resprout from stumps or fallen logs. The young-growth forests can be intensely managed and provide valuable timber resources to the state. However, the habitat value of managed forests for species dependent upon old-growth ecosystems is limited.

Grand fir—Sitka Spruce Forest

This tall, dense, conifer forest consists of two co-dominant trees, grand fir and Sitka spruce, with western hemlock and red alder often present as subdominants. Grand fir and Sitka spruce can tolerate salty sea winds; thus this type of community is found on coastal terraces, slopes, lowlands, headlands and old stabilized dunes from Del Norte County south to

Mendocino County. The forest is characterized by a dense understory of shrubs, vines and ferns, together with thick moss surrounding tree trunks and hanging from branches. Owls, woodpeckers, thrush, hummingbirds, tailed frogs, northwestern garter snake, a variety of salamanders, black bears, elk and many rodent species exemplify the wildlife. Much of this forest type has been logged, leaving brushy areas which will eventually return to a Grand fir-Sitka spruce forest. Some of the more level sites have been cleared for agriculture.

Douglas-fir Forest

Areas of Douglas-fir forest occur within the California coastal region, but the main distribution is found farther to the east. Stands of Douglas-fir are found on generally drier sites than those occupied by redwood and Grand fir-Sitka Spruce forest. The Douglas-fir forest is dominated by Douglas-fir trees, often in pure stands, and sometimes in association with trees from adjacent forest types (e.g. redwood, Sitka spruce). Tanoak is a common hardwood tree species found in the Douglas-fir forest. Other understory species may include poison oak, California hazel, rhododendron, and a variety of wild berries.

The Douglas-fir forest supports an abundance of wildlife. Species of special interest include Spotted owl, Marbled murrelet, and several amphibians. A large proportion of the original extent of the Douglas-fir forest has been logged and is now under intensive management. Like the managed redwood forests, these Douglas-fir forests are very productive for commercial forest products. Some of the original Douglas-fir forests have reverted to brush and tanoak thickets after logging. Depending upon site conditions and fire occurrence, such areas may evolve back to a Douglas-fir forest after a long time.

Managed young growth Douglas-fir forests or post-disturbance hardwood thickets can serve as habitat for a complex of wildlife species which are dependent upon early successional stand conditions or brushy areas. However, as noted above, with the conversion of any of the old-growth coniferous forests to managed forests or to hardwood tree and shrub thickets, habitat values for late succession or old-growth dependent wildlife species are eliminated.

Mixed Evergreen Forest

The dominant trees of this ecosystem include some combination of Douglas-fir and the evergreen hardwoods, madrone, tanoak, California bay, and canyon live oak. Found in the North and South Coast Ranges from Del Norte County to Santa Cruz County, these forests occupy slopes from 60 to 1200 meters elevation. The large hardwood component of this community results in shorter stands of trees than the conifer forest described above. This type of community represents a transition between the coastal conifer forests and the oak woodlands. Black-tailed deer and California quail feed on the acorns, nuts and fruits of the oaks, bays, tanoaks and madrones. This habitat's most abundant amphibian is the ensatina, a smooth-skinned salamander found under bark, rocks and rotting logs. A wide variety of songbirds inhabit this forest type.

Disturbances to the ecosystem include clearing for livestock range, logging for Douglas fir timber, conversion to pure Douglas fir stands for timber and fire suppression. While reduced in extent by human activities, the mixed evergreen forest still occurs in numerous stands. These stands could benefit from the re-introduction of fire, which would result in patches of bare mineral soil for Douglas-fir seedling establishment, and reduce the brushy

fuel load beneath the tree canopy. The hardwood species have sprouting capabilities and would send up shoots from unburned parent roots after a fire.

Coastal Cypress and Pine Forests

Coastal cypress and pine forests are also known as closed-cone conifer forests, in reference to the serotinous nature of the cones of the cypress and pine species found in the type. Serotinous cones remain attached to the tree and closed, thereby retaining their seeds, until heat from a fire stimulates cone opening and release of seeds. Closed-cone pines and cypresses therefore require fire in order to regenerate. After a fire sweeps through these forests, it leaves bare mineral soil exposed and opened cones from which seeds can issue. As the soil is clear of tree and shrub litter, the seeds can germinate in the full sunlight which they require.

There are six coastal variations of closed-cone forests. Besides serotiny and dominance by cypresses and/or pines, the only other unifying feature of the forests includes infertile soils. Other tree species are unable to thrive on these soils and thus do not compete with closed-cone stands for site occupation. Knobcone pine forest, Sargent and Monterey cypress forest, Bishop pine forest, Monterey pine forest, shore pine forest, and the pygmy forest comprise the six type variations. Distributed in disjunct, scattered stands on stabilized dunes and in coastal mountains, these forests vary greatly in density, height, and presence of understory vegetation. Few animals breed in this habitat, although great horned owls and red-tailed hawks nest in the larger pine trees. Other animals, such as tree squirrels and band-tailed pigeons use the type for feeding and cover. These ecosystems are highly sensitive to fire suppression which is an ongoing practice in some areas. Stands are also threatened by sand and gravel mining, logging of Monterey and Bishop pines, and especially urbanization, all of which have diminished their range. One species of the Sargent and Monterey Cypress forest, the Santa Cruz cypress, is on both the state and federal endangered species list.

The Torrey pine is not a serotinous species, but is another conifer which naturally occurs in only very small and widely separated locations. Torrey Pine Forests are found only in two places in the world, near Del Mar in San Diego County and on Santa Rosa Island. The Torrey pine is the most narrowly distributed pine species in California, even one of the rarest worldwide.

Oak Woodlands

Woodlands differ from forests because of their lower tree height and a greater proportion of shrubs, grasses and other herbaceous plants. The coastal oak woodlands include the blue oak-foothill woodland, the southern coastal oak woodland, and the valley oak savanna. The blue oak-foothill woodland, occurring on the drier, less fertile soils, forms scattered communities along the foothills of the central coast. Coast live oak constitute the dominant species of the southern oak woodland found in the central and southern coastal mountains. Valley oak savanna, having valley oaks as almost the exclusive tree species, exhibits a lower tree density than the woodlands and a greater proportion of grass to shrubs. These savannas generally occupy valleys of the North and South Coast Ranges from Mendocino County southward. Oaks play an important role for wildlife by providing acorns, browse, and cover. Thirty bird species known to use oak habitats include acorns in their diet. Eighty mammal

species make the woodlands part of their range. Crop production, livestock grazing, firewood cutting, and residential development continue to reduce the oak woodland habitat, especially the valley oak savannas.

Coastal scrub

Coastal scrub vegetation occurs on bluffs, terraces, stabilized dunes and lower mountain slopes throughout the coast region. It is typified by low-growing, soft-stemmed shrubs with light gray–green foliage which drops in response to drought. Brush species of lupine, coyotebush, California sagebrush, and black sage may grow up to 2.5 meters high. Scrubland plants are subject to moisture stress caused by high soil salinity, wind desiccation, and low soil moisture storage. Adaptations to moisture stress include thick, leathery leaves resistant to water loss, water-storing tissues, and summer dormancy.

Three state and federal endangered animals use the habitat, the peregrine falcon, the Morro Bay kangaroo rat, and the Santa Cruz long-toed salamander. A subspecies of the black-tailed gnatcatcher (a California Department of Fish and Game Species of Special Concern), is found exclusively in southern scrubland. This is a relatively fragile ecosystem and trampling by vehicles, livestock and people removes the vegetative cover and leads to severe wind erosion of dune soil. Off-road vehicles, agriculture, conversion to grassland for grazing, and urbanization have reduced coastal scrubland area, especially in the south coast region.

Coastal Chaparral

This type of community occupies steep slopes of the North and South Coast Ranges. The dominant shrubs of chaparral communities are chamise, manzanita and ceanothus species. Taller than scrubland communities, chaparral shrubs grow up to five meters high. Fire is an important ecological process in this system, occurring once very 10–40 years. Fire clears away senescent brush, and new vegetation readily succeeds the old, since chaparral species have evolved strategies to regenerate after a fire. These fire-adapted shrubs both resprout from unburned roots and regenerate by seed. The seeds have a hard coat to prevent consumption by fire, but they also respond to heat from fire by breaking dormancy and germinating. Characteristic mammals include mule deer, gray foxes, bobcats, brush rabbits and California pocket mice. Birds such as the mountain quail, scrub jay and wrentit inhabit this type of community as well as the representative reptiles: the western fence lizard, coast horned lizard, striped racer and western rattlesnake. Chaparral is sensitive to two types of disturbance: first, suppression of fire leads to an accumulation of senescent vegetation, which both degrades the ecosystem and poses a major fire hazard; secondly, removal of the vegetative cover by trampling or construction causes severe soil loss on these steep, highly erosion-prone sites. Re-introducing fire through prescribed burning remains a formidable challenge to many chaparral land managers. Especially near residential areas, fire is kept out of the ecosystem.

Grassland

Perennial bunchgrass dominated the California prairies prior to European arrival. These grasses sprout in the spring from clumps of overwintering roots, thus growing in bunches and renewing for many years. When the Europeans arrived in this country they brought seeds of annual grasses, whose life cycle is complete in one year: germination from seed in the spring, maturation, seed production and

death in the early summer. These introduced annuals have become widespread throughout the state, even eliminating perennials in the southern coastal grasslands. The grassland type is therefore divided into the annual grassland of the south coast and the perennial grassland of the north coast, with overlap along the central coast. Coastal grasslands occupy clay soils of terraces, inland valleys, foothills, ridges and south-facing slopes. Frequent fires help maintain this ecosystem by preventing shrub and tree encroachment. Characteristic wildlife include the common garter snake, western fence lizard, burrowing owl, western meadowlark, black-tailed jackrabbit, coyotes and assorted rodents. Many grassland ecosystems have been cultivated for crops or grazed by livestock over the last 100 years. The annual grasses withstand heavy grazing more successfully than perennials, since trampling may destroy the perennials' regenerative roots. Residential and commercial development has become another common grassland use.

Coastal Strand

Coastal strand communities are the first terrestrial ecosystems above the high tide line, found on dunes. These are disjunct communities, separated by rocks, inlets or scrublands, but occur throughout the California coastline. Plants of the strand ecosystem must be adapted to a harsh environment: soil that is salty, of low fertility, and subject to constant wind erosion; winds that carry abrasive sand and salt; sunlight that threatens to desiccate. Grasses, such as the native rye grass and the introduced European beach grass, characterize strand vegetation, but more common are prostrate herbs with creeping stems. These plants are able to root at the nodes and send down long tap roots, gaining access to low water tables and allowing survival in shifting sands. Sand verbena, silver beachweed, saltbush and dune morning-glory represent native herbs; exotic herbs sea rocket and some ice plant species are now widespread along the coast. Wildlife such as gulls, plovers and seals frequent the habitat for food or rest, but must also depend on other habitats to fulfill their requirements.

If denuded of vegetation, coastal strands can become active dunes, that is, hills of wind-blown sand with little or no vegetation. Sand movement by wind is a natural process in strand ecosystems, but human activities have reduced the vegetative cover in some areas, creating more active dunes. Stabilizing dunes to prevent accumulation of sand on roads and settled areas has long been a priority among many Californians. To achieve stabilization, the aggressive exotics, (notably ice plant and European beach grass), were planted. Having been successfully established, these introduced species can crowd native plants. In addition to vegetation disturbance, building and sand mining have altered strand ecosystems.

Eucalyptus Forest

Eucalyptus trees, native to Australia, have been widely planted in California since 1856. Many of the present eucalyptus stands include regeneration spread from older, planted trees. Groves occur predominantly along the central and south coast below 500 meters elevation, where a Mediterranean-type climate prevails. This temperate climate usually lacks prolonged or sudden freezing temperatures, weather likely to kill eucalyptus. Vigorous sprouters, prolific seed producers, rapid growers to heights up to 40 meters, and fire adapted, eucalyptus competes aggressively with native species. Eucalyptus can spread rapidly into adjacent grasslands, where soil moisture levels are high,

resulting in a pure stand of this tree with a sparse understory of shrubs and annual grasses. Encroachment over oak woodlands occurs more slowly, resulting in a mixed stand which often includes the shade-tolerant California bay. Eucalyptus forests can provide valuable habitat features for some species, including roosts, perches and nest sites for crows, ravens, and barn owls as well as red-tailed and red-shouldered hawks. Small vertebrates including the alligator lizard, gopher snake and woodrat also utilize eucalyptus stands. Although eucalyptus is planted in some areas as street trees or for pulpwood, and removed in other areas as an unwanted exotic, the tree continues to thrive throughout its adopted range.

Irrigated Pasture

Pasture vegetation consists of perennial grasses and legumes and is maintained for livestock grazing. Pasture productivity depends on natural factors such as soil type and length of growing season and on management practices such as irrigation, fertilization, weed control, type of livestock and animal stocking rate. Distributed throughout the coast, pastures provide habitat for wildlife as well as forage for domestic animals. Antelope, deer, and elk graze pastures; ground-nesting birds such as pheasants and sandhill cranes brood in these fields. Waterfowl and wading birds are prevalent in flood-irrigated pastures.

Cropland

Patches of cropland occur throughout the coast on flat or gently rolling terrain. Intensively managed monocultures of commercial produce such as lettuce, cabbage, artichokes or strawberries, completely replace the natural vegetation. Some wildlife species exploit these lands for food, although farmers try to minimize depredation by fencing, trapping and poisoning. Deer, elk, antelope and wild pigs often succeed at foraging in alfalfa and grain fields. Before the harvesting season some farmers may allow insect-eating birds, birds of prey and game birds to hunt for food. After the harvest, wildlife can sometimes forage unmolested among the residual plant parts. Croplands flooded for weed control, leaching, irrigation or waterfowl hunting serve as freshwater marshes for shorebirds, wading birds and gulls.

Orchards and Vineyards

Orchards and vineyards are similar to croplands in that they are intensively managed monocultures, but because of their permanence and larger structure, they usually provide better wildlife habitat. Trees and staked vines offer cover, nesting sites, and a variety of food, including browse, fruits, nuts, worms and insects. The understory may supply grass, weeds, seeds and insects. Rabbits, raccoons, deer, squirrels and coyotes, as well as many bird species can be found here.

Urban Areas

Cities and towns cover a substantial area of the California coast. Urban vegetation consists of a wide variety of native and non-native grasses, flowers, shrubs and trees. Confined to parks, lawns and rows along streets, vegetated sites are interspersed with streets and buildings of varying heights and in varying densities. This complex landscape hosts a surprising number of wildlife species: possums, raccoons, skunks, deer, mice, squirrels, songbirds, and of course, rats and pigeons.

Wetland Ecosystems

Wetlands are any areas where saturation with water determines the nature of the soil

development and the biotic communities. These transitional areas between terrestrial and aquatic systems which have water tables at or near the surface of the land may be covered by shallow water. Wetlands soils may only be periodically saturated with water which creates a harsh environment for organisms not adapted to this lifestyle.

Coastal Salt Marsh

Salt marshes occur along sheltered inland margins of bays, lagoons and estuaries, where fresh water flowing from streams meets saline ocean water. High tides inundate marshes daily, but upon retreat leave the vegetation exposed to air and the soil saturated with salt water. The degree of soil salinity varies with proportion of fresh water to salt water. Wet seasons (when fuller streams and rivers convey fresh water to marshes), result in less salty conditions than exist during dry seasons. Few plants can survive the changing salinity and water levels characteristic of salt marshes. Pickleweed and cordgrass typify marsh plant species.

Within the upper intertidal areas of salt marshes are barren patches called salt pannes. They accumulate rainfall in the winter and seawater from high tides. During summer, evaporation produces a salty crust on the surface and leaves the pannes dry. The contrasting wet and dry habitat of salt pannes yields two separate ecological communities.

Salt marshes are highly productive, supporting a complex food chain. Organic detritus, algae, plankton and living plants sustain crustaceans, mollusks, insects, gastropods and nematodes. These animals, which are lower on the food chain, become food for mammals, reptiles and especially birds. Along the Pacific Flyway, California coastal marshes provide feeding and nesting sites for migratory as well as resident birds. Mallards, shovelers, coots, gulls, blue herons, egrets, kingfishers and sandpipers are among the many bird species using the marsh habitat. The state's salt marshes now occupy a much smaller area than in pre-colonial times, having been drained or filled for urban development or transformed into marinas. Oil spills and other types of water pollution can contaminate these ecosystems.

Freshwater Marsh

Freshwater marshes are scattered along the coast near river mouths, around lakes and ponds, along slow-moving streams, and at large springs and seeps. Slow-moving or stagnant shallow water saturates marsh soils through most or all of the year, inhibiting soil aeration. This water-logged condition, combined with the presence of soil microorganisms which take up oxygen in respiration, results in anaerobic soil. Plants that can root in this medium generally have stems that are hollow or filled with a porous tissue allowing gas exchange between the exposed parts and the roots. Prevalent marsh species that are adapted in this manner include sedges, rushes, reeds, cattails, and watercress. Providing food, cover and water, freshwater marshes constitute important wildlife habitat. They are feeding grounds for the endangered Aleutian Canada goose, bald eagle and peregrine falcon; breeding grounds for the endangered Santa Cruz long-toed salamander and threatened black toad; and home to the threatened giant garter snake. Marshes also host less rare mammals, reptiles, amphibians and over 160 species of birds.

Marshes are vulnerable to changes in local hydrology, such as a rise or drop in the water table or an altered direction of a river. An increase of water inflow could turn the marsh

into a pond, while a decrease could dry it out. Precipitation patterns, saturation states of subterranean rock beds, and the meandering nature of streams exemplify natural conditions affecting hydrology, and therefore, marshes. Human activities which have an influence on hydrology and marshes include logging, paving, lining watercourses with concrete walls, and heavy use of wells. These practices, along with draining or filling to create cropland, have reduced the extent of coastal freshwater marshes.

Bogs and Fens

Bogs and fens are unique peat-based wetland communities. They occur in small and scattered locations in the North Coast Ranges from sea level to 1800 meters in elevation. Low-growing herbs, shrubs, and often sphagnum moss or the California pitcher plant cover the layers of peat. Limited in both extent and resources, these environments do not constitute important wildlife habitat but are important subjects of ecological and bio-diversity research.

Bogs usually result from bodies of water that have been cut off from freshwater sources other than precipitation and have accumulated large amounts of organic matter. Organic matter decomposes slowly in bogs because the water-logged environment is cold, acidic, and nearly anaerobic, hindering the microorganisms that accomplish breakdown. Thus bogs are filled with partially decomposed organic matter or peat. Fens differ from bogs by receiving trickles of fresh ground water in addition to precipitation. Whereas fens are more nutrient rich and less acidic than bogs, the two ecosystems are similar enough to be discussed together.

Human activities have destroyed some bogs and fens, although the often remote location of the communities has aided their preservation.

Riparian Systems

Riparian ecosystems, occurring along stream banks and on river flood plains, are often sharply distinct from neighboring ecosystems. The year-round high moisture of riparian soils supports plants that are adapted to different conditions from what most California species confront: dry summers with little or no soil moisture. Broad-leaved, water-loving, winter-deciduous trees and shrubs characterize riparian vegetation, vegetation which looks quite different from that of a conifer forest, evergreen hardwood forest, or grassland, through which streams may meander. In the mixed riparian forest, found in the North and South Coast Ranges, generally below 1500 meters, typical trees are black cottonwoods, California sycamores, white alders, and box elders. Elderberry, shrubby willows and blackberry vines contribute to the usually dense understory. The red alder riparian forest, found in the central and north coastal mountains, follows streams from the ocean up to 30 kilometers inland, often merging into the mixed riparian forest. Red alder, in nearly pure stands, dominates the type, with elderberry, salmonberry and willows beneath.

Rich in wildlife, riparian zones provide water, cover, migration corridors, and diverse nesting and feeding opportunities. Songbirds, owls and ducks, mammals (from beaver to coyotes), and a wide variety of reptiles and amphibians use the habitat either exclusively or in combination with other habitats. Riparian communities are among the most threatened in the state. Construction of dams and reservoirs, channelization, waste dumping, urbanization, introduction of non-native vegetation, and agriculture have greatly reduced the number of riparian ecosystems.

Vernal Pools

Vernal Pools are small grass-and wildflower-dominated ecosystems associated with shallow seasonal pools, submerged in the winter, but dry throughout the summer. In California, vernal pools are found grasslands and coastal scrublands in Southern California and in Central Valley grasslands. These are amphibious environments which can cover as much area as a lake. They are located in coastal terraces or prairies where the water table is seasonally perched. The formation of these pools is limited to depressions lined with fairly impermeable surfaces (Zedler, 1987). The pools have four phases; wetting, aquatic, drying and drought. At the beginning of the rainy season, substrate in the pools begins to saturate with water (wetting phase) before they can fill (aquatic phase). Once water begins to seep into the soil, seeds begin germination. When pools fill, animals and plants start growth and reproduction quickly before the rains halt and evaporation causes the pools to dry (drying phase). Once the pools are completely dried, the soil begins to crack (drought phase) (Zedler, 1987).

Vernal pools are not unique to California but the ones here are different from those outside the state. In the southern coastal counties pools can be found from San Diego to Monterey Counties, with the greatest concentration in San Diego County where they are located on the Otay and Cocklebur Mesas in Camp Pendleton, Kearny Mesa and the San Diego Mesa. However, other important pools are located in Santa Barbara County and the Central Valley (Zedler, 1987).

The biota in vernal pools ranges from small unicellular aquatic organisms and crustacea to amphibious plants and animals. These organisms have adapted to a unique environmental situation. The high productivity of vernal pools during the wet seasons provide prey and forage for many species. Most of the aquatic and amphibious organisms associated with the pools have already grown, reproduced, lived and their offspring matured by the time the drought phase arrives (Zedler, 1987).

Aquatic Ecosystems

Estuaries

Estuaries are semi-enclosed coastal areas where freshwater and seawater mix to produce an aquatic boundary between riverine and marine ecosystems. Estuaries support species of ecological, commercial and recreational value and are the primary site of man's interaction with the sea (Phillips, 1984). Hiking, bird watching, camping, offroad vehicle use, sport fishing, sailing, boating and other aquatic sports constitute the primary activities of recreationists using estuarine areas. Commercial fishing and production, salt production, aquaculture, industrial and other commercial interests utilize estuaries. Education and research, including public school visits and extensive research by universities, are other important aspects of man's use of the estuaries (Simenstad, 1983 and Zedler and Nordby, 1986).

Estuaries are not static systems but rather dynamic ones characterized by fluxes in flows and species composition (Simenstad, 1983). Daily tides inundate estuaries with ocean water and then return to the sea to leave portions exposed to the sun and air. Floods, droughts and riverbed movement alter freshwater flows into the estuary. Food production in estuaries exceeds the energy needs of the plants and animals in the ecosystem and the excess food produced is transported to other areas. The distribution of plants and animals depends on

physical and biological factors such as salinity, temperature, competition, predation and food availability (Jones and Stokes Associates, Inc., 1981).

Estuarine areas contain a variety of habitats ranging from marshes to eel grass meadows to deep channels. Marine, anadromous, estuarine and freshwater plants and animals can be found in estuarine ecosystems at some point in their life histories. The importance of estuaries to aquatic species and the uniqueness of the habitat can not be underemphasized; they provide primary production (food), a transitional area for anadromous species, and nursery and spawning grounds for many species.

The California shoreline is dominated by steep mountains and bluffs overlooking rocky shores. For this reason most California estuaries are small and far apart. The major embayments include San Francisco, Tomales, Monterey, Estero, San Luis Obispo and Humboldt Bays. San Francisco Bay is the largest estuary on the Pacific Coast of the United States and accounts for 88% of the total area covered by estuaries and marshes in California (Jones and Stokes Associates, Inc., 1981).

Seven major habitat types can be found in and around estuaries: transitional uplands, wetlands, salt and brackish marshes, salt pannes, channels, intertidal flats, and dunes and beaches (Zedler and Nordby, 1986). This discussion will focus on the aquatic environments.

Estuarine entrances migrate and may close for variable periods of time forming lagoons. Lagoons occur during summer low flows when sand bars form across the entrances to estuaries. In the winter, river flows break these bars. When the lagoon closes, water circulation decreases and salinities change, dramatically affecting biota (Onuf, 1987).

Estuarine channels with surrounding wetland habitats are subject to a wide variety of environmental conditions. Tidal flushing is greatest at the mouths and decreases with distance inland. These channels support organisms ranging from macroalgae and phytoplankton to birds and mammals. Changes in channel and marsh salinities produce changes in the distribution of the biota. Salt intrusions bring in more marine species while an increase in riverine flow results in more freshwater species (Zedler and Nordby, 1986).

Submerged eelgrass meadows comprise an ecological niche of substantial value. They produce oxygen and their roots stabilize sediments. They also provide habitat for aquatic plants and animals and contribute to the food chain both directly and indirectly. Eelgrass stands occur in many California estuaries, especially those protected and away from the open coast such as Humboldt Bay. Dungeness crab, flatfish, shrimp, Pacific herring and other species utilize the meadows as nursery and spawning grounds which provide ample food and shelter (Phillips, 1984).

Freshwater

Freshwater aquatic ecosystems are found in inland rivers, streams, lakes and ponds. Descriptions of these systems usually separate the running waters from ponded ones, and further subdivide these two categories into several types of habitats based on size, and channel and bottom characterisics.

Rivers and streams can be divided into several subsystems. Tidally influenced areas of rivers are characterized by fluctuations in water

velocities and by low gradients. Mud dominates the streambed of this type of river and the floodplain is well developed. Planktonic organisms and organisms which prefer still water are found here. In the upper perennial portion of a river the substrate is typically composed of sand and mud. There is no tidal influence here, water flows are slow, and the gradient is low. The upper perennial has a high velocity of water flow and a steep gradient. Inhabitants of this region of a river are adapted to surviving in running water and are not planktonic. The bottom consists of cobble, gravel or rock, with patches of sand interspersed. Intermittent systems have flowing water in the channel only part of the year. Isolated pools and surface water may be found even when there is no flow.

Lakes and ponds are still water ecosystems found in topographic depressions and dammed river channels. In general terms lakes are large, deep bodies of water, generally having only a small amount of shore vegetation relative to water surface area. Ponds are shallower and smaller with abundant aquatic vegetation.

Regional Description of Aquatic Ecosystems

In the southern portion of the state, estuaries are generally flooded river valleys and coastal plains which exist only intermittently. Brackish marshes are found where seepage or runoff can be impounded and evaporation leads to salts being concentrated. Because of Southern California's mediterranean-type climate, (relatively mild weather with a wet and a dry season), rivers may flow into the estuaries only part of the year. Rainfall occurs half the year and the average evaporation always exceeds the average precipitation. This, coupled with steep, small watersheds with little storage capacity limit the number of estuaries occurring in Southern California (Zedler and Nordby, 1986).

In these areas, ghost shrimp are the predominant crustacean but a variety of other benthic invertebrates can be found. Sand dollars, crabs, shrimp, clams, cockles, mussels, snails and sea cucumbers are all present. Resident and dominant fishes include gobies, California killifish, topsmelt, striped mullet and long-jawed mud suckers. While many of these species are not of commercial importance, they are prey for many sport fishes and sport fishers. California halibut, other flatfish, anchovies (northern, deepbodied, and slough), perch and sea bass are commercially or sport fished. Ghost shrimp are also harvested for bait in many estuarine flats (Zedler and Nordby, 1986).

Southern California rivers generally lack anadromous fish runs with steelhead trout being a notable exception. While Southern California estuaries may not contain salmon and sturgeon, they have croakers and sea bass. Sea bass and croakers are generally absent in estuaries to the north (Fierstine, et al., 1973).

Tijuana River estuary, in southern San Diego County, has three-fourths of its watershed located in Mexico. Designated in 1982 as a National Estuarine Sanctuary by NOAA, this estuary may be the most variable one in the nation. Dominated by wetlands and lacking large embayments, the aquatic habitat of the Tijuana estuary is comprised primarily of tidal channels. In comparison to other areas, few mud and sand flats exist in this estuary (Zedler and Nordby, 1986).

Agua Hedionda Lagoon has a well flushed system and supports a normal population of

mollusks with 74 species present. San Elijo, Los Penasquitos and Batiquitos Lagoons have had extended bar closures. Low salinity conditions exist in San Elijo Lagoon and hypersaline ones in Los Penasquitos and Batiquitos Lagoons (Zedler, 1982).

Several ecological reserves exist in Southern California, accounting for hundreds of acres of remaining wetlands in the area. These wetlands not only preserve the beauty of the area but also provide a safe haven for many aquatic and marine species. The Bolsa Chica Reserve, located between Huntington and Seal Beaches was established in 1973 for a number of purposes: to improve local fisheries by enhancing local nursery grounds, as waterfowl habitat and to provide an unique scientific research and educational site. Buena Vista Ecological Reserve located in a narrow valley at the mouth of Buena Vista Creek near Oceanside contains 192 acres of coastal wetlands. The purpose of this freshwater lagoon is not only to preserve the wildlife and habitat, but also to be a site for public enjoyment and education. Pismo Lake Reserve is a small marsh within the city limits of Pismo Beach which holds all the remaining wildlife habitat of the Meadow Creek drainage. The preserve provides a habitat for fish and wildlife dependent on freshwater marshes and riparian habitats, and allows for human enjoyment or research in the area. Over 700 acres of Upper Newport Bay comprise an ecological reserve designated to protect and enhance aquatic wildlife and habitats, provide unique scientific and educational opportunities and support recreational activities. The primary purpose of this reserve is to restore and maintain the salt marsh which is comprehensive enough in size and quality to provide diverse uses. Newport Bay is vital to many species and contains over sixty species of marine fish and 19 species of amphibians and reptiles (Schulenburg, 1979).

Anaheim Bay, formed on the floodplain of the San Gabriel and Santa Ana rivers, is an important tidal marsh. The bay originally was much larger but now is divided into Anaheim Bay and Huntington Harbor. A portion of the bay is contained for the U.S. Naval Weapons Station. In 1972 this portion of the estuary was declared Seal Beach Wildlife Refuge (Lane and Wood, 1975). Anaheim Bay contains over 115 species of invertebrates comprised mainly of polychaetes, crustaceans and mollusks. Ghost shrimp are the most conspicuous invertebrate resident (Reish et al., 1975).

In contrast to other Southern California estuaries, Mugu Lagoon is relatively large and undisturbed by humans. It has withstood detailed scientific study as a result of its seclusion on a military reserve. In the 130 hectares of water which constitute Mugu Lagoon, 39 species of fish have been recorded. Gobies, topsmelt, staghorn sculpins and surfperch were the most common fish found (Onuf, 1987).

Point Conception is considered a transitional zone for marine biota and is generally considered the dividing point for Southern and Central California. South of Point Conception, a shift in ocean currents results in warmer surface water temperatures. This creates a boundary for distribution of some aquatic plant and animals (Zedler, 1982).

A wider variety of anadromous fishes (sturgeon, chinook salmon, striped bass, etc.) are present in the central region, while species like the slough and deepbodied anchovy are limited to more southern regions. Dungeness crab, especially juveniles, are prevalent in

estuaries. The central coast of California receives more annual rainfall than the southern coast which affects the estuaries and its inhabitants. San Francisco Bay, the largest and most unique estuary on the Pacific coast dominates the central coast. Dungeness crab and salmon support large commercial and sport fisheries, while other anadromous fish also contribute to sport fisheries (Jones and Stokes Associates, Inc., 1981).

In northern Santa Barbara County estuaries and streams lie within the boundaries of Vandenberg Air Force Base (except part of Santa Ynez Lagoon which is a county park). Only two rivers, the Santa Ynez and San Antonio, have well-established lagoons. The Santa Ynez River is the largest river and estuary in Northern Santa Barbara County, with 90% of the watershed contributing to its flows. Diverse habitats characterize the estuaries and freshwater systems in this area. This, combined with being in a transitional zone between Southern and Central California, results in a wide variety of species.

Amphibians and reptiles are also abundant in riparian habitats. Freshwater and marine invertebrates are found in aquatic areas but not clams, crabs or others. The aquatic habitats of Northern Santa Barbara County are in relatively good condition because they are located within Vandenberg Air Force Base and are not utilized extensively (Mahrdt et al., 1976).

The Santa Maria River in San Luis Obispo County has a healthy population of Arroyo chub and sticklebacks. Some steelhead trout may stray into the river also. Unfortunately, it is the only estuary in the watershed which has any ecological value (Jones and Stokes Associates, Inc. et al., 1981).

Morro Bay, a shallow 2,000 acre coastal bay, is located in San Luis Obispo County and is formed from the drainage of the Chorro and Los Osos Rivers. A barrier bar separates Morro Bay from Estero Bay. Even though Morro Bay is north of Point Conception, it has more species of fish in common with Mission Bay (33) than with Elkhorn Slough (10) (Fierstine, et al., 1973). Eelgrass stands, tidal mudflats and marshes comprise the tidally influenced and ecologically important areas for Morro Bay. Twenty-four of the creeks and rivers which dump into Morro Bay have spawning populations of steelhead (Jones and Associates, Inc. et al, 1981).

The Salinas and Carmel Rivers and their tributaries have small spawning steelhead populations. A national wildlife refuge is located on the Salinas River and the mouth of the river is an important estuary which supports some sport fishing (Jones and Stokes Associates, Inc. et al., 1981).

Elkhorn Slough, on Monterey Bay, is the second largest salt marsh in California with 2,500 acres of channels, tidal flats and marshes. The slough and harbor represent significant areas for species that are important to the ecological, recreational and commercial well-being of the area. The area provides nursery grounds for the inshore fishes of Monterey Bay (Pacific herring, flounders, perch, smelt, sharks, rays and others). Striped bass have been known to follow schools of prey fish in the area. Dungeness crab, Pacific and Eastern oysters, mussels, clams and shrimp are the important sport and commercial invertebrates. Moss Landing Marine Laboratories has used the estuary for research and education (Browning, 1972).

The Sacramento–San Joaquin basin covers 40% of the state. The confluence of the

Sacramento and San Joaquin Rivers forms a delta which flows through the Carquinez Straits into Suisun Bay then into San Pablo Bay and out to the ocean. The Delta combined with the bays results in a continuum of aquatic habitats from deepwater channels to shallow marsh pools and from the Pacific Ocean to freshwater (Josselyn, 1983).

Aquatic life in the Bay/Delta System is quite diverse. The estuary provides protection, breeding grounds, food, a resting spot and a transitional zone from freshwater to salt water for many aquatic organisms. The invertebrate fauna of the San Francisco Bay/Delta is probably one of the most diverse in the state. As with most other large estuaries in the state the Bay/Delta estuary and environs are a prime nursery ground for many fish. The Sacramento–San Joaquin River system combine for the largest run of Chinook salmon in California. The only major run of striped bass in the state utilizes this system. Dungeness crab are also prevalent in the Bay/Delta system (Josselyn, 1983).

Tomales Bay, 40 miles north of San Francisco at the southeast end of Bodega Bay, is an important spawning ground for Pacific herring. Herring migrate to their natal bays to spawn on eelgrass. Of the vegetation in Tomales Bay, 75% is eelgrass and over 1000 species of invertebrates have been recorded there (Hardwick, 1973 and Jones and Stokes Associates, Inc. et al., 1981).

Other waterways in this area (Gualala and Russian Rivers, Lagunitas and Salmon Creeks) have runs of steelhead and coho salmon and green sturgeon have even been reported in the Russian River. California freshwater shrimp are in Austin Creek, but their habitat (along with anadromous fish habitat), is threatened by residential development and stream channel alterations. Timber harvest and grazing have impacted these systems also (Jones and Stokes Associates, Inc. et al., 1981).

Estuaries of Central and Northern California can be divided at Point Arena but they still have many characteristics and species in common. Streams and rivers on the North Coast generally have flows year-round due to high annual rainfall. Humboldt Bay is the largest estuary in this region. Anadromous fish are found in most major streams, and some streams have runs of 10 different species. Bay shrimp, crabs and clams are common invertebrate estuarine inhabitants. Salmon and Dungeness crab are commercially important species. These organisms are harvested for sport along with other anadromous fish (Jones and Stokes Associates, Inc., 1981).

In Mendocino County, anadromous salmon and trout runs occur on 37 creeks. Some of the larger streams which have salmonid runs including the Albion, Navarro and Noyo Rivers. Ten Mile and Big Rivers are the only two rivers in this area which have an estuary (Jones and Stokes Associates, Inc. et al., 1981).

The Eel River Delta covers 33,000 acres in Humboldt County and receives water from tributaries in four counties. Variety and diversity describe the habitat types in the delta with freshwater marsh, salt marsh, tidal mudflats, shallow water bays, sloughs, gravel bars and deepwater channels among the major aquatic habitats. Freshwater, anadromous and estuarine fish utilize the sloughs and tributaries of the delta and river for spawning, nursery and feeding grounds. Anadromous fish (salmon, steelhead, coastal cutthroat trout and green sturgeon) occur in the river. Juvenile

Dungeness, bay shrimp and clams are abundant in the delta (Monroe et al., 1974).

North of the Eel River Delta lies Humboldt Bay—home to 95 species of marine fish. The bay and its large stand of eelgrass provide a significant nursery ground for Pacific herring, anchovies, Dungeness crab and English sole. Native oysters, mussels and clams can be found in abundance throughout the bay. Humboldt Bay is quite productive. It supports a large population of feral aquatic species and commercial oyster companies rear enough bivalves to account for up to 95% of the state total (Monroe, 1973).

Two other major rivers in Humboldt County, the Mad and Klamath Rivers, have runs of chinook and coho salmon, coastal cutthroat trout and steelhead. The Klamath also has spawning populations of green sturgeon and Pacific lamprey which are fished by Native Americans (Jones and Stokes Associates, Inc. et al., 1981).

Four small coastal lagoons lie in between the Mad and Klamath Rivers: the Dry, Stone, Freshwater and Big Lagoon. Highway 101 traverses the bar of Freshwater Lagoon which is a popular summer camping spot for tourists. Big Lagoon is the only lagoon which breaches its sand bar every year and has runs of steelhead and coastal cutthroat trout (Jones and Stokes Associates, Inc. et al., 1981).

The Smith River located in northwest Del Norte County is protected under the Waterways Act of 1971 and the Wild and Scenic Rivers Act of 1972 (Munroe et al., 1975). The Smith River Delta contains 46 hectares of marshes and sloughs, and 122 hectares of intertidal flats and channels. Lake Earl, Tolowa and Dead Lake are part of the Smith River floodplain. When the sandbar of Lake Earl breaches, the level of the lake is lowered and tides are able to flow into the lake (Jones and Stokes Associates, Inc., 1981). The Smith River Delta and floodplain are extremely productive and have large fish populations (Munroe et al., 1975). The river is highly valued by sport fishers and recreationsits for the clarity of its water and the anadromous fish runs. It contains 10 species of anadromous fish: chum, coho and chinook salmon, coastal cutthroat trout, steelhead, Pacific lamprey, shad, green sturgeon, sticklebacks and Eulachons. The best run of coastal cutthroat trout in the state spawns in the Smith River (Jones and Stokes Associates, Inc., 1981).

Rare Plants, Animals and Natural Communities

Natural phenomena and/or human activity can have an influence on the rarity of species and natural communities. The Torrey pine forest is a community that has only two natural stands, one on the coast of San Diego County and the other on Santa Rosa Island. Changing geology and climate has left only these two examples of the Torrey pine community. Physical features, such as an unusual soil type or rainfall pattern, may give rise to rare plants. The Mt. Tamalpais jewelflower is restricted to an infertile soil derived from serpentine, a metamorphic rock of limited distribution. An animal may require an infrequently occurring habitat, such as the federally endangered lotis blue butterfly, which depends on sphagnum bogs. A recently evolved species may be rare because it has not had time to spread. The flower *Presidio clarkia* seems to have evolved sometime after the last glacial retreat 12,000 years ago. Its few populations, found only in the San Francisco Bay Area, may reflect its short history. A species may also be a relict

species that was formerly more widespread. Coast redwood, a species believed to be over 100,000 years old, used to occur in Asia, Europe, Greenland and much of North America, but is now confined to the coastal strip from Monterey County to southern Oregon.

Human activities are the primary cause of species decimation. The rarity of riparian communities is a reflection of man's alteration of the landscape: agriculture and urbanization have greatly diminished this once common community. Destruction of a natural community can result from pollution, proliferation of non-native species, mining and deforestation, as well as agriculture and urban expansion. With the loss of a natural community comes the loss of some of the species it supports. The salt marsh harvest mouse, listed as a state and federal endangered species, is endemic to the salt marshes of San Francisco Bay. Reduction of marsh area through draining and filling has threatened the continuation of this species. Coastal communities, such as the salt marsh, torrey pine forest and sphagnum bogs, constitute a third of the rare natural communities of California.

Protecting rare species and communities is the primary focus in current efforts to ensure natural diversity. Preservation of biological diversity is discussed in greater detail in Chapter One. The legal framework for protecting rare, threatened and endangered species is covered in the Regulatory Framework chapter.

DEVELOPMENT AND COASTAL ECOSYSTEMS

"Development" includes so many different projects, (from power-generating installations to residential subdivisions) that it is unrealistic to try to list all the categories which could occur along the California coast. Each proposed project is different in terms of size and purpose, and the site-specific effect on a project's environment varies from project to project. However, all development includes activities—such as road-building, construction of building pads, construction of water impoundments and pipelines, etc.—which always have impacts on the environment (such as accelerated erosion, removal of sensitive vegetation, and fragmentation of wildlife habitat).

Aside from direct loss of habitat, numerous direct and indirect impacts associated with development are responsible for reduction in the size and productivity of ecosystems. Although the processes can be identified and impacts described, the complexity of natural systems makes it difficult to assess the significance of impact without site-specific monitoring of processes and populations.

Ecosystem Characteristics

While both NEPA and CEQA include references to the "maintenance and enhancement of long-term productivity," concern is growing over management practices and the threat to forests and ecosystems along the coast. The ability of a biotic community to maintain resource productivity depends on a number of factors, such as biological diversity, size and succession. A knowledge of these characteristics and processes is essential when decisions regarding development activities are to be made.

Biological Diversity

Biological diversity refers to different kinds of species, genetic types within species, kinds of natural ecosystems and interactions within

ecosystems. In some ecosystems, high diversity indicates a redundancy in ecological functions which may allow internal adjustments to outside forces which could otherwise cause the collapse of the system. Loss of diversity in such a system would increase its vulnerability to degradation and eventual destruction.

Loss of biological diversity may also represent a loss of species valuable for food, fiber or medicine, or reduction in the "ecological services" provided by ecosystems, and a decrease of the diversity of the environment in which people live.

Size

The area occupied by a biotic community or ecosystem is critical for its survival. Ecosystems function and survive when a group of species have the room and resources to interact while meeting their individual needs. Animal species require food water, and cover; plants require sunlight, soil nutrients and water. If natural ecosystems are to function and support their entire natural biota, they must have sufficient land base to provide for the sustained availability of basic needs of the organisms, and for any behavioral, breeding or other interactions between organisms which are related to spacing. Fragmentation of the land base by urban development, logging or agriculture may lead to the elimination of certain species from the ecosystem, or may lead to pieces of ecosystems which are no longer self-sustaining.

Providing sufficient land area will be crucial to the protection of certain threatened or endangered species. For example, with the listing of the Northern Spotted Owl as a threatened species, planning by the U.S. Forest Service now must focus on providing areas of old-growth forest to provide for the owl's habitat needs.

Succession

Succession is the natural process of development of ecosystems. It is characterized by a progressive change in species composition, lifeform and environmental condition. For example, on sand dunes along the California coast, succession begins on bare dunes with the colonization of a few hardy shrubs adapted to the harsh conditions of the dune environment. The first plants provide enough wind and sun protection to enable the establishment of more plants. Over time, as more vegetation grows, soil nutrients improve and evaporative stress decreases. More and more animals can inhabit the site as conditions change with the increase in vegetation. Over a very long time, trees such as Monterey Pine may ultimately survive on a site which was formerly a sand dune.

In certain areas, the process of invasion by new species and modification of the environment continues until an ecosystem develops that is able to maintain itself on the site. Such a stable habitat is called a climax community, and is often characterized by ecosystem complexity, including high species diversity. When an existing plant and animal community is destroyed by natural phenomena such as fire, flood or landslide, the process of succession leading to the climax ecosystem for that site, is reinitiated.

An understanding of succession is necessary for assessing the effects of many kinds of development. In some cases, development may alter patterns of succession, and in other situations, natural succession will lead

eventually to changes in the existing ecosystem regardless of the proposed development.

Effects of Development

The following discussion considers the effect of development on terrestrial and freshwater ecosystems. Not only must the potential effect of activities associated with development be considered, but the importance of the ecosystem and its sensitivity to change. The sensitivity of each individual biotic community to change is unique, depending on factors such as slope, rainfall soil type, and ultimately must be taken into consideration for each site. The importance of an ecosystem may depend on its commodity value, its abundance and its uniqueness. The riparian ecosystem, for instance, is unique for its combination of forest and water, providing cover, food and water for a variety of species. It occurs much less extensively than other forest ecosystems in the coastal region.

The next section presents an overview of impacts due to air pollution, oil spills and construction, on plants and animals in general. The following discussion then addresses development effects on particular ecosystems.

Air Pollution and the General Biota

Although the entire California coastline climate is commonly influenced by marine air, the effect varies along the coast, depending on ocean currents, latitude, orientation of the coastline, terrain and inland temperatures. The abundance and vitality of ecosystems is influenced by local variations in climate. All these factors, along with magnitude and type of development, influence local air quality and can affect the vitality of ecosystems.

In parts of the San Francisco Bay Area and the coastal air basins from Los Angeles to the Mexican border, there has been a history of oxidant levels which exceed allowable standards during a significant part of the year. As a result, extensive ozone damage to conifer forests in Southern California and a long-term decline in forest ecosystems appears to be occurring. Lesser damage has been documented in the Los Padres Forest in Central California and studies of coastal scrub ecosystems in the Santa Monica Mountains show a correlation between air pollution and limitations on species diversity (Westman, 1979).

Ecosystem productivity can also be affected by air pollution. Air pollution levels exceeding the standards set for human health can lead to reduced photosynthesis and damage to foliage. This has been documented in forests and agricultural crops (Mudd, J.B. and T.T. Kowzlowski, 1975). Citrus and grape production in many parts of Los Angeles has been seriously reduced by air pollution. Oxides of sulfur and nitrogen from the burning of fossil fuels combine with water vapor to produce acids which may fall with rain, be carried by fog, or be deposited dry from the atmosphere. These acid deposits impact both plants and soil in terrestrial ecosystems and the pH of water in aquatic systems.

Oil Spills and the General Biota

The impacts of oil spills on rivers, marshes and terrestrial ecosystems can have far-reaching effects on wildlife, vegetation and soils. The recent history of oil spills along the North American coast illustrates the potential magnitude of this problem.

Oil spills in rivers can affect a wide variety of species because rivers are often used as migratory corridors for many types of birds and fish and provide habitat for all types of wildlife.

Water movement in rivers can rapidly move oil spills to sensitive downstream habitats. A spill can have external or internal effects on wildlife. Animals can die directly from asphyxiation or coating. They may suffer from internal effects including contact poisoning or the incorporation of sublethal amounts of oil resulting in reduced resistance to infections and stress (Hutchinson, 1974). Oil which floats in the water and adheres to rocks on riverbanks can interfere with the respiratory processes of animals that have gills and/or attach to the rocks. Sense receptors may become blocked from exposure to toxic compounds interfering with important communication responses. (Hutchinson, 1974). Crude oil can also stunt the growth of many species of fish. Studies have shown that juvenile salmon are particularly sensitive to oil impacts (NOAA, 1985). Studies have also shown that salmonid homing instinct can be affected by long term exposure to crude oil (Wang, 1988).

Aquatic habitats can become contaminated by oil from offshore spills that drift into wetlands. Marshes and estuaries are often used by migratory waterfowl as resting or breeding areas, and by migratory fish as spawning and nursery areas. Steelhead and coho salmon are abundant in coastal wetlands. The tidewater goby, a species endemic to California coastal areas, is only found in four California lagoons. A spill off the coast of Northern California in 1986 was carried into Rodeo Lagoon, one of the four lagoons the goby is found in, causing the fish to temporarily discontinue spawning in the area (Wang, 1988). The goby's spawning habits include burrowing and the use of vegetation. Because of the spill in Rodeo Lagoon the condition of the bottom substrate was not conducive to spawning. Since this spill was small and flushed out rapidly by heavy rains the fish resumed spawning after three months. However, long-term effects could have more serious repercussions on sensitive species and on California fisheries.

Spawning behavior and fish habitat can be affected in a variety of ways by spills, but the most serious problem with spills in wetlands is that birds and other animals are easily oiled as they move through the vegetation.(NOAA, 1985). They may suffer from the external effects of coating, (including asphyxiation or loss of insulation), or internal effects from ingesting lethal products during feeding or preening. These substances are often carcinogenic and are passed along the food chain.

Oil spills immediately inhibit the process of photosynthesis by destroying chlorophyll in plants. Deciduous species often lose their leaves directly following a spill, but are generally able to recover over a long period of time. The exception is when dead branches become infected with wood rotting pathogenic fungi which invade the tree trunk and eventually kill the tree. Long term damage is much more serious to evergreen species since they do not shed their leaves and are unable to get rid of damaged tissue (EPA, 1975).

Damage to wetland vegetation varies with the type of vegetation, type of oil spilled, water level and season of the spill. In general, the short term effect is the death of oiled shoots with new growth from meristems at the plant base. Germination and flowering are reduced during recovery. Perennial plants with underground root systems recover the most quickly. The most susceptible wetland plants are shallow rooting species and seedlings of all kinds (Hutchinson, 1974). Marsh systems are able to recover more quickly where water levels are high, since high water levels prevent more

intense penetration. In addition, studies have shown that oil coating can cause more damage to wetlands when the weather is hot, especially if the plants are in their reproductive stage (Hutchinson, 1974).

Most vegetation, excluding some evergreen species, eventually regenerates after an oil spill, although it may be a long process. Considerable amounts of hydrocarbons were found in a Massachusetts marsh two years after a spill, even though the vegetation had partially recovered (Hutchinson, 1974).

Dry soils with high organic content soak up crude oil quickly. Crude oil changes the structure of the soil by replacing water. This reduces the amount of water available for plant growth and plants in heavily oiled soils show signs of drought (wilting) (Hutchinson, 1974). In marsh soils, oil that penetrates deep into the marsh will persist for a longer time period than on terrestrial soils because of the waterlogged anaerobic conditions of those types of soils.

Oil spills can be dispersed by tides and winds. Rivers that have the ocean as their outlet can be affected when tidal currents traveling upstream against the flow of the current can slow down or stop the flow of the river, thus concentrating the spill (NOAA, 1985). In addition, the intrusion of saltwater leads to a two layer circulation system in which water flows in at the bottom and out at the top. The stronger convergence zone in the lower level of the river has the potential to lead to higher concentrations of oil in the bed load. It has been seen in river spills that oil floating on the surface can be flushed out of the river in a few days while bottom concentrations can remain in the river for several weeks posing long-term environmental hazards (NOAA, 1985).

Winds can blow surface spills onto riverbanks causing a higher concentration of oil or oiled vegetation on one side of the river. This increases potential damage to the resources on that one side.

Construction and the General Biota

Construction activities, such as grading, filling, placement of structures and paving are associated with nearly all types of development and directly result in loss of habitat. The loss of biota and habitat is often exacerbated by development of steep terrain, especially on unstable slopes. Construction can cause changes in the natural drainage pattern because of the placement of the development and the increase in the amount and rate of surface runoff, erosion and streambank cutting. In Southern California, the coastal terrain is generally more accommodating to residential, commercial and industrial development than in Northern California. Large areas of coastal chaparral, coastal scrubland and other ecosystems have been converted into residential and industrial subdivisions. In the north, such development has tended to be smaller in scale, although the cumulative affect of relatively small enclaves of development can result in large changes in wildlife habitat potential. These changes occur not only because of the direct loss of vegetation, but because remaining areas of native vegetation become fragmented and may not be large enough to meet the territory requirements of large or wide-ranging wildlife species. Fragmentation also increase the potential for invasion by exotic species which may in time come to dominate the local ecosystem.

Effects of Development on Ecosystems

Timber cutting is responsible for major changes in the Redwood, Grand Fir/Sitka

Spruce, Douglas-fir and Mixed Evergreen Forests of the coastal terraces, slopes and ridges from Santa Cruz County to the Oregon Border. Currently, controversy surrounds timber management practices, especially related to old-growth Redwood Forests. Concern is growing regarding management practices and the threat to sustainability in the other ecosystems as well. Recently, the habitat requirements of the Northern Spotted Owl (*Strix occidentalis caurina*) have been receiving considerable attention. On June 22, 1990 the U.S. Fish and Wildlife Service listed it as a "threatened species." The Northern Spotted Owl inhabits old-growth forests in parts of British Columbia, Washington, Oregon and northwestern California. However, these owls have also been found in younger stands of forests, though none of the stands were under 50 years of age. The owl habitat is distinguished by the presence of a multi-layered stand structure, a dense canopy tree closure and large trees with cavities or broken tops.

The Northern Spotted Owl population has been estimated at 6,000 birds, an estimated 2,000 breeding pairs. Each pair has a home range which they occupy year-round. A home range varies in size from 1.5–2.1 miles in radius or about 1,000–3,000 acres. This area multiplied by the estimated 2,000 pairs of owls, results in the commitment of a large and valuable block of timber.

It is estimated that there were 7.1 million acres of owl habitat existing in 1989. The owls' preferred old-growth habitat has been reduced 70%–80% from historical levels, primarily in the last 50 years. Reduction of the forests continues today at 1%–2% annually.

Many native ecosystems are dependent on periodic wildfire for regeneration. For reasons of public safety, such fire must be suppressed in areas where people live. Firebreaks, access roads and cleared buffer zones are necessary, further reducing and isolating natural ecosystems. At the same time, increased numbers of residents or recreationists bring with them the potential for starting fires. Changes in natural fire regimes in upland areas are affecting the pattern and rate of succession in many areas, especially shrublands. In the long term, the change in fire regime will result in a modification of the mosaic of ecosystems. The lengthening of the intervals between fires, brought about by human efforts at fire suppression, may favor the development of climax ecosystems in forested areas, or lead to a senescent, unproductive ecosystem in shrub vegetation types.

Development which increases instability on hilly grasslands not only reduces the vegetation cover, but often results in landslides. Disturbance to grasslands, resulting in removal of grass cover, can lead to invasion by weedy species. Some invading species, such as thistles, dramatically reduce the commercial and recreational use of grasslands. These other species add to the fuel load in the grasslands, and the potential for more destructive wildfire is increased.

In coastal strand ecosystems, plant cover is often relatively sparse. Offshore winds can be strong and the loosely-packed sand dunes are unstable and particularly vulnerable to off-trail trampling and off-road vehicle activities. Disturbance of sand dunes can result in "blowouts," which can grow from a few square yards in size to several acres in a short time. Because they are not hospitable to a large number of plants, recovery of blown out areas is very slow.

The eucalyptus forest is a very successful ecosystem which thrives along much of the California coast. Its success is due to its adaptation to the coastal climate and soils, and its ability to compete with native species. Other non-native systems (cropland, orchard and vineyard), are not as competitive and require continual management in order to survive. This management may include application of pesticides, herbicides and fertilizers. Eucalyptus forests and many agricultural ecosystems along the coast are being converted to housing developments.

DEVELOPMENT AND WETLAND ECOSYSTEMS

Coastal marshlands are critical but fragile ecosystems, providing habitat for many rare and endangered species, migratory waterfowl, shorebirds and aquatic organisms. Relatively small changes in marsh systems can create intolerable conditions for many organisms. Marshlands have been dramatically reduced all along the California coast, as a result of activities such as filling, damming, decking and draining.

Dredging to deepen channels can alter water circulation and reduce tidal exchange. The ability of marshes to support and maintain biota can be reduced by changes in salinity and other water quality relationships brought about by dredging.

Riparian ecosystems, because of their linear shape, their comparative sensitivity to change, their relative rarity, the quality of their soil, and attractiveness as residential living space, are especially at risk. Conversion and loss of riparian systems has been proceeding for many years due to development pressure from agriculture and urban growth. Stream bank stabilization and flood control projects have also contributed to the loss of riparian ecosystems.

Development impacts to riparian ecosystems result from changes in stream flow characteristics associated with the construction and operation of dams. Stream flow regulation by dams has changed the seasonal—and in some cases, the daily—water level. Stream levels drop rapidly in the spring when water is held back in dams for irrigation. Under these conditions, the water table will drop at an accelerated rate beneath the riparian vegetation. In some cases this has resulted in the death of existing trees and the failure of tree seedling establishment. Stream levels below hydroelectric dams may fluctuate up and down on a daily basis in response to the daily demand for electricity. As a result, water tables in the riparian zone can surge up and down as much as three to four feet. Flooding of gravel bars and the soils on the terraces along stream channels eliminate oxygen from these soils, and can selectively eliminate certain species.

Dam construction also affects the sediment load carried by streams. The relatively sediment-free water released from dams has great erosive power and often results in the removal of finer sediments from gravelbars and stream beds in waterways below dams. This type of scouring degrades stream channels of spawning gravels and alters substrate conditions for the germination and establishment of riparian plants.

Many vernal pools have been permanently lost to development. Some are seriously disturbed and threatened, while others remain in relatively good shape despite urbanization and grazing. Because vernal pool biota are often endemic and thereby restricted to these limited

habitats, they contain many rare species and need to be protected (Onuf, 1987).

Vernal pools are very fragile. These shallow ponds are easily destroyed by cultivation or by driving over them with heavy construction equipment. Many of the pools which have not been lost to development directly have been seriously disturbed by construction activities. Heavy spring grazing, dumping and acid deposition also threaten vernal pools in some areas.

DEVELOPMENT AND AQUATIC ECOSYSTEMS

Because of the dry climate and relatively steep topography, freshwater is a precious commodity in coastal California. Freshwater aquatic systems are a relatively small and highly-valued resource. Approximately three-fourths of the surface runoff in the state is stored and transported for agricultural or domestic use (California Department of Forestry, 1988). All of the heavily populated areas of the state are dependent on imported water.

Freshwater ecosystems can be affected by development in numerous ways that affect either organisms directly or their habitat. Impacts can result from water diversions, dam construction, sand and gravel extraction, logging or other conversion of forest or woodland ecosystems, removal of riparian vegetation, streamflow regulation, channelization and water pollution.

Estuarine ecosystems have been affected by large-scale habitat destruction through filling, decking and draining. Over two-thirds of the total area covered by estuaries in California has been lost to development (Jones and Stokes Associates, Inc., 1981). In addition, waterflow alteration, toxic and effluent dumping, increased recreational uses, increased sediments from agriculture, residential and industrial development, all have taken their toll on the estuarine environment. In addition, waterway alteration by dredging or by increased sedimentation from upstream erosion can drastically reduce tidal exchange and water circulation. Such changes can affect salinity and other aspects of water quality necessary to maintain wetland biota.

Water quality can be seriously degraded by toxic substances such as petroleum products, pesticides, herbicides and heavy metals, introduced through sewage disposal, surface runoff and accidental spills. These damaging substances may be introduced in relatively minute amounts yet accumulate to harmful levels through biomagnification and bioaccumulation. In other cases, toxic substances enter ecosystems in large amounts from spills. Accidental spills can originate from onshore or offshore sources.

Relatively small amounts of pollutants in wetland or aquatic systems can create intolerable conditions for many organisms. For example, 0.01 mg/l of the soluble fraction of crude oil will disrupt the reproductive behavior of shore crabs (Jones and Stokes, 1981). In biomagnification, toxic substances in low concentrations can be selectively taken up by aquatic insects, such as mosquito larvae, as well as zooplankton, which often concentrate at the surface to feed when the sun is out. Mosquito Fish and small fish of other species can obtain higher than ambient levels, and the larger fish that prey on them can further magnify the effect. Finally, large, fish-eating birds at the end of this food chain can receive significant levels of pollutants (Odum, 1971).

Impacts to Aquatic Ecosystems—Regional Characteristics

Estuaries in Southern California have had major human alterations. Brackish marshes are transitional zones resulting from urban and agricultural encroachment and may be dependent on urban runoff (Zedler, 1982). The paving of rivers in Southern California has destroyed many estuaries (Onuf, 1987). Steelhead trout once migrated up many southern streams, but because of development their distribution is now a fraction of what it was (Figures 2-20 and 2-21).

Figure 2 - 20: Distribution of steelhead (shaded areas) in Pacific Southwest region streams in 1980's (California Department of Fish and Game, pers. comm.; Moore, 1980).

Mexican sewage spills into the Tijuana River drainage dramatically alter the quantity and quality of riverine inflows to the estuary. Scars from past military activity, horse racing, agriculture, filling and offroad vehicles remain (Zedler and Nordby, 1986).

Bridges and other structures restrict lagoon entrances to a single location. This increases the possibility of and probably prolongs the closures thus causing changes in flows and salinity which may effect the biota. A comparative study of four San Diego County lagoons illustrate damage to aquatic organisms from extended lagoon closure. The molluscan fauna was devastated in San Elijo, Los Penasquitos and Batiquitos Lagoons by such closure (Zedler, 1982).

By 1949, the total area of the Anaheim Bay marsh had shrunk by 30%. The majority of the

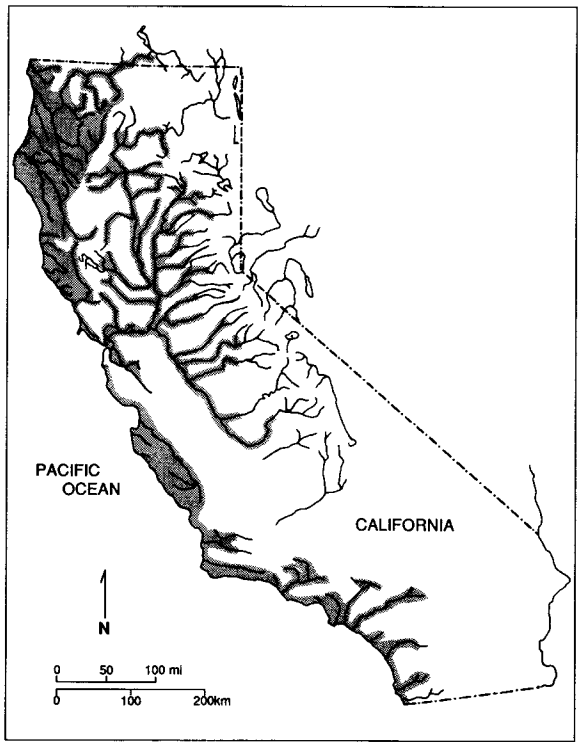


Figure 2 - 21: Distribution of steelhead (shaded areas) in Pacific Southwest region streams in 1900 (National Council on Gene Resources, 1982).

remaining marsh is located in the Naval Weapons Station. During the 1930's up to 23 gun clubs could be found in and around the marsh. The development of Huntington Harbor resulted in the dredging and filling of part of the south portion of the bay. This changed

faunal distributions and eliminated most of the natural intertidal mudflats and vegetation (Kauwling and Reish, 1975). Under the State Tideland Overflow and Recreation Act the marsh was reclaimed, channels were closed and tide gates created (Lane and Woods, 1975).

Central California estuaries and aquatic systems have not had quite the extensive development and human intrusions of their southern counterparts. The San Francisco Bay Area is the most notable exception. Dairy, agricultural, mining and poor timber practices have greatly impacted many of the estuaries and freshwater systems in the central coast (Mahrdt et al., 1976). Overgrazing by livestock has caused sedimentation and erosion of stream banks, and has left many of these streams in need of rehabilitation. Agricultural runoff is the main anthropogenic influence in the many watersheds of this region (Jones and Stokes Associates, Inc. et al., 1981).

The Santa Maria River in San Luis Obispo County has had most flows held at Twichell Reservoir. Now the majority of flows into the stream come from treated effluent. Today only a few stray steelhead migrate into this stream (Jones and Stokes Associates, Inc., 1981). Anadromous runs of steelhead have been eliminated on Old Creek by Whale Rock Reservoir, but a landlocked population remains. Arroyo Grande Creek steelhead runs have been lost from instream sediments caused by agriculture, pesticide and fertilizer runoff and water diversions for irrigation. Little Sur and Arroyo de la Cruz Rivers, located within the Hearst Ranch boundaries, are relatively pristine in comparison (Jones and Stokes, Associates, Inc. et al., 1981).

In 1946, the Moss Landing Harbor (channel) was dredged out in Monterey Bay, seriously altering the environment. By 1972, half of the marshlands had been reclaimed and additional development threatens even more sensitive marshes. Channelization of rivers by farmers prevents them from shifting naturally. Low water quality from effluents from domestic sources, boats and commercial enterprises, and dairy and agricultural runoff has consistently been a concern (Browning, 1972).

The San Francisco Bay/Delta is a unique environment. But decking, filling, pollutants, urbanization and introduction of foreign species have irreversibly changed the area (Josselyn, 1983). The effects of development have left the San Francisco Bay Area marshes at 5% of their original size. The natural wetlands of this area still account for 25% of the state total (Skinner, 1972).

The Gold Rush of the 1850's led to massive development of the Bay Area with a devastating loss of tidal wetlands. Extensive sedimentation and smothered fish nursery areas interfered with navigation, raised the river bed above natural levees and caused extraordinary flooding. Today sedimentation rates are only a tenth of their peak during hydraulic mining. This huge loss of habitat and animals occurred before many species could be catalogued, so the full extent of damage will never be known (Josselyn, 1983).

As cities expanded, the water demand increased. Water diversions for agriculture and domestic use reduced flows into the Delta. In 1943, the U.S. Bureau of Reclamation completed its most ambitious project in the state, the Central Valley Project (CVP). Large dams (such as the Shasta Dam built on the headwaters of the Sacramento River), were constructed. The delivery of water via the Delta-Mendota Canal to the San Joaquin Valley

for irrigation further reduced flows into the Delta. The California State Water Project (SWP) (which begins with the Oroville Dam), carries water to Southern California, the San Joaquin Valley and coastal valleys—this has led to even more water loss from the Delta. Currently, total flows into the Delta have been reduced by 44%. This decrease results in salt water intrusion into the Delta during the dry summer months. Recently, more freshwater has been released from dams during the summer to reduce this process (Josselyn, 1983).

Many tidal marshes lack the flows needed to adequately flush them because of a higher incidence of saltwater intrusions and a reduction of sediment flows. Any additional water diversion would be devastating. Less sedimentation would result in more loss of marshes to rising sea levels, and increase salinities into the Carquinez Straits and Suisun Bay. Other anthropogenic influences include sewage pollution and introduced species (Josselyn, 1983).

Over 90 species of invertebrates have been introduced to the Bay Area—some intentionally—for vector controls, sport fishing, or for culture. Other organisms were accidentally brought into state waters when other species were introduced, or with ballast water, etc. Their full impact on other aquatic species and habitats probably will never be known, but the overall distribution and abundance of native species has seriously been altered (Josselyn, 1983).

Many species of fish have been introduced to the area, including the prized striped bass, other bass, shad, catfish and carp. Out of 31 species of fish collected by Moyle in 1982 in Suisun Bay, 18 were introduced (Josselyn, 1983). Striped bass juveniles, cultured by the Department of Fish and Game for sport fishers, are an important predator in the Delta area, possibly competing with native salmon for food and even devouring them (Ganssle, 1966). Once the dominant fish of the San Francisco estuary included Sacramento and tule perch, large minnows, blackfish, hitch and others, but competition from non-native species has drastically reduced their numbers, sometimes to an endangered status (Kelley, 1966).

In Northern California, human environmental impacts are less prevalent because of the sparse population. However poor timber practices (clear cutting, bad road construction and maintenance), agriculture, grazing, dairy farming, mining and development have left their mark on the environment. These activities have caused erosion, siltation, sedimentation, stream flow alteration, increased stream temperature and loss of aquatic habitat. Overharvesting has also contributed to the decline of salmonid runs. A hatchery on the Mad River managed by the Department of Fish and Game produces salmon and steelhead for harvest by fishers. These fish contribute to sport and commercial catches but interbreeding and competition with wild fish may hurt the natural population (Jones and Stokes Associates, Inc. et al., 1981).

The Mattole River and its tributaries, found in southern Humboldt County, has significantly been influenced by logging and grazing in the watershed. Natural disasters combined with problems associated with logging have made the Mattole one of the most turbid North Coast streams. The turbidity adversely affect the salmon and steelhead runs (Jones and Stokes Associates, Inc. et al., 1981).

The lack of proper watershed management is to blame for the most serious problem of the

Eel River system: sedimentation. Declines in aquatic populations have also been caused by pollution, contamination and increased harvests by sport and commercial fishers. Poor logging practices, overgrazing, road construction, and water diversion for agriculture and development have all contributed to the silt and sediments in the system (Monroe et al., 1974).

Large oyster production sites in Humboldt Bay are located in North Bay in an eelgrass meadow, and on mudflats. Eelgrass is removed from the site which is a prime spawning ground for Pacific herring. Trapping for crabs and dredging for bat rays which predate on the oysters also takes place. The effects these practices have had on the bay and its populations are unknown. Presently, the bay covers 16,000 acres reduced from 27,000 acres by reclamation of sloughs and marshes. Stream channel shifts, siltation, water diversions and pollution have led to a decline in chinook and silver salmon, steelhead and coastal cutthroat trout migrating through the bay to their natal streams (Monroe, 1973).

Logging and recreational use have been the main human impacts on Dry, Stone, Freshwater and Big Lagoons. At Freshwater Lagoon, motorhomes are commonly lined up three deep. Overcrowding and its associated problems have led the National Parks Service to consider limiting the number of campers.

On the Smith River, cattle grazing near the river have caused stream bank erosion and sedimentation. General land disturbances and logging road construction have destroyed fish habitat and resulted in suspended sediment concentrations three times higher than normal. Mill Creek, a tributary to the Smith, is one of the more pristine streams in the area because its course meanders through a state park, relatively undisturbed (Jones and Stokes Associates, Inc. et al., 1981).

PALEONTOLOGY

In California, or elsewhere, the main problem with protecting paleontological resources is that one doesn't know where they are until the damage is done. The best one can do is estimate the probability of finding such resources by looking at the formations they usually occur in, and taking precautions with equivalent formations.

Three types of paleontological resources are known in California. First are "true" fossils—the lithified remains of plants and animals preserved in a rock matrix. These range from microfossils, the remains of shells of prehistoric planktonic plants and animals, to the large bones of extinct animals and whole tree trunks. Secondly, there are fossil "casts"—impressions made in soft clays and muds which subsequently turned to stone, preserving the images of past life—footprints, leafprints and worm tubes. And lastly, there is a resource unique to California, the "breas"—natural seeps of petroleum which trapped hundreds of now extinct animals and preserved their remains. Each of these resources preserves an aspect of California's prehistory that is important in understanding the past and the development of the world as it is today.

In looking at the effects of development, paleontologists generally agree that only damage to larger macrofossils is significant. While microfossils are very important in establishing the age of various formations, interpreting paleoclimates, and marking oil bearing formations, they are so widely distributed that the losses associated with

development are not seen as critical. However, the loss of even one major vertebrate or higher plant fossil could seriously affect our correct understanding of evolutionary development.

In estimating where paleontological resources of significance might occur, one must look at both rock type and specific formations. Significant fossils are found only in sedimentary rock beds. Metamorphism destroys existing fossils and the heat associated with igneous rocks assures that no traces of life would be preserved in the cooled rock. Among sedimentary formations, fossils are known from only a portion of the possible rock beds, and of these, only a few are exposed where development could possibly damage potential resources. To determine if the possibility of damage exists, we first examine the area where the proposed project will take place and check geological maps for the presence of sedimentary rock formations. We then check the literature to see if any fossils have been found in the same formation in other locations. Finally, if this last check proves negative, we check formations of similar ages to see if they contain significant fossils. If the answer to either of these questions is yes, then the possibility exists that the proposed project will impact paleontological resources.

The preferred mitigation for such potential damage is always avoidance. If there is any possibility of re-aligning the project so as not to impact the suspect formation, that is preferable. If that cannot be done, then any earth disturbance must be monitored by a qualified paleontologist who has the authority to stop the project and undertake salvage operations if any significant fossils are found.

CULTURAL RESOURCES IN CALIFORNIA

REGULATORY SETTING

Since the introduction of various federal environmental laws in the 1960s, state, county, and city governments have also developed rules and regulations regarding items or places of "cultural heritage." In general, the State of California has been a leader in developing and testing such legislation due to the state's large amount of proposed and actual development. The coast of Southern California, in particular, has become a focal point for the implementation of regulations from all levels of government for large and small development projects. Especially in the case of cultural resources, this situation is complicated by the fact that proposed developments are taking place in an area that once contained a concentrated prehistoric population with a complex cultural history.

Federal Legislation and Regulations

Most of the regulation from the federal level stems from two sources—the National Environmental Policy Act (NEPA) and historic preservation legislation such as the National Historic Preservation Act of 1966.

NEPA provides for the consideration of historic resources in order to "preserve important historic, cultural, and natural aspects of our national heritage, and to maintain, wherever possible, an environment that supports diversity and a variety of individual choice" (42 U.S.C.A. Sec. 4331).

The system of historic preservation legislation began with the Antiquities Act of 1906, and has continued to expand over the last 80 years. The Antiquities Act of 1906 expressed concern over

the destruction of important historic and archaeological properties, and established a system of permits for the conduct of archaeological studies on federal lands, as well as establishing penalties for noncompliance. Some permits issued under this act are still in force, but new permits are now issued under the authority of the Archaeological Resources Protection Act (ARPA) of 1979 and its implementing regulations. The intent of ARPA is to enhance preservation and protection of archaeological resources on public and Indian lands. ARPA places primary emphasis on a federal permitting process in order to control the disturbance and investigation of archaeological sites on these lands. In addition, ARPA's protective provisions are enforced by civil penalties for violators.

The Historic Sites Act of 1935 declared that it is national policy to "preserve for public use historic sites, buildings, and objects of national significance." The National Historic Preservation Act (NHPA) of 1966 expanded the scope to include important state and local resources. Provisions of NHPA establish a National Register of Historic Places, Advisory Councils on Historic Preservation, State Historic Preservation Offices, and Grants-in-Aid programs. Section 106 of the Act requires that all federal agencies consult with the Advisory Council prior to undertaking any action that would affect a property on or eligible for the National Register. The Advisory Council has developed regulations for Section 106, and these encourage coordination of agency cultural resource compliance requirements under Executive Order 11593 and NEPA with those of Section 106.

The American Indian Religious Freedom Act recognizes that Native American religious practices, sacred sites and objects have not been properly protected under other statutes. It establishes as national policy that traditional practices and beliefs, sites, (including right of access), and the use of sacred objects shall be protected and preserved.

State Legislation and Regulations

The basic policy statements on which cultural resource protective regulations are based are contained in the California Environmental Quality Act (CEQA) of 1970, as amended (Division 13, Public Resources Code, Section 21000 et seq.), and in the California Coastal Act of 1976. Implementation of these two acts is provided under guidelines issued as Appendix K of the Amendments to CEQA Guidelines, the Coastal Commission Archaeological Guidelines, State Office of Historic Preservation Guidelines for cultural resource surveys and data recovery programs, and Native American Heritage Commission guidelines for cultural resources identification and protection.

Appendix K of the CEQA Guidelines also reflects the protections enacted in Senate Bill 297 (1982) for buried human remains. If the remains are of Native American origin, special rules and procedures apply. These rules provide for descendants of the deceased Native American groups to make recommendations to the landowner or proper officials for the means of treating or disposing of the human remains and associated grave goods with proper dignity.

In addition to the above statutes and guidelines, certain portions of the state's legal codes are specifically concerned with the protection of cultural resources located on public or private land. These include:

Penal Code Sec. 622.5—makes it a misdemeanor for any person other than the

property owner to willfully damage any cultural resource on public or private land.

Public Resources Code (PRC) Sec. 5097 to 5097.6—authorizes the State Department of Parks and Recreation to survey state lands for cultural resources when projects are proposed for such lands.

PRC Sec. 5020—created the California Historic Landmarks Committee in 1939, and authorizes the designation of Historic Landmarks and Points of Historical Interest.

PRC Sec. 5097 to 5097.96—established the California Native American Heritage Commission and prohibits public agencies or individuals from disturbing Native American sacred, ceremonial or cemetery sites and from interfering with the free expression of Native American religious practices.

Senate Concurrent Resolution Number 87—provides for the identification and protection of traditional Native American resource gathering sites on state land.

Government Code Sec. 25373 and 37361—allows for county and city governments, respectively, to enact zoning ordinances for the protection and regulation of buildings and structures of special historical value.

Government Code Sec. 65860—enlarges the scope of the zoning power mentioned above to include open space and the space between business, industry and residential areas.

Many local governmental agencies have also developed laws and regulations regarding the protection of cultural resources.

BASELINE CONDITIONS

Three areas come under the heading of "Cultural Resources" as the term is used in environmental documents. The first includes all prehistoric resources, such as evidence left by the developing Native American cultures during their 14,000 or so year occupation of California. Secondly, there are historic resources, tracing the occupation and development of California from the middle of the 17th century up to the present day. And lastly come a group of topics relating to the concerns of present-day Native Americans as they try to maintain elements of their own cultural heritage.

Terminology in archaeological documents can often be confusing to the non-specialist. One has to separate chronological, archaeological, and ethnological terms, often with the same modifier. For example, the Paleo-Indian period is the time of the Paleo-Indian cultures; the Paleo-Indian tradition is the aggregate archaeological manifestations of those cultures; and the Paleo-Indian culture is the actual, traditional, shared, learned behavior and beliefs of the Paleo-Indians. Of course, one can no longer observe the Paleo-Indian culture directly; it must be inferred from the archaeological data of the Paleo-Indian tradition, the remains that date to the Paleo-Indian period (Chetkoff, 1984).

Prehistoric Resources

The prehistory and development of the Native American cultures of California have been of interest to Europeans ever since the earliest Spanish contact. The natives encountered by the early explorers were by no means "primitive"; rather they were singularly complex hunter-gatherers with varied social systems like those of "peoples with presumably greater technological advantages" (Bean, 1976).

The prehistory of California, and particularly its coastal region, is often described in terms of

chronological sequences or cultural groupings. In general, archaeologists today recognize four distinct periods following the arrival of Early Man in California. These four groupings are not arbitrary, but represent time periods in which significant changes in material cultural remains reflect changes in food gathering strategies, social organization, and/or religious beliefs. These four periods are known as Paleo-Indian (or Archaic), Millingstone, Intermediate and Late.

Early Man

The entrance of man into North America—how and when—is a topic full of controversy, and much of the debate deals with findings from different regions of California. The question of when draws the most heated arguments. Estimates range from up to 200,000 years ago, down to only 10,000 years ago. The earliest of these estimates implies that a pre-modern species, probably Homo erectus, migrated to this continent (Leakey, 1970). Most current archaeologists reject this claim, as it implies two separate evolutions from this ancient state, through Neanderthal, to modern man—each ending up at genetically identical positions, a coincidence that seems unlikely at best.

But if not before the coming of more modern human species, what about the period from 100,000 years ago to 40,000 years ago? This was the time of the Neanderthal in Europe. These people were skilled hunters and food gatherers who adapted to a wide range of climatic and environmental conditions. There is no theoretical reason why they could not have made it to this continent, and there are scholars who believe that they did, based on evidence from San Diego and Los Angeles counties and the Channel Islands. In particular, the famous Del Mar skull has been dated using aspartic acid racemization techniques as being 48,000 years old (Bada et al., 1974). But recent re-dating of the skull using radiometric techniques has reduced the age to 11,000 years (Bischoff and Rosenbauer, 1981).

The most conservative and at the present time the most accepted view is that man did not appear in the New World until after the end of the latest Ice Age, from 18,000 to 14,000 years ago (Fagan, 1987). With much of the Earth's water locked up in the continental ice sheets, the sea level was up to 300 feet lower than it is today, and most of the floor of the present day Bering Sea was dry land. More than a bridge, this ancient subcontinent has been called Beringia (Haag, 1962). It stretched up to 1,300 miles (2,090 km) wide, more than the distance from Tijuana, Mexico to Vancouver, British Columbia. It blocked cold Arctic currents from traveling south and it deflected the warm Japan Current along the coast of North America, giving Beringia's southern edge an unexpectedly warm climate (Hopkins, 1979).

The question of where boils down to three hypotheses. In the "Ice Barrier" hypothesis, the very conditions which led to the emergence of Beringia blocked access into the interior of North America. The vast glacial ice sheets which lowered sea level also covered all routes south from Alaska. Migration could only have taken place at the very beginning or very end of a glacial stage (Bryon, 1969). The "Ice Free Corridor" hypothesis states that there was always a way south, through a corridor in the ice cover that extended up the Yukon and Kuskokwim Rivers and then down the Mackenzie River to the eastern flank of the Rockies (Reeves, 1973). Finally, the "Coastal Route" hypothesis states that early man

traveled down a strip of coastline now covered by 300 feet of water. If either of the first two hypotheses is correct, sites in eastern California should be older than those along the coast, while the last hypothesis would reverse the order. Parts of the Southern California coast are so steep, even under water, that any travelers would have had to ascend the cliffs and cross the exposed bluffs, and this is where sites should be found to test the hypotheses. Many such sites are found along the California coast, but the dating of each of them is open to question. The Del Mar, Buchanan Canyon and Yuha Desert sites all have dates claimed for them of from 20 to 30 thousand years of age (Bada et al., 1974; Canby, 1979; Carter, 1980), thus favoring the "Coastal Route" hypothesis. But each of these dates has been disputed (Haynes, 1969; Payen et al., 1978; Riddell, 1969), and without them, the inland migration seems to have the weight of evidence.

California's First Cultures

The Pleistocene to Holocene transition was a time of environmental changes in North America. Major adjustments in both temperature and precipitation affected the distribution of water, flora, fauna and humans (Mehringer, 1977). In California, local environmental shifts were taking place as well. Adapting to these changes, early cultures became increasingly diverse and locally specialized.

The late Pleistocene (circa 22,500 to 14,000 years before the present) climates were cold and moist. This favored glaciation in the mountains and formation of deep pluvial lakes in the basinlands. The easing of these conditions between circa 14,000 and 8,000 years ago brought warmer temperatures, glacial melting and a rise in the sea level. The pluvial lakes reached their greatest extents about 11,000 years ago, and then, as the climate warmed, persisted as increasingly shallow lakes and marshes. After about 8,000 years ago the lakes receded entirely, leaving at first wetlands, and then dry playas and fossil shorelines in the emerging desert.

The discovery in 1926 of fluted projectile points clearly associated with the bones of extinct bison near Folsom, New Mexico, established a greater antiquity for humans in the New World than had been accepted previously. Since then fluted points have been found in virtually every state and province in North America. In the central part of the country these points have long been associated with the remains of large, extinct mammals, and as such, have been considered as markers of the Big-Game-Hunting Tradition. In California, the fluted points were considered rare exotics until recently. The homeland of the Big-Game-Hunting Tradition was east of the continental divide, and the far West was seen as a peripheral outpost of the Great Plains traditions (Wallace, 1978). With more and more finds of Clovis-like points throughout California since the mid-1960s, it has become clear that a better explanation would be that there was a viable, in situ cultural tradition in the state. From remains found so far, this tradition appears to have been less dependent on large mammals than its mid-continent relations, and it is often referred to in California works as the Fluted-Point Tradition.

As the Pleistocene times came to an end so, too, did many animal lineages, especially the large mammals. As many as 20 to 50% of all species became extinct during this period, for reasons that are subject to acrimonious debate. Changing climate, asteroids, over-hunting by man and other reasons, singularly or in

combination, have been proposed. During this time a new cultural tradition established itself throughout the Great Basin and into Southern California. Because the majority of sites demonstrating this tradition are found on the shorelines of long-gone lakes, it is often referred to as the Western Pluvial Lakes Tradition (Bedwell, 1970). It flourished for several millennia after 11,000 years ago, and then gradually disappeared as the climate continued to change.

The exceptional carrying capacity of wetlands, coupled with nearly ubiquitous association of artifacts with early Holocene streams and lakeshores, implies that the Western Pluvial Lakes Tradition population could have been very sizable. Also, they may not have been as nomadic as has been previously assumed.

Language studies of the California Native American groups suggest that the Hokan and possibly the Yukian language stocks are the oldest found in the state (Taylor, 1961 and Hopkins, 1965). It appears safe at the moment to assign pre-Hokan and pre-Yukian languages to the Fluted Point Tradition, and the emergence and early differentiation of these languages to the Western Pluvial Lakes period. By the time this tradition had come to an end, it is believed that Yukian speakers lived from San Francisco Bay north to Klamath River and east to the Sierra foothills, while Hokan speaking groups filled the rest of California.

The various cultures associated with the Millingstone Tradition seem to have appeared about 7,000 years ago, as the lakes of the Great Basin and southeast California became deserts. Since the Hokan-speaking peoples were living in the region where the deserts first appeared, it seems reasonable to assign to these people the development of the new cultural techniques and style (Taylor, 1961). These techniques included the processing of newly-appearing seeds and nuts, as well as a more varied hunting and fishing strategy. It could also have been brought in by migration from the eastern Great Basin, where similar cultures were rising in response to the changing environment. In either event, this cultural tradition was firmly ensconced in California no later than 6,500 to 5,500 years ago.

The next major change in California was the appearance of people from the Columbia Plateau, about 2500 B.C. These people seem to have entered California near the Modoc Plateau and traveled down the Feather and Sacramento Rivers, bringing new cultural elements and a new language stock, known as Penutian (Ragir, 1972). Soon after 2000 B.C., these people had expanded into the Sacramento Valley and reached the San Francisco Bay Area, which became their homeland. By 500 years later, they inhabited the northern portion of the San Joaquin Valley, and had expanded down the central coast, pushing the earlier Hokan speakers south. Eventually the various Penutian groups resided on the coast from Monterey to Tomales, and inland from Tulare Lake to Red Bluff, from the sea to the Sierra foothills.

Another group, of Uto-Aztecan stock, had filtered into the newly deserted Mojave region as early as 5000 B.C., but hadn't gone any further. By about 1000 B.C., however, they began to expand again. By then they were known as "Shoshone," and they expanded into the southern San Joaquin Valley and Los Angeles basin. Some time around 700 B.C. they had learned enough about ocean voyaging to cross to the southern Channel Islands and settle there.

The last influx of Native American groups into California took place 700 to 800 years ago. This was a movement of Athapascan peoples down the coast from western Oregon. Their cultures were very different from the existing groups, and there was a high degree of conflict in most of Northern California as the different peoples adjusted to new tribal territories.

The distribution of tribal groups and language stocks in California circa 1750 A.D., at the onset of the European exploratory period, is shown in Figure 2-22. From this point on, the story shifts to the various European groups, even though Native American groups survived as entities for another century up until the Gold Rush period.

Historic Resources

"On Thursday . . . they sailed about six leagues along a northwest coast and discovered a good closed port in 34 degrees 20 minutes, which they named 'San Miguel'." (Wagner, 1926). It was September 28, 1542, and Juan Rodrigues Cabrillo, with the ships San Salvador and Victoria, anchored in what is now San Diego Bay. There were people where they landed, almost all of whom fled. Presents were given to the few who stayed, but that night when some of the crew set out to fish with nets, three were wounded with arrows. Though the natives had never seen Spaniards before, they had heard much along the trade routes going inland about these white people who traveled in groups, well armed and rapacious. The place of anchorage was near present-day Ballast Point, and the next day a party in one of the ship's boats went further into the bay, and found it large. A violent storm passed during their stay, but it was not felt "as the port is so good." On the following Tuesday, October 3, San Diego's first European visitors sailed away.

Cabrillo had set out from Navidad on the west coast of Mexico in June of 1542 on the orders of Viceroy Antonio de Mendoza. He was to take possession of the lands he reached, search for a large river called "La Senora," and seek for the fabled northwest passage. From San Diego they sailed north, stopping along the way, and reached what was probably Point Reyes, before being turned back by storms. They wintered on San Miguel Island, where Cabrillo died as a result of a fall. Bartolome Ferrer (or Ferrelo) took comand and started north again in the summer. This time they reached Point Arena before the storms drove them south again. With crew exhausted and the ships needing repair Ferrer headed for New Spain. On the way, the San Salvador stopped again at San Diego from March 11 to 17, 1543. Two indian boys were carried off to act as interpreters, but no European vessel ventured along that coast for sixty years.

After Cabrillo, interest in exploration northward lagged. Spain was busy digesting her conquests, and the rich silver deposits of Mexico and South America kept her busy. But in the 1560's, King Phillip II ordered a naval station built at St. Augustine, Florida, and the opening up of the Philippine Islands. In 1564 ships sailed from Mexico to found Manila.

To make trade feasible however, a route from Manila to Mexico had to be found and proved workable. Fray Andres Urdaneta was chosen to test the theory used by Columbus in the Atlantic—to sail north to the latitude of the prevailing westerly winds, ride them across the North Pacific, and then turn south once landfall was made, for Mexico. In 1565 he set forth from Manila in a 500 ton carrack. His trip was favored by currents and winds, but it was still difficult—the voyage took 129 days and 24 lives.

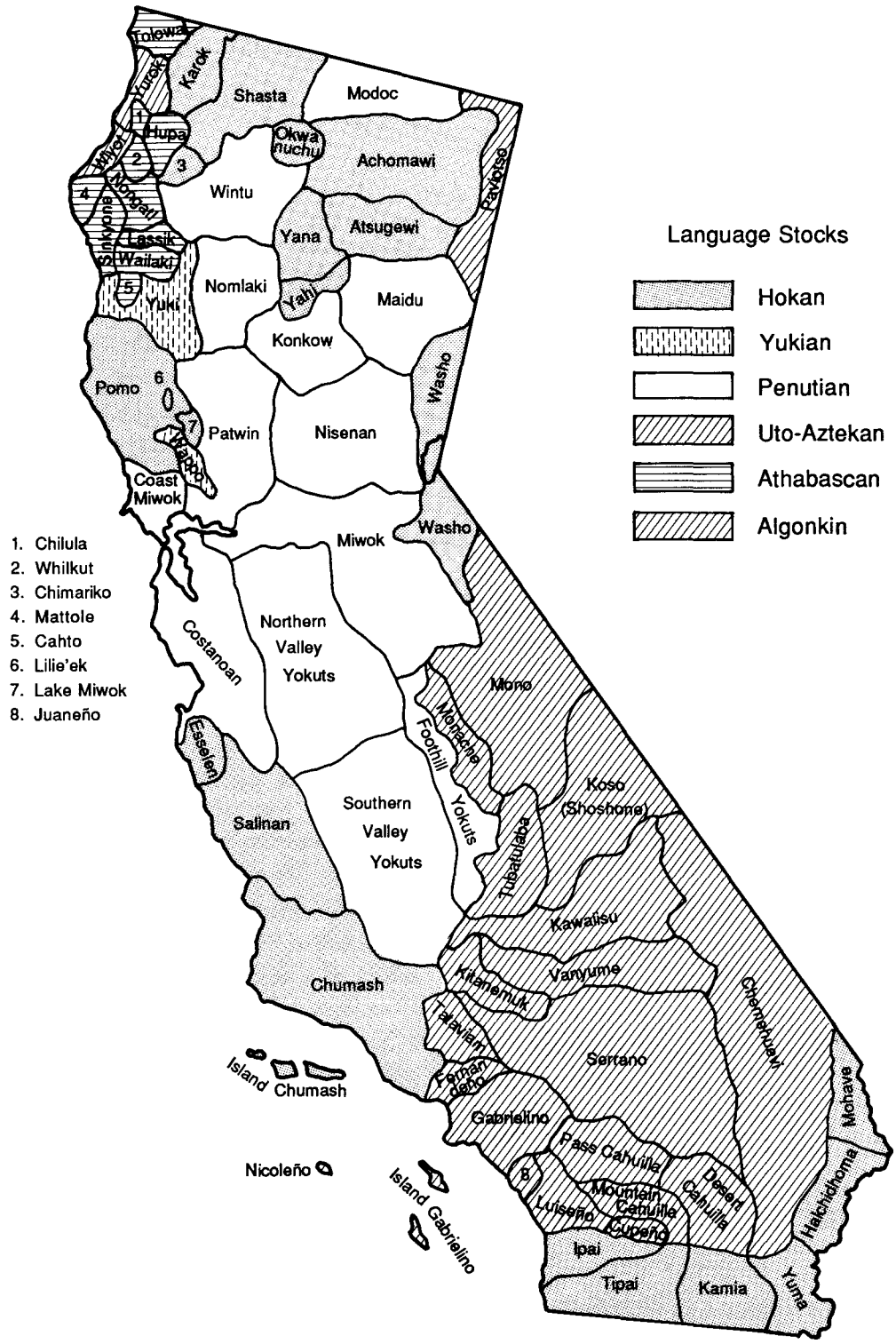


Figure 2 - 22: Native American tribal groups and language stocks at the time of European contact, c. 1770.

The sailing course became immediately popular. Trade was initially unrestricted and many merchants engaged in it. When the Spanish trade barons complained they were losing the markets promised them in New Spain, the King obliged in 1593 by restricting the Manila sailings to one vessel per year.

Yearly, for two and a half centuries, the galleons made the long and lonely voyage across the vast Pacific. No other regular line of ships lasted so long. When the first sailed from Manila, Elizabeth Tudor reigned in England; when the last one pulled into Acapulco, Andrew Jackson had just won the battle of New Orleans. No other regular navigation proved so hazardous, for in its 250 years the sea claimed many ships, disease and accidents killed hundreds of sailors, and many millions in treasure disappeared. And as the richest single ships at sea, the Manila Galleons were the fantasy of every pirate, privateer and freebooter afloat. Four were actually taken, all by the English—the Santa Ana in 1587, the Encarnacion in 1709, the Covadonga in 1743 and the Santisima Trinidad in 1762.

In the English-speaking world the two and a half centuries of Spanish commercial voyaging and the dozens of explorations have been eclipsed by the single stopover by Francis Drake in 1579. As the first pirate (privateer, to the English court) in the Pacific, he had a free run at undefended cities and ships up and down the west coast of Central and South America. When the Spanish defense began to stiffen, and to prepare for an attempt on a Manila Galleon, Drake sailed north, out of Spanish waters, looking for a haven to repair and replenish. Where in California he stayed is a topic guaranteed to bring out the historian's sharpest knives, but the truth is not known. From Goleta Slough, in Santa Barbara county, to Drakes Bay in Marin, sites are proposed, defended, and attacked with great vigor and flimsy evidence. Hoaxes great and small have been perpetrated to defend one site or another.

The one lasting result of Drake's visit was to spur a wave of exploration and settlement among the Spanish viceroys in New Spain. Unamuno, Cermeno, Vizcaino and Galvez explored the California coast by sea between 1595 and 1768, while the expeditions of Kino, Moncada and Portola went by land from 1685 through 1769. Actual settlement got underway at San Diego and Monterey in 1770.

The Spanish pattern of settlement had three elements: the missions, the Presidios and the Pueblos. The missions were the religious element. They were to gather in, convert, and domesticate the natives. Using native labor, they were to become self-supporting, and were given control over large tracts of land for crops and grazing. The military presence was provided for by the Presidios. They were seats of administrative power as well, but primarily they housed the few soldiers New Spain could spare for its northernmost province. Typically they were understaffed, underfed, and in bad repair. The Pueblos were civil settlements, where colonists were encouraged to come and start new lives based on agriculture. All three types are shown on Figure 2-23, with their dates of initial settlement.

From 1770 to 1822, California slowly grew under Spanish government. It came to be relatively prosperous, but never completely self-supporting. Settlement was confined to the strip from the shoreline to the crest of the coast ranges, from Marin to San Diego, although most of the Mojave, the San Joaquin Valley and the lower Sacramento Valley were explored. Twenty-one missions, four Presidios, three

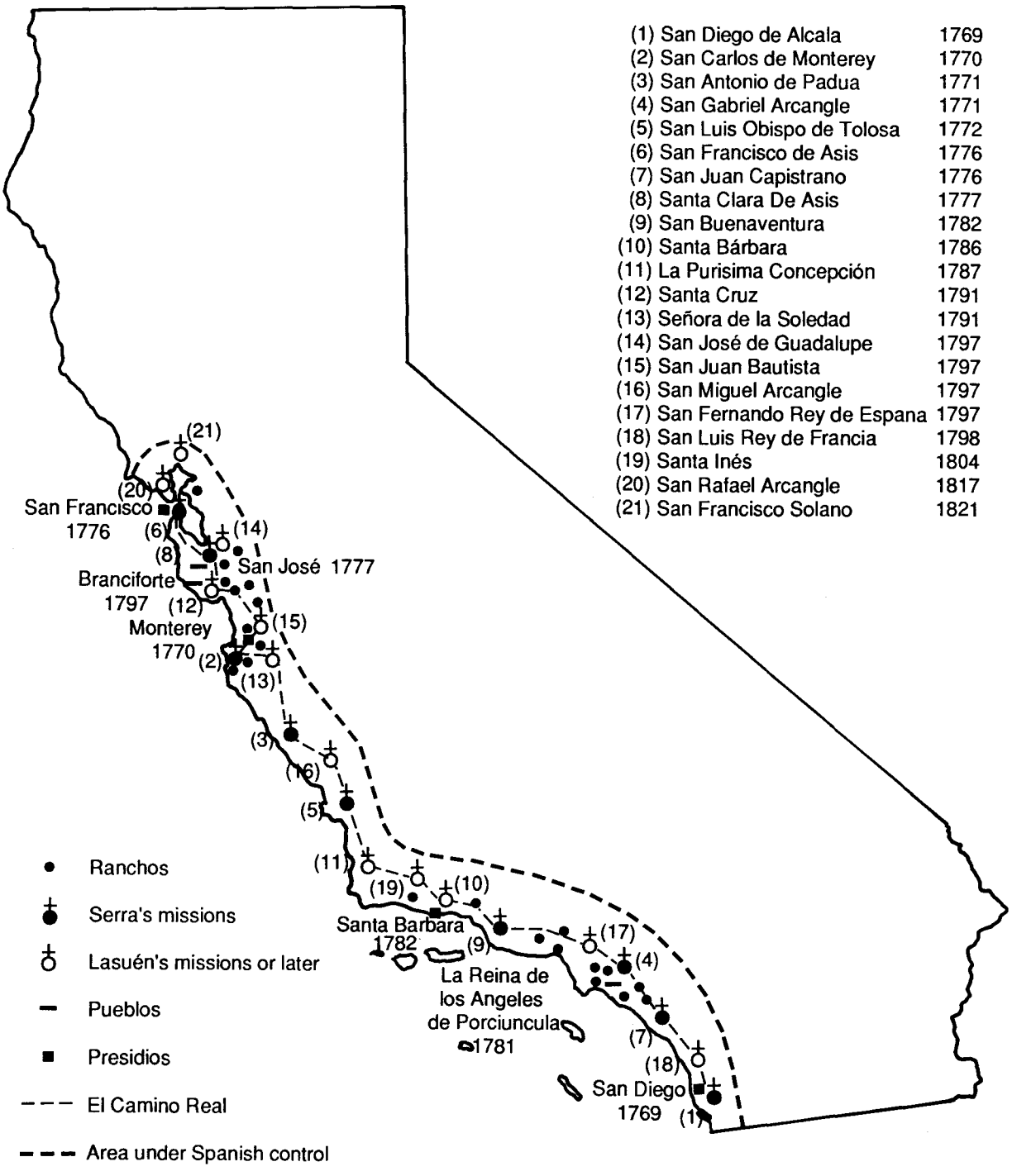


Figure 2 - 23: Spain's California.

Pueblos and numerous ranchos were established by the end of the Spanish period, and a good road connected them all.

The Russian venture into California was brief, by comparison, and always on the ragged edge of disaster. By the 1790s, the Russians had completed a centuries-long advance across Siberia, and were in southern Alaska. It was the sea otter that now pulled them east and south, and the value of the trade with China. They were joined in this venture by Yankees out of New England who sailed around the Horn and up to Russian America, where they joined Russian merchants in fitting out vessels, taking on crews of Aleut Indians, and sailing along the Aleutians or the California coast, taking otters. The pelts were taken to China, where they were traded for finished goods to be brought back to Russia and the United States. In the winter of 1805–06, the main Russian post at Sitka was once again threatened with disease and starvation. Nikolai Rezanov decided to save the colony by opening up trade with Spanish California. His successful trip to San Francisco, and his famous romance with the beautiful daughter of the Spanish commander have passed into California legend. He did save Sitka, and set in motion the establishment of a farming outpost at Fort Ross in 1812. To the expected official Spanish protests, the Russians replied that they had no hostile intent, that Fort Ross was really just a farm, and that they thought that San Francisco, as Spain's northern-most outpost, marked the limits of Spanish authority. More importantly, the Russians knew that the Spanish had no ability to project their power north of San Francisco Bay, so an uneasy detente was established.

In 1822, an American ship brought word that Mexico was independent, and that California was now a Mexican province. As in Mexico, the first years of independence were turbulent, with governors revolting against one another and rebellions by unpaid troops being a normal order of business. By the 1830s, things had settled down, and trade picked up. Overland, a brisk trade in horses, mules, silver and woolen goods was established over the old Spanish trail between Los Angeles and Santa Fe. By sea, the Yankee, British and Russian sailors that had been discouraged by the Spanish were now welcomed—as long as the duties were paid—by the new Mexican rulers. Hides and tallow were the primary goods along the coast, and the ships were "floating department stores" (Dana 1840), providing all the trappings of civilization to the isolated ranchos and missions along the coast.

From 1834 to 1844, under direct orders from Mexico, the California missions were taken away from the Franciscans and secularized. In theory, much of the land from the missions was to go to the Indians for their own use, but in fact, much of it ended up appended to the vast cattle ranchos. These were being established all over California as the new government granted vast tracts of land to individuals provided they would "develop" it.

Americans came to California long before the end of Mexican rule. Traders, trappers, explorers and soldiers had wandered through the province, done business there, and even settled down, usually with a Mexican wife. Some were arrested, some simply escorted out of the country, and some were accepted, depending on the time and place, and the actions of the interlopers. Jedediah Smith (1826), James Ohio Pattie (1826), Ewing Young (1834) and Joseph Reddeford Walker (1833) were early trappers in California. J. J. Warner, Isaac Williams, William Hartnell and John Sutter were ranchers. Abel Sterns,

Thomas Larkin, John Marsh and John Gilroy made early names as traders. By the time of the Bear Flag Revolt in 1845, there were probably fewer than 700 "foreigners" in California, of whom as many as three-fourths were Americans. The Revolt, and the quick campaigns of the War with Mexico (1846–48) consolidated the American position and the United States gained title with the Treaty of Guadalupe-Hidalgo in 1848. Boundaries, gold, slavery and the upcoming Civil War all had an impact on California's short period as a territory, with statehood coming on September 9, 1850.

The California Gold Rush was not only one of the premier events in the state's history, it had world-wide impact. As word of the discovery in Sutter's Mill spread through the summer of 1848, goldseekers flocked in from Mexico, Chile, Hawaii and Oregon. They all retreated to San Francisco when the seasonal rains set in that winter, but the next spring, that of '49, opened the floodgates. The description of Walter Colton, Alcalde (Mayor) of Monterey, was repeated all over the world:

> My messenger sent to the mines has returned with specimens of the gold; he dismounted in a sea of upturned faces. As he drew forth the yellow lumps from his pockets, and passed them around among the eager crowd, the doubts, which had lingered till now, fled . . . .The blacksmith dropped his hammer, the carpenter his plane, the mason his trowel, the farmer his sickle, the baker his loaf, and the tapster his bottle. All were off for the mines, some on horses, some on carts, and some on crutches, and one went in a litter.

Most gold rushes are short-lived, but California's lasted for years, and was central to the economy of the state well into the twentieth century. Other minerals, lumber, cattle, sheep, and farming continued cycles of "boom and bust," but kept the overall economy at a fever pitch. The climate, the promise of easy living, and land hunger brought settlers to the state in the 1850s and continue to do so in the 1990s. The population grew at rates far exceeding other states, and huge cities sprang up around San Francisco and Los Angeles. California's original 33 counties grew to be 58, and the population went from just over 255 thousand in 1852 to well over 30 million by 1990. Each of the historical eras—Spanish, Mexican, Russian, Anglo and modern has left a legacy of historic buildings, roads, ports and artifacts to be interpreted and preserved for future generations.

Native American Concerns

Over the past thirty years, many local groups of Native Americans have begun to publicly express their views about proposed development in California. Many of these individuals share with other Americans a desire to preserve the natural state of the land, but for Indians this concern may have an added importance. Many Indians perceive the development of the land, and the destruction of native plants, animals and cultural remains, as a continuation of an historical pattern of discrimination and neglect of Indians in favor of the interests of the greater American society. It is primarily to counteract this past discrimination that federal, state and local laws now require special consideration for Indian concerns during the assessment of proposals for many development projects.

Concerns of Native American representatives usually concentrate on three areas: sacred territories or places, burial areas, and native plants and animals. Sacred areas include specific sites, village locations and sometimes larger areas, such as Mount Shasta. Concerns

voiced about these areas include preservation of their physical attributes and spiritual feelings, preservation of, and restriction to, access for Native Americans, and maintenance of "buffer" areas around such sites. Native American concerns over burial locations are very different from those expressed by archaeologists. Indians wish, at best, for absolute avoidance of any disturbance to burial sites. Failing this, they demand reinterment under Indian supervision, of both remains and all grave goods. Finally, the concern for preservation of native flora and fauna comes from both spiritual ties to the entire environment and a desire to use these plants and animals to preserve elements of Native American culture, such as basket weaving, folk medicine and ceremonial use.

EFFECTS OF DEVELOPMENT

The effects of different types of development are very similar for prehistoric and historic cultural resources, but very different for Native American concerns. The first two categories are almost unaffected by pollution problems; only construction threatens them. On the other hand, pollution strongly affects many phases of Native American life. There are also some positive effects of development, especially for archaeologists trying to interpret the prehistoric record.

Almost any type of development involving construction threatens cultural resources with destruction. Old buildings are demolished, sacred oak groves are converted into malls, shipwrecks are destroyed by fishing nets and ancient villages become single family homes overlooking the sea. With the exception of more recent historic buildings, any form of construction is usually the antithesis of preservation.

Linear projects, such as pipelines, roads, or rail lines, are often the most destructive of cultural resources. Such projects often reach deep into the ground, destroying buried resources over long reaches of territory, and once in place, make it very difficult for historians or archaeologists to recover any remaining resources. Offshore pipelines and subsea cables can be trenched right through valuable shipwrecks, destroying not only the wreck, but the context of any artifacts on board. The effect is physical destruction of the resource.

Construction projects, such as oil processing facilities, marinas, housing projects or major commercial sites, have similar effects, but they are localized to the construction site. They can be mitigated to a larger extent by careful recording as the construction proceeds. It should be noted, however, that while this mitigation can often satisfy the archaeological community, it does nothing to mollify the Native American concerns. It is the disturbance itself that is the effect to the Indians, while it is the loss of "data" that upsets the archaeologists.

Pollution effects, as from oil spills or degradation of the air quality, do not affect cultural resources as much as they do other segments of the environment. Some stone building materials are affected by acid rains or by smog, but most other cultural resources survive. However, all Native American concerns include the effect of environmental damage by pollution. Their concerns are based on the loss of their "habitat," and follow arguments in the specific sections of this document dealing with biology, water quality and air quality.

On the positive side, surveys done prior to project construction, or even permit application,

have done much to expand our knowledge of the location of prehistoric and historic sites. Many "lost locations" have been re-discovered in the course of mapping pipeline routes or surveying the site of a new shopping center. This information helps archaeologists plot the spatial distribution of the various cultures in California's past. Even Native American groups tend to approve of such surveys, because they can be used to relocate projects to areas where there will be less disturbance of the cultural resources.

LAND USE

To have a basic understanding of how oil and gas developments affect land use it is important to know how land use impacts are assessed in an environmental impact report. It is also important to distinguish that type of assessment from this CCORS review. The following section is intended to identify these distinctions.

CEQA METHODOLOGY

A review of half-a-dozen environmental documents for major energy projects revealed a wide variety of approaches to the analysis of land use impacts. The following description is a composite from those documents reviewed.

The California Environmental Quality Act (CEQA) Guidelines contain a list of significant effects in Appendix G. These significant effects include three (a, u, and y) that are especially relevant to land use:

- Conflicts with adopted environmental plans and goals of the community where it is located;
- Disruption or division of the physical arrangement of an established community; and,
- Conversion of prime agricultural land to non-agricultural use or impairment of the agricultural productivity of prime agricultural land.

These constitute the core issues of land use impact analysis pursuant to CEQA. Although a land use change might be the key factor in creating a conflict, other sections of an environmental analysis often deal with the impacts. Examples could include:

- A new traffic circulation impact discussed in the Transportation chapter;
- A reduction in visitor use discussed in the Tourism/Recreation chapter;
- A new health and safety risk discussed in the System Safety chapter;
- An adverse effect on environmentally sensitive areas discussed in the Biology chapter;
- An increase in ambient noise levels discussed in the Noise/Acoustics chapter;
- An increase in erosion/sedimentation discussed in the Soils/Hydrology chapters;
- An increase in population discussed in the Population/Employment section of the Socioeconomics chapter;
- An increased demand for public services discussed in the Public Services Section of the Socioeconomics chapter; and
- An adverse impact on scenic quality discussed in the Aesthetics chapter.

Specific chapters in a CEQA analysis deal with these issues, in spite of the fact that they may be generated by a land use change.

This leaves two major categories of impacts for analysis in the typical EIR Land Use

chapter: process/regulatory issues and incompatibility with or elimination of existing/proposed uses. The former involves an analysis of the potential conflict a proposed project will create for existing plans or programs. The latter involves an analysis of the issue of land use changes. Impacts are usually identified as being either direct or indirect, and short-term or long-term.

The description above is typical of the CEQA analysis of land use impacts. It is very dependent on having a specific project located at a specific site.

REGULATORY SETTING

In addition to knowing something about the methodology for analyzing land use impacts, it is important to know generally who has authority over land use decisions. There are a number of different agencies that exercise this authority in the coastal areas of California.

Land use decisions at the city and county level are handled through the respective planning departments. Authority for exercising this responsibility is provided by state-passed enabling legislation. Programs conducted under this authority include general planning, local coastal planning and zoning. Project permit applications are reviewed for conformance with plans and ordinances. Typically, the permit review process also entails CEQA compliance.

Local plans provide insights into land use decisions. However, there is no simple way to use these to provide meaningful discussion of land use on a statewide basis. The issue is simply too location specific to provide such a desription.

One statewide land use trend that should be noted is the increasing use of growth control measures. These can take many forms and be used for any number of reasons. The variety of such measures is reflected in Figure 2-24.

Special districts also influence land use decisions by providing services such as water, sewer, etc. The Local Agency Formation Commission (LAFCO) is responsible, under the Knox-Nesbit Act, for approving annexations to cities and special districts. They must also approve the incorporation of new cities. The major planning program of LAFCO is the adoption of Spheres of Influence aimed at identifying areas of future city jurisdiction.

The California Coastal Commission also has an influence on land use planning decisions in the coastal zone. The Coastal Act of 1976 grants them broad permit authority as well as responsibilities for reviewing city and county approved Local Coastal Programs (LCP). Local Coastal Programs are composed of a Land Use Plan (LUP) and a zoning ordinance. Once certified by the Coastal Commission, permit authority over much, but not all, of the coastal zone is returned to the respective city or county. The Coastal Commission retains some authority to hear amendments to LCPs, and appeals to some permit decisions and permit authority in areas of "original jurisdiction" (typically shoreline, wetland areas).

Land use planning for ports and military lands is typically accomplished through master plans by the respective authorities. Provisions in the Coastal Act of 1976 provided incentives for adopting new Port Master Plans in 1980. Planning for military installations is carried out according to federal law.

The State Lands Commission generally has no direct authority over land use decisions. However, as a trustee agency it does make

CCORS SEGMENT	CITY AND COUNTY	GROWTH MANAGEMENT MEASURES												OIL & GAS FACILITY MANAGEMENT MEASURES					
		METHOD OF ADOPTION		NATURE OF THE MANAGEMENT MEASURE										METHOD OF ADOPTION		NATURE OF ACTION			
		Initiative	Legislative Action	General Plan Policies	Established Urban Boundaries	Phased Development Schedule	Annual Building Permit Limit	Population Limit	Projects ranked according to Development Criteria	Specific Residential Exemptions	Maintenance of Transportation Level of Service	Temporary Building Moratorium	Require Vote to approve G Plan Amendment	Initiative	Legislative Action	Facilities Require Vote	Facilities Prohibited	Moratorium	Advisory Only
SEGMENT 8 SAN DIEGO	COUNTY OF SAN DIEGO	—	—	YES	YES	YES	—	—	—	—	YES	—	—	—	—	—	YES	—	—
	City of Imperial Beach	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Chula Vista	—	YES	YES	—	YES	—	—	YES	—	YES	—	—	—	—	—	—	—	—
	City of National City	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Coronado	YES	YES	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of San Diego	—	YES	YES	YES	YES	YES	—	—	YES	YES	—	—	YES	—	—	YES	—	—
	City of Del Mar	YES	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Solana Beach	—	—	—	—	—	—	—	—	—	—	YES	—	—	—	—	—	—	—
	City of Encinitas	—	—	YES	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Carlsbad	YES	YES	YES	—	—	—	YES	—	—	YES	YES	YES	—	—	—	—	—	—
	City of Oceanside	YES	—	—	—	—	YES	—	—	—	—	—	—	YES	—	—	YES	—	—
SEGMENT 7 SANTA MONICA/ NEWPORT	COUNTY OF ORANGE	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of San Clemente	YES	—	YES	YES	—	YES	—	YES	—	YES	YES	—	YES	—	YES	—	—	—
	City of Dana Point	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Laguna Beach	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Irvine	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Newport Beach	—	YES	—	—	—	—	—	—	—	YES	—	—	—	—	—	—	—	—
	City of Costa Mesa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Huntington Beach	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Seal Beach	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	COUNTY OF LOS ANGELES	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Avalon	—	—	YES	—	—	YES	—	YES	—	—	—	—	—	—	—	—	—	—
	City of Long Beach	—	—	—	—	—	—	—	—	—	—	YES	—	—	—	—	—	—	—
	City of Rancho Palos Verdes	—	—	—	—	—	—	—	—	—	—	YES	—	—	—	—	—	—	—
	City of Palos Verdes Estates	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Torrance	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Redondo Beach	—	—	—	—	—	—	—	—	—	—	—	—	—	YES	YES	—	—	—
	City of Hermosa Beach	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Manhattan Beach	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of El Segundo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Santa Monica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Los Angeles	YES	YES	—	—	YES	—	—	—	YES	YES	YES	—	—	—	—	—	—	—
SEGMENT 6 SANTA BARBARA CHANNEL	COUNTY OF VENTURA	—	YES	YES	YES	—	YES	YES	—	—	YES	—	—	—	—	—	—	—	—
	City of Port Hueneme	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Oxnard	—	—	YES	—	YES	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of San Buenaventura	—	YES	YES	YES	YES	YES	YES	YES	YES	—	—	—	—	—	—	—	—	—
	COUNTY OF SANTA BARBARA	YES	YES	YES	—	—	YES	—	—	—	—	—	—	YES	—	—	—	—	YES
	City of Carpinteria	—	—	YES	YES	—	YES	—	—	—	—	—	—	—	—	—	—	—	—
	City of Santa Barbara	YES	YES	YES	—	—	—	YES	—	YES	YES	YES	—	—	—	—	—	—	—
	University of California at S.B.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
SEGMENT 5 SANTA MARIA BASIN	COUNTY OF SAN LUIS OBISPO	—	YES	YES	YES	—	—	—	—	—	—	—	—	YES	—	YES	—	—	—
	City of Grover City	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Pismo Beach	—	—	—	—	YES	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Morro Bay	YES	—	—	—	—	YES	YES	YES	—	—	—	—	YES	—	—	YES	—	—
SEGMENT 4 CENTRAL COAST	COUNTY OF MONTEREY	—	YES	YES	—	YES	—	YES	YES	YES	YES	—	—	YES	—	YES	—	—	—
	City of Carmel	—	—	YES	—	—	—	—	—	YES	—	YES	—	—	—	—	—	—	—
	City of Pacific Grove	—	—	—	—	—	—	—	—	—	—	—	—	—	YES	—	YES	—	—
	City of Monterey	YES	—	—	—	—	—	—	—	—	YES	—	—	YES	—	YES	—	—	—
	City of Seaside	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Sand City	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Marina	—	—	—	—	—	—	—	—	—	—	YES	—	—	—	—	—	—	—
	COUNTY OF SANTA CRUZ	YES	—	YES	YES	YES	YES	YES	—	YES	YES	—	—	YES	—	YES	—	—	—
	City of Watsonville	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Capitola	—	—	—	—	—	—	—	—	—	—	—	—	—	YES	—	YES	—	—
	City of Santa Cruz	YES	—	YES	YES	—	YES	—	YES	—	—	—	—	YES	—	YES	—	—	—
SEGMENT 3 S.F. BAY	COUNTY OF SAN MATEO	—	YES	YES	YES	YES	YES	—	—	YES	—	—	YES	YES	—	—	YES	—	—
	City of Half Moon Bay	—	YES	YES	YES	YES	—	YES	—	—	YES	—	—	YES	—	—	YES	—	—
	City of Pacifica	—	YES	YES	—	—	YES	—	YES	YES	—	—	—	—	—	—	—	—	—
	City of Daly City	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	COUNTY AND City of San Francisco	—	—	—	—	—	—	—	—	—	—	—	—	YES	—	—	—	YES	—
	COUNTY OF MARIN	—	YES	YES	YES	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	See separate chart for Bay Area Communities																		
SEGMENT 2 MENDOCINO /SONOMA	COUNTY OF SONOMA	—	YES	YES	YES	—	—	—	YES	—	—	—	—	YES	—	YES	—	—	—
	COUNTY OF MENDOCINO	—	—	—	—	—	—	—	—	—	—	—	—	YES	—	YES	—	—	—
	City of Point Arena	—	—	—	—	—	—	—	—	—	—	—	—	—	YES	YES	—	—	—
	City of Fort Bragg	—	YES	—	YES	—	—	—	—	—	—	YES	—	—	YES	YES	—	—	—
SEGMENT 1 EEL RIVER BASIN	COUNTY OF HUMBOLDT	—	—	—	—	—	—	—	—	—	—	—	—	YES	—	YES	—	—	—
	City of Eureka	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Arcata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Trinidad	—	YES	YES	YES	—	—	—	—	—	—	—	—	—	YES	YES	—	—	—
	COUNTY OF DEL NORTE	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	City of Crescent City	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Figure 2 - 24

decisions about uses of the tide and submerged lands that could indirectly influence landside development.

VISUAL

No other issue depends so much on individual feelings as the issue of visual quality. Each of us knows a scenic vista when we see it. Each of us also knows visual blight when we see it. Often, though, it is difficult to gain agreement from others about the relative quality of what we have all viewed. It is precisely this subjectivity that makes the evaluation of visual impacts so tenuous.

The difficulty in dealing with visual quality in an objective manner should not, however, be taken as an indication that this issue is somehow unimportant. In fact, this issue sparks some of the strongest feelings and presents some of the most unresolvable conflicts that arise in coastal California.

CEQA ANALYSIS

A number of methodologies have been developed by various agencies for assessing visual impacts. Among these are the Bureau of Land Management's Visual Resource Management Program (VRMP) and the U.S. Forest Service's model. Neither of these formal approaches has been used directly in recent EIRs/EISs for Santa Barbara Channel/Santa Maria Basin offshore oil projects. These systems have, however, been used in some of these documents for general guidance and direction.

Although there is no single CEQA methodology for assessing visual impacts, there are elements common to most of these documents. A review of some of the Santa Barbara area documents revealed the following key elements:

- Existing Landscape—This first element takes into consideration the basic landforms, water and vegetation patterns that makeup the landscape. Any existing man-made features that modify the landscape are also taken into account. The sum of these characteristics is then evaluated to determine "quality" in a relative sense; how attractive it is, whether or not it is unique, etc.

- Viewer Reactions—This element of analysis attempts to account for the people part of the equation. In some of the formal federal models there are actual surveys of public attitudes. In the typical CEQA analysis, gauging public attitudes is another of the judgment calls the analyst must make. Factors such as number of viewers, the frequency they partake of the view, the duration of their viewing are all taken into account. A distinction is often made for public vs. private views, with more weight going to the former. Finally, an estimation of the viewer's expectation is made (e.g., when they take in this view are they expecting to see exclusively natural elements or are they expecting to see man-made features as well?) All of this attempts to account for the emotional reaction people often have when viewing a new element in the landscape, such as an offshore platform.

- Project Elements— This element entails superimposing the project on the baseline landscape. With oil and gas projects this can include temporary exploratory rigs, platforms, pipelines, processing facilities and storage tanks. To-scale images of these various project components can be overlaid on photographs of the sites in order to evaluate the effect. Typically, five

factors are considered including: proximity (platforms up to 13 miles offshore have been judged to cause a significant visual impact), relative scale, duration of visibility, compatibility (includes color, orientation, etc.), and finally, obtrusiveness, which includes the extent to which the project competes for attention.

After reviewing these factors, a judgment must be rendered about the significance of the effect. Such judgment is certainly subject to debate, but at least this system provides a mechanism for explaining how the judgment was made.

It is at this stage, when these various factors are being assembled that critical weighting decisions are made. One project may be set in an undistinguished landscape, but be judged a significant impact because of its proximity to shore and because of the number of people who will see it on a daily basis. Another project might be in a remote location not visible to many, but be judged a significant impact because of the pristine nature of the existing landscape and because of the high expectations of viewers who do make it into the remote area. A variety of considerations (e.g., platform lights at night, numbers of foggy days that will hide the platform, number of existing platforms, etc.) can all factor into the judgment about the significance of the impact.

The products of this effort typically include maps locating crucial vantage points and photographs with key project elements superimposed on the views from those crucial vantage points. Often these photographs are "doctored" in order to present a realistic image. This compensates for the fact that the eye and brain often enlarge the size of key features over the size they are actually recorded on film.

CCORS ANALYSIS

The foregoing discussion should make it obvious that a typical CEQA analysis of visual impacts is extremely dependent on having a specific project in a specific location. We are denied both of these items in CCORS except where EIRs have already been done.

In the more frequent case, where no project or location is identified, CCORS can do little to meaningfully identify the potential adverse visual impacts of oil and gas development.

NOISE

One dictionary defines noise as a " . . . sound of any kind, especially when loud, confused, indistinct or disagreeable." Noise can take on a number of characteristics. It can be transient, like an airplane passing overhead or it can be continuous, like the hum of air conditioning. It can be nondescript like auto traffic or distinctive like an auto horn. It can be as steady as a motor, or as impulsive as a pile driver. These characteristics all have a bearing on the way noise is perceived by people.

Sound is generated by the vibration of an object. This vibration creates sound waves that radiate out in all directions from the source. The greater the strength, or pressure, of the wave, the louder the sound. The strength of these waves is measured in decibels (dB). The dB scale is logarithmic, meaning that each increment of 10 decibels is 10 times as intense as the preceding increment of 10. For example, 10 decibels is 10 times as intense as one decibel, but 20 decibels is 100 times as intense as one decibel.

Another component of sound is pitch, or frequency. Pitch is a function of how fast the sound source is vibrating. It is measured in Hertz (a unit of frequency equal to one cycle per second). High frequency sounds are produced by rapidly vibrating objects, while low frequency sounds are produced by slowly vibrating objects.

The other major measurement of sound deals with duration and time of day. These are measured in standard units of time: seconds, minutes and hours.

People "hear" sound as a complex composite of these three factors: strength/pressure, pitch/frequency and time/duration. For instance, at equivalent decibel levels, people will consistently judge a high frequency sound to be noisier than a low frequency sound. Therefore, adjustments in the dB scale have been made to account for this perception. The result of these adjustments is the A-weighted decibel, commonly identified as dB(A).

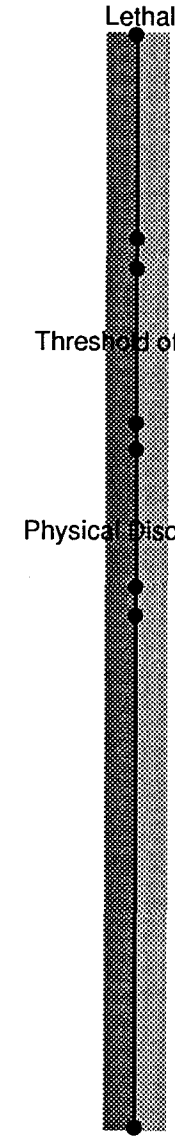
In addition to this, adjustments are made for the purpose of averaging sounds over time. In the real world, noises occur as part of a compilation of sounds. Because noise is rarely an isolated event, it must be measured in a manner that will allow the averaging of the combined noise over a period of time. The time period could be an hour, several hours, or an entire day. The product of such a measurement is called the Equivalent Sound Level represented as"Leg" and expressed in decibels.

Consideration must also be given to the time of day and the location or setting in which noise occurs. People will respond differently to the same noise if it occurs in different settings. The noise of traffic in the street may go unnoticed during the day by residents in a house, but wake them if heard late at night. Similarly, sound from trucks may be acceptable in a business/industrial area but not acceptable in a residential area. Two rating systems, widely used in the regulatory process, adjust for these circumstances. Day–Night Average Noise Level (Ldn) weights noises occurring at night. Community Noise Equivalent Level (CNEL) makes a similar adjustment. Typically, one or the other of these measures is the noise criteria used by permitting agencies to regulate land use and building design.

Translating this all into terms of real world experience, we find that barely audible sounds, such as leaves rustling, register at about 10 decibels. At the other extreme a jet taking off will produce about 120 decibels at 200 feet. Somewhere slightly above this level sounds cause pain (Figure 2-25). At this point, if not long before, sound has become disagreeable enough to be clearly classified as noise.

The effects of noise are many and varied. One major effect—hearing loss—can occur after short exposures to high sound levels or after years of exposure to moderate sound levels (70 dB or more). Physiologically, there are numerous involuntary reactions caused by sound, including increased blood pressure. Psychologically, noise can contribute to the stress of daily life.

Noise can be reduced by modifying the source, increasing the distance between the source and the receptor, developing physical barriers between the source and the receptor or insulating the receptor. With a single source, such as an automobile, noise is reduced at a rate of 6dB with each doubling of the distance. However, with a complex source, such as a freeway at or near capacity, noise will only



	dBA*	
	-180-	
	-175-	
	-170-	
	-165-	
	-160-	
	-155-	
	-150-	
	-145-	
Sonic Boom	-140-	
	-135-	
	-130-	
Jet Takeoff at 200'	-125-	
	-120-	
	-115-	Discotheque
Motorcycle at 20'	-110-	
	-105-	Power Mower
	-100-	
Freight Train at 50'	-95-	
Propeller Plane Fly-over at 1,000'	-90-	Food Blender
	-85-	Electric Mixer
Freeway Traffic at 50'	-80-	Washing Machine; Garbage Disposal
	-75-	Office with Tabulating Machines
Average Traffic at 100'	-70-	Vacuum Cleaner; Portable Fan
	-65-	Electric Typewriter at 10'
	-60-	Air Conditioning Unit
	-55-	
	-50-	Normal Conversation at 12'
Light Traffic at 100'	-45-	Refrigerator
	-40-	
	-35-	Library
	-30-	
	-25-	
	-20-	Motion Picture Study
	-15-	
	-10-	Leaves Rustling
	-5-	
	-0-	

* The unit of sound is the decibel (dBA). The loudness of sound is typically measured using a sound meter, the scale of which corresponds to the way the human ear perceives sound. Thus the sound level for noise evaluations is frequently expressed in dBA.

Source: L.A. County Noise Element

Figure 2 - 25 Acoustical Scale.

drop off at a rate of about 3dB for each doubling of the distance.

REGULATORY SETTING

Noise is regulated at the federal, state and local levels. At the federal level the Environmental Protection Agency has adopted noise level guidelines. At the state level the California Office of Noise Control in the Department of Health Services develops guidelines. City and county regulations are often adapted from these federal and state guidelines based on local conditions.

Two federal agencies within the Department of Transportation have adopted specific noise criteria, the Federal Aviation Administration (FAA) and the Federal Highway Administration (FHWA).

At the state level, the California Department of Transportation has established noise levels for airports operating under its permit authority. Its Transportation Laboratory also publishes a "CALTRANS Noise Manual."

Cities and counties deal with the issue of noise through their general plan process including the adoption of supporting ordinances. The noise element is a mandatory part of the general plan which must consider noise impacts from highways, freeways, primary arterials, major local streets, rail operations, airports, flight paths, industrial plants and other stationary sources. The General Plan Guidelines require development of noise contours for all these uses with expression of noise levels in terms of community noise equivalent level (CNEL) or day–night average level (Ldn). The intent is to establish land use patterns which will minimize the exposure of community residents to excessive noise.

CEQA ANALYSIS

The analysis of noise impacts in the EIR process is fairly straight forward. Baseline conditions must be identified. This can be accomplished by relying on noise contours from the noise element of the local general plan. As an alternative, or as a supplement, actual measurements can be taken on site.

Once this background noise level is established, the noise generating characteristics of a project must then be determined. This information can come from literature review, data files or direct measurements. Calculations must then be made of the sound levels at identified sensitive receptors (e.g. hospitals, schools, etc.). This involves adjusting for distance, topography, sound paths, etc.

The difference between the background noise level and the projected noise level at sensitive locations determines the impact. The significance of this impact depends on the threshold established by the particular EIR. Typically local noise criteria and ordinances figure prominently in this determination.

OIL AND GAS EFFECTS

Sound only becomes noise if someone is present to be disturbed by it. Therefore, identical projects placed in different settings might have very different noise impacts. This fact makes it impossible to generalize about noise impacts. If, however, we assume that people will be present, we can catalog some of the activities that have been identified in past oil and gas projects as causing noise impacts.

During the exploration phase, the drilling operation can produce intermittent noise that is audible onshore, especially at night. Transport of crew and supplies by boat and helicopter

can, depending on route and frequency of trips, also create noise impacts, as can warning devices such as foghorns.

Construction phase impacts can include supply and crew vehicles traveling to and from a platform. Construction noise is also generated along any pipeline installation and at any storage or processing facility.

Operation phase impacts for a platform are limited to crew and supply transport by boat and helicopter. Pump stations along a pipeline might also generate noise impacts, as well as the operation of any storage/processing facility.

In some cases, temporary noise impacts of construction can be mitigated by equipment changes, or alterations in schedules. The long-term impacts of operation activities are frequently mitigated by construction of sound barriers or limitation of adjacent uses.

SOCIOECONOMICS

DEMOGRAPHY

Demography is often defined as the science of population; its size, growth, density, distribution and vital statistics. It describes the patterns of people on the land and how these patterns change over time. For the purposes of this study, we will concentrate on the actual population and its recent changes. Distributions of ages, ethnic groups and vital statistics will not be covered in any detail. We are interested in where the people are and where they are moving, and the effects of development on these two facts.

At the present time (Mid-1990), California's population is just over 30 million people (Preliminary Census Figures). Putting this into perspective, California is not only the largest state in terms of people, it is the largest by far. New York is the next most populous state, and it has over 10 million fewer people than California. We are half again larger than the next biggest state.

The second most important fact about California's population is that it is growing quickly. We've added 5.6 million people since 1980, more than the population of each of 32 states. The change is more than just numbers—California's population characteristics are changing as well. We are becoming older, more ethnic and more crowded. The public services infrastructure is bulging at the seams, and threatens to break at several places (D. Walters, Sacramento Bee 1/21/90).

Much of this growth is directly tied to immigration. Of the 5.6 million new Californians mentioned above, over three million are people who moved into California from other states or countries. With the single exception of Arizona, California accounts for more than ten times the migration of other states. And it is interesting to note that most of Arizona's migration is people from California. According to a report by WESTRENDS, in association with the Council of State Governments, Western Region, all of these trends are likely to continue for both the near and far future. If, as the controversial author Wattenberg has said, "Demography is destiny," then California will get bigger, older and more diverse, and the governments—local and state—had better be ready to cope.

HOUSING

The rapid growth of the economy in many areas of California has largely contributed to the upward movement of housing prices. These high costs are forcing people to live farther and

farther from their work place, causing an imbalance between where the jobs are located and the ability of the workers to find suitable housing within commuting distance. This lack of affordable housing may cause some businesses to locate outside of California, taking the jobs with them.

Because of the changes discussed above under "Demography," housing in California—its availability, location and cost—is a critical issue. California is becoming more and more urban—95.7% of us now live in an urban area. Competition for space, services, water and other necessities is increasing, and developers will have an effect on all of these.

Both permanent and temporary housing can be affected by development, but they will often be affected in different ways. For permanent housing the most important issues are location, cost and types. For temporary housing, which includes campgrounds, hotel and motel rooms and mobile homes, vacancy rates and distribution are the most important considerations.

ECONOMICS

Included under this heading are concerns about labor force economics. The size of the labor force, the employment and unemployment rates, the seasonal nature of the labor force, and average incomes are all part of this. Each of these factors influences both the type of development that will take place and the effects such development will have on an area.

The types of employment available within a region are a major factor defining the local economy. Employment is often broken down into job categories such as agriculture, manufacturing, government, service industries and so on. This allows comparisons between areas, as well as better estimates of development effects.

Discussions of income are made difficult by the variety of data available. Consistency is difficult to achieve. Wherever possible it is best to use comparable figures, but often numbers look similar, but in fact have very little relationship to each other.

According to the California Association of Realtors, growth in California's economy has outpaced that of the nation during the past decade. The state currently produces more than 12% of the nation's total output. California's location has made it one of the most important centers for the $3 trillion in trade generated by the Pacific Rim economies. The success of the state has thus been a major attraction to millions of immigrants looking for employment and a better way of life. In addition, this rapid growth has shifted the state's economy from one that is based on agriculture and primary production, to a highly urbanized industrial and service-oriented society.

Accompanying this trend, has been a lower level of labor productivity, slower income growth, and a labor force that is divided between a small number of highly skilled technicians and professionals and a large number of lower-paid unskilled workers.

The rapid growth of California's economy has been at a cost to the state. Californians are now faced with polluted air and water, a tremendous waste disposal problem, hazardous sewage spills, and major traffic jams.

California has the highest total personal income in the country, $493 billion This is $172 billion higher (154%) than that of the second highest state, New York. But the distribution is

very uneven, with low paying seasonal jobs nestled next to high tech, high pay computer applications jobs. Each region of the state has its own flavor. Unemployment in California currently averages 5.4% (1989), as compared to 5.3% (1989) for the United States as a whole. Again, this varies by county. California is a rich state, even if the wealth is distributed in extremes. There is a large, well trained labor force, though not always where it is needed.

PUBLIC FINANCE

This issue involves the financial condition of the various levels of local government. Analysis of the impact of new development on public finance will often focus on revenues and expenditures. Comparable data for state government can be found in Chapter Five; the revenues and effects of oil development far outweigh any other type of development at the state level.

PUBLIC AND SOCIAL SERVICES

The areas covered in this section make up the infrastructure of a segment from a governmental viewpoint. These areas often make up a large part of people's perceptions of how attractive or undesirable a location may be. These areas are also strongly affected by various types of development. While California as a whole is seen as desirable, the differences between regions is so great that any statewide figures are meaningless.

Water and waste treatment are two of the most critical areas covered under this topic. Most of California, especially the major populated areas, is technically a desert. Competition for water—between geographic areas and between types of users—is fierce. Water will often be a limiting factor when considering types of development. Waste management, as well, limits development. Both solid and liquid waste treatment and disposal are critical areas to most Californians, and as the number of Californians increase, so does the garbage.

The state's highways, sewage systems, schools, prisons, and other public facilities were once the envy of many states. However, the system is facing significant strains now; highways and street networks in many areas are clogged and local sewer systems throughout the state have been pushed to their limit. In addition, school districts in the major population growth areas are suffering from overcrowded classrooms and double sessions.

Public safety, which includes fire and police protection, is critical to the people who live in an area, but it is not always clear how it will be affected by a particular type of development. Types and degrees of fire protection required for oil processing facilities are different from, for example, those needed for a gravel plant. Tying a certain development to changes in police protection is even more difficult.

Health, education and welfare are again important when people are deciding where to locate, but difficult to tie into development scenarios.

TRANSPORTATION

Transportation is simply defined as the business of conveying passengers, goods, or materials. Transportation facilities take many forms: highways, mass transit, railroads, pipelines, airports and seaports. It is easy to take these facilities for granted. Their presence and operation is such an expected part of our society that it is easy to overlook the critical service the transportation systems provide. In

fact, the transportation network in California is essential to the conduct of commerce. It moves workers between home and jobsite; it provides the means to export and import both raw materials and finished products; and, it provides a means of travel for tourists and vacationers.

LAND

There are four major land-based transportation systems that warrant discussion. These are highways, mass transit, railroads and pipelines. Mass transit provides passenger transport exclusively. Pipelines are also an exclusive carrier; in this case, however, of freight, in the form of oil and gas products. Highways and railroads accommodate both freight and passengers.

Highways—At the federal level, highway programs are administered by the U.S. Department of Transportation. The California Department of Transportation (CALTRANS) deals with state level transportation issues.

Cities and counties participate in decisions about transportation services through Regional Transportation Planning Agencies (RTPA), Local Transportation Commissions and Councils of Government. Figure 2-26 shows the statewide distribution of these bodies. They provide input on the local priorities for expenditure of various state and federal funds.

Highway conditions are measured according to Levels of Service (LOS). Each LOS is given a letter designation from "A" to "F" with "A" representing the best operating condition and "F" representing the worst.

Traffic congestion and increased automobile use are highway issues of statewide concern. Although taken from a Southern California Association of Governments (SCAG) document, the following fairly outlines the problem across California: "Projected growth in population, housing and employment, as well as the unbalanced distribution of housing and jobs . . . will contribute to an increase in transportation demand. More people will have to travel long distances from their residences . . . to their place of work . . .".

Under the headline, "State Choking on Growth," the Sacramento Bee reports on the cost to business of traffic congestion and how it diminishes the area's attractiveness as a business location. A study by the Texas Transportation Institute, (affiliated with Texas A & M), placed these costs in 1986 at $9.44 billion for Los Angeles and $2.69 billion for the San Francisco Bay Area.

Projections indicate a growing problem. The Little Hoover Commission's study projects a growth in licensed drivers from 17.45 million in 1985 to 22.10 million in the year 2000. Similarly, the number of vehicle miles travelled is projected to increase from 207.6 million to 271 million miles. They concluded in 1988 that " . . . we can't build ourselves out of the current crisis. Instead, the state must begin to aggressively pursue immediate options to reduce traffic congestion . . .".

Projections for increased vehicle miles travelled have major implications not only for traffic congestion, but also for fuel consumption and air pollution. The public is perhaps better informed about these problems than one might at first assume. They are also well aware of some of the potential solutions. A late 1989 nationwide public opinion survey conducted for the Union of Concerned Scientists found the following:

- An important way to save energy is to make it easier for people to use mass

Regional Transportation Planning Agency Boundaries

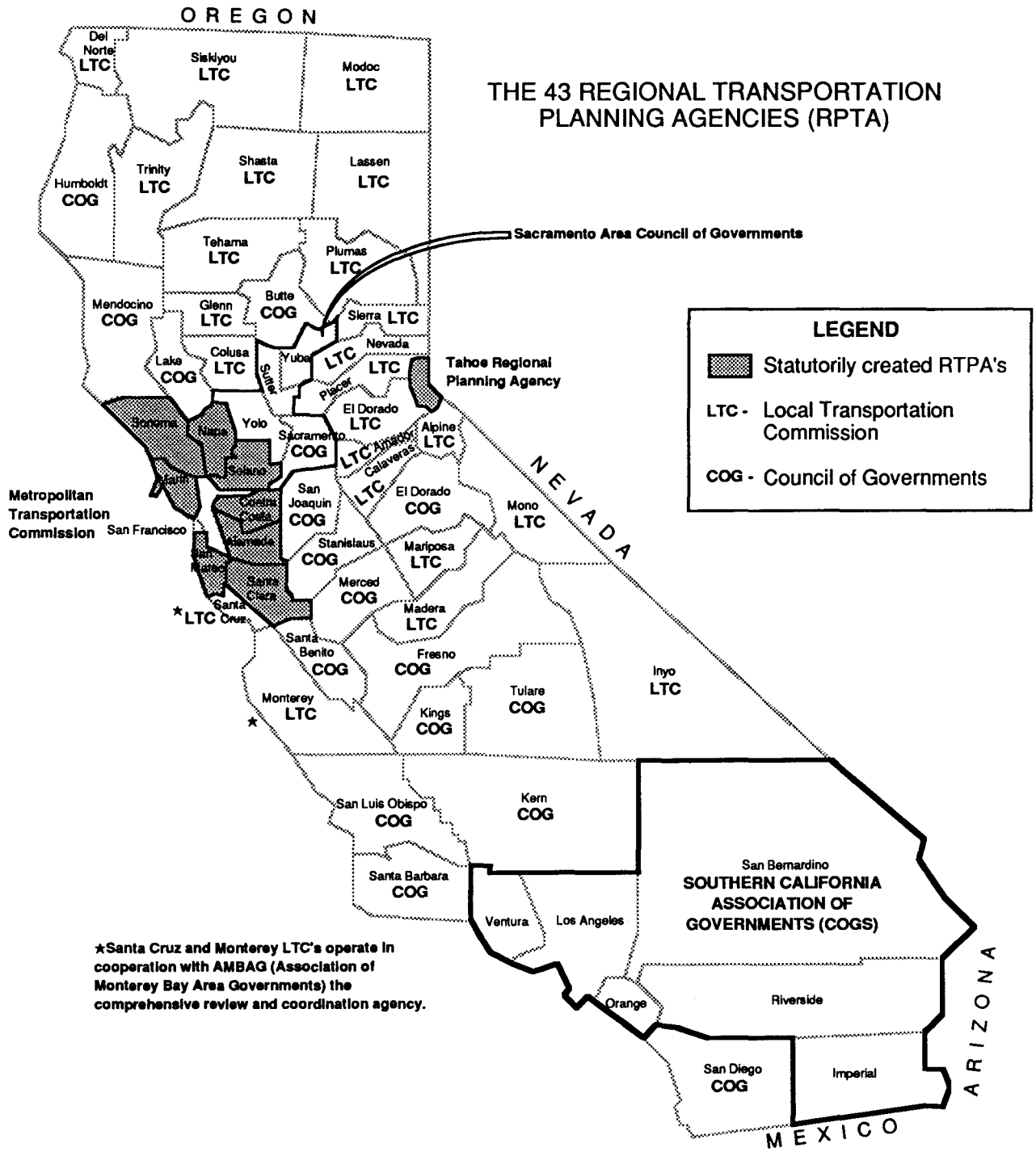


Figure 2 - 26.

transportation and car pooling (87% agree; 56% strongly agree);

- People favor (78%) an increase in federal fuel efficiency standards for cars from the current 27.5 mpg to 45 mpg by the year 2000 (51% strongly favor this);

- People support these increased fuel efficiency standards (83%) even if the cost for a new car goes up by $500, when the added cost is recovered by gas saved within four years.

As shown in the following chart from the Air Resources Board (ARB), Figure 2-27, the mode of transportation can significantly affect the amount of air pollution.

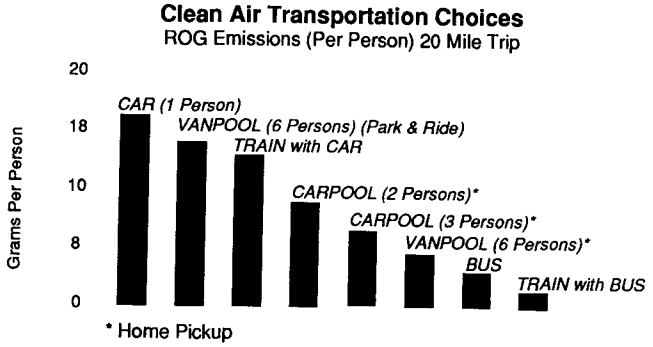


Figure 2 - 27.

In addition to the simple relationship between commute mode and air pollution, congestion can be factored in. As shown in the following quote from the League of Women Voters of the Bay Area, the equation can become very complex, to the point where land use patterns are also involved.

> There is a trade-off to consider when attempting to control emissions by improving traffic flow. Driving habits are more influenced by travel time than by the length of the trip. Increasing average travel speed tends to encourage people to select homes farther from their jobs and to travel farther to shop. This, in turn, can foster lower density land use patterns, greater need for cars and reduced use of alternative, less polluting modes of travel.
>
> Consequently, congestion relief needs to be combined with land use policies and comprehensive demand management programs to ensure that pollution from increases in travel do not overwhelm the air quality benefits of congestion relief.

Mass Transit—The state's present transportation system is heavily dependent on the automobile. Efforts are underway in many urban areas to establish mass transit where none exists and increase ridership and improve service where systems are already in place. These efforts include an initiative of statewide scope sponsored by the Planning and Conservation League.

Identified as Proposition 116, the Rail Transportation Bond Act was approved in the June 1990 election. This measure includes $1.9 billion dollars in bonds for improved rail transit. Most of this funding is slated for projects providing passenger service. Specific project locations include Lake Tahoe, Sacramento, Bay Area, Central Valley, Los Angeles, Orange and San Diego counties.

Presently, there are commuter rail services in Sacramento, the Bay Area (BART and the Peninsula Commute Service which serves San Jose), Los Angeles and San Diego. Consideration is being given to providing inter–regional links between Sacramento and the Bay Area, as well as Los Angeles/Orange County and San Diego.

Railroads—At the federal level, railroads are regulated by the U.S. Dept. of Transportation and the Interstate Commerce Commission. In California, the State Department of Transportation (CalTrans) and the Public Utilities Commission (PUC) provide regulatory oversight.

California has just under 40 railroad systems operating within the state. These systems include major, short line and switching/terminal railroads. Only five of the state's railroads have been categorized as major—Class I railroads (over $50 million annual operating revenues) by CalTrans. According to the State Rail Plan, the major railroads control about 7,000 miles of the 7,900 miles of main and branch lines in the state. Southern Pacific alone controls about 4,000 miles. Since 1982, 360+ miles of line have been abandoned while no new line has been added.

Various short line railroads make up most of the balance of rail service in the state. These Class II ($10,000,000 – $50,000,000 annual revenue) and Class III (less than $10,000,000 annual revenue) railroads may be independent or subsidiaries of the majors. There are also about 10 switching and terminal railroads in the state which operate switching services, terminal trackage, bridges, freight stations, ferries, etc.

Most of the ports and marine terminals have rail service. Short line, switching or terminal railroads often connect the ports with major rail lines. The ports and marine terminals serviced by major railroads are shown in Figure 2-28.

Pipelines—Pipelines transport crude oil and refined petroleum products. The distribution systems for oil and gas can be quite complex. Simplified versions of typical systems are shown in Figures 2-29 and 2-30.

The discussion which follows will focus on major crude oil pipelines, meaning those that connect production sites with processing facilities.

Pipelines are either proprietary or common-carrier; the latter being available to companies other than the owner of the line. Major crude oil pipelines and the corridors they use are shown in Figure 2-31.

Rail-Served Ports and Terminals

Port or Terminal	Serving Railroads
Benicia Port Terminal	SP
Encina Terminals	ATSF, SP, UP
Port Hueneme	SP
Humboldt Bay Harbor District	SP
Port of Long Beach	ATSF, SP, UP
Port of Los Angeles	ATSF, SP, UP
Port of Oakland	ATSF, SP, UP
Port of Redwood City	SP
Port of Richmond	ATSF, SP, UP
Port of Sacramento	SP, UP
Port of San Diego	ATSF
Port of San Francisco	ATSF, SP, UP
Port of Stockton	ATSF, SP, UP

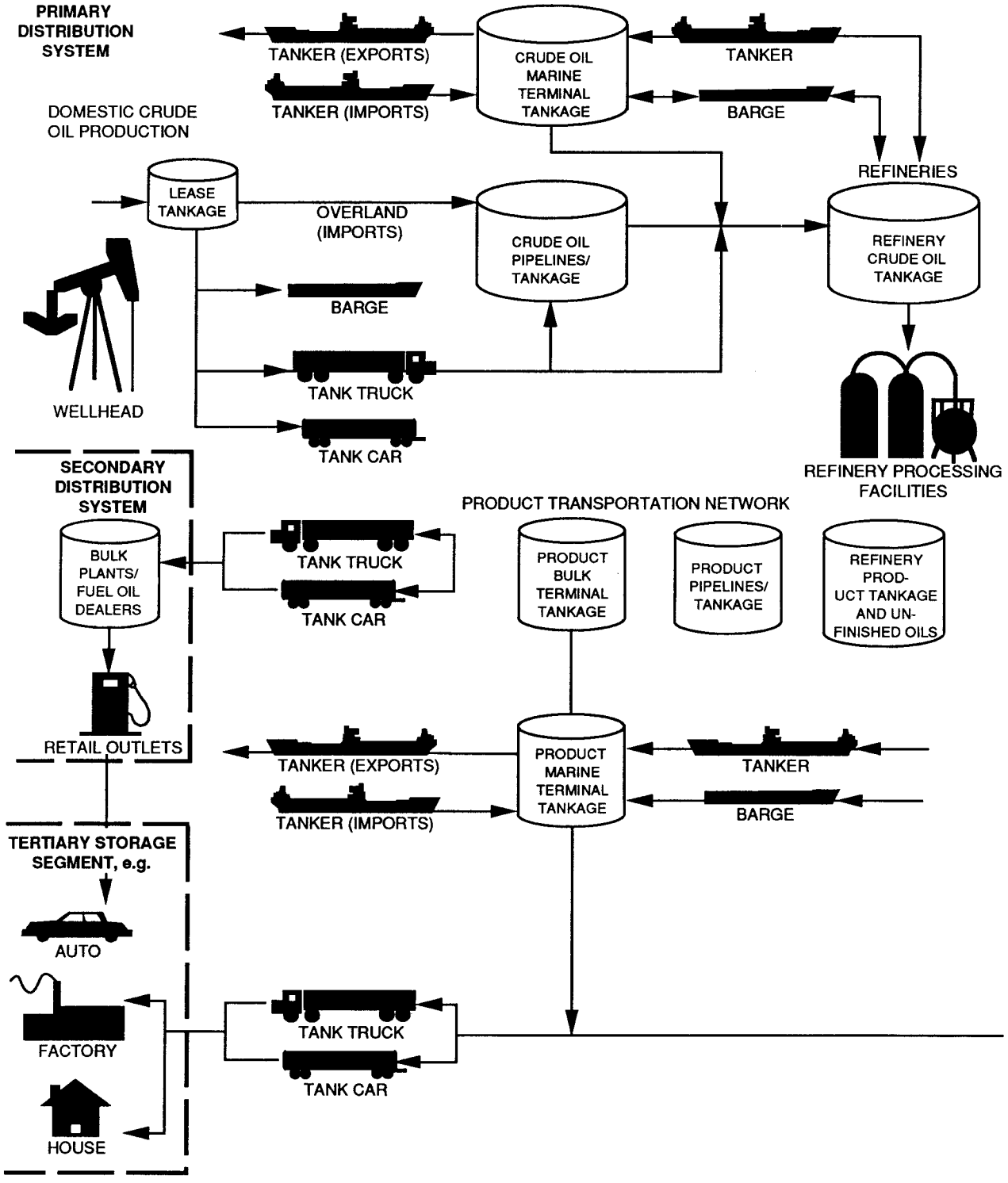
ATSF — Atcheson, Topeka and Santa Fe
SP — Southern Pacific
UP — Union Pacific

Figure 2 - 28

Most of these are not common carrier. The effect of this could be the installation of more pipelines than would be needed to carry the sum total of product. This might provide flexibility and surety of supply to individual companies, but at a potential cost of increased environmental disturbance, due to a proliferation of pipelines.

These pipeline systems service oil imports as well as locally produced oil. Figure 2-32 provides a very generalized illustration of the major crude oil transportation links in the state. In addition to oil from California sources—primarily Los Angeles, Kern, Ventura and Santa Barbara counties—this system serves to transport Alaskan and foreign crude oil.

Pipeline construction is regulated by numerous agencies. The U.S. Department of Transportation establishes construction and engineering standards. The Federal Energy Regulatory Commission (FERC) has approval authority over interstate gas pipelines. The California Public Utilities Commission (PUC) sets rates for common carrier pipelines. Agencies with control of Federal lands, such as BLM and USFS, issue leases for pipelines crossing their land. Although such leases require the pipeline to be "common-carrier",



Source: National Petroleum Council, April 1989

Figure 2 - 29: Simplified diagram of the crude oil and product distribution system.

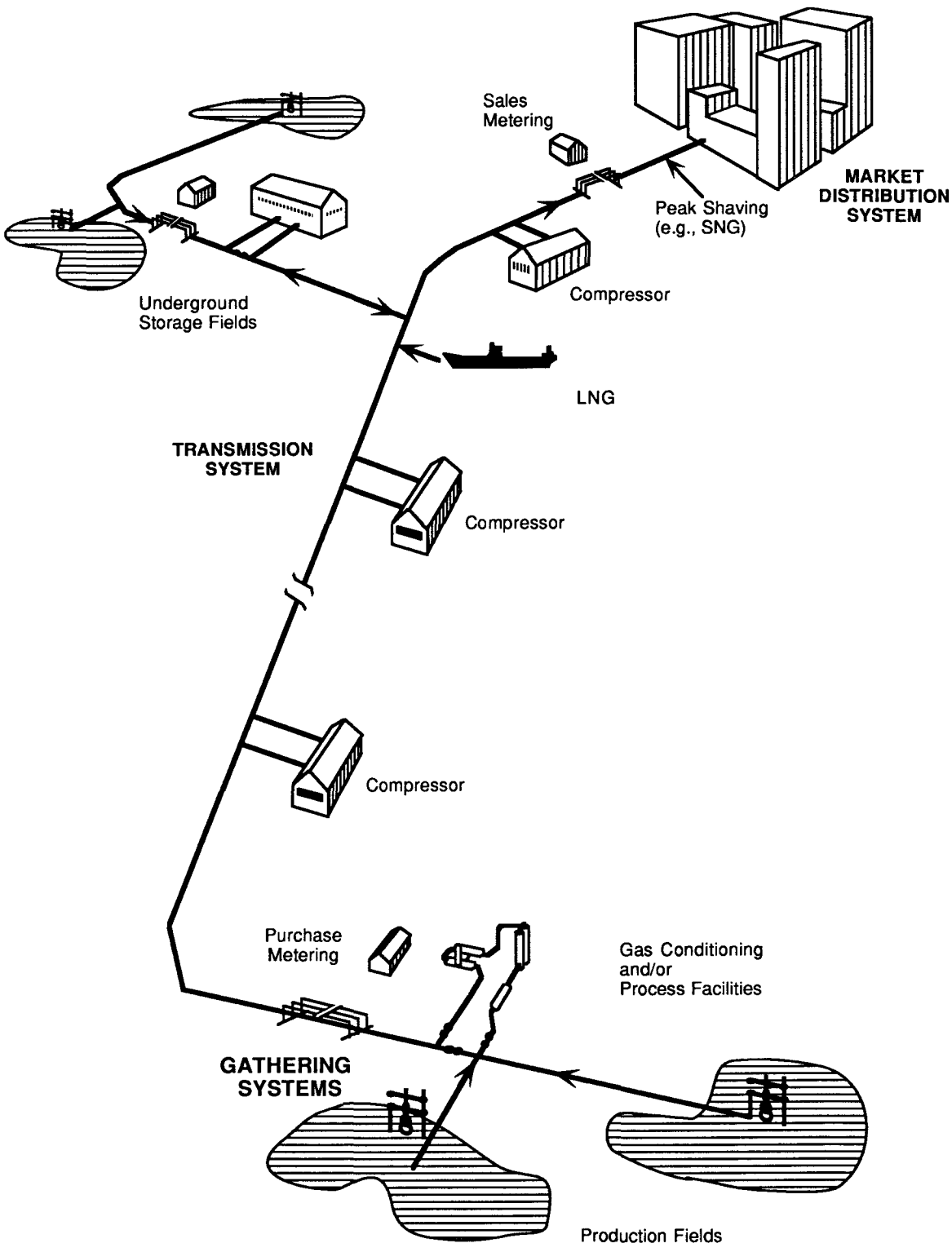


Figure 2 - 30: Typical natural gas pipeline system.

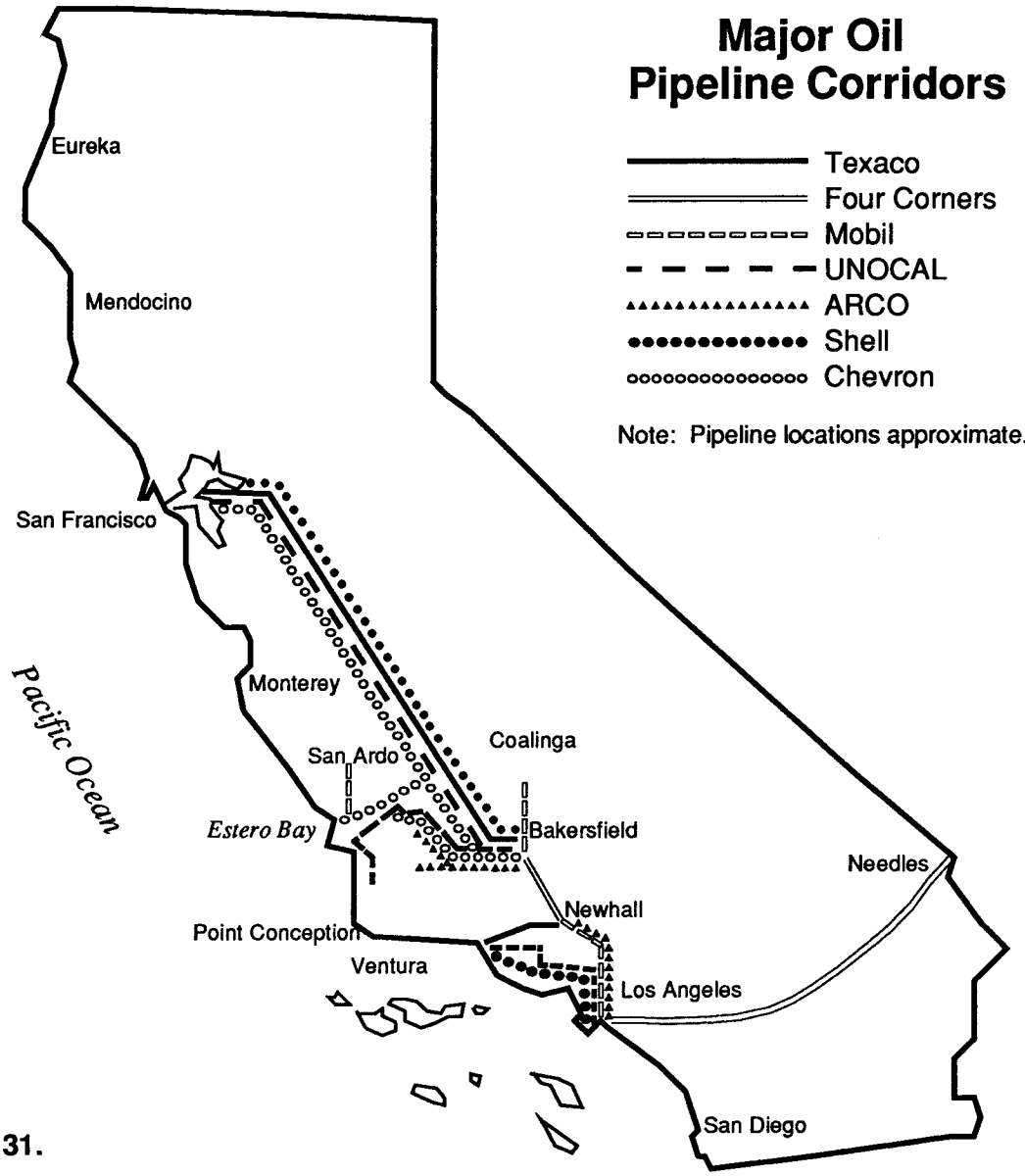


Figure 2 - 31.

Source: Division of Oil and Gas, 1982.
California Energy Commission, 1984.

this requirement is not always fulfilled. The State Lands Commission issues land leases when it approves the crossing of state lands by pipelines.

According to the California Almanac, as of 1987 there were 4,800 miles of crude oil trunk lines in the state. These lines have a capacity of 932,000 barrels per day, only 6% of which (Four Corners Pipeline) is operating as a common-carrier. Refined product lines in California cover 1680 miles with a capacity of 916,000 barrels per day.

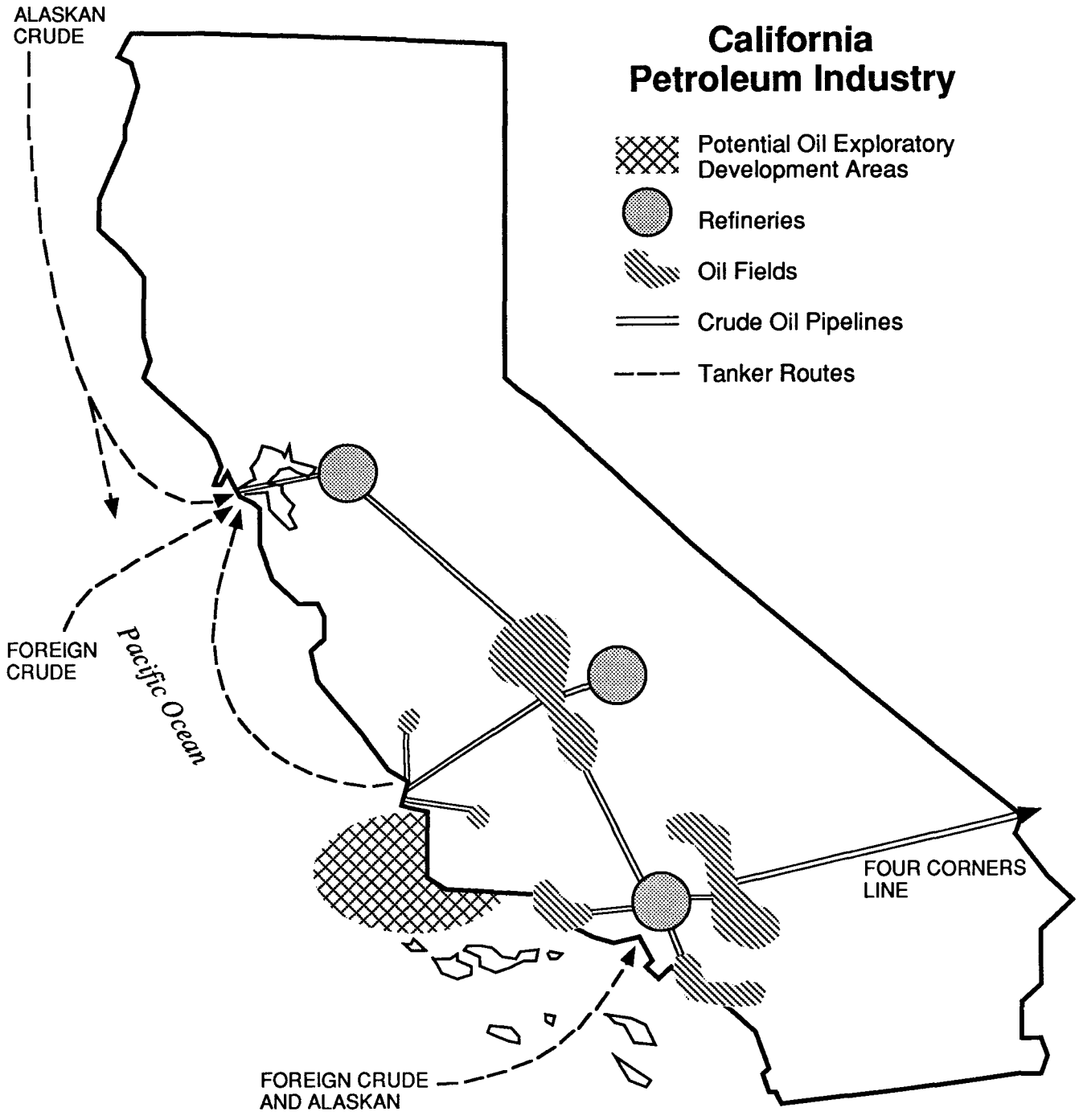

ALASKAN
CRUDE
California
Petroleum Industry
Potential Oil Exploratory
Development Areas
Refineries
Oil Fields
Crude Oil Pipelines
Tanker Routes
FOREIGN
CRUDE
Pacific Ocean
FOUR CORNERS
LINE
FOREIGN CRUDE
AND ALASKAN

Figure 2 - 32.

AIR

Each county which is served by a certificated air carrier from a public airport must establish an Airport Land Use Commission (ALUC) for compatible land uses in the vicinity of the airport. The state law which requires the creation of ALUCs indicates that their purpose is to " . . . provide for the orderly development of public airports and to promote public health, welfare and safety through land use planning actions."

As the population continues to grow in California, the potential for conflicts between air traffic at airports and surrounding uses will increase. Urban uses continue to expand to accommodate increased population to the point where once remote airports are being encroached upon. This raises concerns about safety, as well as, air and noise pollution.

SEA

Major California ports include San Diego, San Pedro (including Los Angeles and Long Beach harbors), Hueneme, San Francisco, (including San Francisco, Oakland, Richmond, San Pablo/Mare Island, Carquinez Strait and Suisun Bay), Sacramento, Stockton and Humboldt. The ability of each port to handle different types and amounts of cargo is affected by the amount of dock space, the depth of channels and shoreside infrastructure, including facilities for unloading, storing and transporting various cargos. Provision of services for ships is also an important function of a port.

Transportation at sea is regulated by the U.S. Coast Guard. Two different measures, shipping safety fairways and traffic separation schemes, can be used by the Coast Guard to provide safe access routes for vessels. The shipping safety fairways are used primarily where the risk of collision is between a vessel and an offshore structure such as a platform. The traffic separation schemes, on the other hand, are used where the primary risk of collision is between two vessels. In April 1989, the Coast Guard proposed a rule change that would amend the traffic separation schemes in the San Francisco and Santa Barbara/Long Beach areas, as well as create shipping safety fairways connecting these two traffic separation schemes. Figure 2-33 illustrates the proposed changes.

Two types of facilities service freight transport vessels—ports and marine terminals. Ports handle all types of freight. The major categories of freight include:

Break Bulk Cargo—General cargo packed and moved as single parcels or assembled together on pallets typically lifted off ships in slings handled by cranes.

Container—General cargo packed in standard size weather–tight boxes. Cargo remains in container from origin to destination and is easily interchangeable between ship, truck and rail.

Neo-Bulk Cargo—Cargoes generally shipped in large quantities and having some characteristics of bulk commodities. Neo–bulk cargoes in the Bay Area are generally autos, steel products, and newsprint.

Dry Bulk Cargo—Cargoes loaded or unloaded in conveyor belts, spouts or scoops, and not placed individually; flowable cargoes; rice, grain, various ores, etc.; stored loose.

Dry Cargo—All break bulk, containerized, neo–bulk, and dry bulk cargoes.

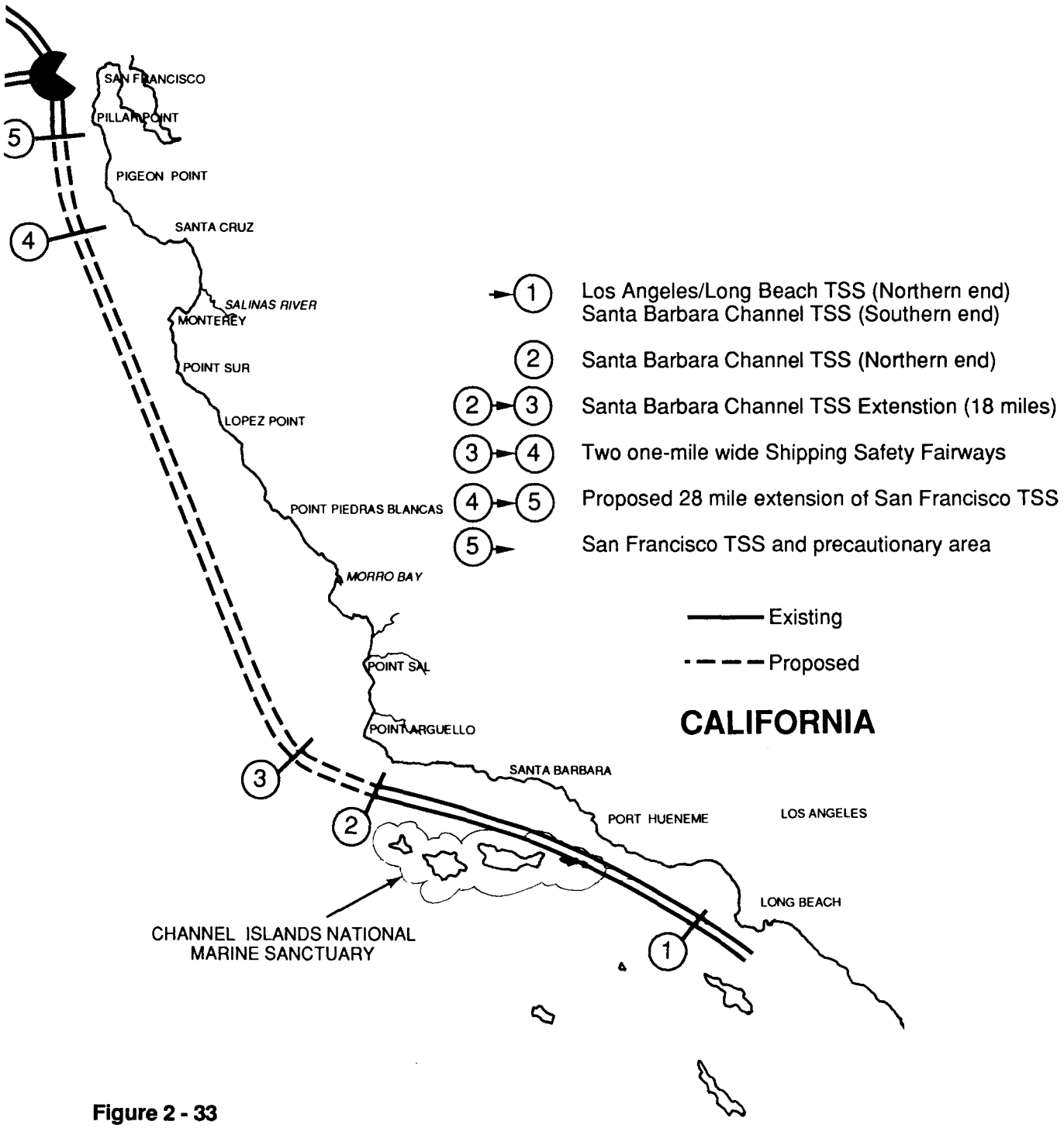

SAN FRANCISCO
PILLAR POINT
PIGEON POINT
SANTA CRUZ
SALINAS RIVER
MONTEREY
POINT SUR
LOPEZ POINT
POINT PIEDRAS BLANCAS
MORRO BAY
POINT SAL
POINT ARGUELLO
SANTA BARBARA
PORT HUENEME
LOS ANGELES
LONG BEACH
CHANNEL ISLANDS NATIONAL MARINE SANCTUARY
1 Los Angeles/Long Beach TSS (Northern end) Santa Barbara Channel TSS (Southern end)
2 Santa Barbara Channel TSS (Northern end)
2 → 3 Santa Barbara Channel TSS Extenstion (18 miles)
3 → 4 Two one-mile wide Shipping Safety Fairways
4 → 5 Proposed 28 mile extension of San Francisco TSS
5 San Francisco TSS and precautionary area
Existing
Proposed
CALIFORNIA

Figure 2 - 33

Liquid Bulk Cargo—Liquid cargoes, such as petroleum or vegetable oil, that are shipped in tanks rather than small individual units.

Roll-On/Roll-Off (RO/RO)—A method of ocean transport which permits wheeled vehicles (e.g., autos, trucks, forklifts) to drive on and off the vessel under their own power.

Lighter Aboard Ship (LASH)—A method of ocean transport which uses lighters (i.e., barges) capable of carrying smaller standard sized containers, general cargo or bulk cargo. LASH barges are taken aboard ship or discharged by shipboard cranes.

There are, according to the Coastal Commission, 70 marine terminals for transportation of crude and petroleum products on the California coast. Four of these are associated with the Port of Humboldt Bay. San Francisco Bay harbors 17. One each is found in San Mateo, Monterey and San Diego Counties. San Luis Obispo County has five, Santa Barbara County has seven and Ventura County has four. Los Angeles County has 28, one at El Segundo, 21 in Los Angeles Harbor and six in Long Beach Harbor. Orange County has one terminal in Huntington Beach.

Marine terminals are used to transfer crude oil from tankers to refineries, or products from refineries to tankers. These terminals may be located within a port or exist independent of any port facility. In either case, they provide a vital transportation link between areas of production, processing and consumption of oil. Over 90% of the refinery capacity on the West Coast is in refineries serviced by marine terminals. Figure 2-34 illustrates the importance of marine terminals to West Coast refining.

Figure 2-34 also provides insight into the predominant role California plays in West

West Coast State Refining Capacities

Operating January 1, 1985

State	No. Plants		Crude Capacity[1]	
	Total	Marine[3]	Marine[2]	Total
California	30[3]	19[3]	2,265,098	2,059,100
Washington	7	7	410,550	410,550
Alaska	4	2	138,930	70,500
Hawaii	2	2	109,500	109,500
Oregon	1	1	15,000	15,000
TOTALS	44	31	2,939,078	2,664,650

[1] Charging capacity in barrels per calendar day.
[2] Including only those refineries in Alaska, Washington, Oregon, California, and Hawaii that process crude or deliver product that is regularly transferred through marine terminals.
[3] Union Oil Co. of Calif's Rodeo and Santa Maria, Calif., refineries are counted as one.

Source: *Oil and Gas Journal*, March 18, 1985.

Figure 2 - 34.

Coast refining—77% done in this state alone. Enough refining takes place on the west coast to produce a surplus. Exports of refined products, both interstate and foreign, result in additional tanker traffic.

Tanker transport of crude oil and refined products is focused on the two major harbors with refinery access—San Francisco and Los Angeles. Each receives about 1,000 oil tankers annually. The average oil tanker size in San Francisco is 60,000 dead weight tons (dwt) or 18,000,000 gallons. In the Port of Long Beach (figures for the Port of Los Angeles were not available), the average oil tanker is about twice as large—120,000 dwt and 34,000,000 gallons.

The amount of oil tanker traffic along the California coast creates an ever present danger of accidents resulting in spills. The U.S. Fish and Wildlife Service has embarked on a controversial sea otter translocation program primarily in response to the threat of tanker oil spills to this central coast species. Many other natural resources are at risk, as well as the economies of tourist-oriented communities.

Finally, a note should be made about the relative capacities of different transportation modes. The following chart from the Iowa Department of Transportation, Figure 2-35, graphically displays equivalent cargo capacities of truck, rail and barge. (To date, CCORS staff has been unable to find a similar representation of relative energy consumption of different modes of freight transportation.)

CEQA METHODOLOLGY

An EIR analysis focuses on how a project may increase the use of existing facilities. First, it establishes the baseline conditions of the current transportation system. Next, it evaluates how each project phase—such as construction and operation—will increase the load on the transportation network. The entire effort aims at identifying thresholds and capacity, or service level constraints.

Such an analysis depends on the specific nature of the project. How large the project is, how long it will last, and what forms of transportation it will use must all be taken into account. The need for new transportation facilities is also a critical factor.

Oil and gas projects are typically analyzed for the following types of transportation impacts:

Highways—Effects on local circulation due to onshore facility construction and operation staff commutes, as well as incoming or outgoing freight.

Mass Transit—Effects of increased commuter use.

Railroads—Effects of increased numbers of train trips.

Pipelines—Availability of existing lines; effects of constructing new lines.

Airports—Effects of increased helicopter trips for offshore crew changes.

Harbors—Effects on harbor facilities of: increased crew and supply trips; need for supply storage space; increased navigation conflicts from crew and supply boats.

Sea Traffic—Effects of platforms, exploratory rigs, testing and service boats on general vessel traffic.

CCORS ANALYSIS

Lacking a specific project, CCORS will not be able to predict specific impacts to transportation systems.

RECREATION AND TOURISM

Not only do Californians play hard and long, but the coastline also attracts visitors for many reasons—the beaches, fishing, the ocean itself and the climate. To these natural features, man has added many attractions, something for almost everyone.

As one moves from south to north up the California coast one experiences a series of gradual changes. One goes from very densely populated areas to those which are sparsely populated, from extensive sandy beaches to rocky cliffs, from the sun belt to the fog belt, and from warm water marine species to sub-arctic species. Each of these changes affects the recreational and tourist aspects of the local regions.

The State Department of Parks and Recreation acquires, develops and operates units of the State Park System, State Preserves,

COMPARE

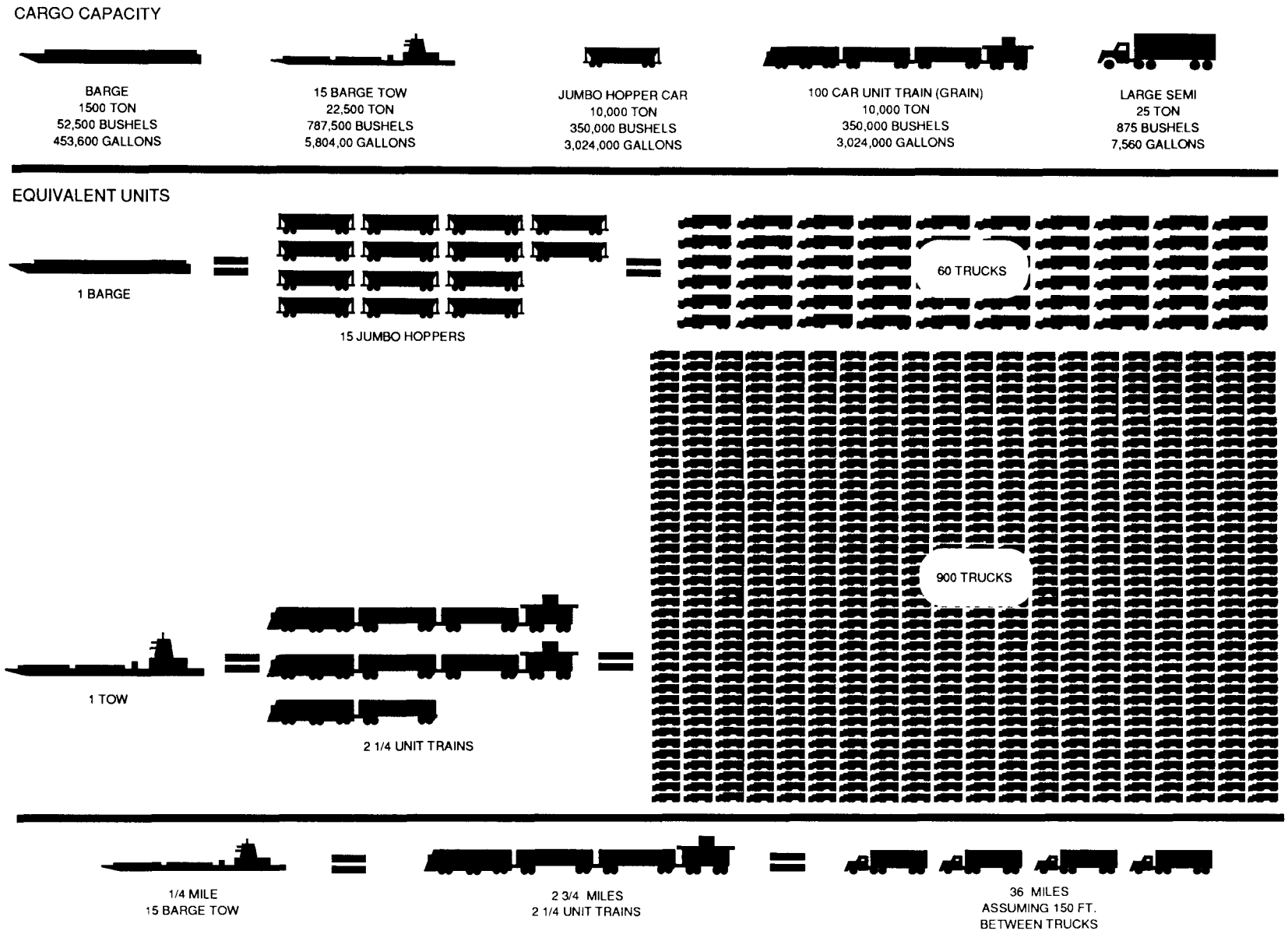


Figure 2 - 35

State Recreation Areas, Historical Monuments and State Beaches. The State Department of Boating and Waterways responsibility includes development of boating facilities, licensing of yacht and ship brokers, conducting programs for boating safety and law enforcement, and participating with the Corps of Engineers and local agencies in the construction of beach erosion control projects. The State Department of Fish and Game issues permits and licenses for hunting and fishing and regulates seasons, and limits the methods, areas and number of taking sports fish and game. The State Department of Motor Vehicles registers boats and vehicles, issues driver's licenses, and administers the financial responsibility laws. The State Department of Water Resources administers recreational facilities created along the various parts of the State Water Project.

The National Park Service administers an extensive system of national parks, monuments, historic sites, and recreation areas for the enjoyment and education of citizens, and for the protection of the natural environment. This includes management of the resource itself and enforcement of laws within the boundaries of the various units. The United States Coast Guard's primary functions include search and rescue, maritime law enforcement, commercial vessel safety, port and environmental safety, aids to navigation, and boating safety. The U.S. Fish and Wildlife Service performs duties similar to the California Department of Fish and Game in areas under Federal jurisdiction and in regard to migratory species. The Federal Bureau of Indian Affairs acts as trustee for lands and moneys held in trust by the United States for the indian tribes and native peoples, and makes regulations applying to lands under tribal jurisdiction and Native American fishing rights.

Cities and counties often administer considerable recreational property, in the form of parks, beaches or zoos. Responsibilities include management, law enforcement and revenue collection, if any. In some areas of California, special districts have been established to administer recreational facilities.

Many of the recreational and touring opportunities along California's coastline are based on its natural features. These can conveniently be divided into those that focus on the water and those that focus on the land. The water based activities include boating, fishing, swimming, surfing, diving, whale watching and beachcombing. The degree to which a particular aspect is available in a particular area depends on climate and geography. Activities based on the land part of the coast include hiking, camping, picnicking and nature appreciation.

Other important destinations for tourists are man-made cultural and amusement areas. Sports arenas, amusement parks, museums, zoos and even shopping malls attract people from near and far. The hotels, motels, inns, nightspots and restaurants in an area can be an attraction in themselves. And many parts of California have special events at different times of the year that can attract many participants. Horse or auto races, music festivals and concerts can all bring large numbers of people into an area for a short time.

One of the major impacts/effects of the recreational/tourist industry is the economic one. A considerable portion of this impact comes from the expense of traveling to or from a recreational destination. Fuel and other supplies, fares and the taxes on these items make up a significant portion of most people's recreation budget. Food and lodging are also

major items, as are the taxes on these items. Then there are direct expenditures on admissions, event fees, fishing equipment or boat charters. Anything involved with boating is expensive.

The effects of any kind of development on recreational or tourist opportunities can usually be divided into those that are connected to construction activities and those that are more permanent, coming from the presence of the development itself. The former include shortages in temporary accommodations such as campgrounds or hotels caused by construction crews moving into an area for a short period of time, overloading the transportation network with construction related equipment, and actual closures of facilities due to construction activities. On the more permanent side, development can remove areas from recreational use, can mar the aesthetics of an area to the point where it ceases to be a "draw," or, in the case of some residential developments, overcrowd an area. A special case exists where a development produces the risk of air or water pollution. Oil spills, chemical leakages, or high levels of air emissions, especially if well publicized, can reduce recreation and tourism significantly.

On the positive side, some development actually creates new opportunities for recreation or tourism. New facilities or attractions can significantly improve an area's drawing ability. Residential developments can provide higher counts at existing facilities. Mitigations for major projects can include restoration of beaches or wetlands for recreational use.

FISHING

COMMERCIAL

The gear used for fishing in California and the fish caught by each gear type were described in Chapter One. Statewide fishing regulations, and the location and status of fish stocks is presented in this section.

Except where noted, the statistics are based on information provided to the California Department of Fish and Game by commercial fish processors when fish are brought into port for sale. For the most part, these are the only data available for commercial fishing in California. The quantity of fish landed depends on multiple factors, including weather, fish availibility, market price and demand, and fishing regulations. For instance, Dover sole landings may decline when the shrimp season opens or when the quota is filled. Thus, landings do not provide direct information on fish stocks. The data does, however, reflect the size of the fishery. The data are compiled by port area, e.g., Eureka, San Francisco, which includes the named port as well as smaller ports in the region. Fish and Game does not provide data for individual ports because the data may be attributed to individual boats in the smaller ports, thus providing information on individual income. Statements herein on the status of fish stocks are based on published reports or on personnel communications from experts at the Department of Fish and Game.

Regulations

Commercial fishing in California is regulated in part by the Pacific Fishery Management Council and in part by the state. In addition, the Inter-American Tropical Tuna Commission develops regulations for yellowfin tuna, and the International Pacific Halibut Commission for Pacific Halibut.

The Pacific Fishery Management Council (PFMC) is one of eight regional councils created in 1976 by the Magnuson Fishery and Conservation Act to manage fisheries in the Exclusive Economic Zone of the United States. The PFMC manages fisheries from the Mexican to the Canadian border.

Regulations for a species or group of species are based on an Environmental Impact Statement and a Fisheries Management Plan developed by the PFMC. After the Fisheries Management Plan is approved, draft regulations are prepared by the National Marine Fisheries Service and published in the Federal Register. After review, final regulations are promulgated and enforced by the U.S. Coast Guard, the National Marine Fisheries Service and state wardens. The state of California adopts the regulations in the Fish and Game Code.

To date, the PFMC has developed fisheries management plans for salmon, anchovy and groundfish. The salmon management plan regulates chinook (king), coho (silver), pink (humpback), and sockeye (red) salmon. The groundfish plan regulates 83 species, (many of which are rockfish and flatfish taken primarily by trawling) and controls all types of fishing. The anchovy management plan regulates the northern anchovy (Engraulis mordax). The plans set management objectives and the framework for regulations. Each year the Council passes specific regulations to implement the management plans, including seasons, management areas and quotas.

The Inter-American Tropical Tuna Commission (IATTC) was formed in 1950 by a Convention signed between the governments of the United States and Costa Rica. The Convention allows other nations to join the Commission after approval by member nations. Member nations now include France, Japan, Nicaragua, Panama and the United States.

The goals of the IATTC are: (1) to study the biology of tropical tuna, tuna baitfish and other fish taken by tuna fishermen in the eastern Pacific Ocean; (2) to deal with problems caused by the relationship between tuna and dolphin; and (3) to recommend appropriate conservation measures to maintain stocks of fish and dolphin.

To date, the Commission staff has only recommended regulations for yellowfin tuna and quotas were in place between 1966 and 1979. Since that time member nations have not been able to agree on implementing regulations, so no quotas or other controls have been adopted.

The International Pacific Halibut Commission (IPHC) was established in 1923 by a Convention between Canada and the United States. The objective of the Convention was to manage stocks of Pacific halibut (*Hippoglossus stenolepis*). The IPHC meets annually to develop regulations which they submit to both governments for approval. After approval, the regulations are enforced by the fisheries agencies of both countries. Pacific halibut is primarily caught in the northern Pacific, particularly Alaska; however, some fish are landed in Eureka and these are subject to management by the IPHC. The PFMC is charged with allocating Pacific halibut among U.S. commercial, recreational, and tribal Indian fishermen in waters south of British Columbia. California halibut (*Paralichtys californicus*), which is more commonly landed in California, is regulated by the state not the IPHC.

All other species of fish landed in California are regulated by the state through the State

Legislature. For the most part, the Legislature retains the right to manage commercial fishing in California. However, in some cases, the Legislature has delegated authority to the Fish and Game Commission.

The Fish and Game Commission (composed of five members appointed by the Governor) controls sport fishing and hunting in California. The Department of Fish and Game is responsible for enforcing regulations set by the Legislature and by the Commission. All fish landed in California are subject to state regulations, regardless of where they are caught; state laws are also enforceable in federal waters. Laws pertaining to fishing and hunting are published in the Fish and Game Code.

Trawling

Most trawling is done in Northern California; there is little south of the Santa Barbara channel (Figure 2-36). Bottom trawling is prohibited within three miles of shore, except for halibut. Halibut may be trawled to within one nautical mile of shore between Point Arguello and Point Mugu. San Francisco Bay, and some areas in Monterey Bay and off Catalina Island are closed to bottom trawling.

In Southern California most trawling is on sand or mud bottoms in less than 700 feet of water. In Northern California trawlers often work as deep as 3600 feet. Throughout the state, trawls may be fished to depths of 4200 feet, particularly for Dover sole (C. Fusaro, personal communication; P. Leipzig, personal communication; L. Quirolla, personal communication).

The principal species caught in trawls are flatfish (Dover and English sole), rockfish, hake (Pacific whiting), sablefish and Pacific ocean shrimp (Figure 2-37). Almost 70% of these species are landed in Eureka. Pacific hake and Pacific ocean shrimp are almost exclusively landed in Eureka. Most of the remainder of the catch is landed in Santa Barbara or San Francisco.

Pacific hake are primarily caught in joint venture fishing; that is, the fish are caught by U.S. fishermen and sold at sea to foreign processing vessels. In 1987, the Soviet Union, Poland, the Republic of Korea and China participated in joint venture fishing. The Pacific Fishery Management Council also set quotas for fishing of underutilized stocks by foreign vessels. Ninety percent of the catch was allocated and taken by Poland. No quota was allocated for foreign fishing vessels in 1989 and 1990. It is expected that joint ventures will be replaced by domestic processing in the near future.

Groundfish stocks, for the most part, are fully exploited; that is, the maximum sustainable yield calculated by the Pacific Fishery Management Council is being harvested.

Seining

In Southern California seines are fished throughout the Southern California Borderland as far as 100 miles from land. Almost 80% of the fish caught by seines in 1987 were landed in Los Angeles; 15% were landed in Santa Barbara (Figure 2-36). Seining is more limited in Northern California, with most activity in Monterey and San Francisco Bays and in the vicinity of Morro Bay (Centaur and Associates, 1981).

The principal species caught by seines are tuna (yellowfin and skipjack), squid, and mackerel (jack, Pacific and unspecified mackerel) and anchovy (Figure 2-37).

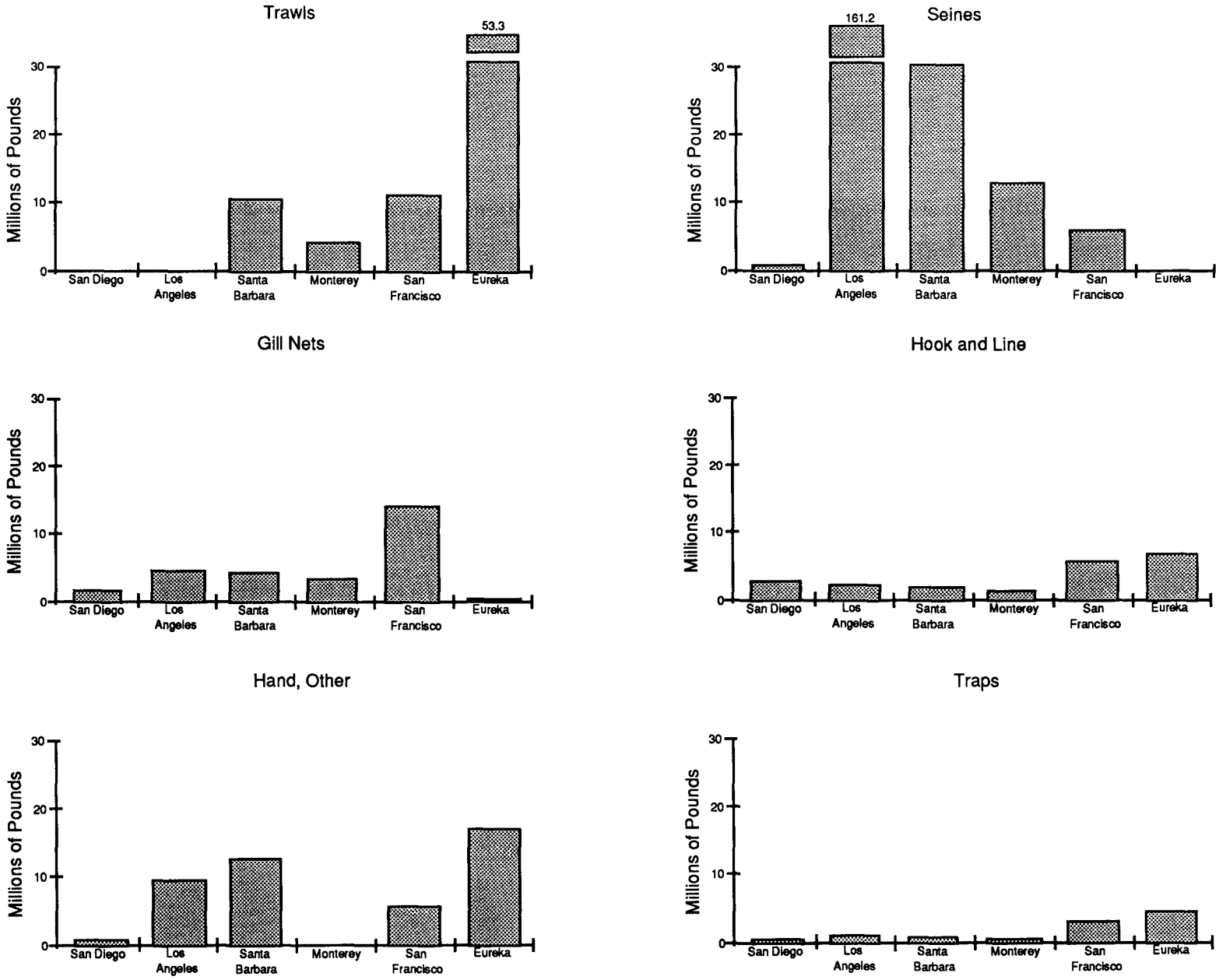


Figure 2 - 36: Pounds of fish landed in each California port by each gear type in 1987. (California Department of Fish and Game, unpublished data.)

Port of Landing	San Diego	Los Angeles	Santa Barbara	Monterey	San Francisco	Eureka
Trawls						
Dover Sole	0.0%	0.0%	23.6%	5.3%	19.7%	51.3%
Rockfish	0.0%	0.0%	7.6%	9.7%	18.4%	64.2%
Pacific Hake	0.0%	0.0%	0.0%	0.0%	0.2%	99.8%
Pac. Ocean Shr	0.0%	0.0%	8.4%	0.0%	0.3%	91.2%
Sablefish	0.0%	0.0%	10.5%	7.7%	19.7%	62.1%
Thorneyhead	0.0%	0.0%	23.1%	3.2%	8.1%	65.7%
English Sole	0.1%	0.0%	5.7%	12.9%	21.3%	60.0%
% Listed Total	0.0%	0.0%	13.3%	5.3%	13.7%	67.7%
Seines						
Pac. Mackeral	0.0%	93.1%	5.6%	1.3%	0.0%	0.0%
Yellowfin Tuna	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%
Mackerel	0.0%	74.3%	22.3%	3.4%	0.0%	0.0%
Market Squid	0.0%	19.1%	52.1%	27.3%	1.5%	0.0%
Jack Mackerel	0.0%	96.6%	0.1%	3.3%	0.0%	0.0%
Skipjack Tuna	0.1%	99.9%	0.0%	0.0%	0.0%	0.0%
% Listed Total	0.0%	78.0%	15.5%	6.2%	0.3%	0.0%
Gill Nets						
Pacific Herring	0.0%	0.1%	0.0%	0.0%	98.9%	1.1%
Rockfish	10.6%	6.4%	29.2%	37.5%	16.3%	0.1%
Swordfish	34.8%	22.0%	25.2%	16.2%	1.7%	0.0%
Market Squid	0.1%	99.7%	0.1%	0.0%	0.0%	0.0%
Angel Shark	3.0%	8.6%	87.6%	0.8%	0.0%	0.0%
Halibut	9.7%	31.3%	53.8%	4.7%	0.5%	0.0%
White Croaker	0.4%	21.9%	24.8%	27.3%	25.7%	0.0%
Pac. Mackerel	1.0%	97.7%	0.9%	0.4%	0.0%	0.0%
Thresher Shark	33.7%	20.5%	33.0%	9.1%	1.7%	2.1%
% Listed Total	13.6%	48.4%	26.7%	8.3%	3.0%	0.1%

Figure 2 - 37: Percent of fish species caught by each gear type in each port in 1987 (CDFG, unpublished statistics).

Tuna are caught primarily in southern waters from Baja California south to Peru or Chile, although bluefin and skipjack tuna are occasionally caught in Southern California. Tuna landed in the state are brought to San Pedro and processed at the only remaining tuna cannery in California. Most tuna caught by U.S. fishermen are processed in Samoa or Puerto Rico. Stocks of yellowfin tuna are generally believed to be declining (Peterson and Bayliff, 1985; Miyabe and Bayliff, 1987; Punsley, 1987); the status of other species is less certain.

Market squid are caught primarily on their spawning grounds in Monterey Bay and in Southern California off the Channel Islands and at Point Dume, Point Mugu, Los Angeles

Harbor and La Jolla (U.S. Department of Interior, 1987). The major fishing effort is in the summer and fall in Monterey Bay, and in the fall and winter in Southern California. Squid are sold for human consumption or as bait.

Squid landings were reduced after the 1983 El Niño. The fishery has recovered in Southern California, but in Monterey, landings are still below average. There is concern that lampara nets used to fish in Monterey Bay may be damaging squid eggs and thus retarding the recovery of the population (California Department of Fish and Game, 1988).

Jack mackerel (*Trachurus symmetricus*) and Pacific mackerel (*Scomber japonicus*) occur throughout California, but are caught primarily in the Southern California Borderland, and landed and processed in San Pedro. The Pacific mackerel fishery produced well from 1935 until the late 1960s, when the catch began to decline seriously. The fishery was closed between 1970 and 1975. By 1980, it had recovered to pre-1945 levels and has been strong since that time. While catch fluctuated from year to year, there was no sign of decline in the catch of jack mackerel.

Historically, sardines and anchovy were the prinicipal species caught in seines. In the early 1900s anchovy were caught for reduction into oil and fish meal; however, when regulations were instituted that limited the number of fish taken, the anchovy catch declined. The sardine fishery flourished in the 1920s and 1930s, but then began to decline and finally collapsed in 1952. As the catch of sardine declined, landings of anchovy increased. Landings of anchovy peaked between 1973 and 1977 and then precipitously declined. Since 1983, the low price of fish meal has limited the anchovy catch to less than 4000 tons per year. Most anchovy are now sold as bait (Department of Fish and Game, 1988). Stocks of sardines have been increasing, and in 1986 the fishery was again opened. In 1987, 2560 tons were caught and much of the catch was sold as bait.

Gill Nets

As discussed in Chapter One, gill and trammel nets may be anchored (set) in place or left to drift with the currents. Set nets are used in shallow water out to a depth of approximately 240 feet. Pacific herring, rockfish, halibut and white croaker are the principal species caught in set gill nets (Figure 2-37).

Virtually all Pacific herring are caught in San Francisco and Tomales Bays, although in some years the fishery is active at Crescent City Harbor and Humboldt Bay. Historically, Pacific herring (*Clupea pallasii*) were caught for oil and fish meal for poultry food; there was limited human consumption. Starting in 1973, herring have been caught for roe which is sold to the Japanese. There is also a small experimental market for herring eggs on seaweed. The fishery is restricted to the peak spawning season from December through March.

The herring fishery is exploited at maximum sustainable yield and regulated by limited entry and a quota system based on spawning biomass. The annual quota in San Francisco for the past couple of years has been around 9,600 tons. J. Spratt (CDFG, personal communication) considers the San Francisco Bay population to be healthy and sustaining average recruitment. The fishery in Tomales Bay, however, has declined since the 1983 El Niño. Declines may also be drought related (J.Spratt, CDFG,

personal communication). Consequently, the Tomales Bay fishery was closed in 1989-90.

Rockfish (*Sebastes*), a group of more than 50 species, are caught throughout California but, the areas of highest take are on rocky outcrops between San Francisco and Santa Barbara. Almost 30% of all gill net landings of rockfish, involving more than seven million pounds, occur at Santa Barbara and 38% at Monterey. Primary species are widow rockfish, boccacio, canary, and chillipepper.

California halibut (*Paralichthys californicus*) are commercially fished by many techniques; however, set gill nets account for around 63% of all halibut taken (California Department of Fish and Game, 1987). Halibut are fished commercially throughout California where there is a sedimentary bottom; however, the majority are taken between San Francisco and San Diego. Average tonnage landed has not changed significantly in the past decade, averaging around 500 metric tons. Nevertheless, halibut populations off California have declined for several decades possibly due to loss of spawning habitat in estuaries (U.S. Department of Interior, 1987). Although halibut are caught year-round, the major fishing effort is from July to September in Central California, and July to November in Southern California. (Regulations have been enacted in recent years to protect non-target species, particularly sea otters and seabirds, and restrict where and when nets may be used.) Halibut are currently fished at maximum harvest levels and the fishery appears healthy (M. Voykovich, CDFG, personal communication).

Drift nets are used to fish the upper 10–20 meters of the water column in deeper waters around the Channel Islands and along the continental slope in the Southern California Borderland. Recently the fishery has expanded to the continental shelf off central California. Swordfish, several species of shark including angel, bonito and thresher sharks, and more recently mackerel, opah and albacore are the primary species caught in drift nets (Figure 2-37). High seas drift nets, which may be 30 miles long, are used by foreign vessels in waters 400–1500 miles off California. This fishery will be discussed only as it affects state fisheries.

Swordfish (*Xiphias gladius*) are caught in the summer and fall when they migrate into Southern California. They are caught in surface water in offshore areas out to 800 fathoms, particularly in areas of bathymetric change. Most swordfish are landed in San Diego and San Pedro. 2.68 million pounds were landed in 1987, a significant decline in the catch in 1985 (5.25 million pounds) and 1986 (3.62 million pounds). The reasons for the decline is unknown, but may be related to variations in annual migration. The eastern Pacific stock may be declining, but the California stock appears healthy (J. Sunada, personal communication). However, little is known about population status or migratory movements.

Historically, sharks were processed for vitamin and mineral extracts of the liver. Now they are caught for food. Several shark species are targeted and most are caught in Southern California, although in recent years the fishery has been shifting to Central California.

Between 1974 and 1983, shark landings in California increased from less than 500,000 to around three million pounds annually; the number of participating boats increased from around 15 in 1977, to around 230 in 1985. The thresher shark (*Alopias vulpinus*) was the

primary fish during initial years, but recently primarily angel sharks (*Squatina californica*) have been caught.

Thresher sharks are caught in depths ranging from 200–400 fathoms, particulary close to shore near promontories and upwelling areas. Thresher shark landings and catch per unit effort have declined in California since 1982. Reportedly, fishing is negatively impacting the population (Department of Fish and Game, 1985, 1988). J. Sunada (CDFG, personal communication) notes that the decline in landings has leveled off in the past three years. This improvement may be attributed to new restrictions on take.

Angel sharks (*Squatina californica*) are landed primarily in Santa Barbara and are a coastal bottom fish. Landings of angel sharks have also declined in the past couple of years (J. Sunada, CDFG, personal communication).

Albacore, mackerel, and Pacific bonito, although mostly caught by other methods, are increasingly being targeted in the gill net fishery. Around 14% of all albacore landed in Southern California was caught by gill nets (Department of Fish and Game, 1987). Albacore will be discussed further under "Hook and Line Fishing."

Hook and Line

Commercial fishing by hook and line includes stationary, trolling, and longline fishing (see Chapter One). Stationary hook and line fishing occurs both nearshore beyond the surfline, and offshore over soft or rocky bottom, depending upon the target fish. Rockfish are commonly taken by hook and line. Trolling is primarily for open ocean or migratory species such as salmon, albacore and bonito. The longline fishery targets sablefish within 200 miles of the U. S. coast, often at the edge of submarine canyons.

Almost 60% of all fish caught by hook and line are landed in San Francisco and Eureka. Another important port is San Diego which receives about 15% of all fish landed by hook and line (Figure 2-36). Salmon and albacore are the primary species caught by hook and line. Rockfish, sablefish and yellowfin and skipjack tuna are important as well.

Salmon are caught primarily north of Point Conception in 25-75 fathoms of water as far as 20 miles from shore. The season extends from about May through September. Most salmon are landed in San Francisco (42% of total) and Eureka (47%).

Two primary species of salmon spawn in California: chinook (king) salmon (*Oncorhynchus tshawytscha*) and coho (silver) salmon (*Oncorhynchus kisutch*). Chinook account for most of the salmon caught, representing more than 80% of all salmon landed in the state.

The salmon fishery is closely regulated by a quota system developed by the PFMC under the Fisheries Management Plan for Ocean Salmon Fisheries off Washington, Oregon and California. The fishery is managed by seasonal closures, and size and bag limits; regulations change year to year and even within seasons.

Chinook landings for 1983 were the lowest since landing statistics were compiled. The poor catch was, in part, related to the El Niño. Landings have increased since that time, and in 1987, were around 9.5 million pounds, 56% higher than the previous 10–year average; coho salmon landings, though, were around 26,000 pounds, or 60% of the previous 10–year

average (Pacific Marine Fisheries Commission 1988). More information on salmon is presented in the section on Inland fisheries.

Rockfish are caught from smaller boats that set buoys with hooks and lines on rocky outcrops close to shore. Sablefish (*Anoplopoma fimbria*) are caught by longlines set on the bottom in 600–1800 feet of water. Rockfish and sablefish are caught primarily in Northern and North-Central California.

Tuna account for around 30% (six million pounds) by weight of all fish caught by hook and line in California (Figure 2-37). Tuna are fished in the mid-level of the water column (20-200 meters) either close to shore or out to 300 miles. Trolling for tuna usually occurs along escarpments and submarine rises; however, location varies considerably. Yellowfin tuna (*Thunnus albacares*) is the primary species landed by weight; however, seining is the preferred method of capture for this species. Most yellowfin tuna are landed at San Diego (67%) and San Pedro (33%).

Albacore (*Thunnus alalunga*) is a summer migrant throughout the state. It is often caught at the offshore edge of fronts between clear oceanic water and turbid coastal water (Laurs, et al., 1984), and is landed predominantly between Southern California and Monterey. The 1987 albacore catch represented a 50-year low for the fishery, down to 15% of the previous 25–year average. M. Larson (CDFG, personal communication) indicated that the fishery has been poor for the past five years, with landings declining as much as 50% per year. The low trend has continued into 1989, with only a few scattered schools of albacore occurring off Central California. Low landings have been attributed to poor fish availability and consequent lack of effort. There is concern by federal agencies that the high seas drift net fishery may be impacting the albacore population in the eastern Pacific.

Traps

Traps are primarily used close to shore in water less than 180 feet deep. Almost 65% of all landings by trap occur from San Francisco north to the Oregon border, whereas only 22% occur from Los Angeles south (Figure 2-36). Dungeness crab is the primary item, accounting for 71% by weight of all species landed. Lobsters, rock crabs, spot and ridgeback prawns are targeted south of Point Conception. Sablefish are caught in 600–1800 feet of water throughout California.

Dungeness crabs (*Cancer magister*) are fished on mud or sand bottoms from Morro Bay to Crescent City in waters 2–100 fathoms. Particularly important areas extend from Klamath to Trinidad Head, south of Trinidad Head to Humboldt Bay, and Fort Ross to Point San Pedro. Around 66% of all landings occurred at Eureka in 1987 followed by 34% at San Francisco.

Dungeness crabs cycle in abundance, with 9–10 years between lows and 13–17 years between highs. These lows and highs are induced by natural environmental factors, rather than man–made ones. Landings reflect these cycles. The 1982–3 season was very low after a trend downward from the 1970s. However, in 1987, about seven million pounds of crab were landed, beginning an upswing in the cycle.

The fishery is healthy in Northern California but the San Francisco Bay fishery has been down since the 1960's. Multiple factors may be involved, including a warm water trend since the 1950s, predation by salmon, pollution and

habitat loss (Wild and Tasto, 1983). Landings in 1987, however, were the best since 1959, with approximately 1.6 million pounds landed.

CFG and PFMC regulate the Dungeness crab fishery by size of individual and season of take. Female crabs are protected, and males are regulated by size of carapace width. Fishing is closed near major bays and harbors where spawning occurs. The fishery is legal from December to July but peak fishing occurs from December to March. Deep water areas are fished early in the season and nearshore areas later as crabs migrate inshore.

Rock crabs are fished south of Morro Bay in waters up to 40 fm and along the shelf region of the Channel Islands. Rock crabs are taken throughout the year and presently are not regulated, although recently there has been a call for protection during production.

The spiny lobster (*Panulirus interruptus*) is caught in the Southern California Borderland. Lobsters are trapped in water 30 fm deep in sandy and rocky areas. The most productive areas include the Channel Islands and the mainland from San Diego to Encinitas (P. Swartzell, CDFG, personal communication). San Diego received the largest proportion of lobster landings (42%), followed by San Pedro (33%) and Santa Barbara (26%).

Most lobster are caught in fall and winter, but may be legally fished October to March. Take is restricted by area, gear, size, season and quota. Lobster landings have increased in recent years. 1987 produced the third highest level of landings for the past 20 years, with approximately 500,000 pounds landed (Department of Fish and Game, 1988). The stock declined between the mid-1950s to 1974–75 due, in part, to poaching and below legal size take. In 1974, new restrictions on gear were instituted that allowed undersized lobster to escape from traps; coincidentally, lobster landings have trended upward. The fishery appears to be healthy and fished at maximum sustainable yield (P. Swartzell, CDFG, personal communication).

A new and growing hagfish (*Eptatretus*) fishery has developed in the last few years. In 1988, there were six or seven boats landing 700,000 pounds of fish and in 1989, there were 25–30 boats landing almost two million pounds (C. Barsky, CDFG, personal communication). Hagfish are caught in plastic traps set in 40–160 fathoms (S. Kato, NMFS, personal communication). The hagfish are frozen and sent to Korea for processing into "eelskin" products such as wallets and handbags. Processing may occur in California in the future. At that time the meat would be used for human consumption. There is at present no information on the status of the stock and no restrictions on the fishery.

Hand/Other

Harvesting of fish and invertebrates by hand includes harpooning, dip netting, and hand picking (see Chapter One). Most species are landed at Eureka (37%), Santa Barbara ((28%), and San Pedro (21%) (Figure 2-36). The primary species collected by hand include sea urchin, market squid, abalone and swordfish (Figure 2-37).

Swordfish are the only species fished by harpoon. Although historically this was the primary method of catching swordfish in California, most swordfish are presently landed by drift nets. This fishery occurs offshore in deeper waters of the Santa Barbara Channel and around the Channel Islands south to

Mexico. Around 86% of the swordfish are landed between San Pedro and Santa Barbara.

There are eight species of abalone (*Haliotis*) in California. Only red, black, green and pink abalone are harvested. Red and black abalone constitute the majority of the landings. Abalone is a luxury food item and almost all the catch is consumed within the state. Mariculture of abalone is discussed in Chapter One.

Abalone are taken from shallow rocky areas (< 150 ft.), particularly south of Point Conception around the Channel Islands and from the Farallon Islands. Only red and black abalone are harvested around the Farallon Islands. The commercial take of abalone is prohibited north of San Francisco Bay.

In 1987, most red (66%) and black (76%) abalone were landed in Santa Barbara. Twenty-eight percent of the red abalone was also landed in San Francisco. Total poundage landed in California in 1987 equalled almost 750,000 pounds.

The abalone fishery has declined over the past couple of decades. Causes include sea otter predation in Central California, and over exploitation. Abalone are vulnerable to over-exploitation because they are slow growing, have irregular recruitment, and are easily accessible nearshore. Injury to sublegal size shellfish may also be a factor. Abalone are often injured when removed from rocks with an iron bar. Injured abalone often do not survive. The decline of kelp beds during the 1983 El Niño may also have affected the fishery.

Presently, the fishery is regulated by limited entry of divers, size limits, and restrictions on fishing areas, gear and season; the season is closed in February and August. There is no restriction on the number of red abalone that may be taken. Despite restrictions, commercial catch continues to decline and new legislation will likely be passed to reduce the number of permits, limit daily take and restrict fishing during January (D. Parker, CDFG, personal communication).

Sea urchins (*Strongylocentrotus franciscanus*) comprised nearly 97% of all fish caught by hand in 1987. This burgeoning industry has become one of the top five species fished in California in the past decade (U.S. Department of Interior, 1987).

Urchins are fished for the reproductive organs of both sexes. The roe—called "uni" in Japan—is processed in the U.S. and marketed to Japan (90% of the market). Sea urchins are, therefore, harvested before spawning which generally occurs in winter in California (U.S. Department of Interior, 1987). The peak period for the fishery is late summer and fall, and from January to April.

The fishery in California increased from 76,000 pounds in 1972 to around 46 million pounds in 1987, and 49 million pounds in 1988. The fishery for sea urchins began in southern California around the Channel Islands but, in 1985, shifted to Northern California after market conditions improved and virgin stocks were fully exploited in Southern California. In 1987 around 24 million pounds of sea urchins were landed in Northern California and 22 million in Southern California. Ports in the vicinity of Eureka (primarily Fort Bragg) received 37% of all landings, Santa Barbara 28%, and San Pedro 21%. Less than 5% were landed in San Diego or Monterey. Total harvest for the state in 1987 was 46.6 million pounds, the second largest fishery by weight.

Sea urchins are currently harvested at a rate beyond sustainable yield. In 1987, CDFG

recommended placing a moratorium on new permits and partially restricting fishing effort from April to August (Heimann, et. al., 1987). P. Kalvass (CDFG, personal communication) stated that a new regulation package has been submitted which limits the size of take (to around 3.5″), the number of entrants, and closes the season in July and some additional days. Area limitations may also occur.

RECREATIONAL

The types and locations of marine recreational fishing were described in Chapter One. This section focuses on the species caught by recreational fishermen. The following account is based on the NMFS survey, "Marine Recreational Fishery Statistics Survey, Pacific Coast, 1986," Department of Commerce (1986). While the Department of Fish and Game collects data from commercial recreational fishing boats (party boats), the NMFS survey is the only source of data on shore fishing and on fishing from small boats. The NMFS survey is based on telephone surveys and interviews at popular fishing spots. The 1986 survey was used because the sample size of the 1987 survey was limited (S. Crook, CDFG, personal communication). Many of the target species of commercial and sport fisheries come from the same stock and the status of most of these species is discussed in the commercial fishery section. There are few sources for information on the number and kind of marine invertebrates taken by sport fishermen.

Restrictions on take by recreational fishermen vary with species. Salmon fishing, for example, has restrictions on area, season, time of day, fish size, number of fish, and type of hook. Abalone take is restricted by season, area, time of day, type of gear, number and size of abalone. The type of trap used for catching crabs and lobsters is regulated so that smaller animals can escape. For some marine species such as albacore and squid, there are no restrictions on take by recreational fishermen. For fin fish, there is usually a daily bag limit. The daily limit on the number of shellfish varies with species. There are also restrictions in state and federal parks and marine reserves for many species.

The top 10 species caught throughout California in 1986 included rockfish, mackerel, kelp bass, bonito, barred sea bass, white croaker, surf smelt, surfperch, barracuda and halibut (Figure 2-38). Most species are caught for human consumption; however, bonito and mackerel in Southern California, and rockfish in Northern California are also fished for bait.

NORTHERN CALIFORNIA		SOUTHERN CALIFORNIA	
Species	Number	Species	Number
Rockfish	3,424,000	Mackerel	7,086,000
Surf Smelt	1,556,000	Rockfish	5,804,000
Surfperch	1,447,000	Kelp Bass	4,500,000
Sculpins	1,127,000	Bonito	3,970,000
Sharks	758,000	Barred Sand Bass	2,270,000
White Croaker	738,000	White Croaker	2,117,000
Other Fish	433,000	Surfperch	1,382,000
Pacific Herring	277,000	Halibut	1,339,000
Lingcod	264,000	Other Fish	1,180,000
Sanddabs	236,000	Barracuda	1,160,000

Figure 2 - 38: Top ten fish species caught by recreational fishermen in southern and northern California in 1986 (from Department of Commerce, 1986).

There is a strong division between the type of species caught north and south of Point Conception. Rockfish—including blue, black and chilipepper rockfish—are the predominant group caught in Northern California, accounting for 31% of the catch. Surf smelt, surfperch and sculpin each account for 10–14% of the catch. Salmon, surf smelt, sturgeon, sculpins, sanddabs, herring and striped bass are caught exclusively in Northern California.

Mackerel is the most commonly caught fish in Southern California, accounting for 20% of the fish taken. Rockfish, kelp bass and bonito

each account for 11–17% of the catch. The dominant species of rockfish are chilipepper, blue, gopher and bocaccio. Bocaccio was reported to represent 23% of all fish taken by sport fishermen between 1975 and 1978 (Department of Interior, 1986). Kelp bass, barracuda, Pacific bonito, and barred sand bass are caught exclusively in Southern California.

In Central California—the area of overlap between Northern and Southern California—rockfish, surfperch, lingcod, salmon and flatfish (such as California halibut), are popular sport fish.

Several species are not caught in large numbers but are, nevertheless popular targets for sport fishermen. Though only 134,000 fish were caught in 1986, salmon fishing is a major recreational fishery in Northern California. In 1988, 207,000 chinook and coho salmon were landed. Striped bass are fished in the ocean in Northern California; however, only 2% of the total catch occurs in the ocean compared to inland waters (Striped bass are discussed in the section on inland fisheries). Sturgeon ranked in the top five fish sought in Northern California. Halibut are a popular target fish both in Northern and Southern California. Swordfish are prized in Southern California.

The location of boat fishing varies by region. In Northern California, near Eureka and Fort Bragg, most fishing is done within 10 miles of harbors in 10–50 fathoms of water. Only rockfish are caught in appreciable numbers more than three miles from shore. In Central California, around San Francisco and Monterey bays, fishermen also fish nearshore in 20–50 fathoms of water seeking salmon, rockfish, lingcod and halibut. They venture offshore mostly in search of rockfish and lingcod at seamounts such as Cordell Bank, around the Farallon Islands, and in sea canyons such as Pioneer Canyon.

Southern California fishermen are drawn to productive offshore islands from 15–50 nautical miles offshore where they fish for rockfish, tuna, bonito, kelp bass and mackerel. Spiny lobster and abalone are also popular sport targets around islands. Kelp and barred bass, tuna, bonito, rockfish, white croaker and mackerel are the main nearshore species fished.

Shore fishing occurs throughout California on sandy beaches, rocky headlands and jetties, to name a few popular fishing spots. In Northern California, surf smelt is by far the most numerous marine fish caught onshore, followed by surfperch, sculpins and herring. Salmon and steelhead are caught as they collect near mouths of streams on their way inshore to spawn. In Southern California surfperch are the primary target species, followed by queenfish, mackerel, croaker and halibut.

Sport fishermen catch many invertebrate marine species; however, data on location and number caught are not available. Popular marine invertebrate species include spiny lobster, crabs (Dungeness and rock), abalone, clams (Pismo, littleneck, razor, butter, Washington), mussels and squid.

Most lobster are taken by hand by scuba divers. Some are taken with baited hoop nets. The most productive areas for spiny lobster are the Channel Islands, and near San Diego from Point La Jolla to Point Loma.

Crabs are caught with baited traps and pots set from piers and skiffs. They may also be fished with baited hoop nets or hook and line.

The recreational fishery for rock crabs is large and thought to be fully exploited (Hardy, et al. 1982).

The abalone sport fishery has declined over the last few decades in Northern and Southern California. The Northern California fishery is not exploited commercially nor exposed to predation by sea otters. The cause for the decline may be attributed to poaching, injury to sublegal size shellfish, failure of larval recruitment, or over exploitation by recreational fishermen. Estes and VanBlaricom (1985) note that the recreational take of abalone may exceed that of the commercial fishery.

Until recently digging for Pismo clams was a popular sport, particularly in Morro and Monterey Bays, at Pismo Beach, and beaches in Ventura, Los Angeles and San Diego counties. However, severe storms during the 1983 El Niño reduced stocks in Southern California clam beds. Sea otter predation in Central California has reduced the number of Pismo clams in Central California. At the present time there is little sport fishing for Pismo clams in California. (Hardy, CDFG, personal communication). The status of the population is unknown but it has not fully recovered from commercial exploitation. Low recruitment of young, vehicle traffic on some beaches such as Atascadero, and exploitation by fishermen may have contributed to the population's decline (Estes and VanBlaricom (1985).

There are several other clams harvested by sport fishermen including northern razor, butter, Washington, littleneck, gaper, horse and softshell. Cockles and rock scallops are also harvested. The softshell, Washington and horse clams are exploited commercially to a limited degree in Humboldt Bay. There are no records available on the status of these fisheries or on sport landings. Clam distributions are shown in Figure 2-39.

SPECIES	DISTRIBUTION
Northern Razor Clam	Aleutian Islands to Pismo Beach
Butter Clam	Aleutian Islands to San Francisco
Washington Clam	Humboldt Bay to Baja California
Softshell Clam	Alaska to Monterey Bay
Littleneck Clam	Aleutian Islands to Baja
Gaper Clam	British Columbia to Baja
Horse Clam	Alaska to San Francisco

Figure 2 - 39: Distributions of clams taken by sport fishermen in California.

Mussels are collected by sport fishermen in California and small commercial interests. Mussels are eaten and used for bait. Mussels and clams concentrate a poison from dinoflagellates that causes paralytic shellfish poisoning; consequently, seasonal restrictions often are implemented when dinoflagellates bloom. Squid are fished with dip nets and are used mostly for bait rather than for food.

Ethnic groups harvest a variety of invertebrates including limpets, turban snails and octopus, from rocky intertidal areas of California. Cusk eels and tidepool blennies are also taken. The invertebrates are caught for food and, in some cases, may form a significant portion of the diet.

INLAND

This section presents an overview of the life histories of the major inland fisheries species. It also discusses the human impacts and influences on these fisheries.

Salmon and Trout

Salmon and trout have similar life and spawning characteristics. Coho and chinook

salmon, coastal cutthroat and steelhead trout all begin in freshwater as juveniles (Barnhart, 1986 and Laufle et al., 1986), but soon venture out to sea to grow and become adults. They then return to their natal river to spawn. Once there, they quit feeding. Salmon which make it upstream, die soon after spawning (Beauchamp et al., 1983 and Hassler, 1987). Steelhead and coastal cutthroat trout which survive the rigors of migration and spawning return to the ocean and prepare to spawn the following year (Barnhart, 1986 and Pauley et al., 1989).

Chinook salmon in the Sacramento River have four separate runs; spring, summer, fall, and winter (Allen and Hassler, 1986). Steelhead have a summer and winter run, although the summer run is now absent from California streams (Barnhart, 1986). Pink salmon have the most distinct runs because they are divided into even and odd years. Pink salmon spend precisely two years at sea before returning to spawn. Even and odd year runs do not mix, so that loss of spawning for one year can result in the permanent loss of a population. Since other anadromous salmonids spend variable (one to four or more years) amounts of time at sea, they can recolonize a river if a year class has been lost (Bonar et al., 1989).

Striped bass

Striped bass spend much of their life in estuaries, moving back and forth between salt and freshwater. They generally spawn in large rivers with sufficient flow to keep their eggs and young suspended off the bottom. In the estuary, juveniles forage on large populations of small invertebrates. As adults, striped bass eat other fish. Females mature in four to six years while males may mature at the end of their first year (Hassler, 1988 and Moyle, 1976).

Sturgeon

Because green sturgeon are less abundant more is known about white sturgeon. White sturgeon spend a good deal of their lives in an estuary while green sturgeon spend more time in the ocean. However, both species are anadromous. Sturgeon are benthic feeders having barbels on their snouts to find prey or go close to the bottom. Sturgeon diet includes clams, crabs, shrimps, amphipods and fish. Female white sturgeon mature around the age of 11-12 years. Sturgeon produce a considerable number of eggs, a 2.8 meter (FL) female white sturgeon captured in the Sacramento River contained 4.7 million eggs. Unlike salmon, sturgeon do not die after spawning and return to salt water. While white sturgeon populations appear to have somewhat recovered from declines suffered from over-fishing, no one knows for sure if sturgeon populations have recovered. Green sturgeon are listed as being common, but lack of information leaves this in question (Moyle, 1976 and Moyle et al., 1989).

American shad

American shad return to the rivers to spawn after three to five years at sea. Shad first appear in the rivers in late March and early April but spawning peaks in May and June. Shad are mass spawners and usually die after spawning. After they hatch, young shad gradually move out to sea spending only several weeks to several months in an estuary. Most shad enter the ocean from September to November. While in the estuary, juveniles feed on zooplankton at the surface (Moyle, 1976).

Catfish

Catfish are typically nocturnal bottom feeders that lack scales. White catfish prefer the lower reaches of large coastal streams and are found

in the Sacramento–San Joaquin Estuary. Blue and channel catfish are adapted to channels of large streams. Channel catfish prefer pools beneath log jams or undercut banks and move into riffles to feed at night. Blue catfish hold in large, deep pools (8–10 meters) during the day and find rapids or swift flows for night feeding. As juveniles, catfish eat aquatic invertebrates. But as they grow, fish become an increasingly important part of their diet. They have also been known to eat small mammals on occasion. (Moyle, 1976).

Effects of Development

Human impacts on the ecology of California streams, lakes and estuaries are numerous and varied. Past hydraulic mining and poor timber practices choked the waterways with silt, sediments and debris, devastating many fish populations before the turn of the century. These impacts not only suffocated fish and eggs directly, but also spoiled precious habitat (Skinner, 1962). Today, the effects of past mining and logging still adversely affect rivers because of continuing erosion and dowstream sedimentation. Current logging practices have much-improved stream protection measures, but significant impacts due to loss of streamside vegetation and instream organic matter, as well as sedimentation can still result. Some progress towards restoring aquatic habitat and fish populations has been made recently (see Restoration and Enhancement).

Water diversion and dams pose a great threat to many fish in California. The federal Central Valley Project (CVP) and the State Water Project (SWP) have diverted and changed flow regimes in the the Trinity, Sacramento and San Joaquin River systems, creating problems in up- and down-stream fish migration, poor temperature conditions for spawning and rearing, and alterations to the physical river habitat. These impacts caused major declines in anadromous fish populations. The dams created by the CVP and the SWP also stand as barriers to spawning grounds. Hatchery fish replace some of the losses but fish runs are still much reduced from their historic levels. Fish ladders allow a certain number of fish to migrate past some of the barriers but not all fish (especially sturgeon) can maneuver over the ladders.

Winter-run chinook salmon in the Sacramento system and summer steelhead statewide are in the most danger of being lost. Both these runs meet the state definition of endangered or threatened but have yet to be listed. Spring chinook salmon also appear to be in trouble (Moyle, 1989).

CHAPTER THREE

THE ASSESSMENT AND MITIGATION OF ENVIRONMENTAL IMPACTS

One of the most important sections in any environmental document, after the project description and the description of the location's environment, is the listing of the anticipated impacts to the environment and the mitigations that are proposed to limit those impacts. For many individuals, this is the only part of large documents that is read carefully and completely. For the decision makers who must use the document, this is the section that outlines the hard decisions. In this chapter we will lay out the legal framework for discussing impacts, how such impacts are classified, the use of probability in assessing the risks from the impacts and some of the typical methods of mitigating the impacts. None of this discussion is, of necessity, project-specific. And while we have made an attempt to discuss the effectiveness of many of the mitigations commonly used, it must be borne in mind that no area of environmental assessment is as fraught with discord and honest disagreement as the evaluation of mitigation measures.

THE LEGAL FRAMEWORK FOR IMPACT ASSESSMENT

The National Environmental Policy Act of 1969 (NEPA) and the California Environmental Quality Act of 1970 (CEQA) require an assessment of the various ways that proposed projects can affect their surroundings. These assessments are contained in Environmental Impact Statements (NEPA) and Environmental Impact Reports (CEQA). The purposes of NEPA and CEQA are similar, although the emphasis is slightly different in each:

1. To help public officials make decisions that are based on understanding of environmental consequences, and take actions that protect, restore, and enhance the environment; inform governmental decision-makers and the public about the potential significant environmental effects of proposed activities.

2. To identify the ways that environmental damage can be avoided or significantly reduced.

3. To prevent significant, avoidable damage to the environment by requiring changes in projects through the use of alternatives or mitigation measures when the governmental agency finds the changes to be feasible.

4. To disclose to the public the reasons why a governmental agency approved the project if significant environmental effects are involved.

One of the differences in emphasis between CEQA and NEPA is that the latter places greater emphasis on problem solving and developing acceptable alternatives. In the NEPA Guidelines it is stated, "An environmental impact statement is more than a disclosure document. It shall be used by

Federal officials in conjunction with other relevant material to plan actions and make decisions." Although CEQA insists that an EIR is an informational document (Paragraph 15121,a), the inclusion of mitigation measures and alternatives provide a basis for planning. The recent legislative requirement for mitigation measure monitoring plans (AB 3180) further moves the EIR toward becoming a planning document.

NEPA requires that the discussion of environmental impacts include the following:

1. Any adverse impacts which cannot be avoided if the proposed project was implemented.

2. The relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity.

3. Any irreversible or irretrievable commitments of resources.

4. Direct, indirect and cumulative effects and their significance.

5. Possible conflicts between the proposed project and other proposals known to the regulatory agency.

CEQA includes the same requirements as NEPA, except that "direct" and "indirect" impacts are called "primary" and "secondary" impacts and there is an additional requirement for a discussion of "growth-inducing" impacts.

CLASSIFICATION OF IMPACTS

Any environmental analysis must investigate not only the full range of disciplines (air, water, biology, aesthetics, etc.) that might be affected by a project, but it must also consider the various sources of these impacts. Do the impacts occur during a specific project phase such as construction, operation, abandonment or upset conditions? Are they direct or indirect? What is the duration of impact, short or long-term? Is the extent of the impact local or regional in scope? Is the impact significant, growth inducing or cumulative? Finally, is the impact adverse or beneficial? All of these factors must be considered in the environmental analysis and reported in the impacts section of the environmental document.

Project Phase

Construction impacts are often of short duration, but may be intense. As an example, the noise associated with construction equipment might be significant, but limited to daylight hours when ambient noise levels are higher and people are generally engaged in sensitive (quiet) activities. In contrast, the impacts from the operational phase of a project will likely be longer in duration, since they will occur over the life of the project. Abandonment of a project typically produces impacts similar to the construction phase. Upset conditions (accidents) may produce a range of impacts depending on the severity of the accident. For many projects, it is these "upset" impacts that generate the "worst case" scenarios, and the most interest and discussion among both the public and the decision-makers.

Direct and Indirect Impacts

Direct impacts are those which are caused by actions associated with the proposed project and which occur at the same time and place. Indirect impacts are those which occur later in time or in another location from the original action and impact. The difference between

direct and indirect is best indicated through example. An accidental spill resulting from an offshore shipwreck is a direct effect which could lead to many indirect effects (reduction in water quality, destruction of habitat, loss of faunal populations, diminished aesthetic quality and recreation use, reduction in commercial fishing) sometime later at a distant location. Another example is the disturbance of the toe of an unstable landslide mass while building an access road which could result in the direct effect of a landslide during a wet winter. As mentioned above, these impacts are referred to as "primary" and "secondary" impacts in CEQA documents.

Duration of Impact

The distinction between short and long-term impacts is obviously a relative one. With respect to noise, the presence of a pipeline construction spread for a day or two in the vicinity of a residential neighborhood might be regarded as a short-term impact, whereas two or three months of activity in the same location would be regarded a long-term. Taking biological systems into account, the loss of habitat values for a single season might be considered short-term, but persistent impacts over several seasons would be viewed as a long-term effect. The assessment of long-term impacts generally requires stricter application of criteria than does the assessment of short-term impacts.

Local and Regional Impacts

The geographic extent of an impact is also an important consideration. A significant adverse impact that is extremely localized may not be as important to a decision-maker as a less severe impact that is widely distributed. Local and regional are, again, relative terms. A "local" impact in a document produced for the federal government might be deemed a "regional" impact in a city, county or state document.

Growth-Inducing Impact

Most development carries with it the potential for increasing growth in an area. This growth itself can be seen as an impact. The magnitude and significance of this growth-inducing effect depends on a number of factors, including:

1. The location of the development in relationship to existing services.
2. The demand for services to the project.
3. The precedent-setting nature of the development.
4. Established policy regarding development.
5. The size and density of the project with respect to its surroundings.

Cumulative Impacts

A cumulative impact is defined as one which is individually minor but, when combined with other similar impacts, could be significant. In order to be useful, the term "similar" must be defined so that a limited universe of actions is assessed. For example, the cumulative effect of reduction in water quality may be limited to that watershed in which the action occurs. However, if the change in water quality affects a threatened species of bird, the cumulative effect might extend to an assessment of all of the areas where the bird's habitat occurs. NEPA defines such actions as "other past, present and reasonably foreseeable future actions regardless of what agency or person

undertakes such other actions," a very broad definition. CEQA cautions that the discussion of cumulative impact should be guided by the standards of practicality and reasonableness, but should contain either 1) a list of past, present, and reasonably anticipated future projects, including those projects beyond the control of the lead agency, or 2) a summary of projections contained in an adopted general plan or related planning document. Recent court cases have established that agencies take a broad view of "anticipated" projects.

Significance Levels

Later in this chapter there is a list of impacts often found in EIRs and EISs related to development along the California coast. In an environmental document prepared under either NEPA or CEQA, each such effect must be rated in terms of significance. A significant effect on the environment is defined in the CEQA Guidelines as "a substantial adverse change in the physical conditions which exist in the area affected by the proposed project. Further, when an EIR identifies a significant effect, the government agency approving the project must make findings on whether the adverse environmental effects have been substantially reduced or if not, why not," and as to whether the impact is irreversible (CEQA Guidelines, Sec. 15126,f).

This reduction in environmental effect can be accomplished by adopting one of the alternatives discussed in the environmental document, by changes to the project (mitigations), or by disapproving the project in whole or in part. In a CEQA document every impact identified must be rated, after mitigation, in one of the following categories:

1. Impacts found to be not significant.
2. Impacts mitigated to the point of insignificance.
3. Significant impacts which cannot be avoided if the project is implemented.

PROBABILITY AND RISK ASSESSMENT IN ENVIRONMENTAL DOCUMENTS

"The real trouble with this world of ours," as G. K. Chesterton once said, "is not that it is an unreasonable world, or even that it is a reasonable one. The commonest kind of trouble is that it is nearly reasonable, but not quite." This "not quite" is due to the fact that in real life it is only in rare instances that we meet problems which have just one certain answer. The usual case, and particularly in questions dealing with biological or social matters, is the answers to these questions are more vague and complicated than a yes-or-no, black-or-white answer. We never have enough knowledge to come to a definite and certain conclusion.

To reach conclusions in such a setting requires the use of probabilistic reasoning; the technique of the educated guess. One of the most important and striking aspects of modern science is the almost unlimited usefulness of probabilistic reasoning. This viewpoint has been developed and accepted chiefly over the last half century, although the general public is still suspicious of the idea. In spite of using probability instinctively every day, most people are usually convinced that "statistics" means fraud. In particular, in environmental documents the use of statistics and probability calculations is subject to much abuse, both by the authors and the readers.

Mathematical Basis of Probability

Probability is a relatively new branch of mathematics, and possibly its unsavory

reputation stems from the fact that it grew out of the needs of Victorian gamblers. Probability, like many branches of mathematics, depends on viewing the world as a series of "models," or mathematical abstractions. Geometry, for example, deals with assumptions that a "point" has no dimensions at all, while a "line" has direction, but no thickness. Even though no such object could exist in our world, the theorems derived from geometry have clear usefulness in that world. The same is true for probability. Many theories are developed about "equally probable outcomes" even though real events are rarely exactly equal in probability.

One applies probability analysis to situations in which a number of different outcomes can occur, and what is needed is some guide to the relative likelihood of these different outcomes. All of these alternative outcomes that might occur can be called simple "events." If you roll one die, there are six possible simple events. If you roll two dice, there are 36 possible events. If you toss a "fair" coin, there are only two possible events, Heads or Tails. If, on the other hand, you are considering surgery, how many events, or outcomes, are there? There will doubtless be a wide range of possibilities, from complete and prompt recovery to death, with various degrees of recovery as intermediate possibilities. So there would be many outcomes or simple events, but you might be concerned with only a single question: Do I survive or not?

These examples differ in an important regard. When one rolls a die, it seems reasonable to apply to this real event the results of the mathematical model which is based on the assumption that six possible outcomes are equally probable. But for the surgery it is obvious that all possible outcomes are not equally probable. If, for example, the surgery is minor, and one is in vigorous health, then it is extremely likely that one will survive the operation, and extremely unlikely that it will prove fatal. This comparison has a further important peculiarity. A large part of one's willingness to consider as equally probable the various outcomes of rolling dice depends on the fact that one can roll dice as many times as one pleases, and can observe that the "equally probable outcomes" do in fact tend to happen equally often. In the case of the surgical procedure there is, of course, the record of surgical experience in similar cases. But the operation, with all one's special qualifications, can be made only once.

When studying real situations then, there are two kinds of situations involving probability considerations. In the first type of situation, an investigator can say "There are involved here x number of possible outcomes and it appears reasonable to consider them all equally likely." In this case there is no difficulty in setting up a model with useful application to the real situation.

In the second case, it may not be possible to sort out the possible outcomes, or it may be obvious that they do not have equally possible chances to occur. In this case it is still possible to construct reasonable models of the real events using more complicated probability theorems, but more care must be taken with the assumptions that go into the construction of the models and the interpretation of the results.

Calculating Probabilities

As can be seen from the above, there are usually two ways to calculate the probability of an event, numerically or historically. Both are equally valid, and both have pitfalls that can distort the final event's probability.

To numerically calculate the probability of an event occurring one has to first analyze all possible outcomes. In the example of rolling one die, for instance, there are six possible outcomes. One must then decide if all the outcomes are equally likely. For dice the chance that any given side will come up is the same for each side of the die. This results, then, in a one-sixth chance that any given number will appear when the die is rolled, or a probability of .167.

In terms of environmental documents there are very few examples of this type of probability calculation. It is rare where all possible outcomes or their relative likelihood of occurrence can be divined for either natural phenomena or complex projects.

The second method of calculating the probability of an event is to use historical data. The number of times the event of interest has occurred is tracked over time, distance or other base, and a unit value is calculated, giving an indication of how often the event will take place in the future. The two biggest pitfalls with such an approach are the tendency to assume that future conditions will match past conditions, and that the probability is somehow causative. For example, the probability of a coin coming up "heads" when flipped is .5. If a coin has been flipped 10 times, and has come up "tails" each of those 10 times, the probability of it coming up "heads" is still .5.

One common example of this type of probability calculation seen often in environmental documents is the "100-year storm." Weather data gathered over a long period of time is analyzed, and a prediction is made of the largest storm that would occur in a 100 year period. Of course, there is no guarantee that a 100-year storm will not occur the year following a previous 100-year storm, or even the month after. It is also very difficult to say that long-term climatic conditions over the near future will be the same as they were over the past. If conditions are wetter or dryer, then the 100-year storm event calculations will be out of phase with the new reality.

Another calculation of this type shows up in estimating the probability of a transportation accident; for example, oil tanker groundings. Instead of using time, these calculations often measure the number of accidents that happened historically compared to the number of trips made, or miles travelled or amount of cargo carried. These can be combined; one can see a figure like "one accident per million barrel-miles", indicating either a million barrels carried for one mile, or one barrel carried for one million miles. Reading the fine print of such documents is essential to ensure that the conditions being predicted match the historical conditions used in the calculations. For example, in calculating tanker groundings there can be a large difference in the final probability depending on what tanker trips are counted. Does one use all tanker trips world-wide? Does one only use tankers that are "flagged" in the United States? The first figure would probably be too high, as it would include tankers grounded during the recent war in the Middle East, a factor which shouldn't (hopefully) affect California coastal traffic. And the second figure, although used by MMS, is too low, both because there are a considerable number of foreign flag tankers that use California ports, and because many US flag tankers travel waters far safer than the California coast. To be most accurate, the conditions used in the probability calculations should match as closely as possible the conditions being predicted. For the calculation discussed above, for example, one might look at all steamship traffic within a

certain distance from the California coast over the last 25–40 years to develop an accident rate, and apply that to tankers.

Multiple Event Probabilities

Many situations being discussed in environmental documents are not simple events in the probabilistic sense. They are multiple events. For probability's sake, such events can be classified as "mutually exclusive," "independent" or "dependent," and the calculations for each type of interaction are different.

If, of two events A and B, the one has no conceivable relationship with or influence on the other, then the two events can be called "independent" events. If event A is "throwing a six with a die" and the event B is "cutting a deck of cards and obtaining a face card," then A and B are independent. The two procedures are clearly unrelated.

If event A is "getting 'heads' in the first toss of a certain coin" and event B is "getting two successive 'heads' by tossing the same coin a second time," then A and B are not independent events. For B cannot happen as a result of two tosses unless A happens on the first toss. The two events are interlocked, and dependent.

When events are related, or dependent, there is one special case of interrelation that deserves a separate name. If the dependency is of such a nature that if A occurs B simply cannot occur, whereas if B occurs A simply cannot, then the two events are called mutually exclusive.

When calculating the probability of mutually exclusive events, their probabilities add to give the probability that one or the other will happen. If two (or more) events are independent, then their individual probabilities multiply to give the final probability that both (or all) will occur. For multiple events which are not independent or mutually exclusive, the calculation of a final probability becomes more complex than we can discuss here.

Probability Interactions—Effects plus Impacts

In environmental documents there are often probabilistic interactions combining the event which is to happen, and the effect of that event happening. For example, one can calculate the probability of an earthquake of a given size happening in a certain location. You can then calculate the probability of that size earthquake generating a particular effect (say a certain acceleration on the ground). And you can go on to calculate the probability of that acceleration causing a degree of damage. Some of these effects are purely "engineering" calculations, others are probabilistic, and still others are some combination, but the final result is invariably presented to the reader as a probability that a bridge, building or pipeline will fail due to earthquake. To check that the final result is correct requires that each separate calculation be reviewed for the correctness of the assumptions made, and that the results have been correctly combined. Often the calculations are in separate parts of the document, with the probability of an earthquake happening and the size of the event in the "Geology" section, and the probability of failure due to the earthquake being calculated in the "System Safety" section.

Low Probability Events

Many of the events of interest in environmental documents have very low probabilities of occurrence, and most people have great difficulty dealing with these low

probabilities. And many studies (summarized in Zeckhauser and Viscusi, 1990) indicate that most people react irrationally to small probabilities.

Small probabilities of occurrence are shown in environmental documents in one of two ways. The first is the traditional mathematical representation of the event's probability and is shown as "a probability of 10^{-7}," which is equal to a probability of .0000001. The second is a presentation of the "odds" of an event happening, for example, 1 in 10 million. Both of these methods of presentation have problems. For example, most people will not differentiate between a risk of 10^{-7} and one of 10^{-5}, a risk 100 times as large. Even when presented as odds (1 in 10 million as opposed to one in 10 thousand), most people will have trouble accurately assessing the relative risks.

Even when they are able to deal with the mathematics of low probability events, people react to such numbers on factors irrelevant to the events under study. People generally overestimate the likelihood of low probability events they have no control over (death by tornado), and underestimate the likelihood of events they do have a degree of control over (death by heart attack or stroke) (Fischoff,et al, 1981). It is also typical to allow societal "norms" to distort probabilities; most of us would not drive off on a 10-minute errand leaving an infant unattended in our home, even though infant deaths in automobiles far outnumber infant deaths in the home. These kinds of effects lead people to violently oppose an event that has a chance of one in 10 million of occurring due to some type of development, while cheerfully accepting the 1 in 5000 odds of dying on the highway.

Methods of Presentation

Of all the areas where probability information is subject to manipulation, none is more abused then the final presentation of results. It is very easy, intentionally or unintentionally, to present this type of information in a way that misleads, confuses or even misstates the actual results.

Graphics are often used to summarize statistical data of all types. They have the advantage of showing a lot of data in a form that most people understand, but this leads to the disadvantage that people can easily think they have a clear picture when the basis of the graph or table does not rest on firm foundations. A common example comes from news magazines or newspapers, where graphs often have the lower values left off to save space, or have scales which are distorted to show large changes when in fact the changes are very small. An increase (or decrease) in the United States federal budget of .00001 per cent is trivial, but graphed as a change of "x hundred dollars" looks like the end of the world. Picture graphs can be even worse, since the changes are proportional to the area of the figure, but most people interpret only the change in length or height.

One tool used in environmental documents, especially in discussing the system safety aspects of a project, is a "fault tree analysis" or "failure tree" (Figure 3-1).

This type of illustration shows the relationships among all the possible types of system failures, and can go on to show the possible results of each type of failure. It is also possible to show the calculated probability of each event occurring. Then it is a matter of combining whatever string of events one is interested in to arrive at a final probability. For

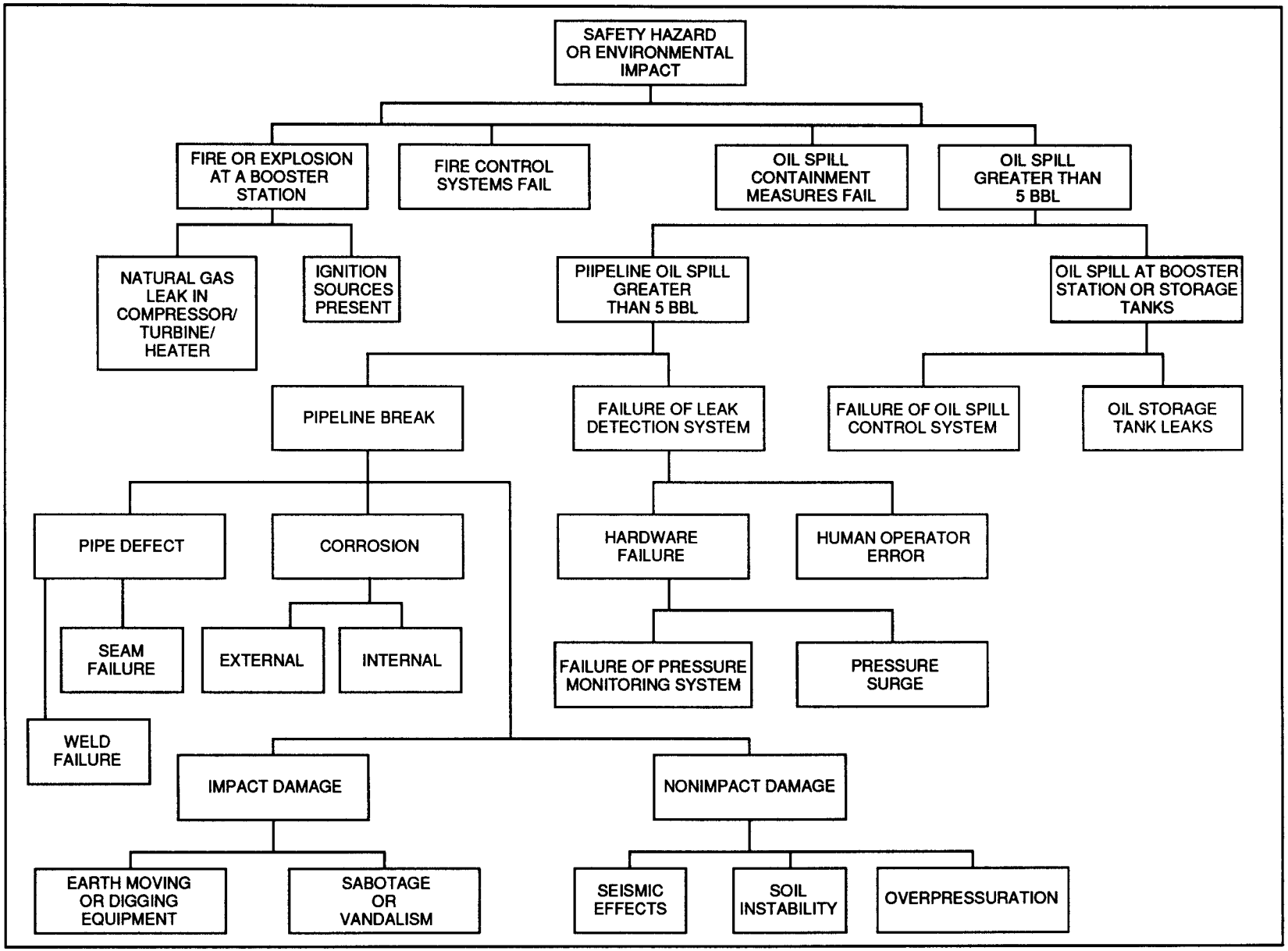


Figure 3-1: Fault Tree for a Heated Oil Pipeline System.

example, in the attached figure, under "pipe defect" are two categories: weld failure and seam failure. If the probability of weld failure is calculated at one in 10,000 and the probability of seam failure is the same, one in 10,000 (both of these numbers were invented), then the chance of a "pipe defect" is two in 10,000, or one in 5000.

Another tool used in analyzing various risks and their consequences is a matrix showing possible events down one side and resultant impacts across the other axis. As shown in the attached figure, this allows one to compare the probability of an event with the severity of its impact. The more severe the potential impact, the lower the probability of the event happening must be to be acceptable.

As an aside, one often hears demands that the probability of an adverse result should be reduced to zero. The plain fact is that it can't be done. Given enough time, any conceivable event (and many which we can't conceive of yet), has a finite probability of occurring. The probabilities can be reduced to levels that may be considered acceptable, but the level of acceptability and the level of potential damage will be a non-zero value in every case.

Acceptable Risks

One widely held ideal in this country is that the decision-making process should be an optimizing one. That is, a desired solution is that which maximizes the social welfare, while being as equitable as possible in distributing both costs and benefits among various segments of society. Another ideal is that decisions should be reached by desirable (democratic or participatory) processes, even if the result is not optimal for social welfare (White and Hamilton, 1983).

The term "risk" is now used to refer to the probability of occurrence of a certain level of impact in most environmental literature. In common usage, "risk" is often equated with "hazard," to mean simply exposure to a danger. In this section, we will use the word in the first manner. In risk analysis the evaluation of the significance of the risk results in a determination of "safety." Indeed, the distinction between empirical observation and judgement of significance appears several times in the language of decision theory, as shown in the accompanying table. In this usage, the concepts of "impact" and "risk" are analogous, except that by convention, "impacts" usually refer to effects on the natural environment and human welfare, whereas "risk" usually refers to effects on human health.

Terms in Decision Theory

In assessing the social acceptability of a new risk (for example, nuclear power), you can compare it to risks whose social acceptability is better appreciated. You could compare the radiation exposure risk of a nuclear power plant worker to normal background radiation or medical exposures. Or you could compare the health risks of working in such a plant to the risks of working in other types of power generation industries. While such comparisons are useful, they can also be deceptive when taken in isolation. In the above examples, for instance, the decision-makers will have to take into account that the nuclear power plant worker will be exposed to the background radiation as well as that from the plant, and that radiation damage is cumulative.

Another distinction can be made between the social acceptability of voluntary risks and involuntary risks. In the nuclear power plant example, though a worker may be willing to

accept voluntarily the additional radiation dose in exchange for the benefits of the job, a person living in the vicinity of the plant and deriving electrical energy from a windmill on his/her property may be much less willing to accept an ambient radiation dose from the plant, both because the dose is involuntary and because there is no compensatory benefit. Several studies have attempted to quantify some of these relationships (Starr 1972, Otway and Cohen 1975 are examples) with mixed results. One summarizing list (Kates 1978) looks like this:

1. The rate of death from disease sets an upper guide in determining acceptable risk, somewhat less than one in 100 years.

2. Natural disasters (Acts of God) tend to set a base guide for risk similar to the 'noise' level of physical systems. This level, about one in a million years can be considered negligible for man-made risks.

3. As expected, societal acceptance of risk increases with the benefits perceived. The relationship appears to be non-linear, with the acceptable level of risk an exponential function of the benefits, real and imaginary.

4. The public appears willing to accept voluntary risks roughly 1,000 times greater than involuntary risks.

Modeling

One last fact of probability analysis used frequently in environmental documents should be discussed, the "modeling" of either natural events or proposed developments. Such things as air pollution, oil spills, traffic densities or population growth are often modeled, usually using large computers and impressive graphic outputs. These models can be used to show that effects are within acceptable limits or that they pose unacceptable risk, depending on the assumptions fed into the model; assumptions that are very rarely displayed with the final results.

The heart of every computer model of events is a function which generates the probability of an event's happening. The event can be as simple as a pipeline failing on Tuesday next, or as complex as a given parcel of air moving from Point A to Point B in a given time under given conditions. In every model the assumptions are greatly simplified. It is simply not possible to cover every possible interaction in even fairly simple man-made processes, let alone natural ones. The assumptions made in the specific model need to be assessed by the user of the final results before accepting those results.

One of the most common ways of generating probabilities within computer models involves preparing a historical list of actual outcomes and generating a random number to choose among those outcomes. For example, let's look at a model used to determine if pollutants released into the air at a specific location will reach a second specific location. At the first location (the source of the pollution) one must first determine how often, in the course of a year perhaps, the wind blows from each direction. Let us say that we find that the wind blows from the north 50% of the time, from the west 40% of the time, from the east 8% and from the south only 2% of the time. Then, in our computer, when it comes time to model the pollutant's path, we generate a random number between zero and one. If the number comes up between zero and .5, we say the wind was blowing from the north that day. If it comes up between .51 and .90, the wind was blowing from the west. A number between .91

and .98 means an easterly breeze. And we only say there was a south wind if the random number is .99 or 1.0. The key for this process is the historical data set. Often the data is not for the specific site you wish to examine, but for one "near by", and it is up to you to determine if the data would have been the same at the actual site. Sometimes the data isn't complete—maybe there is data for the wind for nine months out of the year, but not for the other three, or one only has a year's data, which may or may not have been a typical year. All aspects of the data, in addition to the program design and the simplifications made count as "assumptions" which must be evaluated when looking at the results of modeling.

Another method used to generate "occurrences" in computer models is the "Monte Carlo Method" or the "Random Walk." This assumes that the occurrence itself is randomly distributed over time or distance, and uses the random number generated by the computer directly. In the example above, we could have taken our random number (between zero and one) and multiplied it by 360 and called the result the direction in degrees of the compass that the wind was blowing from on that day. The key assumption here is that whatever you are simulating is truly distributed in a random manner, and that is a very difficult thing to prove to everyone's satisfaction.

MITIGATION OF IMPACTS

Once the various impacts of a potential project have been identified, and the potential risks analyzed, it is time to develop mitigation measures that will reduce both the impacts and the risks as much as reasonably possible. Mitigation measures are generally available which have the potential to reduce the magnitude, intensity or duration of many possible environmental impacts, but there are many assumptions which must be made before these mitigations are implemented.

First, it must be assumed that the impact in question has been found to be "significant," otherwise mitigation measures are not required, either by NEPA or CEQA. For instance, a number of measures may be proposed as a means of maintaining the health of a wetland, but there is no requirement to apply these measures unless the project carries with it the potential for significant change in the wetland or in factors which might affect the wetland.

Second, assumptions must be made concerning the applicability of a mitigation measure to a specific set of conditions.

Third, many questions about how the mitigation measure is to be implemented must be answered. For instance:

1. Who will finance the work, both initially and in the long term?

2. Is it the right time of year to proceed or will the project proponent have to wait until the following year to begin a mitigation program?

3. In the case of large-scale measures, such as the provision of a new interchange, are there potential impacts associated with the mitigation measure itself?

4. Is there enough available information concerning the recommended mitigation measure to make its success likely?

Both NEPA Regulations and CEQA Guidelines (Section 15370) recognize five categories of mitigation:

1. Avoiding the impact altogether by not taking a certain action or parts of an action.

2. Minimizing impacts by limiting the degree or magnitude of the action and its implementation.

3. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.

4. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.

5. Compensating for the impact by replacing or providing substitute resources or environments.

The CEQA Guidelines require that the basis for selection of a specific mitigation (from a list of mitigations) be identified. It is recognized that a mitigation may itself cause adverse impacts and such effects should be discussed.

In order for an environmental document to be fully used in the planning process, mitigation measures must be presented in a form that is direct and to the point. In general, when preparing mitigation measures, indefinite phrases such as "coordinate with . . . ," " . . . further study" and "consult" should not be used. When monitoring is called for, special care should be used in providing for the necessary ability to follow up the monitoring with action.

The recently-added requirement that an EIR contain mitigation monitoring plans (Public Resources Code, Section 21081.6) adds to the usefulness and importance of these documents. In the past, mitigation measures have been implemented on a hit-or-miss basis, but the process now "institutionalizes" implementation of mitigation measures, including levying necessary fees for the program. In addition, if a "Responsible Agency" requires a mitigation measure, that agency may be required to prepare the necessary monitoring program.

Several cases were tried during the 1980s regarding mitigation under NEPA and CEQA. Most of the decisions placed a heavy burden of proof on the lead agency to prove that mitigation measures would be effective in reducing impacts to an acceptable level, whether an Environmental Impact Statement (EIS) was prepared, or if simply an Environmental Assessment (EA) and a Finding of No Significant Impact (FONSI) were done. Similar standards of review have been used in cases related to EIRs.

There is a specific requirement in CEQA and NEPA for the inclusion of energy conservation measures in environmental documents. This is an area of mitigation which has not received much attention to date. Specific measures, either relating to transportation alternatives, reduction in heating and air conditioning, or land use patterns are needed in order to result in energy conservation.

Specific Assessment Criteria, Impacts and Mitigations

The following lists of impacts and mitigation measures are meant to be a general guide and are not intended to be applied to a specific project without further information about the project, the site and the status of the surrounding environment. They are organized by topic areas typically used in environmental documents, and each topic includes a listing of criteria used to determine the significance of a given impact, a listing of impacts often found in

projects in California, the corresponding mitigations usually applied, and a discussion of their effectiveness. It must be kept in mind that these mitigations and the discussions of their effectiveness are "generic"; decision makers must evaluate the specific impacts generated by an actual potential project in a specific location.

A. AIR QUALITY

Criteria for impact assessment

Will the proposed project result in:

1. Deterioration of airshed quality.
2. Emissions resulting in exceedence of any air quality standard for any parameters, including:

   a. Carbon Monoxides
   b. Total Hydrocarbons
   c. Nitrogen Oxides
   d. Sulphur Oxides
   e. Total Suspended Particulates
   f. Ozone
   g. Other

3. Objectionable odors.

Will the project conform to:

1. The requirements of the regional Air Quality Attainment Plan (AQAP).
2. The requirements of the appropriate Air Quality Management District (AQMD).
3. The requirements of the National Ambient Air Quality Standards (NAAQS).

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Exceed one percent of total basin emissions.	*Transit incentives, ride-sharing incentives, mixed-use.*
Exceed particulate matter standards.	*Grading control plan, use chemical dust inhibitors, limit hours.*
Exceed state one-hour or 8-hour (SO2, NOx, ozone) standards.	*Install SO2 scrubbers on exhausts, use low NOx burners at refinery, use electricity instead of gas or oil. Van pool and bus service for employees.*
Expose populations to objectionable odors. Affect sensitive receptors.	*Control odors at source through system changes, consider wind speed and direction as part of siting criteria.*

The significance of air quality impacts is identified by their relationship to standards or threshold levels, either individually or as part of a cumulative effect. Where sensitive receptors (such as hospitals or playgrounds) would be directly affected, or where the project could be affected by sources emitting odoriferous or hazardous compounds, significant impacts may occur. Emissions result from land-use related mobile sources and stationary sources, which must be assessed in different ways.

Mitigation measures which serve to reduce emissions from mobile sources are generally not technological in nature; instead, they are related to land use and transportation planning, regulation and management. Their purpose is to reduce vehicle trips, length of trips and pollutant emissions per vehicle mile.

Mitigation measures which serve to reduce emissions from stationary sources are either associated with technological control of the source or relocation of the project to a site which does not directly affect a sensitive receptor.

B. GEOLOGY and SOILS

Criteria for impact assessment

Will the project:

1. Expose people or structures to geologic hazards, such as the effects of seismic events, landslides, mudslides, tsunamis.
2. Result in unstable geologic conditions.
3. Substantially change topography.
4. Increase soil erosion.
5. Result in changes in deposition or erosion of beach sands.

Will the project conform to the requirements of the Uniform Building Code, including specific local requirements?

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Alter topography/soils.	*Balance cut and fill, utilize contours in design, revegetate w/native species.*
Penetrate landslide masses, increasing slope instability.	*Avoid, stabilize, drain or remove landslides.*
Potential for seismic hazard, resulting in slope failure, lateral spreading, subsidence, liquefaction.	*Identify risks, conform to design standards for seismic shaking.*
Coastal erosion rate.	*Set back from beach or bluff.*
Tsunami runup hazard.	*Investigate potential, set back from beach.*
Scour.	*Reroute surface drainage, place buried pipeline, or conduit, below stream scour*
Increase erosion and gullying as a result of vegetation removal.	*Temporary erosion-control measures (e.g., straw matting), minimize amount and time of soil exposure and revegetate, provide drainage structures (use materials and methods associated with maintenance), utilize berms.*
	Avoid construction during rainy season, stabilize removal and excavation.
Subsidence.	*Avoid ground water withdrawal, monitor to detect, reinjection of water.*

Many geologic "impacts" are the result of activities which place development in a position where physical processes, such as landsliding, fault activity or erosion can affect the development or where development activities exaggerate already-existing trends. Often, the best mitigation is to avoid the physical

condition (such as the toe of a landslide). If the location of development cannot be changed, an engineering solution is usually called for. If the condition is associated with small-scale physical processes, biological controls are available and should be given priority over engineering controls.

C. MARINE WATER QUALITY

Criteria for Impact Assessment

Will the proposed project result in:

1. Discharge of any toxic, radioactive, or bioactive chemicals or organisms into marine or estuarine waters.
2. Changes in pH, temperature, salinity, metals or nutrient loading or dissolved oxygen content of any local marine or estuarine waters.
3. Significant increases in local turbidity.
4. Accumulation of chemicals or elements in local bottom sediments.
5. Significantly increased risks of accidental release of toxic, bioactive or mutagenic materials into marine or estuarine waters.
6. Discharge of pathogenic organisms.

Will the project conform to:

1. RWQCB regulations and Basin Plan requirements.
2. Clean Water Act regulations, including NPDES permit regulations.

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Alteration of physical and/or chemical characteristics of the water column and sediments from a major spill or collision.	*Contingency plan to clean up and contain any spilled chemicals. Discharges should be treated to remove or neutralize harmful chemicals.*
Alteration of physical and/or chemical characteristics of the water column and sediments from a discharge.	*Prohibit ocean discharges.* *Increase dilution to meet regulatory standards.*
Increased turbidity from construction or discharges.	*Prohibit ocean discharges. Use construction methods that minimize turbidity.*
Local water temperature increases from discharges of cooling or process waters.	*Stabilize discharge temperature before release.*

There are several levels of mitigations that concern discharges into marine waters. The mitigation preferred by many environmental scientists is to prevent the discharge altogether. This recognizes that many of our near-shore waters appear to have already reached their capacity to handle such discharges.

Beyond avoiding the discharge, the next step is to treat the proposed discharge prior to releasing to reduce its impact on the environment. Proposed treatments range from simple screening, to biological removal of organic material, to tertiary treatment plants. These treatments vary tremendously in both cost and effectiveness.

The most common mitigation is simply diluting the discharge. This can be done in combination with some level of treatment, or can stand alone. One factor that may make a large difference in the effectiveness of dilution is the condition of the pollutant of interest. Water-soluble contaminants pose a very different problem than do particulate ones. While there is disagreement in the scientific community over the effectiveness of dilution as a mitigation, there appears to be agreement that only a case-by-case analysis can be used to make such a determination.

A special case of discharges is drilling muds and cuttings. Here, too, there is a wide divergence of scientific opinion on the effects of these discharges on the marine environment. Studies have been published in scientific journals that indicate such discharges have little or no effect on the environment (NRC 1983). Other studies have shown toxic effects, long term bioaccumulation of drilling compounds and large-scale burial of benthic communities (CGI 1987). The literature covering this issue was summarized by the Chambers Group in 1987 as part of the environmental work for the Arco Coal Oil Point project.

Not only is there dispute over the effect of muds and cuttings, there is dispute over how to treat them in terms of mitigation. Some people advocate barging all such material ashore and disposing of it as a toxic waste on land. Others believe it is sufficient to require that the muds contain no toxic materials, have any incidental hydrocarbons removed, and be discharged in sufficient depth so that they spread out a bit. At present, there is no clear-cut solution.

D. ONSHORE WATER RESOURCES

Criteria for impact assessment

Will the project:

1. Result in changes in rates of bank erosion or deposition in streams, lakes, estuaries or other water bodies.
2. Change in surface water quality (see FRESHWATER BIOLOGY).
3. Interfere with ground water recharge.
4. Change the amount or rate of surface runoff
5. Alter the quantity, rate of flow or direction of ground waters.
6. Decrease ground water quality.
7. Alter stream hydrology, change amounts and timing of flows, change flood frequency.
8. Expose people or property to floods.

Will the proposed project conform to the requirements of the Regional Water Quality Control Board?

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Degradation of surface water quality, including turbidity, pH, BOD, heavy metals, temperature, etc.	*Baseline study and monitoring program, retention basins, control discharge, realign routes, transport toxic waste, using thicker pipe, high-quality valves where conduits cross water bodies and other sensitive areas, use valves at appropriate locations, frequent inspection (See TERRESTRIAL and FRESHWATER BIOLOGY).*
Alter drainage patterns, thereby causing erosion and bank sloughing.	*Prepare drainage management plan.*
Flood hazard.	*Calculate 100 yr flood and construct accordingly.*
Increase streamflow.	*Retention basins.*
Increase sediment loading, as a result of construction activities.	*Retention basins, sediment traps (See GEOLOGY and SOILS).*
Cause groundwater basin overdraft.	*Desalinization, water re-use, artificial recharge.*
Allow discharges to reach and contaminate groundwater.	*Line ponds or wells, discharge into basins protected by non-permeable formations.*

As with geological impacts, impacts associated with on-shore water resources can be mitigated best by re-siting the project. For instance, building below the level of the 100 year flood plain is generally not allowed. Preparation of a drainage plan at an early stage of planning may reveal ways to avoid alteration of stream channels. Like freeways, water bodies such as streams, lakes and estuaries can exceed capacity, and not be able to continue to function. Since water in California is limited, streamflow and water quality changes are especially critical to the ecosystems in the state and require special attention.

E. MARINE BIOLOGY

Criteria for Impact Assessment

Will the proposed project result in:

1. Alteration of local biological communities.
2. Impacts to sensitive habitats.
3. Reduction in the numbers of significant species.
4. Interference with breeding or migrating species.
5. Increased bioaccumulation of bioactive chemicals.
6. Toxicity or reproductive effects.

Will the project conform to;

1. U.S. Fish and Wildlife and California Department of Fish and Game requirements for protection of threatened, rare or endangered species.
2. California Department of Fish and Game permit regulations.
3. California Coastal Commission consistency findings and permit regulations.

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Damage to kelp canopy from vessel traffic. Disturbance or loss of kelp habitat from construction or structure placement.	*Avoid kelp areas, including use of vessel traffic lanes.* *Kelp restoration plans.*
Disturbance to hardbottom habitats from construction or structure placement.	*Avoid hardbottom areas.* *Artificial reef to replace the habitat lost.*
Impacts of chemical spills on intertidal habitats, seabirds, harbor seal haul-outs, Areas of Special Biological Interest, research areas, fish species, and benthos.	*Develop contingency plan to keep spilled chemicals away from critical areas.*
Vessel collisions with marine mammals.	*Vessel operator training programs.*
Injury to marine mammals or birds from blasting operations.	*Have marine biologist on-site to ensure mammals or birds are not in area during blasting.*
Disturbance of nesting birds or marine mammals by low level aircraft or helicopter flights.	*Reroute flight paths or set minimum altitudes.*
Impacts on rare, threatened, or endangered marine species.	*Avoid particular species and their habitats.* *Baseline studies and monitoring programs.* *Creation of new habitat and restoration of degraded habitat.*

The field of marine biology is so complex that there is likely to be argument over any proposed impact or mitigation. Many of the processes active in the ocean and its associated biota are not understood at the present time. Thus, the effect of potential projects cannot usually be fully understood. For any given impact, there is usually a range of possible mitigations, and there will be legitimate debate over the most appropriate one to use.

In terms of habitat disturbance the preferred mitigation is avoidance. This applies whether the habitat is hard bottom reef, kelp forest or rocky intertidal. Habitat restoration has been attempted in wetlands and kelp beds with mixed results. "New" reef habitat (artificial fishing reefs) has been created out of various materials, but the relationship between production of fish and the reefs has not been demonstrated. Restoration of other marine habitats is not presently possible.

Much more research is necessary before we have a real idea of the impacts of many proposed projects. The life cycles of many marine organisms remain unknown or poorly understood, and many potential impacts are unknown. The fates of various chemicals and wastes in the ocean system are equally unknown. It was previously thought that

anything dumped in the ocean would simply "disappear," and would be quickly broken down into harmless components. We now know that this simply isn't true for many compounds, some of which can exist for years in the ocean without losing their ability to do harm. Other compounds, thought to be benign, turn out to have effects that are harmful to some species.

As with marine water quality, there is often honest debate within the scientific community on the potential impacts of different types of projects, or on the effectiveness of proposed mitigations. What is harmful to some is beneficial to others. Much research that has been done in one geographic area is applied to other areas, a practice that is not universally accepted as appropriate. And there is no research at all in many topic areas and geographic regions that are critical to the evaluation of the effects of development on our coastlines.

F. TERRESTRIAL & FRESHWATER BIOLOGY

Criteria for impact assessment

Will the proposed project:

1. Reduce or destroy valuable or sensitive habitat.
2. Reduce diversity.
3. Substantially reduce wildlife populations.
4. Remove plant community.
5. Introduce new species.
6. Interfere with movement or other behavior of resident or migratory wildlife species.
7. Change water quality, including dissolved oxygen, temperature, heavy metals, . . .
8. Change water flow, causing scouring, deposition, increased water temperature, turbidity.
9. Interfere with movement of resident or migratory fish species and habitat.
10. Alter stream channel morphology, meanders and erosion/deposition, bottom substrates.

Will the proposed project conform to:

1. U.S. Fish & Wildlife, National Marine Fisheries Service, State Department of Fish & Game and Native Plant Society lists of threatened, rare and endangered species.
2. U.S. Forest Service, BLM policies and guidelines, State Dept. of Forestry, local Heritage (or hardwood) Tree standards.
3. Department of Fish & Game regulations.
4. Fish and Game Commission policies.
5. Clean Water Act requirements.
6. Migratory Bird Treaties (e.g., swallow nests, ducks, etc.).

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Remove plant community. as a result of road building and pipeline construction.	*Relocate to alternate site or re-contour, stabilize and re-vegetate w/local native species. Realign access and conduit routes, minimize construction rights-of-way, restore vegetation offsite, in extreme cases salvage (transplant) rare plants*

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Loss of threatened plants and wildlife species.	*Baseline study and monitoring program, realign access and conduit routes, develop alternate site. See mitigations for Remove Plant Community, above.*
Effects of noise, light, human presence, erosion and sedimentation on sensitive habitats and species.	*Baseline study and monitoring program, use alternative construction methods, construct retention basins, restrict blasting, select alternative flight path, construct noise buffers.*
Disrupt breeding, nesting.	*Alter construction schedule, restrict and monitor vehicle/pedestrian movements.*
Sour gas leak affects sensitive species.	*See RISK of UPSET.*
Loss of habitat.	*Baseline study and monitoring program. Avoid habitat, create and maintain similar habitat (greater amount than that lost). See mitigations for Remove Plant Community, above.*
Clearing for project components could isolate habitat.	*Provide corridors for wildlife.*
Effect of runoff on freshwater habitat.	*See ONSHORE WATER RESOURCES and GEOLOGY and SOILS.*
Increase wildfire hazard.	*Fire safety and fuel management program, prescribed burning or other vegetative manipulation.*
Expose soils.	*Avoid construction during rainy season, moisten surface during construction, prepare revegetation plan. See GEOLOGY and SOILS for erosion control methods.*
Expose sand dune surface, resulting in damage to vegetation and wildlife habitat due to shifting sand.	*See GEOLOGY and SOILS (Topography/Soil Alteration).*
Damage to vegetation due to presence of new resident (human and associated domestic animals) population.	*Provide fencing, regular patrol.*
Increase potential for invasion by non-native species.	*Remove by hand. Reestablish native habitat, utilize vegetation management techniques such as "competition."*
Damage to vegetation due to air pollution (ozone, acid rain).	*Install improved refinery equipment and operations, install SO2 scrubbers.*

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Accidental spills could impact fish and benthic invertebrates, wetlands and terrestrial habitat.	*See RISK of UPSET.*
Remove fish spawning & rearing habitat	*Replace gravel, rip gravel, plant riparian vegetation, add logs and boulders.*
Block fish migration	*Remove blockade, install fish ladders*

Appropriate mitigation for impacts to biological resources depends on the type of disturbance and characteristics of the species and habitats involved. However, there are some generally accepted guidelines for mitigating sensitive resources. The first choice is that impacts should be avoided or minimized to the maximum extent possible. For impacts that cannot be avoided, measures should be taken to remedy or rectify them at the site of impact, such as revegetation or other reclamation practices. As a last resort, unavoidable impacts should be compensated for by providing substitute resources for those which are destroyed.

This priority of actions has evolved with improved knowledge and experience of ecological restoration and conservation of biological diversity. Many practices thought to be adequate in the past have been shown to be inadequate and even cause impacts themselves. For example, reestablishment of naturally functioning populations and habitats has proven to be very difficult. In addition, the creation of new habitats may cause the loss of existing habitat values. Artificial propagation methods such as fish hatcheries can weaken the genetic make-up of populations and are vulnerable to disease outbreaks. Lastly, remediation measures may cause worse damage than the original impacts, such as many oil spill clean-up measures.

G. CULTURAL RESOURCES

Criteria for impact assessment

Will the proposed project:

1. Adversely affect a prehistoric or historic archaeological site.
2. Adversely affect a site or property of cultural significance to a community or ethnic group.
3. Restrict existing uses which are religious or sacred to a recognized group.

Will the proposed project conform to:

1. Appendix K of the CEQA Guidelines.
2. Legal requirements for dealing with human remains.
3. Needs of the Native American community.

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Disturb prehistoric sites.	*Avoid significant sites, subsurface testing to identify significance and boundaries of sites. Where avoidance not feasible, institute salvage program, negotiate MOA with Native American community, conduct genealogical, ethno-historical and ethnobotanical studies, protect sites during construction.*
Disturb burial sites	*Avoid site, reburial, negotiate MOA with Native American community*
Disturb native plants valued by Native Americans.	*Conduct study to determine significance and sensitivity of plants, avoid sensitive locations, minimize right-of-way, relocate plants (3 to 1 ratio).*
Disturb areas/viewsheds considered sacred by Native American groups.	*Avoid site, negotiate MOA, restoration plans.*
Disturb historic sites.	*Conduct study to determine significance and boundaries of sites, avoid significant sites, stabilize structures in nearby areas, document historic resources w/photos, drawings, etc.* *Provide educational programs for construction crews.*

Mitigation for cultural resources involve the protection of prehistoric sites, artifacts, historic locations and resources having particular significance to Native Americans. Since each location is unique, the preferred mitigation is avoidance and preservation.

A major problem with many of these resources is that they are buried, and may not be detectable on the surface. This means that they can be discovered at times only when a project—such as a building foundation or pipeline trench—disturbs them. For this reason it is common practice to have experts monitor ground-disturbing construction in areas where cultural deposits are likely to be found. These experts can be paleontologists, archaeologists, historians or representatives from the appropriate Native American communities, depending on what may be encountered on the particular project site.

What happens if a known site cannot be avoided, or if a new site is discovered in the course of construction, is a matter of some controversy. Archaeologists prefer to have sites involving prehistoric artifacts and remains

excavated under expert supervision, and to have the discoveries conserved in a museum. On the other hand, Native Americans would usually prefer that objects and remains be re-buried with proper ceremony. This is a recurring conflict that does not yield easily to compromise.

There is usually no acceptable mitigation for loss of areas or habitats having religious significance to Native Americans. Since it is the location that is sacred, any modification to the location is seen as a clear invasion. Destruction of plants or ecological communities of importance to these groups can sometimes be mitigated by restoration in a manner similar to that used for other biological communities.

Historic properties are usually subjected to the test of meeting criteria for the National Register of Historic Places. If a site meets eligibility for the Register, it usually also merits increased protection from development, and preservation is often required.

H. AESTHETIC RESOURCES

VISUAL

Criteria for impact assessment

Will the proposed project result in changes in views:

1. From primary travel routes and use areas.
2. Which include a component for which there is public interest and concern (e.g., historic monument).
3. Of a sensitive or unique natural community.
4. On the horizon.

In addition, the significance of the impact on the visual resource depends on the condition of the resource, the degree of variety exhibited by the resource, the distance of the object from the viewer, viewer expectations, number of viewers, public vs. private views, duration of view, duration of project activity and duration of impact.

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Affect views from recognized viewpoints by:	
Light and Glare	*Modify, shield source, use non-reflective surfaces*
Change on horizon	*Build below sight-line.*
Linear clearing	*Avoid steep slopes, avoid more visually-sensitive plant communities (e.g., chaparral), revegetate less steep slopes, control erosion.*
Cuts and fills related to road, pipeline and building construction	*Avoid steep slopes, revegetate less steep slopes w/deeper soils, follow contours.*
Pipelines crossing drainage	*Combine w/existing bridge, use color, trench pipeline.*
Pads or other rectilinear construction sites	*Locate on edge of plant community, select secluded location, plant vegetative screen.*
Erosion of earthen catch basins	*See GEOLOGY and SOILS.*
Construction activities	*Avoid rainy season construction, avoid steep slopes, work w/contours,*
Structures block view	*Rearrange/reorient structures, maintain view corridors.*

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Structures degrade views	*Decrease and break-up mass, use color and texture.*
Accidental spill	*Employ containment, clean-up plan. See RISK of UPSET.*
Degradation of air qualify affects views.	*See AIR QUALITY*

Some impacts to visual quality can be effectively mitigated. The size of a building or its location might be modified to remove it from the line of sight. However, some structures—offshore platforms for instance—cannot be effectively mitigated. Changes in size, color, orientation, etc., might reduce, but cannot eliminate, the impact. Landscaping may eventually screen a building from view, but the impact could persist for as long as it takes for the plantings to mature. Since the visual quality issue is so subjective to begin with, the question of mitigation effectiveness cannot be expected to be less so; therefore, controversy over this issue should come as no surprise.

NOISE

Criteria for impact assessment

Will the proposed project:

1. Result in substantial increase in existing noise levels.
2. Exposure of existing or future population to noise levels which exceed standards.

Will the proposed project conform to:

1. California Department of Health Services, Office of Noise Control.
2. Federal Aviation Administration.
3. Local noise requirements.
4. EPA Noise Level Guidelines, 1974.
5. Federal Highway Administration noise abatement criteria.
6. California Department of Transportation.

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Construction and/or operational noise exceeds state and local standards.	*Require noise reduction, limit hours, construct barriers, insulate sensitive receptors, restrict adjacent land use.*

Mitigation measures are generally effective in reducing impacts from long-term operational noise generated by a stationary source. In such cases construction of barriers, insulation of the source, or even restriction of adjacent land uses may be practical solutions. In contrast, short-term mobil sources of noise, such as a pipeline construction spread, are more problematic. In these cases, regulation of the time-of-day work takes place and requiring source controls (mufflers) may be the best, even if not totally effective, mitigations available.

I. INFRASTRUCTURE

Criteria for impact assessment

Will the proposed project:

1. Increase traffic to the degree that intersections and thoroughfares will reach an unacceptable level of service.
2. Affect existing on-street or off-street parking.
3. Over-utilize existing mass transportation systems.
4. Increase traffic hazards to motor vehicles, pedestrians or bicyclists.
5. Substantially reduce the available capacity of public water supply, sewage treatment, energy systems, schools, solid waste, toxic waste, public safety personnel and facilities.

Will the proposed project conform to regulations and standards of:

1. Local plans, ordinances or capital improvement programs.
2. California Coastal Act.
3. Solid Waste Management Board.
4. Water Resources.
5. Energy Commission.
6. Water Resources Control Board.
7. California Department of Transportation.
8. California Department of Health Services.
9. Federal Highway Administration.

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Construction activities disrupt traffic.	*Coordinate activities w/peak hour. Provide temporary safety personnel and equipment.*
Approach critical level of service in transportation network.	*Financial assistance for capital improvements, contribute to fund, especially for improved intersection capacity. Reduce traffic generation, reduce project, provide bussing. Shift traffic to non-peak hours.*
Transportation of hazardous materials.	*Prepare and implement plan for safety and emergencies.*
Capacity of public services and utilities (including water, energy, waste, public safety) supply, storage and distribution facilities may be exceeded.	*Capital improvements, contribute to fund, reduce demand through reduction of project size, conserve water, energy; participate in monitoring program and adjust use based on results.*

Each community will generally have established standards which define the level at which services are considered adequate. Providing effective mitigations to long-term impacts which exceed these standards is often problematic, especially when the impact is cumulative. Monetary contributions may be used to develop a pool of funds from a number of projects. However, such mitigation measures may not result in service improvements at the same time as the impacts are first felt. It should be recognized that until the funds are spent, the impacts will remain unmitigated.

J. LAND USE POLICIES

Criteria for Impact Assessment

Will the proposed project conform to the goals and policies of planning and zoning documents prepared by local agencies as mandated by the State Subdivision Map Act, the General Plan Guidelines and the Local Coastal Program (LCP requirements of the California Coastal Act).

Will the proposed project conform to the goals and policies of regional and statewide agencies as mandated by the Coastal Act, State Lands Commission Significant Lands Inventory, etc.

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Inconsistent with local General Plan polices or State plans or programs.	*Revise project to be consistent, or request General Plan amendment. Statement of Overriding Considerations.*
Commitment of land, elimination of future land use options.	*Relocate project.*

Commitment of land (e.g., development on prime agricultural land) in most cases is a long-term impact with no reasonable expectation of reversal of the process. Possible exceptions would occur if a well were drilled along the edge of a productive agricultural unit and careful mitigation employed.

Often, projects conflict with existing land uses without actually converting the property to a new land use. For example, agricultural productivity can be reduced because of emissions from nearby industrial activities or freeways filled to capacity. The quality (and therefore, the popularity) of adjacent recreational experiences can be affected in a similar way. Since recreation and tourism is the state's most lucrative industry, activities which affect the enjoyment of recreation are an important to the state.

EIRs and EISs are the result of more specific data than is available in the preparation of an LCP or local general plan. This may lead to revisions in these plans as a result of evidence presented in the environmental documents. The burden of proof is on the project proponents, however, and decision-makers should require thorough assessment of such proof in the environmental document.

K. PUBLIC FINANCE/ECONOMICS

Criteria for Impact Assessment

Will the proposed project result in:

1. Significant changes in public revenues.
2. Significant changes in public agency expenditures.
3. Changes in local property values.

Will the project conform to:

1. Local land use and coastal plans.
2. Capital improvement programs.

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Fiscal impacts on local governments due to demand for additional services.	*Establish offset funds for public agencies.*
	Implement general growth control measures.
	Establish conservation measures/reuse programs.
Increase demand for housing stock.	*Contribute to fund, provide housing referral service.*
Increase employment demand.	*Hire local workers, participate in training programs, provide temporary housing*

As the population of the state grows and elements of the infrastructure approach their capacity to function without expensive additions, the relationship between costs and revenues becomes more complex. For example, completion of a large development may create jobs and added to the tax base, but at the same time may bring about the need to build freeway interchanges and find new sources of increasingly scarce water supply. Handling of toxic substances can be very expensive and is the subject of complex regulations.

As the cost of housing increases, it becomes more difficult to find local housing for employees, resulting in the need to subsidize housing or to transport workers over long distances.

L. RISK OF UPSET

Criteria for Impact Assessment

Will the proposed project lead to risk of property damage, injury or death due to fire, explosion, release of gas or toxic spill.

Will the proposed project conform to:

1. U.S. Department of Transportation
2. DOG—Division of Oil & Gas (DOG)
3. Best Available Control Technology (BACT)
4. Professional Engineering Standards
5. Coast Guard

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Accidental spill (oil pipeline break or leak, gas pipeline break)	*Develop containment and cleanup or management plans, inspect equipment frequently, install valves in appropriate locations. Clean up small spills, using techniques such as skimming, installation of booms, removal of contaminated soil.*
Sour gas leaks.	*Monitor for H_2S, install valves in appropriate locations, restrict adjacent land use.*

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Potential pipeline rupture with fire. Potential toxic gas release.	*Improve engineered designs and plans, modify operational procedures, control adjacent land uses, renew and improve emergency response procedures, improve worker safety training.*
Increase in wildfire risk, as a result of development in high-fire risk areas and greater public use.	*Fire suppression activities, including fire breaks, education and training, controlled burns, fuels management.*

M. PHYSICAL OCEANOGRAPHY

Criteria for Impact Assessment

Will the proposed project result in:

1. Exposure of people or structures to significant hazardous risks from severe wave action, sand movement, bottom slumping or tsunami.
2. Increased wave erosion or scour.
3. Substantially altered seabed bathymetry.
4. Changes to local depositional or erosional environments.
5. Decreased efficiency of clean-up operations following accidental releases of chemicals or materials under wave and weather conditions to be expected in the area.
6. Substantially altered currents or water transport.

Will the project conform to;

1. U.S. Coast Guard requirements.
2. U.S. Army Corps of Engineers permit requirements.
3. Appropriate building codes and marine engineering guidelines.
4. National Marine Fisheries regulations.

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Potential damage to structures from extreme conditions.	*Design offshore structures to withstand extreme weather or wave conditions.* *Development of critical operations curtailment plans.* *Bottom facilities should be designed to withstand exposure and extreme sand movement.* *Cement bottom structures in place to reduce chances of rupture during extreme weather.*
High seas during a chemical spill will hamper containment and recovery operations.	*None with current technology.*
Damage to onshore structures from tsunamis or extreme wave conditions.	*Seawalls can be constructed to provide partial protection.*
Alteration of currents and transport in the project area.	*Design structure to reduce sand alteration.* *Model new transport and develop remedial measures.*

Many of the mitigations in this area deal more with what the environment can do to projects, rather than the other way around. The concerns center around severe storm conditions, tsunamis and wave damage. Most of the mitigations typically proposed deal with designing structures to engineering standards appropriate for the conditions likely to be encountered at the project site.

Problems with proposed mitigations involve estimating the severity of conditions that a proposed project must be designed to withstand. For example, in determining the maximum wave height and force that a project might encounter during its life, one has to use estimates of wind speeds, storm intensity and duration, and wave direction. These all come from historical climatic records that are often incomplete or extrapolated from other areas. Many parts of the California coastline do not have enough weather records to make such estimates with a high degree of confidence.

Once there is agreement on the nature and severity of possible threats to a proposed project, there appears to be agreement on most design standards from an engineering point of view. There is a considerable body of experience world-wide designing structures that can survive almost any known storm or wave conditions.

N. COMMERCIAL FISHING

Criteria for Impact Assessment

Will the proposed project result in:

1. Interference with significant seasonal fishing activities.
2. Pose increased risks of damage or loss to various types of commercial fishing gear.
3. Exclusion of commercial fishing operations from productive catch areas.
4. Interfere with or damage existing or planned mariculture operation.
5. Pose significantly increased risks of damage to commercial species from upset or accidental conditions.

Will the project conform to:

1. National Marine Fisheries, U.S. Fish and Wildlife Service and California Department of Fish and Game guidelines and regulations.
2. California Coastal Commission permit regulations.

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Structures exclude fishing operations.	*Relocate structures to avoid prime fishing catch areas.*
	Create fund for research to develop improvements in fishing gear to allow exploitation of new areas or species or decrease space/use conflicts.
Construction through kelp beds damages living or nursery habitat.	*Avoid kelp beds.*
	Restore kelp.
Construction damages hardbottom reef habitat.	*Avoid hardbottom areas.*
Dredging or disposal buries biota and increases bottom turbidity of water column.	*Dispose of dredgings, cuttings, etc., on land.*
	Dispose outside productive fishing areas.
Anchor scars damage trawl equipment.	*Restore bottom topography.*
	Compensate for lost equipment.
Operations disrupt mariculture operations.	*Improve quality of discharge. See WATER QUALITY.*
Loss of gear or traps due to vessel traffic.	*Strict adherence to vessel traffic corridors.*
	Compensation for lost or damaged gear.
	Notify fishermen of time and locality of operations.
Temporary exclusion by construction projects during peak fishing seasons.	*Schedule construction during nonfishing seasons.*

O. RECREATION

Criteria for Impact Assessment

Will the proposed project conform to the goals and policies of federal, state and local agencies responsible for recreation management.

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Change in character from recreation to industrial.	*Consolidate industrial facilities in areas not related to recreation activities.*
Disruption of coastal access and coastal trail alignments or corridors.	*Provide both lateral and vertical coastal access, provide for establishment and maintenance of coastal trails.*
Increase access to recreation experience, resulting in overuse.	*Investigate project location alternative, limit access, provide regular patrols.*
Accidental spill.	*Not mitigatable to insignificant levels. See RISK OF UPSET.*
Degradation of air quality affecting recreation experience.	*Compensate for lost tourism, provide prompt and thorough clean-up, provide post clean-up publicity. See AIR QUALITY.*

P. AGRICULTURE

Criteria for Impact Assessment

Will the proposed project:

1. Conform to the goals and policies of local agencies.
2. Result in the reduction of prime agricultural lands as defined by the U.S. Department of Agriculture Soils Conservation Service.

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Loss of agricultural productivity due to changes in land use.	*Avoid commitment of prime agricultural land to other uses, review potential for alternate site.*
Potential reduction in agricultural productivity due to changes in adjacent land use patterns, population pressure, pollution, erosion or deposition.	*See LAND USE POLICIES and RISK of UPSET.*

Q. MILITARY

Criteria for Impact Assessment

Will the proposed project result in:

1. Interference with current or planned military operations in training or operational areas.
2. Significant risk to military operations in case of upset or accident.
3. Increased risk of accident from current military operations.

Will the project conform to:

1. U.S. Department of Defense regulations and guidelines.

Impacts and Mitigation Measures

POTENTIAL IMPACTS	*TYPICAL MITIGATIONS*
Risk of impact from missile impact during test launches.	*Exclude all traffic during launch periods.*
Personal disruption from aircraft noise.	*Limit overflights to sub-sonic speeds over inhabited areas, elevate or redirect flight.*
Flight/shipping conflicts with military traffic.	*Coordinate flight paths and vessel traffic lanes with proper military operations area.*

CHAPTER FOUR

THE ADMINISTRATIVE AND REGULATORY PROCESS AFFECTING THE CALIFORNIA OFFSHORE AREA

INTRODUCTION

This section describes the complex system of controls governing California coastal development. A number of federal, state and local public entities have authority to make decisions regarding management of public property, both onshore and offshore. Other agencies regulate certain defined activities in coastal areas or, acting pursuant to police powers, have broader planning authority over both public and private lands. An understanding of this complex structure of authority is necessary to appreciate what any development proposal must confront.

In Figure 4-1, a matrix reference identifies which state regulations, agencies, and/or principles affect various resources or activities; Figure 4-2 is a similar matrix presenting federal elements. While these checklists are not intended to be exhaustive in scope nor technical in nature, they do provide a general overview of regulatory responsibilities.

FEDERAL AND STATE JURISDICTION

Generally speaking, the state of California has authority over offshore lands out to three nautical miles from ordinary high water, an area called the "marginal seas." The federal government has complete control beyond the three-mile boundary. The federal government also has authority over all territory within the United States, but only with respect to matters delineated by the Constitution.

Since the state of California was established in 1849, the state has had sovereign authority over the marginal seas.[1] Prior to 1947, the state believed this authority meant it owned the marginal seas, but the U.S. Supreme Court that year held that the marginal seas were federally owned lands within California.[2] As such, the State would have the authority, as a function of its police power, to impose regulations on conduct within these territorial waters, but only in the absence of conflicting federal legislation.[3]

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[1] For the legal foundation of the state's boundaries, see Article III, Section 2 of the present state Constitution, Article XII, Section 1 of the Constitution of 1849, and United States v. State of California, 382 U.S. 448, 15 L.ed.2d 517, 86 S.Ct. 607.

[2] See United States v. California, 332 US 19, 91 L.ed. 1889, 67 S.Ct. 1658 (1947).

[3] The principles governing state regulation of federal offshore lands are illustrated in Toomer v. Witsell, 334 U.S. 385 (1947). Also bearing substantially on this issue is the case, Kleppe v. New Mexico, 426 U.S. 529, 49 L.Ed 2d 34, 96 S. Ct. 2285 (1976).

STATE REGULATORY MATRIX

STATUTE/ REGULATION/ AGENCY	RESOURCE / ACTIVITY														
	Public Access and Public Trust Uses	Leasing and Management	Coastal Zone Protection	Air Resources	Water Resources	Hazard Waste/ Toxics	Wildlife/ Endangered Species	Native American Interests	Oil & Gas Activities, Mining,Dredging, Geothermal	Geology and Land Resources	Energy Resources	Forestry and Fire Protection	Land Use Policy	Transportation	Utilities
PUBLIC TRUST DOCTRINE	◆	◆			◆		◆		◆					◆	
CEQA		◆	◆	◆	◆	◆	◆	◆	◆	◆					
MITIGATION MONITORING		◆	◆	◆	◆	◆	◆	◆	◆	◆		◆			
AB 884		◆			◆	◆			◆	◆	◆	◆	◆	◆	◆
CA COASTAL ACT	◆		◆						◆	◆	◆		◆	◆	
CLEAN AIR PROVISIONS			◆	◆					◆					◆	
CLEAN WATER PROVISIONS		◆	◆		◆	◆	◆		◆						
ENDANGERED SPECIES ACT	◆		◆		◆		◆		◆			◆	◆		
NATIVE AMERICAN REMAINS			◆					◆	◆						
SIGNIFICANT LANDS INVEN.		◆	◆				◆	◆	◆	◆					
STATE LANDS COMMISSION	◆	◆	◆		◆	◆	◆		◆	◆		◆	◆		
COASTAL COMMISSION	◆	◆	◆		◆	◆	◆		◆	◆	◆	◆	◆	◆	
FISH & GAME (Dept./Comm.)	◆		◆		◆	◆	◆		◆	◆		◆	◆		
SECTY. OF ENVR. AFFAIRS													◆		
Air Resources Board				◆					◆					◆	
State Water Res. Control Bd.					◆	◆			◆						
Reg.Water Qual. Control Bd.					◆	◆			◆						
Waste Management Bd.						◆			◆						
Offshore Development			◆						◆	◆					
Hazardous Substances						◆			◆						
Toxic Data Management						◆									
DEPT. OF WATER RES.					◆						◆				◆
DEPT. OF CONSERVATION			◆						◆	◆					
ENERGY COMMISSION									◆		◆				◆
BCDC	◆		◆			◆			◆	◆			◆		◆
COASTAL CONSERVANCY	◆		◆			◆	◆		◆	◆			◆		
DEPT. OF PARKS & REC.	◆	◆	◆			◆	◆	◆		◆					
Office of Historical Preserv.			◆					◆							
ANTIQUITIES ACT (Fed.)								◆							
ARCH. RES. PROT. ACT (Fed.)								◆							
DEPT. OF FORESTY	◆	◆					◆			◆		◆	◆		
DEPT. OF BOAT. & WTWYS.	◆													◆	
OFFICE OF PLANNING & RES													◆		
DEPT. OF TRANSPORTATION	◆								◆					◆	
PUBLIC UTILITIES COMM.									◆		◆			◆	◆
NATIVE AM. HERIT. COMM.			◆					◆	◆						
LOCAL GOVERNMENTS															
Local Coastal Programs	◆		◆			◆			◆				◆	◆	◆
APCD'S			◆	◆					◆					◆	
AM. INDIAN REL. ACTIV.-								◆							
Joint Resolution (Fed.)															

Figure 4 - 1

FEDERAL REGULATORY MATRIX

STATUTE/ REGULATION/ AGENCY	RESOURCE / ACTIVITY											
	Mining	Oil and Gas Development, Leases, Sales	Coastal Zone Protection	Air Resources	Water Resources	Pollution	Wildlife/ Endangered Species	Fishing	Historic Preservation	Transportation	Communications	Pipeline Regulations
OCS LANDS ACT		◆		◆		◆						
NEPA	◆	◆	◆	◆	◆	◆	◆		◆			
CZMA			◆									
CLEAN AIR ACT			◆	◆								
CLEAN WATER ACT			◆		◆	◆						
REFUSE ACT			◆		◆	◆						
OCEAN DUMPING ACT			◆		◆	◆						
ENDANGERED SPECIES ACT			◆				◆					
MARINE MAMMAL PROTECT. ACT			◆				◆	◆				
MAGNUSON CONSERVATION ACT			◆				◆	◆				
HISTORIC PRESERVATION ACT	◆		◆						◆			
DEPARTMENT OF INTERIOR	◆	◆	◆				◆					
Minerals Management Service	◆	◆										
U.S. Fish & Wildlife Service			◆			◆	◆	◆				
National Park Service			◆				◆					
Bureau of Land Management			◆				◆		◆			
Bureau of Reclamation			◆		◆							
U.S. Geological Survey	◆	◆										
COMMERCE - NOAA - NMFS		◆	◆	◆		◆	◆	◆			◆	
ENVIRON. PROTECTION AGENCY			◆	◆	◆	◆	◆					
U.S. ARMY CORPS OF ENGINEERS		◆	◆		◆	◆	◆	◆	◆			
U.S. COAST GUARD		◆	◆		◆	◆		◆		◆		
FEDERAL AVIATION AGENCY										◆		
FED. COMMUNICATIONS COMM.											◆	
FED. ENERGY REG. COMM.										◆		◆
SURFACE MINING & RECLA. ACT	◆											
HARBORS & NAVIGATION CODE		◆	◆		◆	◆				◆		◆
FISH & WILDLIFE COORD. ACT					◆	◆	◆					
MIGRATORY BIRD TREATY ACT					◆		◆					
ARCHAEOL. RES. PROTECT. ACT									◆			
ANTIQUITIES ACT									◆			
RES. CONSERV. & RECOVERY ACT						◆						
COM. ENV. RES. COMP. & LIA. ACT						◆						

Figure 4 - 2

In response to the Court's ruling, Congress enacted the Submerged Lands Act, found in 43U.S.C. Sections 1301 et seq. This Act relinquished to the coastal states, including California, all right, title, and interest of the United States to all lands covered by navigable waters within the boundaries of the respective states.[4]

The Act only defines state and federal ownership. The Act did not affect existing law regarding federal authority over state lands with regard to navigation, commerce, national defense and other matters of federal concern. State regulatory authority extending beyond the three-mile limit is also unaffected. However, the Act does provide that the laws of the adjacent state are adopted as the federal law applicable to adjacent outer continental shelf where there are no superseding federal laws on the subject.[5]

It is unclear whether Congress may repeal or modify the grants under the Submerged Lands Act. In fact, the Act has been modified in one respect already. The definition of the term "boundary" contained in Section 1301 was amended to provide that, once the coordinates of a boundary are fixed by final decree, the boundary shall remain immobilized and shall not be ambulatory.

The seaward limit of federal control is a function of international law. In 1988, the boundaries of the United States' territorial seas were established by presidential proclamation at 12 nautical miles from shore. In 1983, the president also established the Exclusive Economic Zone of the United States of America, whereby the United States declared its authority, subject to international law, over economic activities within 200 nautical miles from shore.[6]

FEDERAL CONTROLS

Significant Federal Statutory Controls

The following are major provisions of federal law which directly affect the planning process governing California's coast.

Outer Continental Shelf Lands Act (OCSLA)

The provisions of the Outer Continental Shelf Lands Act (OCSLA) govern development and other activities in federal offshore areas. It was enacted in 1953 largely to facilitate offshore oil and gas development, although extensive amendments in 1978 strengthened environmental safeguards. The basic policy provisions of the Act provide that federal offshore lands should be made available for expeditious and orderly development, subject to environmental safeguards and rights of navigation and fishing.[7]

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[4] 43 U.S.C. Sec. 1311. The specific areas transferred to the State of California by the Submerged Lands Act were clearly determined by the U.S. Supreme Court in United States v. California, 381 U.S. 139, 14 L.Ed.2d 296, 85 S.Ct. 1401; reh. den. 382 U.S., 889, 15 L.Ed.2d 127, 86 S.Ct. 159 (1965); Supplemental Decree, 382 U.S. 448, 15 L.ed.2d 517, 86 S.Ct. 607.

[5] See Chevron Oil Co. v. Huson, 404 U.S. 97, 30 L.ed.2d 296, 92 S.Ct. 349 (1971); Nations v. Morris, 483 F.2d 577 (1973); Gulf Offshore Co. v. Mobil Oil Corp., 453 U.S. 473 at 480–481; [69 L.Ed. 784, 101 S.Ct. 2870] (1981); Rodrigue v. Aetna Casualty & Surety Co., 396 U.S. 352, 23 L.Ed.2d 360, 89 S.Ct. 1835 (1969); and Laredo Offshore Constructors, Inc. v. Hunt Oil Co., 754 F.2d 1223 at 1229–1230 (1985).

[6] See 48 Code of Federal Regulations (CFR) 10605.

[7] 43 U.S.C. Sec. 1332.

The Secretary of Interior is directed to administer OCSLA and is authorized to implement appropriate regulations.[8] The Secretary carries out these duties through the Minerals Management Service (MMS).

Under the Act, leasing and development is carried out in four stages: preparation of a leasing program, the lease sale, exploration, and development and production.[9]

First, the Secretary prepares the leasing program through five-year lease plans, establishing where and when leases will be offered to the public during each five year period.[10] These plans are subject to Congressional approval. The Secretary must also submit annual reports to give Congress an opportunity to review and modify the leasing programs.[11]

Next is the Lease Sale.[12] The Act provides for public notice and requires the Secretary to take into account comments by the governor of affected states.[13] The Act specifies certain lease requirements regarding lease ownership and operation, such as assignment; pooling and pipeline access; compliance with environmental controls, such as the Clean Air Act; and compensation, including royalties, bonus bids, net profit shares and the like.[14]

The next stage, exploration, includes both geophysical surveying and exploratory drilling.[15] A lessee is required to carry out exploration in accordance with an approved exploration plan.[16] The plan must include a schedule of anticipated activities, a description of equipment to be used, the general location of proposed exploratory wells, and any other information required by MMS.

The final stages, development and production, are generally governed by 43 U.S.C. Section 1351. This provision was enacted as part of a 1978 amendment package and applies only to leases issued after September 18, 1978. Under this provision, a lessee cannot develop the lease unless MMS has approved a development plan describing proposed

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[8] 43 U.S.C. Sec. 1334.

[9] A discussion of this process may be found in Secretary of Interior v. California, 464 U..S. 312, 78 L.Ed.2d 496, 104 S.Ct. 656 (1984).

[10] 43 U.S.C. Sec. 1344

[11] See 43 U.S.C. Section 1343.

[12] Oil and gas leases are authorized under 43 U.S.C. Sec. 1337.

[13] 43 U.S.C. Sec. 1345.

[14] 43 U.S.C. Sec. 1334, 1337 and 1340.

[15] 43 U.S.C. Sec. 1331, subsection k, and 43 U.S.C. Section 1340. Geophysical work may be carried out by anyone with an MMS permit. While many surveys are performed on leased land, considerable work is also performed before any leasing or lease-planning takes place. Those permits require that MMS receive all information from the surveys. MMS therefore has access to most data available and uses it to develop its five-year leasing plans. MMS's geophysical permit program allows a permit to be issued by MMS to anyone meeting public notice requirements, if there are no apparent problems regarding scheduling. No environmental review is required for the permit, because the agency has declared the activity to be categorically excluded from the National Environmental Policy Act (NEPA). See 51 FR 1855.

[16] 43 U.S.C., Sec. 1340, subsection (c).

construction, environmental safeguards, safety standards, development and production schedules and other relevant information required by MMS. Environmental review is required for approval. The provision also prohibits approval of a plan under certain specified conditions, although the lease may be extended to allow the lessee to reapply. Provisions also are made for cancellation of the lease and reimbursement to the lessee.[17]

The OCSLA also authorizes offshore leases for other minerals, such as sulphur, but the Act contains few specific details about such leases.[18] Presumably, any such lease issued would be similar to those for oil and gas.

The OCSLA also governs distribution of revenues from offshore development. While revenues generally go to the federal government,[19] Section 8(g) of the OCSLA [20] provides that a state is to receive a portion of the revenue received through production from those portions of tracts located within three nautical miles of the state's seaward boundary. This applies only to tracts leased after September 18, 1978. California currently receives 27% of the federal revenues from these lands.

The U.S. Coast Guard, in consultation with the Department of Interior, is directed to promulgate regulations governing safety and health during drilling and production operations.[21] MMS and the Coast Guard are also directed to carry out on site inspections of work facilities at least once a year and are authorized to carry out enforcement proceedings.

The Offshore Oil Spill Pollution Fund, administered by the Departments of Transportation and Treasury, is established under OCSLA for spill removal costs and damage claim recovery where polluters cannot be identified. Three cents per barrel is charged to the lessee for maintenance of the fund at $100 to $200 million.[22]

The Fishermen's Contingency Fund is managed by the National Marine Fisheries Service to reimburse fishermen for damage or loss of fishing gear and loss of profit due to offshore oil and gas operations where the responsible party is not known. Lessees are assessed up to $5000 annually.[23]

National Environmental Policy Act

The National Environmental Policy Act (NEPA), adopted in 1969, requires all administrative agencies of the federal government to consider the environmental

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[17] It was this cancellation provision which the court cited in Secretary of Interior v. California, 464 U.S. 312, 78 L.Ed.2d 496, 104 S.Ct. 656 (1984) as the reason why a federal lease issued after 1978 does not give the lessee a right to develop; i.e., that the lease sale, by itself, does not impact the coastal zone and therefore need not be subjected to consistency review under the (Coastal Zone Management Agency) CZMA.

[18] 43 U.S.C. Sec. 1337, subsections (i), (j) and (k).

[19] 43 U.S.C. Sec. 1338 and 1339.

[20] This section is codified in 43 U.S.C. Sec. 1337, subsection (g).

[21] 43 U.S.C. Sec. 1347 and 1348.

[22] 43 U.S.C. Sec. 1811.

[23] 43 U.S.C. Sec. 1841 et seq. and 50 CFR 296.

impacts of their actions [24] in the process of project development and decision-making. It also allows other officials, Congress and the public to independently evaluate the environmental consequences of government action.[25] Finally, it directs all federal agencies to carry out their duties, to the fullest extent possible, to preserve and protect the environment and public health, safety and productivity.[26]

In many respects, the core requirement of NEPA is Section 102,[27] under which environmental impact statements (EIS) are required. Under this provision, every recommendation or report on proposals for major federal actions significantly affecting the quality of the human environment must include a detailed statement on: the environmental impact of the proposed action; any adverse environmental effects which cannot be avoided should the proposal be implemented; alternatives to the proposal; the relationship between local short-term uses of the environment and the maintenance and enhancement of long-term productivity; and any irreversible and irretrievable commitments of resources involved in the proposal. According to the Council on Environmental Quality Guidelines, the primary purpose of an EIS is to ensure that the policies and goals of the Act are carried out. Federal agencies are to make their decisions based on the information contained in the EIS as well as on other material.[28]

The threshold question is whether an environmental impact statement is even required. The answer depends on whether the proposal under consideration constitutes a "major federal action significantly affecting the environment." "Federal action" means both actions which a federal agency undertakes and those the agency merely has the discretion to permit or approve.[29] The "major action" provision allows agencies to avoid preparation of an EIS for minor matters with little potential for adverse impact.[30] The standard "significantly affecting the quality of the human environment" means having an important or meaningful effect, direct or indirect, upon a broad range of aspects of the human environment. The cumulative impact with other projects must be considered.[31]

In the event that the federal agency determines an action will have no significant impact, an "Environmental Assessment" is

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[24] See 115 Cong. Rec. (Part 30) 40416 (1969) and Environmental Defense Fund v. Corps of Engineers of the United States Army, 470 F.2d 289 at 294 (1972).

[25] See Columbia Basin Land Protection Association v. Schlesinger, 643 F.2d 585 (1981).

[26] 42 U.S.C. Sec. 4331, subsection(b), and 4332.

[27] Codified in 42 U.S.C. Sec. 4332.

[28] 40 CFR Sec. 1502.1.

[29] See Sierra Club v. Morton, 514 F.2d 856 (1975); reversed on other grounds 427 U.S. 390, 49 L.Ed.2d 576; and Scientists' Institute for Public Information, Inc. v. Atomic Energy Commission, 481 F.2d 1079 (1973); and Defenders of Wildlife v. Andrus, 627 F.2d 1238 (1980).

[30] See Hanly v. Kleindienst, 471 F.2d 823, (1972), and Township of Ridley v. Blanchette, 421 F.Supp. 435, (1976).

[31] See Natural Resources Defense Council, Inc. v. Grant, 341 F.Supp. 356 (1972).

prepared.[32] This is a concise document briefly providing sufficient evidence and analysis for determining whether the proposal would have a significant impact and aiding the agency in complying with the Act when no EIS is necessary.[33]

The basic rule for determining whether an EIS is adequate is: (1) whether the agency in good faith has taken an objective look at the environmental consequences of a proposed action and alternatives; (2) whether the EIS provides detail sufficient to allow those who did not participate in its preparation to understand and consider the pertinent environmental influences involved; and (3) whether the EIS explanation of alternatives is sufficient to permit a reasoned choice among different courses of action.[34] Particular attention must be given to the analysis and comparison of alternatives to the proposed project.[35] Most of the details regarding EIS contents may be found in the NEPA Guidelines adopted by the Council on Environmental Quality.[36] The Council itself was created under NEPA to assist with the implementation of the Act.

Coastal Zone Management Act (CZMA)

The Coastal Zone Management Act (CZMA) provides for state review of activities in federal waters.[37] It was enacted in 1972 to encourage and assist states in preparing and implementing management programs to preserve, protect, develop and where possible, to restore or enhance the resources of the nation's coastal zone.[38]

The statute affects planning in the "coastal zone," defined as coastal waters and the adjacent shorelands and waterways, strongly influenced by each other and in proximity to the shorelines. The zone extends inland from the shorelines only to the extent necessary to control shorelands, the use of which have a direct impact on coastal waters.[39] Federal lands are not considered part of the coastal zone.

The Act provides two kinds of incentives to states to accomplish its goals: monetary grants and partial control of OCS development. Along with money for research, preservation and restoration projects, grants are also made available to states for development and administration of coastal zone management plans.[40] The California Coastal Commission is

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[32] 40 CFR Sec. 1501.3.

[33] 40 CFR Sec. 1508.9.

[34] Isle of Hope Historical Association, Inc. v. U.S. Army Corps of Engineers, 646 F.2d 215 at 220 (1981); Save Our Sycamore v. Metropolitan Atlanta Rapid Transit Authority, DeKalb County, Georgia, 576 F.2d 573 at 576 (1978).

[35] 40 CFR Section 1502.14. See also Rankin v. Coleman, 394 F.Supp 647 at 658 (1975).

[36] Title 40, Chapter V of the Code of Federal Regulations (Sections 1500.1 et seq.).

[37] The programs under the Act are administered by the Department of Commerce, through the National Oceanic and Atmospheric Administration (NOAA). NOAA's regulations concerning coastal zone management are in 15 CFR Parts 920, 923, 925 through 928, and 931 through 933.

[38] 16 U.S.C. Sec. 1452.

[39] 16 U.S.C. Sec. 1453.

[40] 16 U.S.C. Sec. 1454 and 1455.

currently financed in part through these grants. Each state's management program must be submitted to NOAA for approval and must contain a number of elements, including use priorities, the organizational structure for the plan's implementation, shorefront access plans, and planning processes for energy facilities and erosion control.

The state is also given a right to review proposals for adjacent OCS areas.[41] Under this provision, any applicant for a required federal license or permit to conduct an activity affecting land or water uses in a state's coastal zone must provide a certification that the proposed activity is consistent with the state's approved management program. Plans for exploration and development under the Outer Continental Shelf Lands Act are expressly required to submit to review under the appropriate state management plan. However, if the state determines the project to be inconsistent with its management plan, the Secretary of Commerce may nevertheless approve issuance of the requested license or permit if he finds that the activity is consistent with the objectives of the CZMA or is otherwise necessary in the interest of national security.

Clean Air Act

The Clean Air Act (CAA), enacted in 1963, provides the current federal framework governing air quality regulation. The CAA amendments of 1970 required the Environmental Protection Agency (EPA) to develop and promulgate the National Ambient Air Quality Standards (NAAQS). This represented a significant change from the 1967 Amendments which provided that the states develop their own air quality standards.

The basic program entails the creation and enforcement of EPA-approved state programs established for specified regions. EPA is required to list those pollutants which may endanger public health or welfare, which are emitted from numerous or diverse mobile or stationary sources.[42]

A distinction is made between those pollutants for which ambient air quality standards are established and those that are regulated through emission limits or control technology requirements.[43] A criteria pollutant is one for which the EPA is required to establish national primary and secondary ambient air quality standards.[44] The current criteria pollutants are sulfur dioxide, carbon monoxide, particulate matter, nitrogen dioxide, photochemical oxidants and lead.[45] There is also a list of pollutants defined as hazardous, regulated by the establishment of emission standards. These include asbestos, benzene, beryllium, coke oven emissions, arsenic, mercury, radionuclides and vinyl chloride.[46]

The next step is the establishment of State Implementation Plans (SIP). While the

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[41] 16 U.S.C. Sec. 1456.

[42] 42 U.S.C. Sec. 7408(a)(1).

[43] 40 U.S.C. Sec. 7408 (a)(2)and (b).

[44] 42 U.S.C. Sec. 7409.

[45] 40 CFR Sec. 50.2.

[46] 40 CFR Part 50.

standards are established by the EPA, each state is required to adopt plans for their implementation, maintenance and enforcement in every air quality control region in the state.[47] EPA must review each plan and approve it only if it meets certain inspection, enforcement and administration criteria. The plan must also specify remedial actions, such as construction restrictions, installation of special technology and stricter monitoring, for areas not attaining ambient standards.[48] The SIP is not so much a document as a comprehensive collection of all air quality data and regulations collected and promulgated by a state. However, for general purposes, the basic outline of California's plan may be found in 40 CFR Part 52, Subpart F (Sections 52.220 through 52.280)

EPA establishes penalties and assessment procedures for noncompliance.[49] Each state submits procedures for approval by EPA. Either the state or EPA itself may enforce those penalties.[50] The penalties are intended to recover any economic advantage the violator may accrue as a result of the violation.[51]

One consideration with respect to offshore developments in federal waters is that they are not governed by California's implementation plan. The Outer Continental Shelf Lands Act does require federal lessees to comply with the national ambient air quality standard pursuant to the Clean Air Act, to the extent that activities authorized under that subchapter significantly affect the air quality of any state.[52] Under this provision, MMS has adopted its own air quality regulations to comply with ambient air quality standards. However, these regulations are not consistent with either California's own air quality laws or the EPA-approved SIP.

Federal Water Pollution Control Act (CLEAN WATER ACT)

The Federal Water Pollution Control Act, commonly called the Clean Water Act,[53] was originally enacted in 1948, but extensively amended in 1972 and 1977.[54] The Act's objective is to restore and maintain the chemical, physical, and biological integrity of the nation's waters.[55] While its administration is in the hands of the EPA, management of water pollution control generally is the responsibility of the states.[56] Allocation of water is also expressly left to the states.[57]

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[47] 42 U.S.C. Sec. 7410.

[48] 42 U.S.C. Sec. 7502.

[49] 42 U.S.C. Sec. 7420.

[50] 42 U.S.C. Sec. 7413. 40 CFR Part 66 establishes procedures for EPA assessment of penalties, and 40 CFR part 67 provides the guidelines for state penalty programs.

[51] 40 CFR Sec. 66.1.

[52] 43 U.S.C. Sec. 1334, subsection (a)(8).

[53] Section 518, Pub.L No. 95-217, provided that: "This Act [This chapter] may be cited as the 'Federal Water Pollution Control Act' (commonly referred to as the Clean Water Act)."

[54] The Act is generally found in 33 U.S.C. Sec. 1251 through 1387.

[55] 33 U.S.C. Sec. 1251, Subsection (a).

[56] 33 U.S.C. Sec. 1251.

[57] 33 U.S.C. Sec. 1251, subsection (g).

The Act is divided into 5 Titles.[58] Titles I and II cover basic policy and direct EPA to carry out grant, research and educational programs.[59] Title V is devoted to general matters, such as definitions and administrative provisions.[60]

Title III provides for the establishment of water quality standards and for enforcement.[61] Section 1311 makes unlawful the discharge of any pollutant of any kind by any person, except in compliance with specific provisions of the Act.[62] The same section also provides for the establishment of effluent limitations within a specified time schedule. Title III also contains provisions for establishment of more stringent controls on particular point sources, state establishment of water quality control standards, establishment and publication of water quality criteria, biennial state reporting to EPA, state control of discharge sources, establishment of effluent standards and controls for toxic pollutants, and control of sewage discharges from vessels.[63] When the EPA finds a violation of state standards, it notifies the state first and, if the state does not act, then order the violator to comply with the standard or seeks an injunction ordering compliance.[64]

Section 1321 (33 U.S.C.) deals specifically with oil pollution and discharges of hazardous substances. The discharge of oil or other hazardous substances into any navigable waters or the Outer Continental Shelf is expressly prohibited. Criminal and civil penalties and civil liability of the owners of oil facilities and vessels are set. The president is also directed to establish a national contingency plan for the removal of discharged oil and hazardous substances.[65]

The National Estuary Program is found in Section 1330.[66] Funded by Congress and administered by the U.S. Environmental Protection Agency's Office of Marine and Estuarine Protection, this 1987 legislation is aimed at maintaining the health and ecological integrity of specified estuaries. The funding (not to exceed $12 million per fiscal year through FY 1991) is to be shared by the 11 designated estuaries, including San Francisco, and any others subsequently approved by the Administrator of EPA following nomination to the program by the governor of any state. The Santa Monica Estuary Project is now also included in the Program.

The agenda for the Program is ambitious. Each project must:

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[58] In the Code, the five Titles are Subchapters I through V.

[59] 33 U.S.C. Sec. 1251 through 1266 and Sections 1281 through 1299.

[60] 33 U.S.C. Sec. 1361 through 1376.

[61] 33 U.S.C. Sec. 1311 through 1328.

[62] 33 U.S.C. Sec. 1312, 1316, 1317, 1328, 1342, and 1344.

[63] 33 U.S.C. Sec. 1312 through 1317 and 1322.

[64] 33 U.S.C. Sec. 1319. This section also contains provisions for criminal and civil penalties.

[65] Provisions regarding oil pollution control may also be found in 40 CFR Parts 109 through 114.

[66] 33 U.S.C. Sec. 1330.

- Assess trends in water quality, natural resources and uses of the estuary.
- Collect, characterize and assess data on toxics, nutrients, and natural resources within the estuarine zone to identify the causes of environmental problems.
- Develop the relationship between the inplace loads and point and nonpoint loadings of pollutants to the estuarine zone and the potential uses of the zone, water quality and natural resources.
- Develop a comprehensive conservation and management plan that recommends priority corrective actions and compliance schedules addressing point and nonpoint sources of pollution, to restore and maintain the chemical, physical and biological integrity of the estuary.
- Develop methods for the coordinated implementation of the management plan by participating federal, state and local agencies.
- Monitor the effectiveness of action taken pursuant to the plan.
- Review all federal financial assistance programs and federal development projects to determine whether they would be consistent with and further the purposes and objectives of the plan.

Title IV provides for the National Pollutant Discharge Elimination System (NPDES), governing permits and licensing for authorized discharging.[67] Any party proposing to conduct some activity which may result in discharges into navigable waters must obtain a permit from the EPA or the state in which the discharges will be made.[68] The EPA is directed to establish a national permit program. However, if a state wants to establish its own program, EPA must suspend its program in that state, as long as the state's program is approved by the EPA as meeting all of the agency's requirements. Any permit, state or EPA, must include various specified conditions, including the requirement that permitted discharges must meet all water quality standards and effluent limitations provided under Title III of the Act.[69]

Authority over discharge of dredged or filled material is treated somewhat differently. Authority in this area is delegated to the Army Corps of Engineers, subject to guidelines by the EPA.[70] The EPA may prohibit the specification of any defined area as a disposal site, but there are many exceptions. As with other discharge permit programs, each state may also administer its own program for dredged and fill material, subject to EPA approval.

Rivers and Harbors Appropriations Act of 1899 (REFUSE ACT)

Most of the Rivers and Harbors Appropriations Act concerns construction in or

[67] 33 U.S.C. Sec. 1341 through 1345.

[68] 33 U.S.C. Sec. 1342.

[69] 33 U.S.C. Sec. 1341 and 1342.

[70] 33 U.S.C. Sec. 1344.

modifications to navigable waterways.[71] The Act requires Army Corps of Engineer approval for any of the following activities in navigable waters: construction of bridges, causeways, dams, dikes, wharfs, piers, jetties, or other structures or obstruction; the deposit of any refuse material; possession of, injury to or other action affecting any wharfs, piers, sea walls and such of the United States; and obstruction of navigable waters by vessels.[72]

Fundamental pollution control provision is in Section 407, which declares it unlawful to discharge refuse matter of any kind, other than that flowing from streets and sewers in a liquid state, into any navigable waters of the United States, unless a permit is first obtained from the Army Corps of Engineers. The permit program provided in Section 407 has been largely supplanted by the permit program established by the National Pollution Discharge Elimination System.[73] It is unclear how much of Section 407 has survived the continuing emergence of the Clean Water Act as the primary federal vehicle for controlling water pollution.

Marine Protection, Research, and Sanctuaries Act of 1972 (The Ocean Dumping Act).

The Marine Protection, Research, and Sanctuaries Act generally covers ocean dumping and the establishment of marine sanctuaries. Titles I and II cover ocean dumping, while Title III governs the sanctuaries.[74] Under Section 1411, subsection (a), no person may transport any material from the United States, for the purpose of dumping it into ocean waters, unless authorized by a permit under this act. "Ocean waters" means all waters lying seaward of the mean high tide line and the mouths of inland waters. "Material" is defined as anything except sewage from vessels.[75] The Act covers all disposition of materials except effluents regulated under the Clean Water Act, the Refuse Act, or the Atomic Energy Act; routine effluent discharges from vessels; construction of structures or artificial islands authorized under a federal or state law; or development, maintenance or harvesting of fisheries resources under a federal or state law.[76]

EPA is charged with carrying out the permit program for all materials except dredge spoils.[77] Selection and approval of disposal sites must take into consideration the need for the proposed dumping; effects on human health and welfare, fisheries, wildlife, and the marine ecosystem; the persistence and permanence of the effects; and the availability of alternatives to the proposal. The effects of disposal are also periodically reviewed, to determine if the

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[71] 33 U.S.C. Sec. 401 through 467e.

[72] 33 U.S.C. Sec. 401 through 409.

[73] 33 U.S.C. Sec. 1342.

[74] 33 U.S.C. Sec. 1401 through 1445.

[75] 33 U.S.C. Sec. 1402.

[76] 33 U.S.C. Sec. 1402.

[77] 33 U.S.C. Sec. 1412 (102).

permits should be changed or revoked.[78] All the disposal sites currently approved by EPA are listed in 40 CFR 228.12.

Control over dredged material disposal is divided between the EPA and the Army Corps of Engineers.[79] The Corps is given primary direct control over the disposal permit program, but the agency is also directed to follow the criteria set forth by the EPA for site selection. As a practical matter, it is not clear which agency has ultimate control over dredge spoil disposal.

In 1972, Congress enacted Title III of the Act, the marine sanctuary provision, whereby certain offshore areas could be set aside for special planning. Under the Act, a specific area of marine environment may be designated a national marine sanctuary if it is of special national significance and if designation as a sanctuary will enhance resource protection, scientific research and public education.[80] The program's goal is to provide enhanced resource protection through comprehensive and coordinated conservation and management; support, promote, and coordinate scientific research on the sanctuary areas; enhance public awareness, understanding, appreciation and wise use of the marine environment; and facilitate multiple uses of the sanctuaries.[81] Off California, the areas currently in federal marine sanctuary are the Santa Barbara Channel Islands, the Gulf of the Farallones and the Cordell Bank. Monterey Bay is also to be added.

After designation of the area as a sanctuary, the National Oceanic and Atmospheric Administration (NOAA), in conjunction with other agencies having jurisdiction over some aspect of the sanctuary, will develop and implement a management plan. An example of a management plan is the Channel Islands National Marine Sanctuary Management Plan. This plan provides for joint management by the National Park Service, the California Department of Fish and Game and NOAA. It includes consideration of various uses, including recreation, commercial fishing and mariculture, commercial shipping, military activities, research and education and offshore oil and gas activities.[82]

Endangered Species Act

The purposes of the Endangered Species Act, adopted in 1973, are to conserve threatened and endangered species and the ecosystems upon which they depend, and to carry out programs pursuant to international treaties and conventions regarding fish, migratory birds and other wildlife.[83]

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[78] See 40 CFR 228.10 regarding permit change requirements.

[79] 33 U.S.C. Sec. 1413.

[80] 16 U.S.C. Sec. 1433, subsection (a)(2).

[81] 15 CFR Sec. 922.1(b). The regulations governing national marine sanctuaries generally may be found in 15 CFR Part 922.

[82] The sanctuary boundaries include a number of preexisting federal lease tracts. Designation as a sanctuary does not terminate any valid, preexisting lease or permit, although exercise of the lease or permit must be consistent with NOAA regulations. [16 U.S.C. Sec. 1434(c)] No platforms are currently located or proposed within the sanctuary boundaries.

[83] Sec. 2, subsection (b) of the Act (16 U.S.C. Sec. 1531, Subsection (b).

The Act provides for the establishment of lists of threatened and endangered species. Any inclusions or deletions in the lists must come after proper notice and, if requested, public hearing. The lists are reviewed every five years to determine if any species should be removed or have its status changed. The Secretary of the Interior may also identify critical habitat and impose regulations governing those areas.

For the most part, the decision whether to include a species on one of the lists rests with the Secretary of the Interior. However, if the Secretary of Commerce determines that a species under its jurisdiction, such as certain marine mammals, should be included on the lists, the Secretary of the Interior must comply. Both the Secretaries of Commerce and Interior must concur if any of those species are deleted from one of the lists.

The Secretary of the Interior is also directed to establish programs for the conservation and recovery of listed species, including acquisition of land or other interests affecting habitat. The Act directs the Secretary to cooperate with state governments to implement these programs.

Section 7 of the Act [84] also requires that all federal agencies consult with the Secretary of Interior to determine if an action by that agency will affect any threatened or endangered species. The Fish and Wildlife Service within the Interior Department makes these determinations.[85] Each agency is required to insure that any action authorized, funded, or carried out by the agency is not likely to jeopardize the continued existence of any threatened or endangered species or result in the destruction or adverse modification of habitat critical to such species. While an agency is not bound to consult with Fish and Wildlife if it determines that no such adverse effect would result from a particular project,[86] Fish and Wildlife may nevertheless request consultation.

Because each agency is required by the Act to protect threatened and endangered species, a jeopardy opinion by the Secretary of Interior (i.e., an opinion that the project is likely to jeopardize a listed species) virtually prevents the project from proceeding. The only recourse is for the agency to appeal for an exemption to the Endangered Species Committee, comprised of the Secretaries of Agriculture, Army and Interior, the Chairman of the Council of Economic Advisors, and the Administrators of the Environmental Protection Agency and the National Oceanic and Atmospheric Administration.[87]

Section 9 of the Act [88] expressly prohibits any person from taking any threatened or endangered species within the United States or on the high seas. "Taking" means any form of harassment, harm, capture or killing. Also

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[84] This is codified in 16 U.S.C. Sec. 1536.

[85] Regulations implementing this consultation process may be found in 50 CFR Part 402.

[86] 50 CFR Sec. 402.04.

[87] 16 U.S.C. Sec. 1536, subsections (e) and(g).

[88] This provision is codified in 16 U.S.C. Sec. 1538.

prohibited are importing, possessing, selling, delivering, carrying, transporting or shipping such species. Any action by any individual which kills or otherwise harms members of a listed species may therefore be prevented. Exceptions are provided for scientific or other specified purposes.[89] The Act also provides for civil and criminal penalties for violation of the Act, provides the Secretary of the Interior with authority to investigate and enforce the Act, and authorizes private citizens to commence civil lawsuits to enjoin any person or agency from violating the Act or to compel the Secretary to enforce the Act.[90]

Marine Mammal Protection Act

Under the Marine Mammal Protection Act, Congress provided special protection for marine mammals, established grant programs for research, and created the Marine Mammal Commission. The Act prohibits taking or importing marine mammals or marine mammal products except under special permits.[91] The term "marine mammal" includes all seals and sea lions, whales, dolphins and porpoises, manatees, dugongs, sea otters and other mammals which primarily inhabit marine environments, such as polar bears.[92] Permits are generally limited to scientific research and public display. Incidental takes during fishing are permitted, but efforts must be made to reduce their occurrence.

Responsibility for carrying out the provisions of the Act and issuing permits is divided between the Secretaries of Commerce and Interior. The Secretary of Commerce, overseeing NOAA and the National Marine Fisheries Service (NMFS), has responsibility for cetaceans and pinnipeds other than walruses.[93] The Secretary of the Interior has responsibility for all other marine mammals through the U.S. Fish and Wildlife Service.[94] The Act expressly prohibits enforcement of any state law or regulation regarding taking of marine mammals unless the federal government has transferred authority to the state. Under current law, the state of California has been given no such authority.

The Marine Mammal Commission is established to review and study existing national and international laws and the condition of marine mammals, and to make appropriate recommendations. Any permits for taking marine mammals must be reviewed by the Commission prior to issuance.

Magnuson Fishery Conservation and Management Act of 1756

The Magnuson Act governs fishing in all U.S. waters throughout the U.S. Exclusive Economic Zone. The purpose of the Act is to promote conservation and sound management of commercial fishing resources. The Act covers

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[89] Sec. 10 of the Act (Section 1539).

[90] Sec. 11 (16 U.S.C. Section 1540).

[91] 16 U.S.C. Sec. 1371 and 1372.

[92] 16 U.S.C. Sec. 1362, Subsection (5).

[93] 16 U.S.C. Sec. 1362, subsection (11)(A). NMFS's regulations on the subject may be found in 50 CFR, Chapter II, Subchapter C (Parts 215 through 228).

[94] 16 U.S.C. Sec. 1362, subsection (11)(B). Fish and Wildlife Service's regulations on the subject are contained in 50 CFR Part 18.

all species of marine animals and plants, including anadromous species, except for marine mammals, birds and highly migratory species of tuna.

The Act establishes national standards regarding fishing in U.S. waters [95] and regional fishery management councils to manage fisheries in specified regions. California is a member of the Pacific Council, which also includes Oregon, Washington and Idaho. The Council is required to prepare and submit to the Secretary of Commerce a fishery management plan for its region.[96] The plans—covering all fishing operations in U.S. waters—must include conservation and management measures for both foreign and domestic fishing vessels. The Secretary may approve, disapprove or revise the Plan.[97]

The Act contains an express provision that the Act does not extend or diminish any state authority over or within its boundaries. The Pacific Fisheries Management Council therefore does not supersede the authority of the California Department of Fish and Game in California waters.

The Council must be distinguished from the Pacific Marine Fisheries Commission. The Commission is an interstate body created in 1947 by interstate compact between California, Oregon and Washington. Its purpose is to promote the better utilization of fisheries and to develop a joint program of protection and prevention of physical waste of fisheries. The Commission's authority rests on the states' jurisdiction, rather than the federal government. The Commission's actions complement those of the Council by dealing with subjects outside the parameters of federal authority.

National Historic Preservation Act of 1966 (16 U.S.C., Section 470 et seq.)

This Act authorizes the Secretary of the Interior to expand and maintain the National Register of Historic Places, which is composed of districts, sites, buildings, structures and objects significant in American history, architecture, archaeology, engineering and culture. It also directs the Secretary to promulgate or revise regulations for State Historic Preservation Programs, and establishes criteria for establishment of State Historic Preservation Offices (now existing in every state and U.S. territory).

The portion of the Act applicable to this document is Section 470 (F), commonly known as Section 106 (Public Law 89-665). Under this section, a federal agency undertaking a project or issuing a license or permit for a project must first assess historical values which may be impacted. The State Historic Preservation Office plays an active role in all such assessments in California. (Please see State Agencies—Department of Parks and Recreation, Office of Historic Preservation).

Federal Agencies

The Department of Interior

The jurisdiction of the Department of the Interior is broad and diverse. The Department

[95] 16 U.S.C. Sec. 1851 through 1861.

[96] 16 U.S.C. Sec. 1851, subsection (h).

[97] The regulations may be found in Chapter VI of Title 50, Code of Federal Regulations (Parts 601 through 681).

is charged with the supervision of certain specific public business within the United States and its territories, including management of some, but not all, federal lands, wildlife, mining and petroleum operations.[98] The general policies and direction of all of the various bureaus come from the Secretary of the Interior, who reports directly to the President.[99]

The bureaus within the Department have more clearly defined roles than the Department as a whole. Those bureaus with the most significant authority over offshore oil and gas projects are the Minerals Management Service and the United States Fish and Wildlife Service, although actions by other agencies may affect coastal development indirectly.

Minerals Management Service

The Minerals Management Service (MMS) was created by Secretarial Order on January 19, 1982,[100] to implement the Outer Continental Shelf Lands Act.[101] Subject to the supervisory authority of the Secretary, the Director of MMS carries out or supervises all operations and activities conducted in connection with oil, gas and mineral leasing and development in federal waters, including collection of rents and royalties.[102]

The first step toward oil and gas development is preparation of the five-year leasing programs for all federal waters, using geophysical and geological data obtained from the U.S. Geological Survey and various private sources.[103] An EIS is prepared, reviewing the entire national scope of the plan. It is a relatively general document without the detail of the subsequent document prepared for the individual lease sales. Congress reviews the plans on an annual basis and directs modifications it deems appropriate. The most recent five-year plan was approved on July 2, 1987, and has been subsequently modified several times.

Once the five-year program is developed, MMS follows a 10 step process for reviewing, publicizing and issuing leases.[104] The first stages entail notifying the public, gathering information about the proposed sale, and more clearly defining the leasing area. The next several steps involve preparation of the Draft and Final Environmental Impact Statement required under the National Environmental Policy Act (NEPA).

A proposed Notice of Sale is then prepared, stating the decision of the Secretary on the sale, identifying the areas to be leased, describing the mitigations adopted, and providing information

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[98] 43 U.S.C. Sec. 1457.

[99] Rules for appealing decisions by the various bureaus to various appellate boards or to the Secretary directly have been established. For regulations regarding the Department of Interior's appellate process, see 43 CFR, Part 4 (Sec. 4.1 through 4.1310).

[100] 47 Fed. Reg. 4751.

[101] 30 CFR Chapter II (Sec. 200–290.70).

[102] 43 U.S.C. Sec. 1337, subsection (i), (j), and (k), and 30 CFR Sec. 250.10. With regard to collection of rent, royalties and other payments, see 30 CFR Part 201.

[103] 43 U.S.C. Sec. 1344.

[104] 30 CFR Part 256.

about bidding and lease terms. The Proposed Notice, along with a letter explaining the rationale for the leasing decision, is sent to the governor of the affected state, who then has sixty days to comment on the size, timing and location of the proposed lease sale.[105]

A Final Notice of Sale is then released, which includes the date, time and place of sale; areas available; stipulations on mitigation measures, bidding systems and lease terms; and other pertinent information. Sealed bids are then accepted and reviewed for adequacy. High bids for each tract offered are accepted if they assure receipt of fair-market value. Other bids may be accepted if economic, geophysical and geological data indicate their acceptance is appropriate. The lease is then issued to the winning bidder.[106]

The lessee must then explore for hydrocarbons on the lease through more geophysical and geological surveying and exploratory drilling. Exploratory drilling is the only sure way of determining if hydrocarbons are present within a lease tract. However, it is very expensive and entails many of the same environmental risks as developmental drilling. A lessee intending to perform such drilling must first submit an exploration plan to MMS, which includes a detailed description of the proposed activity. Also included is an oil spill contingency plan identifying response equipment and procedures and responsible agencies and personnel. Exploratory drilling projects must be reviewed under NEPA and the CZMA.[107]

Finally, MMS must give its prior approval to any development on the federal lease tracts. As with exploratory drilling, the decision whether to permit development is a separate exercise of discretion, requiring separate review under both NEPA and the CZMA. The decision regarding development must consider both the most efficient and productive means of development and the most environmentally sound option.[108]

Even after a development project is approved, each well drilled requires prior MMS approval of an Application for Permit to Drill. The purpose of this is to ensure that the well is drilled to optimize production and to prevent damage to the producing structure. MMS carries out frequent inspections of all operations on platforms in federal waters.

U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service (Fish & Wildlife) was first established in the Department of Interior in 1939.[109] The service is responsible for most matters relating to fish and wildlife resources, including wild birds, endangered species, certain marine mammals,

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[105] 43 U.S.C. Sec. 1345.

[106] Contents of the lease are governed by 43 U.S.C. Sec. 1337 and 30 CFR Part 25.

[107] See Secretary of State v. California, 464 U.S. 312, 78 L.Ed.2d 496, 104 S.Ct. 656 (1984).

[108] The factors which MMS must consider in any decision to approve a development proposal may be found in 43 U.S.C. Section 1344.

[109] The legal foundation for the existence of the service may be found in 16 U.S.C., Chapter 9 (Sections 741 et seq.).

inland sport fisheries, wildlife habitat protection and specific fishery and wildlife research activities.[110]

The agency is divided into regional offices to facilitate management. The Regional Office for California, Hawaii, Idaho, Nevada, Oregon, and Washington is located in Portland, Oregon. Field offices in California are located in Sacramento and Laguna Niguel.

The program through which Fish & Wildlife may have the most significant effect on California coastal planning is the administration of the Endangered Species Act.[111] As previously discussed, a finding by the service that a project requiring federal approval may jeopardize a threatened or endangered species may effectively halt the project. Any planning along the coast must give considerable attention to the location, habitat and distribution of threatened and endangered species listed by the service.

Enforcing federal laws affecting wildlife also falls under the authority of Fish & Wildlife. The Division of Law Enforcement within Fish & Wildlife enforces the Endangered Species Act, the Migratory Bird Treaty Act, the Marine Mammal Protection Act and the Lacey Act, as well as international treaties and conventions, such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Currently, the division is most frequently engaged in preventing the importation of protected species.

The service also monitors and provides support for migratory birds, manages national wildlife refuges, provides research and support for restoration of fisheries, provides information and support for international negotiations regarding fisheries, migratory wildlife, and protected species, carries out restoration programs, and conducts research and monitoring of the nation's wildlife generally.

Other Bureaus

Most of the other bureaus within the Department of Interior which may have an effect on California's coastal planning are primarily concerned with onshore activities.

The National Park Service manages several coastal parks and recreational areas. Most significant within California are Redwood National Park, The Golden Gate National Recreation Area, Point Reyes National Seashore, and Channel Islands National Park.

The Bureau of Land Management (BLM) controls large areas of federally owned lands onshore, shares administrative duties on the Channel Islands, and manages scattered federal holdings along the coast. The largest coastal area under BLM's jurisdiction is the King Mountain Range, southwest of Humboldt Redwoods State Park in Humboldt County. This land, along the Mattole River, is a National Recreation Area.

The Bureau of Reclamation carries out inland irrigation and flood control projects which affect water flows into and across coastal communities. These activities ultimately affect the configuration and use of coastal projects, as well as the natural condition of coastal environments.

Finally, the U.S. Geological Survey carries out geology and seismology surveys which affect decisions on offshore oil and gas leasing and earthquake preparedness.

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[110] See The United States Government Manual, 1988/89, at page 315.

[111] 16 U.S.C. Chapter 35, Sections 1531 et seq., discussed above.

Commerce Department—The National Oceanic and Atmospheric Administration (NOAA)

Coastal planning is affected by the U.S. Department of Commerce primarily through the National Oceanic and Atmospheric Administration (NOAA). NOAA carries out a large number of research and administrative functions concerning activities in and near the ocean.

Among the agency's responsibilities is administration of the CZMA. It administers the grant programs under the act, reviews individual coastal programs of states receiving grants to determine compliance, and carries out various research, restoration and protection programs under the act.

The National Marine Fisheries Service (NMFS) within NOAA has jurisdiction over most marine mammals and certain specified fish. While commercial species are generally managed by NMFS and other species by Fish and Wildlife, the division of authority is not so clearly defined. For example, NMFS has exclusive jurisdiction over all whales, dolphins, seals and sea lions.

Another service within NOAA, the National Ocean Service (NOS), responds to releases or potential offshore releases of oil or hazardous substances. NOS also assists the Environmental Protection Agency (EPA) with coordination of response and clean-up of offshore spills. NOS produces nautical charts and other aids in navigation and ocean passage; maintains the National Getic Reference System for mapping and charting; measures ocean conditions and characteristics on a global scale; and manages estuarine sanctuary and research programs.

NOAA also administers a number of other major research and information programs significant to coastal planning, including the Sea Grant Program, a grant program supporting research, education and advisory service; the Office of Oceanic and Atmospheric Research; the National Environmental Satellite, Data and Information Service; and the National Weather Service.

Environmental Protection Agency (EPA)

The Environmental Protection Agency (EPA) is another federal agency with sprawling jurisdiction over a large number of environmental matters. Created as an independent agency within the executive branch, the agency's purpose is to coordinate government action to abate and control pollution.[112] To that end, it has been given certain research, monitoring, standard setting and enforcement authority. Among the many acts and programs EPA administers, the most significant with respect to coastal planning are the Clean Air Act, the Clean Water Act and the Marine Protection, Research and Sanctuaries Act (the Ocean Dumping Act), discussed above.

Army Corps of Engineers

The Army Corps of Engineers has broad authority over navigable waters and wetland areas. Any work involving fill, construction, or modification in any offshore or coastal waters requires Corps review or approval. There are basically three grounds for authority: the Rivers and Harbors Act, Section 404 of the Clean

[112] 40 CFR Sec. 1.3.

Water Act, and the Marine Protection, Research and Sanctuaries Act.

An interesting aspect of the Corps' jurisdiction is that, in many cases, its involvement is the only reason why many projects may be subject to NEPA. The federal government employs a very expansive definition of "navigable waters," so that often a project which will result in some fill on seasonal wetlands must comply with federal environmental review regulations. In many cases, the effect is primarily procedural, in that the environmental document prepared for the project must comply with both NEPA and the California Environmental Quality Act (CEQA) and the Corps will take an active role in preparation of the document.

U.S. Coast Guard

The Coast Guard is a branch of the armed forces, but is a service of the Navy only in times of war. Otherwise, it is a service of the Department of Transportation.[113] Its primary duties are to enforce federal laws and treaties of the United States on the high seas and waters subject to U.S. jurisdiction and to aid in the rescue of individuals in peril because of accidents or other emergencies on U.S. waters. As the agency primarily responsible for controlling navigation, the Coast Guard must also approve any buoys, signal lights and other aids to navigation which may be installed as part of any offshore project.

It is also the federal agency responsible for directing the clean-up of any spills of oil or other pollutants offshore or in navigable waters. To that extent, the Coast Guard must be consulted in the development of oil spill contingency plans under the Clean Water Act. The Coast Guard also has the primary responsibility for inspecting and enforcing the licensing provisions governing oil transportation ports in federal waters.

Agencies With Incidental Jurisdiction

The Federal Aviation Administration (FAA) has jurisdiction where a coastal project involves air traffic. Aside from such obvious examples as airports, the FAA must also approve helicopter traffic proposals for offshore platforms.

Federal Communications Commission (FCC) may be called upon to approve a communications license for radio communications between offshore projects and shore.

The Department of Defense (DOD) owns considerable property along the coast, most notably, Vandenberg Air Force Base and Camp Pendleton. The Department will require that any activities approved offshore of those bases not interfere with military operations.

The Forest Service (within the Department of Agriculture), must approve any projects within national forest Lands. Insofar as parts of the Los Padres National Forest in Ventura, Santa Barbara and Monterey Counties are on or near the coast, Forest Service approval may occasionally be required for projects in those areas.

The Federal Energy Regulatory Commission (FERC) has jurisdiction over all interstate natural gas pipelines. It recently adopted new regulations governing gas pipelines from federal waters, including a requirement that all such

[113] 14 U.S.C. Sec. 1.

pipelines be common carriers.[114] While these regulations have more relevance to the Gulf Coast, they must be considered in any planning for offshore gas projects.

STATE CONTROLS

For the most part, the state has exclusive jurisdiction from the ordinary high water mark out to three nautical miles from shore. Management of areas above the high water mark (i.e., onshore areas) is largely left to local governments, therefore coastal development is affected by a combination of state, county, city, and regional controls.

Significant State Legislation and Principles

The Public Trust Doctrine

The Public Trust Doctrine is a legal principle established by the courts, not the Legislature, which limits public and private activities with regard to offshore lands.

All navigable waterways, tide and submerged lands within the state fall under the doctrine. These are sometimes called "sovereign lands" because they were acquired as a function of statehood in 1850. This distinguishes them from "proprietary lands" which the state acquires as a landowner or through condemnation.

Simply stated, the doctrine holds that sovereign lands are held by the state in trust for the benefit of the people for certain water-related purposes such as commerce, navigation, fisheries, recreation and ecological preservation.[115] Because these lands are held in trust, the state's authority to alienate them or permit other activities on the lands is limited.[116] However, court opinions have shown that the state has broad authority to prohibit activities on these lands which interfere with the trust and to allow one trust activity at the expense of another.[117]

Public Resources Code, Division 6 (PRC, Section 6000, et seq.)

This division governs leasing and management procedures for state sovereign lands, including leasing and development of tide and submerged lands. It also defines the authority of the State Lands Commission over

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[114] Disagreement exists over whether crude oil pipelines which carry OCS oil must be classified as common carriers. As stated, FERC holds that they must be so classified. The State Lands Commission and some oil companies agree. However, several pipelines in California which transport OCS oil do not operate as common carriers.

[115] While the doctrine was originally considered solely for protection of commerce, navigation and fisheries, it has been expanded to include environmental preservation and certain kinds of recreational activities. See Marks v. Whitney (1971) 6 Cal. 3d 251 and National Audubon Society v. Superior Court (1983) 33 Cal. 3d 419, 189 Cal. Rptr. 346, 658 P. 2d 709.

[116] The doctrine, inherited from English common law and European civil law, appears in some form to date back to ancient Rome and the Justinian Code of 529 A.D. For a history of the doctrine, see Stevens, The Public Trust: A Sovereign's Ancient Prerogative Becomes the People's Environmental Right (1980) 14 U.C. Davis L. Rev. 195, Sax, The Public Trust Doctrine in Natural Resource Law: Effective Judicial Intervention (1970) 68 Mich. L. Rev. 471, and Liberating the Public Trust Doctrine from Its Historical Shackles (1980) 14 U.C. Davis L. Rev. 185.

[117] Boone v. Kingsbury (1928) 206 Cal. 148; Colberg, Inc. v. State of California, ex rel. Department of Public Works (1967) 67 Cal. 2d 408, 62 Cal. Rptr. 401, 432 P. 2d 3; City of Long Beach v. Mansell (1970) 3 Cal. 3d 462 at 482, 91 Cal. Rptr. 23, 476 P. 2d 423, ftnt. 17; and Marks v. Whitney, supra (Id at 260–261).

offshore development of oil and gas resources, and defines areas where leasing is prohibited.[118]

California Environmental Quality Act (CEQA—Public Resources Code, Section 21000, et seq.) and the CEQA Guidelines (California Code Regulations, Title 14, Section 15000, et seq.)

CEQA was enacted in 1970 in response to growing concern over environmental protection and has four basic purposes: to inform the public and governmental decision-makers of potential environmental effects of proposed activities; to identify ways to reduce or avoid environmental damage; to prevent damage by requiring changes in projects through alternative projects and/or mitigation measures; and to make the public aware if an approved project will have significant environmental effects.

Any activity proposed, funded, or permitted by a state or local public agency which has the potential for resulting in a physical change in the environment, is considered a "project" by CEQA. Unless a project is statutorily or categorically exempt from CEQA review, either a Negative Declaration (ND) or Environmental Impact Report (EIR) must be prepared to assess potential impacts to the environment. Generally, if a project, individually or cumulatively, may have a significant effect on the environment an EIR is required. If there is no substantial evidence that a project may cause a significant effect on the environment, then an ND may be prepared.[119]

Very clearly, CEQA has a profound effect on applications for all types of proposed activities. Most public agencies have devised internal policies, systems and environmental management divisions to maintain responsibilities as required by CEQA.

CEQA is continuously modified and interpreted by legislation and court decisions which reflect environmental changes and concerns of public agencies, developers, special interest groups and the general public.

Mitigation Monitoring (Public Resources Code, Section 21081.6)

Legislation adding this section to CEQA was enacted in 1988 to assure that mitigation measures imposed in an environmental document are monitored for proper compliance and to analyze the effectiveness of the measures. A public agency must adopt a reporting and monitoring program whenever it makes a finding relative to mitigating or avoiding significant environmental effects of a project.[120] This program puts "teeth" in the CEQA process by causing public agencies to monitor projects they have approved so that specified mitigation measures are not ignored, avoided, or modified.

Permit Streamlining Act ("AB 884"; Government Code, Section 65927, et seq.)

The Permit Streamlining Act was enacted in 1977 to expedite and simplify public agency permit processing for proposed development projects. The following significant provisions

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[118] Public Resources Code, Division 6, Section 6000, et seq.

[119] Public Resources Code, Section 21000, et seq. (CEQA), and California Code Regulations, Title 14, Section 15000, et seq. (CEQA Guidelines).

[120] Public Resources Code, Section 21081.6.

are included in the legislation: A public agency designated as a "lead agency" for a proposed development project must approve or deny such project within one year from the date an application is accepted as complete; a public agency must compile lists which specify information required from any applicant for a development project; specific time limits are established for lead and responsible agencies for various stages of application review, and environmental document preparation, review and approval.[121]

The Permit Streamlining Act has created a more predictable and less burdensome application process for developers, and a "clock" for public agencies with "alarms" throughout the application and environmental review process.

California Coastal Act (Public Resources Code, Section 30000, et seq.)

The Coastal Act was enacted in 1976 as successor to the California Coastal Zone Conservation Act of 1972. The goals of the Act are to: protect, maintain, enhance and restore the quality of coastal zone environment; assure balanced utilization and conservation of coastal zone resources; maximize access and recreation along the coast consistent with sound conservation principles and private property rights; assure priority of coastal-dependent and coastal related development over other development on the coast; and encourage state and local cooperation in planning and implementing mutually beneficial uses in the coastal zone.[122]

The Act establishes the coastal zone boundaries, policies governing the coastal zone, the Coastal Commission, implementation through local coastal programs, and consistency review of projects in federal waters under the federal Coastal Zone Management Act. (See STATE AGENCIES-California Coastal Commission)

California's Clean Air Provisions (Health and Safety Code, Division 26, Sections 39000 through 44071)

California's air quality legislation establishes two separate levels of air quality management: the State Air Resources Board and the local and regional districts.

The State Air Resources Board (ARB) establishes overall coordination and review of air pollution control efforts in the state and controls all mobile emission sources. It carries out substantial research and provides funding to certain local districts for control purposes.

The Board monitors pollution and establishes which areas of the state are meeting air quality standards. It does this by dividing the state into air basins for which state air quality standards have been established, then establishing criteria for designating a basin in attainment or non-attainment of those standards.

Local and regional districts have primary responsibility for control of air pollution from all sources within their jurisdiction other than emissions from motor vehicles. These districts, while managed by city and county governments and filled by local government officials, are considered state agencies. (See LOCAL GOVERNMENT-APCDs)

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[121] Government Code, Section 65927, et seq.

[122] Public Resources Code, Section 30000, et seq. (California Coastal Act).

Vehicular air pollution control is generally regulated by the ARB rather than the county and regional districts. California has more stringent restrictions concerning automotive emissions than does the federal government. The state also has an extensive inspection program for automotive emission control equipment.

In 1987 the Air Toxics "Hot Spot" Information and Assessment Act was enacted. It provides for inventory and assessment of certain existing and potential sources of toxic contaminants in order to better facilitate their control.[123]

The many provisions of air quality control measures have a significant impact on coastal development primarily because many of the areas generating the worst air quality problems are on or near the coast. Governments considering development projects generally give at least as much weight to air quality considerations as to any other factor.

California's Clean Water Provisions

Porter-Cologne Water Quality Control Act (Water Code, Division 7, Section 13000, et seq.)

The Porter-Cologne Act of 1969 is the basic water quality control law for California.[124] It establishes the State Water Resources Control Board and each regional board as the principal state agencies for coordination and control of water quality.

Among the policies set forth in the Act, Section 13142.5 (a) states "Highest priority shall be given to improving or eliminating discharges that adversely affect . . . ocean areas subject to massive waste discharge."

The State Water Resources Control Board is directed by the Act to formulate a water quality control plan for the state's ocean waters, known as the Water Quality Control Plan for Ocean Waters of California (Ocean Plan). California Ocean Plan [125]

The State Board adopted the Ocean Plan in 1972 and has revised it periodically. The Plan presents water quality objectives and establishes the basis for regulation of wastes discharged into California's coastal waters. The State Board adopts the Plan and any revisions, and the Regional Boards implement and interpret the Plan.

The Ocean Plan contains sections on beneficial use designations, water quality objectives, waste management requirements, effluent and receiving water requirements, discharge prohibitions, and general provisions for exceptions and monitoring programs.

The Plan identifies uses of marine waters which can be preserved only through water quality control. They include marine life and areas of Special Biological Significance (designated by the state Board), fish migration, fish spawning, shellfish harvesting, rare and endangered species, recreation, industrial water supply, commercial and sport fishing, mariculture, aesthetics, and navigation. The

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[123] See generally, 42 U.S.C. 1857, et seq. (Clean Air Act), 40 CFR 51.18 (Review of New Sources and Modifications), Health and Safety Code, Division 26, Sections 39000–44071.

[124] Water Code, Division 7, Section 13000, et seq. (Porter-Cologne Water Quality Control Act).

[125] Water Code, Division 7, Section 13170.2.

Board has established a set of narrative and numerical water quality objectives to protect these beneficial uses.

The Ocean Plan also contains guidelines for the development of new discharges into marine waters, objectives for effluent and receiving water, discharge prohibitions (e.g. municipal or industrial sludge, bypassing, discharge into areas of Special Biological Significance and others), and provisions requiring dischargers to monitor their activities. Exceptions to the Ocean Plan are permitted under special circumstances, provided beneficial uses are protected and the public interest is served.

The Porter-Cologne enabling legislation has allowed the State Board and Regional Boards to initiate and maintain many programs, activities, and studies, most of which may have some effect on coastal development. They include:

Toxic Pits Cleanup—A program regulating surface impoundments containing liquid hazardous wastes.

Waste Discharge Requirements—Regional Boards issue requirements to control the discharge to land of both hazardous and nonhazardous waste; requirements are mandated for all new and existing facilities.

Solid Waste Disposal Program—Identifies hazardous waste leakage from solid waste disposal sites.

Underground Storage Tank Program—Involves prevention and detection of leaking storage tanks that contain gasoline or other hazardous substances.

Nonpoint Source Program—Under a program mandated for every state by the federal government in 1987, the Board develops an inventory of nonpoint source problems (pollution sources not coming from the end of a pipe, such as irrigation drainage), a ranking system, a statewide assessment and management recommendations.

Pollution Detection—Through review of self-monitoring reports and unannounced compliance inspections for adherence to NPDES permits (see Significant Federal Legislation—Federal Water Pollution Control Act); special investigations of citizen complaints; spill investigations; and information supplied by other agencies.

Surveillance and Monitoring Programs—The Toxic Substances Monitoring Program, State Mussel Watch Program, and Surface and Ground Water Quality Monitoring Networks have been conducted by the State and Regional Boards for over 10 years. Assistance is provided by the Department of Fish and Game, Department of Water Resources and U.S. Geological Survey.

Enforcement—The Regional Boards maintain an effective enforcement program which includes administrative notices, cleanup and abatement orders, cease and desist orders, administrative imposition of civil liabilities, and referral to courts for criminal prosecution and more costly civil liability actions.[126]

[126] State Water Resources Control Board, California Waterscape 1986–88, August, 1989.

California Endangered Species Act (California Fish and Game Code, Section 2050, et seq.)

The California Endangered Species Act (CESA) as amended in 1987 (California Fish and Game Code Sections 2050–2098) includes provisions intended to improve the protection afforded endangered and threatened species affected by development projects subject to the California Environmental Quality Act (CEQA).[127]

CESA states that it is the policy of the state that state agencies should not approve projects as proposed which would jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of habitat essential to those species. To accomplish this, CESA introduces the concept of state lead agency consultation for endangered and threatened species. Section 2090 (a) provides that "Each state lead agency shall consult with the (Fish and Game) Department, in accordance with guidelines developed by the Department, to ensure that any action authorized, funded, or carried out by that state lead agency is not likely to jeopardize the continued existence of any endangered or threatened species."

The Department of Fish and Game, trustee agency for endangered and threatened species under CEQA, and other State agencies now have a more clearly defined mutual responsibility to avoid potential conflicts and resolve actual conflicts. The effect of CESA on coastal development is to add another hurdle in the environmental review process in order to protect sensitive species and their habitat.

Native American Remains (Health and Safety Code, Section 7050.5; Public Resources Code, Sections 5097.94, 5097.98, 5097.99)

This legislation is intended to provide protection to Native American human burials and skeletal remains from vandalism and inadvertent destruction. In addition, it provides a means by which Native American descendants can make known their concerns regarding the need for sensitive treatment and disposition of Native American burials, skeletal remains and items associated with Native American burials.[128]

Grave sites, cultural sites, religious or spiritual sites and artifacts may be protected by federal, state and/or local laws and ordinances. Generally, development projects requiring a public agency permit are subject to environmental review (through the NEPA and/or CEQA process). Archaeological, cultural and Native American resource issues must be addressed within such review.

The Lempert-Keene-Seastrand Oil Spill Prevention and Response Act: Title 2, Division 1, Chapter 7.4 (commencing with §8670) and Chapter 7, Article 3.5 (commencing with 1) of the Government Code and Division 7.8 (commencing with §8750) of the Public Resources Code. (SB 2040, Chapter 1248, Statutes of 1990)

On September 24, 1990, this Act took effect as an emergency measure. The legislation provides a comprehensive approach to oil spill prevention, response, liability, and contingency planning. Two funds, one each for response and

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[127] Fish and Game Code, Section 2050, et seq. (California Endangered Species Act).

[128] Health and Safety Code, Section 7050.5; Public Resources Code, Sections 5097.94, 5097.98, 5097.99.

administration, are established and funded by fees on oil. An Administrator for oil spill prevention and reponse is to be appointed as part of the Department of Fish and Game. A comprehensive system of state, local, and industry contingency plans will be developed in accordance with regulations adopted by the Administrator. Regulatory and inspection programs will be implemented by the Administrator and the State Lands Commission to ensure full protection of the coast from oil discharges.

The Act will have an effect on coastal planning insofar as all oil-related projects along the coast will require contingency planning, review, and monitoring under its provisions. Any new marine terminals and offshore facilities must be located, constructed, and operated according to State Lands Commission regulations. New vessel traffic service systems will be established along the coast, harbor safety plans will be implemented, and navigational regulations will be adopted, all of which will have effects on shipping and harbor activities. The result will be a coordinated, statewide effort to reduce the risks of damage to the coast from oil spills.

Protection of Lands and Resources Within the Coastal Zone (California Administrative Code, Title 2, Division 3, Article 6.5, Section 2501, et seq.)

This article implements and supplements certain policies of the California Coastal Act, as they apply to the State Lands Commission's area of jurisdiction and statutory changes. Provisions are presented to protect against oil spills, regulate dredging, diking and filling, restore sand supply, control development on or adjacent to environmentally sensitive areas, and generally protect the coastal environment.

"Significant Lands Inventory" (Public Resources Code, Section 6370, et seq.)

Public Resources Code, Section 6370, was enacted in 1970. It required the State Lands Commission to: inventory all unconveyed state school, tide and submerged lands; identify lands which possess significant environmental values; and adopt regulations necessary to assure permanent protection of such lands.

The State Lands Commission will not allow sale, lease or other use of environmentally significant land without:

- Finding that adequate provisions have been made for the permanent protection of the environmentally significant characteristics.

- Finding that granting of the application for a specific use will have no significant effect upon such characteristics.

For projected use of a parcel upon which no determination has been made as to significant environmental values, Commission staff must determine if such land should be classified as having significant values.

The analysis under Public Resources Code, Section 6370, is separate and apart from CEQA review.

State Agencies

Resources Agency

The Resources Agency is the state agency which oversees the largest portion of regulation and management of state resources. As such, it has a considerable impact on the course of coastal development.

The following entities fall under the general authority of the Resources Agency: the State Air Resources Board, the Colorado River Board, the State Energy Resources Conservation and Development Commission, the State Water Resources Control Board, each California Regional Water Quality Control Board, the State Lands Commission, the Division of State Lands, the Departments of Conservation, Fish and Game, Forestry and Fire Protection, Navigation and Ocean Development, Parks and Recreation, and Water Resources.[129] Also within the Resources Agency, but under separate statutory authority, are the California Coastal Commission, the California Coastal Conservancy, the Tahoe Conservancy, the California Waste Management Board, and the California Conservation Corps.[130]

The Secretary for Resources may play a direct and substantial role in the operation of a board or commission which is appointed entirely by the governor. However, where most or all of the membership of the controlling board or commission is appointed by persons other than the governor, the organization operates largely independent of the Resources Agency. Such is the case with the State Lands Commission and the California Coastal Commission. Nevertheless, the Secretary has considerable influence over coastal planning through participation in the development of the Governor's environmental, planning and budgetary policies, and by sitting on many of the boards and commissions within the Agency.

State Lands Commission

The Legislature gives the California State Lands Commission exclusive jurisdiction over all tide and submerged lands, the beds of navigable rivers and lakes, swamp and overflowed lands, and school lands within the state.[131] The Commission also manages other state-owned mineral resources.[132] Tide and submerged lands and navigable waterways are often called "sovereign" or "public trust" lands, because they are owned by the state as a function of statehood and are subject to the public trust. (See Significant State Legislation and Principles-Public Trust Doctrine). The other lands were granted to the state by the federal government under special legislation.

In a sense, the Commission is the state's property manager with respect to these lands. Its authority is derived from the state's position as landowner and trustee of the public trust, and from its police power to protect the public health and welfare. Thus, the Commission has broad power to ensure the appropriate use of the lands under its jurisdiction.

In some cases, jurisdiction over offshore areas or navigable waterways has been delegated to other governmental bodies. Many coastal cities have been granted offshore lands within their boundaries for purposes of harbor and waterfront development. For example, most of the state lands in Santa Monica Bay are within legislative grants to the City of Los Angeles and other beach cities. Some state lands offshore have been leased to the Department of

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[129] Government Code, Section 12805.

[130] Public Resources Code, Section 30300.

[131] Public Resources Code, Section 6216 and 6301; Monterey Oil Company v. The City Court of the City of Seal Beach (1953) 120 Cal. App. 2d 31, 260 P. 2d 846.

[132] Public Resources Code, Sections 6401–6407.

Parks and Recreation for use as underwater parks. In all such cases, the Commission retains oversight authority over the various leases and grants.

The State Lands Commission is comprised of the Lieutenant Governor, the Controller and the Director of Finance. The Commission operates through the Commission staff, technically referred to as the Division of State Lands. The staff carries out its responsibilities under the direction of the Executive Officer, who serves at the pleasure of the Commission. Although the staff is organized as part of the Resources Agency, it acts entirely at the direction of the Commission.

With the exception of fishing, virtually all offshore activity involving state lands—and many activities on adjacent shores—will involve some level of Commission review. This includes offshore oil and gas activities, harbor development and management, construction and operation of any offshore pipelines or other facilities, dredging, reclamation, development, use of filled lands, studies of ocean floor topography and geology, sewage disposal, and other activities such as the preservation of offshore and coastal lands for conservation and recreational uses.

A considerable amount of the agency's time is spent merely determining the nature and extent of the state's interests. Under Public Resources Code, Sections 6210 and 6210.1, the Commission is responsible for surveying and maintaining records of all state sovereign and school lands, as well as settling issues of title and jurisdiction. Changes in the landscape make this a difficult task, particularly with regard to determining the boundaries of navigable waterways. The state's ownership interest in its sovereign lands is based on the historical location of navigable waterways, tide and submerged lands and other wetlands. Over time, people have altered shorelines, filled wetlands and otherwise made it difficult to determine the exact location of state-owned lands. Illegal fill along the shore, for example, does not change the state's title to the historic tide lands.

The Commission staff, therefore, must engage in extensive reviews of historical maps, title descriptions and surveys in order to determine the location and extent of historical waterways.

Where a potential development site may include state sovereign lands, the Commission must become involved either in settling title ambiguities or in affecting the development process. This has occurred to a considerable extent around San Francisco Bay due to legal and illegal reclamation projects since the middle of the nineteenth century. The Commission is also a major party in development matters around Bolsa Chica and Marina del Rey.

Generally, the Commission oversees activities carried out by local agencies. In some cases, however, the Legislature has granted authority over harbor development and management within local boundaries to city and county governments. Commission staff reviews local actions to ensure that the local government grantee does not exceed its authority. For example, a grantee may not use revenue earned from port operations for programs unrelated to the public trust.

In other cases, the Legislature has granted regulatory control over offshore activities to other agencies but left property management in the hands of the Commission. For example, the Water Resources Control Board regulates

sewage discharge, but a lease-right-of-way from the Commission is required for installation of the disposal pipeline.

The Commission has no current offshore oil and gas leasing program. Since the last offshore lease was issued in August 1968, the only oil and gas leases issued by the Commission have been onshore sites in the Sacramento–San Joaquin River Delta and under navigable waterways. These newer leases have been primarily for natural gas production. The Commission does, however, carry out substantial monitoring of exploratory and production activity on existing leases to protect the environment and other state interests.

Under the recently adopted Lempert-Keene-Seastrand Oil Spill Prevention and Response Act, the Commission will be taking a more active and substantial role in oil spill prevention. It has always carried out an extensive inspection program on offshore exploration and production facilities on its leases. The legislation will provide the Commission with greater flexibility and authority to improve those programs. The Act also gives the Commission responsibility for ensuring the safe operation of all marine terminals in the state, whether or not on Commission leases. A comprehensive set of regulatory and inspection programs are being established to ensure the full protection against spills resulting from terminal operations.

California Coastal Commission

The California Coastal Commission was originally created as the California Coastal Zone Conservation Commission under Proposition 20, passed by voters in 1972. It was established as a temporary body to prepare, adopt and submit to the Legislature a California Coastal Zone Conservation Plan. Four years later, it was given its present name and configuration, and made a permanent agency under the California Coastal Act of 1976.[133]

The Commission has authority over activities within the coastal zone, an area which includes all land and water from the state's seaward boundary to a line inland, specified by the Legislature. The landward boundary of the zone is generally a thousand yards from shore, but varies substantially. The Commission also has some jurisdiction over activities in federal waters offshore and on federal land within the coastal zone.

The Commission is comprised of twelve voting members. The Governor, the Senate Rules Committee and the Speaker of the Assembly each appoint four members to the Commission. Also sitting on the Commission in nonvoting capacities are the Secretaries of the Resources Agency and the Business and Transportation Agency, and the Chairperson of the State Lands Commission.

The Commission's duties may be divided into five general categories: inventory and planning, review of projects in federal waters, review of projects in the coastal zone prior to implementation of an applicable local coastal plan, and consideration of appeals.

While the preparation of local coastal plans is generally left to local governments, a local government may request that the Commission

[133] Public Resources Code, Section 30000, et seq. (see discussion of California Coastal Act under Significant State Legislation and Principles).

prepare the plan. (See LOCAL GOVERNMENT-LCPs and Coastal Development Permits). The Commission must also review and certify local coastal plans before they are effective. Prior to certification of an applicable local coastal plan, development within the coastal zone usually requires a development permit from the Commission.

The local government may adopt procedures for processing, reviewing, approving or denying coastal development permits prior to obtaining certification of a coastal plan; but the Commission must also issue a permit if the proposal is for a major public work or energy facility or a project located in specified areas.[134]

Fish and Game Commission and Department of Fish and Game

The Fish and Game Commission and the Department of Fish and Game are the agencies primarily responsible for ensuring the proper protection and management of fish and wildlife resources within the state. These resources are considered the property of the state, and are held in trust for the people.[135]

While the federal government, through the Departments of Interior and Commerce, exercise some authority over wildlife where interstate commerce or other federal concerns are effected, ordinary management and control is the responsibility of the Commission and the Department.

In addition, while the federal government has primary responsibility for wildlife resources in areas under federal control (e.g. Bureau of Land Management lands, federal waters), the Commission may also have authority over activities on those lands where the federal government has not enacted regulations occupying the field.[136]

Article IV, Section 19 of the State Constitution expressly provides for a Commission of five members appointed by the Governor and approved by the Senate. The Legislature has granted the Commission authority to regulate the taking or possession of birds, mammals, fish, amphibia and reptiles, subject to the limitations established in the Fish and Game Code.[137] The Regulations provide detailed limits on size, number, method and timing of takes.[138]

The Department administers the Code and the Commission's regulations. The Department is administered by the Director who is appointed by the Governor. While policy differences between the Commission and the Director may be expected to occur rarely, insofar as all the parties are the Governor's

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[134] Public Resources Code, Section 30601.

[135] People v. Stafford Packing Company (1924) 193 Cal. 719 at 725. See also People v. K. Hovden Company (1932) 215 Cal. 54.

[136] In People v. Weeren (1980) 26 Cal. 3d 654, 163 Cal. Rptr. 255, 607 P. 2d 1279, the court held that California had the right to impose criminal penalties for a violation of state fishing laws in federal waters. Also, in Skiriotes v. Florida (1940) 313 U.S. 69, 85 L. Ed. 1193, the U.S. Supreme Court held that a state has the right to govern the conduct of its citizens on the high seas with respect to matters in which the state has a legitimate interest and where there is no conflict with federal law.

[137] Fish and Game Code, Section 200, et seq.

[138] Fish and Game Code, Section 703.

appointees, the Director will look to the Governor in the event of any disagreement.

The Department has the authority to enforce state laws and regulations pertaining to fish and game. It is also authorized to acquire, improve and exchange lands, and to establish and operate fish hatcheries, game farms, wildlife refuges, and other facilities to protect and improve wildlife resources. Any alteration or crossing of a waterway also requires a stream alteration agreement with the Department.

There is also in the Department the Wildlife Conservation Board. It consists of the President of the Fish and Game Commission, the Director of the Department and the Director of Finance.

The Board's primary duties are to investigate and determine which areas are most essential and suitable for wildlife propagation and preservation. The Board has authority to acquire land for these purposes either through purchase or by eminent domain.

As the primary managers of the state's wildlife resources, the Commission and Department have a potentially substantial influence on the course of coastal development.

The Department may prevent development in certain areas through the establishment of refuges, ecological preserves or other specially designated wildlife areas.

Under the Endangered Species Act,[139] the Department is empowered to protect threatened and endangered species. Thus, the Act may have a profound effect on development proposals in areas containing habitat for these species. (See Significant State Legislation and Principles-California Endangered Species Act).

A Streambed Alteration Agreement must be entered into with the Department by anyone who intends to divert or obstruct the natural flow or substantially change the bed, channel or bank of any river, stream or lake, or use any material from a streambed.[140] This process is not subject to CEQA review, but neither does it supplant the CEQA review process. But in most cases, particularly where the proposed activity is minor, the Agreement is the only protective measure a waterway may receive. The process affects a substantial number of projects along the coast.

The Department's comments on environmental documents have considerable influence on decisions regarding wildlife impacts. The Commission and Department have a greater impact on the development of the state's fishing industry than any other governmental agency.

The Department of Fish and Game is also given the largest role under the new Oil Spill Prevention and Response Act. The Administrator of the Office of Oil Spill Prevention and Response wil be chief deputy director of the department. The Administrator will chair the State Interagency Oil Spill Committee in updating the state contingency plan. The office must also implement regulations and guidelines governing industry and local government plans and ensure that they are fully coordinated with the state plan. Navigational safety will also be coordinated and

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[139] Fish and Game Code, Section 2050, et seq.

[140] Fish and Game Code, Section 1600, et seq.

regulated by the office. Finally, in the event of a spill, the Administrator wil have paramount state authority to response operations, in coordination with the Coast Guard.

Pacific Fisheries Management Commission

This body is not a state agency, but an interstate commission created by compact among Alaska, California, Idaho, Oregon and Washington.[141] Its purpose is to promote better utilization and to prevent physical waste of Pacific fisheries through joint coordination. While the Commission coordinates multi-state activities and programs it does not limit the power of each member state to enact its own regulations and establish its own programs.

California has three representatives on the Commission—each appointed by the Governor with advice and consent of the Senate—one of whom is an officer of the Department of Fish and Game.

Secretary of Environmental Affairs

The Secretary of Environmental Affairs is a member of the Governor's Cabinet and serves as the principal advisor on major policy and program matters regarding environmental protection. The role of the Secretary is to understand the interrelationship of environmental issues so that a coordinated environmental program is developed and maintained.[142]

The Secretary has oversight authority for and coordinates the activities of a number of boards and offices which administer the state's programs dealing with air and water quality and nonhazardous waste management. The boards are independent and, as such, have separate statutory authority. Several are of particular significance with regard to planning along the coast.

California Air Resources Board (ARB)

The ARB is the state agency with overall responsibility for the state's efforts to reduce air pollution. It has nine members appointed by the Governor with the consent of the Senate. The Board is responsible for control of emissions from motor vehicles, and coordination, review and encouragement of efforts by all other levels of government as they affect air quality [143] (see Significant State Legislation and Principles-California's Clean Air Provisions).

State Water Resources Control Board

The Water Board's two major responsibilities are to regulate water quality and to administer water rights. The Board carries out its water pollution control responsibilities by establishing waste-water discharge policies, issuing discharge permits and taking enforcement actions against polluters. The Board also has express authority to deal with toxic discharges from underground storage tanks, underground injection wells and

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[141] Fish and Game Code, Sections 14000-14207.

[142] The Secretary's position, originally designated "Special Assistant for Environmental Protection," was established in 1975 by Governor Brown's Executive Order No. B2-75. Governor Deukmejian subsequently raised the position to cabinet level and increased the degree of responsibility. By statute, all of the offices and bureaus operating under the Secretary are within the Resources Agency.

[143] Health and Safety Code, Section 39500.

surface impoundments. (See Significant State Legislation and Principles-California's Clean Water Provisions).

State Regional Water Quality Control Boards

There are nine Regional Boards ranging from the North Coast Region to the San Diego Region. Each acts as the Water Resources Control Board's first line enforcement authority in pollution control activities, and implements the standards and policies established by the Board. The basis for pollution control efforts in each Region is a basin plan which identifies the Region's water bodies, their beneficial uses, objectives to protect those uses and an implementation strategy. These Regional Boards act only in matters of water quality regulation; administration of water rights is handled by the Water Resources Control Board.

California Integrated Waste Management Board

The Waste Management Board is responsible for ensuring that nonhazardous wastes are disposed of and managed in a safe and environmentally prudent manner, and for encouraging the adoption of sound alternative waste disposal practices, such as recycling and waste-to-energy conversion. The Board also conducts oversight inspections of landfills, reviews disposal permits issued by local enforcement agencies and approves county solid waste management plans. While not directly related to coastal planning, the presence of landfill sites near the coast gives the Board some responsibility with regard to coastal issues.

Other Areas of Responsibility

In addition to overseeing the activities of the three environmental boards, the Secretary has responsibility in four program areas that cut across departmental boundaries:

Offshore Development

The Secretary serves as the Governor's Outer Continental Shelf (OCS) Policy Coordinator. In this capacity, the Secretary coordinates the federal, state and local environmental review process for offshore and related onshore leasing and development projects. The Secretary develops policy positions for the Governor on OCS-related issues, such as oil transportation and OCS revenue sharing; serves as the Governor's spokesperson on OCS-related issues; and serves as a central point of access for environmental groups, industry, local agencies, and the public to relay their concerns to the Governor. In this role, the Secretary also administers the Coastal Resources and Energy Assistance Program, which provides grants to local governments for planning and mitigation programs related to offshore oil and gas, and the Local Marine Fisheries Impact Program, which addresses impacts to commercial fishing.

Hazardous Substance Cleanup Arbitration Panel

The Secretary administers this panel which promotes the cleanup of hazardous waste sites on the California State Superfund List by swiftly arbitrating disputes over cleanup cost liability.

Registration of Environmental Assessors

The Environmental Quality Assessment Act of 1986 was enacted to assure compliance with legal requirements for the management of hazardous substances. The Secretary has developed and adopted regulations and publicized criteria for the voluntary registration of environmental assessors. The Secretary

encourages the use of Registered Environmental Assessors to achieve higher degrees of compliance with environmental laws.

Toxics Data Management

The Secretary manages the Office of Hazardous Materials Data Management which has been established to improve the collection, management and dissemination of toxics-related information. This office maintains an index of databases, a list of chemicals regulated under various toxics programs, and an interagency facilities inventory that centralizes and cross-indexes a listing of the facilities regulated by toxics programs.

Department of Water Resources (DWR)

The Department of Water Resources was established by the Legislature in 1956 with a goal of protecting, conserving, developing and managing California's water.

DWR's major responsibilities are: operating, maintaining and expanding the State Water Project (an immense system of dams, reservoirs, aqueducts, and pumping and power plants which deliver water to urban and agricultural areas throughout much of the state); evaluating current and projected needs for water, and developing programs that assure the best use of the resource; protecting the public through water quality improvement, flood control and dam safety programs; and assisting local water agencies with funds, expertise and technical support to improve their water delivery systems and meet the increasing demands of their communities.[144]

The Department is organized into divisions, each of which has a separate role.

The Division of Planning develops water management strategies which help the state meet future water requirements. Work includes collection and analysis of data on surface and ground water, population and land and water use; estimation of needs, surpluses and deficiencies by major hydrologic areas; construction and operation of environmentally sound projects to increase the State Water Project's supply and conveyance capacity; and improvements to Sacramento–San Joaquin Delta channels and levees.

The Local Assistance Division works with federal, state and local agencies to develop strategies to best use existing water resources and meet future needs. Functions of this Division include investigation of fishery, water supply and quality problems; watermaster services; restoration of urban streams and fisheries; development of water conservation projects and ground water recharge financing programs; and planning and development of recreational facilities. Staff of this Division work closely with local/regional water and irrigation districts.

The other divisions manage different aspects of the state water system. Staff of the Design and Construction Division builds additions and alterations to the State Water Project.[145] It also designs and oversees construction on other water projects, such as dams and pumping plants. The Division of Operations and Maintenance manages all State Water Project facilities, including its pumping and

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[144] Water Code, Section 125.

[145] Department of Water Resources, The California State Water Project.

hydroelectric plants, dams, reservoirs, aqueducts and buildings. The Energy Division satisfies the power requirements of the State Water Project—California's largest single user of electricity. The Safety and Dams Division examines and approves the design, construction, operation, alteration, repair and maintenance of more than 1,200 nonfederal dams in California. The primary role of the Flood Management Division is to prevent and minimize flood damage. Duties include forecasting, participation in flood control projects, maintenance of flood control facilities, and disaster relief coordination. The Land and Right of Way Division clears the way for construction of State Water Project facilities.

Although DWR is generally not directly involved in coastal development, it is important to note that its activities are vital to the protection, conservation and management of the state's water supply. Development along the coast is at least indirectly affected by ongoing activities of DWR.

Two projects before the Department do affect coastal planning directly. The proposed Coastal Aqueduct, an 86-mile subsurface water pipeline from the California Aqueduct, is slated to deliver water to San Luis Obispo and Santa Barbara Counties and is subject to environmental review and approval by the two subject counties. The Water Resources Development Bond Act provides financial assistance to local agencies, including coastal communities, for development of water projects.

Department of Conservation

The Department of Conservation oversees the conservation of earth resources within the state. The Department has specific responsibility over mines and geology, oil and gas operations, resource conservation and recycling.[146] Although the Department is technically part of the Resources Agency, it is administered by the Director of Conservation who communicates directly with and serves at the pleasure of the Governor.

The Department is divided into the following areas of responsibility: Division of Oil and Gas, Division of Mines and Geology, State Mining and Geology Board, the Office of Land Conservation, the Division of Recycling and the Beverage Container Recycling Advisory Committee. Also within the Department is the Energy Resources, Conservation and Development Commission.

The Division of Oil and Gas (DOG) within the Department of Conservation, is primarily involved in regulating oil and gas activities. Unlike the State Lands Commission, which permits and regulates oil and gas only on state sovereign and school lands, the Division has regulatory authority over all such operations throughout the state.[147] The decision whether to allow such activities at all, either onshore or offshore, is left to other agencies. Once the activity is permitted, though, it is strictly monitored by this Division.

The State Mining and Geology Board represents the state's interests in the development, utilization, and conservation of California's mineral resources, in the reclamation of mined lands, and in federal matters pertaining to mining. The Board also establishes surface mining and reclamation

[146] Public Resources Code, Section 607.

[147] State of California, Resources Agency, Departments, Boards and Commissions, June, 1987.

policy.[148] The Division of Mines and Geology, headed by the State Geologist, administers the policies set forth by the Board. In addition to implementing the Surface Mining and Reclamation Act of 1975, the Division also obtains and provides information on geology and minerals which is essential for resource management and maintenance of adequate earthquake preparedness. As with the Division of Oil and Gas, the Board and the Division of Mines and Geology have little effect on coastal planning. However, insofar as mining and reclamation occur under the supervision of these entities, their functions may have a significant effect on those activities in coastal areas.

The Office of Land Conservation administers the Open Space Subvention Program, reviews contracts and agreements for agricultural preserves, reviews environmental documents under CEQA, provides support staff for the Soil and Conservation Districts, maps farmland in the state, and monitors conversion to and from agricultural uses.[149] While the Office has some responsibilities in preserving agricultural lands along the coast, its impact on coastal development and planning is limited.

Energy Resources, Conservation and Development Commission

The Commission was established by the Warren-Alquist State Energy Resources Conservation and Development Act of 1974 in order to address the difficult energy challenges facing the state.[150] It is the state's principal energy planning organization and is the largest of its kind in the United States. Since its inception, successive administrators, with bipartisan support from the Legislature, have enacted over 150 laws to assist in implementing state energy policy.

The Commission is comprised of five members who are appointed by the Governor for five-year terms, subject to Senate approval. The Commissioners represent the fields of physical science or engineering, law, economics, environmental protection and the public at large. The Governor selects a Chairperson from among the Commissioners every two years, and also appoints a Public Adviser who ensures that Commission proceedings have sufficient representation from the general public and interested groups.

The Executive Office provides policy and management direction to the Commission staff, and management support to the Commissioners. The General Counsel's Office represents the Commission in administrative hearings before the Public Utilities Commission and Federal Energy Regulatory Commission, at state and federal court proceedings, and at the Commission's own proceedings, such as power plant siting cases.

The Commission is organized into five divisions: Administrative, Siting and Environmental, Forecasting and Planning, Energy Efficiency and Local Assistance, and Technology and Development. The major areas of responsibility include: forecasting future statewide electricity needs; licensing power plants; promoting energy conservation;

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[148] Public Resources Code, Section 672.

[149] State of California, Resources Agency, Departments, Boards and Commissions, June, 1987, Page 30.

[150] Public Resources Code, Section 2500, et seq. (Warren-Alquist Act of 1974).

developing renewable energy resources and alternative energy generating technologies; and planning for and directing state response to energy emergencies.

The Commission is required by the Legislature to forecast energy trends every two years. It satisfies this mandate through a biennial report entitled the California Energy Plan which provides the basis for California energy policy and makes 5-, 12-, and 20-year projections of state growth and energy needs. This document is supported by a number of more specific policy publications including the Electricity Report, Conservation Report, Energy Development Report, and Biennial Fuels Report.

Although energy requirements, consumption and production may be significant issues in coastal development, the Commission has little direct involvement in such activity, beyond power plant certification and adoption of energy efficiency standards for buildings and appliances. However, the Commission's capabilities in forecasting energy demands, recognized as some of the most advanced in the nation, provide an invaluable planning resource for all coastal development.

San Francisco Bay Conservation and Development Commission (BCDC)

BCDC was established by the Legislature in 1965 as a study commission, and later became a permanent state agency.[151] The Commission has 27 members appointed by federal, state, and local entities.

The Executive Director oversees staff operations, divided into Administrative, Regulatory and Planning branches.

The four major areas of responsibility include: regulation of all dredging and fill activities in Suisun and San Francisco Bays; regulation of development within the area 100 feet inland from the bays' highest tidal action (with concentration on maximizing public access to the bay); minimizing pressures to fill the bay; and carrying out provisions of the Suisun Marsh Protection Plan.

The Commission evaluates permit applications based on the proposed project's conformity with the McAteer-Petris Act and the San Francisco Bay Plan. The McAteer-Petris Act establishes the Commission's powers and responsibilities for regulating shoreline development, adopts the San Francisco Bay Plan as the development guide for the area, and requires the Commission to make decisions that comply with the Bay Plan. The San Francisco Bay Plan describes development policies and sets priorities for land uses in specific shoreline areas.

Applications to BCDC for minor projects (e.g. maintenance dredging, new dredging of less than 100,000 cubic yards, small dock construction, levee and bulkhead repair) may be administratively approved by the Executive Director, whose decision is effective unless the Commission votes to hear the matter. Applications for projects of a larger scale must be presented to the Commission.

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[151] Government Code, Section 666000, et seq. (McAteer-Petris Act).

Coastal Conservancy

The Coastal Conservancy was formed by the State Legislature in 1976.[152] It is controlled by a seven-member board: the Chairperson of the Coastal Commission, the Director of Finance, a representative from the Resources Agency, and four public members (two appointed by the Governor and one each by the Senate and Assembly).

The Executive Officer directs a relatively small staff in activities along the entire length of California coastline and around the 1,100-mile coastal zone of San Francisco Bay. The key functions of the Coastal Conservancy include urban waterfront enhancement and access programs, agricultural preservation activities in coastal areas, and acquisition of key coastal areas for public use.

Department of Parks and Recreation

Established by the State Legislature in 1928, the State Park System is headed by a Director who is appointed by the Governor, and two Chief Deputy Directors, also gubernatorial appointees.[153]

There are four major geographical regions administered by the Department, three of which have coastal access: Northern, Central Coast and Southern Regions. Another smaller region, the San Simeon Region, is also located along the coastline. Districts within these regions are broken into areas which contain individual units. A unit is designated as one of the following: State Park, State Recreation Area, Off-Highway Vehicle Park, State Beach, State Historical Unit, State Reserve, or State Wilderness. A Natural Preserve or Cultural Preserve may be established within a unit. Such designations are made by the nine-member State Park and Recreation Commission, whose members are also appointed by the Governor, and who contribute to Department policy and planning decisions.

Coastal development may be affected by the Department in a number of ways. The Acquisition Division acquires coastal lands for park and recreational use and negotiates rights-of-way in coastal areas. Proposed coastal development which may affect a unit of the State Park System or public use thereof is generally reviewed by the Department during the CEQA and/or NEPA environmental review process, at which time the Department has the opportunity to object to any perceived adverse impacts. The Office of Historic Preservation has broad review authority over proposed activities for potential effects on historical and archaeological values (see further discussion below). The Advisory Board on Underwater Parks and Reserves recommends coastal areas with potential values for park or reserve designation, and advises on enhancement of existing underwater units.

Office of Historic Preservation (OHP)

Created by the National Historic Preservation Act of 1966,[154] the OHP is administered by a Preservation Officer and a nine-member State Historic Resources Commission, all appointed by the Governor. The Office, which has a counterpart in every other state and U.S. territory, was created to locate and designate important historical sites

[152] Public Resources Code, Section 30000, et seq.

[153] Public Resources Code, Section 500, et seq.

[154] U.S. Code, Title 16, Section 470, et seq.

and structures and ensure their protection and preservation. A small staff of archaeologists, historians, and administrative personnel is funded by state and federal governments and participates in numerous programs (e.g. State Landmarks Program, Points of Historical Interest), including the review of proposed activities which may impact historical and/or cultural values.

The OHP works in conjunction with federal agencies to review proposed projects and make recommendations pursuant to Section 106 of the National Historic Preservation Act, and enters into agreements with agencies and the Advisory Council with respect to mitigation for anticipated impacts.

Department of Forestry and Fire Protection

Within the Department is a nine-member State Board of Forestry which provides policy guidance for administration by the Department. This includes establishment of forest practice rules and classification of specified private wildlands as state responsibility for fire protection purposes.

The Director serves at the pleasure of the Governor, and members of the Board are all appointed by the Governor for four-year terms.

Under the umbrella of the Resources Agency, the Department manages fire protection services for privately owned wildlands, and administers or has contracts for various local government fire protection. It also regulates logging practices on private forest land, provides forest management advice to small landowners, regulates controlled burning of brushlands, manages seven State Forests and the State Forest Tree Nursery Program, and provides for assessment of the state's forest and rangeland resources.[155]

The Department's impact on coastal development is fairly limited. The only State Forest managed by the Department near the coast is the Jackson State Demonstration Forest near Fort Bragg. However, the Department's regulation of lumber activities on private lands near the coast may affect the course and direction of coastal development, particularly along the North Coast.

Department of Boating and Waterways

The Department began as the Division of Small Craft Harbors under the Department of Parks and Recreation (then called the Division of Beaches and Parks under the Department of Natural Resources). The Division was transformed into the Department of Navigation and Ocean Development under a state agency reorganization plan in 1969, and became the Department of Boating and Waterways in 1978.

The Boating and Waterways Commission, consisting of seven members appointed by the Governor, provides advice and consent on Departmental policy and actions. The Director, also appointed by the Governor, heads the Departmental Divisions of Administrative Services, Boating Facilities and Boating Operations.

The Department is responsible for the planning and development of boating facilities in environmentally acceptable areas, and administers the state's beach erosion control

[155] See generally, Public Resources Code, Division 4, and State of California, Resources Agency, Departments, Boards and Commissions, June, 1987.

programs. Through grant and loan programs, the Department funds marina development and boat launching facilities, and co-sponsors construction of beach erosion control projects with federal and local governmental agencies.[156]

The Department is involved in coastal development through planning new or rehabilitated/expanded small craft harbors which may include breakwater construction, dredging, boat berthing facilities, utilities, landscaping and irrigation, restrooms, fuel docks, boat sewage pumpout stations and public access bike/walkways. Erosion control projects may involve seawall construction, groins, breakwaters, or a combination of these to trap or replenish transported sand.

Office of Planning and Research (OPR)

OPR is situated within the Governor's Office and is administered by the Director of State Planning and Research who is appointed by the Governor.

The Office is responsible for developing state land use policies, coordinating planning of all state agencies, and assisting and monitoring local and regional planning. However, OPR was given no direct operating or regulatory powers over land use, public works, or other state, regional, or local projects or programs.[157]

OPR is responsible for developing and adopting guidelines for the preparation and content of the mandatory element of city and county general plans required by Government Code, Section 65300, et seq. It also prepared guidelines for the California Environmental Quality Act (CEQA) (California Code Regulations, Title 14, Section 15000, et seq.).[158]

Within OPR is the Office of Permit Assistance which assists state and local agencies in expediting their permit processes and provides information to project applicants concerning CEQA. The State Clearinghouse, within the Office, circulates environmental documents to appropriate state agencies, assuring adequate review in compliance with CEQA.

OPR may affect coastal planning in the same fashion that it affects all planning within the state: by coordinating and facilitating statewide planning and ensuring that planning efforts by all state, regional and local agencies comply with state standards and policies.

Department of Transportation

Although the State Legislature appointed Surveyor General S. H. Marlette to plan a system of roads in California in 1850, it was not until 1972 that the California Department of Transportation (Caltrans), as we know it today, was legislatively created.

Within the Business, Transportation and Housing Agency, Caltrans has evolved into one of the largest and busiest state departments which not only builds and maintains highways, but helps plan transit and aeronautics. The

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[156] State of California, Resources Agency, Departments, Boards and Commissions, June, 1987.

[157] Government Code, Section 65035.

[158] Public Resources Code, Section 21083.

Department has 12 district offices and 300 maintenance stations throughout California.[159]

Caltrans receives funding from state taxes on gasoline and diesel fuel, from the federal government, and from a portion of truck weight fees and license fees paid through the Department of Motor Vehicles. Other funding sources include local transportation assessments and private developers.

The Department provides data for the State Transportation Improvement Program (STIP), the state's blueprint for highway construction and rehabilitation, mass transit and aeronautics. The STIP is updated every two years by the California Transportation Commission, a nine-member panel appointed by the Governor which establishes funding priorities.

To meet the challenge that 25 million motorists present the state, the Department's engineering staff designs and oversees the building of new highways and bridges, and maintains existing facilities. While most construction projects are contracted out, maintenance is performed by Caltrans crews. More than 6,600 people maintain the highways and care for the 17,000 acres of landscaping and roadside rest areas.

Caltrans helps to plan a statewide transit network in a number of ways: making grants and giving operating assistance to intercity bus companies; developing light rail systems; co-sponsoring passenger rail service programs; and designing and constructing intermodal stations.

With more passengers boarding air carrier flights in this state than in any other, the demands placed on Caltrans are considerable, for example, dealing with traffic congestion in the vicinity of airports, aircraft noise, and airport terminal congestion. The Department responds with safety and permit inspections to insure safety standard compliance and compatibility with surrounding communities, noise level regulation, and airport operational improvement programs.

Caltrans collects, analyzes and disseminates transportation data to state, local and regional planning agencies. It analyzes transportation problems and proposals to determine the long-range economic, environmental and cultural impacts of transportation decisions. In addition, it coordinates federal and state grants for transportation measures that conserve energy, promote improved air quality, and encourage the most effective use of existing facilities.

The Department's Transportation Laboratory (Translab) tests materials to be used in Caltrans projects (e.g. "Bott's dots" lane markers and wheelchair securing equipment for buses), and develops new technology (e.g. alternative fuels and asphalt recycling).

All proposed activity—unless conducted under the auspices of Caltrans or Caltrans contract forces—involving encroachments within, under or over a state highway right-of-way must be authorized by an encroachment permit. This requirement applies even to local and state agencies and utilities. Caltrans will review applications for such permits to ensure compatibility with primary uses of the state highway system, ensure safety and protect the state's investment.

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[159] California Department of Transportation, The State Highway Program, August, 1988.

The encroachment permit process (as well as that for airport and heliport permits), is Caltrans' most direct effect on coastal development. However, to the extent that development projects depend on land and/or air ingress and egress, as well as traffic lanes to various points of business activity, the influence of Caltrans on coastal development is substantial.

Native American Heritage Commission

The Commission was formed by the State Legislature in 1976 and is a nine-member body, with all members and the Executive Secretary appointed by the Governor. Five of the members are Indians native to California.

Although the Commission does not issue permits or enforce regulations, it does have a potentially considerable effect on any proposed development in the state.[160] The relatively small staff reviews environmental documents, works with the Office of Historic Preservation (see STATE AGENCIES-Department of Parks and Recreation) and consults with Indian communities throughout the state to insure avoidance of, or proper mitigation for disturbance to, cultural resources such as village and burial sites.

Public Utilities Commission

The Public Utilities Commission (PUC) is responsible for regulating privately-owned public utilities.[161] The term "public utility" includes gas, electric, telephone, trucking, bus, and railroad operations. Certain oil and gas pipelines are also regulated by the Commission.

The PUC's primary objective is to ensure adequate facilities and services for the public at reasonable and equitable rates, consistent with a fair return to the utility on its investment. It is also required by state and federal statutes to promote energy and resource conservation in its various regulatory decisions.

The PUC has a significant effect on coastal development through its ability to regulate the transportation of crude oil and products within the state, and exercise controls over specific modes of transportation.

Expansion of a utility's services into non-contiguous areas generally requires a certificate of public convenience and necessity from the PUC. Each certificate carries special conditions unique to the particular proposal. But before a certificate is issued, the utility's application may be subject to PUC staff analysis, pre-hearing conferences with an administrative law judge (ALJ), a formal certificate hearing (similar to a court trial), and Commission consideration. The Commission may issue the certificate, refuse to issue it, or issue it for a modified project. The State Supreme Court is the only court with jurisdiction to hear appeals from utilities which have been denied a re-hearing by the PUC.

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[160] Health and Safety Code, Section 7050.5; Public Resources Code, Sections 5097.94, 5097.98, 5097.99.

[161] Public Utilities Code, Section 201, et seq.

LOCAL GOVERNMENTS

Planning Departments

General Regulation Measures

City and county governments regulate development within their jurisdictions through several methods.[162] They include:

- o General Plan/Amendment

Every city and county in California has prepared a General Plan which includes a land use element and map showing the existing or planned land use for all land in the jurisdiction, major public works and transportation facilities. Land uses are presented by category such as residential, industrial, commercial, or open space. Any property owner who is proposing to develop land for a use other than that designated for the particular property in the General Plan, must apply for a General Plan Amendment. The local planning commission will make its recommendations to the governing body (city council or county board of supervisors) based on input from the local planning agency. The governing body will then approve, deny or modify the proposed amendment.

- o Specific Plan

Any landowner who has prepared a detailed Specific Plan for development of his or her property which is consistent with the General Plan but which provides more precise development standards must obtain approval of the Specific Plan. The plan is adopted in the same manner as a General Plan, however, a Specific Plan may be adopted by ordinance as well as by resolution.

- o Zoning Ordinance Amendment

A landowner who proposes to develop property for a land use which is not permitted, either by right or conditionally in the zone in which the property is located, must obtain a Zoning Amendment. Such proposed amendments which change the zone designation of a parcel or which modify the applicable development standards are generally referred to the planning commission for its recommendation to the governing body; if approval is recommended, the governing body must give notice and hold a public meeting on the application.

- o Special or Conditional Use Permit

A property owner proposing a use of land which is not permitted in the zone in which the property is located, but which is allowed subject to special conditions, requires a Conditional Use Permit. This device is used where a land use is desirable within the zone, but not at every location within the zone unless special requirements or limitations are set forth. These conditions are tailored to fit the specific location to avoid problems associated with the proposed use.

Unlike the General Plan Amendment and the Zoning Amendment, which are both quasi-legislative actions, the Conditional Use Permit is an administrative action (i.e., authority for granting the permit is delegated by the governing body to an administrative zoning

[162] Governor's Office, Office of Planning and Research, Office of Permit Assistance, 1987 California Permit Handbook.

body or a designated officer). The permit will be approved or denied, at a public hearing.

- Subdivision Map Approval

Any property owner who proposes to divide a parcel into five or more parcels must (with certain exceptions) obtain subdivision map approval from the city or county in which the property is located. The purposes of this process are to: ensure that the subdivision's design and improvements are consistent with improvements on adjacent lands; ensure that improvements will be made initially by the subdivision so they will not become an undue fiscal burden on taxpayers; and avoid fraudulent land sales. In addition to certain findings required by state law to be made by a city or county prior to approving a subdivision (Government Code, Section 66410, et seq.), the local government generally reviews applications for compliance with community standards for streets, drainages, parks and governmental services, as well as consistency with the General Plan and zoning ordinances.

Local Coastal Programs (LCPs) and Coastal Development Permits

The California Coastal Act of 1976 (Public Resources Code, Section 3000, et seq.) is largely implemented by local governments. Each local government with jurisdiction over areas within the coastal zone must prepare a local coastal program (LCP) which regulates all development within the zone. (See Significant State Legislation and Principles-California Coastal Act). The program is then submitted to the Coastal Commission which is authorized to review it only to ensure that it conforms with policies of the Act. After Coastal Commission certification, permitting of development reverts to the local government. Many local coastal programs have been at least partially certified.[163]

The Coastal Commission retains permit authority over tidelands, submerged lands, and certain lands held in the public trust. It also retains authority to determine whether federal project activity in the coastal zone and the Outer Continental Shelf are consistent with state policies for the coast.

A Coastal Development Permit must be obtained by anyone wishing to develop within the coastal zone.[164]

Prior to certification of a Local Coastal Plan by the Coastal Commission, a local government may establish procedures for review of permit applications as part of its normal land use control process. If such procedures are not established, the applicant must seek a permit from the Coastal Commission. (In certain specified cases, the applicant must obtain the permit from the Commission regardless of establishment of procedures by the local entity.)

After certification of the LCP, the local government has the authority to approve or deny development permit applications. However, as previously mentioned, the Commission may determine appeals to most local decisions. Certain development activities, such as additions to single-family dwellings and

[163] Public Resources Code, Section 30000, et seq. (California Coastal Act).

[164] Governor's Office, Office of Planning and Research, Office of Permit Assistance, 1987 California Permit Handbook; Public Resources Code, Section 30000, et seq. (California Coastal Act).

maintenance activities, are exempt from permitting requirements.

Air Pollution Control Districts (APCDs)

Generally, there is an air pollution control district for each county. However, regional and unified districts may be created by joining all or parts of more than one county.

For example, two special districts—the Bay Area Air Quality Management District (BAAQMD) and the South Coast Air Quality Management District (SCAQMD)—were created for the state's two largest metropolitan areas. The BAAQMD includes all of Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo and Santa Clara Counties, and portions of Solano and Sonoma Counties.

The SCAQMD includes those parts of Los Angeles, Orange, San Bernardino and Riverside Counties in the south coast air basin. The SCAQMD is governed by the "Lewis Air Quality Management Act," Health and Safety Code, Sections 40400 through 40540, an extensive series of statutory provisions applying specifically to the South Coast basin. Individual city and county authorities within the basin may adopt air quality regulations which are stricter than, but not in conflict with, those of the SCAQMD, but otherwise have no authority over air pollution control.

Any person or organization proposing to construct, modify, or operate a facility or equipment that may emit pollutants from a stationary source into the atmosphere must first obtain an Authority to Construct Permit from the county or regional Air Pollution Control District (APCD).[165] APCDs issue permits and monitor new and modified sources of air pollution to ensure conformance with national, state and local emission standards, and to ensure that emissions from such sources will not interfere with the attainment and maintenance of ambient air quality standards adopted by the State Air Resources Board (ARB) and the Federal Environmental Protection Agency (EPA).

Each APCD determines which emission sources and levels have an insignificant impact on air quality and, therefore, are exempt from permit requirements.

Many projects also require a permit subject to Prevention of Significant Deterioration (PSD) review from the EPA, unless the local APCD has been delegated the authority to issue such permits. The EPA requires this permit when two conditions exist: The project's emissions exceed 100 tons per year for certain industrial activities and 250 tons per year for other industrial activities; and/or the project is in an area where the ambient air quality standard is not being exceeded for the pollutants that the proposed project will emit.

As mentioned previously, the State Air Resources Board and the Federal Environmental Protection Agency have established standards which govern the quality of the surrounding atmosphere, known as ambient air quality standards. Emission limits for specific types of equipment have been set in order to assure that ambient standards are attained and maintained. In addition to emission limits and ambient air quality

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[165] 2 U.S.C. 1857, et seq. (Clean Air Act); Health and Safety Code, Sections 39000–43834; Governor's Office, Office of Planning and Research, Office of Permit Assistance, 1987 California Permit Handbook.

standards, APCDs have adopted what are commonly known as New Source Review (NSR) Rules.

Some districts regulate toxic air contaminants for which there are not ambient standards in order to prevent endangerment of the public health. Applicants may be required to provide information, risk assessments and control methods for these pollutants in such districts.

While PSD rules apply to attainment pollutants, NSR rules apply only to non-attainment pollutants. They regulate all new or modified sources whose emissions exceed a specified limit for any pollutant for which there is a state or national ambient air quality standard, or which is a precursor to such a pollutant. This limit is generally 250 pounds per day; however, NSR Rules vary among districts. Standards exist for sulfur dioxide, nitric and nitrous oxides, hydrocarbons, ozone, total suspended particulates smaller than 10 microns and carbon monoxide. The APCD also determines whether the new emissions violate any carbon monoxide standard at the ground level point where they are most concentrated. All new or modified stationary sources with a net increase in emissions greater than the limit must be constructed using the best available control technology (BACT).

Even in areas where the ambient air quality standards are not being violated, an APCD may determine that additional emissions would cause a violation of a standard at the point of greatest concentration at ground level. The developer-applicant must reduce these emissions to a level where no violation exists.

In areas where ambient air quality standards are being violated currently, the APCD will only approve a new or modified source with a net increase in emissions over a certain number of pounds per day (the average offset cutoff is 250 ppd), if the developer-applicant provides "offsets" for all net emissions increases. The APCD will approve the source only if the applicant reduces emissions from within the source at a 1–to–1 ratio, or reduces other emission sources in the area by a minimum ratio of 1.2:1, after application of BACT. For example, an applicant proposing a new or modified source producing 1,000 pounds of pollutants per day with the use of BACT, must eliminate a minimum of 1,200 pounds of pollutants per day from other existing sources. Offsets must be located either upwind in the same or adjoining counties or within 15 miles of the proposed new or modified source. If the emission offset is located more than 15 miles from the source, the required offset ratio in many cases may exceed 1.2:1.

If an applicant obtains emission offsets outside the areas described above, or if one type of pollutant is offset against another type, the applicant must show through modeling that these offsets will result in a net benefit to air quality. Modeling combines the emission rates from the facility with identified meteorological conditions to indicate the point of maximum concentration at ground level. The emission reduction from these offsets must improve the air quality in the area affected by the emissions from the source.

In most districts, if developer-applicants reduce emissions below the level required by the local APCD, they may "bank" the extra emission reductions for use as offsets for future projects. Generally, applicants cannot bank emission reductions that occurred before they applied to the APCD for a permit. Local practice may vary, but most districts will also not allow applicants to bank emissions for more than five years.

CHAPTER FIVE

ECONOMICS OF OIL

DETERMINING THE PRICE OF OIL-ECONOMIC THEORY CONSIDERATIONS

Modern economic theory provides a widely accepted framework for considering how prices of goods are determined in open markets: prices are determined by the interaction of supply and demand. The economic concepts of supply and demand are, in turn, each composed of other individual factors. Economic theory allows us to draw influences regarding the ultimate impact of these underlying factors on the market price of goods.

In the case of crude oil, this market theory of supply and demand can analyze pricing over the short-term much as it can analyze the pricing of any other commodity. Over the long-term, however, the analysis of crude oil pricing differs somewhat from that of other commodities due to the fact that crude oil is a non-renewable resource.

Figure 5-1 shows one simplified model [166] of short-run domestic crude oil supply and demand.

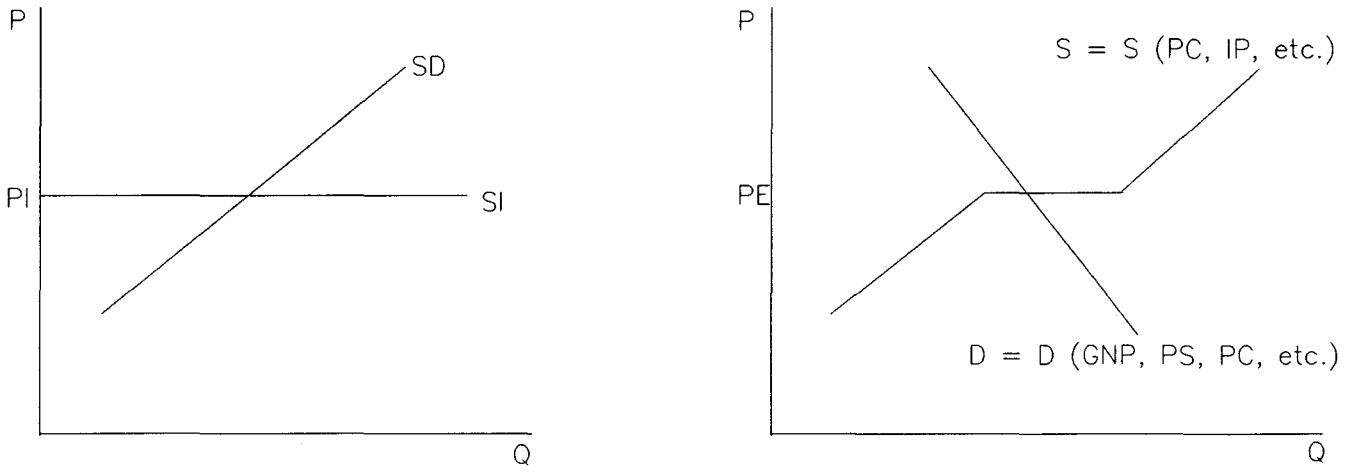

Figure 5 - 1: Simplified aggregate crude oil supply and demand.

[166] See, e.g., Energy Economics: Theory & Policy, R.C. Pirog and S.C. Stamos, Prentice Hall, 1987.

This type of model is a good starting point for understanding the factors affecting supply and demand. The left hand portion of the figure considers the short-run domestic supply curve as composed of two parts: domestic production (SD in the notation of the figure), and imports (SI).

The quantity of domestic production supplied may depend strongly on crude oil prices. At high prices, crude from remote regions or crude that is expensive to recover (e.g., tertiary production in some areas) will be brought to market, while with lower prices, some of this crude oil may be shut in. Imports, on the other hand, might be thought of as available in arbitrary quantities at a single "world market" price. Such a model would, for example, approximate a unified OPEC with no other marginal source of imported crude to the United States. These two sources combine to produce the supply curve shown in the right hand portion of the figure. This aggregate supply curve is a function of domestic production costs (PC), and prices set for imported crudes (IP), among other factors.

The right hand portion of Figure 5-1 also illustrates the domestic demand for crude oil. As we will discuss, the short-run domestic demand for crude oil, while not strongly dependent on crude oil prices, is itself a function of factors such as the national economy (GNP), and prices of substitutes and complimentary goods (PS and PC). The intersection of aggregate supply and demand produces an equilibrium market price for all crude (PE).

Theoretical analyses such as those shown in Figure 5-1 are, however, generally simplifications of reality: the issue of the determinants of crude oil pricing is in fact substantially more complex. As a practical matter, if we wish to know what influences or determines the price of crude oil, not only do we have to specify what crude oils we would consider (for example, imported crudes, domestic crudes, or specific California crudes), but also we must specify what type of prices (e.g., spot prices or posted prices, among others) are relevant. Beyond these considerations, it also becomes necessary to consider whether some determinants of crude oil prices have different impacts over time, i.e., whether such factors influence long-run or short-run prices, and whether any "market imperfections" preclude or alter any of the analysis of classical economic theory.

While practical considerations of crude oil pricing certainly complicate the application of economic theory, that framework nevertheless remains the best method for considering the separate and disparate impacts of individual factors on the price of oil. In the following section, we briefly describe the various crude oil markets and price levels. These descriptions will provide a basis for understanding the general impact of the various determinants of crude oil supply and demand on such markets and price levels.

Crude Oil Markets and Prices

At any particular time, a given crude oil may be bought and sold under long-term supply contracts, or it may be offered in the short term or "spot" market.[167] In this section, we provide some background on the institutional aspects of

[167] Financial markets have also recently developed organized trading in crude oil futures contracts. These markets allow crude oil traders to enter into hedging or speculative transactions for deliveries of crude oil at specified prices at future dates. See, e.g., S.L. Brown and S. Errera, Trading Energy Futures: A Manual for Energy Industry Professionals, Quorum Books, 1987 for a discussion of these markets.

these different types of prices and markets, and discuss briefly how they relate to the economic analysis of prices.

It is easily observed that different types of crude oil prices—such as spot prices and contract prices—often differ for similar or even identical crude oils. Because prices of crude oils sold under long-term contracts are typically determined by long-run considerations of supply and demand while "spot" markets are more influenced by short-run considerations, it is possible (and frequently occurs) that during periods of dynamic market conditions, the "spot" price for a given crude may vary somewhat from prices quoted for long term supply contracts for the same crude. During more stable market conditions, "spot" prices and long-term prices tend to reach equilibrium.

A vivid example of this difference in price levels is the price for Saudi light crude oil from 1970 through the mid-1980s. Figure 5-2 compares the "Official Selling Price" (OSP) to the reported spot market price of the crude.

The OSP of Saudi crude oil, like that of many foreign crude oils, is set by the government or producing entity; it is purported to be the price paid for the crude oil by its first purchasers. The spot market price, however, is the price reported for transactions taking place in secondary trading markets such as (for Saudi crude), Rotterdam. As can be seen from Figure 5-2, the spot price can be substantially different from the OSP at some times; at other times, it can be close. While the volume of crude oil bought and sold in world secondary markets is typically only a fraction of the total quantity of crude oil produced, the spot price is nonetheless very important. It not only represents a price typically reached in "arm's-length" transactions, but also provides a leading indicator of changes in official price levels. As Figure 5-2 shows, when the spot price is substantially in excess of the official price, the official price tends to rise until some equilibrium is reached. This process occurs in both rising and declining markets and is generally to be expected to a greater or lesser degree with all commodities. During the period 1979-1981, the OSP of Saudi crude was kept below "market value" by the Saudi government, although spot market and other transactions involving Saudi crude valued it closer to the market level.

In the U.S., crude oil refiners (rather than producers) have historically set "posted" prices for crude oil; these prices often figure in both long-term and short-term contracts entered into by refiners for crude oil supplies. Typically, posted prices are published for crude oil from each field. Posted price schedules will usually reflect differing prices for crudes from various fields depending on the refiner's perception of the differences in crude quality. In addition, because crude oil produced from a particular field may vary in API gravity over time, posted price schedules often express crude oil prices as a function of gravity.

The crude oil market in California (or, more broadly, the U.S. West Coast) differs from other major domestic crude markets (such as the U.S. Gulf Coast), in several respects. First, fewer companies post prices for crude oil in California. For instance, throughout most of the 1980s, only four or five companies posted prices in California, while in the U.S. Gulf Coast and some mid-continent areas, a dozen or more companies may have published price

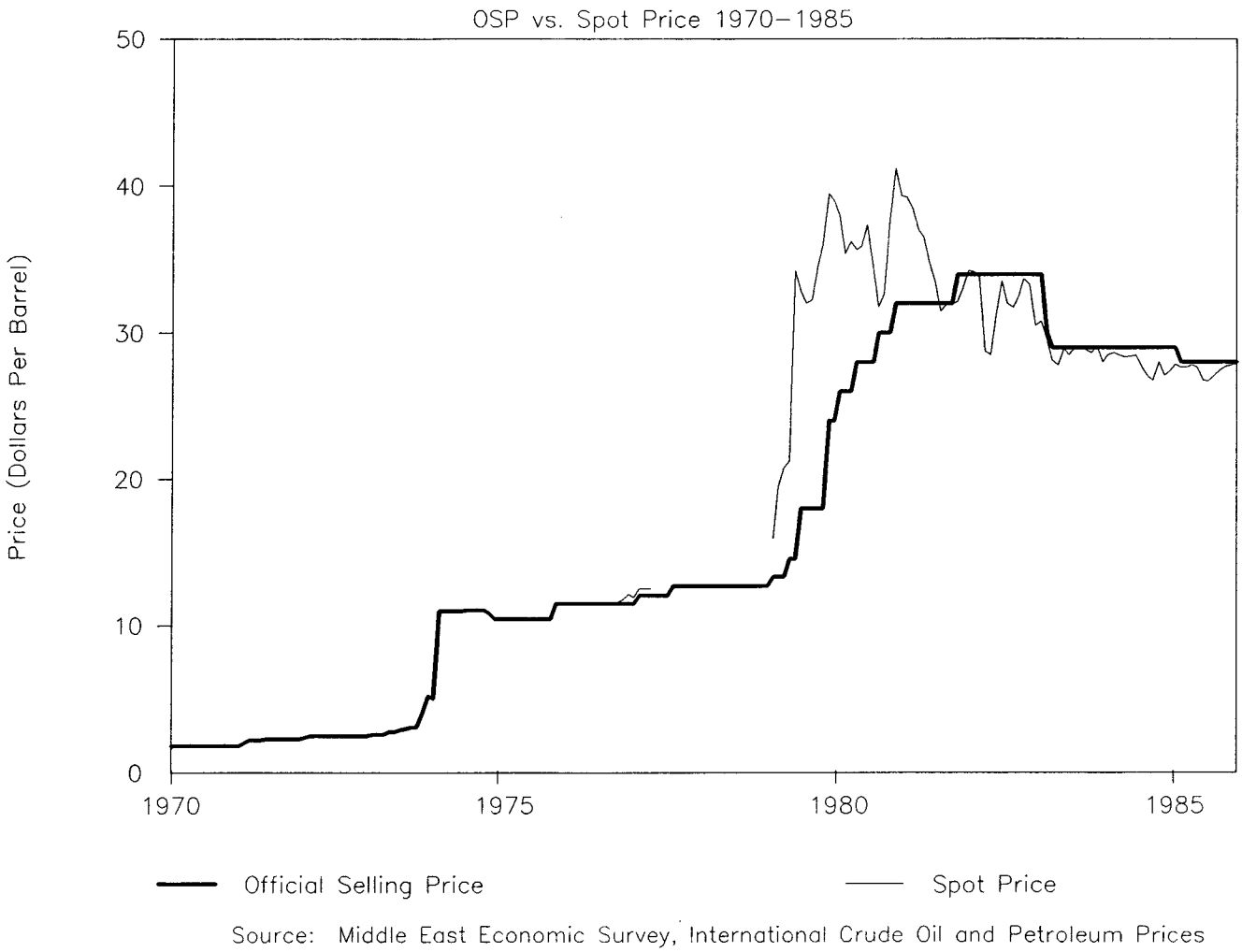

Figure 5 - 2: Saudi light crude oil prices.

schedules at any given time.[168] Also on the West Coast, the intra-field price variation with crude oil gravity present in posted price schedules has historically been substantially greater than the typical variation in other regions. Finally, on the West Coast, widely quoted spot prices for local crude oils are a more recent phenomenon, and are more limited in scope than those in other areas. Some of the possible underlying causes and effects of these idiosyncracies of the California (and West Coast) market are described in the section on "Market Imperfections" below.

In summary, we see that not only are a variety of crude oil prices in existence at any one time, but also that some of the institutional aspects of crude oil pricing on the U.S. West Coast differ from those in other parts of the country. While it is important to recognize the

[168] Platt's Oil Price Handbook and Oilmanac, McGraw Hill, various years.

differences in crude oil prices and industry practices, the economic factors described are relevant to all prices and practices, albeit with differing levels of impact. In describing the impact of various factors of crude oil supply and demand in the ensuing sections, we will use the term "price" to refer generally to the overall level of the multi-tiered structure of crude oil prices described above. Specific references to posted or spot prices, however, do refer to those particular segments of the crude oil price structure.

Determinants of Supply

The total crude oil market supply for U.S. domestic refiners is composed of domestic production and imported crude oils from both OPEC and non-OPEC nations. In abstract terms, we may think of each of these sources as individual fields from which controlling entities make decisions regarding volumes of crude oil to supply at given prices; the aggregate volumes which might be offered at any price combine to produce the aggregate market supply curve. In the long run, prices also serve as an incentive for producers to explore and develop new fields.

In reality, of course, the situation is more complex. Crude oil producers make output decisions based not only on current prices, but also expectations of future prices and obligations made under long-term contracts, and efficient rates of production. Quantities and prices of some crudes imported into the U.S. may be set through purely political, rather than economic, considerations. Factors such as these combine with the simple model described above to render the dynamic behavior of aggregate crude oil supply quite complex.

In the U.S., aggregate crude oil supplies have been marked by an increasing reliance on foreign imports, although for the past several years the pattern has been volatile. Figure 5-3 focuses on domestic supply patterns since 1960. It shows U.S. consumption of imported crude accelerated from the late 1960s to a peak in 1976, followed by a gradual decline.

Consumption of imports has been on the rise again since 1985, and most projections indicate that this trend will continue.[169]

In the U.S. West Coast crude oil market, the situation has been somewhat different. As Figure 5-4 shows, imports have apparently played a much less important role on the West Coast in terms of meeting total crude oil demand. However, despite the apparent lack of reliance on foreign imports in California during recent years, crude oil prices should nevertheless be influenced by global crude oil markets, at least over medium to long-term time horizons. For instance, as one analyst has noted:

> California's dependence on oil makes its economy extremely vulnerable to oil supply disruptions in the Persian Gulf. Although California imports little oil from the Persian Gulf, California oil prices are directly tied to world oil markets. As in 1973 and 1979, a disruption in Persian Gulf supplies could cause a rapid hike in world oil prices as oil buyers bid for limited supplies.[170]

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[169] See "Projections of Supply," infra.

[170] California Energy Commission, "Fuels Report," December 1987.

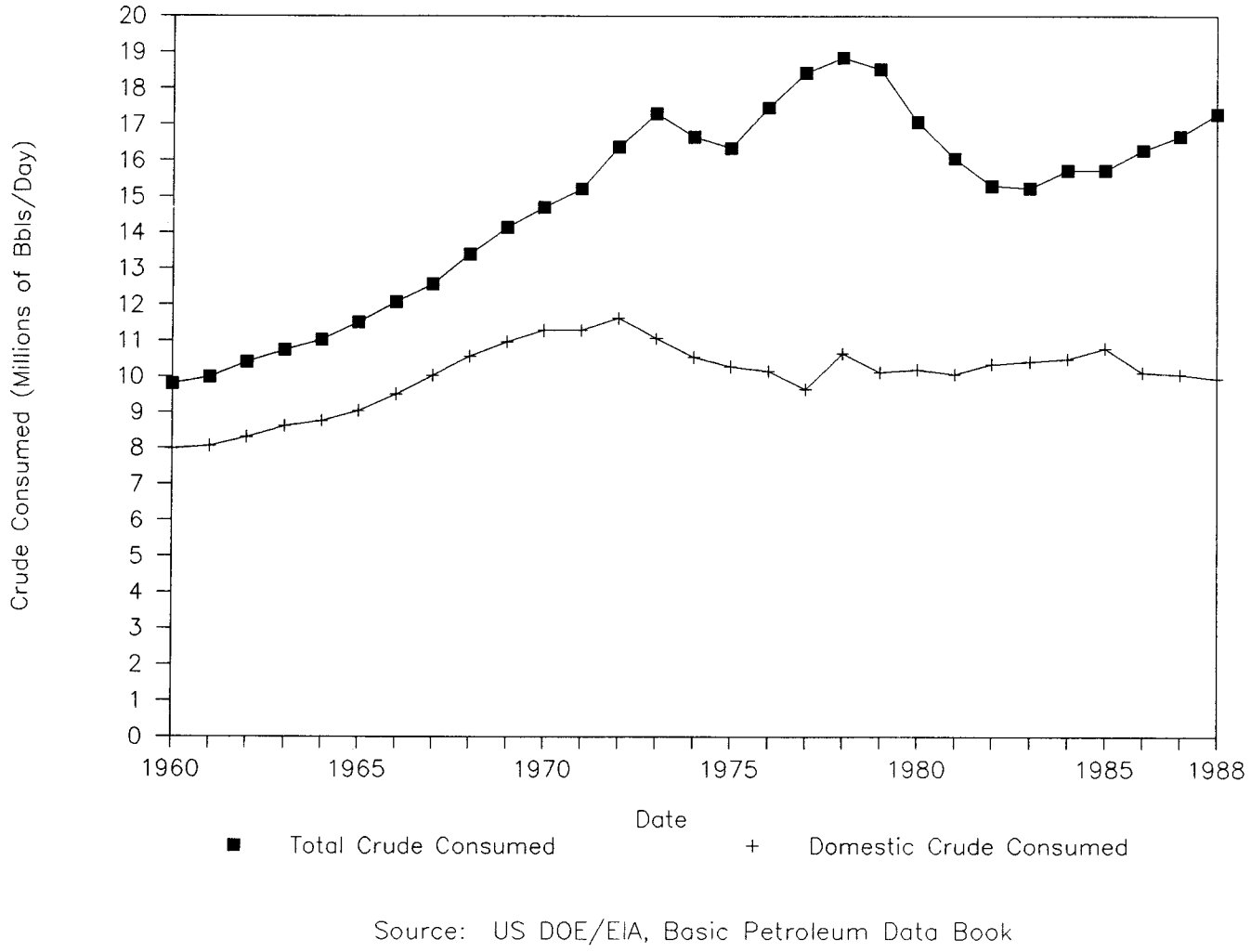

Figure 5 - 3: U.S. crude oil consumption 1960 — 1988.

In the following sections, we discuss the major factors influencing domestic crude oil supply and imports.

As Figures 5-3 and 5-4 have already shown, crude oil production rates in both the U.S. as a whole and California in particular reached peaks around 1970, followed by periods of decline in the 1970s, and a general levelling off in the 1980s. Even in Alaska, production has peaked (at least temporarily), and started to decline. Most analysts appear to agree that while several factors may contribute to the decline, two economic factors are key: first, a drop in current prices, (triggered, perhaps, by a lowering of world crude prices through actions of the crude oil exporting countries), may render some domestic production uneconomic to produce. Second, the diminishing number of accessible areas for exploration and development in the U.S., coupled with low current prices and lower expectations of future prices, may reduce the attractiveness of new exploration and development.

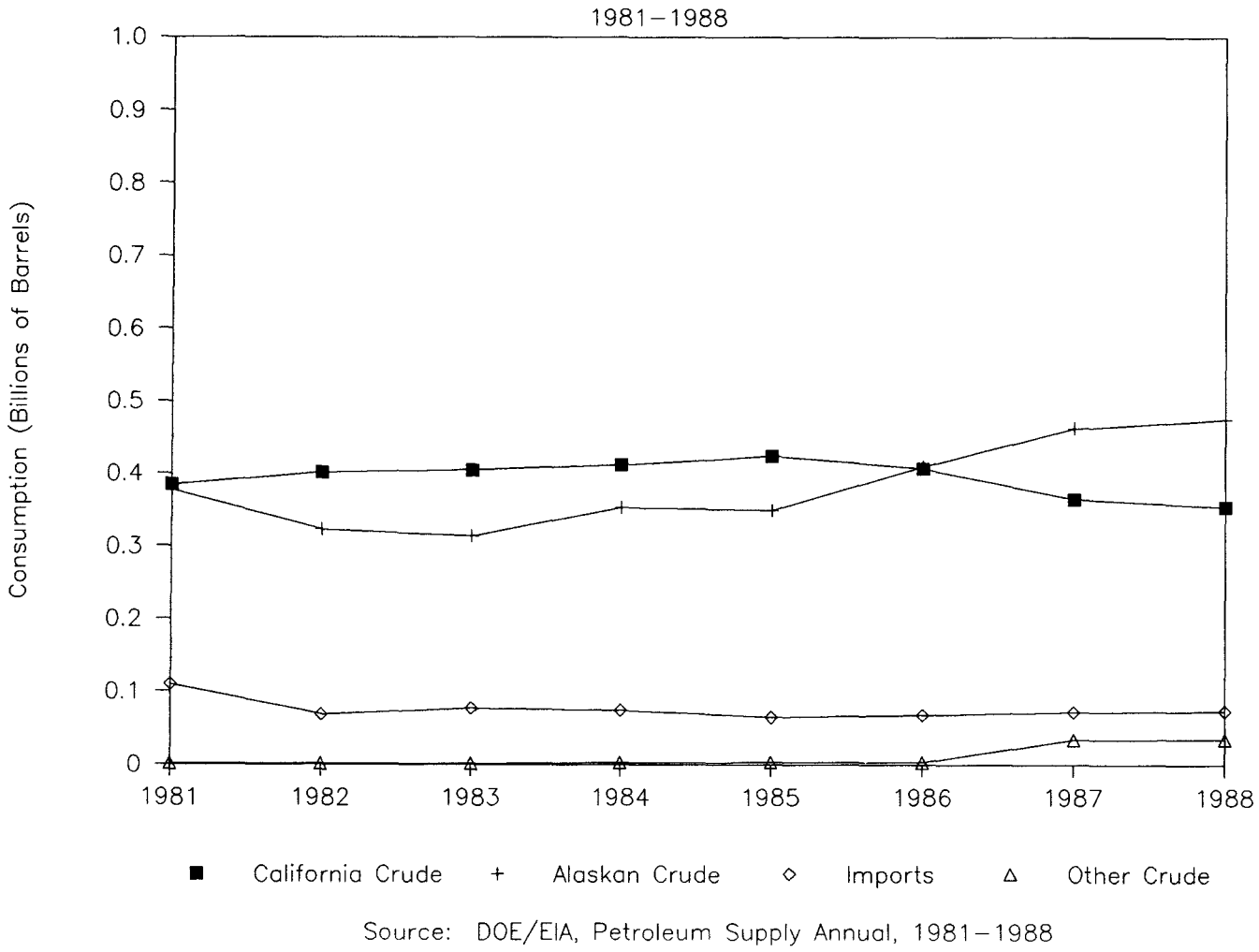

Figure 5 - 4: California crude oil consumption.

The first of these factors would come about as a result of the relatively high cost of production from some domestic properties. For instance, some have estimated the average U.S. lifting cost of crude oil to be in excess of $7.00 per barrel, compared to costs of less than $1.00 per barrel in OPEC nations.[171] Because this lifting cost is an average and does not include some transportation costs, it is probable that some remote properties in the U.S. would have even higher total costs of production.

Figure 5-5 shows a simplified version of the process through which lower current prices may result in reduced domestic production.

Starting from the conceptual components of aggregate supply introduced in Figure 5-1, we

[171] Arthur Anderson & Co. statistics quoted in "Factors Affecting U.S. Oil and Gas Outlook," National Petroleum Council, February 1987.

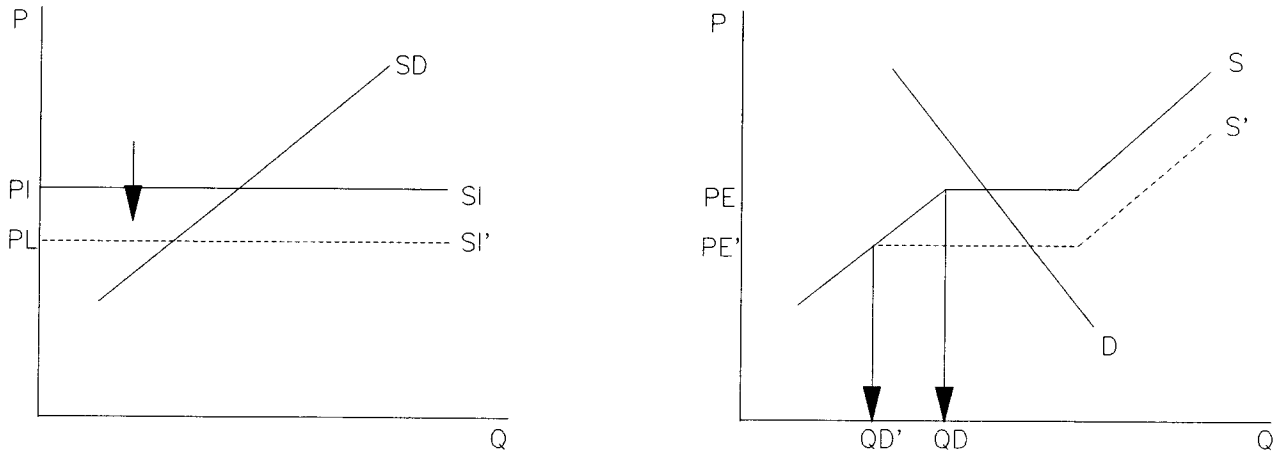

Figure 5 - 5: Supply and demand dynamics — reduced import prices.

might presume that the supply of imported crude shifts from its initial price of PI to a new lower price of PL; this is illustrated by the shift in the supply curve for imports (SI) from PI to the new level PL. The industry aggregate supply curve shown in the right hand diagram—still being the sum of domestic supply and imports—shifts from S to S' and the intersection of supply and demand falls from PI to PL. The quantity of domestic production thus drops along the domestic supply curve from QD to QD'. At this simplified level of analysis, this confirms the intuitive notion that lower world crude oil prices may act to increase consumption of imports and back out some high cost domestic production.[172]

The extent to which this particular effect operates depends, however, on the slope (or, in economic terms, the elasticity) of the domestic supply curve. Although we have noted that the average lifting cost in the U.S. may be very high because crude oil production is generally a very capital intensive operation, some producers may be willing to operate in the short term at price levels which are substantially below total (i.e., fixed plus variable) costs once their investments are in place. This would tend to make the short run domestic supply curve somewhat steeply sloping. Most analysts appear to agree that quantities produced from existing domestic wells are in fact not very responsive to price in the short term.[173] Furthermore, the precise shape of the domestic supply curve depends not only on producers' costs of production, but also on factors such as efficient rates of production from each field, transportation costs, and so on. While these additional factors certainly render the analysis of the domestic supply function more complex, the existence of these factors does not alter the general conclusions which may be drawn regarding the role of world crude oil prices on

[172] Historically, the effect of lower foreign crude oil prices leading to increased domestic consumption of foreign crudes has played a part in establishing the rationale for U.S. Government programs such as the Voluntary (ultimately, Mandatory) Oil Import Program of the late 1950s which was often described as an attempt to enhance U.S. energy security by reducing domestic dependence on "cheap" foreign crude supplies.

[173] See J.P. Kalt, The Economics and Politics of Oil Price Regulations, MIT Press, 1983, p. 97.

domestic production. For example, speaking about the dramatic drop in world crude prices in 1986, the Department of Energy noted:

> Primarily because of the collapse in oil prices during 1986, U.S. crude production declined last year [1986] by close to 800,000 barrels per day. Some of that decline represents temporary shut-in of production that could return with higher oil prices.[174]

The second key factor influencing crude oil supplies described above involves the ability and incentives of the crude oil producing industry to explore for and develop new supplies. In brief, to the extent that producers may believe low oil prices will persist into the future, exploration development will be seen as less profitable and hence be deferred or perhaps abandoned. While the magnitude of impact from this fact on crude oil prices is uncertain[175], it is certain that the impacts that do occur will happen over the long-term. For example, as U.S. DOE analysts noted regarding the impacts of the 1986 crude price decline:

> Current low oil prices discourage investment in both exploration and development. U.S. production fell substantially in 1986, and additions to U.S. reserves and U.S. oil production will be further reduced if the expectation of low prices continues to discourage such investment. Oil exploration and production require a long lead time from the initial investment for preliminary surveys to significant levels of production. In known onshore oil regions, the lead time can be on the order of 3 to 5 years. In offshore areas and in harsher climates, the lead times can exceed 10 years.[176]

In terms of the abstract economic model, this would be evidenced by a gradual shift in the domestic supply curve as less production becomes available at all prices as reserves are not replaced over time. This is shown in Figure 5-6 as the domestic supply curve shifts from SD to SD'.

This shift results in a similar shift in the aggregate supply from S to S' as shown in the right hand portion of the diagram. Depending on the location of the aggregate demand curve, this will result in either greater reliance on imports, a rise in equilibrium price levels, or both.

In addition to the major factors described above, other factors can also act to affect the domestic and imported crude oil supply curves. These other factors are, however, somewhat more independent than the major factors driven by the dynamics of the supply and demand process. These factors include items such as environmental regulations. An increase in the costs associated with such regulations can shift the domestic supply curve upward in a manner analogous to that shown in Figure 5-6, leading to similar ultimate impacts on price levels and supply. Another frequently discussed policy factor is that of import tariffs—either combined

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[174] United States Department of Energy, "Energy Security: A Report to the President of the United States," March, 1987.

[175] Kalt, op cit., describes several studies leading to ranges suggesting that the long run responsiveness of the domestic supply curve to current price levels might be 5 to 10 times greater than in the short run. He provides a range of elasticity estimates for long run supply of 0.5–1.0.

[176] United States Department of Energy, "Energy Security: A Report to the President of the United States," March, 1987.

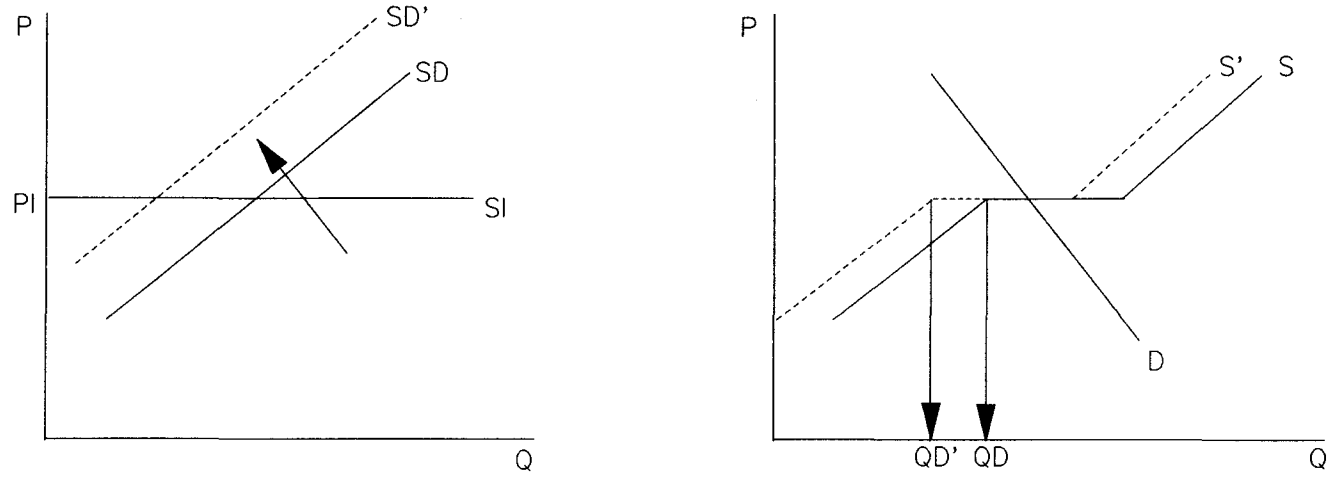

Figure 5 - 6: Supply and demand dynamics — reduced domestic supply.

with or without wellhead taxes on domestic production. In the abstract model, this would shift the affected supply curve upward, thus causing reduced total demand and increased price. Clearly, to understand the ultimate effect of such policies one must understand the differences between short run and long-run effects, and the short-run and long-run responsiveness of supply and demand to price level changes.

Any projection of future crude oil supply patterns will probably be linked to some projection of future crude oil prices. It is probably not meaningful to discuss or compare such projections without at least noting on what pricing basis those projections are made. However, as we have seen above, overall crude oil price levels may be strongly influenced by external factors—such as changes in the levels of exporting countries' crude oil prices—which may change abruptly. Any near-term projections of future domestic supply and price levels may become outdated quickly. The most striking recent example of this abrupt change in world price levels is the dramatic drop in world crude prices of 1986. While several long term crude oil market projections made just prior to 1986 had somewhat higher base prices and production rates than more recent projections, most "mainstream" projections agree on the overall long term trend of domestic production.

Two examples of recent supply projections are shown in Figure 5-7.

The first, the most recent of the Energy Information Administration's (EIA) Annual Energy Outlook series, shows world crude prices rising about 5% annually in real (i.e., inflation adjusted) terms throughout the first portion of the 1990s, and increasing at a 6% annual rate from there through the end of the century. Domestic crude production is expected to decline at a 4% annual rate through 1995, slowing to a 1% annual decline thereafter. Total domestic consumption of crude oil is maintained only through an increasing dependence on imported crudes which are projected to account for over half of domestic consumption by the mid-1990s.

	Actual		Forecast		
	1985	1988	1990	1995	2000
DOE/EIA Annual Energy Outlook					
World Oil Price (1988 $/ Bbl)	-----	$14.70	-----	$20.60	$28.00
Domestic Crude Oil Production (MMB/D)	-----	8.18	-----	6.17	5.89
Import Percentage of Consumption	-----	37%	-----	52%	55%
National Petroleum Council					
NPC Lower Price Trend:					
World Oil Price (1988 $/Bbl)	$27.00	-----	$14.70	$17.90	$22.10
Domestic Crude Oil Production (MMB/D)	9.00	-----	7.10	5.70	4.50
Import Percentage of Consumption	27%	-----	48%	60%	68%
NPC Upper Price Trend:					
World Oil Price (1988 $/Bbl)	$27.00	-----	$23.10	$29.40	$37.90
Domestic Crude Oil Production (MMB/D)	9.00	-----	8.00	7.00	6.00
Import Percentage of Consumption	27%	-----	38%	47%	52%

Sources: U. S. Department of Energy , Energy Information Administration, "Annual Energy Outlook" 1989 National Petroleum Council, "Factors Affecting U. S. Oil and Gas" March, 1987.

Figure 5 - 7: Comparison of selected domestic supply forecasts.

The National Petroleum Council (NPC) projection shown in Figure 5-7 is similar to the EIA's view. The NPC based its outlook on surveys of industry analysts using two differing assumptions of crude oil price scenarios: an upper trend which projects crude oil price real growth rates of about 5% throughout the 1990s, and a lower trend which starts from a lower price level and carries an assumption of 4% annual real growth through the 1990s. The price levels of these two trends generally bracket the EIA's projection. Thus, it is not surprising to find that the domestic production rates of the NPC projection also bound the EIA's values; the NPC projects domestic production to decline at rates of two to almost 5% annually throughout the decade of the 1990s. As with the EIA projection, total domestic consumption can only be met with an increasing reliance on imported crude.

These projections for future patterns of aggregate domestic supply are not inconsistent with some views of the situation in California. For instance, as early as 1986, the California Energy Commission stated:

> Although California oil supplies seem adequate in the near term, during the 1990s supplies will tighten . . . the need for Alaska oil, California's marginal oil supply, is expected to decline between 1985 and 1990 because of increasing California and federal OCS production, . . . However, after 1997 the requirement for foreign crude oil is expected to rise rapidly as production from Alaska and California declines.[177]

Thus, while the California supply situation currently differs in composition from the balance of domestic supply, the long-run factors influencing aggregate domestic supply will continue to play analogous roles in the West Coast market.

Currently, imported crude oil satisfies about 55% of total domestic demand, a percentage which is generally expected to increase throughout the 1990s.[178] Figure 5-8 compares the sources of imports for the U.S. as a whole and the U.S. West Coast.

Although the West Coast is generally less dependent on imports, it does rely more on imports from the OPEC nations, particularly Indonesia. While the U.S. may appear to be currently only moderately dependent on OPEC

(Thousands of Bbls)

	U. S. Total	West Coast
Foreign Imports:		
OPEC	986, 654	45,295
Canada	249,077	5,470
Mexico	246,545	—
United Kingdom	92,910	—
Other	293,819	22,877
Total	1,869,005	73,642
Total Consumption	4,848,175	941,672

Source: U. S. DOE/EIA Petroleum Supply Annual, 1988.

Figure 5 - 8: 1988 import supply patterns.

as a source of imports, Figure 5-9 suggests that this dependence may increase over the long term. The OPEC nations collectively control by far the largest share of crude reserves among the market economies.

	Production (Million B/D)	Proved Reserves (Billion Bbl)
Algeria	0.985	8.50
Ecuador	0.172	1.62
Gabon	0.156	0.65
Indonesia	1.311	8.40
Iran	2.426	92.85
Iraq	2.079	100.00
Kuwait	1.361	91.92
Libya	0.972	21.00
Nigeria	1.340	15.98
Qatar	0.304	3.15
Saudi Arabia	4.186	166.98
UAE	1.541	92.20
Venequela	1.751	56.30
Subtotal OPEC	18.584	659.55
United States	8.349	25.27
Canada	1.533	6.83
Mexico	2.540	48.61
United Kingdom	2.476	5.20

Source: U. S. DOE/EIA "International Energy Outlook 1989"

Figure 5 - 9: Reserve statistics, selected countries.

Although OPEC [179] was formally established in 1960, its role in world crude oil markets was probably not widely recognized outside the industry for some years. Its impact on the oil

[177] California Energy Commission, "1986 Biennial Fuels Report."

[178] See "Projections of Supply," supra.

[179] The Organization of Petroleum Exporting Countries currently consists of Algeria, Ecuador, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela. Many sources are available describing the history and economic behavior of OPEC; see, e.g., F.E. Banks, The Political Economy of Oil, Lexington Books, 1980.

resources of its member states and, indirectly, on the oil resources of other countries has been twofold: first, the member states have over time succeeded in taking control of their oil production; second, the member states have at times shown the ability to exercise tremendous influence on crude oil price levels.

The first stirrings suggestive of OPEC's goals came in 1968 when the group adopted a policy position that the member states would assume responsibility for the technical and economic management of their oil resources as soon as possible. Because prior to that time the member states' producing assets had been managed by the major international oil companies either directly or through joint venture and concessionary agreements—few believed that the member countries would have the wherewithal to implement their policy. By 1970 however—after Libya moved to force Occidental Petroleum to increase not only the price of Libyan oil, but also the government's share of oil profits—the member states collectively moved to wrest greater payments from the oil companies. Over the course of the next 10 years or so, the producing assets of the member states were either nationalized, or otherwise placed in the effective control of the member governments.

Dramatic demonstrations of the group's influence on crude oil price levels occurred in 1973–1974 and again in 1979. OPEC demonstrated that by collectively managing the supply through a system of negotiated quotas, the group could maintain desired price levels, at least in the short term. While the focus of discussions regarding crude oil price levels in 1990 is on the effects of lower than historical levels since the market decline of 1986, it is generally agreed that attempts to put upward pressure on prices will again come from the OPEC nations.

However, several factors moderate OPEC's ability to set its prices consistently over long periods. For example, the long run domestic supply curve in the U.S. and in other non-OPEC crude producing countries has some elasticity; as all oil price levels rise, greater exploration and development is encouraged, ultimately reducing the demand for imports, at least temporarily. This effect is essentially the reverse of that demonstrated in Figure 5-5. It is worth noting that if the estimates of proven reserves shown in Figure 5-9 are at least directionally correct, this mitigating influence will not persist as the relative availability of resources in the crude producing nations becomes even scarcer relative to OPEC.

Another mitigating factor is that demand for crude oil is also sensitive to price; this factor can have a much greater near-term impact on imported crude demand than the responsiveness of domestic supply. Reduced world crude oil demand following the 1979 oil price shock caused many analysts to doubt that OPEC could maintain its ability to manage price levels.[180]

Probably the most important factor affecting OPEC's ability to manage prices in the short term is the group's success (or lack of it), in maintaining individual production quotas for its member nations. The classic economic theory of cartels suggests that because individual members may have incentives to maximize their individual profits by cheating—both on price and quota allocation—the group as a whole may be unable to maintain price levels. Some

[180] U.S. DOE/EIA "Annual Energy Outlook 1989."

have suggested that OPEC's behavior might be modeled as shown in Figure 5-10.[181]

If OPEC acted effectively to set price, its supply curve could be thought of as that shown as SI in the left hand diagram; the cartel would be willing to supply any quantity (up to the maximum limit of production) at a single price level, PI. In reality, however, cheating occurs around any equilibrium import quantity, QI, demanded. This cheating evidences itself in the existence of bonuses or discounts for supplying levels above or below the equilibrium quantity. The supply curve is thus not the horizontal line of the price setter (SI), but rather the more traditional upward-sloping supply curve (SI').

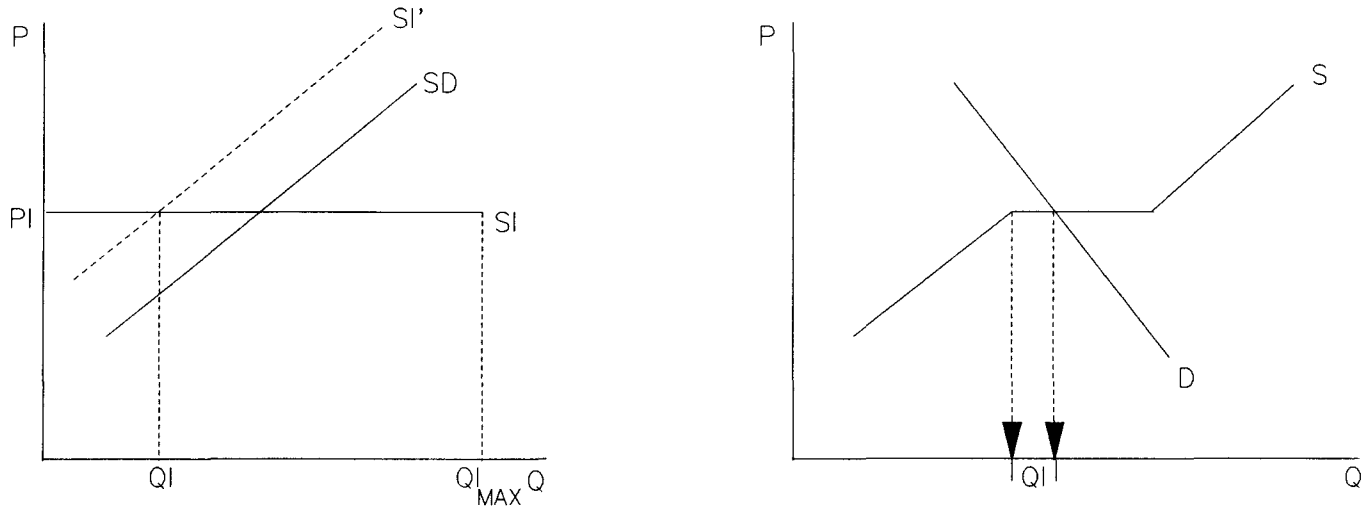

Figure 5 - 10: Hypothetical OPEC supply behavior.

Understanding the factors underlying OPEC's short run behavior is of critical importance if one wishes to understand the determinants of crude oil price levels over time. Unfortunately, because many of these factors are unpredictable (i.e., which OPEC nations will offer discounts or extra supplies), the best that can be done is to recognize the range of possibilities. As the EIA noted in commenting about OPEC's current situation:

> Near the end of 1988 the OPEC ministers reached a new production agreement that was to go into force after the first of the following year. Nevertheless, if OPEC as a whole (or a single large producer, such as Saudi Arabia) is unwilling to adjust production downward when needed to stabilize prices in the future, the old pattern threatens to repeat itself so long as excess production capacity remains. Wide fluctuations in price can recur, as OPEC tries again and again to manage its own output; and the situation may persist until the mid-1990s . . .[182]

Despite the possibility of short term fluctuations, the EIA expects OPEC's market share of world oil production, currently at about 42%, to rise to about 53% by the end of the century.[183]

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[181] See, Pirog & Stamos, op cit.

[182] U.S. DOE/EIA "Annual Energy Review 1989."

[183] U.S. DOE/EIA "International Energy Outlook 1989" U.S.

Determinants of Demand

The demand for crude oil is a so-called "derived demand"—derived from the demands for the products which can be manufactured from it, such as gasoline, distillate fuels, heavy fuel oil, and petrochemical feedstocks, among others. The demands for these individual products are influenced by prices, levels of economic activity, and the price and availability of substitute and complementary goods. These individual product demands are ultimately met by the refining sector, and the refining sector in turn acts to produce an aggregate demand for crude oil. This aggregate demand for crude also depends on the determinants of individual product demands, and will be influenced by the joint nature of the production of refined products. In the following sections, we discuss the salient determinants of crude oil demand.

Aggregate Influences

Total energy demand in general, and crude oil demand in particular, are strongly influenced by the overall level of economic activity. It is important to note, however, that the relationship between energy demand and economic activity has shown a steady trend throughout the entire century. Specifically, while the average rate of growth in domestic energy consumption almost exactly paralleled that of economic activity over the entire first three-quarters of the twentieth century (3.2% average annual energy growth compared to 3.3% real annual growth in GNP), the rate of energy growth has steadily dropped relative to the rate of growth of economic activity.[184] For example, between 1880 and 1920, the growth rate of energy consumption was about half again as great as the growth rate of GNP, while from 1920 through 1965, the growth rate in energy consumption was only about three-quarters the rate of GNP growth. Some current projections [185] place the expected growth rate of energy consumption in the U.S. to be slightly less than half the growth rate of GNP throughout the 1990s, reflecting a continuing trend of greater overall energy efficiency with respect to economic growth.

The demand for crude oil will of course not only be influenced by the factors driving overall energy demand, but also by the determinants of what fraction of overall energy demand will be met by petroleum. The most recent data [186] show that approximately 43% of aggregate U.S. energy demand and about 49% of aggregate California energy demand are satisfied from petroleum resources.

Several factors contribute to the ultimate determination of what fraction of energy demand will be satisfied through petroleum resources. These factors can be related to everyday economic forces, or they can be imposed by policymakers. An example of a policy factor affecting this fraction might be the Powerplant and Industrial Fuel Use Act of 1973 which reduces petroleum's share of energy demand by removing heavy fuel from consideration as a source of new baseload electricity generation. In contrast, some manufacturing operations with the capability of burning either heavy fuel oil or natural gas in industrial boilers may select what fraction of their energy demand to satisfy from petroleum sources (i.e., heavy fuel oil), on the basis of the

[184] See, e.g., H.W. Richardson, Economic Aspects of the Energy Crisis, Lexington Books, 1975.

[185] See U.S. Department of Energy, Energy Information Administration, "International Energy Outlook 1989."

[186] U.S. DOE/EIA, "State Energy Data Book 1987," April, 1989.

current relative prices of the two fuels. Thus, familiar market forces can also influence the ultimate petroleum supply fraction.

In terms of the abstract economic model, it is important to recognize the difference between forces or actions which shift the demand curve, and forces or actions which react to changes in equilibrium price and quantity levels along a single demand curve. To see an example of the latter, recall Figure 5-5 which conceptually illustrated the effects of a lowering of world crude oil prices on equilibrium price and quantity levels. The result of the lowering of crude prices caused the equilibrium quantity of crude consumed to rise (in the figure, from QT to QT'). This increase came about in the face of static demand and depended only on the sensitivity of the demand curve to changes in price levels (in economic terms, the "elasticity" of the demand curve; in less precise graphic terms, the slope of the demand curve in Figure 5-5).

Figure 5-11 illustrates the contrasting example of shifts in the entire demand curve as opposed to simple movements along the demand curve.

If, for example, long run economic growth induces a greater demand for all forms of energy, and, ultimately, a greater demand for crude oil, greater quantities of crude oil will be demanded at all prices, reflected in an outward shift of the crude oil demand function from D to D'. Not surprisingly, this would result in greater quantities of imported crude oil to be consumed, and if the demand shift were large enough, greater quantities of domestic crude oil as well.

Components of End Product Demand

As we have previously noted, petroleum products are consumed in a variety of end-use sectors, from domestic use as heating oil, industrial use as boiler fuel, or manufacturing use as petrochemical feedstocks for the production of many different goods, including plastics. The dominant end-use sector for petroleum products, however, is for transportation. Within the U.S. as a whole, the transportation sector accounts for about 63% of the nation's petroleum use.

Within the transportation sector, the demand for fuels for gasoline-powered vehicles dominates. Figure 5-12 illustrates this

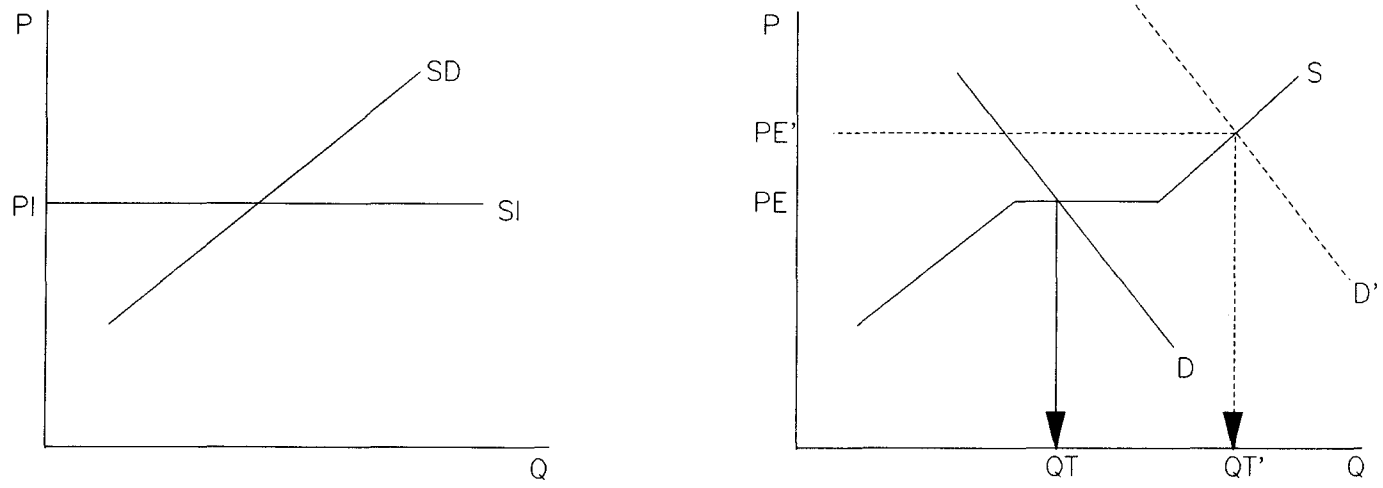
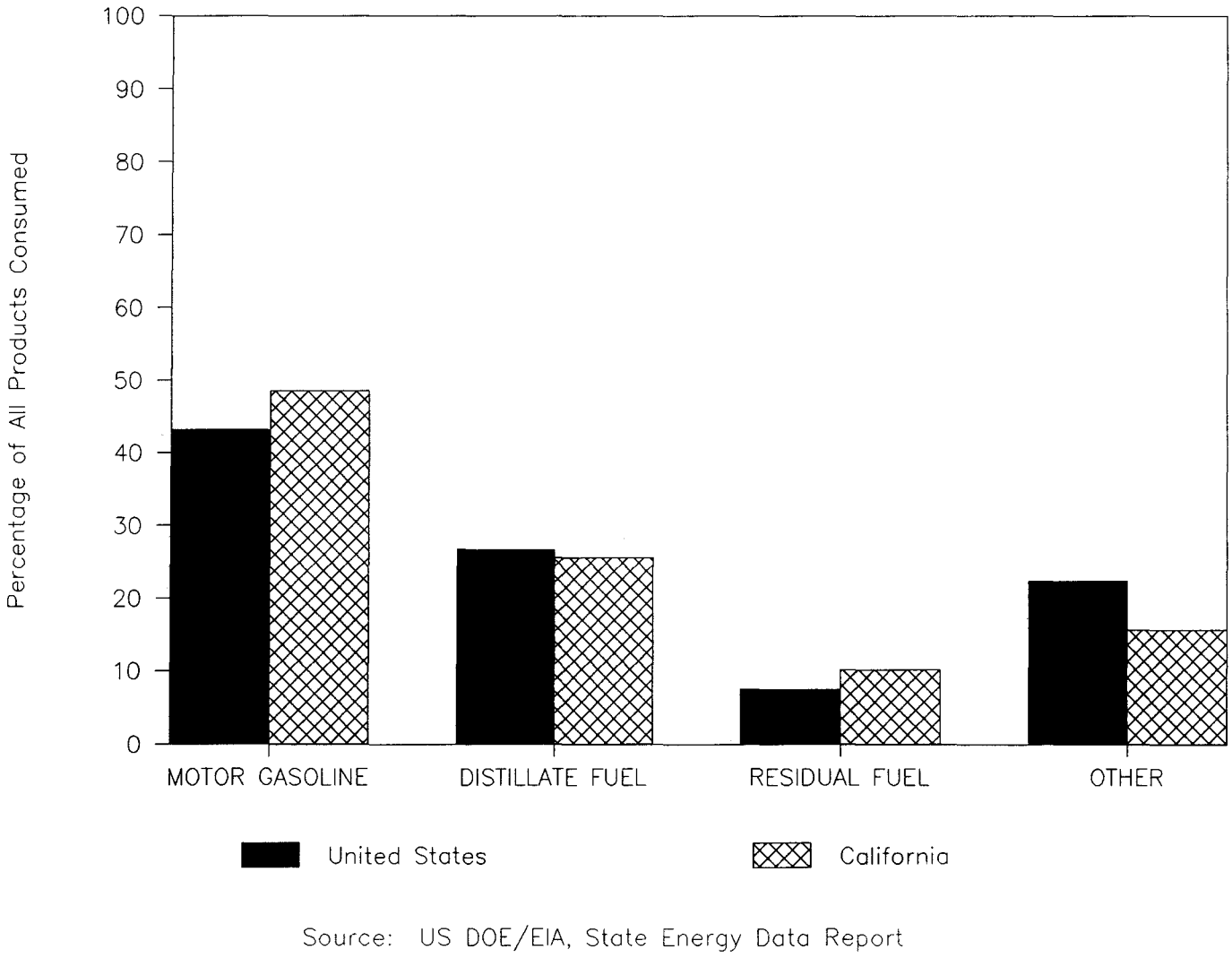


Figure 5 - 11: Supply and demand dynamics — shifts in aggregate demand.

preponderant demand by comparing the production of various classes of petroleum products in both the U.S. and California.

The consumption of motor gasoline has generally increased in both the U.S. and California for many years. Figure 5-13



Source: US DOE/EIA, State Energy Data Report

Figure 5 - 12: 1987 Petroleum products consumption.

While total transportation sector demand is met through products including both motor gasoline and distillate fuels [187], it is the production of motor gasoline which dominates in the U.S. and to an even greater extent in California.

compares the growth rates of motor gasoline consumption in the U.S. and California since 1960.

As the figure shows, throughout the 1960s, demand for gasoline increased more rapidly in California than in the U.S. as a whole, although

[187] Distillate fuels predominantly include jet fuel, kerosene, and home heating oil.

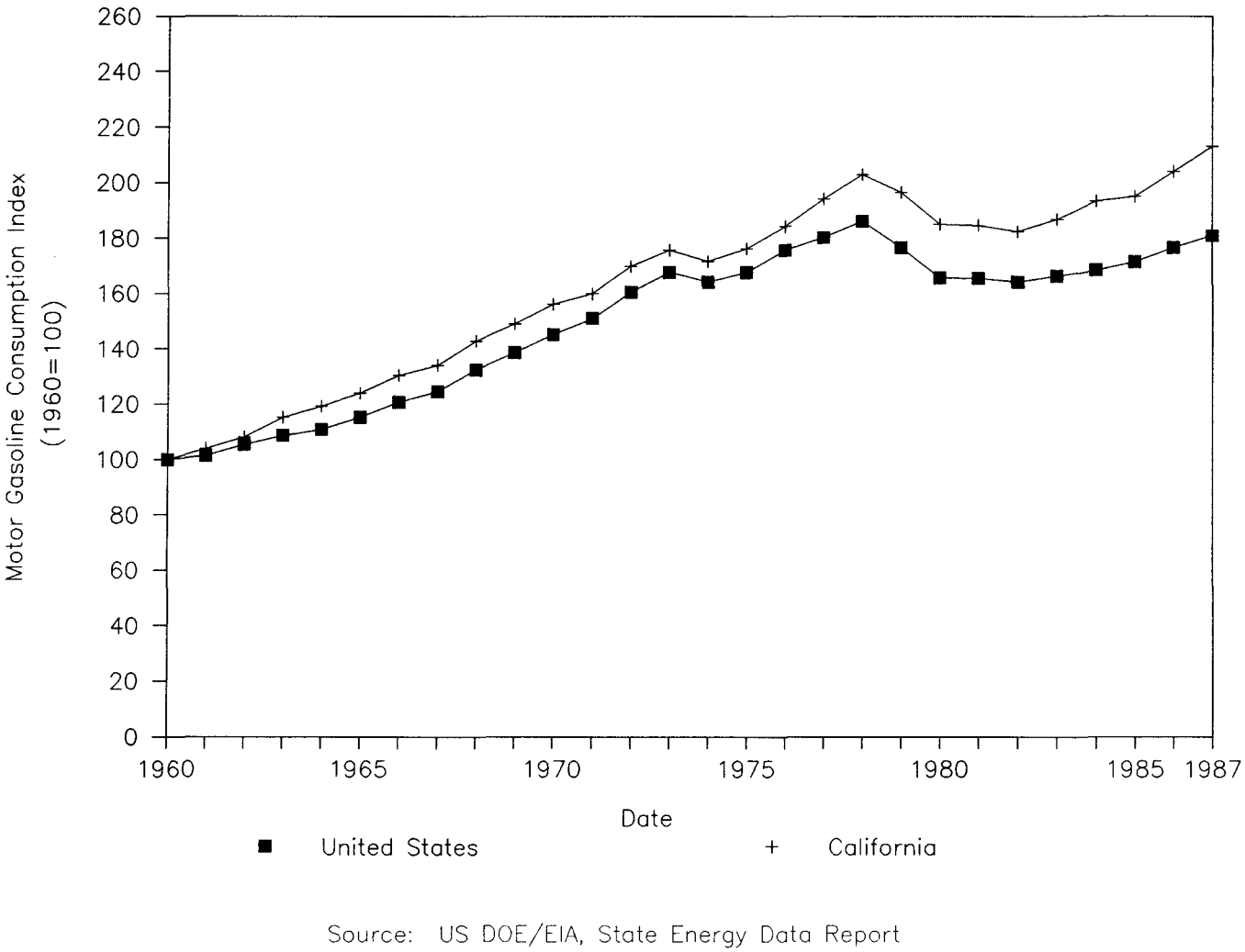


Figure 5 - 13: Motor gasoline consumption 1960-1987.

since about 1980, the growth rates have been similar. Figure 5-13 also suggests that gasoline demand (in both California and the U.S.) is generally responsive to changes in price levels; demand dropped sharply after the price shocks of 1979. While there is no doubt some price responsiveness reflected in these drops, it is important to recognize that generally slower economic growth throughout this period has had some effect on demand for all products.

Substitutes and complements

Other factors influencing aggregate demand for crude oil (or any commodity), are the prices and availability of complementary and substitute goods. In economic terms, two goods are substitutes if one may replace the other in use under a particular set of conditions; common examples of substitute goods are coffee and tea, or buses and taxicabs. As the price of one of the two goods rises relative to the other, more of the less expensive substitute will be demanded. Complementary goods, on the other

hand, are goods which "go together"; a common example might be coffee and cream. As the price of one of the complementary goods rises relative to the other, less is demanded of both goods.

To consider the role of substitute goods in crude oil supply and demand, we must first note that crude oil itself does not have a substantial number of practical substitutes [188], though products made from crude oil do have practical substitutes. The predominant substitute good is natural gas. Gas competes with fuel oil in both industrial and home heating applications, and can also serve as a petrochemical feedstock in the place of some light petroleum fractions. The importance of natural gas as a substitute for petroleum products is well-known and the U.S. Department of Energy currently sees natural gas as an available substitute for imported crude oil:

> Gas can substitute for oil in a variety of applications: fuel-switchable industrial users can switch from oil to gas almost immediately; existing electric utility boilers can switch easily from oil to gas; new electric powerplants can use gas-fueled combined-cycle technology; and natural gas can serve as an industrial feedstock in lieu of certain petroleum products. Finally, compressed natural gas or methanol vehicles could allow gas to substitute for oil in transportation. Economic factors affect the ability of gas to substitute for oil. In particular, gas and oil compete based on their relative prices.[189]

The California Energy Commission also sees natural gas use as the best opportunity for adhering to clean air standards and limiting foreign oil imports:

> Substituting cleaner fuels for oil presents major opportunities for cleaning the air while simultaneously reducing threats to energy security due to imported oil. The greater opportunities in the near and mid-term are with natural gas. Gas is an abundant resource in North America and elsewhere, competitively priced now and for the immediate future, and easy to substitute for oil in most stationary (nonmobile) uses, such as boilers and turbines. For example, increased reliance on natural gas could play a key role in meeting air quality standards for electricity generation.[190]

Without regulatory intervention to require substitution of natural gas for petroleum, however, it will be the relative economics of the two fuel sources which will drive decisions regarding whether fuel switching will occur. Furthermore, Figure 5-14 suggests that a substantial degree of fuel switching away from petroleum to natural gas has already occurred in California relative to the U.S. as a whole.

As this figure shows, in all end use sectors except for transportation, natural gas already supplies a greater fraction of total energy inputs in California than it does in the U.S. In addition to this, in several sectors—notably residential, commercial and electricity generation—the prospects for further switching away from petroleum to natural gas seems remote in California. For instance, petroleum

[188] Here it is important to note that we are speaking of all crude oils taken together. If we were to consider the demand for a particular crude oil (e.g., Alaskan North Slope crude), then all other crude oils might be considered substitute goods.

[189] U.S. DOE/EIA, "Energy Security A Report to the President of the United States," March 1987.

[190] California Energy Commission, "Fuels Report (Draft)," October 1989.

(Trillion BTU)

	Coal	Natural Gas	Petroleum	Electricity	Other	Natural Gas Share	Petroleum Share
Residential Sector:							
U. S. Total	65.6	4,436.3	1,542.2	2,898.9	0.0	49.61%	17.24%
California	0.0	516.6	23.3	206.5	0.0	69.21%	3.12%
Commercial Sector:							
U. S. Total	99.4	2,483.0	1,076.2	2,582.4	0.0	39.79%	17.24%
California	0.0	218.4	59.9	260.3	0.0	40.55%	11.12%
Industrial Sector:							
U. S. Total	2,672.1	7,283.2	8,188.2	2,884.0	0.0	34.64%	38.94%
California	44.9	570.7	629.0	181.8	0.0	40.01%	44.10%
Transportation Sector:							
U. S. Total	0.0	538.0	20,800.5	12.6	0.0	2.52%	97.42%
California	0.0	19.4	2,589.4	0.8	0.0	0.74%	99.23%
Electricity Generation:							
U. S. Total	15,114.8	2,933.7	1,256.9	N/A	8,245.5	10.65%	4.56%
California	0.0	667.8	22.9	N/A	889.4	42.26%	1.45%

Source: U.S. DOE/EIA "State Energy Data Report 1987".

Figure 5 - 14: Sectoral consumption.

provides less than 2% of the state's electricity production needs, and only about 4% of residential energy needs.

Thus, while the substitutability of natural gas for petroleum will always play a role in the economics of petroleum prices, individual sector demands for energy would probably be little affected by rising petroleum prices, (although some reverse fuel switching might occur if natural gas price levels were to rise relative to petroleum prices). The transportation sector remains the primary candidate for future fuel switching away from petroleum. Research is attempting to provide transportation energy from compressed natural gas, methanol manufactured from natural gas, and gasoline manufactured from natural gas. If these or other processes become commercially competitive, it is possible that natural gas will make a larger contribution to transportation sector energy demands.

As we have noted above, complementary goods may be thought of as goods which "go with" one another. In the case of petroleum products, goods such as automobiles and gasoline or airline flights and jet fuel may be thought of as complementary goods. A more formal definition of complementary goods would be goods which are related in the sense that when the price of one good rises, the quantity demanded of the other good falls (or, in the alternative case, when the price of one good falls, the quantity demanded of the other good rises).

There is an enormous number of complementary goods affecting the demand for petroleum products in all sectors. In the end use sectors which dominate petroleum use—the industrial and transportation sectors—one of the most important and most widely discussed complementary goods affecting petroleum use is environmental protection. Although we may not typically think of environmental protection as a "good" in the same sense as gasoline or crude oil, within the framework of economic analysis it may play such a role. For example, users of certain petroleum products are mandated to, in effect, "purchase" environmental protection—typically by installing and using equipment designed to reduce emissions associated with petroleum fuels use. As the expense of such equipment adds to the cost of using petroleum fuels, lower quantities of such fuels will be demanded, all else being equal. Similarly, as automobile price levels rise due to additional equipment or more sophisticated technology to reduce emissions, fewer automobiles will be demanded, leading to somewhat reduced gasoline demand.

Requiring users of petroleum products to pay at least some of the costs of environmental protection has an effect on crude oil demand analogous to the effect of requiring any increasingly expensive complementary good to be purchased: demand for the primary good, crude oil and/or petroleum products, is reduced from the level it otherwise would have reached. The extent to which demand is reduced naturally depends on the costs associated with the complementary good and the sensitivity of demand with respect to price.

Assessing the costs of environmental protection associated with crude oil and petroleum product use is a daunting task. Some are obvious and easy to relate to per-barrel costs. For example, the Superfund [191] excise tax adds about eight cents per barrel to refiners' acquisition costs of crude oil. The majority of such costs, however, are not simple per-barrel taxes, but rather are associated with compliance with a series of technical regulations ranging from construction and operation of production facilities to product manufacturing and performance specifications, to transportation and distribution requirements. The cost impacts of these types of regulations are most heavily felt in California, particularly Southern California, as Los Angeles Basin refiners are recognized as being subject to the most severe environmental restrictions in the world,[192] and certain end-use standards—such as those for automobile emissions—are among the most strict in the U.S.

The costs associated with environmental protection regulations will ultimately be passed on to consumers to the extent that industry

[191] The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), commonly known as Superfund, provides funds to clean up old and abandoned hazardous waste sites.

[192] National Petroleum Council, "U.S. Petroleum Refining," October 1986.

participants are able to do so. And there is little doubt that these costs will increase. It has been estimated that the nation's refining industry alone faces increased costs of compliance with new and upcoming environmental regulations of from $18.8 to $22.2 billion per year [193], which would translate to from three to four dollars per barrel of increased costs at current consumption levels. Cost increases of this magnitude would certainly have significant and long-lasting impacts on petroleum demand in the U.S.

"Market Imperfections"

The preceding discussions have taken place in the framework of economic theory, that is, in the world of abstract supply and demand forces acting in perfectly competitive markets. We must recognize, however, that markets are not always perfectly competitive, and that other factors often act to influence crude oil prices. These factors may include regulatory or tax policies, industry structure and industry behavior. The effects of several important factors will be discussed in this section, although we note that this is not a comprehensive presentation of all the external factors which could (and do) influence crude oil prices.

Broad Influences

Two factors which stand out as having broad influence on national crude oil price levels are the behavior of OPEC as a political rather than economic entity, and the organizational structure of the petroleum industry. The role of OPEC and the factors affecting its ability to influence crude oil price levels have been discussed previously; here we add the observation that while sometimes OPEC's motivations in setting prices or output quotas may be politically driven rather than based on economic considerations, their practical effect on crude oil prices will not only be the same as economically driven prices and output quotas, but the same limitations and moderating influences will tend to apply. We note, however, that there is substantial controversy over what if any pricing and output decisions OPEC has made on political grounds, and what the ultimate effect of these decisions on world crude oil prices has been.[194]

The organizational structure of the petroleum industry and its impact on crude oil prices has itself been the subject of voluminous studies and analysis.[195] To somewhat condense this subject, the structural factors which influence prices generally center on issues of vertical integration and market power. The term "vertically integrated" is used in the petroleum industry (and other multi-segment industries) to describe firms which participate in more than one segment of the industry. For instance, a firm could participate in both crude oil exploration and production, as well as transportation and refining. Alternatively, it could participate in any of those sectors in addition to the marketing sector. To the extent that a firm participates in more rather than fewer of these sectors, as well as to the extent

[193] "Environmental, related issues taking their turns in restructuring industry," Oil & Gas Journal, January 22, 1990.

[194] For instance, there is debate over whether the so-called Arab Oil "Embargo" of 1973–1974 was effective or had any direct influence on prices. See, e.g., D. Gately, "A Ten-Year Retrospective: OPEC and the World Oil Market," Journal of Economic Literature, September 1984.

[195] Perhaps the seminal publication on this subject has been M.G. deChazeau and A.E. Kahn, Integration and Competition in the Petroleum Industry, Yale University Press, 1959.

that the sectors are physically linked, the firm is often loosely referred to as being more fully integrated than other firms.

Firms often have obvious economic incentives to pursue vertical integration: costs may be saved in administration and management, and access to raw materials or products to market may be more assured. For the purposes of this discussion, however, vertical integration allows a firm considerable discretion in determining how the overall profit earned in the firm's total operations may be allocated among its different operating sectors. The greater the extent of the firm's vertical integration, the greater this ability.

This ability to shift sectoral profits is important because it may allow a firm to take advantage of or to avoid certain tax laws or other regulations, while a non-vertically integrated firm might not be able to make such a choice. There are several instances where this ability was viewed as quite important for vertically integrated firms. For example, until the Oil Depletion Allowance was repealed, a firm which both produced and refined crude oil might have benefitted from higher crude oil prices. Profits lost in refining expensive crude oil would be made up in production and the firm would simultaneously earn a greater depletion tax shield than it would under low crude oil prices. Thus, the firm would have an incentive to price its production higher than it otherwise would have under similar aggregate supply and demand conditions without the depletion tax policy. In contrast, the recently repealed Windfall Profits Tax gave integrated firms a strong incentive to keep crude oil prices below the windfall profit "base price" to avoid the extremely high (70%) tax on prices above the base price. Currently, the state of Alaska and the Internal Revenue Service are investigating allegations that the prices of Alaskan crude oils were kept artificially low by the vertically integrated companies at least in part because of this issue.

The concept of market power is often rather broad; it may be thought of as the ability of a firm (or group of firms), to influence the economic parameters within which it operates. For instance, OPEC has at times shown a great degree of short-run market power as it has had the ability to strongly influence crude oil prices. Of late this market power has eroded due to the organization's inability to act cohesively. The extent to which domestic firms have sufficient market power to influence crude oil prices is a widely debated subject. One frequently used measure of the potential for market power within an industry is the level of concentration in the industry. This measure is used by the U.S. Justice Department in evaluating the competitive effects of mergers within industries. The influences of concentration and market power are important in considering how crude oil prices are determined because they each represent deviations from the abstract world of "perfectly competitive" markets.

West Coast Issues

The petroleum industry on the U.S. West Coast has historically been geographically isolated from the rest of the country and tends to behave in some respects as an independent market and in some respects as a linked market.[196] As such, in addition to the broad influences described above, there are several

[196] The recent construction of crude oil pipelines between the West Coast and the Texas/Gulf Coast region will be a factor which will tend to act over time to further link the economics of the petroleum industry on the West Coast to the rest of the U.S. Because the West Coast market has been isolated from that of the rest of the country for so long, however, it seems likely that this linkage will be gradual.

issues specific to the West Coast which deserve consideration in assessing influences on West Coast crude oil prices. We note that this subject has for some time been of more than academic interest: it has long been recognized that West Coast crude prices are very low compared to prices prevailing in the rest of the country, and attempts to explain the economic underpinnings of this often conclude that no competitive market explanation may be available.[197] Some but not all of the factors currently of interest in the West Coast market include the level of industry concentration specific to the West Coast, the control of transportation systems within the industry, and the statutory ban on exports of domestic crude oil, specifically Alaskan crude oil. Each of these is discussed briefly below.

As we have described above, high levels of concentration within an industry are often associated with the potential for high levels of market power. For instance, a highly concentrated refining sector may be able to reap greater profits than an unconcentrated industry through an ability to set lower raw material prices or maintain higher finished product prices, or both. On the U.S. West Coast, particularly in California, which is the dominant refining region, the level of concentration in the refining sector is sufficiently great that concerns about the potential existence of undue market power would normally be raised in the course of industry mergers or other structural changes. Figure 5-15 shows the fractions of total refining capacity controlled by the four largest California refiners in various years since 1970.

Year:	1970	1975	1980	1985	1989
Total Capacity:	1,617.9	1,900.6	2,506.4	2,265.1	2,278.6
Socal	416.0	446.0	796.0	796.0	600.0
Un ion	199.0	219.0	219.0	219.0	220.9
Shell	183.4	196.0	212.0	199.4	284.0
Arco	165.0	185.0	177.0	215.0	214.0
Four Firm Subtotal	963.4	1,046.0	1,404.0	1,429.4	1,319.0
Percent of Total	59.55%	55.03%	56.02%	63.1%	57.89%

Source: Oil and Gas Journal Refining Capacity Surveys, Various Years
(All Values in Thousands of Bbls per Calendar Day.)

Figure 5 - 15: California refinery capacity concentration.

As the figure shows, the four-firm concentration level was never below 55% and even exceeded 60% in one of the years examined. While high concentration alone is not necessarily an indicator of the exercise of market power to influence crude oil prices, it does represent a departure from the assumptions underlying how crude oil prices are determined in competitive markets.[198]

Concentration in the state's crude oil production has been on the rise in recent years as many independent producers have been acquired by integrated firms. The four-firm concentration ratio in crude production was only 40.5% in 1980. By 1988, concentration

[197] A recent concise, unbiased review of some of the issues surrounding California and other West Coast crude oil prices can be found in C.P. Shirkey and R.A. Speir, "California Crude Oil Price Levels," U.S. DOE/EIA Petroleum Marketing Monthly, April 1987. We also note that the levels of California crude prices and the practices of certain participants in the California petroleum industry have been the subject of currently unresolved federal and state antitrust actions.

[198] In addition, a significant number of independent refiners have exited the refining industry in California during the 1980s. This may have been due to a number of factors including the elimination of government subsidy programs for small refiners, control of crude supplies by the integrated majors in California, and higher costs of crude supplies faced by independents.

had increased to 57% at the four firm level.[199] Furthermore, in 1980 two of the four largest producers were independent (non-integrated) firms; in 1988, the four largest producers were all integrated majors. Again, this relatively rapid increase in concentration should be viewed with some concern as it indicates increasing control of the market by fewer and fewer participants.

Another factor to consider in the California oil market is the unique nature of the state's crude oil transportation system. Generally, it is accepted that the most efficient method of overland transportation of crude is by pipeline. Throughout most of the U.S., major "trunk line" pipelines must be operated under public utility rules as "common carriers." As such, these pipelines are operated to provide transportation services for any producers of crude oil who request them, subject to the terms of the common carrier's publicly filed tariff. The existence of these common carrier pipelines is generally thought to produce more efficient crude oil markets by allowing producers to seek high prices through access to a variety of refiners and by allowing many refiners access to a variety of crude oils.

Until recently, California had more privately operated major crude oil pipelines than any other state. [200] A private carrier, unlike a common carrier, has no statutory obligation to provide transportation services for individuals seeking such services. Thus, in California, many independent crude oil producers are faced with the choices of constructing their own pipelines (an expensive, and probably untenable solution due to environmental constraints), selecting inefficient modes of transportation such as tank trucks, or negotiating with major oil companies operating pipelines as private carriers who are under no obligation to provide transportation services. In addition, independent refiners at times have had difficulties obtaining California crude supplies due to the lack of common carrier pipelines in the state.

In its report reviewing the potential competitive effects of the Texaco-Getty merger on the California petroleum industry, the Federal Trade Commission described the impact of the privately-owned pipelines as follows:[201]

> Most California producers are tied to pipeline gathering systems that are privately-owned, which in turn are tied to trunkline systems that are also privately owned. Unlike the systems in most states, California pipelines are not common carriers. Non-integrated refiners are therefore not guaranteed access to much of the local crude oils production. The above factual situation may have led to a "two-tier" market. Major gathers may be able to post at one price, while non-integrated refiners may be required to pay premiums above the posted price for the more limited supplies of crude oil available to them.

Finally, several analysts have discussed the importance of Alaskan crude oil in the West

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[199] Conservation Committee of California Oil Producers, Annual Report, 1980, 1988.

[200] The Four Corners Pipeline Company has provided common carrier service on some lines from the San Joaquin Valley to the Los Angeles area since 1977. More recently (in 1988), the Shell Oil Company moved to change the status of its pipeline from Ventura to Los Angeles to that of a common carrier; all other major crude pipelines in California remain privately operated.

[201] Comments of FTC re Texaco-Getty Merger, Federal Register, March 7, 1984.

Coast market and its effect on West Coast prices. Some take the position that the statutory ban on the export of Alaskan, specifically Alaskan North Slope (ANS), crude oil results in an inefficient allocation of domestic crude oil supplies and depresses West Coast crude oil price levels. Others believe that these effects, if they exist, are small.[202]

Further complicating the matter is the fact that the Jones Act requires Alaskan crude oil, which moves by tanker from Valdez to the West Coast (and ultimately Gulf Coast) ports, to be transported by U.S. flag vessels. Because U.S. flag carriers generally operate at higher costs than other international tankers, the costs of landing ANS to domestic ports are higher than they are otherwise. It appears that the debate over the influences of these policy factors will continue as long as they are in place and as long as Alaskan crude continues to provide an important fraction of domestic crude oil supplies.

OIL AND THE PRIVATE SECTOR ECONOMY

Most economic studies of the impact of oil price changes on the aggregate economy have focused on the effects of sharp increases in oil prices, such as those which occurred in 1973–1974, and again in 1979. Historically, these oil price shocks had net negative effects on the aggregate economy. Numerous studies have provided estimates of these effects.

Figure 5-16 shows one such study's comparison of the impact of the 1973–1974 oil price shock compared to the 1979 oil price shock.

1973 - 1974 Oil Price Shock	3Q 1984	3Q 1975	3Q 1976
Real GNP (Percent Change)	(0.4)	(2.1)	(2.7)
Contribution to Inflation (Percent Points)	2.6	0.8	0.8
Contribution to Unemployment Rate (Percent Points)	0.2	1.0	1.4
Nonresidential Fixed Investment (Percent Change)	0.2	(3.4)	(6.1)
1979 - Oil Price Shock	**4Q 1979**	**4Q 1980**	**4Q 1981**
Real GNP (Percent Change)	(0.9)	(2.8)	(3.6)
Contribution to Inflation (Percent Points)	2.5	2.6	1.8
Contribution to Unemployment Rate (Percent Points)	0.3	1.3	1.9
Nonresidential Fixed Investment (Percent Change)	(0.7)	(4.3)	(6.6)

Source: Wharton Economic Forecasting Associates, quoted in "Factors Affecting U.S. Oil and Gas Outlook," National Petroleum Council, February 1987.

Figure 5 - 16: Estimated economic impacts of oil price shocks.

The figure shows that the impacts of each were felt over several years in the economy. For instance, real GNP was reduced over several years, coupled with an increased national unemployment rate. Non-residential fixed investment was depressed at an increasing rate over time, suggesting that even longer term adverse economic effects may have occurred. Contributions to inflation, on the other hand, are generally felt most immediately after each oil price shock. However, while the impact on inflation rates fades over time, the increases in price levels are permanent—at least until the oil price shock is reversed. Similarly, reductions in the overall level of economic activity (as measured by real GNP), are also long-lasting.

If the aggregate effects of the oil price shocks of the 1970s were both negative and long-lasting, it might be tempting to conclude that dramatic reductions in crude oil prices (such as occurred in 1986), might be positive and equally long-lasting. While the net aggregate effects of such price level declines are generally recognized to be positive, the benefits are probably not equal in magnitude to the costs suffered by the economy during periods of comparable oil price increases. The asymmetry between aggregate net costs to the economy and aggregate net benefits may be traced at least in

[202] Compare, e.g., U.S. Department of Commerce "Report to Congress on Alaskan Oil," June 1986 and Shirkey and Speir, op cit.

part to costs incurred in the economy during the process of adjustment from one set of relative factor prices to another. These costs of adjustment may be physically manifested in changes in capital equipment used, changes in distribution and allocation systems, and reoptimization of industrial capacity under new sets of input prices.

Despite the costs of adjustment, lower oil prices were perceived to have a large net benefit to the aggregate economy in the short term. Oil price declines directly benefit consumers and energy-intensive industries. As energy bills are reduced, consumers' real disposable income increases, as does the profitability of energy-intensive industries. Both of these effects lead to other positive macroeconomic effects, particularly in terms of consumption and investment. The magnitude and duration of these benefits depends, however, not only on the path of adjustment to new oil price levels such as we have recently witnessed, but also on expectations regarding the duration of the new price levels.

Finally, lower prices for imported crude oil may have helped to reduce capital outflows to the oil exporting countries; in 1986, for example, the value of net U.S. crude oil imports fell to approximately $34 billion from the 1985 level of $45 billion [203], despite a substantial increase (over 30%) in the volume of imported oil. The aggregate economic effects of trade surpluses and/or deficits with foreign countries are, however, widely debated by economists.

Whether the net effects of changes in oil price levels on the aggregate economy are positive (as in the case of lower price levels), or negative (as in the case of price increases), there may be sectoral "winners" and "losers" as a result of such shifts. In general, sectors which are net consumers of petroleum products will see benefits from reduced oil prices, and sectors which are net producers of petroleum products will see losses from reduced prices. Within these categories, however, there may be very different impacts across industry groups or types of consumers. In this section, we highlight the types of impacts felt by several important sectors. Much of this section was written prior to the rapi runup in petrtoleum prices following the Iraqi invasion of Kuwait in August 1990. Many, if not most of the conclusions in this section regarding the "benefits" of lower petroleum prices are felt in exactly the opposite direction with increases in petroleum prices.

The most obvious group one might think of as benefitting from lower petroleum prices would be ordinary consumers, who feel the benefits of lower oil prices in several ways. First, because lower oil prices act over time to increase real GNP, overall employment rates will tend to rise. One recent study [204] found that a 20% real decline in oil prices led, on average, to a continuing half percentage point decline in unemployment rates. For purposes of comparison, crude oil prices in the U.S. declined by almost 50% in real terms between 1985 and 1986 (and by almost 60% in real terms between 1981 and 1986)[205]; we might thus expect that positive effects on aggregate employment on the order of one-half percentage point or greater may be attributed to the crude

[203] National Petroleum Council, "Factors Affecting U.S. Oil and Gas Outlook," February 1987.

[204] B.G. Hickman and H.G. Huntington, "Macroeconomic Impacts of Energy Shocks: An Overview," Energy Modeling Forum, Stanford University, 1984.

[205] See, e.g., Degolyer & MacNaughton, "Twentieth Century Petroleum Statistics 1988."

oil price decline. Of course, as we will further note below, some industries, particularly petroleum production, may have suffered employment declines even as the entire economy gained jobs.

The second manner in which consumers may benefit is in the form of lower prices for purchased goods. The extent to which this benefit is enjoyed by consumers, however, depends on whether or not the industries providing such goods are inclined, or forced by the marketplace to pass on the savings resulting from lower petroleum prices. For example, in the case of direct purchases of petroleum products such as gasoline or home heating oil, consumers benefit from lower prices, but only to the extent that refiners' and resellers' margins are not increased. If refiners and resellers enjoy greater margins, then the benefit of lower petroleum prices may be split among the different groups. There is of course no question that consumers have enjoyed at least some of the benefits flowing from the 1986 reduction of crude oil prices. The DOE has estimated [206] that the 1986 drop in oil prices has resulted in savings of over $.25 per gallon for the average automobile owner, and annual household savings of about $300. Yet, as petroleum product prices have risen this fall, consumers have also felt the increasing cost of paying as much as $.40 per gallon more for gasoline than was the case only four months ago.

Consumers also benefit from reduced crude oil prices when they purchase many other goods, although the benefits may seem less obvious as energy costs may make up relatively small percentages of some manufactured goods' total costs. The determinants of the allocation of cost savings between consumers and manufacturers are similar to those described above: to the extent that market conditions dictate that producers pass on cost savings, they will tend to do so, and to the extent that they are not required to do so, they will enjoy greater profits. The conditions determining these allocations vary by industry and depend generally on the sensitivities of industry supply and demand to price changes, and the industry's competitive structure. One important industry in which fuel prices play a prominant role in determining costs is the airline industry; the DOE has estimated that the 1986 reduction in fuel prices resulted in total savings of $3.2 billion [207]. Some of this was passed on to consumers in the form of lower fares, and some was no doubt also captured by the industry. The recent large increases in airfares and operating losses reported by the major airlines point out the negative impacts that higher oil prices have had on this industry.

The petroleum industry sector is one of the most important in the U.S. economy. Figure 5-17 illustrates the number of jobs accounted for by the various components of the industry; between 1985 and 1988, the petroleum industry as a whole accounted for from 1.4% to 1.7% of total U.S. non-agricultural civilian employment.

While each of the components of the petroleum industry is important, two sectors—production and refining—stand out. The production sector is important not only because it is, except for retail sales, the largest employer in the industry, but it is also the sector which most directly and immediately feels the impact of changes in petroleum price levels. In

[206] See U.S. DOE/EIA, "Energy Security A Report to the President of the United States," March 1987.

[207] Ibid.

	(Thousands)			
	1985	1986	1987	1988
Petroleum Industry:				
Extraction	582.9	450.0	406.7	423.2
Refining	141.4	131.1	127.8	129.5
Paving & Roofing	26.3	26.1	27.9	27.9
Pipelines	18.7	18.1	18.7	17.0
Gas Production	174.8	167.4	168.9	170.8
Wholesale	205.9	200.5	199.6	206.3
Retail	588.5	596.0	618.2	641.4
Subtotal:	1,738.5	1,589.2	1,567.8	1,616.1
Total Non-Agricultural Civilian Employment	103,971.0	106,434.0	109,232.0	

Sources: Petroleum industry sectoral employment from "Basic Petroleum Data Book," American Petroleum Institute 1989; Aggregate employment statistics from "Economic Report of the President," 1988.

Figure 5 - 17: U.S. petroleum industry sectoral employment.

particular, independent producers who do not have refining or other operations to help offset losses or reduced income may be especially hard-hit by falling crude oil prices. This is particularly disturbing since in the past, it has been the independents who have discovered the majority of new oil and gas in the lower 48 states.[208] As Figure 5-17 shows, it is the production sector which suffered by far the most dramatic drop in employment following the crude oil price decline in 1986. Given the magnitude of this drop, it seems possible that there may be delays in reaching appropriate staffing levels of skilled personnel as oil prices rise to previous levels. Similar employment reductions may have occurred in other related sectors, such as the oil field services industry, thus exacerbating this problem.

The importance of the refining sector is belied by the relatively small fraction of total petroleum sector employment for which it accounts: less than 10% of petroleum industry employment and less than one-half of 1% of employment in all manufacturing industries. Nevertheless, the refining sector can have a very large impact on the aggregate economy. For example in 1985, petroleum refining accounted for over 6% of assets and almost 4% of all capital expenditures in manufacturing industries. In California, petroleum refining accounted for over 10% of all manufacturing industries' capital expenditures.[209] Thus, when the refining industry is active, other sectors of the economy—such as the construction industry and sectors which produce capital equipment—will benefit from supplying its investment needs. Paradoxically, while there is no question that the economic activity of the producing sector is hurt by declining crude oil prices, the refining sector may stand to benefit from lower crude prices since lower petroleum product prices will stimulate demand, all else being equal. As with the producing sector, it will be the independent (i.e., non-integrated) companies within this sector which will feel the economic impact of crude oil price swings most acutely.

As we have noted, while the net effects of a crude oil price decline on the aggregate economy are positive, the effects on certain sectors tied to the petroleum industry (e.g., the producing and oil field services industries) are negative (and vice-versa with an oil price increase). Because the industries feeling negative effects are highly concentrated geographically, and because the benefits of lower crude oil prices are spread out somewhat more evenly over the nation, certain geographic areas may feel negative economic impacts from an oil price decline even while the aggregate economy feels positive effects.

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[208] Ibid.

[209] U.S. Department of Commerce, Bureau of the Census, "1985 Annual Survey of Manufacturers: Expenditures for Plant and Equipment," and U.S. Department of Commerce, Bureau of Census, "Census of Manufacturers Geographic Area Series: California."

The states which may feel the greatest net negative effects from a price decrease will be those where crude oil production and related industries play the most important economic roles. These states include: among others, Alaska, New Mexico, Oklahoma, Texas, and Louisiana. They are heavily dependent on petroleum-producing and related industries not only in terms of employment, but also in terms of state revenues. For instance, Alaska and New Mexico currently derive about 85% and 41%, respectively, of all state revenues from oil and gas taxes and royalties. Drops in oil prices not only reduce the states' share of revenues, but also act to increase burdens of unemployment claims. In 1986, for example, while unemployment rates averaged about 7% nationally, Louisiana endured rates of about 14%, while Texas and Alaska had unemployment rates of about 11%. It is important to note that while California produces more crude oil than New Mexico or Oklahoma, California's larger and more diverse economy allows it to absorb adverse economic impacts more easily.

OIL AND PUBLIC MONEY

In this section we examine the importance of the petroleum industry to the public sector in terms of the revenues generated by the industry for public use. The primary sources of public revenue from the petroleum industry include royalties from oil production on federal and state lands, direct payments for oil produced from state lands, income taxes, and other forms of tax revenue.

National Revenues

The oil industry contributes a significant amount of money to the U.S. Treasury in the form of tax and royalty revenues. For example in 1988, total royalties from federal lands amounted to almost one billion dollars. This represents royalties collected by the Department of Interior Minerals Management Service's Royalty Management Program. Minerals Management Service (MMS) has responsibility for royalties collected from all oil properties on federal lands.

Figure 5-18 summarizes federal royalties collected by the MMS between 1980 and 1988 broken out according to offshore and onshore properties.

As can be seen, total royalty revenues peaked in the early 1980s when oil prices were at their peak and production levels were high. Offshore revenues have consistently exceeded onshore revenues by a margin of three to one due to extensive activity in the federal Outer Continental Shelf (OCS), especially in the Texas-Louisiana and California areas.

In addition to royalty revenues, the federal government also collects revenues from the oil companies in the form of income taxes and, until recently, from the Crude Oil Windfall Profit Tax. Published data do not exist on how much income tax the oil companies pay to the U.S. Treasury each year. One would expect that since these companies are among the largest corporations in the United States,[210] they

[210] Three oil companies rank among the top ten largest industrial companies.

1980-1988
($000)

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Offshore	$837,237.4	$1,575,316.5	$1,740,288.0	$1,603,942.8	$1,823,447.8	$1,707,184.9	$1,015,037.7	$999,273.5	$747,454.7
Onshore	$413,403.2	$604,782.9	$524,530.2	$522,661.1	$519,046.6	$492,367.9	$268,689.6	$289,069.7	$230,896.9
TOTAL	$1,250,640.6	$2,180,099.4	$2,264,818.2	$2,126,603.9	$2,342,494.4	$2,199,522.8	$1,283,727.3	$1,288,343.2	$978,351.6

Figure 5 - 18: Federal oil royalty revenues.

contribute a significant amount in income taxes. Nevertheless, many of these companies have extensive foreign operations and foreign owned subsidiaries which enable them to earn substantial revenues abroad, beyond the reach of U.S. tax authorities.

Until 1988, oil companies were also subject to the Crude Oil Windfall Profit Tax. This tax was enacted in 1980 as crude oil price controls were being phased out. The purpose of the tax was to place a relatively heavy tax burden on the difference between the controlled price of oil and the uncontrolled price. It was computed on the difference between a "base price level" which was a 1980 uncontrolled price, adjusted each quarter for inflation and the actual price of the crude oil, and paid by the producing company. The rapid increase in crude prices in the early 1980s meant that a significant amount of tax revenue was collected. With the price collapse in 1986, base price levels exceeded market prices and virtually no tax revenue was collected from 1986 until 1988 when Congress repealed the tax.

In California and Alaska outstanding issues remain as to whether some of the oil companies have paid sufficient Windfall Profit taxes.[211] As noted above, the major oil companies have extensive control over the crude oil market in California due to their proprietary pipeline system, and they exercise similar control over the transportation and distribution of Alaskan oil. This has provided them the opportunity to keep wellhead prices low and thus pay less in Windfall Profit Tax while still charging market prices for refined products and earning higher profits in the transportation, refining and marketing segments of the company.[212]

California Revenues

California derives tax revenues from the petroleum industry in both direct and indirect ways. Direct ways include royalties, bid bonuses and other payments from oil and gas development projects in the state. Indirect ways include sales tax revenue from gasoline, diesel and LPG product sales, and federal royalties returned to the state.

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[211] See Martin Lobel and Henry M. Banta, "Billions in Windfall Profits Taxes Still to be Collected," Tax Notes, July 24, 1989.

[212] The effective Windfall Profit tax rate is substantially higher than the corporate income tax rate which provides these companies with an incentive to transfer profits "downstream" away from production and to transportation and refining.

Year	Oil & Gas Royalties	State Lands Bid Bonuses	State Lands State Portion Long Beach	Mineral Royalties	Total Revenues
1960-61	$9,755,978	$10,905,111	$6,380,505	$65,990	$27,107,584
1961/62	$11,266,763	$6,655,518	$6,741,966	$68,628	$24,732,875
1962/63	$16,728,843	$21,167,654	$11,210,069	$126,091	$49,232,657
1963/64	$17,795,529	$33,781,572	$10,689,983	$117,369	$62,384,453
1964/65	$19,429,433	$34,108,012	$14,231,575	$337,895	$68,106,915
1965/66	$17,146,103	$7,349,334	$20,228,062	$322,118	$45,045,617
1966/67	$21,737,370	$2,819,879	$18,785,921	$270,179	$43,613,349
1967/68	$25,375,949	$1,846,854	$19,842,718	$187,067	$47,252,588
1968/69	$20,963,846	$3,147,134	$20,563,594	$144,159	$44,818,733
1969/70	$17,550,318	$58,322	$24,996,169	$76,021	$42,680,830
1970/71	$16,863,025	$6,000	$17,194,450	$115,274	$34,178,749
1971/72	$16,806,985		$44,986,374	$117,238	$61,910,597
1972/73	$20,865,085		$83,836,747	$107,615	$104,809,447
1973/74	$25,906,426		$93,874,614	$143,440	$119,924,480
1974/75	$27,749,331		$98,520,645	$169,601	$126,439,577
1975/76	$28,624,355		$84,654,576	$157,771	$113,436,702
1976/77	$23,726,891		$84,261,168	$95,442	$108,083,501
1977/78	$23,838,564		$69,862,222	$118,748	$93,819,534
1978/79	$33,249,922		$74,975,304	$199,741	$108,424,967
1979/80	$53,337,149		$251,565,562	$278,158	$305,180,869
1980/81	$89,918,674		$385,371,622	$424,066	$475,714,362
1981/82	$113,214,168		$349,206,476	$413,918	$462,834,562
1982/83	$95,282,139		$357,381,920	$306,142	$452,970,201
1983/84	$93,659,995		$290,803,360	$510,280	$384,973,635
1984/85	$96,814,667		$408,338,436	$423,619	$505,576,722
1985/86	$80,257,589		$345,149,433	$494,773	$425,901,795
1986/87	$38,246,309		$133,672,752	$318,315	$172,237,376
1987/88	$32,273,444		$187,180,497	$545,898	$219,999,839
1988/89	$29,246,000		$89,333,000	$367,000	$118,946,000

Figure 5 - 19: California revenues from oil and gas developments.

Figure 5-19 indicates the amount of direct revenues generated in California from various sources from 1960 to 1989.

Total revenues peaked in the early 1980s when oil prices were high, and have diminished significantly since 1985. Oil and gas royalties and California's share of revenues from the Long Beach tidelands properties comprise a major source of the state's non-tax revenues. In the 1960s when the state was putting many of its tidelands properties out for bid, it received significant revenues in the form of bid bonuses which were paid out in the first years of the contracts. Since 1971 no revenues have been received for bonus bids since no new properties have been leased.

Figure 5-20 lists various state funds that have utilized the oil revenues discussed above.

State tidelands oil revenues / expenditures

	Total Revenues		Expenditures
76-77	$107,988,000	• California Water Fund	$25,000,000
		• Central Valley Project Construction Fund	$5,000,000
		• Capital Outlay Fund for Public Higher Education	$73,288,000
		• General Fund	$4,700,000
77-78	$93,700,000	• California Water Fund	$25,000,000
		• Central Valley Project Construction Fund	$5,000,000
		• Capital Outlay Fund for Public Higher Education	$58,234,000
		• General Fund	$5,466,000
78-79	$108,225,000	• California Water Fund	$25,000,000
		• Central Valley Project Construction Fund	$5,000,000
		• Capital Outlay Fund for Public Higher Education	$71,853,000
		• General Fund	$6,372,000
79-80	$304,902,000	• California Water Fund	$25,000,000
		• Central Valley Project Construction Fund	$5,000,000
		• Capital Outlay Fund for Public Higher Education	$268,542,000
		• General Fund	$6,360,000
80-81	$475,095,000	• California Water Fund	$25,000,000
		• Central Valley Project Construction Fund	$5,000,000
		• State Parks & Rec. Fund	$7,800,000
		• Energy & Resources Fund	$91,381,000
		• State Parks & Rec. Fund	$35,000,000
		• Capitol Outlay-State Bldgs.	$304,095,000
		• General Fund	$6,819,000
81-82	$462,421,000	• California Water Fund	$25,000,000
		• Central Valley Project Construction Fund	$5,000,000
		• Capital Outlay Fund for Public Higher Education	$84,259,000
		• State School Building Lease-Purchase Fund	$200,000,000
		• Energy & Resources Fund	$73,138,000
		• State Parks & Rec. Fund	$35,000,000
		• State Transportation - Transportation & Planning Account	$25,000,000
		• Capitol Outlay-State Bldgs.	$8,466,000
		• General Fund	$9,558,000
82-83	$452,964,000	• California Water Fund	$14,710,000
		• Capital Outlay Fund for Public Higher Education	$71,133,000
		• Off-Highway Vehicle Fund	$1,000,000
		• State School Building Lease-Purchase Fund	$100,000,000
		• Energy & Resources Fund	$64,066,000
		• State Parks & Rec. Fund	$12,417,000
		• Spec. Acct. for Capitol Outlay	$54,725,000
		• General Fund	$134,913,000
83-84	$384,463,000	• Capital Outlay Fund for Public Higher Education	$69,635,000
		• Energy & Resources Fund	$24,048,000
		• Special Account for Capital Outlay	$17,816,000
		• Santa Monica Conservancy Fund	$5,000,000
		• General Fund	$267,864,000
84-85	$515,943,000	• California Water Fund	$25,000,000
		• Central Valley Project Construction Fund	$5,000,000
		• Capital Outlay Fund for Public Higher Education	$102,168,000
		• State School Building Lease-Purchase Fund	$150,000,000
		• Special Account for Capital Outlay	$219,168,000
		• General Fund	$14,607,000

Figure 5 - 20A

State tidelands oil revenues / expenditures

	Total Revenues		Expenditures
85-86	$425,407,000	• California Water Fund	$25,000,000
		• Fisheries Restoration Fund	$5,000,000
		• Central Valley Project Construction Fund	$5,000,000
		• Capital Outlay Fund for Public Higher Education	$125,992,000
		• State School Building Lease-Purchase Fund	$150,000,000
		• Energy and Resources Fund	$5,682,000
		• General Fund	$108,733,000
86-87	$168,866,000	• General Fund	$32,128,000
		• California Water Fund	$5,854,000
		• Fisheries Restoration, F & G Preservation Fund	$5,000,000
		• Capital Outlay Fund for Public Higher Education	$10,085,000
		• Cal. Housing Trust Fund	$10,000,000
		• Capital Outlay State Buildings	$105,799,000
87-88	$219,454,000	• California Housing Trust Fund	$10,000,000
		• California Water Fund	$3,640,000
		• Capital Outlay State Buildings	$107,423,000
		• General Fund	$98,391,000
88-89	$118,323,000	• California Water Fund	$7,200,000
		• Fisheries Restoration Account	$1,250,000
		• California Housing Trust	$4,000,000
		• Capitol Outlay-State Buildings	$82,599,000
		• General Fund	$23,274,000
89-90	$143,566,000	• Capitol Outlay-State Buildings	$86,225,000
		• General Fund	$57,341,000

Figure 5 - 20B

The bulk of the money has been used to fund state education related projects. Over a third of the money generated since 1976 has gone to two education related funds:

- **Capital Outlay Fund for Public Higher Education—Funds are allocated to community colleges, state colleges and universities for new buildings, improvements, or refurbishing.**

- **State School Building Lease-Purchase Fund—Funds are allocated to public school districts (Kindergarten through High School) for improvements, renovations or refurbishing of existing buildings. The School District is required to provide matching funds under this program.**

Clearly these revenues have played an important role in the funding of education-related facilities in the state at a time when the need for such facilities has been very great. With the decline in oil prices and consequent

decline in oil-related revenues in recent years, less money has been available for such programs.

Other revenues have been generated indirectly as a result of the activities of the petroleum industry in California. For example, the state derives revenues from gasoline taxes, as well as taxes on diesel fuel and LPG (liquified petroleum gas). In addition, the state receives a share of federal royalties (the 8(g) program).

Figure 5-21 presents data on these indirect sources of revenue for the last 10 years.

Year	Gasoline Tax Rev.	Diesel, LPG Tax Rev.	Fed. Royalty Ret. to State	TOTAL
1978-79	$822,200	$74,400	$16,700	$913,300
1979-80	$773,000	$79,100	$15,400	$868,200
1980-81	$758,400	$81,600	$17,400	$857,400
1981-82	$752,100	$81,300	$20,000	$853,400
1982-83	$835,400	$93,200	$25,500	$954,100
1983-84	$1,087,500	$125,700	$31,600	$1,244,800
1984-85	$1,028,500	$131,200	$43,300	$1,203,000
1985-86	$1,062,600	$131,000	$31,700	$1,225,300
1986-87	$1,107,900	$141,700	$24,500	$1,274,100
1987-88	$1,131,900	$147,900	$22,700	$1,302,500
1988-89	$1,166,100	$159,500	$22,800	$1,348,400

Figure 5 - 21: Indirect sources of revenue from the petroleum industry.

The majority of this revenue comes from the state gasoline tax which increased significantly during the 1980s as prices rose and as demand increased. These revenues are not earmarked for special uses (as is true for the State Tidelands oil and gas development funds), and instead go to the general fund.

OIL DEVELOPMENT ECONOMICS

The development of oil resources from an economic cost/benefit standpoint depends heavily upon one's expectations of future oil prices. As was discussed in this chapter, many factors influence the price of oil, and it is equally clear that development of petroleum resources depends heavily on the price of oil as well as the price of alternative energy sources. Development of petroleum resources is on the decline at current "low" price levels, and we are becoming increasingly dependent on foreign oil once again. On the other hand, efforts to increase development at a time when oil prices are low is difficult and results in fewer tangible "benefits" than when oil prices are high.[213] Also increasing dependence on foreign crude oil supplies never appears as alarming when oil prices are low than when they are high.

Nevertheless, when considering increased development activity, it is important to be aware of some of the economic costs and benefits. Figure 5-22 summarizes some of the costs and benefits from increased oil development given current and future price projections.

Benefits	Costs
Less dependence on imported oil	Environmental hazards of increased development
More favorable trade balance	Less royalty revenue from development than if prices higher
Increased tax, royalty revenues	Ability to use resources for other purposes
Improved outlook for employment	Less pressure to develop alternative energy sources and conservation measures
Increased flexibility to deal with an energy "crisis"	

Figure 5 - 22: Costs and benefits of increased oil development.

Perhaps the most significant cost of increased oil development is the increased risk of environmental damage. Recent events in Prince Edward Sound in Alaska and off Huntington Beach demonstrate that even at current development levels the risks of environmental disaster are significant. It is extremely difficult to quantify the costs of such environmental disasters, but as we have seen, the relative risks are indeed substantial.

[213] For example, with low prices, taxes and royalties are less than with higher prices.

The most obvious benefit of increased oil development is the lessening of our dependence on foreign imported oil, and the increased flexibility we would have to deal with an "energy crisis." This benefit, however, comes with a "hidden" cost. As we have seen in recent years with low oil prices and ample crude oil supplies, efforts to conserve more and invest in alternative energy technologies tend to diminish as consumers are less willing to take action on the possibility of a future "energy crisis."

Finally, in the short run, increased oil development would lead to higher royalties and tax revenues. At the state and local level there is also the benefit of increased investment and employment stemming from oil development efforts, although again these effects tend to be short-lived.

Given California's tremendous oil and natural resources, the costs and benefits of increased oil development must be considered carefully. Given low crude prices, the financial incentives for increased development are not nearly as strong as they would be with higher prices. However, increased dependence on foreign oil creates a strong "public" incentive for increased development (at least on a national scale, if not within California). The critical question becomes where is increased development most appropriate, and where will it cause the least economic harm.

Regional Considerations

Within a nation as economically diverse and geographically large such as the U.S., it is not surprising and, indeed, possibly to be expected, that regional considerations will play substantive roles in resource development decisions. This comes about because the costs and benefits of resource development are generally not distributed uniformly over all parts of the economy, nor are the effects of economic variability induced by resource development. An understanding of the regionally differentiated pattern of costs and benefits is often necessary to fully assess the debate which usually accompanies resource development decisions.

It is easy to understand how regional asymmetries in the costs and benefits of petroleum development can arise. In broad terms, we may think of the benefits as generally being much less concentrated than the associated costs. Figure 5-23 summarizes some of the costs and benefits associated with petroleum resource development and shows qualitatively how one might think of these costs and benefits as distributed across different economic sectors.

	Local	Regional	National
Benefits			
Energy Needs:			
Increased Supplies	°	°	°
Energy "Security"	°	°	°
Defer Unattractive Sources	°	°	°
Employment & Investment:			
Direct	°	°	
Indirect	°	°	°
Government Revenues:			
Taxes & Royalties	°	°	°
Improved Trade Position			°
Costs			
Environmental:			
Industrial Development	°	°	
Pollution Risk	°	°	
Energy Needs:			
Reduced Future Production	°	°	°
Defer Conservation, Research	°	°	°

Note: " ° " denotes the sectoral levels across which the individual generally occur; the relative magnitude of the various impacts over different sectors is not indicated.

Figure 5 - 23: Conceptual distribution of development benefits and costs.

The most obvious benefits of petroleum resource development may be in serving energy needs, encouraging employment and investment, and increasing government revenues through royalties and taxes. Considering energy benefits, Figure 5-23 suggests that these may be realized in at least three areas: increased energy supplies, enhanced energy "security," and

deferral of the development of less attractive energy sources. Of these, the first component is the most straightforward. Oil resource development will presumably lead to greater domestic supplies, possibly leading in turn to a reduction in petroleum product prices.[214] If lower product prices are realized, then consumers will benefit at least on a local and regional level relative to where the products are marketed, and possibly on a national level as well. The geographic extent of the benefit naturally depends on the quantity of additional supplies achieved through the additional development. the development of ANS crude oil, for example, has influenced product supplies (and, possibly, prices) on a regional and national level.

Development of domestic resources also enhances perceived energy "security," usually on all geographic levels. The concept of energy security is defined differently in different contexts; the term is most often used to describe the extent to which the nation does not "rely" on foreign sources for its domestic energy needs. As with the impact of development on supplies and product prices, the benefits of enhanced energy security will be felt on a regional level and possibly on a national level, depending on the extent of the reduction of imported oil. Finally, domestic oil development may allow some degree of deferral in the implementation of certain societally unattractive technologies for meeting energy needs. This deferral may result in technological improvements in new energy supply sources which are ultimately utilized.

The second set of benefits comes in the area of employment and investment. The direct effects of employment and investment are obvious: petroleum resource development involves local employment of construction and production workers and often requires substantial local investment in fixed assets. Indirect effects may be less obvious and are dispersed over regional and even national areas. As increased production from petroleum resource development leads to increases in the total quantity of petroleum demanded, it may be expected that the refining, transportation and marketing sectors of the petroleum industry will also enjoy increased employment and investment. As Figure 5-17 [215] has shown, these "downstream" sectors have historically accounted for almost twice the number of jobs generated by the production sector. Because these jobs, particularly those in the marketing areas, are located geographically distant from production centers, the benefits of increased employment in these sectors become geographically dispersed.

The final set of benefits comes in the area of government receipts. Increased domestic production will result in greater payroll and income tax payments to both state and federal authorities, greater property tax payments to state and local authorities, and greater royalty payments to landowners, which are in many cases federal, state, or local governments. Obviously, the allocation of these benefits across national, regional, and local sectors will follow the pattern of resource development.

In terms of the costs of petroleum resource development, it is environmental costs—both

[214] Whether or not increased domestic supplies actually do lead to reduced prices for petroleum products depends on a number of factors, including the price and quantity demanded of foreign imports, and whether the petroleum industry would tend to pass through reduced crude oil prices in the form of reduced product prices.

[215] Figure 5-17 is found in the section titled "Costs and Benefits of 'Cheap' Oil."

direct and perceived—which cause the greatest concern. On the most visible level, petroleum resource development is often accompanied by industrial development of various kinds, ranging from construction of drilling rigs and/or offshore platforms, to pumping stations, tank farms and even refineries near some large development sites. While some of this development can be relatively unobtrusive, some cannot. All such development has some degree of impact on the environment. The extent to which such environmental impacts are adverse is a matter for analysis in assessing the development decision. Regardless of the ultimate magnitude of any potential adverse impacts, such impacts will be borne primarily locally, and perhaps regionally.

However, the environmental cost of greatest concern in development decisions is not that of physical development, but rather that of pollution risks. Such risks arise from at least two sources. First, there are risks of petroleum losses at the point of production or spills during transportation. While such events are fairly rare, their costs can be enormous, as recently demonstrated in the oil spill in Alaska's Prince William Sound. Such risks are generally localized at production points or areas surrounding transportation routes. Although the clean up costs of such events are usually borne by responsible parties or by insurers, the non-monetary costs (in economic terms, loss of utility), are generally borne by the locality and by entities not participating in the economy, including wildlife.

The second general source of pollution risks arise from increased local and regional crude oil processing and refining. This is characterized by catastrophic risks akin to those of production and transportation, and by daily risks of "normal" operations, including either airborne or wastewater emissions of pollutants. These risks and their associated costs are also borne or in the case of airborne emissions, regionally.

Other "costs" of increased petroleum resource development come in the area of energy needs. These costs are more subtle and somewhat harder to evaluate than environmental costs; nevertheless, they should be considered in making development decisions. One set of costs has to do with reduction of future consumption of petroleum caused by current development of petroleum reserves. Because crude oil is a finite, non-renewable resource, current consumption necessarily reduces opportunities for future consumption. This represents a cost not only in the sense that future consumers lose the opportunity to select a given amount of petroleum consumption as an energy supply option, but also in the sense that future uses of petroleum resources might be in higher value-added applications than current uses.

Another cost which current petroleum resource development imposes is that an increase in energy supplies may reduce incentives for conservation and/or development of alternative energy sources. Obviously, to the extent that conservation is reduced, costs similar to those described above are imposed on society as a whole; reduced activity in the development of new or alternative energy sources will ultimately delay benefits which could likewise be seen across all sectors.

As we have shown in the discussion above, while the overall balance of costs and benefits associated with any particular development decision may be a net benefit, the regional variation in costs and benefits may result in the regional or local net benefit being smaller than the overall net benefit, and may even result in

regional or local net costs. Going hand-in-hand with the differential distribution of costs and benefits across these sectors is a differential distribution of the dependence of the sectoral economy on the petroleum industry, and hence a differential volatility of the sectoral economy with respect to the petroleum industry. While greater economic volatility in a particular sector may be accompanied by average net benefits within that sector, the promotion of greater volatility may ultimately deter some development decisions.

Economic volatility in the local and regional economies of petroleum producing states is unquestioned. Gulf Coast and Mid-Continent states which enjoyed unprecedented economic growth during the oil price shocks of the 1970s were particularly hard-hit by the oil price declines experienced in 1986. For example, while national unemployment in 1986 averaged about 7%, the unemployment rates in Louisiana, Texas, and Oklahoma averaged 14%, 11%, and 9% respectively. Over time, the economies of these states (and/or more localized economies), can and no doubt will adjust to new sets of energy prices; the costs of that adjustment process, however, must be balanced against the benefits gained during more positive economic times.

CHAPTER SIX

THE ENERGY PICTURE

INTRODUCTION

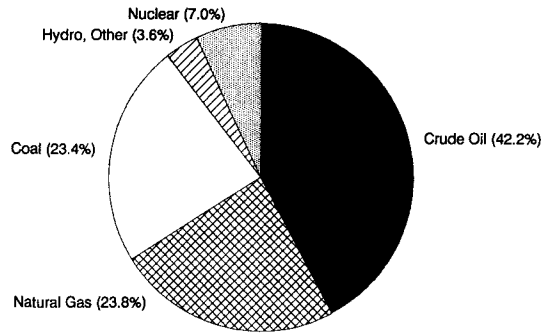
This chapter provides an overview of the role of energy in our economy and environment. We define the various sources of energy, the principal users of energy, the role of California as both a user and a provider of energy and the role that petroleum products play within the overall framework of our energy resources. We also consider our dependence on petroleum resources, the likely and available alternative sources of energy, and efforts underway to moderate the effects of a possible curtailment of oil supplies.

California's role as both an energy user and provider is important to understand when evaluating its offshore oil and gas projects. This chapter provides background information and data on California's role in the energy field.

CONSUMPTION

Principal sources of energy are crude oil, natural gas liquids (liquid fuels), dry natural gas, coal, hydropower and nuclear power. Crude oil (including natural gas liquids) accounts for about 40% of total world energy consumption or 127 quadrillion BTU.[216] Coal production contributes over 28% or 90 quadrillion BTU. Dry natural gas accounts for 20% or nearly 66 quadrillion BTU. Hydroelectric power accounts for nearly 7% of total energy consumption or 21 quadrillion BTU followed by nuclear electric power at slightly more than 5% or 17 quadrillion BTU.

Figure 6-1 indicates the consumption of energy by various energy types in the United States in 1989.



Source: EIA, Monthly Energy Review

Figure 6 - 1: U.S. energy consumption by fuel type, 1989.

Crude oil accounted for 42% of the total U.S. energy consumption, with coal and natural gas accounting for 23% and 24% of total energy consumption respectively. Nuclear electric power accounted for 7% and hydroelectric power accounted for 4% of total U.S. energy needs in 1988.

The pattern of energy consumption by energy source in California is illustrated in Figure 6-2.

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[216] A British Thermal Unit or BTU is an engineering unit for heat, or the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit. It is often used as a means of measuring and comparing the output of energy from various sources.

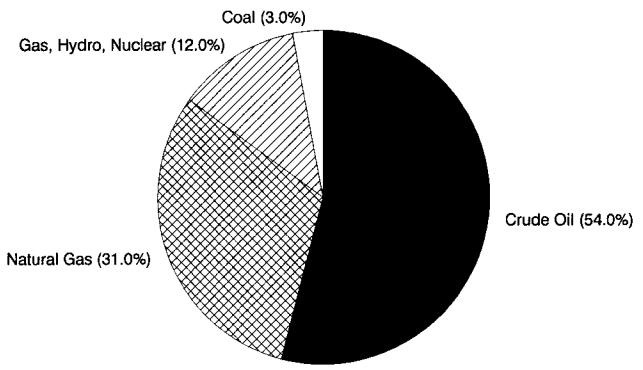

Figure 6 - 2: California energy consumption by fuel type, 1988.

Figure 6-2 indicates that crude oil plays a more important role in California than in other states, accounting for 54% of energy needs, with natural gas comprising 31% of the state's energy consumption. Hydroelectric, geothermal and nuclear power contribute 12% of the state's energy needs, and coal supplies a relatively small 3%.

Energy consumption steadily increased throughout the 1980s. The demand for energy in the U.S. grew at an annual rate of less than 0.5% throughout the 1980s, and is projected to grow at a similar rate during the 1990s. In contrast, California energy consumption increased at a rate of 3.5% in 1986, 4.6% in 1987 and 2.2% in 1988, a rate considerably more rapid than that for the nation as a whole.

OIL WITHIN THE ENERGY PICTURE

Since 1982, the nation's economic and population growth, combined with a decline in real energy prices, has led to increased oil consumption despite more efficient energy use. More oil products were consumed during 1988 than any previous year since 1980, with the demand hovering at about 17 million barrels per day (B/D).

Figure 6-3 provides data on the consumption of crude oil in California by source.

In recent years, Alaskan crude oil has taken on more importance as California supplies have decreased slightly. Foreign crude oil imports comprise a relatively small share of total inputs to California refineries, although forecasts over the next 20 years project that by 2009 imports will comprise over 30% of total crude oil consumption in California.[217]

The transportation sector has increased consumption of oil significantly. The greater efficiency of today's cars is more than offset by the greater number of cars, the greater distances and speeds they are going, and the increasingly important role played by trucks, which consume two of every five gallons of gasoline. Sixty three percent (63%) of oil consumed in the U.S. is used for transportation. Cars and trucks alone used up the equivalent of the entire daily production of the nation's oil fields last year (8.3 million barrels per day).

Gasoline

Gasoline is the largest portion of petroleum consumption and in the last few years U.S. demand for gasoline has again increased after a decline in the early 1980s, rising in 1988 to an all-time high of 128 billion gallons.

Figure 6-4 compares data on gasoline consumption in the U.S. and California.

[217] California Energy Commission, Fuels Report, December 1989.

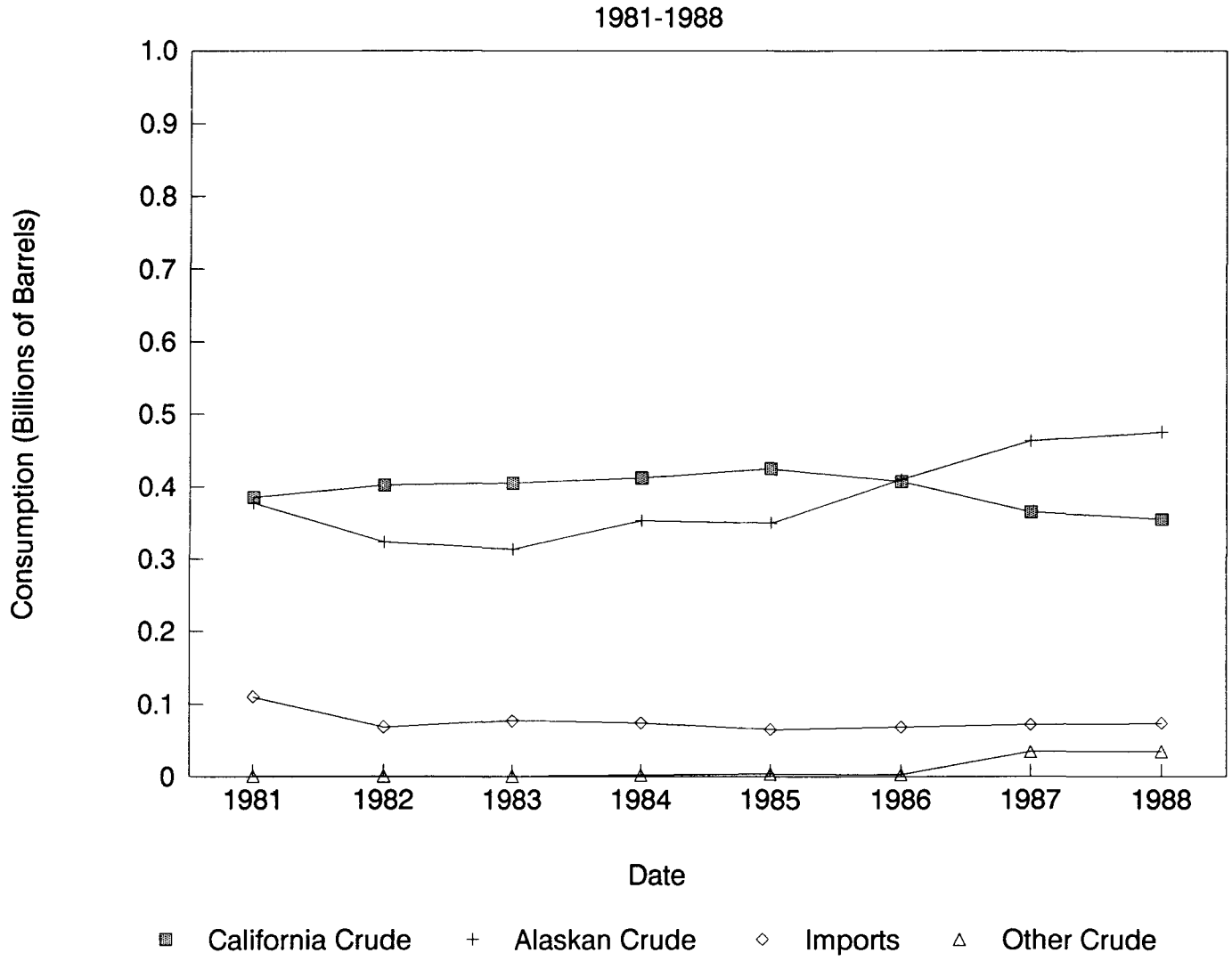

Figure 6 - 3: California crude oil consumption by source.

The increased rate of consumption in California has been greater than in the United States as a whole, especially in the last four years. According to the December 1989 Fuels Report, Appendix A, gasoline consumption in California increased 4.5% between 1986 and 1988 (from 12.23 to 12.79 million gallons) and total gasoline consumption is expected to continue to grow at an average annual rate of 1-2% per year. California consumes 10.1% of the gasoline used in the United States.

Natural Gas

Approximately 30% of the nation's and the state's total energy needs are met by natural gas. In California, 35% of the state's electricity generation needs are met by natural gas. Residential customers of natural gas use 24% of total available supplies, and industrial and commercial customers use 39% of total supplies.

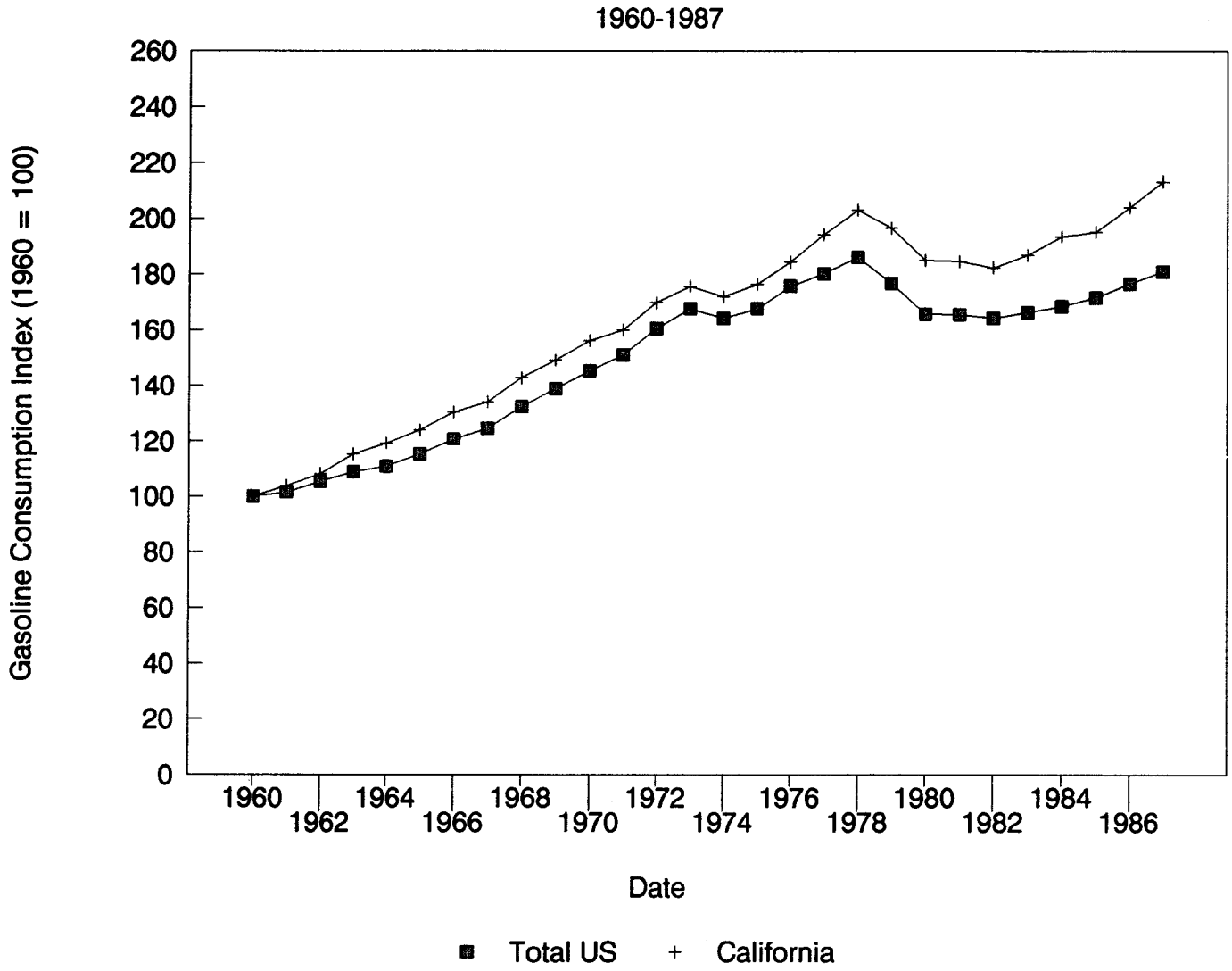

Figure 6 - 4: Motor gasoline consumption.

CALIFORNIA OIL USE BY SECTOR

Transportation

Figure 6-5 demonstrates the sources and uses of energy in California in 1987.

Transportation requirements represent 49% of total statewide energy consumption. This sector relies almost exclusively on petroleum products to fuel its needs. The California Energy Commission forecasts that gasoline demand will remain relatively flat over the next 20 years, but aviation fuel demand is expected to increase 26% and diesel fuel demand is forecast to increase 106%.[218] In 1989 motor gasoline comprised 55% of total transportation end user fuel consumption with aviation fuels,

[218] See California Energy Commission, Fuels Report, December 1989.

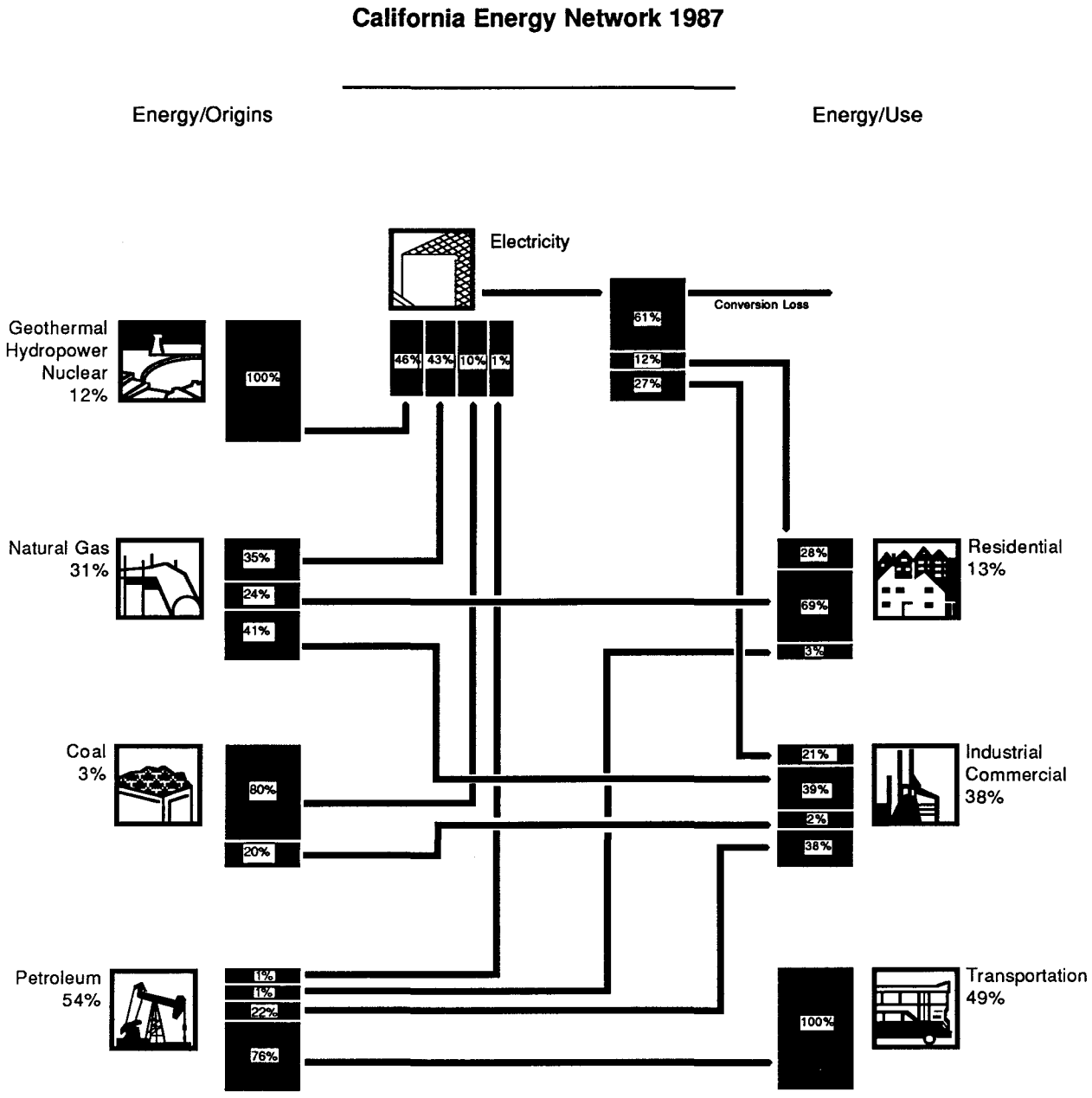

Figure 6 - 5: California energy network, 1987.

distillates and residual fuels accounting for the remaining 45%. Petroleum is expected to remain the primary source for transportation fuels in California in the future.

Electrical Generation

In 1988, California received about 75% of its electricity from power plants in the state and 15% from out of state sources in neighboring states. With natural gas prices at relatively low levels, 43% of the state's electricity was generated by use of natural gas and oil. The remaining 57% was generated by coal (10%) and nuclear, hydropower, geothermal and other sources (47%).

Industrial and Commercial

Industrial and commercial end users accounted for roughly 40% of the energy used in California in 1988. The primary energy sources for this sector of the economy included natural gas and petroleum products. Projections of energy demand indicate industrial and commercial energy users will increase their demand for energy by at least 2% per year over the next 10 years. Increased use of natural gas, electricity and petroleum products will be the primary sources of energy to fuel this growth in demand.

Residential Users

Residential users of energy consumed approximately 13% of California's energy supplies in 1988. These users relied primarily on electricity and natural gas. Residential electricity demand is forecast to increase 44% over the next 20 years.

WORLD ENERGY PRODUCTION

World energy production must continually increase to meet the demands of energy consumers. In a thirteen year period, from 1974 through 1987, energy production increased approximately 29%, or 2.2% per year. The total world energy produced in 1987 was an astounding 321 quadrillion BTU. This was the largest amount of energy ever produced in a given year. Forecasts for the period through the year 2000 indicate that world energy consumption will continue to increase at an annual rate of approximately 2%.

Figure 6-6 shows that the world's primary energy sources were crude oil and natural gas liquids.

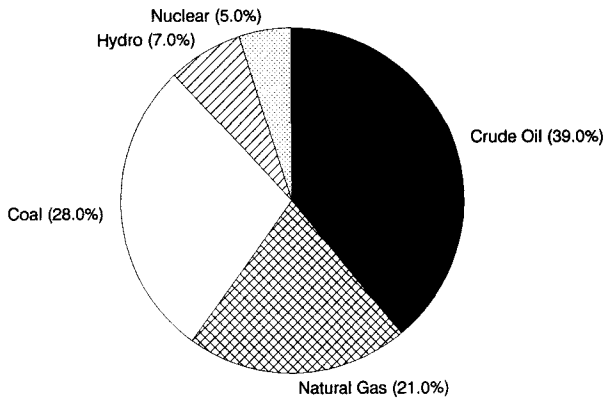

Figure 6 - 6: Worldwide energy production by fuel type, 1987.

Other energy sources included: coal (28%), dry natural gas (21%), hydroelectric power (7%), and nuclear electric power (5%). Geothermal power did produce 16.2 billion BTU worldwide which represented less than one-half of one percent of the world's energy production. Of interest is the fact that the United States accounted for 42% of the total geothermal energy produced.

Between 1977 and 1987 all energy sources, except for crude oil, registered an increase in output. During this period crude oil registered a 4% decline in production due to the decline in crude oil production by the Organization of

Petroleum Exporting Countries (OPEC). This group was attempting to regain control of world oil markets by means of an agreement on output levels. While not completely successful, this accord resulted in a reduction of OPEC crude oil production from 31 million barrels per day to 18 million barrels per day.

During the same period, nuclear electric power registered the greatest percentage increase by any energy source. In 1977 nuclear power produced by non-communist countries equaled 472 billion gross kilowatthours. By 1987, that figure had jumped to 1,591 billion gross kilowatthours, an increase of 237%. This increase in the generation of nuclear energy occurred primarily in France, Japan and West Germany. In 1987 these countries accounted for 593 billion gross kilowatthours of nuclear electric power.

The greatest increase in BTU output for 1977-1987 was achieved by coal. Coal production increased from 3,834 million short tons to 5,071 million short tons, resulting in a net BTU gain for 1987 of 21.8%. The most dramatic increases in coal production occurred in countries where formerly marginal coal deposits emerged as viable alternatives to higher priced liquid fuels, including China, the United States, South Africa, Australia and India.

Out of the 34 countries listed as primary energy producers, only six are responsible for producing the majority of the world's energy. Figure 6-7 indicates the shares of total energy production accounted for by these countries.

The U.S.S.R. and the United States account for over 40% of the world's production of energy. Together these six countries account for 59% of the world's energy production.

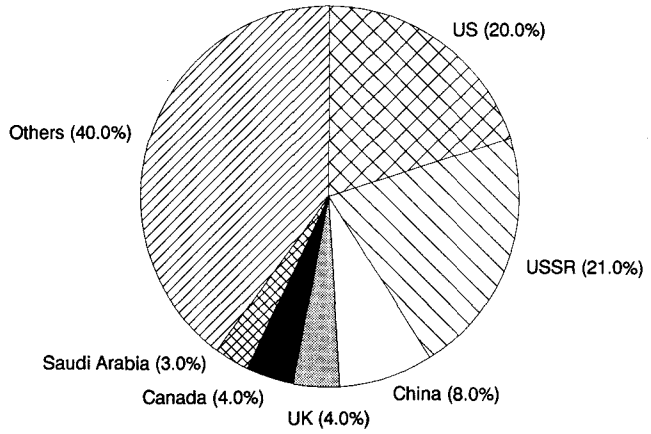

Figure 6 - 7: Primary producers of energy, 1987.

World Oil Production

As discussed earlier, crude oil and natural gas liquids provided 39% of the world's energy production for 1987. World production of crude oil and natural gas liquids totaled over 60 million barrels per day in 1987, two million barrels below the 1977 daily production rate and significantly below the 1979 peak production level of 66 million barrels per day.

Figure 6-8 illustrates the pattern of crude oil production by region between 1970 and 1987.

All regions except Africa and the Middle East showed increases in crude oil and natural gas liquids production. In 1987 alone, these five regions accounted for eight million barrels of additional production per day over 1977. In the Middle East and Africa, production declines reflected reduced production from OPEC members. By 1987, the two regions had experienced a net loss of 10 million barrels per day from 1978, thereby overshadowing the increased production from other regions. The largest producers of crude oil in 1987 were the U.S.S.R., the United States, and Saudi Arabia. These countries together contributed more than 43% of the world's crude oil production.

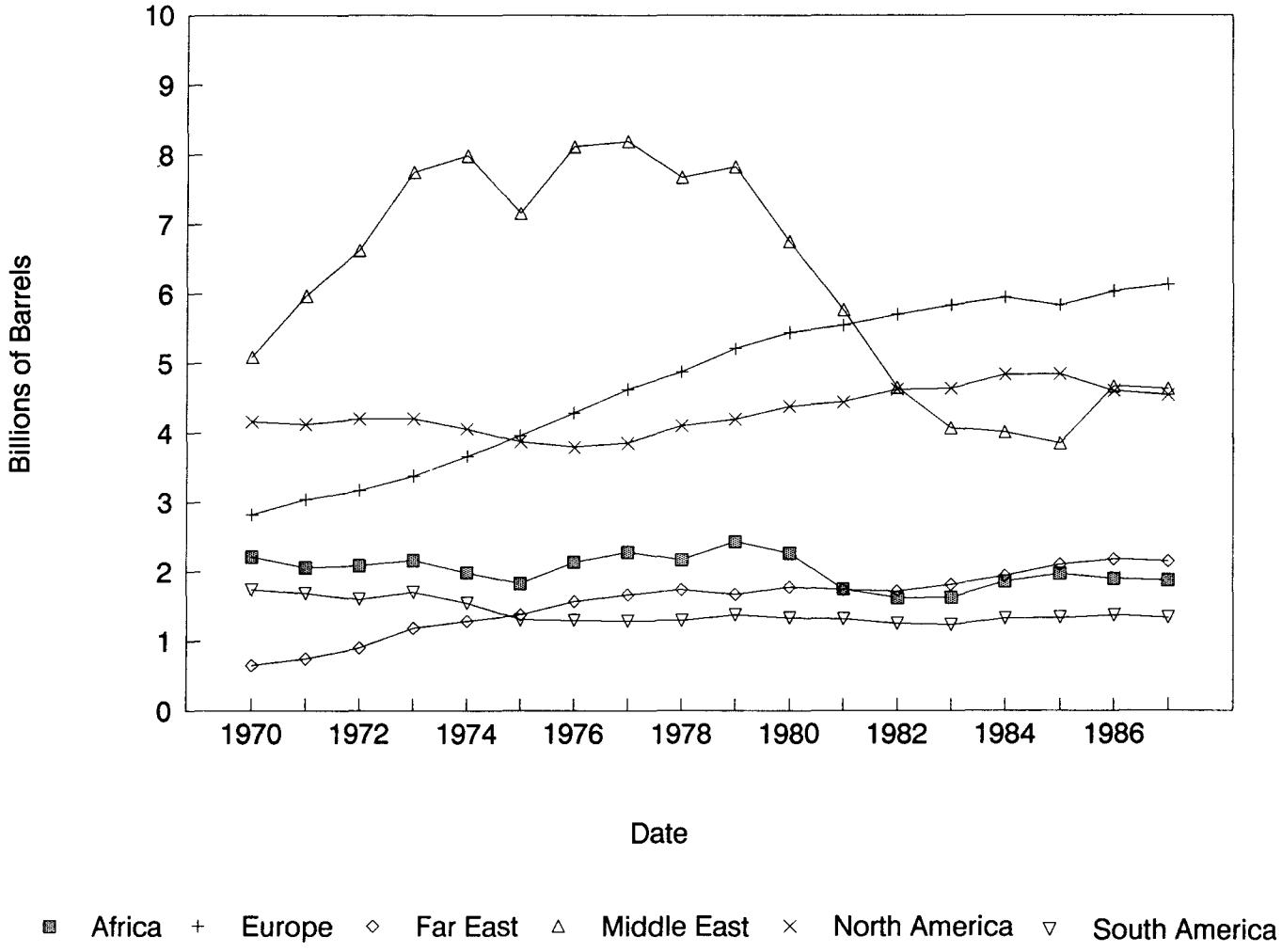

Figure 6 - 8: World crude oil production, 1970-1987.

World production of natural gas liquids increased from 3.1 million barrels per day in 1977 to 4.5 million barrels per day in 1987. The United States was the leading producer in 1987 with 1.6 million barrels per day, followed by the U.S.S.R., and Canada. Other significant producers of natural gas liquids were Saudi Arabia and Mexico.

Oil Production in the United States

In 1978 crude oil production in the United States totaled 8.7 million barrels per day. In contrast, by 1988 U.S. production had declined to 8.1 million barrels per day, a decrease of 6.9%. Most of the decline in crude oil production occurred between 1986 and 1987, when crude oil prices collapsed. The collapse in crude oil prices was primarily due to the disintegration of the "reduced production accord" by OPEC members. With the disintegration of the accord as well as refusals by non-OPEC members to price in accord with benchmarks set by OPEC, members of OPEC

attempted to increase production thereby reducing the world price of oil.[219]

In the United States, stripper wells (defined as wells producing 10 barrels per day or less) were hardest hit by the lower price of crude oil. Higher prices were considered necessary to offset operating expenses of each well, consequently, states such as Texas, Oklahoma, and Louisiana experienced large drops in oil production because a substantial portion of their production came from stripper leases.

In 1978, over three-fourths of the crude oil produced in the United States came from four states: Texas (34%), Louisiana (17%), Alaska (14%), and California (11%). By 1987, the same four states contributed 77% of the total U.S. crude oil production. Texas was still the leading contributor with 25% or 2.13 million barrels per day; Alaska, 23% or 1.96 million barrels per day; Louisiana, 16% or 1.33 million barrels per day; and California, 13% or 1.08 million barrels per day. The fields leading in production for each of those states were East Texas—Texas, Prudhoe Bay—Alaska, Mississippi Canyon Block 194—Louisiana, and South Belridge—California. Alaska was the only state to experience an increase in oil production between 1985 and 1987.

Figure 6-9 presents a comparison of crude oil production in the United States vs. California from 1969 through 1986.

This graph illustrates that production in California has remained relatively constant, whereas overall U.S. production peaked in the early seventies and has dropped significantly since that period. In particular, domestic production has been declining since the oil price collapse of 1986, and is expected to continue a downward trend through the end of the century. According to the Energy Information Administration, Annual Energy Outlook 1989:

> Total crude oil production is projected to fall from 8.2 million barrels per day in 1988 to 5.9 million barrels per day in 2000, an annual decline rate of 2.7%.

The biggest declines are expected from onshore producing regions of the lower 48 states, while production from offshore regions is expected to remain relatively steady.

Given the projection of higher petroleum demand and declining domestic production, it is concluded that higher petroleum imports in the future are inevitable. Furthermore, the Energy Information Administration concludes:

> In this year's outlook, net petroleum imports of crude oil and refined products (i.e., imports minus exports) are forecast to increase from 6.3 million barrels per day in 1988 to 10.2 million barrels per day in 2000.

California Oil Production

During 1988, California's crude oil production declined for the third year in a row. Production totaled 386.9 million barrels in 1988, compared with 397.0 million barrels in 1987, and 407.3 million barrels in 1986. The primary reason for this decline is continuing instability in crude oil prices coupled with a general depletion of aging reserves as well as government regulation. Low prices for oil, along with reduced production per well and government restrictions on new exploration, have resulted in uneconomical operations in

[219] See the discussion in Chapter V regarding the impacts of changes in crude oil production on crude oil prices.

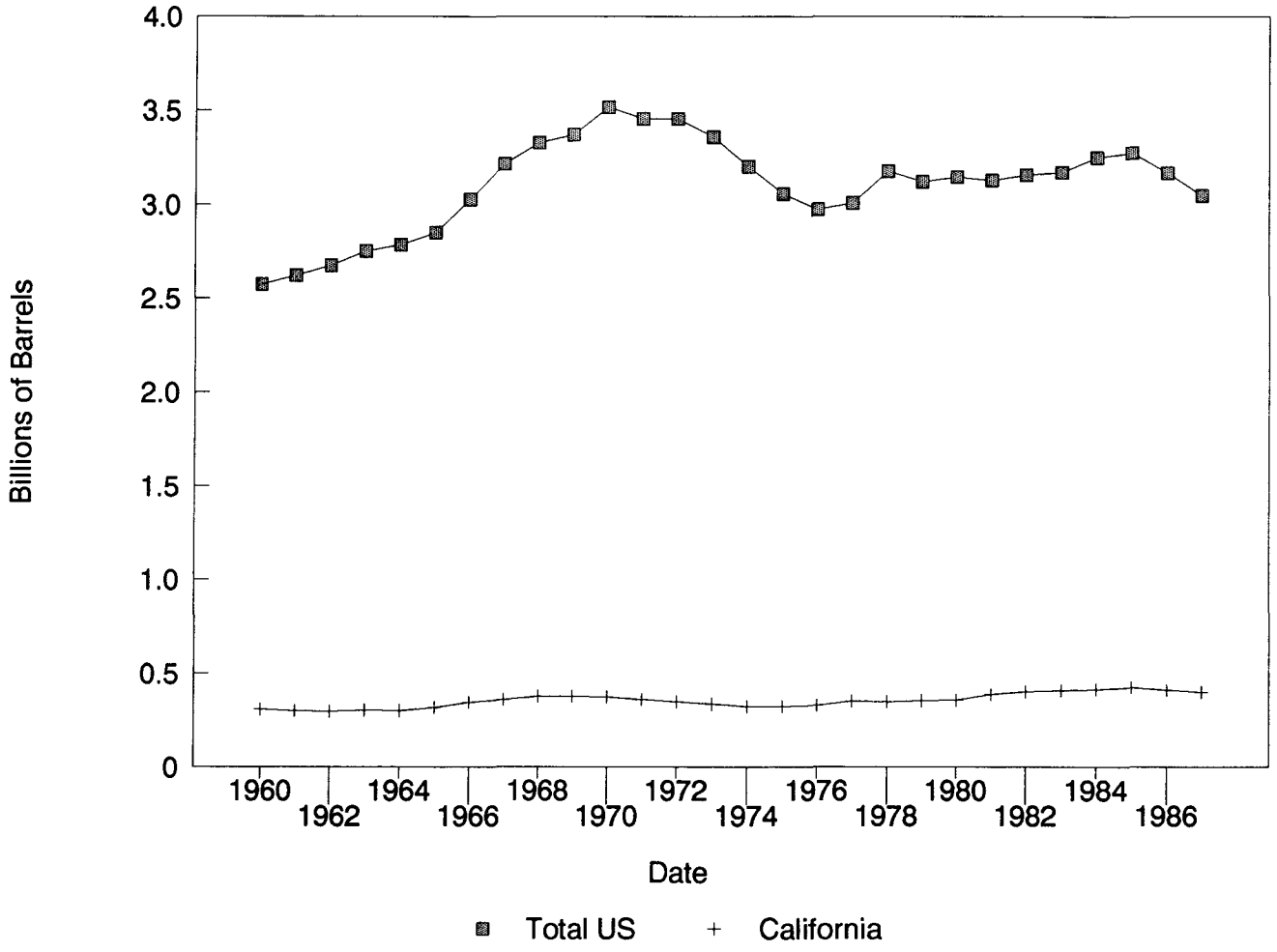

Figure 6 - 9: Crude oil production, 1960-1987.

many areas of the state, the shut-in of many wells and reduction in exploration of new areas.

In 1988 326.4 million barrels of oil were produced from inland fields (down from 330.5 million barrels in 1987) and 60.4 million barrels were produced from offshore fields (down from 62.5 million barrels in 1987). Production from federal offshore fields (31.4 million barrels) remained about the same as 1987, while production from state offshore (tideland) leases dropped 1.4 million barrels to 28.9 million barrels.

Significant increases in production in 1988 were recorded at several federal outer continental shelf (OCS) fields, including Point Pedernales which experienced a 30.7% increase in production. In addition, continued development efforts in several onshore fields in the San Joaquin Valley area contributed to increased production in the Kern River (3.0% increase), Belridge North (46.4% increase), and Cymric (8.7% increase) fields. The largest decline in production was experienced in the Belridge South field, the Wilmington field and Elk Hills Naval Petroleum Reserve.

Offshore in 1988, 46% of the oil produced off California's coastline was produced from four state tideland leases. The four leases were: Wilmington, Huntington Beach, South Elwood, and Carpinteria. Wilmington produced 20.8 million barrels in 1988, while Huntington Beach produced 3.6 million. South Elwood and Carpinteria produced 2.6 and 0.7 million barrels respectively.

Although the tidelands continue to provide a substantial portion of California's offshore oil, they decline at an alarming rate. The Wilmington field alone registered a loss in production of 3.9 million barrels between 1986 and 1988. In addition, the Huntington Beach field registered a loss of 1.4 million barrels, and the remaining tideland leases accounted for 0.3 million barrels in production losses between 1986 and 1988.

Offshore production increases during 1988 occurred at the Point Pedernales, Hondo, and the new Sockeye fields in federal waters. Production increased by over one million barrels in the Point Pedernales field and by 0.3 million barrels in the Hondo field. The Sockeye field came on line in 1988 and produced a total of 0.2 million barrels during the year.

In January 1989, California's oil was produced from 243 fields at a rate of 1.002 million barrels per day, compared with 1.077 million barrels per day at the end of 1988 and 1.182 million barrels per day in 1985. There were 43,467 producing wells at the end of 1988, a decrease of over 3,000 wells from 1987 (this includes wells produced in federal waters offshore California).

Reserves

Reserves measure the quantity of crude oil that it has been estimated can be produced in the future. Those reserves which are already discovered and can be produced economically with existing technologies are labeled "proven reserves." Undiscovered or potential reserves include: (1) deposits that may contain petroleum resources; or (2) deposits which might be economically exploitable by using improved technology.

It is estimated that there is in excess of 900 billion barrels of proven oil reserves throughout the world.[220] Various sources estimate that potential or probable reserves could include another 500 to 600 billion barrels. Figure 6-10 indicates that the vast majority (75%) of these remaining petroleum resources reside in the OPEC producing countries. Saudi Arabia alone accounts for 25% of the world's known crude oil reserves.

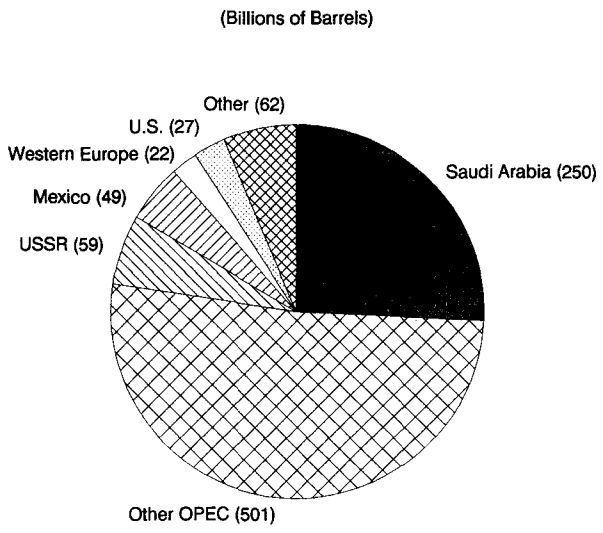

Figure 6 - 10: 1988 world oil reserves of major producers.

[220] See Energy Information Administration, "International Energy Outlook," 1990.

In the United States, recent estimates place known crude oil reserves at 27.3 billion barrels or approximately 5% of total known reserves. Three states account for over three-fourths of those reserves. These states include: Texas (7.2 billion barrels), Alaska (7.4 billion barrels), and California (5.8 billion barrels). California's proven reserves of 5.8 billion barrels represents 21% of the nation's total proven crude oil reserves.

Potential or probable reserves in the United States are estimated to range from a low of 20 billion barrels to as high as 50 billion barrels depending upon assumptions regarding future energy prices, technology, and geologic factors. In California, probable reserves have been estimated to range from three billion barrels to 10 billion barrels.

Figure 6-11 presents data on proven and probable reserves for both oil and gas in California by region. Both onshore and offshore regions are included.

Region	Proven Oil Reserves	Probable Oil Reserves	Proven Gas Reserves	Probable Gas Reserves
	(Billion bbls)		(Trillions of Cubic Feet)	
Onshore				
San Joaquin Valley	3.208	1.07	NA	NA
Coastal	.625	.298	NA	NA
L. A. Basin	.361	.105	NA	NA
Offshore				
Northern Coastal	0	.130	0	1.61
Central Coastal	0	1.55	0	1.93
Santa Maria Basin	.634	.790	1.338	.690
Santa Barbara/Ventura	1.69	.370	1.717	.950
L. A. Basin	.180	.320	.107	.450
Inner Basins and Banks	0	.450	0	.780
Outer Basins and Banks	0	.330	0	1.55

Figure 6 - 11: Proven and probable reserves in California by region.

As can be seen, the bulk of proven reserves are in the onshore San Joaquin Valley area. Probable reserves are more evenly distributed throughout the state, but of course, their eventual availability depend upon a number of assumptions regarding economic and technological feasibility.

GLOBAL WARMING

Concern about global warming and the "greenhouse effect" has been rising steadily in recent years among individuals and elected officials within California, the nation and throughout the world. But, while there is public conern about this important issue, there are also serious scientific questions about what causes global warming, the degree of impact it might have on the ecosystems on our and if the "greenhouse effect" is even happening at all.

The Swedish chemist Svante Arrhenius coined the term "greenhouse effect" at the turn of the century. He observed that the water vapor and carbon dioxide found naturally in the earth's atmosphere allow sunlight to penetrate but retain outgoing infrared radiation, in a manner somewhat similar to the glass panels of a greenhouse. Arrhenius estimated then that if the combustion of fossil fuels were to result in a doubling of atmospheric carbon dioxide levels, global temperatures might rise by 5° C.

And what if the temperatures around the globe rose that much, what then? Most of the consequences of global warming would result from one of three physical changes: sea level rise, higher local temperatures, or changes in rainfall patterns. Some scientists estimate that sea level could rise 30 to 200 centimeters in the next century (Dean et. al. 1987). A median rise of one meter (100 cm) could put an area the size of Massachusetts under water in the United States, almost 7,000 square miles. Beaches could be set back 100 to 200 meters, while

aquifers near the coasts would become increasingly saline (Titus 1989). Climatologists generally expect important seasonal and geographic variation in precipitation and temperature changes. The warming, for example, is likely to be greatest in winter and at higher latitudes. But no one can predict how the climate of a particular region will change. There is a general expectation of wetter winters and dryer summers in mid-latitude continental areas (Manabe and Wetherald 1986). The growing areas for many crops could shift northward, while deserts would expand. Higher temperatures would increase evaporation, so demands for irrigation water would increase. Snow packs would melt several weeks earlier, so there would be less water for California's Central Valley (Lettenmaier et. al. 1989).

CAUSES OF GLOBAL WARMING

While there is disagreement over some of the causes of overall global warming, the major influences remain those discovered by Arrhenius 90 years ago; carbon dioxide (CO2) and water vapor.

The most important greenhouse gas is carbon dioxide. It is produced when fossil fuels (coal, oil, gas) or wood is burned. In the developed countries fossil fuels are used for transportation, heat and the generation of electricity. The average American is responsible for the emission of 55,000 pounds of carbon dioxide and its equivalent in other greenhouse gases every year, mainly through the use of energy (DeCicco et. al. 1990). It totals some six billion tons annually in the United States, more than 20% of the world's total, even though we have just 5% of the world's population.

Industry generates 35% of the greenhouse gases in the United States each year. Transportation is next, with 33%; followed by residential—(18%) and commercial—(14%). When individual contributions are analyzed, use of the private automobile is the greatest offender, responsible for 14.6% of all greenhouse gases, while residential appliances, lighting and space heating account for 14%. Clearly, these are areas where conservation by individuals will make all the difference in the world. (Figures 6-12 and 6-13)

Water vapor is the next most important component of the greenhouse mixture, but no one yet has a handle on what, if anything, Man has done to change the balance of water vapor in the atmosphere.

Another source of "greenhouse" activity is synthetic chemical compounds known as halocarbons, the best known of which are the chloroflourocarbons, or CFC's. In the atmosphere, they produce the same result as 1.4 billion tons of carbon dioxide per year (EIA 1986). This puts these gases just below the Transportation sector in terms of importance. Twenty-four percent of the CFC emissions come from mobile air conditioners. Solvent cleaning produces another 16%, foam plastic insulation another 16%, all stationary air conditioners (home and commercial) only 4% and all other sources, 40%.

Methane and nitrous oxide are also gases that many scientists believe have a "greenhouse effect." But since their effects are unclear, as are the total yearly amounts produced, they are usually not included in analyses of the problem. Landfills and rice production are primary sources of methane, while transportation is the major source of nitrous oxide.

MAGNITUDE OF THE TEMPERATURE RISE

Just how much has the average global temperature increased? The typical answer is

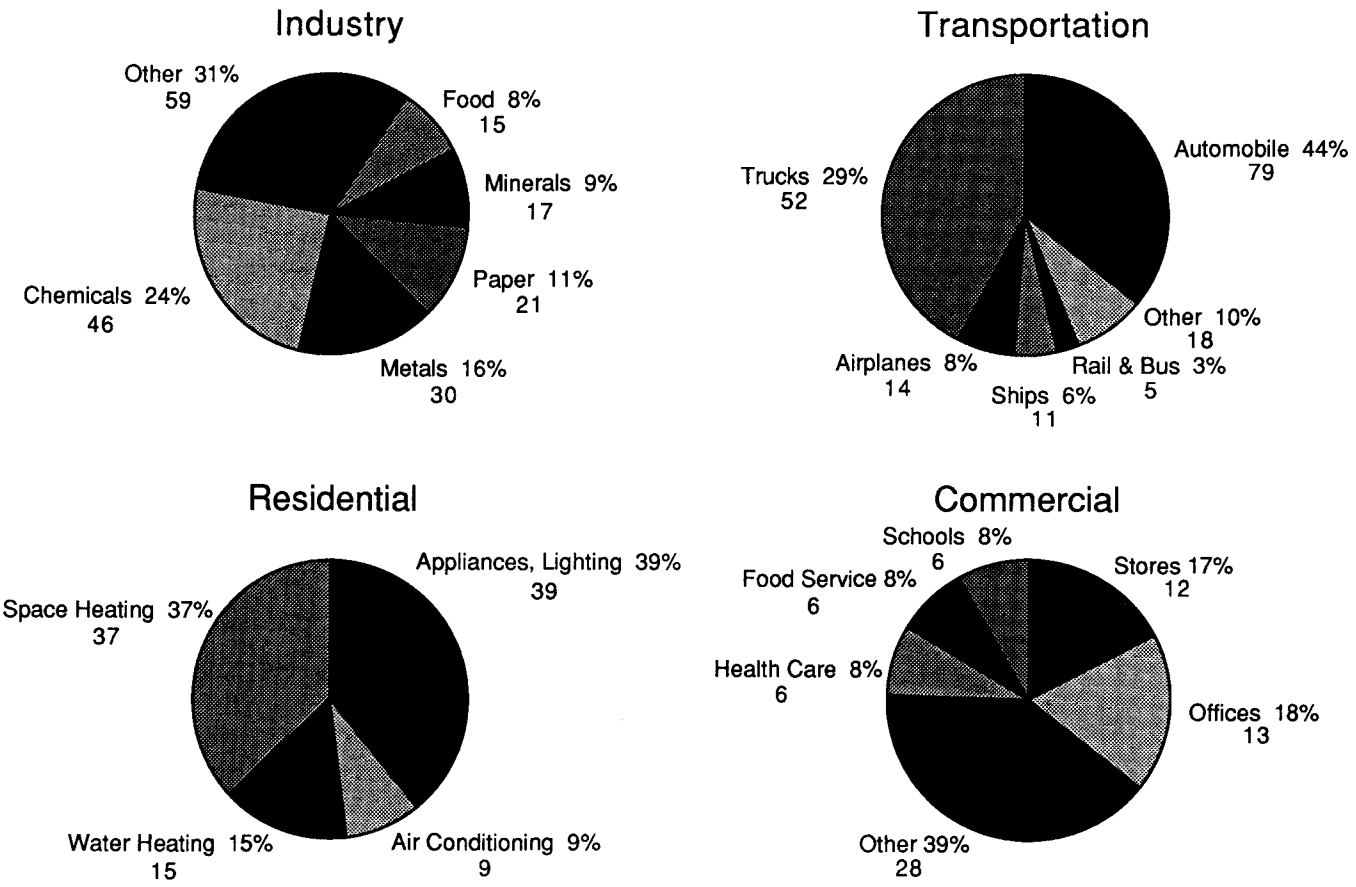

Figure 6 - 12: Percentage of greenhouse gases generated in the U.S.

0.5° C. But the answer depends on what time interval is chosen. There was a substantial temperature increase from 1880 to 1940. However, from 1940 until the 1960's, the temperatures dropped fostering predictions of a coming ice age (Spencer and Christy 1990). New precise data from satellite observations raise further questions about warming. From 1979 to 1988 large temperature variabilities were recorded on weekly to multiyearly time scales, but no obvious temperature trend was noted during the 10-year period (Abelson 1990).

Much of the work on global warming in recent years has been the result of computer modeling. At least 14 different groups are conducting large scale models of global climate at the current time. They are largely concentrating on the effect of doubling the amount of greenhouse gases in the atmosphere. As might be expected, the results vary. The range of temperature increases resulting from these models is from 1.5° to 5.0° C. The one thing that all researchers agree on is that the models are deficient. For example, they do not adequately address the issue of clouds. Clouds can have both positive and negative effects on warming; they can reflect light from the sun

back into space, cooling the earth, or they can trap radiated heat from the earth, raising the temperature (Mitchell et. al. 1989).

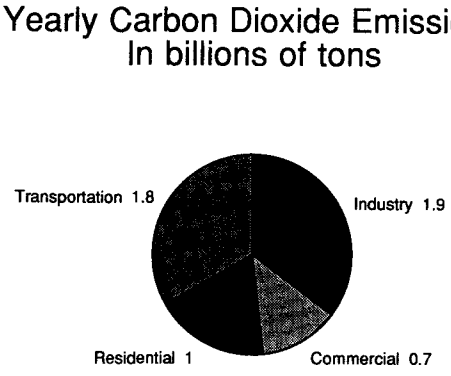

Figure 6 - 13: Yearly carbon dioxide emissions in billions of tons.

It is fashionable to say that the doubling of atmospheric carbon dioxide will occur by the middle of the next century. But past predictions of energy usage have been wildly inaccurate. At the current rate of emissions, the doubling time would be on the order of 200 years (Abelson 1990). For a doubling to occur by 2050 there would have to be a very large exponential increase in usage and emissions.

REDUCTION OF GREENHOUSE GASES

It is clear from the statistics above that responsibility for reducing greenhouse gases is in the hands of many individuals. While industry does produce much of the CO_2 that gets into the atmosphere, a far larger percentage comes from private automobiles and homes. The expansion of mass transit and the abandonment of the one-person commute will do more to reduce the emission of greenhouse gases than any other step.

Actions that can be taken by governments to aid in the reduction of greenhouse emissions require that politicians make hard choices. Electric power generation is a major producer of greenhouse gases at the present time, and nuclear power generation would completely eliminate this source; but it is unlikely that such a choice will be made in the near future. Other alternate forms of energy production could also reduce emissions, but they require funding that industry is not ready to make, and that government doesn't have. Draconian controls on commuting, or wood-burning stoves seem out of line at the present. So does outright bans on all plastic foams, halocarbons or agricultural burning. Any such action would reduce the volume of greenhouse gases that enter the atmosphere each year by a significant amount, if that becomes a statewide or national goal.

If active intervention by government in the production of greenhouse gases is not feasible, then it becomes necessary to consider what sort of planning activities should be done to deal with the possibilities of climatic change. If it is agreed that the current course will lead to a significant temperature rise, leading to a rise in sea level, then it is incumbent on governmental leaders to restrict coastal uses or plan for the protection of the entire California coastline. Changes in the crops grown in California will be necessary because of higher temperatures for longer periods of time, and diminished water supplies. Water is already in short supply in California; if the predictions of some scientists come true there will be no possible way to provide enough water for growth, agriculture and recreation in California. In fact, there will not be enough water for the present population, present crops or present wildlife requirements.

CALIFORNIA PETROLEUM

SOURCES OF REFINED PRODUCTS USED IN CALIFORNIA

Crude oil produced in California is used in refineries and petrochemical plants to produce refined products. The most important refined products produced in California include motor gasoline, jet and aviation fuels, diesel fuels, heating oil, asphalt, and bunker fuel oil.

Crude oil fields are located in different sections of the state, whereas refineries and petrochemical plants are most often located near population centers where refined products are consumed. As a result, much of California's crude oil must be transported considerable distances to reach its destination. Figure 6-14 indicates the location of the major crude oil and natural gas fields in California.

As can be seen, the most significant groupings of crude oil fields are located in the San Joaquin Valley-Bakersfield area, the Coastal zones near Santa Barbara-Ventura, and in the Los Angeles Basin. In 1988, crude oil produced in the San Joaquin Valley area accounted for 68% of total California production, with Coastal production representing 15% and L.A. Basin production comprising 17%. As Figure 6-14 also indicates many gas fields are located in Northern California in the Sacramento Valley.

Crude oils may vary in quality; common measures of quality are "gravity," which measures the weight of the oil, and sulfur content. As discussed below, both factors are important in terms of their effect on the ability of refineries to convert different quality crude oils into refined products.

API gravity is a standard measurement used in the petroleum industry which measures gravity in "degrees API." The lower the gravity of the oil, the "heavier" or more viscous it is. Lighter crude oils (commonly measured as 20° API or higher) are less thick or viscous. Crude oil fields in California contain significant quantities of both heavy and light crude oils. In 1988, approximately 70% of the crude oil produced in the state was classified as "heavy" crude oil (20° API or lower).

From the time crude oil leaves the ground until it reaches the consumer, it can be moved via pipelines, tank trucks, railroad tank cars, barges and ocean tankers. Crude oil is passed from the wellhead into field storage tanks through a pipeline about two inches in diameter and then on to trunk lines which move the crude to refining centers. In California, these pipelines have diameters up to 36 inches. Pumps are used to move the oil through the pipelines with pumping stations placed at intervals along the pipeline route. Some pipelines are heated to assist in moving of particularly "heavy" or viscous crude oil.

Figure 6-15 illustrates the location of major pipelines in California which transport crude oil to refining centers.

A unique feature of crude oil pipelines in California is their proprietary status. Unlike most pipelines in the country, crude oil pipelines in California are privately owned and operated by the major oil companies for their own use. In other parts of the country, pipelines are regulated as common carriers and must provide transportation service to any shipper desiring transportation at a fair and reasonable rate. As discussed in Chapter Five, this feature of the California petroleum marketplace has had a very detrimental effect

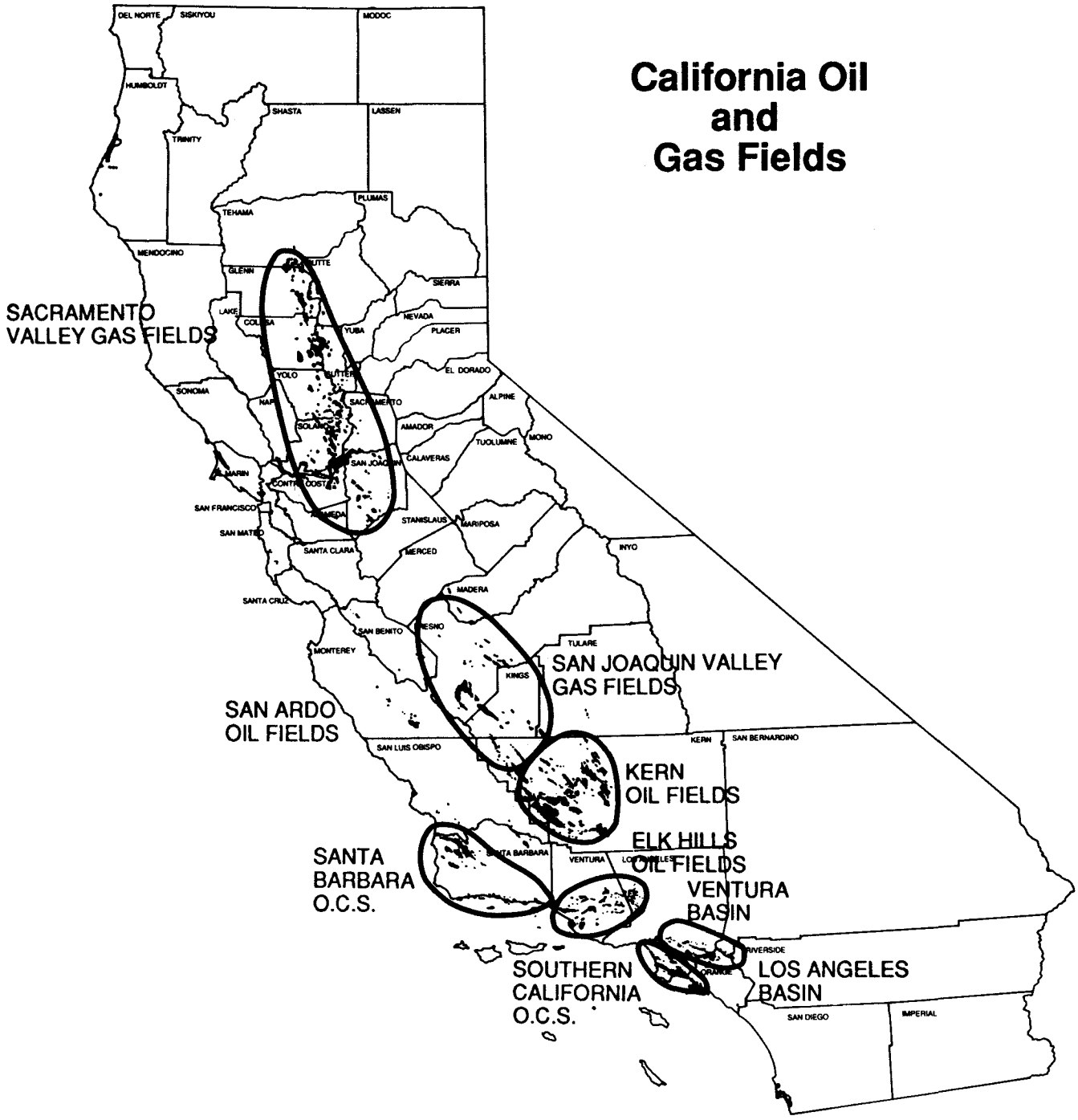

Figure 6 - 14.
Source: California Division of Oil & Gas, 1988.

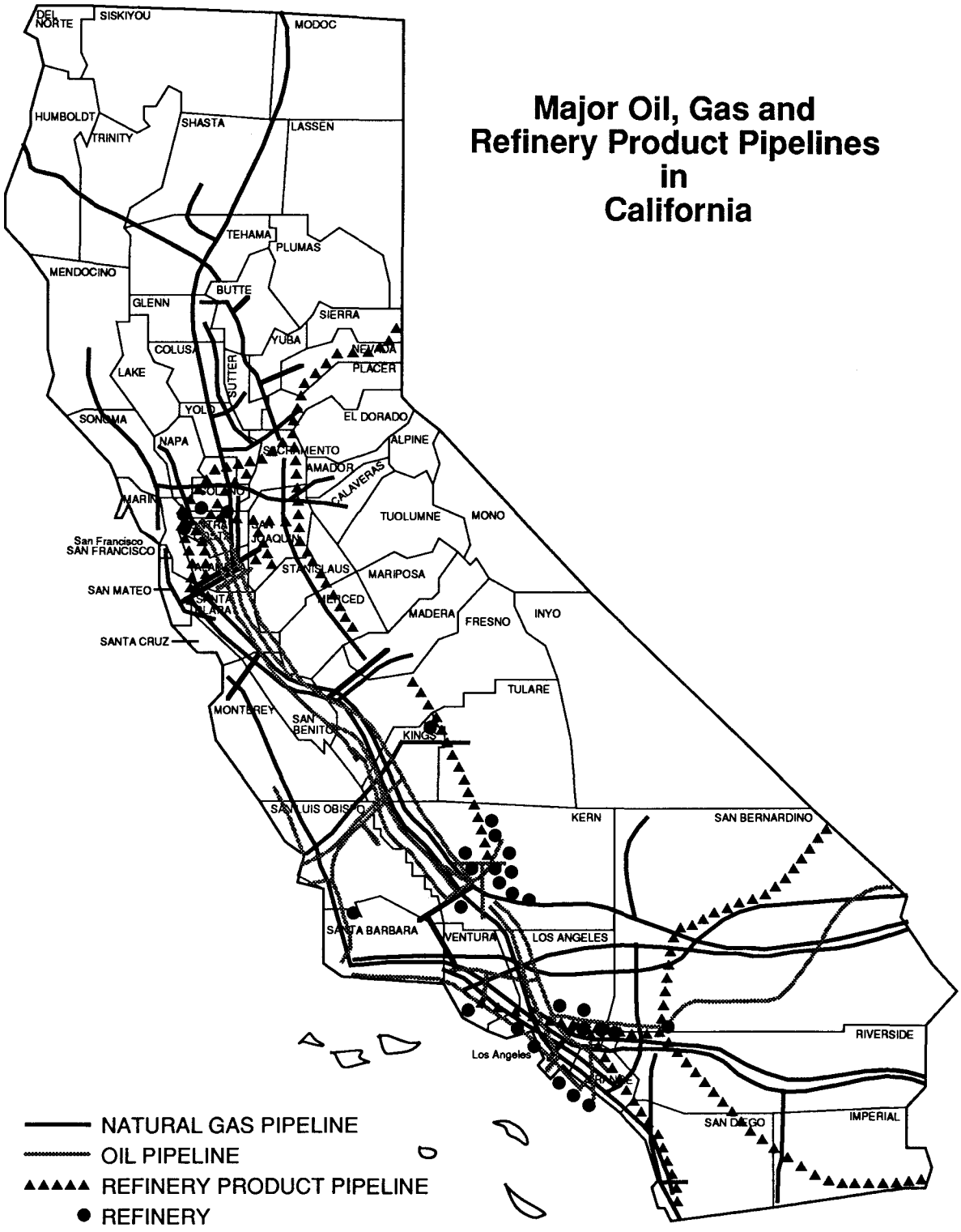

Figure 6 - 15.

Source: California Division of Oil & Gas, 1988.

on the ability of independent producers and refiners to compete with the major companies.

Crude oil is also transported by tank trucks and unit trains. Tankers and barges transport crude oils from offshore areas or marine terminals to refining centers.

In California, natural gas is transported entirely through pipelines. Some reservoirs contain only gas, called nonassociated gas. When nonassociated gas is produced, it is dehydrated and routed directly from the wells into a utility company's collecting pipeline. When gas occurs with crude oil, it is called associated gas. When associated gas is produced, the oil-gas mixture is routed through a separator, or trap, which separates the gas from the oil. From the trap, the gas flows through a pipeline to a gas plant where other liquid hydrocarbons are removed.

The gas then flows from the gas plant to the utility company facilities. Here, chemicals called mercaptans are added to natural gas to provide it with an odor for safety reasons, natural gas generally has no odor. Then the gas is sold.

To meet peak demands during winter months, utility companies use depleted oil and gas reservoirs to store large volumes of natural gas. Gas is pumped into the reservoirs during the summer when demand for natural gas is low. When the demand increases during the winter, the gas is withdrawn as needed.

At the end of the pipeline, crude oil is moved into refineries or petrochemical plants where it is stored prior to processing into marketable products. Feedstocks from refineries or natural gas processing plants are delivered to petrochemical plants for production of various petroleum-based chemicals and products.

Refineries in the United States tend to be located near crude oil production facilities or population centers. Petrochemical plants are generally located near refineries, often within the same overall facility. In California, refining capacity is mainly located in the populated areas of the San Francisco and Los Angeles regions, and the oil producing portions of the San Joaquin Valley.

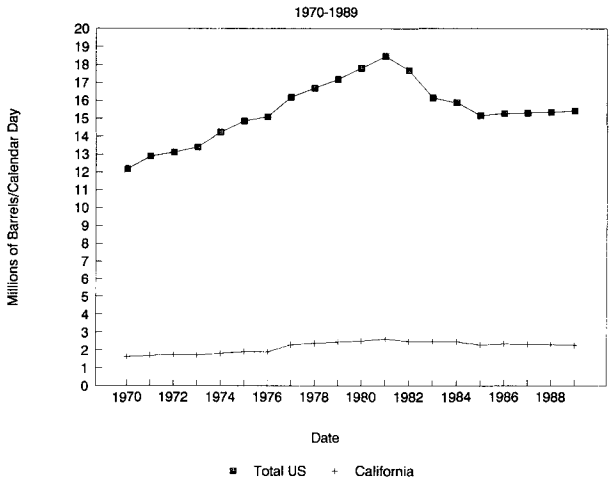

Figure 6 - 16: Refinery capacity.

Figure 6-16 presents data on total refining capacity in the U.S. and California.

Total U.S. refining capacity has decreased significantly in recent years, due in part to the demise of many independent refiners and also as a result of a general worldwide surplus in refining capacity. This recent decrease in refining capacity in the U.S. has implications for our ability to meet refined product demand in the future as demand for gasoline and heavy fuels increases.[221] Refining capacity in

[221] Forbes, September 3, 1990, p. 36.

California has remained relatively constant, experiencing a slight decline since 1982, due primarily to the exit of several independent refiners.

REFINERIES AND PETROCHEMICAL PLANTS

A refinery is a vast network of towers, furnaces, reactors, pumps, compressors, heat exchangers and tanks. The complexity of the refinery is a direct result of the crude oils received and the multitude of products created—products ranging from liquified gases used in cooking and heating, to asphalt used in roofing and road construction. The refining process is needed to separate the complex chemical compounds that form crude oil into useful products.

In addition to the process area, refineries include storage facilities and auxiliary buildings for offices, an electrical substation, a dispensary, fire fighting equipment, etc. A refinery complex also includes transportation systems for road, rail and pipeline access.

Partially processed petroleum contains hydrocarbon compounds having a range of boiling points, and containing various amounts of oxygen, sulfur, nitrogen, salt, water and trace metals. A refinery separates the natural components into marketable products such as diesel fuel, gasoline, fuel oil, asphalt and propane. The refining process includes a number of interdependent operations receiving crude oil, separating it into components and blending the components into petroleum-derived products. Process configurations vary from refinery to refinery and are chosen, arranged and interrelated based on the type of crude being processed and the products produced. Thus, the type and size of processing units vary. Although in theory any petroleum product can be produced from any type of crude, a refinery is designed to make the most efficient use of the characteristics of available crude oil and to meet demand for products produced.

A significant characteristic of refineries is the large amount of land required for the site. The process equipment site occupies only a portion of the entire land area. A significant amount of land may be used for storage and waste water treatment. A buffer zone separating the refinery from adjacent properties adds to the total land needs. This additional land can also be used for expansion purposes and increase of the complexity of refining capabilities. A refinery with capacity of handling 250,000 barrels per day can require 1000 to 1500 acres of clear, flat, industrially zoned land; of this total, about 200 acres is used for the actual processing unit. The amount of land used for storage depends on several considerations including crude delivery, product delivery, refinery complexity, seasonal demand, shutdown time and number of feedstocks used.

Petrochemicals are relatively pure chemical substances derived from petroleum and natural gas, and can be divided into three broad categories: (1) aliphatics, (2) aromatics and (3) inorganics. The aliphatics and aromatics are organic, or carbon-based, compounds. The aliphatics are either straight or branched chain or alicyclic compounds. They can be divided into two classes: paraffins which are saturated compounds, and olephins which are unsaturated.

The processing of petrochemicals occurs in three stages. First, primary petrochemicals are derived from feedstocks produced by either petroleum refineries or natural gas processing

plants. Primary petrochemicals are then converted into intermediate petrochemicals or directly into finished products. Finally, the intermediate petrochemicals are converted into finished products.

Petrochemical plants are often located near refineries because the petroleum feedstocks used are produced in refineries. Like refineries, petrochemical plants use large amounts of land, and the processing and storage facilities account for only a portion of that land. A buffer zone area is usually provided between the industrial site and adjacent properties.

USES FOR CALIFORNIA CRUDE OIL

The ability of a particular refinery to produce particular refined products depends in part on the quality of crude oil it processes and also the type of refining units in the refinery. A refinery generally produces a wide range of finished products including:

1. Volatile products
2. Light oils
3. Distillates
4. Lubricating oils and greases
5. Petroleum waxes
6. Residues
7. Chemicals

Volatile products are the lightest materials produced during the refining process. They are gases at atmospheric pressure such as hydrogen, methane, ethane and ethylene, propane and propene, and butanes and butenes. Except for butanes, a considerable portion of which are blended into gasoline, the bulk of these gases is either charged to further processing or burned at the refinery as fuel. Some of the heavier gases are combined and sold as LPG (liquefied petroleum gas). LPG is primarily used as motor fuel, a raw material used to produce chemicals, and heating and cooking fuel.

Products of light oils include gasolines, aviation and jet fuels, solvents, tractor fuel and kerosene. Except for the earliest days of the petroleum industry, gasoline has been the principal light product. The demand for gasoline continues to increase at a very rapid rate and refineries in California are particularly well-suited to produce a large proportion of gasoline from available crude supplies.

Distillates fuels are petroleum stocks that boil in the range of 350° to 700°F and have a flash point of 120°F. They include kerosene, heating oils, diesel fuels, industrial distilled fuels, spray oils, insecticides, smudge oil, straw oil, absorption oil and gas oil. In the early days of the industry, distillate fuels were the prime products. Now they rank second in importance to gasoline.

Lubricating oils were originally high-boiling, high-viscosity oil fractions from which undesirable components had been removed. As technology developed and service requirements became more severe, additives were incorporated to improve the performance of lubricants. Additives now constitute the major part of lubricating technology. Lubricating oils are formulated for particular applications. Because it is impossible to meet all requirements with a universal product, a large variety must be produced. Lubricating oils may be divided into four categories: motor oils, industrial oils, gear oils and greases.

Petroleum waxes fall into two categories: paraffin and microcrystalline. Paraffin waxes are white, relatively hard translucent solids, with melting points between 105° and 180°F. Approximately 80% of the paraffin wax produced in the United States is used to make waxed papers and cartons. Other consumers of paraffin waxes include candles, matches, rust preventives, fruit and vegetable coatings, electrical and communication equipment and dental wax. Microcrystalline waxes are tough, flexible solids ranging in color from white to brown, with melting points in the range of 145° to 190°F. Applications for microcrystalline wax range from yarn lubricant to electrical insulation.

Residual petroleum products include residual fuel oil, fuel oil for diesel engines, road oil, spray oil, coke and asphalt used in paving, roofing and paint. Of the residual products, coke is the only solid. Coke is often used as commercial fuel, and in the manufacturing of electrodes, abrasives, artificial graphite and calcium carbide. Asphalt has proven to be a relatively profitable product to produce in recent years due to its tremendous demand for use in highways and other forms of construction.

Figure 6-17 presents data on the production of major refined products in California in 1988.

This figure indicates that the volume of motor gasoline produced in the state is more than double the amount of any other product produced, indicating its importance.

The production of petrochemicals during the refining process creates many common household items. Personal items produced from petroleum include perfume, shampoo, hand lotion, makeup and medicine. Other items include house paint, detergents, plastics, weed killers, insecticides, fertilizer, synthetic rubber and synthetic fibers such as rayon, nylon, Orlon, Dacron and acetate.

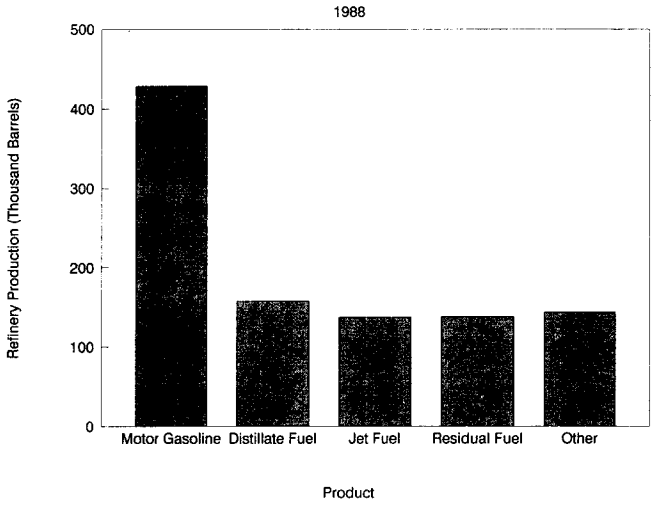

Figure 6 - 17: California production of refined products, 1988.

HISTORY OF CALIFORNIA PETROLEUM DEVELOPMENT

California petroleum development dates back as early as the 1500s when Spanish explorers landed in California and found Indians using asphaltum gathered from natural seeps in baskets and jars to fasten arrowpoints to shafts. Interest in crude oil became widespread after the 1859 discovery of oil in Pennsylvania and the use of kerosene as an illuminant became generally known. In 1850, Andreas Pico began distilling oil into kerosene near Newhall, California for use at the San Fernando Mission. The first drilling activity in California was reported in 1861 and by the mid 1870s there was considerable crude oil production underway.

The first gas production was achieved near the city of Stockton around 1855. Most of the early gas produced in the state was associated

gas (gas produced with oil); gas began to be produced in nonassociated wells with the discovery of the Buttonwillow field in 1926.

The first oil refinery in the state was built at Newhall with a capacity of 20 barrels per day. Most drilling activity was centered in this area and west in Ventura county; the first development in the Los Angeles area commenced in the 1890s with the L.A. City field. About the same time, oil was discovered offshore in Ventura county and the Summerland field was developed using wooden piers constructed from the shoreline.

In the early 1900s, production expanded, with extensive activity focusing on the Santa Maria Valley area and around the city of Bakersfield. The Midway-Sunset field was first drilled in early 1910, and the "Lakeview Gusher" started flowing on March 15, 1910. The well flowed out of control for 18 months and produced a total of 18 million barrels during that period.

By 1910 total production in the state reached 77.7 million barrels. With the exception of the Wilmington field, all of the large fields in the Los Angeles area were discovered between 1920 and 1930. Other discoveries occurred during this period contributing to an oversupply and lower prices of crude oil. During the Great Depression, drilling activity and production declined. The Wilmington field was discovered in 1932 as were several fields in the San Joaquin Valley. By 1940, 223 million barrels were produced (which was four million less than had been produced in 1930).

Production increased during the 1940s in response to the war effort and as the result of several new discoveries. By 1950 production had increased to 330 million barrels. Exploration and development efforts began to focus more on offshore oil resources in the 1950s and 1960s as technology improved to make offshore drilling and production more feasible. Large discoveries were made in the Santa Barbara area including the Summerland Offshore and Conception fields. During the 1960s two major discoveries were made in adjacent offshore waters; these were the Carpinteria and Dos Cuadras fields.[222] Production peaked in California in 1968 at 375 million barrels and has never regained that level. New offshore discoveries were made during the 1970s and 1980s, although for various reasons these fields have not come on line as quickly as many had anticipated.

Natural gas production increased considerably during the 1940s and 1950s. By the late 1940s a gas shortage developed in the state due to the tremendous growth in population and industry. Forty-four new gas fields were found in the Sacramento Valley area during the 1970s. Despite these new discoveries, by 1980, California imported over 80% its gas needs.

The federal government opened the Elk Hills Naval Petroleum Reserve in 1976, in response to the 1973 Arab oil embargo. By 1980, this field had become the largest oil producing field in the state. During the early 1980s, while world oil prices remained high, significant effort was expended in applying enhanced oil recovery methods to increase the rate of production in many state fields. Enhanced oil recovery

[222] A major blowout occurred in the Dos Cuadras field in 1969 causing a large spill, and leading to a moratorium on offshore drilling on state lands for several years.

methods include the use of water, pressure, heat and chemicals to overcome the natural forces that impede oil recovery. Because much of the state's oil is relatively heavy, the most effective method used in California is steam. The steam lowers the viscosity of the oil making it flow more easily. As a result of these activities, production had been increased by the mid to late 1980s, at several heavy crude fields in the state including the Kern River, Midway-Sunset and South Belridge fields.

MODERATING VARIATIONS IN OIL SUPPLY

DEFINING A CRISIS

Recent events in the Middle East have demonstrated the fragility of the supply/demand balance of world oil markets. Despite the apparent stability of oil prices in the late 1980s, increasing demand for petroleum products and falling domestic oil production along with unforeseen political events have restored to some extent OPEC's ability to dictate world oil price and production decisions. Also California remains heavily dependent on oil and petroleum based products, despite progress in developing alternative energy sources. As noted above, both California and the nation as a whole are expected to become increasingly dependent on imported oil over the next ten to fifteen years.

Although energy forecasting is always difficult, "crises" should never come as a surprise, as the events of the 1970s and 1990 have taught us. It is important, however, to recognize that the potential for a "crisis" is always real and what our state of readiness to cope with such an eventuality. Indeed many energy forecasters now believe that sometime between now and the year 2000 we will be faced with another "crisis" stemming from a severe curtailment of oil supplies. Whether the events in the Middle East during the summer of 1990 will trigger such a crisis is still unknown, but it is likely that such events could indeed cause such a crisis.

Due to the uncertain nature of political, social, economic and technological events, it is difficult to predict when or how a "crisis" could arise. As little as a year ago, it seemed unthinkable that political events in Iraq and Kuwait could have caused such turmoil in petroleum markets as we have recently witnessed during the summer of 1990. Indeed even defining what would constitute a crisis is difficult. As this chapter is written in late summer of 1990 it is impossible to determine whether we are in the midst of yet another "crisis." It is clear, however, that deliberate manipulation of world oil markets resulting in substan-tial cutbacks in oil supplies is the most common "crisis scenario." Determining the extent of a supply curtailment that could trigger a "crisis" is extremely difficult.

One need only observe the effect of various production cutbacks during the Arab embargo in 1973 and the Iranian crisis in 1979–1980 to get a picture of the variations in supply cutbacks required to trigger a panicked response among energy consumers. During the Arab embargo in 1973, world oil production declined almost 5 million barrels per day in less than two months. Over one million barrels per day were removed from the market literally overnight! During the Iranian crisis, the production cutbacks were more gradual, and other producers were able to moderate to some extent the curtailment of supplies from Iran (and later Iraq).

Nevertheless, crude oil prices reacted in much the same manner during the second oil

crisis as they did during the Arab embargo. This was due in part to the response of consumers who 'feared the worst' and also to relatively poor preparation by the industrialized nations in coping with a moderate crude oil supply crisis.

Given our prior experience, it is probably easier to forecast the likely source of an oil supply crisis than it is to predict its likely impact on energy prices and on the world economy in general. As recent events have shown, the Middle East, especially the Persian Gulf, is especially sensitive to a crisis due to its strategic location and its vast oil reserves. Revolutions, regional wars or conflicts in the Middle East can disrupt oil supplies and cause economic hardship for the United States and other industrialized nations. In addition, political instability in the Middle East and the ongoing Arab-Israeli dispute are a continuing threat to this region. The economic leverage of oil as a political and economic weapon cannot be ignored either as a potential cause for a future energy crisis.

Other potential sources of a crisis could be as close as Alaska—as the grounding of the Exxon Valdez in March 1989 so graphically illustrated. Supplies from Alaska were cut off for only four days; however, gasoline prices on the West Coast increased dramatically partially as the result of panicked buying, and partially by fears of an extended oil shortage on the West Coast. As that incident demonstrated and as more recent events have shown, the major oil companies have generally been willing to take advantage of short-term market disruptions at the expense of consumers.

One example of a potential crisis may serve to illustrate the uncertainty that a supply disruption could have on energy demand and prices.[223] Assume that war or revolution in the Persian Gulf forces the closure of the Straits of Hormuz at the end of the Gulf causing a net production loss of 10 million barrels per day, and that the disruption lasts for approximately six months. It is forecast that such a disruption could cause oil prices to increase $10 to $30 per barrel depending on the ability of the major industrial economies to draw down stockpiled reserves (such as the Strategic Petroleum Reserve), as well as consumer responsiveness to price hikes and commercial inventory behavior. Indeed the recent supply curtailment of approximately five million barrels per day at a time of general surplus caused a rapid increase in oil prices of roughly $10 per barrel on spot markets.

Initially some public panic and temporary shortages would be observed in the marketplace. However, the petroleum market is perhaps better able to handle a severe supply disruption than 10 years ago, and effects may be moderated depending on the response of industry and consumers. Recent events in the Middle East and the dramatic upward move in gasoline prices suggest that this may not necessarily be the case. Petroleum markets also tend to respond more quickly to changes in supply conditions than was true 15 years ago. If suppliers drew down inventories in an effort to fill the supply gap while consumers quickly reduced energy use in response to the price increase, the overall impact would be dampened and prices would tend toward the lower end of the range. Other economic consequences would also follow, including the increased possibility of a recession or depression. Conversely, if consumption remained high and uncertainty

[223] Taken from EIA, International Energy Outlook, 1990, p. 16.

caused suppliers to maintain high inventory levels (due to uncertainty regarding the duration of the crisis), the effect on prices would be far more severe.

The aftermath of such a disruption would also be uncertain, although it is likely that prices would tend to move erratically for a considerable period after the crisis. The impact on world economic conditions of such a crisis is also difficult to predict, but given historical experience it is clear that the impacts would be severe. When more money is spent on energy resources as would be the case during a crisis, less money is available to spend on nonenergy expenditures. Lower nonenergy expenditures generally lead to decreased economic activity, increased inflation and higher unemployment. The overall impact would be to lower GNP, employment and income, which tends to create political and social unrest.

CHANGING OIL'S PLACE IN THE ENERGY EQUATION

The role played by oil in our overall energy needs cannot be overemphasized. Despite California's apparent freedom from dependence on imported oil, it remains vulnerable to a crisis. Imports in California and throughout the U.S. are expected to increase substantially in the next decade, and various factors will affect our vulnerability to a supply crisis as well as our ability to respond effectively to such a crisis.

Energy vulnerability will depend on three main factors:

1. Our dependence on foreign sources of energy, especially petroleum, which may be subject to disruption.
2. The risk that a disruption could occur and be so severe so as to have a major impact on the economy.
3. The capability to respond, in terms of the state of the national economy at the time, to a disruption by means of stockpiles, drawdown of reserves, alternative energy sources and conservation activities.

As noted in previous sections of this chapter, we are increasingly dependent on foreign sources of oil and oil will continue to play a vital role in our energy needs. This is especially true in California because of the rapid growth in the demand for energy in California, especially transportation fuels.

The risks of a significant "crisis" in the near future become more significant as our dependence on OPEC supplies increases. As discussed, it is impossible to define precisely the level of a disruption that would be required to cause a crisis, but history has taught us that given current trends and uncertainties, the likelihood of a crisis is very real.

Efforts are underway to alter oil's place in the energy equation, thereby reducing our dependence on oil; however, many of these efforts require substantial development time. The nation is in an improved position to respond to a supply crisis for several reasons. Most industrialized nations have in place strategic petroleum reserves capable of

offsetting a supply disruption.[224] Plans exist among the industrialized nations that would provide a coordinated response to a supply curtailment. For example, California has in place a contingency plan for dealing with energy emergencies. The plan provides a response depending on the level of the emergency and facilitates coordination among state and federal agencies as well as private industry.

Other actions are underway in California to cope with its vulnerability to an energy crisis and to decrease dependence on oil in the future. Increasing the use of natural gas as a substitute for petroleum, especially as fuel in enhanced oil recovery projects is underway. The state is also expanding research efforts focused on alternative transportation fuels and technologies, as well as improved methods of enhanced oil recovery. Also discussed below, significant efforts have been made to promote energy efficiency and conservation. The false sense of security created by low oil prices should not permit such activities to abate.

In the following sections, we discuss the various ways of coping with our dependence on oil and ways in which oil's role in the energy equation may be changed in the future. First, the role of the Strategic Petroleum Reserve is discussed, followed by a description of current petroleum exploration and production efforts, a discussion of the role of energy conservation, and finally, expectations regarding alternative energy technologies.

Strategic Petroleum Reserve (SPR)

From September 1973 to April 1974, the United States and other oil importing nations experienced both a disruption in Persian Gulf oil supply and a fourfold increase in oil prices.

This was due to the Arab oil embargo which had two primary components: 1) an intended absolute embargo on shipments to the United States and Holland (as punishment for support of Israel); and 2) a loosely implemented reduction of about 20% of the oil liftings for all Organization of Arab Petroleum Exporting Countries (OAPEC) members.

During this period, the United States ordinarily received about 25% of its imports from the Persian Gulf. Western Europe received 66% and Japan 74% of their respective supplies. By January 1974, U.S. imports were down 2.7 million barrels per day from September of the previous year. Oil prices rose dramatically; almost quadrupling by the time the Arab embargo ended on March 18, 1974. For example, spot market prices for Mideast Light Crude 34 went from $2.70 per barrel in the third quarter of 1973 to $13.00 per barrel in the first quarter of 1974. Long-term contract prices for the same oil went from $2.55 in the third quarter of 1973 to $9.60 in the second quarter of 1974. This situation prompted quick reaction from the President of the United States and the Congress.

In January 1975, President Ford sent his proposed energy Independence Act to Congress. It contained thirteen titles. Title I called for full development and production from the naval petroleum reserves and the creation of a military strategic petroleum reserve (SPR) of 300 million barrels. Title II of the Act called for the creation of a domestic strategic

[224] However, governments must be willing to utilize these reserves to moderate supply disruptions. The failure of the U.S. to draw on the Strategic Petroleum Reserve immediately after the invasion of Kuwait by Iraq and the resulting loss of 5 million barrels per day of world production calls into question our willingness to actually use this reserve.

petroleum reserve of up to one billion barrels for the purpose of providing the United States with sufficient petroleum reserves to minimize the effects of any future oil supply interruption. The SPR Plan was submitted to Congress by the Federal Energy Administration (FEA) on December 15, 1976.

The Act required that within seven years, the SPR contain a reserve equal to the volume of crude oil imports during the three consecutive highest import months in the 24 months preceding December 22, 1975—approximately 500 million barrels. The Act further required the creation, within three years, of an Early Storage Reserve (ESR) of 150 million barrels as the initial phase of the SPR to provide early protection from near-term disruptions in the supply of petroleum products. As part of the National Energy Plan, President Carter proposed to the Congress in 1978 that the SPR be expanded to a total volume of one billion barrels.

A total of eight candidate early storage reserve (ESR) sites were selected. Of the eight sites evaluated, four were selected for use as storage facilities. They include the West Hackberry Salt Dome in Cameron Parish, Louisiana; the Bayou Choctaw Salt Dome in Iberville Parish, Louisiana; the Bryan Mound Salt Dome in Brazoria County, Texas; and the Weeks Island Salt Mine in Iberia Parish, Louisiana. Implementation of the SPR Plan began at a fast pace in April 1977. The first storage sites were acquired in Louisiana and Texas. Construction of the initial surface facilities began in June 1977. On July 21, 1977, injection of oil into caverns at the West Hackberry site near Lake Charles, Louisiana began. On October 1, 1977, the Department of Energy (DOE) was created to take over the SPR program from FEA. In November 1978, the SPR office established a schedule, calling for the availability of 500 million barrels of storage capacity by the end of 1985, rather than by the end of 1982 as required in the original SPR Plan.

In September 1980 Phase I facilities (which called for the use of existing caverns), were completed, providing 260 million barrels of storage capacity, which can support a drawdown rate of about 1.7 million barrels per day. Phase II would add new caverns at three of the sites to increase storage capacity to 538 million barrels.

At the end of 1980, the Carter Administration sought funds for construction of Phase III which continued expansion of the same three sites. Phase III facilities were planned to add an addition-al 212 million barrels of storage capacity by the end of 1989, bringing the total to a 750 million barrel reserve.

In the spring of 1979, the nation experienced a second oil shock. A revolution in Iran cut off Iranian oil exports to the United States, demonstrating this country's vulnerability to oil shortages. SPR purchases were suspended for 18 months, with 92 million barrels of oil in storage. In September 1980, as world oil markets began to recover, crude oil purchases were resumed. The SPR contained 107.8 million barrels of oil at the end of 1980. By the end of 1981, it contained about 230 million barrels, which was 20 million less than the estimated volume to be in storage by the end of 1978.

In 1982, the reserves passed the 250 million barrel level. In December 1983, the SPR reached 375 million barrels—the midpoint of its 750 million barrel goal—and five months later

passed the 400 million barrel level. On June 1, 1986, the 500 millionth barrel of crude oil was added to the growing stockpile, and by late 1988, the SPR was approaching the 560 million barrel level. As of December 31, 1988, the SPR crude oil inventory was 559.5 million barrels, an increase of 18.9 million barrels over the 1987 year-end inventory of 540.6 million barrels. The SPR was filled at a rate of 51,781 barrels per day during calendar year 1988.

According to U.S. crude demand for 1988 (13,507,000 barrels per day), 600 million barrels of crude oil in the SPR will last for about 95 days. The demand number includes crude into the SPR which accounts for about 52,000 b/d. However, with reliance on petroleum imports currently increasing, the days of supply accounted for by the SPR will tend to diminish.[225]

Currently, the entire West Coast region (including Alaska) is a net exporter of crude oil to other areas in the U.S. California is a net importer and if current trends continue, the entire West Coast region is forecast to become a net importer in the near future. Because transportation systems between the West Coast and the East of the Rockies region are limited, a future foreign oil supply disruption could result in the East of the Rockies region being partially supplied by SPR oil while the West Coast may have no equivalent safety net.[226]

The crude oil stored in the SPR is purchased based on price and the need for a specific type of oil. The oil consists of a mixture of both domestic and foreign crudes. The first barrel of crude oil bought for the SPR was from Saudi Arabia in 1977. Since then, purchases have been from 18 different countries. U.S. crude accounts for the third largest amount of oil in the SPR, about 38 million barrels.

Developing offshore oil and gas resources requires preparation of a leasing and development program. After a company has leased an offshore parcel in the OCS or state tidelands, lease provisions require that exploration and development proceed within a specified period. Exploration and development plans for state tidelands are reviewed and approved by the State Lands Commission. Similarly, the Minerals Management Service (MMS) reviews and approves the OCS plans. Other state and local government agencies also review and assess these proposed development plans.

Exploration involves selecting sites to drill exploratory wells based on predictions of the area's subsurface stratigraphy and structure. Certain proven methods have been used to success-fully carry on exploration activity, such as seismic, geological and geophysical surveys. Seismic survey is a method used to determine the structure of the earth below the water surface and below the sea floor. It results from the introduction of an acoustic energy pulse and the study of the reflected or refracted response. Once an oil field has been discovered, the field is developed by drilling additional wells to drain the proven reserves.

In late November 1984, the Department of Energy, Energy Information Administration, stated:

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[225] Most recent projections by the Energy Information Administration indicate that current SPR stocks are sufficient to displace imports for 72 days.

[226] The California Energy Commission has examined the feasibility of establishing a regional strategic reserve to benefit the western states.

large oil discoveries would be required to replace declining production from old fields if U.S. oil production was to be maintained.

The study also stated that if production from old fields continued to decline at about 3% per year, replacement oil required to maintain the 1982 output level will amount to 518 million barrels in 1990, and 783 million barrels by 1995.

In 1986, seismic exploration activity in the U.S. was down from the previous year, as were active rigs, well completions and production. These reflected continued weak prices for oil and gas. Average crude prices hit an all time high of $31.77 per barrel in 1981, slipped to $24.09 per barrel in 1985, then plunged to $12.66 per barrel in 1986.

Declining oil and gas prices have seriously affected drilling activities. According to Baker-Hughes Inc., average rig count increased to a record 3,970 in 1981 before plummeting to only 970 in 1986. The decline continued during the first four months of 1987 when the average weekly count stood at 809, down 38% from the same period in 1986.

In 1988, the oil industry was expecting a modest recovery for U.S. exploration and development. Most signs pointed to increased drilling on the strength of firm demand and moderate advances in oil and gas prices. Baker-Hughes Inc. predicted a gain in U.S. drilling, which would be fueled largely by rising gas prices. The average weekly rig count of 1,069 rigs in the U.S. was up 14% from 1987.

In 1989, the U.S. petroleum industry reported a decline in every principal operation including geophysical surveying, drilling and production. Chances of a sharp increase in the near future are slim unless oil and gas prices show a marked price rise. However, it is expected that increases in oil demand could lead to an upward trend in prices.

The latest available count of U.S. land crews and seismic vessels by the Society of Exploration Geophysicists stood at 129 in May 1990 (104 onshore and 25 offshore). The API's tally of exploratory well completions has been dropping steadily, falling to 6,140 in 1988 from 15,066 in 1984. The count of 382 completions for the first two months of 1988 is only about one third of similar counts for the past two years. The slide in field operations has placed added importance on purchases of producing leases as a means to buoy reserves.

Gas production was on an upswing and headed for a return to 18 tcf/yr or so in 1989. Drilling is lagging because operators, with an eye on prices and rising imports from Canada, are responding cautiously to forecasts of an end to a persistent gas supply surplus.

In California, most new drilling activity has been concentrated the onshore area of San Joaquin Valley. In 1988 there were a total of 1,902 new wells completed, and over 90% of these were in the San Joaquin Valley. In 1987, new wells totalled 1,714 in California.

Another indicator of exploration and development activity is the number of drilling notices filed. In 1988 there were 2,516 drilling notices filed, a decline of almost 25% from 1987.

As these data indicate, the pace of exploration activity has slowed relative to the early 1980s. The emphasis has shifted to the development and production of discoveries resulting from earlier exploratory efforts (Pacific Summary/Index June 1, 1986 –July 31, 1987). In federal offshore areas, drilling activity

in 1987 remained about the same as in 1986. Four exploratory wells and 33 development wells were drilled in 1987. In 1988, only three exploratory wells and 29 development wells were drilled in federal offshore waters. The number of seismic crews and exploratory wells pinpoint the decline in California exploration. According to the Division of Oil and Gas in 1987 and 1988, no new oil or gas fields were discovered.

Drilling activity in state waters has declined significantly, with nine wells drilled in 1987, compared with 22 new wells in 1986 and 63 new wells in 1985. Clearly, as oil prices have declined dramatically, exploration and development activity in California has followed a similar decline.

ALTERNATIVES TO OIL USE

CONSERVATION AND ENERGY EFFICIENCY

Conservation is probably the single most effective way to reduce the consumption of oil in California, or the United States. There is no question that conservation, and the broader issue of energy efficiency, can save significant amounts of the total energy used in California, especially given the dependence on oil noted above.

Energy efficiency is more than conserving energy, with its connotations of reduced comfort and convenience; it is, rather, taking advantage of opportunities to acquire the same or improved services using less energy by substituting energy-efficient technologies and practices. Energy efficiency has the benefit of reducing the costs of oil dependence and the costs of adverse environmental impacts from industrial and transportation emissions, costs which ultimately have a major influence on the State's economic well-being.

During the energy crises of the 1970s and 1980s conservation by energy consumers made significant inroads into energy consumption patterns and trends. At the same time analysts have also studied consumer reaction to energy conservation programs, noticing several important facts. The first is that conservation is basically boring. Consumers are willing, but not excited, about conservation. To conserve consistently, consumers have to believe that the conservation is necessary for some greater good, that all other users are conserving first, and that any burdens are fairly distributed. Many consumers have developed a false sense of security about the energy future, based on the current situation of adequate oil and gas supplies, energy capacity, and lower energy prices. There are clear indications that the good conservation habits acquired in the 1980s are being replaced with more wasteful practices. The lack of a clear energy policy on a national level, and former President Reagan's well publicized disdain for conservation did not help re-set our priorities.

The following material discusses conservation efforts as they relate to transportation, commercial use of energy and residential use of energy.

Transportation

California spends 50% of all its energy on transportation. Transportation also consumes three-fourths of all the state's oil supplies (CEC 1989 Fuels Report), making it the most vulnerable of all sectors to changes in fuel supplies and prices.

Private automobiles and light trucks use more than half of all fuel used in California.

While autos are getting more miles per gallon than in the past, lower fuel prices in recent years are encouraging more driving, and sales of the larger, less fuel-efficient cars are again increasing. The federal government is holding fuel economy standards for American-manufactured cars to 26 miles per gallon, while new Japanese cars average 30 miles per gallon. In view of this, the three largest American car companies are dismantling their programs to develop smaller, more fuel efficient cars.

In spite of all this Californians continue to love their cars and love their driving. A major reason for consumer indifference to efforts to reduce private automobile use is that drivers never pay the full costs of their transportation, including costs for road building and maintenance, noise and air pollution, public safety and the effects of congestion on health and loss of productivity. Overall, the use of private automobiles exacts millions of dollars in uncounted economic losses (Flaven and Durning, 1988).

To reduce fuel use by the transportation sector calls for a collection of strategies that fall into three categories: improving vehicle efficiency, transportation system management strategies, and changing land use and work patterns. In addition, there are a number of alternate technologies discussed in the following section that have the potential to reduce transportation energy expenditures.

The main focus on improving vehicle fuel efficiencies has come from the federal government, which has used the Corporate Average Fuel Economy (CAFE) standards as its primary weapon. But, in 1985, the federal government decided not to increase the standards for 1986 from 26 to 27.5 miles per gallon (mpg), despite the fact that such a move would have substantial impact on reducing oil consumption. For example, the increase in average fuel efficiency of American cars from 13 mpg in 1973 to 18 mpg in 1985 cut U.S. gasoline consumption by 20 billion gallons per year, lowering oil imports by 1.3 million barrels per day, roughly equivalent to two-thirds of Alaskan peak production (Flaven and Durning, 1988).

As pointed out by the California Energy Commission, the states are currently pre-empted from setting vehicle fuel standards which exceed the federal standards. This pre-emption hinders California's ability to reduce its transportation energy use and forces unnecessary waste of petroleum fuels.

Transportation system management includes use of car pool lanes, public mass transit, car and van pooling, bike lanes, signal timing and education and information programs. Each of these strategies has a beneficial impact on fuel use.

In 1988 California operated 10 stretches of highway as High Occupancy Vehicle (HOV) Lanes, for a total of 86 miles. Such HOV lanes increase ridesharing by requiring two or more occupants of each vehicle using the lane and offering the benefits of reduced travel time during peak periods or free access to certain tollways. Studies by SCAG indicate that HOV lanes are one of the most preferred commute changes; carpools in Los Angeles HOV lanes have increased at a much faster rate than overall traffic, showing substantial acceptance, and this appears to be true statewide as well.

Public mass transit is estimated to be over three times more energy efficient than personal vehicle travel. Unfortunately, it has not captured a large enough share of commuter

travel to significantly decrease either congestion or fuel use. In all of the western states including California, public transit's share of commuter traffic increased only from 5.9% to 6.2% over the last decade.

Major service improvements are needed to significantly increase the use of mass transit, and such improvements will cost large amounts of money. Revenue generated by users of mass transit will not be able to provide the up-front money for such improve-ments, because the ridership will not increase until after the improvements are made. This means that the money will have to come from other parts of the transportation sector, general funds, or private investment.

Various forms of ridesharing have been more successful than mass transit in attracting and holding new riders. Since the mid 1970's the State has participated in three major commute management programs: Rideshare, Park and Ride and Vanpooling. State and local governments have also begun requiring companies in their jurisdictions to develop trip reduction plans. Overall these programs have been estimated to have saved 156 million gallons of fuel since 1973 (CalTrans, 1987).

Commercial

California currently spends an amount equal to about 7% of the state's $590 billion Gross State Product (GSP) for energy. While this is better than the national average, every 1% reduction in energy costs for business and industry could increase the GSP by $400 million (Rosenfield and Mills, 1987). To stay economically competitive, California businesses must continue to decrease their energy costs without losing productivity. Energy costs in commercial businesses can account for up to 10% of total operating budgets. Since business profits typically range from three to 10%, a reduction of even 1% of sales in energy costs can have a major impact on profits.

Despite this, commercial consumers rarely see reducing energy costs through investments in energy efficient equipment as a significant factor to increase profits or to reduce overall costs. In fact, some businesses are concerned that such a reduction will hurt sales by reducing the attractiveness or comfort of offices or salesrooms. Managing energy costs has a relatively low priority among businesses because such costs often seem to represent only a small percentage of overall business costs. This perception may be one reason why electricity demand has grown faster in the commercial sector than in any other sector during the 1980's. Much of this growth can be traced to major increases in construction of new commercial buildings, and also to increases in energy intensity per square foot, as computers and their associated equipment have permeated the workplace.

The rapid growth in commercial floor space in California makes encouraging energy-efficient design and control systems more important than ever before. There is a potential to overlook such opportunities in the midst of a building boom, but studies have shown that "built-in" energy efficiency has the highest payoff in terms of reducing fuel use over the relatively long lives of commercial buildings. Ensuring that energy efficient systems are included in the design and building of such space can substantially reduce operating and capital costs.

Many factors affect the interest of the commercial consumer in energy management. Larger firms are more likely to use an energy

manager and to establish formal procedures to improve energy use than are smaller firms. Renters and landlords have less interest in energy management than do those operating out of buildings that they own. Industries with high energy use as an intrinsic part of their business are more likely to be interested in energy savings than those with only moderate energy useage.

The most likely areas in which to reduce energy useage in this sector are improvements in lighting, space heating and cooling, and production practices. Lighting is a significant portion of many commercial user's energy bill. Lighting is used for advertising, security, and to establish a favorable environment. Many new high technology lighting systems can significantly reduce energy expenditures without reducing the amount of light produced, but the commercial sector requires more information on these systems before any substantial impact is felt.

Heating and cooling commercial space is still the single highest item of energy expenditure in this sector. Major improvements can be made if initial building designs are handled properly. Passive solar heating, natural lighting, convection heating and cooling, and other techniques can reduce energy expenditures by up to 30%, but all must be incorporated in a building's design to be effective. Existing buildings can usually be improved in the areas of insulation and upgrading equipment, or by using more efficient load management techniques.

Residential

Over the last decade, according to the California Energy Commission, residential consumers have shown a real desire for more energy efficient homes and appliances. Energy efficiency has ranked only after general cost and location in considering buying a new home. People buying new appliances consistently rate energy efficiency as one of the primary considerations. Government and utility educational programs, along with rising energy prices, have successfully raised consumer consciousness and knowledge of energy efficiency.

There is still a need to develop more energy efficient products. For example, although most consumers express a willingness to pay for homes that exceed current California building efficiency standards, fewer than 10% of new homes being built actually offer more efficient furnaces or insulation. Most builders do not build homes that more than meet the minimum state efficiency standards. Nor do they promote specific energy conservation features to new home buyers (PG&E, 1987). In fact, many homebuilders market their homes as energy efficient simply because they meet the minimum standards. There is little or no incentive to build homes that more than meet the minimum standard.

Since the early 1980s, utilities have offered audits, low interest loans and cash rebates to encourage energy efficiency in private homes. A review of such programs has indicated that these programs did significantly reduce the state's energy expenditures. The research also indicated that such programs are most successful when they focus on identifying customer needs, offer consumer choices, and provide feedback on the energy saving results. Experiments have also shown that consumers respond well to real-time price signals by changing their energy use patterns if the difference between on- and off-peak rates is significant.

Another potential area for increased energy efficiency is the development of home energy use ratings for new and used homes, similar in concept to the labels now found on appliances. Such a program has been pilot tested over three recent years by the California Energy Commission, with mixed results. Rating the energy efficiency of homes proved much more difficult than had been hoped. Even fully qualified auditors had trouble understanding the data requirements needed to rate homes. The real estate industry showed active disinterest in the system, and was concerned that courts might make it mandatory for full disclosure for all homes. Also, consumers did not seem to use the information presented in making their final purchase decisions.

Clearly, more market research is needed before such a system should be mandated by the State. But the Energy Commission and the California Building Industry Association are cooperating on a method of rating energy efficiency in new homes that would recognize homes that are 10% to 15% more efficient than required by the State. Then methods will have to be developed to market these more efficient homes and test consumer reaction.

OTHER TECHNOLOGIES

Several technologies—old and new—have the potential to greatly reduce the need for petroleum products. In the sections below the most widely discussed of these technologies are reviewed, beginning with a description of the technology, a discussion of the advantages and disadvantages of its use, and finishing with a look at the current status and future of that particular technology. The bulk of these technologies involve power production for national or regional power grids. Some are more applicable for local use, and finally, some deal primarily with transportation.

WIND POWER

After the oil embargo of 1973, the U.S. government launched one of its biggest campaigns ever to explore wind power. A series of tax incentives and federal energy exemptions encouraged entrepreneurs to create windplants.

In California, steady Pacific winds enhanced by topography, favored construction of windplants at San Gorgino Pass (northwest of Palm Springs), Tehachapi Pass (a low mountain saddle between the Sierra Nevada and Coastal ranges), and Altamont Pass (due east of San Francisco). Each of these areas experience ocean winds funneled into passes, intensifying the velocity. Seventy percent (70%) of all wind power generated worldwide comes from California, and there is a total installed capacity worldwide of 1500 megawatts.

Windmills have existed for centuries in Europe, but the concept of a "windplant" was originated by U.S. Windpower in 1981, the private company that built at Altamont Pass. A windplant consists of a cluster of mid-sized turbines operating as a single generating system. A number of computers act as a centralized communication system that allows a single operator to communicate electronically with the microprocessor in each windmill. Hundreds of windmills can be controlled while simultaneously generating electricity. The database includes maintenance and repair histories, problems diagnosis, inventory control and emergency communications [U.S. Wind Power Booklet (Altamont Pass)].

Wind power offers many advantages, especially here in California. California has

strong, stable ocean breezes, insuring that wind will usually be present over properly chosen sites. Recent technological improvements are reducing the cost of wind power and windpower is also emission free. Most of all, wind machines can be moved about easily; the technology is modular and can be applied on any scale. Wind machines are quickly installed: a medium-sized turbine can be installed in one day, and a windfarm can be up and running within one year.

At this time power companies will not commit to greater usage of wind power because of what they perceive as the instability of the source. Wind speed and reliability are essential. Higher voltages are produced during periods of stronger winds, but constant voltage is necessary for the electricity to be used in power grids. Wind power cannot be economically stored or completely equalized for power grids. Environmentalists have also discovered a few disadvantages. They've stated that the loud low frequency "thump" created by wind turbines disturb wildlife, and people who live near the windplants. Wind turbines have proven to be a hazard to birds, particularly raptors. There have been reports of thrown turbine blades, and turbine interference with radio transmission. Included is the fact that wind power still remains relatively expensive compared to oil, nuclear power and coal; some experts feel that wind power is only in the market because of governmental price fixing.

Despite some disadvantages, wind power technology is promising positive advancements for the future. Engineers believe that wind tapping would be easier if they could erect high concrete towers right at ocean's edge to hold specially designed turbines. The U.S. Navy has launched independent programs by installing wind machines on the California seashore and out in the ocean. The Navy states that a 10-kilowatt turbine can be designed to carry computers and equipment that communicate with airplanes as well as generate electricity.

The future for wind power, windplants and advanced wind power usage look bright. Thanks to new designs and third generation wind turbines under development, the cost of wind power may come down to five cents per kwh by 1995. With coal, oil and nuclear energy costs at two cents per kwh, wind power will still be considered in the running as a viable energy alternative.

SOLAR ENERGY

Interest in solar power increased significantly in the late 1970s. Research and solar development became extremely popular, especially in the Sun Belt states. But by 1986, lower oil and gas prices sped the elimination of residential renewable energy tax credits, and solar power's popularity declined. Here in California, however, interest in solar power remained high. One can find solar trackers on the Carrizo Plain, just east of San Luis Obispo, and in San Diego. A research and development facility exists in Davis, California.

There are many techniques to collect, concentrate and convert solar radiation into useful energy. The most basic methods are collectors which absorb relatively low-temperature heat and then transfer it to water or air. Somewhat more complicated systems concentrate sunlight producing higher temperature heat for steam or electricity. Finally, solar power can take advantage of the photovoltaic effect to convert the sun's rays directly into electricity (Sun World, 1988).

Solar power can be generated quietly and cleanly. Computer driven trackers, such as

those located near San Luis Obispo, are made up of photovoltaic cells made of chemically altered silicon and can convert sunlight into thousands of kilowatts of electricity. Also solar power can be an environmentally sound source of energy; it doesn't destroy land, deplete resources, or emit pollutants. Installations can vary from huge solar trackers providing power directly to regional grids, to smaller units installed on rooftops.

The main disadvantage of solar power is expense. High-performance solar cells or units cost too much to produce at the present time. Because of this, solar power currently costs about three times as much as oil, coal or nuclear power. The goal of the research facilities in Davis and San Luis Obispo is to find a way to curb this cost, by a much as 50%. Researchers predict this will happen within the next three to ten years. Another problem is the highly toxic chemicals used in the manufacture of solar cells which causes environmental concerns. Finally, large solar collector farms would occupy large amounts of space, and land is itself becoming a very precious resource.

In spite of continuing research and development activities, solar power will not be considered for major commercial use until the cost of solar energy production declines.

In terms of the more distant future, orbiting solar collectors could convert solar energy to electricity above the atmosphere's screening. This energy would then be converted to microwaves and beamed down to receiving stations on earth, where it could be re-converted into electrical energy and flow onto regional grids. While there are still many technological obstacles to overcome with this concept, especially the control of the high-energy microwave beam, NASA continues to seriously study this option.

GEOTHERMAL

Geothermal energy is energy which is stored and available through the thermal differential (heat) within the Earth's mass. This internal underground heat is found throughout the state in a broad range of temperatures, from a few degrees above the surrounding soil temperature to ultimate reservoir temperatures over 400° fahrenheit. This energy can be tapped directly from flowing natural hot springs, drilling flowing hot water wells, deeper fluid dominated hot steam and dry steam super hot wells and ultimately hot dry rock. The higher temperature resource requires more expensive and complex drilling and production technologies to achieve an economic production, but it is often still more economical than some conventional energy sources.

Tapping the geothermal resource can furnish hot water for direct space heating, hydroponic agriculture, mariculture, pools (hot baths), and geochemical byproducts including basic mineral water. Hotter fluid-dominated steam systems (wet steam) can be utilized in flash steam turbine or binary power plants, which use a transfer fluid from the wellwater heat source to the steam turbines to generate electricity. Hot dry rock reservoirs are conceptually man-made reservoirs created by hydraulically fracturing hot rock which contains no accompanying groundwater and pumping in water to create steam. Under the right conditions, these technologies can be linked together for two or three uses from a single source.

California's coastal counties have geothermal resources spanning this whole spectrum. Hot springs are found in Los Angeles, Santa

Barbara, San Luis Obispo, Monterey, Marin, Sonoma and Mendocino Counties. Some are in "Known Geothermal Resource Areas" (KGRA's) set aside for geothermal prospecting and development. Steam dominated systems have been found at The Geysers in Lake, Mendocino and Sonoma Counties, as well as other localities outside the coastal counties.

Geothermal energy has been utilized since prehistoric times, primarily for its curative or therapeutic value. In 1921, steam was tapped to power a geothermal engine to generate electricity. This operation, conducted at The Geysers Field, continued until 1925 when lack of a viable market caused its demise. In 1955, renewed interest in development at The Geysers led to the largest geothermal complex in the world with generating capacity of 370 megawatts.

With proper management, geothermal energy can be a readily available, inexpensive resource to develop. Low energy geothermal resource is within reach of the average person. With a modest initial investment, space heating or set-up for a small greenhouse/mariculture industry is possible. Larger or deeper and hotter resources will require greater initial investment for exploration and development. Except in cases where extreme corrosiveness of reservoir fluids creates technical problems, geothermal technology is straightforward and relatively economical to utilize.

A primary disadvantage of geothermal resource is that it must be developed right at the site. It cannot be put in a truck and moved, nor can it be piped a great distance without dramatic energy losses. Often, the locations of geothermal resources are convenient enough for agricultural or maricultural purposes. Some areas are convenient and scenic enough for recreational resorts as in Calistoga, Sonoma County. Many other sites, especially electrical power facilities are located in remote areas, but here generators convert steam energy to electricity where it can be hooked into the power grid.

Another disadvantage is handling the produced fluid—it's hot, under high pressures and can contain environmentally hazardous substances requiring disposal. These problems can be solved with properly designed closed systems allowing the conversion of steam energy to electricity and return of fluids to the reservoir with minimal impact to the environment.

The development of geothermal energy has a potential to displace other conventional energy sources. Its use is applicable on a broad scale of industry needs. As the technology advances, its scope broadens to include simpler low energy uses as well as improved use of the high energy resource.

Geothermal energy is being used and still being experimented with throughout California. Coastal zone usage includes large scale electric generation at The Geysers, mineral water and mineral baths in Sonoma County, mineral bath resorts in San Luis Obispo County, and past developments in Contra Costa County and other localities. Geothermal energy is also being extensively developed outside coastal counties.

As fossil fuels become more difficult to develop or their handling creates controversy, the use of geothermal resources will increase. However, increased use of geothermal resources for electric generation will not be immediate in the coastal zone. After known fields are explored and harnessed, industry will turn to lesser-known areas. The Geysers will continue

to be intensively developed with adjustments to counteract pressure decline and increasing corrosiveness.

There will be an increase, though gradual, as greenhouse agriculture uses geothermal heating. Mariculture will continue to explore geothermal as it accelerates growth rates of certain shrimp and fish. These activities are primarily in Southern California and around The Geysers area.

Since electric generation depends on hot reservoirs with lots of reservoir fluid to drive turbines, these facilities will be restricted to known reservoir areas.

Hot dry rock technology is in its infancy with a few experimental synthetic reservoirs being tried. These are still laboratory toys for now.

As with any resource, the primary barrier to active development of geothermal resources is the economic balance. Conventional energy sources are cheaper and easier to develop than geothermal. The technology is available for almost all forms of geothermal development including hot dry rock and "volcano power," but the expense of developing these resources is just too great compared to oil, gas, nuclear and hydroelectric sources.

A technology to handle the highly corrosive geothermal fluids which corrode facility hardware from wellheads to steam turbines would greatly increase the available resource base.

NUCLEAR FISSION

Cheap, clean electricity from nuclear fission was the dream of the 50s and the hope of the 60s. Nuclear power plants were built worldwide, including five in California. But high costs, dangerously toxic waste products and plant failures have caused such public disenchantment with nuclear power that it seems few, if any, new plants will be built.

While there are several types of nuclear plants in operation or on drawing boards, they all have certain basic operating systems in common. Unstable heavy elements are allowed to fission, or split, in the reactor's core, a process which generates considerable heat. A working fluid is circulated around the core, where it is converted to steam. This steam drives generators which produce electricity, and then is condensed back to fluid so it can be re-used.

Of the different types of nuclear reactors in the world today, most are the type known as Pressurized Water Reactors (PWR). These dominate the market in the United States. They have two water systems: a primary reactor coolant system and a secondary steam-generation system that actually produces the electricity.

The Boiling Water Reactor (BWR) is another nuclear generating system. In this system, the reactor cooling water is boiled directly and used to activate the turbines. This exposes much more of the entire system to high level radioactivity than the PWR system.

High Temperature Gas-Cooled Reactors (HTGR), a third type of system, are used commercially in Europe and Japan. A pilot HTGR plant exists in the United States. In this design, the reactor core consists of ceramic coated microparticles of fissionable material embedded in graphite blocks. The coolant and operating fluid is helium or carbon dioxide gas, which is heated to a pressure high enough to

operate a turbine. The process has several advantages in that workers are exposed to far less high level radiation, and the plant cannot undergo the kind of catastrophic cooling failure that PWR or BWR plants can.

The last major type of reactor undergoing commercial evaluation is the Liquid Metal Fast Breeder Reactor (LMFBR). In this reactor, liquid sodium is used as the coolant and working fluid. It is also unique because it produces more fissionable material than it uses, so it becomes a fuel source.

All nuclear power options have several advantages in common. They produce no emissions; do not use petroleum products; can produce virtually unlimited electrical power for a growing population; and they have demonstrated they can compete economically with other power sources. Various breeder reactors also have the advantage of not needing an external source of fuel once they are in operation. While safety is a concern, military reactors (on naval vessels) have a very good safety record, at least in the United States, and the commercial production of electrical power here and in Europe has gone on for over twenty years with only a few major accidents.

All nuclear plants produce highly radioactive waste products that can last for thousands of years at very dangerous levels. To date, no one has developed a satisfactory plan to dispose of these wastes, so they continue to accumulate. The few accidents that have occurred in nuclear power plants, especially at Three Mile Island in the United States, and Chernobyl in the Soviet Union, have been so spectacular that public opinion appears to be against further development of this power source at this time.

Of California's five nuclear plants—Humboldt Bay, Rancho Seco, Diablo Canyon and two plants at San Onofre—only Diablo Canyon and San Onofre are still in operation. It is very unlikely that a new nuclear plant could be built in the state under present environmental laws and with the current public perception of the industry's safety record.

And yet, nuclear plants offer the most readily available source for large scale commercial electric power generation without severe air emission risks. Europe and Japan continue to build plants, although public resistance in those areas is growing. New research in plant design in the United States is geared primarily to the military, not commercial, requirements. And the major utilities have taken a "hands off" attitude towards any new nuclear research.

THERMONUCLEAR (FUSION)

Fusion power—harnessing the power of the sun itself—has been a goal of energy scientists since the early 50s. Unlike fission, which takes place when the nuclei of heavy atoms such as uranium split, fusion occurs when two nuclei—usually of light atoms such as hydrogen or helium—merge into one, releasing large amounts of energy in the process. Many schemes for inducing fusion have been proposed over the last 40 years, but attrition and a lack of steady funding have reduced the contenders to two serious options: the traditional magnetic confinement and inertial confinement.

Magnetic confinement was first attempted in the early 1950s, and is still the most widely pursued approach, according to John Horgan in the February, 1989 issue of Scientific American. This process calls for heating and compressing a plasma (a gas whose molecules have been stripped of their electrons) confined by a magnetic field, often called a "magnetic bottle." A major breakthrough took place in Russia in

the late 1960s with the invention of a doughnut-shaped containment vessel called the tokamak.

Several tokamaks, including one at Princeton, have created plasmas hotter than the interior of the sun, but none have been able to contain the plasma for longer than an instant, before it gets loose and rapidly loses temperature and density. All of the machines in existence today are at least an order of magnitude away from achieving true ignition: that point where the fusion reactor produces enough heat to maintain its own reaction.

Inertial confinement is a spin off of laser research done in the mid-1960s. Instead of modeling the sustained reaction of the sun, as magnetic fusion, inertial confinement aims to recreate in miniature the thermonuclear explosion of the H-bomb. The idea is to blast a small capsule of deuterium and tritium from all sides with laser radiation. The resulting implosion makes the fuel so dense and hot that it ignites. Almost all work on inertial confinement is now done as part of weapons research, so it is hard to get facts on its progress. Experiments have been done at the Nevada test site using weapons-generated X-rays to ignite test capsules. However, work on a usable "driver" that can produce the same result has not been markedly successful.

The primary advantage of fusion generated power is its potential for generating almost unlimited power. All proposed schemes under consideration also generate far less initial radiation than fission reactors, and the waste products are both less radioactive and have shorter half lives than those produced by fission reactors. Depending on the fuel used, radiation levels can be reduced by several orders of magnitude. A deuterium-helium 3 fuel, for example, would burn without producing any neutron radiation at all. The reactions used in fusion plants would also be fail-safe; any damage to the containment vessel would end the reaction instantaneously.

The biggest disadvantage of fusion power is that the technology simply isn't sufficiently developed to be a practical alternative as yet. According to best estimates, usable fusion power is still at least a decade away. Many of the fuels proposed for various fusion reactors are rare on Earth, or must initially be made in breeder fission reactors. The start-up power requirements and control systems have increased many times over recent proposals, to the point where fusion plants are now seen as being as large and as complex as current fission reactors.

The Energy Department currently plans to build a tokamak reactor at Princeton, using a tritium-deuterium plasma, that will be available for experiments by 1996. This reactor does not include any facilities for converting the energy generated to electricity.

The U.S., the U.S.S.R, Japan and a European consortium are considering banding together to build a prototype generator called the International Thermonuclear Experimental Reactor (ITER), that could be operating early in the next century.

Workers on inertial confinement reactors are still disagreeing on basic design strategies, and are at least a decade behind magnetic confinement systems.

In the near term, fusion power is still a dream. In the long run, funding will be the key. The day when commercial quantities of fusion generated electricity will reach the public is at least 20 to 40 years off.

INCREASED HYDROELECTRIC POWER

Conventional hydroelectric systems operate by transforming the energy and pressure contained in falling water into electrical energy through water wheels or hydraulic turbines.

The Energy Commission has classified hydroelectric projects into five categories: run-of-river, diversion, storage, pumped-diversion, pumped-storage, or combined pumped-storage. Facility efficiency ranges from 85–90%.

Hydroelectric power has an established record of lower total costs than either fossil fuel or nuclear plants. It does not involve massive air quality or waste disposal issues. It relies on renewable energy resources. Hydroelectric power is a competitive energy option under most conditions for utility applications.

Hydroelectric power is dependent upon the flow and pressure of water. During drought periods, or times of reduced flows power generation varies. Therefore, hydroelectric power is not consistent for load management purposes.

Depending on the location and application, project design could require the costly installation of large pipes to obtain maximum water flow and pressure. Proximity and capacity of transmission lines are also a major consideration. Long-term financing and suitable resource siting are two other constraints.

Environmental issues to be addressed at hydroelectric installations include: adequate fishery bypass flow, partial dewatering of a portion of the waterway, blocking fish passage, diversion of fish through powerhouse, destruction of wildlife habitat and white water recreation, siltation, coordination of projects in the same watershed, and increased human activity in the area.

The Energy Commission reported in 1988 that over 260 projects were operating in California.

Projects at existing hydraulic structures are preferred resources because they have less potential for adverse environmental effects than undeveloped sites.

Hydroelectric technology is commercially available under most conditions. Location of the water source and design dictate the productivity of the end use.

The Energy Commission has termed hydroelectric power as a fully-developed, beneficial technology that is commercially used and will not require further state policy action to promote its use. However, the current energy market does not allow new hydroelectric projects to be cost-competitive.

WASTE TO FUEL

Landfill gas recovery is based upon the natural degradation of municipal solid waste by anaerobic microorganisms in sanitary landfills. Low pressure wells (ranging from one to three feet in diameter), are drilled into the landfill and connected by a pipe system. These are placed dependent upon the size, location and moisture content of the waste. A low vacuum is used at each well to extract the gas, with the rate of production and composition of gas being dependent on the composition of the waste. Once the gas is collected, it can be processed into higher grades of gas for use in generating steam or electricity.

Landfills produce an average of .075 cubic feet of gas for every pound of garbage, producing 50% methane, 50% carbon dioxide and traces of other gases. This gas must be treated prior to burning, with the type of treatment depending on how the gas will be used. Once the gas is cleaned, it has higher heating potential and therefore increases in value. Usually two grades of gas can be obtained from the treatment process. Medium gas can be used for boiler fuel and small scale electricity producing plants, while the higher grade of gas are piped to facilities using natural gas.

Municipal solid waste is a problem in California, with most sanitary landfills reaching capacity within this decade. Recovery of landfill gas will reduce emissions into the surrounding soil and atmosphere, as well as slightly reducing the total volume of the fill. This technology is a cost competitive energy option, with commercial technology available under most conditions.

Initial set-up of a gas recovery plant may be costly. Upgrading the gas obtained from direct recovery will have a direct effect on its potential end use. The Energy Commission indicates that methods of handling and disposing of landfill gas condensate need to be further researched. Access to a natural gas pipeline system or suitable industrial users can be an additional constraint.

There are over 30 landfill gas recovery projects located in California, with Puente Hills the largest facility currently operating. The Energy Commission indicates there are several commercial developers and suppliers on the market.

Landfill gas conversion is expected to more than triple in California over the near term. Tests are currently in progress to demonstrate the possibility of using landfill gas in place of natural gas in an advanced fuel cell application. New landfills should be designed to include a gas recovery system; however, future demand will depend on statewide regulations requiring landfill gas collection systems.

TIDAL ENERGY

Ocean energy—power generated by natural tidal action—appears to be a promising source of additional energy. Tide mills have provided mechanical power for centuries.

The first major hydroelectric plant to use tidal energy went into operation on the Rance River in France, November 26, 1966. Designed in 1959, the Rance River project cost approximately $100,000,000.

In Soviet and French plants, an upstream basin or retaining bay is created by cutting an estuary or bay with a dam. Water rushes through opened sluices at incoming tides and the sluiceway is closed when high tide is reached. Water releases at low tide through turbines (in which the power is generated) into another basin or back to the sea. Using reversible blades, the turbine generates power at ebb and flood tides, as the reservoir empties and fills.

By choosing the times to open and close tide gates, power can be synchronized with peak demand periods of the day. Though tides are precisely predictable, they are distorted by land masses, narrow water passages and shallow depths.

There is some similarity between a tidal power plant and a hydroelectric plant. However, the tidal power plant copes with a two-directional flow, salt water and tides that

are predictable and consistent, while rivers only flow in one direction, are fresh, and go through flood and drought periods.

Tidal plants have no related fuel costs. Once the plant is operating, its capital investment can be recovered and it continues to produce cheaper electricity. Tidal energy can, therefore, be more economical than nuclear or thermal power.

Additional advantages include the dependable power supply and possible use of the dam as a road or railroad right of way.

The main deterrent to harnessing tidal power is economics. Startup costs for the dam and turbines along with environmental concerns delay widespread use of tidal power.

Large and expensive structures are required to impound water against a poor power return from the low maximum head (or pressure) available from the tides at most sites.

Environmental effects may include impacts to a variety of birds and fish that are dependent upon changes in tidal flow and range. Visual and recreational resources may also be impacted.

According to Tidal Energy, it is difficult to justify a tidal plant on economic grounds solely on savings in fuel oil cost. There must be a minimum reliable output to enable it to be regarded as an alternative to a standby thermal plant of similar output.

Economic problems have prevented the development of tidal power plants. Canadians have studied several sites in the upper end of the Bay of Fundy for a large plant, but, economic and environmental problems cause concern.

Two small tidal power plants are currently operating; one is across the mouth of the LaRance Estuary in Northern France, and one is in Russia; both have been operating over twenty years. There are also small plants operating in China, but no details of them are available.

The major hydroelectric plant on the Rance River in France continues to operate with very limited impacts.

Construction of a tidal plant in the United States is further from reality than in Canada, Korea, or elsewhere. However, as energy concerns continue, tidal power, may be a power source of our future.

THERMOCLINE

The world's largest collector of solar energy is the ocean, which absorbs solar radiation equivalent in heat content to approximately 250 billion barrels of oil (Scientific American) every single day. Several countries continue to pursue conversion of this energy into electricity. This technology, called ocean thermal-energy conversion (OTEC), utilizes warm seawater as the source of thermal energy in an OTEC system.

There are two ways in which warm seawater generates electricity. In one, the warm water evaporates a working fluid with a low boiling point (closed cycle system). In the other, the seawater itself boils in a vacuum chamber (open system). For the open system the pressure is lowered and the chamber reduces the boiling point of the water. In both instances, the resultant vapor drives a turbine which generates electricity. Cold water is drawn upward from depths of approximately 600–1000 meters which condenses the working fluid and completes the cycle. Temperature differences of

approximately 20° C must exist between the warm upper layer and the deep water so that useful amounts of net power can be generated.

The vapor that is discharged from the turbine at low pressure continues through a second heat exchanger (the condenser) that is cooled by water being pumped up from the depths of the ocean through a cold-water pipe. The pumps then send the condensed fluid back to the evaporator to begin the cycle once again.

For the open-cycle system the warm seawater boils violently in the vacuum chamber producing low-density steam. Extremely large amounts of warm water must be pumped through the plant in an effort to generate enough steam to run the turbine. The cycle is complete when cold seawater condenses the steam.

A thermocline plant can be on land, on a moving ship, or just offshore. The electricity may be delivered to a utility grid or employed at the site to manufacture other products such as hydrogen, methanol and refined metals.

The cold-water generated by the OTEC system contains nutrients necessary to sustain large quantities of plankton and algae that support animal life in marine ecosystems. This cold water which is pumped up by OTEC generated electricity can support marine farming operators. Additionally, this water has other secondary uses such as refrigeration and air conditioning.

Early systems consumed more power than they were able to generate and waves destroyed the cold-water pipes as they were being deployed. Other complications included corrosion of the system apparatus by seawater and fouling by marine organisms.

In the open-cycle system, low pressures create problems which can include the tendency of dissolved gases to evolve out of the seawater. As the gases cannot be condensed, they may render the system inoperable unless they are continuously removed.

Experiments are still underway to improve various aspects of the OTEC systems.

During the 1970s the United States, as well as other countries, devoted serious attention to OTEC. Mini-Otec, a closed cycle system mounted on a barge moored off the island of Hawaii, was the first OTEC plant to produce a net output of electric power. The plant, operating for 10 days at a time during a four month period, generated 50 kilowatts of gross power and 15 kilowatts of net power. Another system, OTEC 1, was installed on a Navy tanker and proved the validity of the heat exchanger and that a plant can operate by moving at low speed through tropical waters.

Sometime later a closed cycle system was built in the island republic of Nauru in the Pacific. Using freon as the working fluid, the plant operated intermittently from October 1981, to September 1982, generating 100 kilowatts of power (35 net kilowatts). These pilot plants, all testing OTEC systems, were not expected to produce the amount of power that would be expected of commercial plants. The Nauru plant was the last field test of such a system, but work on OTEC components continue.

In 1981, Hawaii deployed a long small polyethylene pipe at the National Energy Laboratory of Hawaii that provides the world's only manmade, continuous supply of cold water from the deep ocean. This is the location of the

primary research and development center for conducting experiments on OTEC systems.

According to Scientific American (January 1987), two types of systems are nearing efficient power generation and commercialization. One operates as a closed cycle system, the other operates as an open cycle system.

The Argonne National Laboratory has adopted a modified brazed aluminum heat exchanger that tests show will last for approximately 30 years, with a thin protective coating, in a corrosive marine environment. They also discovered that fouling should not be a problem for parts of the plant exposed to cold seawater only; and, regarding warm seawater, fouling can be controlled by intermittent chlorination. However, according to Scientific American (January 1987), these results have yet to be applied in a closed-cycle pilot plant.

Regarding closed cycle plants, the United States is researching improvements on the heat exchanger which would decrease costs by approximately 20%.

Plans are underway for closed cycle pilot plants in Hawaii, Tahiti, Bali, and for a floating British plant, although financing appears to be the major holdup. According to U. S. estimates, a 50-megawatt plant would cost approximately $200–$500 million.

Regarding open-cycle systems, federal support is sponsoring research. Although these systems have not been developed as fully, open cycle systems appear to have some advantages over the closed-cycle system. Open systems do not require freon or ammonia as a working fluid. They have less expensive heat exchangers that are potentially more effective, and their heat exchanger can be composed of plastic rather than metal making it less susceptible to fouling in warm seawater.

SYNFUELS

Synthetic fuels, or synfuels, include a variety of fuel raw materials and fuel products. Coal-based fuels, synthetic natural gas, methanol, ethanol, oil shale, biomass and other clean burning fuels produced from petroleum coke and heavy crude oil are all classified as synthetic fuels.

Synfuels can be used as a fossil fuel replacement in automobiles, industrial boilers and electric power plants.

Synfuel plants require a major capital investment and pose major environmental considerations. According to the CEC 1981 Biennial Report, shale oil and coal synthetics two–four barrels of water for every barrel of fuel produced. As most shale oil and coal resources are found in dry regions of the western U.S., new water projects would be required. Waste disposal, unknown air quality impacts from burning certain types of synfuels, and massive population growth in thinly populated Rocky Mountain areas are also of concern.

The federal government attempted to overcome these obstacles by the creation of the U.S. Synthetic Fuels Corporation (SFC). According to the California Energy Commission's (CEC) 1981 Biennial Report, the SFC was responsible for preparation of a comprehensive synfuels program which would result in a significant production of synfuel. Production estimates ranged from 500,000 barrels/oil equivalent/day proposed in 1987 to nearly two million barrels by 1992. The SFC would also acquire significant financial obligations in the form of fuel purchase

agreements, price guarantees and loans to facilitate synfuel production.

Fewer beneficial effects were seen and the SFC was eventually terminated in 1985, even though the nation is more dependent than ever on imported fuel.

The Great Plains Plant was the nation's first commercial synthetic fuels plant, but because of difficulties between the U.S. Department of Energy (DOE) and the plant's sponsors, it was abandoned.

A brief discussion follows on some of the more well known markets for synthetic fuel. Methanol and biomass will be covered separately in the Alternative Fuels Section.

Ethanol

Ethanol, or grain alcohol, is produced primarily from corn and barley. It is used as a transportation fuel, replacing gasoline by close to one percent. It has some of the same characteristics as methanol and is considered to have a higher energy content than methanol.

Ethanol is considered less toxic than gasoline. It possesses a higher octane rating, produces fewer hydrocarbon emissions, and contains no known carcinogens.

Dean McIlroy, Director of North Dakota's Agricultural Products Utilization Commission reported that in 1985 there were over 150 ethanol production facilities in the U.S. Of those 150 plants, 20 plants provided 90% of the total ethanol production. It is considered highly unlikely that many of these plants will achieve commercial success given the current state of agriculture and the low price of petroleum.

While most production facilities are located in the Midwest, California has three operating ethanol plants producing approximately eight million gallons a year, according to the California Energy Commission (CEC).

The CEC reports that ethanol has been and will continue to be economically viable as a gasoline blending agent. Other research indicates that despite federal tax incentives, without continued federal assistance ethanol is likely to cost twice as much as gasoline by the year 2000.

Oil Shale

Oil shale involves special processes which produce petroleum from rock. Oil shale deposits are primarily located in Utah, Colorado and Wyoming. The Green River oil shale formation is said to contain the equivalent of more than two trillion barrels of oil.

California is said to contain important undeveloped oil shale resources. Deposits were estimated to be approximately 300 million barrels. The CEC reported in 1981 that a 100,000 barrel/day oil shale processing facility would require a capital investment of between $3–5 billion.

Popular Science (September 1987), reported studies of a new technology which is capable of producing 30–60% more oil shale per operation than was previously thought. This technology is considered most attractive to energy companies concerned about finding alternative replacements for oil.

Research indicates that if efficient development is possible, oil shale conversion could provide 100 years of usable petroleum, at the current rate of consumption.

Natural Gas

Synthetic natural gas is considered a viable synthetic fuel. It possesses the same chemical composition as natural gas and, along with Low and Medium-BTU gas, can easily replace oil in industrial boilers and electric power plants.

Technology exists now for using compressed natural gas as an effective and economical transportation fuel alternative. The CEC 1989 Biennial Report indicates that significant supplies of natural gas, along with its clean burning characteristics, point to its use as part of a short-term approach to reduce California's petroleum dependency.

Sluggish performance, bulky storage needs, high initial costs in equipping vehicles and supply stations are cited as the main disadvantages to the use of natural gas as an alternative transportation fuel.

Hydrogen

Hydrogen is produced mostly from natural gas through a chemical process and is considered by some to be the most environmentally preferred alternative fuel. It is primarily used in the aerospace industry.

According to a January 1990 Popular Science article, hydrogen is the only alternative fuel under consideration that does not produce carbon dioxide when burned.

Drawbacks to hydrogen-powered vehicles are drivability and safety problems.

Research and development continues to focus on lowering the costs of hydrogen production through the application of solar technology.

Commercial development of synthetic fuels has been hampered by technological, financial and environmental problems. Most experts feel development will have to wait until it becomes economically attractive. How scarce will petroleum have to become for economic development of synthetic fuels? Most research indicates this will be several decades away.

FUEL CELL ENERGY

A fuel cell operates much like a storage battery. It produces electricity by an electro-chemical reaction between hydrogen and oxygen in which water is converted to electricity and hydrogen.

There are three components to the fuel cell powerplant. The fuel processor, the fuel cell power section and the power conditioner. The hydrogen is removed from the fuel by the processor and then fed to the fuel cell power section. Here the cells are stacked to form a powerplant. Small "stacked" power plants would be used mostly for multi-family dwellings, commercial buildings and light industries. The lead time to set up such an installation is approximately two years. The energy efficiency is approximately 36–40%.

Larger fuel cell stacks could be used by electric utilities and industries for use in cogeneration facilities. They require a three–five year lead time to install, and require 1/2–1-1/2 acres to operate. The energy efficiency is about 40–44%. The lifetime of a large-stack fuel cell power plant is 20–30 years.

This form of alternative energy uses renewable resources. Its range of uses includes heat for domestic hot water, space heating, and low-level process heat for industrial uses, all the way to subsidiary utility power generation. Overall, fuel cells generate electrical power efficiently with fewer environmental impacts than combustion technologies.

Fuel cells were originally developed by the United States as part of the space exploration program. Historically, fuel cells have been very expensive. The fuel cell power section is the most expensive part of the operation, requiring 40% of the total cost. Fuel cell energy is relatively unmarketed and it will take some time before this technology earns the confidence of investors. Operating and maintenance costs, as well as life and reliability, will play key roles in the development of this market.

Fuel cell technology is still not widely used commercially, with its utilization still facing research, development and deployment issues.

In 1986, the Energy Commission reported field testing of fuel cells by the Gas Research Institute for use in stationary source applications. Southern California Edison and Pacific Gas and Electric Company are the local utilities participating in the testing process.

The Energy Commission reported in 1988 that there were eight projects sponsored by utilities. In terms of air emissions, fuel cells powered by methanol or natural gas are very clean. Methanol is much easier to convert to hydrogen than natural gas; however, there are economic and distribution problems to overcome before methanol becomes the fuel of choice. Use of the demonstration units should bring limited commercial application.

COAL GASIFICATION

Coal gasification is a process by which coal is heated to form fuel gas, liquid hydrocarbons, and a solid residue called char. In the mild gasification process coal is heated, without oxygen, to between 1100° and 1500° F. In larger-scale applications, coal gasification involves heating coal to much higher temperatures in an environment rich in oxygen.

According to a report by the Congressional Office of Technology Assessment (OTA), coal gasifiers have been commercially used since the early 1800s. Due to the low cost and availability of natural gas, interest in coal gasification was maintained at a low level. However, greater interest continued overseas where circumstances favored the development of this technology.

The 1970s brought renewed interest in both surface and underground gasification. Coal gasifiers offered important advantages—greater reliance on vast reserves of domestic coal and less dependence on oil and gas. Environmental impacts were considered less severe than conventional coal-fired equipment.

Combining a coal gas with a combined-cycle system appeared to meet growing demand for efficient energy generation. This formed the basis for what is known as the Integrated gasification/combined cycle (IGCC) plant.

Principal corporations developing gasifiers include Texaco, the Shell Corporation, Allis Chalmers Corporation, Dow Chemical, British Gas Corporation, Kellog Rust, and Lurgi Gesellschaften.

In mid-1985, Southern California Edison Company and Texaco bagan the Cool Water Demonstration Project in Southern California as a joint effort. According to OTA, it is the world's first demonstration of an IGCC system using commercial scale components. Indications are that the plant is considered a success in terms of construction schedule, cost and operation.

The Tennessee Eastman Corporation Coal Gasification Plant is also considered an initial

success. Plans for other IGCC plants are underway in the U.S. and could be operational in the 1990s.

Integrated coal gasification offers important advantages:

- Greater reliance on vast domestic coal resources;
- Less dependence on oil and gas;
- Environmental impacts considered to be less severe than conventional coal-fired equipment;
- Liquid hydrocarbons produced have potential for producing valuable feedstock for chemical production;
- Phased construction which allows some production of electrical power before entire plant is completed;
- Less land and water required than a conventional coal-fire plant;
- Coal gasification plants could be sited near coal mines to cut down on transportation costs.

Disadvantages of the IGCC plants include:

- The likelihood of long lead times for early commercial units because of regulatory delays, construction and operational difficulties;
- Limited experience may constrain deployment of future plants;
- Environmental concerns with production of significant amounts of solid waste; however, new research and development applications have the potential to reduce this amount.

An article by T. M. Beardsley in the December 1987 Scientific American reported that the Federal Department of Energy (DOE) had awarded four contracts for further studies of mild gasification and its economic prospects. If results of the studies are positive, it is hoped that DOE will commission a demonstration plant capable of processing 1,000 tons of coal a day.

Development and demonstration schedules appear adequate to allow IGCC technologies to be a viably commercial alternative in the 1990s. The economic uncertainty of transporting coal from producing states is a major obstacle to coal facilities being located in California.

Underground coal gasification is still considered unproven. European research exceeds that done in the United States, though conditions appear far more favorable for underground coal gasification mining in the western U.S. Some research indicates that this method provides substantial benefits to warrant further research and development.

OTA reports that unless strong steps are taken by government and major utilities to work more closely, there may be insufficient time for IGCC technology to make a significant contribution before the year 2000. Projects would have to be initiated no later than 1993 in order to be operational within the 1990s.

Dwain F. Spencer, Seymour B. Alpert and Michael J. Gluckman, authors of the July 1989 Chemtech article, "Coal Gasification Plus," indicate that,

> Exciting possibilities for improving the performance of gasification-based systems are being offered . . . If we add the potential for producing key coproducts such as methanol, ammonia, hydrogen, or oxychemicals, the economic viability and opportunity for gasification-based plants appears unlimited.

METHANOL

Methanol is one of the most well-known alternative fuels currently being researched, developed and used in automobiles. Methanol is formed by a process which increases the chemical reaction of carbon monoxide with hydrogen. Raw materials, primarily natural gas and coal, provide the necessary carbon monoxide. Natural gas, reacting with water or oxygen, forms carbon monoxide and hydrogen. Natural gas is the most inexpensive way of producing methanol.

The California Energy Commission (CEC) has conducted over 10 years of research on methanol. According to the September 1986 Biennial Fuels Report, the CEC implemented a methanol demonstration program in 1982 which relied on a three part system to remove obstacles to development and demonstrate performance. In 1983 over 500 methanol fueled autos operated in public/private fleets, with approximately 24 fueling stations established throughout the state. After six years of operation, these vehicles have accumulated nearly 22 million miles and most are still in service.

Some of the advantages of methanol are:

- Potential for improving air quality. Methanol burns cleaner than gasoline, thus reducing emission of nitrogen oxides.
- Easily produced from abundant sources of coal and natural gas.
- Of alternative fuels being developed, methanol is least likely to be disruptive to consumers, automobile manufacturers, and fuel distribution industry.
- Higher energy content per volume than other alternative fuels.

Differing opinions exist with regard to ozone reduction levels. In the November 1989 edition of Scientific American, Charles L. Gray, Jr., Director of the U.S. Environmental Protection Agency's Emission Control Technology Division, and Jeffrey A. Alson, Assistant Director, report that "methanol can reduce by 90% the vehicle emissions that form ground-level ozone, the most serious urban air pollutant."

There is environmental concern about methanol and its emission of formaldehyde. In 1993, new California standards will be in effect for formaldehyde emissions. The Environmental Protection Agency reports promising results for advanced catalyst designs which achieve formaldehyde emission rates significantly lower than the 1993 standard.

Methanol use has several disadvantages. It is reported that:

- Methanol produces more formaldehyde than gasoline—estimates range from two to three times more.
- Methanol is highly toxic. Small amounts ingested or absorbed can cause blindness, permanent neurological damage, and even death.

- Methanol is presently more costly than gas on an energy equivalent basis. Twice as much methanol must be used to travel the same distance as in gasoline fueled automobiles. In addition, production costs of methanol on a large scale would have to be passed on to the consumer.

- Methanol would not significantly enhance energy security. If there is widespread use of methanol, foreign sources of natural gas will be available much more cheaply than domestic sources.

- Only about 3% of the nation's automobiles could be fueled with the entire world's production of methanol. According to the American Petroleum Institute, $20 billion would have to be invested in methanol production facilities to supply California alone.

- Increased production from coal could increase carbon dioxide to levels exceeding that burned by gasoline.

According to the Congressional Office of Technology Assessment, methanol fuels were cited as the least cost-effective way of reducing hydrocarbon emissions.

It should be noted that some experts question these disadvantages. In the November 1989 edition of Scientific American, Charles L. Gray, Jr., director of the U.S. Environmental Protection Agency's Emission Control Technology Division, and Jeffrey A. Alson, assistant director, stated that "many of the criticisms are based on 'gasoline clone' vehicles that do not incorporate even the simplest design improvements that are possible with methanol."

Methanol production today comes from 75 plants located in over 30 countries. While existing methanol supply would make only a limited contribution to the fuel supply, it would be significant enough to begin a transition from gasoline to methanol.

According to an article in the December 1989 issue of Scientific American, Tim Beardsley reports that the three U.S. automobile manufacturers—Ford, Chrysler and General Motors—responding to President Bush's Clean Air package, are beginning a joint research program with many gasoline producers to "permit objective assessment of relative reductions in vehicle emissions and improvements in urban air quality . . . achievable with reformulated gasolines and with methanol fuels."

Most automobile manufacturers are developing "flexible-fuel" vehicles which can run on a combination of methanol and gasoline.

M85 was developed from fuel advisory specifications of the Ford Motor Company. A mixture of 85% methanol and 15% gasoline, M85 is being touted as an answer to the Administration's call for use of a "clean fuel."

According to the 1989 CEC Biennial Report, the CEC is encouraging increased use of methanol fuels. General Motors has agreed to deliver 2,200 "flexible-fuel" demonstration vehicles to California by 1992. CEC has begun a program to place 1,000 methanol-fueled school buses in service beginning in 1990. Research and development of heavy-duty methanol-fueled buses and trucks is underway. The CEC is securing fuel supply and price commitments and is expanding the state's network of methanol fueling stations.

Legislation enacted in 1987 created the California Advisory Board on Air Quality and

Fuels whose role is to advise the Legislature on the impacts/feasibility of cleaner transportation fuels in California.

The CEC reports that the Advisory Board recently completed a series of workshops and hearings. While the Board's focus was aimed at different alternative fuels, their findings indicated that "Methanol has the best potential for substantial market penetration into the general vehicle population . . .".

Diesel engine applications of methanol are also being studied for use in heavy duty trucks and vehicles. Significant air quality benefits exist if this technology is successful. However economically, methanol is less likely to be competitive with diesel fuel.

In order for methanol to become a viable alternative, methanol commercialization programs must be continued. Ford and General Motors have plans underway to produce many numbers of methanol demonstration vehicles and institute mass commercial production. The CEC is continuing its research and development of methanol and other alternative fuels. Future application of Corporate Average Fuel Economy (CAFE) performance standard credits is near, and would provide an incentive to auto manufacturers to produce vehicles capable of using methanol.

There is, however, significant skepticism surrounding methanol and a wide range of opinion on it as a preferred alternative fuel. Clearly, the technology and resources now exist to produce methanol. Impacts on air quality, economic viability and supply must be evaluated carefully to determine if methanol can be a safe replacement for petroleum.

Electric Cars

Passenger vehicles can be powered by energy stored in forms other than liquid fuels. Among these alternatives are rechargeable batteries that convert chemical energy into electrical energy, which is then capable of driving a direct current or, through an inverter, an alternating current motor. Many of the first vehicles built around the turn of the century, used battery-electric power.

A hybrid which is an extension of the electric battery concept is a conventional heat engine. This engine can drive a generator that supplies power to an electric motor directly or charges batteries, or both, depending on the needs of the driving cycle.

Generally, electric vehicles are considered one of the cleanest forms of urban transportation. The source of the electricity to charge the batteries could help conserve liquid petroleum if it is from a coal or nuclear generating plant, or any other nonpetroleum energy source.

The limitations of electric cars far outweigh any advantages gained from saving petroleum. Battery systems for automotive application generally suffer from low power and low energy densities which can limit the amount of energy that can be carried and restrict acceleration to the detriment of safety.

Production costs are also high and many prospective battery systems have a limited life. Batteries generally need to be replaced—at high cost—before the vehicle reaches the end of its useful life. In addition, safety problems exist from potential spills of corrosive chemicals in an accident.

A limited number of electric vehicles, assembled by private companies and the auto industry, are on the road providing acceptable service as passenger/delivery vans and compact commuter cars, but there are currently no mass marketed models.

Other electric conveyances also exist for industrial goods movement, recreational uses, and personal transportation for the disabled and elderly over a short distance.

General Motors' limited production of a medium Griffon electric van has been in testing and demonstration service by a number of utility companies since 1984. This initial testing period was successful, and GM has been prompted to initiate United States production of a full-size electric van. The first prototypes of this full sized van are being used by Southern California Edison and operate on an improved lead-acid battery that should easily adapt to advanced batteries when available.

Widespread use of battery-electric vehicles will greatly depend on the performance of battery systems. Major "breakthroughs" may be somewhat unlikely as fuel cells technology will probably progress and be more attractive by the time the battery systems are greatly improved. Electric vehicles that don't burn fuel at all and don't spew emissions into the air may be a real possibility one day, and certainly an environmental advantage.

Recent breakthroughs of heat–to–electric energy devices have made such cars possible. Applications for use of such vehicles are now being developed.

It is likely that the production of such cars would be less expensive than that of cars using new fuel such as methanol.

Any approach that could reduce vehicle emissions will continue to be examined. According to the Energy Commission, recent progress has prompted new activities in California. Current efforts are underway to develop passenger and cargo electric vehicles for commercial use. Efforts are also underway to produce nickel iron batteries. Extended vehicle range, lower cost, higher power output, and lighter weight are some of the objectives of these new batteries.

If availability of petroleum declines much more than expected, electric cars will become a more viable energy alternative.

Mass Transit

Mass transit can be classified as the de-emphasizing of the role of the private passenger car, especially in relation to commuter travel. According to a 1988 California Energy Commission Conservation Report, public mass transit is estimated to be three times more energy efficient than use of personal vehicles. However, there are not enough commuters utilizing this mode of transportation and it has grown at a very slow rate over the last 10 years.

Public mass transit is an efficient mode of transportation that can help reduce traffic congestion, air pollution emissions and fuel consumption. According to the Energy Commission, each passenger trip can save as much as two-thirds of the fuel consumed by the same trip in a single occupant vehicle.

Along with these advantages, incentives/advantages through programs for mass transit commuters include preferred parking for carpools/vanpools, establishment of flextime and shuttle bus provisions.

The expense of building mass transit systems, along with current land practices make implementing such systems a rather difficult undertaking. Efforts to make these systems more appealing to the public may be difficult as long as parking is available and oil prices are relatively low. Additionally, personal vehicle users prefer the flexibility of having access to their own transportation. For many commuters, service is not frequent enough, too much time is involved in travel, different types of public transportation are not integrated, and improvements in service amenities are needed. These improvements could increase the desirability of public transit.

Local governments, including Sacramento, are adding to existing light rail systems. These facilities have greater appeal to the public than other forms of mass transit; however, total impact on congestion will probably not be felt in the near future.

In December 1987. the South Coast Air Quality Management District approved a program that requires thousands of companies in the Los Angeles Air Basin to develop trip reduction plans. Even though other local governments have set up similar programs, this is the largest effort ever undertaken.

Many government agencies, private businesses and industry, and the public at large, are needed to develop a strategy to address the problems of transportation energy supply and use. Several state agencies, including the Energy Commission, the Department of Transportation and the Air Resources Board, as well as several local agencies, are laying the groundwork for such efforts.

Superconduction

Strictly speaking, superconduction is not an energy alternative, but an alternative user of energy. It has the potential to alter the ways electrical energy is generated, stored and used.

Heike Kamerlingh Onnes discovered superconductivity 80 years ago when he cooled mercury with liquid helium down to four degrees Kelvin (approx. -454°F) and discovered that the metal lost all electrical resistance. Fifty years went by before researchers discovered that alloys of niobium-titanium and niobium 3-tin could carry useful currents. But these materials still had to be cooled down to 4°K with expensive liquid helium, greatly limiting any applications.

Then, three years ago, several ceramic oxides were discovered by different groups that became superconducting at temperatures of 60–90°K, a temperature that can be achieved with inexpensive liquid nitrogen.

Many elements can be either normal conductors or superconductors; a superconductor has zero resistance and can sustain a direct current without losing power or generating heat. Those substances which can be in either state have a "transition temperature" above which they are normal, and below which they are superconducting.

What is the importance of superconducting at 77°K, rather than 4°K? It is less expensive. To keep a superconductor working one must continually replace coolant vaporized by heat leaking in from the outside. This loss would cost $50,000 per year for liquid helium at today's prices, compared to $35 per year for liquid nitrogen. This is not very significant for large applications, where the cost of refrigeration is a small fraction of the total cost, but it is very significant for medium or small applications.

Several applications using the principal of superconduction are discussed briefly below, but it is important to realize that new applications are likely to be found as new materials are tested, fabricated and placed on the market. Questions that need to be answered include how "workable" the new materials are; can they be drawn into wires, can they be made flexible without losing their properties and can they be shaped into industrial configurations? Working current loads will have to be determined and tested under a variety of conditions as well. But the principles of superconduction are already tested and being used, it is only increased practicality that awaits.

It is in connection with magnets that the new high-temperature materials are most attractive. Most modern magnets used in industry, power generation and transmission, medicine and science are electromagnets made by winding an insulated copper wire around a soft iron core. Superconductors have the potential to carry large currents and to dispense with the heavy core. Such magnets are already being used in hospitals; they are the heart of the new magnetic resonance imagers being used as a major diagnostic tool.

Magnets are also important in generating electricity. Small scale superconducting generators already built in the U.S. and Japan indicate that such generators will operate at 99.5% conversion efficiency.

The transmission of electricity on large utility networks using superconduction technology has also been studied. Where electrical lines are already buried, superconducting lines can be economically viable. Brookhaven National Laboratory has built and tested a 1,000 megawatt ground level line cooled with helium, proving the concept feasible.

Electrical storage on regional grids is another area where superconduction is potentially useful. A full scale superconducting magnetic energy storage (SMES) unit has been designed to store about 5,000 megawatt-hours of electricity, with the ability to charge or discharge at a rate of 1,000 megawatts per hour. The system would be a major engineering challenge, and was estimated in 1987 to cost about $1 billion. On a smaller scale, SMES could be used to smooth the transmission of power generated by highly erratic sources, such as an array of windmills. Such a device was built by Los Alamos National Laboratory and used from 1983 through 1984, where it performed well.

One of the most widely discussed uses for high temperature superconductors is the maglev (magnetically levitating) train. Such a vehicle can travel at high speeds, suspended above a guideway by magnetic forces. A system has been developed in Germany, where the train travels at 250 miles per hour, but it is inherently unstable, and must be continuously controlled by computers. Japan's National Railway is developing a stable version that will be operating within the next few years. Because the cost of the entire system is so high, the difference between high- and low-temperature superconductors is not much of an issue here. A line from Sacramento to Los Angeles, for example, could cost from $1.5 billion to $4.5 billion (Wolsky, et. al., 1989), with the vehicles costing only 10 per cent of the total, and the refrigeration accounting for only one per cent. Could such a system attract enough riders to make it viable? Possibly. The train's high speed would make it competitive with air travel on

trips of 60 to 400 miles and, if the system went into existing airports, would not entail a change in travel habits.

Small scale use of superconduction in industry also offers potential payoffs. Powerful magnets are used in industry to remove impurities from food and raw materials, and the first superconducting magnetic separator was put into place in 1986. This system operates on about one-fifth the electric power used by a non-superconducting system. Another use for superconduction is refrigeration in food processing plants. Such devices would be more compact, twice as energy efficient, and cheaper to operate than conventional systems. They would also serve as an alternative to chlorofluorocarbon based systems, implicated in atmospheric ozone reduction.

Other uses and advantages of superconductors are certain to appear over the next few years. Many of these are not foreseen at present, and will appear as "breakthroughs" in the future. At present work is concentrating on the theoretical basis of superconduction, commercial production of the new high temperature materials, and processing of these materials into commercial shapes such as wire and ribbon.

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GLOSSARY

acid cloud

A cloud high in acid concentrations generated by dioxins resulting from the combustion of fossil fuel.

acid rain

Rain with a high concentration of acids produced by sulfur dioxide, nitrogen dioxide, and other compounds. Harmful to plant and aquatic life and is the result of burning fossil fuels.

aggregate demand curve

Quantities of a product that would be bought given certain prices.

aggregate economy

The market economy taken as a whole.

air basins

Air spaces determined by physical features such as mountain ranges or by boundaries set by ordinances or agreements.

algae

Simple, primitive plants which lack roots or stems, either one celled or colonial forms often found in water or damp places. For example: seaweeds, "pond scum," and thallophyte.

algin

A colloidal polysaccharide made from algic acid used as a stabilizer and emulsifier in foods such as ice cream.

anadromous fish

Fish which live in saltwater and seasonally spawn in freshwater, such as rivers, creeks, or sloughs.

anaerobic microorganisms (679)

Includes tiny plants, animals, and bacteria that live in environments where oxygen is scarce.

angling

Fishing with hook and line.

antifouling

Preventing unwanted growth of animals and plants on surfaces such as ship hulls.

aquaculture

The cultivation or raising of water plants and animals for food or other needs.

arthropod

Any of the largest phylum (*Arthropoda*) of invertebrate animals with jointed legs, a segmented body, and an exoskeleton, including insects, crustaceans, arachnids, and myiapods.

aspartic acid racemization

A means of determining dates on fossil tissue by analyzing the amino acid $COOHCH_2CH(NH_2)COOH$.

associated gas

Gas that is found in association with an oil reservoir.

Athapascan

A family of North American Indian languages. The Hupa and other of the Na-Dena Stock of Northwestern California belong to this family.

Baleen Whales

Whales that feed by straining water through a comb-like structure in the mouth.

bank armoring

Riprap, gunnite, or other means of protecting the bank of a water course or coastline from erosion.

bathymetric

"Bathymetric" maps are topographic maps of the floor of a water body such as an ocean or a lake. Term also refers to measurements of depth.

benthic organisms

Creatures that live on the bottom of the ocean.

bioaccumulation

Accumulation of pollutants in tissues of organisms.

biofouling

Growth of plants and animals on surfaces such as boat hulls.

biomagnification

The increase in the concentration of a pollutant through the food chain; that is, higher-level food chain organisms have higher concentrations of contaminants than lower-level organisms.

biomass

The total mass or amount of living organisms on a particular area.

biota

Animal and plant life.

black sand deposits

Accumulations of black sands often containing gold or heavy minerals found offshore from the mouths of rivers.

brails

Dip nets used for catching fish such as smelt or squid.

break bulk cargo

Goods packed and moved as single parcels or assembled together on pallets typically lifted off ships in slings handled by cranes.

breas

Asphalt deposits in which are commonly deposited and found vertebrate fossils making them valuable in paleontological research.

breeder reactors

A nuclear reactor generating atomic energy and creating additional fuel by producing more fissile material than it consumes.

broodstock

Infant or starter adult organisms used for "seeding." Often used in the context of mariculture, for example, young oysters planted in oyster beds are broodstock.

bryozoans

Minute water animals that form branching, moss-like colonies and reproduce by budding.

California undercurrent

A 40 to 50 km wide current in the Pacific Ocean that flows along the Continental shelf. Its direction is northwest—opposite of the overlying California Current which flows southward.

Cape Mendocino Escarpment

A submarine ridge trending in a west–northwesterly direction created by the parallel trend of the San Andreas Fault, located off Cape Mendocino, California.

cetaceans

Whales and dolphins.

chlordane

A highly toxic pesticide compound that was banned in the 1970's.

chlorinated pesticides

Pesticide compounds with a chlorine base.

closed cycle system

Also known as binary systems which employs a thermal transfer fluid between the well and the power plant in geothermal use.

coal gasification

The process of transforming raw coal into gas by heating it.

coastal zone

A strip of land stretching from Mexico to Oregon along the California coast. It ranges from three miles off the coast, to 1/2–3 miles inland.

coke

A solid residue left after the distillation of petroleum and after most of the gases have been removed from coal. Coal coke is used as an industrial fuel.

coliform

Aerobic bacillus normally found in the colon. A coliform count is often used as an indicator of fecal contamination of water supplies.

common carrier pipelines

Pipeline systems that serve many companies, many of whom may not operate or own the pipeline.

complementary goods

Goods and services that are acquired to maintain, operate, or enhance other goods and services.

container vessels

Ships that transport cargo stored in metal, truck-trailer sized containers.

Continental Borderland

A geomorphic province off the Southern California coast bounded by the north Channel Islands of Santa Barbara, the San Diego coastline to the east, and the Patton Escarpment to the west.

continental shelf

A relatively shallow area in the ocean, usually less than 600 feet deep, that is adjacent to the continents.

Cordell Bank

One of a series of submarine ridges in the Continental Borderland.

croaker

Any of various "drum" fishes that make croaking or grunting sounds.

cultural resource

Includes archaeological sites of all ages—prehistoric and historic, ethnographic traditions, historical records, artifacts, architecture, cemeteries, and other cultural products of historical or social value.

dacthal

A synthetic organic compound with bioaccumulative potential when released to the environment.

desalination

A process of removing minerals from water either through distillation or osmosis.

diatoms

Single-celled plants that have an external skeleton made of silica.

dieldrin

A toxic pesticide compound.

dinoflagellates

Single-celled plants that are propelled by two whip-like structures.

dredge spoils

The unearthed mud and sediment that results from dredging of a waterway.

drilling fluids

Fluids composed of water and various mixtures of "muds" employed in maintaining hydrostatic pressure in well drilling operations to prevent blowouts.

dry bulk cargo

Non-liquid cargo that is not packaged or containerized (e.g. grain, ore, etc.).

ecosystem

A living process. A community of organisms interacting with each other and their habitat.

eggshell breakage

Incidence of eggshells collapsing and breaking in abnormal frequencies commonly associated with concentrations of DDT or other pesticides.

El Niño

A change in ocean currents that causes warm, low nutrient water to move north along the Pacific coast from the equator.

endosulfan

One of several synthetic pollutants with bio-accumulative properties posing potential hazard to human health.

endrin

A highly toxic isomer of dieldrin. It is used in insecticides.

enterococcus bacteria

An intestinal bacteria of the coccal family.

epidermal tumors

Abnormal growth on the outside layers of the skin.

escarpments

A steep slope or long cliff resulting from erosion or faulting.

estuary

An inlet or arm of the sea often formed by the wide mouth or delta of a river where salt water and fresh water mix.

euphotic zone

The upper layer of water that received enough sunlight for plants to exist.

federal offshore fields

Offshore oil fields that are beyond three miles offshore (state jurisdiction) and are within the EEZ.

feedstocks

Petrochemicals produced from petroleum refineries or natural gas processing plants for supply to petrochemical processing facilities.

filter feeding

Feeding by pumping water through tissues that filter material from the water.

fin erosion

The physical disintegration of the fins of fish primarily occuring at the margin and progressing toward the base in advanced cases. A sign of weakened health or illness, can be brought on by a degradation of fish habitat.

fog belt

A strip of California coastline that regularly receives fog that drifts inland from the Pacific Ocean.

freon

A chlorofluoro carbon based gas used as a refrigerant. It is one of the products that destroy the ozone layer in the atmosphere.

front

In terms of marine biology, it means the boundary between two water masses. For meterology, it refers to the boundary between two air masses.

fuel cell

A electrochemical cell which produces energy by the reaction of two fuel liquids such as liquid hydrogen and oxygen to produce direct electric current.

fuel cell stacks

A battery of fuel cells.

fulmars

A gull like bird (*Fulmarous glacialis*) of arctic regions.

fusion power

The creation of atomic energy by the union of light atoms commonly of dueterium to create high energy.

gamefish

Fish that are regularly caught for sport.

gastroenteritis

An inflammation of the stomach and intestines.

geochemical byproducts

Chemical substances that are dissolved solids, or precipitated solids or gases associated with the production of geothermal fluids; silicates, boron, etc.

geologic hazards

A dangerous situation created by events involving movement of the earth's surface such as earthquakes, landslides, and volcanic eruptions.

geomorphic provinces

Physical regions characterized by unique topographic features and geologic structure.

geophysical surveying

Acquisition of subsurface geologic data by various technologies using seismic instrumentation and stimulation equipment (explosives, machines that thump the ground, or other vibrating or sound-generating equipment).

geothermal energy

Heat energy created by a basaltic intrusion. Often used to generate electricity and for direct heating purposes.

gradient

Rate of increase or decrease, slope.

grave goods

Artifacts that are interned with human graves.

grebes

An order of birds (family *Podicipedidae*), that can dive or swim. They typically have lobed, fleshy membranes (webs) along each toe and a pointed beak.

grey water

Waste water which has not been associated with fecal material or sewage.

groins

A strong, low sea wall built at a right angle to the coast to reduce shoreline erosion.

ground water recharge

Replacement of groundwater by natural processes, through injecting surface water into subsurface strata, or by using settling ponds to let water seep underground.

habitat diversity

The range of variety of environmental types.

hazardous wastes

Refuse that poses health risks such as toxic chemicals or radioactive materials.

heat exchanger

Any device, as a radiator or condenser, for transferring heat energy from one medium to another.

heavy crude oil

Unrefined oil that has a low API gravity (less than 20° API).

hemispheric wind

Dominant windflow associated with the northern and southern hemisphere, also known as the "jet stream."

historical location of navigable waterways

Location of navigable waterways at time of statehood.

hot dry rock reservoir

Underground strata of hot rock that lack water. May have the potential of energy production by injecting water into the rock to create steam.

hydroponic agriculture

The growing of plants in nutrient rich solutions, or moist inert material, instead of growing in soil.

inorganics

Matter that is not animal or vegetable; not having the organized structure of living things. Any chemical compound not classified as organic or as lacking carbon.

intertidal

Between the highest and lowest tide.

introduced species

Non-native species that were brought into California by man.

jetty

A wall built out into the water to restrain currents or to protect a harbor or pier.

kelp beds

Large groups of kelp plants growing together.

lease sale

Leasing state owned lands to private citizens for the development of mineral resources, timber harvesting, and geothermal development.

lease-right-of-way

A lease for the use of state lands for the establishment of pipelines, electrical transmission lines, roadways, sewer outfalls, etc.

Levels of Service

Traffic engineering standards for assessing remaining capacity at key streets and intersections.

light crude oils

Thinner, freely flowing crude oil of a light specific gravity (20° API and higher).

lighter aboard ship

A method of ocean transport which uses lighters (i.e., barges) capable of carrying smaller standard sized containers, general cargo or bulk cargo. LASH barges are taken aboard ship or discharged by shipboard cranes.

liquefied petroleum gas

Petroleum gas which is processed and compressed to high pressures forming a liquid state for transport.

liquid hydrocarbons

Fluid compounds with a carbon-hydrogen complex.

littoral cells

Subdivisions of the longshore current flow along a coastal stretch forming closed loops. They often possess a sediment source, deposition zone and a sediment loss zone.

low pressure wells

Oil or gas wells with a low reservoir pressure which require well pumps to produce the wells.

low probability events

Winning Lotto.

low-level radioactive wastes

Refuse that has a low level of radioactivity.

lower atmosphere

From sea level to approximately ten thousand feet, which is the area that supports the biosphere.

magnetic confinement

Magnetic lines of force that will confine a hot plasma in a nuclear reactor. It keeps the plasma away from the walls of the chamber.

mariculture

Marine aquaculture, growing of marine species in the ocean for commercial harvest.

marine snow

Minute organic particulate material (fragments) which is associated with planktonic matter suspended in a water column.

marine terminals

Coastal piers or buoys where tankers load or unload crude oil or oil products.

market imperfections

Those things that aggravate Reaganomics.

marsh intertidal pools

Small, isolated water bodies found in the marsh environment within the tidal zone.

maximum sustainable yield

The amount that can be harvested without reducing the size of the population.

mobile emission sources

Movable mechanisms that produce air pollution such as cars, trucks, airplanes, boats, etc.

native species

Plant or animal species that are native to California.

nekton

Larger aquatic free-swimming animals in lakes, seas, and ponds. Includes creatures such as squid, fish, seals, and whales.

neo-bulk cargo

Commodities generally shipped in large quantities and having some characteristics of bulk commodities. Neo-bulk cargoes in the Bay Area are generally autos, steel products and newsprint.

neurotoxins

A toxin that destroys nerves or nervous tissue.

nonpoint source pollution

Contamination from non-localized sources such as street runoff, aerial fallout, wildfires, ocean vessel discharge, or river storm water.

North Pacific Gyre

The prevalent current or movement of Pacific Ocean waters resulting from the winds, the position of the continents, and the coriolis force (caused by the spin of the earth around its axis).

ocean outfalls

Pipe outlets where waste water is discharged into the ocean.

OCS

Outer Continental Shelf

oil shale

Shale that has a high concentration of oil.

old growth forests

Often used in reference to forests that have achieved a high percentage of old and mature trees.

olephins

Any of a class of unsaturated hydrocarbons such as ethylene (general formula C_nH_{2n})

orthophosphate

A clear, colorless, syrupy liquid or colorless, crystalline solid produced from phosphorous rock. Is used in the manufacture of fertilizers.

osmosis

Diffusion of a fluid through a semipermeable membrane.

Outer Continental Shelf

The margin of the Continental Shelf distant from the continental mass.

Ozone (O_3)

Molecule composed of three oxygen atoms normally associated with the upper atmosphere acting as a protective shield against ultraviolet radiation. In the lower atmosphere it is a byproduct of photochemical smog.

Pacific Flyway

An aerial pathway used by Pacific migratory birds.

paraffin waxes

A mixture of strait-chain, saturated hydrocarbons obtained from distilling oil. Used for making candles, sealing preserving jars, and waterproofing paper.

Paralytic Shellfish Poisoning

A disease caused by eating shellfish contaminated with naturally occurring dinoflagellates that are toxic.

passive solar heating

A means of transferring heat energy from the sun to another medium.

pathogens

Any agent including micro organisms that can cause disease such as bacteria and viruses.

PCBs

Polyclorinated byphenyls. Complex organic compound often used in cooling oils for high voltage electric transformers and other electrical equipment. Highly toxic.

pentachlorophenol

One of several indentified synthetic pollutants and biomagnifying toxins that have potential risk for human health.

petrochemical feedstocks

The supply chemicals produced from petroleum refining available for secondary processing or use in manufacturing.

petroleum stocks

Petroleum resources available for refining.

petroleum waxes

Waxes associated with unrefined petroleum.

phalaropes

A family of small shore birds.

photochemical oxidants

Chemical pollutants which react with CO reactants (e.g. reactive organic gases and NO_2) aided by sunlight creating ozone (O_3).

photosynthesis

The process in plants that uses the energy of the sun to create carbohydrates from carbon dioxide and water.

photovoltaic effect

The generation of electricity at the junction of two different materials in response to visible or other radiation.

phthalate esters

Ester based compounds that are biomagnifiying toxins which are a risk to human health.

phytoplankton

Microscopic plants that drift in the ocean.

pinnipeds

Seals and sea lions, etc.

plankton

Small plants or animals that drift in the ocean.

platform

A construction with a deck to serve as a working platforms for oil well development and production equipment. It is elevated above sea level.

playas

A desert basin that temporarily fills up with water after heavy rains.

pluvial lakes

Lakes that existed in the past when precipitation rates were greater per year. In wet years they sometimes fill with water, only to dry up again when the precipitation rate drops.

point sources

Stationary sources of pollutants from single or individual stationary sites such as industrial factories, quarries, or outfall pipes.

polychlorinated biphenyls (PCBs)

Polyclorinated byphenyls. Complex organic compound often used in cooling oils for high voltage electric transformers and other electrical equipment. Highly toxic.

polymetallic sulphide nodules

Natural accretions often containing nickel, found in concentrations off the California coast.

polynuclear aromatic hydrocarbons

Complex organic molecules with a benzine type molecular structure and hydrogen/carbon components, found in petroleum products.

probable reserves

Statistical estimate to how much oil may be left in the ground.

productivity

The ability to produce plant and animal life.

proprietary pipeline system

A pipeline for exclusive use by its owners or operators.

proven reserves

Identifying economically retrievable oil still in the ground.

province

A geographic region with shared characteristics.

rare-earth metal

Metals composed of rare earth compounds such as cesium, gallium, or iridium.

reformulated gasolines

Gasoline that contains certain additives or is refined in such a way that reduces the emissions of certain pollutants when burned.

reproductive failures

When a species losses its ability to bear viable offspring. This can occur when a species is exposed to certain toxins.

riparian vegetation

Vegetation that lives in the vicinity of streams, rivers, or lakes.

salinity

Concentration of salt molecules often in reference to water.

salmonids

Fish that can be classified as *Salmonidea*.

school lands

Lands granted to the state by the federal government for the use of supporting education usually the sections 16 and 36 in each township.

sea-surface microlayer

A microenvironment consisting of the uppermost layer of the sea to a depth of approximately 50 microns. and the atmosphere just above it.

seamounts

Isolated flat-topped, singular, underwater mountain peaks in the ocean.

sediment load

The amount of sediment suspended in a given water column.

sessile

Non-mobile.

short line railroads

Railroads whose track milage is low. They usually tie a major railroad company line to local industries or ports. Sometimes they serve as a transfer service between main railroads.

shrublands

Large tract of land dominated by woody plants of relatively low height identified as shrubs.

Significant Lands Inventory

An inventory of lands nominated by various government agencies as having important resource values (mineral, cultural, biological). Prepared pursuant to PRC 6370.

slumping

A slow failure or downhill creep of a hillside often caused by a combination of a steep slope and soil saturated by water.

soft bottom

An ocean floor that is sandy as opposed to rocky (hard bottom).

solar cells

Units that use the photovoltaic effect to generate electricity.

Southern California Borderland

An area of complex botto, topography between Point Conception and Cape Colnet, Baja California, offshore to the Santa Rosa-Cortez Ridge.

Southern California Countercurrent

Similar to the California Current, but is located within the Southern California Borderland. It moves in a counterclockwise motion.

straw oil

One of a family of distillate fuels with a boiling point between 350° and 700°F and a flash point of 120°F. Historically, one of the first kinds of fuel oil made.

subarctic

The region south of the Arctic Circle.

subtidal

Below the influence of the tides.

suspended solids

Particulate matter suspended in water.

suspension feeding

Feeding by catching particles in the water.

synfuels

Fuels that are derived from processes of distillation to produce substitutes for petroleum based fuels. Substitute include methanol and coal gasification.

thermocline

Change in the thermal gradient over a measured distance.

tidal flushing

The exchange and movement of water in an intertidal zone or estuary creating a flushing action that provides fresh sea water to the intertidal area.

timber harvesting

Logging.

traffic separation schemes

U.S. Coast Guard designated transit lanes for large commercial ships. For example, the north–south shipping lanes along the coast of California.

turbidity

Cloudiness in the water caused by the presence of particulate matter and microscopic organisms.

underground aquifers

Subsurface strata of rock that contain water or allows free movement of groundwater.

undersea banks

Horizontal subsea features similar to a shelf with the tops generally less than two degrees in slope.

vibrio

Any of various S-shaped or comma shaped micro organisms of the genus *Vibrio* which causes cholera.

waste to fuel

The process of using refuse to generate electricity. For example, burning waste paper or gas produced by landfills to generate electricity.

water column

The mass of water between the surface and the bottom.

water mass

A region of water with shared physical characteristics.

zooplankton

Small animals that drift in the ocean.

Federal and State Regulatory Agencies Involved In Resource Management

Federal Agencies

Endangered Species Committee

Environmental Protection Agency
- National Pollutant Discharge System
- Office of Marine and Estuarine Protection

Federal Aviation Administration

Federal Communications Commission

Federal Energy Regulatory Commission

Marine Mammals Commission

Pacific Fisheries Management Council

Pacific Marine Fisheries Council

U.S. Dept. of Agriculture
- U.S. Forest Service

U.S. Dept. of Commerce
- National Oceanic and Atmospheric Administration
  - National Marine Fisheries Service
  - National Ocean Service
- Secretary of Commerce

U.S. Dept. of Defense
- Dept. of the Army
  - U.S. Army Corps of Engineers

U.S. Dept. of Interior
- Bureau of Land Management
- Bureau of Reclamation
- Minerals Management Service
- National Park Service
- Secretary of Interior
- U.S. Fish and Wildlife Service

U.S. Department of the Treasury

U.S. Dept. of Transportation
- U.S. Coast Guard

California State Agencies

Office of Planning and Research

Public Utilities Commission

Secretary of Environmental Affairs
- Hazardous Substance Cleanup Arbitration Panel
- Office of Hazardous Materials Data Management

Secretary of State and Consumer Services
- Office of Fire Marshal

State Interagency Oil Spill Committee

The Business and Transportation Agency
- California Dept. of Transportation (CALTRANS)

The Resources Agency
- Air Resources Board
- California Coastal Commission
- California Coastal Conservency
- California Integrated Waste Management Board
- California Regional Water Quality Control Board
- California State Lands Commission
- Dept. of Boating and Waterways
- Dept. of Conservation
  - Division of Mines and Geology
  - Division of Oil and Gas
  - State Mining and Geology Board
- Dept. of Fish and Game
  - Fish and Game Commission
  - Wildlife Conservation Board
- Dept. of Forestry and Fire Protection
- Dept. of Parks and Recreation
  - Native American Heritage Commission
  - Office of Historic Preservation
- Dept. of Water Resources
- Energy Resources, Conservation and Development Commission
- San Francisco Bay Conservation and Development Commission
- State Regional Water Quality Control Board
- State Water Resources Control Board

REFERENCES

Abbott, I.A. and G.J. Hollenberg.
1976 **Marine Algae of California.** Palo Alto: Stanford University Press."

Abelson, Philip H.
1990 *Uncertainties About Global Warming.* **Science.** 247(4950): 1529.

Ainley, D. G.
1990 Personal communication. Director of Research, Point Reyes Bird Observatory. Stinson Beach.

Ainley, D. G. and L. Spear, J. Penniman, and C. Strong.
1987 **Foraging Ecology of Seabirds in the Gulf of the Farallones National Marine Sanctuary.** NOAA Technical Memorandum No. NOS MEMD13. Washington, D.C.

Ainley, D. G. and R. J. Boekelheide eds.
1990 **Seabirds of the Farallon Islands; Ecology, dynamics, and structure of an upwelling-system community.** Los Altos:Stanford University Press.

Alameda, County of, Mosquito Abatement District.
1989 **54th and 55th Biennial Report.**

Allen, M.A. and T.J. Hassler.
1986 **Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)—Chinook salmon.** U.S. Fish and Wildlife Service Biological Report 82(11.49). Washington, D.C.

American Petroleum Institute.
1989 **Basic Petroleum Data Book.** Washington, D.C.

Andrews, Mark and S.S. Saluja.
1986 *Energy in the Eighties and Nineties.* **In Search for a Bridge to the Energy Future.** Pp. 11-16. Grand Forks: University of North Dakota, School of Engineering and Mines.

Anonymous.
1990 **International Petroleum Encyclopedia.** Tulsa, Ok.: Penwell Books.

Anonymous.
1989 *Department of Fish and Game Investigates the Planting of Hatchery Reared Pelagic Fish.* **California Aquatic Farming.** California Aquaculture Association.

Anonymous.
1981 *Relating Synfuels Cost to Oil.* **Science News.** 120: 105.

Anonymous.
1989 *Annual Refining Survey.* **Oil and Gas Journal.**
1990 *Annual Refining Survey.* **Oil and Gas Journal.**

Arnold, R.K. and S. Levy, V. Nourse.
1982 **Recreational Activity in California and Ten Regions of the State 1980-2000.** Vol. 1. Palo Alto: Center for Continuing Study of the California Economy.

Arthur D. Little, Inc.
1990 **Santa Barbara County Crude Oil Transportation Analysis.** Prepared for the County of Santa Barbara.

Bada, J.L. and G.F. Carter, R.D. Schroeder.
1974 *New Evidence for the Antiquity of Man in North America Deduced from Aspartic Acid Racemitation.* **Science.** 184: 791-793.

Baily, E. H.
1966 **Geology of Northern California.** California Division of Mines and Geology Bulletin 190.

Bakker, Elna.
1971 **An Island Called California.** Berkeley: University of California Press.

Banks, F. E.
1982 **Resources and Energy.** Lexington, Ma: Lexington Books.

Barber, R. T. and F. Chavez.
1983 *Biological Consequences of El Niño.* **Science.** 222:1203-1210.

Barbour, M. G. and J. Major, eds.
1977 **Terrestrial Vegetation of California.** New York: John Wiley and Sons.

Barngrover, Bruce.
1989 Personal communication. Hatchery Manager, Prairie Creek Hatchery. Orick, Ca.

Barnhart, R. A.
1986 **Species Profile: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)—Steelhead salmon.** U.S. Fish and Wildlife Service Biological Report 82(11.60). Washington, D.C.

Barsky, Christine.
1990 Personal communication. Biologist, California Department of Fish and Game. Santa Barbara.

Bauder, Ellen T.
1987 *Threats to San Diego Vernal Pools and a Case Study in Altered Pod Hydrology.* **Conservation and Management of Rare and Endangered Plants.** ed. Thomas S. Elias. Pp. 209-213. Sacramento: California Native Plant Society.

Bean, L. J. and T. C. Blackburn.
1976 *Social Organization in Native California.* **Native California.** Pp. 99-123. Ramona, Ca.: Ballena Press.

Beardsley, T.M.
1987 *A Mild Alternative? Government Takes a New Look at a Coal Gasification Process.* **Scientific American.** 257: 37.

Beauchamp, D. A. and M. F. Shepard, G. B. Pauley.
1983 **Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)—Steelhead.** U.S. Fish and Wildlife Service Biological Report 82(11.60). Washington D.C.

Bedwell, D. F.
1970 **Prehistory and Environment of the Pluvial Fork Rock Lake Area of South-central Oregon.** Ph.D. dissertation. Eugene, Ore: University of Oregon, Dept. of Anthropology.

Berman, A. J.
1990 *Biomass Renewable Energy.* **Science.** 249(4974): 1227.

Bischoff, J.L. and R.J. Rosenbauer.
1981 *Uranium Series Dating of Human Skeletal Remains from the Del Mar and Sunnyvale sites, California.* **Science.** 213: 1003-1005.

Bonar, S. A. and G. B. Pauley, G. L. Thomas.
1989 **Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)—Pink salmon.** U.S. Fish and Wildlife Service Biological Report 82(11.88). Washington D.C.

Bonnell, M. L. and M. O. Pierson, and G. D. Farrens.
1983 **Pinnipeds and Sea Otters of Central and Northern California, 1980-1983: Status, abundance and distribution.** MMS Report No. 84-0044. Santa Cruz: U.C. Santa Cruz, Center for Marine Studies.

Bradley, Joyce.
1989 Personal Communication. California Department of Health Services, Environmental Management Branch. Sacramento, Ca.

Briggs, K. and E. Chu, D. Lewis, Wm. Tyler, R. Pitman.
1978 **Summary of Marine Mammal and Seabird Surveys of the Southern California Bight Area, 1975-1978.** Los Angeles: Bureau of Land Management.

Briggs, K.T. and K.F. Dettman, D.B. Lewis, W.B. Tyler, D.N. Nettleship, G.A. Sanger, R.F. Springer.
1984 *Phalarope feeding in relation to autumn upwelling off California.* **Marine Birds: Their Feeding Ecology and Commercial Fisheries.** Ottowa: Canadian Wildlife Service.

Briggs, K.T. and W.B. Tyler, D.B. Lewis, D.R. Carlson.
1987 *Bird Communities at Sea off California: 1975 to 1983.* **Studies in Avian Biology.** 11: 74.

Brock, William.
1989 Personal communication. U.S. Fish and Wildlife Service, Weaverville, Ca.

Browning, B.M.
1972 **The Natural Resources of Elkhorn Slough: Their present and future use.** California Department of Fish and Game, Coastal Wetland Series No. 4. Sacramento.

Bryon, A. L.
1969 **Pleistocene Man at Calico.** Second edition. Redlands: San Bernardino County Museum Association.

Burnett, John L. and Mary C. Woods.
1988 *1987 California Mining Review.* **California Geology.** 41(10).

Burns, J.J. and K.J. Frost, L.F. Lowry.
1985 **Marine Mammals Species Accounts.** California Department of Fish and Game Technical Bulletin No. 7. Sacramento.

Calambokidas, J.
1986 **Chlorinated Hydrocarbons in Harbor Porpoise from Washington, Oregon, and California: Regional differences in pollutant ratios.** Administrative Report No. LJ-86-35C. La Jolla: National Marine Fisheries Service, Southwest Region.

California Association of Realtors.
1989 **Matrix of Land Use Planning Measures 1971-1989.** Los Angeles: California Association of Realtors.

California Coastal Commission.
1987 **California Coastal Resource Guide.** ed. Madge Caughman and Joanne Ginsberg. Berkeley: University of California Press.
1988 **Bi-annual LCP Status Report. San Francisco.**

California Department of Conservation.
1979 **California Soils: An assessment.** Sacramento.

California Department of Conservation, Division of Mines and Geology.
1979 **California Surface Mining and Reclamation Policies and Procedures.** Vol. 51. Sacramento.
1980 **Interpretation of the Gravity Map of California and Its Continental Margin.** Mines and Geology Bulletin No. 205.

California Department of Conservation, Division of Oil and Gas.
1977 **63rd Annual Report of the State Oil and Gas Supervisor 1977.** Sacramento.
1982 **California Laws for Conservation of Petroleum and Gas.** Sacramento.
1986 **72nd Annual Report of the State Oil and Gas Supervisor 1986.** Sacramento.
1987 **73rd Annual Report of the State Oil and Gas Supervisor 1987.** Publication No. PR06. Sacramento.

California Department of Finance.
1988 **California Statistical Abstract.** Sacramento.

California Department of Fish and Game.
1969 **Trout of California.** Sacramento.
1979 **Anadromous Fishes of California.** Sacramento.
1985 **Pelagic Shark/Swordfish Drift Gill Net Fishery.** Management Information Document. Sacramento: Dept. of Fish and Game, Marine Resources.
1987 **Review of Some California Fisheries for 1986.** CAL COFI Report No. 28. Sacramento.
1988a **California Natural Diversity Data Base.** Sacramento.
1988b **Review of Some California Fisheries for 1987.** CAL COFI Report No. 29. Sacramento.
1989 **1989/1990 Fisheries Restoration Project Proposals: Salmon projects approved by committee for Proposition 70 funds.** Unpublished list. Sacramento.

California Department of Fish and Game, Endangered Species Section.
1988 **California Least Tern Field Study 1988 Breeding Season.** Sacramento.

California Department of Fish and Game, Wildlife Management Division.
1988 **Brown Pelican Use of the Moss Landing Wildlife Management Area.** Sacramento.

California Department of Food and Agriculture, Agricultural Statistics Service.
1988 **Summary of County Agricultural Commissioner's Reports.** Sacramento.

California Department of Forestry and Fire Protection, Forest and Rangeland Assessment Program.
1988 **California's Forests and Rangelands: Growing conflict over changing uses.** Sacramento.

California Department of Health Services, Vector Biology and Control.
1985 **Laws Relating to Local Agencies Engaged in Mosquito and Vector Control.** Sacramento.

California Department of Parks and Recreation.
1984 **San Diego Coastal State Park System General Plan— Torrey Pines State Beach and State Reserve.** Vol. 8. Sacramento.

California Department of Transportation
1987 **Report on the Status of the Highway Program.**

California Department of Transportation, Division of Mass Transportation, Rail Planning Branch.
1982 **1982 California State Rail Plan.** Sacramento.

California Employment Development Department.
1988 **Agricultural Employment. Calendar Year 1987.** No. 882A. Sacramento.

California Energy Commission.
1983 **California Oil, Gas and Geothermal Resources.** Sacramento.
1985 **Oil and Gas in California.** Sacramento.
1987 **Fuels Report.** Sacramento.
1988a **California Energy Demand 1987-2007.** Sacramento.
1988b **Conservation Report.** Sacramento.
1988c **Energy Development Report.** Sacramento.
1988d **Southern California Gas Company's 1987-88 Curtailment.** Sacramento.
1989a **Energy Agenda, Biennial Report.** Sacramento.
1989b **Fuels Report.** Sacramento.

California Environmental Trust.
1987 **Wildlife Habitat Values of Leslie Salt Company Property Around San Francisco Bay: Summaries of 54 Studies.** Prepared for the Leslie/Interagency Group. San Francisco: California Environmental Trust.

California Mosquito and Vector Control Association Inc.
1988 **1988 Yearbook.** California Mosquito and Vector Control Association, Inc.

California Office of Planning and Research.
1987 **State of California General Plan Guidelines.** Sacramento.

California Office of Planning and Research, and the California Department of Water Resources.
1979 **California Water Atlas.** Sacramento.

California Office of Planning and Research, and the OCS Project Task Force, California Coastal Commission.
1977 **Offshore Oil & Gas Development: Southern California.** Vols. I and II. Sacramento.

California State Lands Commission.
1976 **Hydrocarbon Potential of California Offshore Lands and San Pablo Bay.** Sacramento.
1987 **Inventory of Ungranted Tidelands.** Survey priority study. Sacramento.

California Water Resources Control Board.
1984 **Water Quality Pesticides: A California Risk Assessment Program.** Sacramento.
1987 **Toxic Substances Monitoring Program.** Sacramento.
1988a **Water Quality Control Plan, Ocean Water of California—California Ocean Plan.** Sacramento.
1988b **California Ocean Plan: Amendment of the Water Quality Control Plan for Ocean Waters of California.** Sacramento.
1989 **California Ocean Plan.** Sacramento.
1990 **California Ocean Plan.** Sacramento.

California Water Resources Control Board, Division of Water Quality.
1988 **Nonpoint Source Assessment Program.** Sacramento.

Canby, T. Y.
1979 *Search for the First Americans.* **National Geographic.** 156(3): 330-363.

Canghy, John Walton and Norris Hundley.
1982 **California, History of a Remarkable State.** New York: Prentice-Hall, Inc.

Carter, G. F.
1980 **Earlier Than You Think.** College Station: Texas A & M University Press.

Cass, V.
1972 *Exploitation of California Sea Lions,* **Zalophus californianus,** *Prior to 1972.* **Marine Fisheries Review.** 47: 36-38.

CBEDS Data Collection.
1987 **California Public School District Certified Staff Statistics 1987-88.** Sacramento.

Centaur Associates, Inc.
1981 **Assessment of Space and Use Conflicts Between the Fishing and Oil Industries.** Vols. I - V. Prepared for the Bureau of Land Management. Los Angeles.

Chartkoff, Joseph L. and Kerry Kona Chartkoff.
1984 **The Archaeology of California.** Palo Alto: Stanford University Press.

Chelton, D. B. and P. A. Bernal, J. A. McGowen.
1982 *Large Scale Interannual Physical and Biological Interaction in the California Current.* **Journal of Marine Research.** 40:1095-1125.

Citizens for a Better Environment.
1983 **Toxics in the Bay: An assessment of the discharge of toxic pollutants to San Francisco Bay by municipal and industrial point sources.** San Francisco.

Clarke, R. and O. Paliza.
1988 *Intraspecific Fighting in Sperm Whales.* **Reports of the International Whaling Commission.** 38: 235-241.

Cochrane, S.
1985 *Why Rare Species?* **Outdoor California.** 46(5):17-18.
1986 **Programs for the Preservation of Natural Diversity in California.** Administrative Report No. 84-2. Sacramento: California Department of Fish and Game, Non-game Heritage Program.

Conservation Committee of California Oil Producers.
1980 *Section I: Production Record.* **Annual Review.** Los Angeles.
1981 *Section I: Production Record.* **Annual Review.** Los Angeles.
1982 *Section I: Production Record.* **Annual Review.** Los Angeles.
1983 *Section I: Production Record.* **Annual Review.** Los Angeles.
1984 *Section I: Production Record.* **Annual Review.** Los Angeles.
1985 *Section I: Production Record.* **Annual Review.** Los Angeles.
1986 *Section I: Production Record.* **Annual Review.** Los Angeles.
1987 *Section I: Production Record.* **Annual Review.** Los Angeles.
1988 *Section I: Production Record.* **Annual Review.** Los Angeles.
1989 *Section I: Production Record.* **Annual Review.** Los Angeles.
1990 *Section I: Production Record.* **Annual Review.** Los Angeles.

Corcoran, Elizabeth.
1988 *One for the Road.* **Scientific American.** 259(6): 110.

Corwin, Miles.
1988 *Dirt: Some vendors are cleaning up.* **Los Angeles Times.**

Costa Mesa, City of.
nd. **Local Coastal Plan.** Costa Mesa, Ca.

County Supervisors Association of California.
1989 **California County Fact Book 88-89.** Sacramento.

Crook, S.
1990 Personal communication. California Department of Fish and Game.

Dana, Richard Henry Jr.
1986 **Two Years Before the Mast.** Harmondsworth, England: Penguin Books.

DeCicco, John and James Cook, Dorene Bolse, Jan Beyea.
1990 **CO_2 Diet for a Greenhouse Planet.** New York: National Audubon Society.

DeGoyler and McNaughton.
1988 **20th Century Petroleum Statistics.**

Diamond, S. L. Scholl, J. P. and Hanan, D. A.
1987 **Drift Gill Net Observations for the 1985-1986 Fishing Season.** Administrative Report No. SWR-87-4. La Jolla: National Marine Fisheries Service, Southwest Region.

Dohl, T. P. and K. S. Norris, R. C. Guess, J. Bryant, M. W. Honig.
1978 *Summary of Marine Mammal and Seabird Surveys of the Southern California Bight Area, 1975-78.* **Cetaceans.** 3(2):1-414. Los Angeles: Bureau of Land Management.

Dohl, T. P. and R. C. Guess, M. Duman, R. C. Helm.
1983 **Cetaceans of Central and Northern California: Status, abundance, and distribution; Final Report.** Minerals Management Service OCS Study No. 84-0044. Los Angeles: Minerals Management Service, Pacific OCS Region.

Drake, D. E. and David A. Cacchione, Herman A Karl.
1985 *Bottom Currents and Sediment Transport on San Pedro Shelf, California.* **Journal of Sedimentary Petrology.** 55(1): 15-28.

Edgar, Blake.
1990 *First Californians.* **Pacific Discovery.** 43(4): 26-33.

Edon, C.
1989 *Fixin' it The First Five years.* **Outdoor California.** 50(5): 18-22.

Ellinwood, Jud.
1989 Personal communication. Manager, Humboldt Fish Action Council Freshwater Creek Facility Representative, Steelhead and Trout Restoration Federation. Arcata, Ca.

Emery, K. O.
1960a *Basin Plains and Aprons Off Southern California.* **Journal of Geology.** 68:464-479.
1960b **The Sea Off Southern California.** New York: John Wiley and Sons.

ESA/Madrone.
1982 **Wetlands Policy Assessment: California case study.** Sacramento: State Assembly Office of Technology Assessment.
1984 **Status and Trends of California Wetlands.** Prepared for the Assembly Resources Subcommittee on Status and Trends. Sacramento: California State Legislature, Joint Publications Office.

Estes, J. A. and G. Van Blaricom, J. R. Beddington et al.
1985 *Sea Otters and Shell Fisheries.* **Marine Mammals and Fisheries.** Boston: George, Allen and Unwin.

Evans, P.
1989 *Intensive System Developed.* Aquaculture Magazine. 15(1): 60-63.

Fagen, Brian M.
1987 The Great Journey: The peopling of ancient America. New York: Thames and Hudson.

Fauchald, K. and G. F. Jones.
1972 *Benthic Macrofauna.* Southern California Baseline Study, Final Report. Vol. 3. No. 2.4. Los Angeles: Bureau of Land Management.
1978a *A Survey of Benthic Macrofauna of Five Additional Southern California Study Sites.* Southern California Baseline Study Year II Benthic Study. Los Angeles: Bureau of Land Management.
1978b *Variation in Community Structure of Shelf, Slope and Basin Macro.* Southern California Baseline Study, Year II. Los Angeles: Bureau of Land Management, Pacific OCS Office.
1979 *A Survey of Five Additional Southern California Sites.* Southern California Baseline Study Year II. Vol. II. Pacific OCS Report No. 18. Los Angeles: Bureau of Land Management, Pacific OCS Office.

Ferren, Wayne R.
1985 Carpinteria Salt Marsh: Environment, history, and botanical resources of a Southern California estuary. Santa Barbara: University of California, Santa Barbara.

Fiedler, P.C.
1984 *Some Effects of El Niño 1983 on the Northern Anchovy.* California Cooperative Oceanic Fisheries Investigative Reports. 15(5): 53-58.

Fierstine, H. L. and K. F. Kline, G. R. Garman.
1973 *Fishes Collected in Morro Bay, California, Between January, 1968 and December, 1970.* California Fish and Game. 59(1): 73-88.

Flavin, Christopher and Alan B. Durning.
1988 *Building on Success: The Age of Energy Efficiency.* Worldwatch Paper 82. March. Pg. 23.

Foster, M. S. and D. R. Schiel.
1985 The Ecology of Giant Kelp Forests in California: A Community Profile. U.S. Fish and Wildlife Biological Report 85(7.2). Washington, D.C.

Ganssle, D.
1966 *Fishes and Decapods of San Pablo and Suisun Bays.* Ecological Studies of the Sacramento-San Joaquin Estuary, Part 1. ed. D. W. Kelly. Fish Bulletin No. 133. Pp. 64-99. Sacramento: California Department of Fish and Game.

Gatline, Carl.
1960 Petroleum Engineering Drilling and Well Completions.

Gentry, R.L. and G. Kooyman.
1986 Fur Seals: Maternal strategies on land and at sea. Princeton, NJ: Princeton University Press.

Geraci, J. R. and D. J. St. Aubin.
1982 Study of the Effects of Oil on Cetaceans. No. AA551CT929. Washington D.C.: Department of Interior, Bureau of Land Management.

Glantz, William E. and Peter L. Meserve.
1982 *An Ecological Comparison of Small Mammal Communities in California and Chile.* Dynamics and Management of Mediterranean-type Ecosystems. ed. Eugene C. Conrad, and Walter C. Oechel. Pp. 220-226. General Technical Report PSW-58. Berkeley: U.S. Forest Service, Pac. SW Forest & Range.

Godwin, L.H. and L. B. Haigler, L. J. R. Muffler, R. L. Rioux, R. G. Wayland.
1971 Classification of Public Lands Valuable for Steam and Geothermal Resources. U.S. Geological Survey Circular No. 647. Reston, Va.

Golay, Michael W. and Neil E. Todreas.
1990 *Advanced Light Water Reactors.* Scientific American. 262(4): 82-89.

Goldman, H.B.
1966 Stone, Crushed and Broken: Dimension. Bulletin 191. Sacramento: California Division of Mines and Geology.

Graham, N.E. and White, W.B.
1988 *The El Niño Cycle: A Natural Oscillation of the Pacific Ocean -Atmosphere System.* Science. 240: 1293-1301.

Grambsch, A.
1985 Analysis of the 1985 National Survey of Fishing, Hunting, and Wildlife-associated Recreation: Trout fishing in the U.S. 1985. U.S. Fish and Wildlife Service Report No. 85-6. Washington D.C.

Grinnell, J.
1933 *Review of the Recent Mammal Fauna of California.* **University of California Publications in Zoology.** 40(2): 71-234.

Gunn, Robert D. and S. S. Saluja.
1986 *Underground Coal Gasification: Its role during an energy emergency and its long range potential.* **Proceedings: Search for a Bridge to the Energy Future.** Grand Forks: University of North Dakota, School of Engineering.

Hanan, D. A. and J.P. Scholl, S. Diamond.
1989 **Harbor Seal** *Phoca uitulina richardsi,* **Census in California May-June 1988.** National Marine Fisheries Service Administrative Report No. LJ 89-13. La Jolla.

Hanan, D. A. and S. L. Diamond, J. P. Scholl.
1987 **An Estimate of Harbor Porpoise Mortalities in California Set Net Fisheries, April 1, 1985 Through March 31, 1986.** National Marine Fisheries Service SW Region Administrative Report No. 87-5. La Jolla.

Hanes, Ted L.
1977 *Chaparral.* **Terrestrial Vegetation of California.** ed. Michael G. Barbour and Jack Major. Pp. 417-470. New York: John Wiley & Sons.

Haug, William G.
1962 *The Bering Strait Land Bridge.* **Scientific American.** 206(1): 112-123.

Hardwick, J. E.
1973 *Biomass Estimates of Spawning* **Herring Clupea hangengus pallasi,** *Herring Eggs, and Associated Vegetation in Tomales Bay.* **California Department of Fish and Game.** 59(7):36-61.

Hardy, R. F. and J. D. Wendell, D. E. Martini, B. Cicin-Sain, P. M. Grifman, and J. B. Richards.
1982 *A Status Report on California Shellfish Fisheries.* **Social Science Perspectives on Managing Conflicts Between Marine Mammals and Fisheries.** Pp. 328-340. Santa Barbara: University of California, Santa Barbara.

Harger, B.
1983 *A Historical Overview of Kelp in Southern California.* **The Effects of Waste Disposal on Kelp Communities.** ed. W. W. Bascom. Pp. 70-83. Long Beach: Southern California Coastal Water Research Project.

Harris, Walter M.
1988 **Federal Offshore Statistics: 1986.** Vienna, Va.: U.S. Minerals Management Service.

Hartman, O.
1966 *Quantitative Survey of the Benthos of San Pedro Basin, Southern California. Part IV. Final Results and Conclusions.* **Allan Hancock Pacific Expeditions.** Vol. 19. Pp. 185-456.

Hassler, T. J.
1988 **Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)—Striped bass.** U.S. Fish and Wildlife Service Biological Report No. 82(11.82). Washington D.C.

Hayes, Judge Benjamin and Col. J. J. Warner, Dr. J. P. Widney.
1876 **Historical Sketch of Los Angeles County.** Los Angeles: O.W. Smith.

Haynes, C. V. Jr.
1969 *A Scientist Disagrees.* **Encyclopedia Britannica Yearbook of Science and the Future.** Pp. 76-77. New York.

Hays, H. and R. Risebrough.
1972 *Pollutant Concentrations in Abnormal Young Terns From Long Island Sound.* **Auk.** 89:19-35.

Heady, Harold F.
1977 *Valley Grasslands.* **Terrestrial Vegetation of California.** ed. Micheal G. Barbour and Jack Major. Pp. 491-514. New York: John Wiley & Sons.

Hedgepeth, Joel W.
1985 *Coastal Barriers of the Pacific Coast: Summary report.* **Coastal Barrier Resources System.** Appendix D. Washington, D.C.: U.S. Department of the Interior.

Heimann, Richard F. G. and Peter Kalvass, David O. Parker.
1987 **Recommendations for the Management of Red Sea Urchins in California.** Sacramento: Department of Fish and Game, Resources Division.

Heizer, Robert F. ed.
1978 **Handbook of North American Indians, Volume 8: California.** Washington, D.C.: Smithsonian Institution.

Hengstebeck, R. J.
1959 **Petroleum Processing, Principles and Applications.** New York: McGraw-Hill Book Company, Inc.

Hickey, Barbara M.
1979 *The California Current System -Hypothesis and Facts.* **Progress in Oceanography.** 8: 191-279.

Hoese, H. D.
1971 *Dolphin Feeding Out of Water in a Salt Marsh.* **Journal of Mammalogy.** 52: 222-223.

Holdren, John, and P. Fowler, T. Kenneth.
1989 *Fusion's Future: Discussion.* **Scientific American.** 260(5): 18-22.

Holland, Robert F. Ph.D.
1986 **Preliminary Descriptions of the Terrestrial Natural Communities of California.** Sacramento: Department of Fish & Game, Nongame-Heritage Program.

Holland, V. L. and D. J. Kiel.
1986 **California Vegetation.** San Luis Obispo: California Polytechnic State University.

Hopkins, D. M.
1979 *Landscape and Climate of Beringia During Late Pleistocene and Holocene Times.* **The First Americans: Origins, affinities, and adaptations.** New York: Fischer.

Hopkins, N. A.
1965 *Great Basin Prehistory and Uto-Aztecan.* **American Antiquity.** 31(1): 48-60.

Horn, M. H. and L. G. Allen.
1978 *A Distributional Analysis of California Coastal Marine Fishes.* **Journal of Biogeography.** 5: 23-42.

Hornor, Edith R.
1988 **California: Cities, Towns & Counties.** Palo Alto: Hornwood Press.

Houghton, Richard A. and George M. Woodrell.
1978 *Global Climate Change.* **Scientific American.** 260(4): 36-47.

Hung, S.O.
1989 *Practical Feeding of White Sturgeon.* **Aquaculture Magazine.** 15(1): 60-63.
Resolution of the City Opposing Proposed

Huntington Beach, City of.
1987 Five-Year OCS Leasing Program For 1986-1991. Resolution No. 5758.
1988 Resolution of the City Opposing Any Increase in Oil Operation or Number of Platforms Offshore Orange County. Resolution Number 5917.

Hutchinson.
1974 **Oil Spills and Vegetation at Norman Wells, North West Territories.** Environmental Social Committee, Northern Pipelines Task Force on Northern Oil Development, Report No. 73-43. Toronto: University of Toronto, Institute for Environmental Studies.

Imbrecht, Charles R.
1989 **Testimony before the U.S. Senate Committee on Environment and Public Works Subcommittee on Environmental Protection.** Sacramento: California Energy Commission.

Independent Petroleum Association of America.
1989 **Petroleum Independent: The Oil and Gas Producing Industry in Your State 1988-1989.**

Irvine, City of.
nd. **Local Coastal Plan.**

Jones and Stokes, Associates, Inc., and Harvey and Stanley Associates, Inc., John Blayney Associates.
1979 *Protection and Restoration of San Francisco Bay Fish and Wildlife Habitat.* **Volume II Habitat Description, Use and Delineation.** Vol. 2. Prepared for the California Department of Fish and Game and the U.S. Fish and Wildlife Service. Sacramento.
1981a *Basic Ecological Concepts.* **Ecological Characterization of the Central and Northern California Coastal Region.** Vol. I. U.S. Fish and Wildlife Service Biological Report No. FWS/OBS-80/41. Washington, D.C.
1981b *Regional Characterizations.* **Ecological Characterization of the Central and Northern California Coastal Region.** Vol. II Part 1. U.S. Fish and Wildlife Service Biological Report No. FWS/OBS-80/42. Washington, D.C.
1981c *Species Accounts.* **Ecological Characterization of the Central and Northern California Coastal Region.** Vol. II Part 2. U.S. Fish and Wildlife Service Biological Report No. FWS/OBS-80/43. Washington, D.C.

1981d *Watersheds and Basins.* **Ecological Characterization of the Central and Northern California Coastal Region.** Vol. IV. U.S. Fish and Wildlife Service Biological Report No. FWS/OBS-80/45. Washington, D.C.

1987 **Sliding towards extinction: The state of California's natural heritage.** Prepared for the Nature Conservancy. Sacramento.

Jones, Philip D. and Tom M. L. Wigley.

1990 **Global Warming Trends.** *Scientific American.* 263(2): 84-91.

Josselyn, M.

1982 **Wetland Restoration and Enhancement in California.** La Jolla: California Sea Grant College Program.

1983 **The Ecology of San Francisco Bay Tidal Marshes: A community profile.** FWS/OBS-83/23. Washington D.C.: U.S. Fish and Wildlife Service, Division of Biological Services.

Kalvass, Peter.

1990 Personal communication. Biologist, California Department of Fish and Game. Fort Bragg.

Kato, S.

1990 Personal communication. Biologist, National Marine Fisheries Service. Tiburon.

Kauling, T. J. and D. J. Reish.

1975 *A Quantitative Study of the Benthic Polychaete Annelids of Anaheim Bay and Huntington Harbor, California.* **The Marine Resources of Anaheim Bay.** Fisheries Bulletin 165. Sacramento: Department of Fish and Game.

Kelley, D. W.

1966 *Description of the Sacramento-San Joaquin Estuary.* **Ecological Studies of the Sacramento-San Joaquin Estuary, Part 1.** Fish Bulletin No. 133. Pp. 8-17. Sacramento: Department of Fish and Game.

Kennedy, Grant M. and Hugo T. Shogren, Lewis C. Leifer, Gordon E. Shipman.

1979 **Erosion and Sediment in California Central Coast Watersheds.** Sacramento: California Water Resources Control Board.

Kolpack, Ronald L. and David E. Drake.

1985 *Transport of clays in the eastern part of Santa Barbara Channel, California.* **Geo-Marine Letters.** 4: 191-196.

Kroeber, Alfred L. and Samuel A. Barrett.

1960 *Fishing Among the Indians of Northwestern California.* **University of California Anthropological Records.** 13(1): 1-156.

Kuchler, A. W.

1977 **Map of the Natural Vegetation of California.** 1:1,000,000 Lambert Conformal Conic Projection, 47x41 in. colored. Lawrence: University of Kansas, Department of Geography.

Lane, J. M. and A. Woods.

1975 *A Natural History of Anaheim Bay.* **The Marine Resources of Anaheim Bay.** Fish Bulletin No. 165. Sacramento: Department of Fish and Game.

Larson, Mary.

1990 Personal communication. Biologist, California Department of Fish and Game. Long Beach.

Laufle, J. C. and G. B. Pauley, M. F. Shepard.

1986 **Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)—Coho salmon.** U.S. Fish and Wildlife Service Biological Report 82(11.48). Washington D.C.

Laurs, R. M. and P. C. Fiedler, D. R. Montgomery.

1984 *Albacore tuna catch distributions relative to environmental features observed from satellites.* **Deep Sea Research.** 3(9): 1086-1099.

Leakey, L. S. and B. T. Clements, R. Berger, J. Witthoft.

1970 **Pleistocene Man at Calico.** Redlands: San Bernardino County Museum Association.

1972 **Pleistocene Man at Calico.** Redlands: San Bernardino County Museum.

League of Women Voters of California.

1982 **California Agriculture: Land, economy, ecology.** San Francisco.

Leffler, William.

1982 **Refinery Technology for the Non-Technical Person.** Tulsa, Ok.: Penwell Books.

Levering, T. and H. A. Hoppe, O. J. Schmid.

1969 **Marine Algae: A survey of research and utilization.** Hamburg, Germany: Cram De Gruyter and Company.

Levin, J. E. and McNeil, W. J.

1989 *A New Polyculture: Seaweed Grown in Salmon Culture Effluent.* **National Coastal Resources Institute News.** Newport, Ore.: National Coastal Resources Institute.

Lewallen, J.
1990 Personal communication. Mendocino Sea Vegetable Company.

Lynn, R. J.
1986 *The Subarctic and Northern Subtropical Fronts in the Eastern North Pacific Ocean in Spring.* **Journal of Physical Oceanography.** 16(2): 209-222.

Mahrdt, C. R. and T. A. Oberbauer, J. P. Reiger, J. R. Verfaillie, B. M. Browning, J. W. Speth.
1976 **Natural Resources of Coastal Wetlands in Northern Santa Barbara County: Their present and future use.** Coastal Wetland Series No. 14. Sacramento: Department of Fish and Game.

Marine Mammal Commission.
1990 **Annual Report of the Marine Mammal Commission, Calendar year 1990.** Washington, D.C.: U.S. Congress.

Maslory, Dean L.
1986 *U.S. Ethanol: Its Historical Present and Future Growth.* **In Search for a Bridge to the Energy Future.** Grand Forks: University of North Dakota, School and Engineering and Mines.

Matsen, Sue.
1989 Personal communication. Yurok Tribal Member, Yurok Commercial Fisher, Klamath River Fisheries Management Council—Non-Hupa Representative.

Mayer, K. and W. Laudenslayer, Jr.
1988 **A Guide of Wildlife Habitats of California.** Sacramento: Department of Forestry and Fire Protection.

Mayo Associates.
1988 **The California Hatchery Evaluation Study for the Department of Fish and Game.** Prepared for the California Department of Fish and Game. Sacramento.

McKeag, Tom.
1988 *Patterns of Honorable Discharge.* **Waterfront Age.** Summer: 26-31.

Mehringer, P. J. Jr. and D. Fowler.
1972 *Great Basin Late Quaternary Environments.* **Desert Research Institute Publications in the Social Science.** 12: 128-132. Reno: Desert Research Institute.

Meske, C.
1985 **Fish Aquaculture: Technology and experiments.** Oxford: Pergamon Press.

Meyer, Phillip A.
1989 **Socio-economic Issues of Importance to Oil Related Activities in the Coastal Zone off California.** Presented to California State Lands Commission Hearing on Potential Effects of an Oil Spill on the California Coast, June 7, 1989. Sacramento: California State Lands Commission.

Meyer Resources, Inc.
1985 **The Economic Value of Striped Bass** *(Marone saxatilis)*, **Chinook Salmon** *(Oncorhynchus tshawytscha)*, **and Steelhead Trout** *(Salmo gairdneri)*, **of the Sacramento and San Joaquin River Systems.** Administrative Report No. 85-3. Sacramento: Department of Fish and Game, Anadromous Fisheries Branch.

Miller, Daniel and J. Hardwick, James E Dahlstrom, A. Walter.
1975 **Pismo Clams and Sea Otters.** Marine Resources Technical Report No. 31. Sacramento: California Department of Fish and Game.

Mishuck, Eli and E. Gary Stickel, E.
1978 **Archaeological Literature Survey of Southern California Bight.** Vol. 2. Los Angeles: Bureau of Land Management.

Mitchell, J. F. and B. C. A. Senior, W. J. Ingram.
1989 *Clouds in Computer Climate Models.* **Nature.** 342: 132.

Miyabe, N and W. H. Bayliff.
1987 *A review of the Japanese Longline Fishery for Tunas and Billfishes in the Eastern Pacific Ocean 1971-1980.* **Inter-American Tropical Tuna Commission Report.** 19(1):1-163.

Mobil Oil Corporation.
1988 *Methanol: Good News and Bad.* **Los Angeles Times.** Dec. 15.

Monroe, G. W.
1973 *The Natural Resources of Humboldt Bay.* **Coastal Wetlands Series.** Vol. 6. Sacramento: Department of Fish and Game.

Monroe, G. W., and F. Reynolds, B. M. Browning, J. W. Speth.
1974 *The Natural Resources of the Eel River Delta.* **Coastal Wetland Series.** Vol. 9. Sacramento: Department of Fish and Game.

Mooers, C. N. K. and A. R. Robinson.
1984 *Turbulent Jets and Eddies in the California Current and Inferred Cross-shore Transports.* **Science.** 223: 51-53.

Mooney, Harold A.
1977 *Southern Coastal Scrub.* **Terrestrial Vegetation.** ed. Michael G. Barbour and Jack Major. Pp. 471-489. New York: John Wiley and Sons.

Moratto, Michael J.
1984 **California Archaeology.** San Francisco: Academic Press, Inc.

Morris, Greg.
1989 Personal Communication. Leslie Salt Company. Newark, Ca.

Moyle, P. B.
1976 **Inland Fishes of California.** Berkeley: University of California Press.

Moyle, P. B. and J. E. Williams, E. D. Wikramanayake.
1989 **Fish Species of Special Concern of California. Final Report.** Rancho Cordova, Ca.: Department of Fish and Game, Inland Fisheries Division.

Mudd, J. B. and T. T. Kozlowski.
1975 **Response of Plants to Air Pollution.** New York: Academic Press, Inc.

Murdoch, W. W. and R. C. Fay, B. J. Mechalas.
1989 **Final Report of the Marine Review Committee to the California Coastal Commission: Marine Review Committee Document.** No. 89-02. Santa Barbara.

Murray, S. N. and M. M. Littler, I. A. Abbott, D. M. Power.
1980 *Biogeography of the California Marine Algae with Emphasis on the Southern California Islands.* Proceedings: **The California Islands, A Multi-disciplinary Symposium.** Santa Barbara: Santa Barbara Natural History Museum.

National Audubon Society.
1986 **Ballona Wetland Habitat Management Plan (Draft).** Sacramento.

National Petroleum Council.
1979 **Refinery Flexibility.** Washington, D.C.
1980 **Refinery Flexibility.** Washington, D.C.
1986 **U.S. Petroleum Refining.** Washington, D.C.
1987 **Factors Affecting U.S. Oil and Gas.** Washington, D.C.

Newman, William and A. J. Gray, A. Boucot.
1979 *Californian Transition Zone: Significance of short-range endemics.* **Historical Biogeography: Plate Tectonics and the Changing Environment.** Corvallis: Oregon State University Press.

Nivola, Pietro S.
1986 **The Politics of Energy Conservation.** Washington, D.C.: Brookings Institute.

Norris, K. S.
1966 **Whales, Dolphins and Porpoises.** Berkeley: University of California Press.

Odum, E. P.
1971 **Fundamentals on Ecology.** 3rd edition. Philadelphia: Saunders, Co.

Onuf, C. P.
1987 **The Ecology of Mugu Lagoon, California: An estuarine profile.** U.S. Fish and Wildlife Service Biological Report No. 85(7.15). Washington, D.C.

Pacific Gas & Electric Company.
1987 *Resource Planning Approach.* **Common Forecasting Methodology 7.** Vol. I. Pg. 3.7-3.

Pacific Marine Fisheries Commission.
1988 **40th Annual Report of the Pacific Marine Fisheries Commission for the Year 1987.** Report to the Congress of the United States and to the States of Alaska, California, Idaho, Oregon and Washington. Washington, D.C.

Page, G. W. and J. E. Kjelmyr, L. E. Stenzel.
1989 **Results of the 21-24 April 1989 Shorebird Census of San Francisco Bay and Coastal Wetlands of the Point Reyes/Bodega Bay Area.** Special Report of the Point Reyes Bird Observatory. Stinson Beach.

Palmer, Harold D.
1965 *Submarine Geography Off Southern California.* **Journal of the West.** 7(1):77-94.

Parfit, Michael.
1987 *It was a Dark and Stormy Night.* **Smithsonian.** 17(11): 38-49.

Parker, Harry W. and Salyja, S. S.
1986 *Engineering and Economic Constraints on the Development of Syn Fuels and Alternative Energy Sources.* **In Search for a Bridge to the Energy Future.** Grand Forks: University of North Dakota, School of Engineering and Mines.

Parker, David.
1990 Personal communication. Biologist, California Department of Fish and Game. Long Beach.

Pase, Charles P. and David E. Brown.
1982 *California Coastal Scrub.* **Desert Plants Special Issue. Biotic Communities of the American Southwestern United States and Mexico.** Vol. 4. No. 1-4. Pp. 86-90. Superior: University of Arizona, Boyce Thompson SW Arboretum.

Pauley, G. B. and B. M. Bortz, M. F. Shepard.
1986 **Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)—Steelhead trout.** U.S. Fish and Wildlife Service Biological Report 82(11.62). Washington D.C.

Pauley, G. B. and K. Oshima, K. L. Bowers, G. L. Thomas.
1989 **Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)—Sea-run Cutthroat trout.** U.S. Fish and Wildlife Service Biological Report No. 82(11.86). Washington D.C.

Payen, L. A. and C. H. Rector, E. Ritter, R. E. Taylor, J. E. Ericson.
1978 *Comments on the Pleistocene Age Assignment and Association of a Human Burial from the Yuba Desert.* **American Antiquity.** 43(3): 448-453.

Pean, L. J. and T. C. Blackburn.
1976 **Native Californians: A Theoretical Perspective.** Ramona, Ca.: Ballena Press.

Pelaez, Jose and John A. McGowan.
1986 *Phytoplankton pigment patterns in the California Current as determined by satellite.* **Limnology Oceanography.** 31(5): 927-950.

Peterson, C. L.
1985 **Tropical Tuna Commission; Special Report.** No. 5. Inter-American Tropical Tuna Commission.

Philbrick, Ralph N. and J. Robert Haller.
1977 *The Southern California Islands.* **Terrestrial Vegetation of California.** ed. Michael G. Barbour and Jack Major. Pp. 893-906. New York: John Wiley and Sons.

Phillips, D. J. H.
1987 **Toxic Contaminants in the San Francisco Bay-Delta and their Biological Effects.** Richmond, Ca.: Aquatic Habitat Institute.

Phillips, George Harwood.
1975 **Chiefs and Challenges.** Los Angeles: University of California Press.

Phillips, R. C.
1984 **The Ecology of Eelgrass Meadows in the Pacific Northwest: A community profile.** U.S. Fish and Wildlife Service Biological Report No. 84-24. Washington, D.C.

Pirog, R. L. and S. C. Stamos.
1987 **Energy Economics: Theory and Policy.** Englewood Cliffs, NJ: Prentice Hall.

Port of Los Angeles and Port of Long Beach.
1988 **2020 Plan: OFI Study Summary.**

Preston, Larry.
1989 Personal communication. Fishery Biologist, California Department of Fish and Game.

Punsly, R.
1987 *Estimation of the relative abundance of yellowfish tuna (Thunnus albacares) in the eastern Pacific Ocean during 1970-1986.* **Inter-American Tropical Tuna Commission Bulletin.** 19(3): 306.

Ragir, Sonia R.
1972 *The Early Horizon in Central California.* **Contributions of the University of California Archaeological Facility.** No. 15.

Ratafia, Manny and Terry Purinton.
1985 *Emerging Aquaculture Markets.* **Aquaculture Magazine.** 15(4): 32-46.

Reading, Harvey.
1989 Personal communication. Hatchery Manager, Prairie Creek Hatchery, Orick, Ca.

Rean, Walton.
1982 **California: An Interpretive History.** New York: McGraw-Hill, Inc.

Remsen, J. V.
1978 **Bird Species of Special Concern in California: An annotated list of declining or vulnerable bird species.** Department of Fish and Game, Wild Management Branch Administrative Report No. 78-1. Sacramento.

Resh, Vincent H and Steven S. Balling.
1983 *Tidal Circulation Alteration for Salt Marsh Mosquito Control.* **Environmental Management.** 7(1): 79-84.

Richardson, H. W.
1975 **Economic Aspects of the Energy Crisis.** Lexington, Ma: Lexington Books.

Riddell, F. A.
1969 *Pleistocene Faunal Remains Associated With Carbonaceous Material.* **American Antiquity.** 32(2): 177-180.

Robinson, David L.
1988 **San Diego's Endangered Species Our Vanishing Resources.** San Diego:

Rosenfeld, Arthur and John Mills.
1988 *Energy Efficiency and Least-Cost Planning.* **1988 Draft Conservation Report.** Prepared for the California Energy Commission. Sacramento.

Ross, Philip E.
1990 *Clean Air Fuels for the 90's.* **Popular Science.** 236(1): 47-51.

Ryther, R. H. and Dunstan, William M.
1971 *Nitrogen, Phosphorus and Eutrophication in the Coastal Marine Environment.* **Science.** 171: 1008-1013.

Saluja, S. S. and J. J. Saluja ed.s.
1986 **In Search for a Bridge to the Energy Future.** Grand Forks: North Dakota University, School of Engineering.

San Clemente, City of.
nd. **Local Coastal Program.**

San Diego Association of Governments.
1984 **Aviation Facilities Inventory, 1983.** San Diego.
1988 **1988 Five-Year Regional Transportation Improvement Program.** San Diego.

San Diego, City of, San Diego Visitors and Convention Bureau.
1988 **General Facts on San Diego Tourism.**

San Diego, County of.
1982 **San Diego County Local Coastal Plan and Zoning Document (Draft).**

San Diego, County of, Department of Agriculture, Weights and Measures.
1987 **Annual Crop Report.**

San Diego, County of, Planning Department.
1979 **San Diego County General Plan.**

San Diego, Port of, Planning Department.
1987 **Port Master Plan.**

San Diego Interagency Water Quality Panel.
1989 **San Diego Bay 1988 Annual Report: A Report to the Water Resources Control Board and the California Legislature. San Diego.**

San Francisco Bay Conservation and Development Commission.
1969 **Bay Plan.** San Francisco: Bay Conservation and Development Commission.
1975 **The Regulation of Dredging.** Vol. 1. San Francisco: Bay Conservation and Development Commission.

Santa Barbara County-Cities Area Planning Council.
1989 **What's Wrong With Our Roads.** Santa Barbara.

Scheuring, Ann F. and Zoe McCandless-Grossman.
1982 **Agricultural Resources of California Counties.** Special Publication No. 3275. Berkeley: University of California, Division of Agricultural Sciences.

Schnieder, Robert W.
1987 *Terraces, Tilting, and Topography of Cordell Bank.* **California Geology.** 40(11): 258-264.

Schulenberg, R. W.
1979 **The Ecological Reserves of California.** Wildlife Management Bulletin No. 1. Sacramento: Department of Fish and Game.

Science Applications International Corporation.
1987 **Final Report California Seabird Ecology Study. Vol. 2 Satellite Data Analysis.** Minerals Management Service OCS Study No. 87-005. Los Angeles.

Shea, Cynthia.
1988 *The Promise of Renewable Energy.* **Sun World.** 12(2):38-45.

Shell Pipeline Corporation, West Coast Division.
1987 **California Pipeline Systems.** Anaheim.

Shirkley, Charles and Robert Spier.
1987 *California Crude Oil Price Levels.* **Petroleum Marketing Monthly.** March.

Simenstad, C. A.
1983 **The Ecology of Estuarine Channels of the Pacific Northwest Coast: A community profile.** U.S. Fish and Wildlife Service Report No. FWS/OBS-83/5. Washington, D.C.

Skinner, J. E.
1962 **An Historical Review of the Fish and Wildlife Resources of the San Francisco Bay Area, California.** Water Resources Projects Branch Report No. 2. Sacramento: Department of Fish and Game.
1972 **Ecological Studies for the Sacramento-San Joaquin Estuary.** Department of Fish and Game, Delta Fish and Wildlife Protection Study Report No. 8. Sacramento.

Smith, E.J. and D.H. Fry, H.W. Frey.
1976 **Coastal County Fish and Wildlife Resources and their Utilization.** Sacramento: California Department of Fish and Game.

Smith, G. J. and D. E. Gaskin.
1983 *An Environmental Index for Habitat Utilization by Female Harbor Porpoises with Calves Near Deer Island, Bay of Fundy.* **Ophelia.** 22: 1-15.

Smith, James Payne Jr. and Ken Berg.
1988 **Inventory of Rare and Endangered Vascular Plants of California.** Special Publication No. 2. Sacramento: California Native Plant Society.

Smith, R. C. and P. Dunstan, D. Au, K. S. Baker, E. A. Dunlap.
1986 *Distribution of cetaceans and sea-surface chlorophyll concentrations in the California Current.* **Marine Biology.** 91: 385-402.

Sonoma County Planning Department.
1986 **Sonoma County General Plan.**

Southern California Association of Governments.
1988 **The State of Santa Monica Bay: Executive summary.**

Southern California Coastal Water Research Project.
1973 **The Ecology of the Southern California Bight: Implications for water quality management.** No. TR104. El Segundo, Ca.: Southern California Coastal Water Research Project. **Catalog of California Seabird Colonies.** U.S.

Sowls, A. L. and Al De Grange, J. Nelson, G. Lester.
1980 Fish and Wildlife Service Biological Services Program Report FWS/OBS 80-37. Washington, D.C.

Spratt, Jerome.
1990 Personal communication. Biologist, California Department of Fish and Game. Monterey.

Sport Fishing Institute.
1988 **The Economic Impact of Sport Fishing in the State of California.** Washington, D.C.

Springer, Clifford H. and R. E. Herliby, R. T. Mall, R. I. Beggs.
1966 **Statistical Inference.** Homewood, Ill.: Richard D. Irwin, Inc.

Stempo, Mike.
1989 Personal communication. Fishery Biologist. U.S. Fish and Wildlife Service, Weaverville, Ca.

Stinson, M. L.
1984 **Biology of Sea Turtles in San Diego Bay, Ca. and in the Northeastern Pacific Ocean.** Masters Thesis. San Diego State University.

Stow, Douglas and W. Chang, H. Howard.
1987 *Magnitude-Frequency Relationship of Coastal Sand Delivery by a Southern California Stream.* **Geo-Marine Letters.** 7: 217-222.

Strub, P. T.
1987 *Seasonal Cycles of Currents, Temperature, Winds and Sea Level Over the Northeastern Pacific Continental Shelf.* **Journal of Geophysical Research.** 9.

Sunada, John.
1990 Personal communication. Biologist, California Department of Fish and Game. Long Beach.

Swartzell, Phillip.
1990 Personal communication. Biologist, National Marine Fisheries Service. La Jolla.

Taylor, W. W.
1961 *Archaeology and Language in Western North America.* **American Antiquity.** 21(4): 71-81.

Texas Transportation Institute, Texas A & M and the U.S. Department of Transportation, Federal Highway Administration.
1988 **The Impact of Declining Mobility in Major Texas and Other U.S. Cities.** College Station, Tex.: Texas A & M University System, Texas Transportation Institute.

Thompson, B. E. and B. F. Jones.
1987 *Benthic Macrofaunal Assemblages of Slope Habitats in the Southern California Borderland.* **Allan Hancock Foundation Occasional Papers New Series.** 6: 1-21.

Trondsen, Eilif and Walter J. Mead.
1977 **California Offshore Phosphorite Deposits: An economic evaluation.** IMR Reference No. 77-106. La Jolla, Ca: University of California, Institute of Marine Reservoirs.

United Nations, Food and Agriculture Organization.
1982 **Mammals of the seas: small cetaceans, seals, sirensians and otters.** Vol. 4. New York.

University of California Davis, Division of Agricultural Sciences.
1982 **Agricultural Resources of California Counties.** Berkeley: University of California Press.

U.S. Congress, Office of Technology Assessment.
1987 **Technologies to Maintain Biological Diversity.** No. OTA-F-330. Washington, D.C.: U.S. Government Printing Office.

U.S. Department of Commerce.
1988 **Marine Mammal Protection Act of 1972: Annual Report 1987/88.** Washington, D.C.
1989 **Report to Congress on U.S. Crude Oil Exports.** Washington, D.C.

U.S. Department of Commerce, Marine Mammals Commission.
1990 **Annual Report of the Marine Mammal Commission.** Washington, D.C.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration.
1985 **Fate and Effects of the Mobile Oil Spill in the Columbia River.** Washington D.C.: Office of Oceanography and Marine Services.
1988a **PCB and Chlorinated Pesticide Contamination in U.S. Fish and Shellfish: A Historical Assessment Report.** National Oceanic and Atmospheric Administration Technical Memorandum No. 49. Seattle, Wa.
1988b **United States Coast Pilot: Pacific Coast. Vol. 7. Washington, D.C.: National Ocean Service.**
1989 **National Benthic Surveillance Project: Pacific Coast.** Seattle, Wa.

U.S. Department of Commerce, Office of Technology Assessment.
1985 **U.S. Natural Gas Availability: Gas supply through the year 2000.** Washington, D.C.: National Technical Information Service.

U.S. Department of Defense, Department of the Army, Army Corps of Engineers, Los Angeles District.
1979 **Reconnaissance Report for San Pedro Ports, California.** Los Angeles.

U.S. Department of Defense, Department of Army, Army Corps of Engineers, Waterborne Commerce Statistics Center.
1987 **Waterborne Commerce of the United States: 1985.** Springfield, Va.: National Technical Information Service.
1988 **Waterborne Commerce of the United States: 1986.** Springfield, Va.: National Technical Information Service.
1990 **Waterborne Commerce of the United States; Calendar Year 1985; Part 4 Waterways and Harbors, Pacific Coast, Alaska, and Hawaii.** Springfield, Va.: National Information Service.

U.S. Department of Energy.
1987 **Energy Security.** Washington, D.C.: U.S. Government Printing Office.
1988 **Photovoltaics: Technical Information Guide. Springfield, Va.: National Technical Information Service.**

U.S. Department of Energy, Energy Information Administration.
1986 **Characteristics of Commercial Buildings.** Washington, D.C.: U.S. Government Printing Office.
1987 **Annual Report to Congress, 1987.** Washington, D.C.: U.S. Government Printing Office.
1988a **Annual Energy Outlook for 1989.** Washington, D.C.: U.S. Government Printing Office.
1988b **Annual Energy Review 1987.** Washington, D.C.: U.S. Government Printing Office.
1988c **Basic Petroleum Data Book.** Washington, D.C.: U.S. Government Printing Office.
1988d **Petroleum Supply Annual.** Washington, D.C.: U.S. Government Printing Office.
1989a **Annual Energy Outlook.** Washington, D.C.: U.S. Government Printing Office.

1989b **Annual Energy Review 1988.** Washington, D.C.: U.S. Government Printing Office.
1989c **Petroleum Supply Annual.** Washington, D.C.: U.S. Government Printing Office.
1989d **State Energy Data Book.** Washington, D.C.: U.S. Government Printing Office.
1990a **Annual Energy Outlook.** Washington, D.C.: U.S. Government Printing Office.
1990b **International Energy Outlook.** Washington, D.C.: U.S. Government Printing Office.
1990c **Petroleum Supply Annual.** Washington, D.C.: U.S. Government Printing Office.

U.S. Department of Energy, National Petroleum Council.
1989 Petroleum Storage and Transportation - Executive Summary. Washington, D.C.: National Petroleum Council.

U.S. Department of the Interior, Bureau of Land Management.
1979 **U.S. Department of the Interior Draft E.I.S., O.C.S. Sale No. 48.** Los Angeles.
1980 **Final Environmental Statement, Proposed Five-year O.C.S. Oil and Gas Lease Sale Schedule.** Los Angeles.
1988 **Federal Regulations Geothermal Leasing.** Washington, D.C.

U.S. Department of Interior, U.S. Fish and Wildlife Service.
1981 **Klamath River Fisheries Investigation Program: Annual Report, 1980.** Arcata, Ca.: Fisheries Assistance Office.
1982 **1980 National Survey of Fishing, Hunting, and Wildlife-associated Recreation.** Washington, D.C.
1985 **Klamath River Basin Fisheries Resource Plan.** Redding.
1988a **1985 National Survey of Fishing, Hunting and Wildlife-associated Recreation.** Washington D.C.
1988b **The Economic Impact of Sport Fishing in the State of California.** Washington, D.C.

U.S. Department of the Interior, Minerals Management Service.
1973 **Minerals Revenues Annual Report.** Washington D.C.
1974 **Minerals Revenues Annual Report.** Washington D.C.
1975 **Minerals Revenues Annual Report.** Washington D.C.
1976 **Minerals Revenues Annual Report.** Washington D.C.
1977 **Minerals Revenues Annual Report.** Washington D.C.
1978 **Minerals Revenues Annual Report.** Washington D.C.
1979 **Minerals Revenues Annual Report.** Washington D.C.
1980 **Minerals Revenues Annual Report.** Washington D.C.
1981 **Minerals Revenues Annual Report.** Washington D.C.
1982 **Minerals Revenues Annual Report.** Washington D.C.
1983a **Cetaceans of Central and Northern California: status, Abundance and Distribution.** No. MMS84-0044. Santa Cruz: University of California, Center for Marine Studies.
1983b **Minerals Revenues Annual Report.** Washington D.C.
1984 **Minerals Revenues Annual Report.** Washington D.C.
1985 **Minerals Revenues Annual Report.** Washington D.C.
1986 **Minerals Revenues Annual Report.** Washington D.C.
1987a **Baseline Socioeconomic Profiles of Coastal Communities in the Southern California Planning Area.** Los Angeles.
1987b **Ecology of Important Fisheries Species Offshore California.** No. MMS 86-0093. Los Angeles.
1987c **Minerals Revenues Annual Report.** Washington D.C.
1987d **Pacific Summary/Index June 86-July 87.** Vienna, Va.
1987e **Seabird Oil Toxicity Study.** Minerals Management Service OCS Study MMS-87-005. Los Angeles.
1988 **Minerals Revenues Annual Report.** Washington D.C.
1989 **Benthic Reconnaissance of Central and Northern California OCS Areas. Final Report.** Vols. 1 and 2. Minerals Management Service OCS Study MMS-89-0039. Los Angeles.

U.S. Department of the Interior, U.S. Geological Survey.
1980 **OCS Oil and Gas Information Program-Pacific Index.** Reston, Va.

U.S. Environmental Protection Agency.
1975 **Environmental Effects of Schuylkill Oil Spill.** No. 68-01-9781. Washington, D.C.: Office of Water Program Operations.

U.S. Environmental Protection Agency and the U.S. Department of the Interior.
1972 **Noise Pollution.** Washington, D.C.: Environmental Protection Agency, Office of Public Affairs.

U.S. Government Accounting Office.
1988 **Energy Security: An overview of Changes in the World Oil Market.** Washington, D.C.

U.S. House of Representatives, Committee on Science, Space, and Technology, Subcommittee on Energy, Research, and Development.
1989 **Renewable Energy Development Hearings.** 100th Congress. First Session, July 8th and 9th, No. 74.

Valentine, James W.
1966 *Numerical Analysis of Marine Molluscan Ranges on the Extratropical Northeastern Pacific Shelf.* **Limnology and Oceanography.** 11: 198-211.

Valls, M.
1987 **Petroleum Supply Modeling in a Dynamic Optimization Framework.** Washington, D.C.: Resources for the Future.

Van Blaricom, G.
1990 Personal communication. U.S. Fish and Wildlife Service.

Van Olst, J. C. and J. M. Carlberg.
1990 *Commercial Aquaculture of Hybrid Striped Bass: Status and Potential.* **Aquaculture Magazine.** 16(1): 49-59.

Van Waganen, B.
1990 Personal communication. ECOSCAN.

Vogl, Richard J. Wayne P. Armstrong, Kevin L. White, Kenneth L. Cole, Michael G. Barbour, Jack Major.
1973 *The closed-cone pines and cypresses.* **Terrestrial Vegetation of California.** Pp. 295-358. New York: John Wiley & Sons.

Voykovich, M.
1990 Personal communication. Biologist, California Department of Fish and Game. Long Beach.

Wagner, H. R.
1926 *Spanish Voyages to the Northwest Coast of American in the 16th Century.* **California Historical Society Special Publications.** 4.

Wallace, W. J.
1978 *Post-Pleistocene Archaeology.* **Handbook of North American Indians, Vol. 8 California.** Washington, D.C.: Smithsonian Institution.

Walters, Dan.
1990 *State's Growth Reaches Crises.* **The Sacramento Bee.** January 21, Pg. A3.

Wang, J.
1988 **Assessment of an Oil Spill on Selected Fishes in Rodeo Lagoon and Muir Beach.** San Francisco: Cooperative National Park Resources Study Unit, University of California, San Francisco.

Warner, Glenn E.
1989 Personal Communication. Western Salt Company, San Diego, Ca.

Warner, Richard E. and Kathleen M. Hendrix.
1984 **California Riparian Systems Ecology, Conservation and Productive Management.** Berkeley: University of California Press.

Warren, C. N.
1967 *The San Dieguito Complex.* **American Antiquity.** 32(2): 168-185.

Weaver, Warren.
1963 **Lady Luck, The Theory of Probability.** Garden City, NY: Doubleday and Co. and Anchor Books.

Weber, F. Harold; and Roe M. Kepner Jr., George B. Cleveland, R.M. Stewart.
1963 **Geology and Mineral Resources of San Diego County.** No. 3. Sacramento: California State Resources Agency.

Westman, Walter E.
1979 *Oxidant Effects on California Coastal Sage Scrub.* **Science.** 205: 1001-1003.
1981 *Diversity, relations and succession in California coastal sage scrub.* **Ecology.** 62: 170-184.
1982 *Coastal Sage Scrub Succession.* **Dynamics and Management of Mediterranean-type Ecosystems, June 22-26, San Diego, Ca.** ed. Eugene C. Conrad and Walter C. Oechel. Pp. 91-99. General Technical Report No. PSW-58. Berkeley: U.S. Forest Service, Pacific Southwest Forest and Range Experimental Station.

Wheeler, Gary P. and Jack M. Fancher, Richard E Warner and Kathleen M. Hendrix.
1984 *San Diego County Riparian Systems: Current Threats and Statutory Protection Efforts.* **California Riparian Systems.** Berkeley: University of California Press.

White, Robert M.
1990 *The Great Climate Debate.* **Scientific American.** 263(1): 36-45.

Wild, P. and R. N. Tasto.
1983 **Life History, Environment and Mariculture Studies of the Dungeness Crab** *(Cancer magister)*, **With Emphasis on the Central California Fishing Resource.** California Department of Fish and Game Bulletin No. 172. Sacramento.

Williams, E. and A. K. Massa.
1983 **Siting of Major Facilities: A practical approach.** New York: McGraw-Hill Book Company.

Williams, R. G. et al.
1980 **A Climatology and Oceanographic Analysis of the California Pacific Outer Continental Shelf Region.** Washington, D.C.: National Oceanic and Atmospheric Administration.

Wilson, K.
1989 Personal communication. Department of Fish and Game.

Wilson, K and R. Mc Peak.
1983 *Kelp Restoration.* **The Effects of Waste Disposal on Kelp Communities.** Pp. 199-216. Long Beach: Southern California Coastal Water Research Project.

Wolsky, Alan M. and Robert F. Giese, Edward J. Daniel, Edward.
1989 *The New Superconductors: Prospects for Applications.* **Scientific American.** 260(2): 60-74.

Wulff, Scott M. and Randall Little, Delmar J. Helgenson, Roger G. Johnson, S. S. Saluja.
1986 *The Changing Economics of Producing Fuels From Agricultural Products.* **In Search for a Bridge to the Energy Future.** Grand Forks: University of North Dakota, School of Engineering and Mines.

Zedler, J. B.
1982 **The Ecology of Southern California Coastal Salt Marshes: A community profile.** U.S. Fish and Wildlife Service Biological Report No. 81/54. Washington, D.C.
1988 *Restoring Diversity in Salt Marshes; Can We Do It?* **Biodiversity.** E. O. Wilson ed. Washington, D.C.: National Academy Press.

Zedler, J. B. and C. S. Nordby.
1986 **The Ecology of Tijuana Estuary, California: An estuarine profile.** U.S. Fish and Wildlife Service Biological Report 85(7.5). Washington, D.C.

Zedler, Paul H.
1987 **The Ecology of Southern California Vernal Pools: A community profile.** U.S. Fish and Wildlife Service Biological Report 85(7.11). Washington, D.C.

Zetler, B. D. and R. E. Flick.
1985 *Predicted Extreme High Tides for Mixed Tide Regions.* **Journal of Physical Oceanography.** 15: 357-359.
1986 *Predicted extreme high tides for California 1983-2000.* **Journal of Waterways, Port, Coastal & Ocean Engineering.** 111(4): 758-764.

INDEX

A

abalone sport fishery 171
Abel Sterns 130
abrasives 28, 318
absorption oil 317
abstractions 179
Acapulco 128
acceptable risks 184
accidental discharges 45
accidental spill 177, 199, 202, 206
accidental spills 59, 70, 115, 196
acetate 318
acetone 36
acid cloud 61
acid rain 68, 195
acidity 64
acidity/alkalinity 64
acorns 12, 94, 95
acquisition of land 223
adverse effect 133, 223
adverse environmental effects 178, 215, 338
adverse impacts 27, 41, 176, 187, 249, 295
Advisory Board on Underwater Parks and Reserves 249
Advisory Councils on Historic Preservation 121
aerial fallout 67-70
aerial sprayings 68
aeronautics 251, 252
aerospace 14, 69, 344
aerospace industry 344
aerospace wastes 69
aesthetic resources 198
aesthetics 92, 133, 158, 176, 234
Africa 303
aggregate demand curve 267
aggregate economy 284, 285, 287
agricultural crops 59, 110
agricultural development 16, 30
agricultural industry 30
agricultural lands 13, 30, 45, 58, 206, 247
agricultural practices 30
agricultural preservation 249
agricultural products 343
agricultural sectors 59
agriculture 14, 18, 20, 29, 30, 37, 68, 94, 96, 100, 108, 109, 114-119, 128, 142, 206, 223, 230, 311, 333, 335, 343
aids to navigation 157, 230
air basins 110, 233
Air Force 48, 105, 230
air operations 49
air pollutants 60
air pollution 47, 60, 73, 110, 144, 146, 185, 195, 233, 234, 243, 256, 328, 350
Air Pollution Control District (APCD) 256
air quality 60, 61, 110, 132, 146, 188, 199, 206, 217, 218, 233, 234, 243, 252, 256, 257, 277, 338, 342, 347-349, 351
air quality impacts 188, 342
air quality standards 188, 217, 218, 233, 256, 257, 277
Air Resources Board 146, 233, 238, 243, 256, 351
Air Toxics 234
air transportation 48
airbases 48
airborne emissions 295
aircraft 48, 49, 193, 207, 252
aircraft noise 207, 252
airline industry 286
Airport Land Use Commission 152
airport terminal 252
airports 47, 140, 143, 152, 155, 230, 252, 353
Alameda 39, 48, 256
Alaskan crude 281-284, 298
Alaskan North Slope 284
Alaskan rookeries 85
albacore 5, 82, 164-166, 169
alcohol 343
Aleut Indians 130
Aleutian Islands 76
Aleutians 82, 130
algae 26, 31, 33-35, 37, 65, 73, 76, 99, 341
algin 36
aliphatics 316
alkalinity 64
Allis Chalmers Corporation 345
Alopias vulpinus 164
Altamont Pass 331
Alteration Permit 60
alternative energy sources 292, 295, 320, 322
alternative energy technologies 293, 323
alternative transportation fuels 323
alternatives 15, 175, 176, 178, 187, 215, 216, 221, 303, 327, 349
alternatives to oil use 327
alternatives to the proposal 215, 221
ambient air quality standards 188, 217, 218, 256, 257
American History 225
American Indian Religious Freedom Act 121
Americans 1, 8, 10, 12-14, 107, 122, 130-132, 197, 198
ammonia 66, 342, 347
ammonium 65
amphibia 241
Anacapa Island 91
anadromous fish 8, 12, 21, 24, 25, 34, 103, 105-107, 173
anadromous fishes 12-14, 25, 34, 104
anadromous salmonids 8, 172
anadromous species 102, 225
anaerobic microorganisms 338
anchovy 4, 104, 159, 160, 163
Andreas Pico 318
Andrew Jackson 128
angel 164, 165
angling 6, 10
Annual Energy Outlook 268, 305
Anoplopoma fimbria 166
Antiquities Act 120
APCD 256, 257

API 261, 312, 326
API gravity 261, 312
Appendix G 133
Appendix K 121, 196
appliances 248, 309, 330, 331
Application for Permit to Drill 227
aquaculture 21, 22, 25, 31, 33, 35, 36, 101
Aquaculture Development Act 31
Aquatic Habitat Institute 66
aqueducts 46, 245, 246
Arab embargo 320, 321, 323
Arab Oil Embargo 319, 323
Arcata Bay 31
archaeological 40, 121, 122, 132, 196, 236, 249
Archaeological Resources Protection Act (ARPA) 121
archaeologists 40, 123, 132, 133, 197, 250
archaeology 225
architecture 225
Argonne National Laboratory 342
Arizona 141
armed forces 230
Army 2, 46, 48, 49, 203, 220-223, 229
Army Corps of Engineers 2, 46, 203, 220-222, 229
aromatics 316
ARPA 121
arsenic 66, 68, 70, 217
arthropod 43
arthropod species diversity 43
artificial graphite 318
artificial islands 221
artillery ranges 48
asbestos 217
aspartic acid racemization 123
asphalt 252, 312, 316, 318
asphaltum 318
assessment and mitigation of environmental impacts 175
associated gas 315
astronomical tides 56
Atascadero 171
Athapascan 126
Atomic Energy Act 221
Authority to Construct Permit 256
auto 48, 137, 157, 349, 350
automobile price levels 279
automobile yards 2
automobiles 182, 279, 311, 327, 328, 342, 347, 348
aviation fuels 300, 312
avocados 30

B

BAAQMD 256
background noise level 140
bacteria 31, 33, 45, 67, 68, 70
Baja California 78, 87, 90, 91, 162
Bakersfield 312, 319
Bali 342
Ballast Point 126
bank armoring 46
barges 154, 312, 315
barnacles 13, 75
barracuda 169, 170
barred sea bass 169
BART 146
Bartolome Ferrer 126
base price level 289
Baseline Conditions 51, 122, 140, 155
baseline study 192, 195
basic training 48
bathymetric 164
Bay Conservation and Development Commission 39, 248
Bay of Fundy 340
Bay Plan 39, 248
Bayou Choctaw Salt Dome 324
BCDC 37, 248
beach sand 47
beach sand supply 47
beach seines 13
beachcombing 157
Bear Flag Revolt 131
Begg Rock 90
Belridge South 306
benthic organisms 66
benzene 217
Beringia 123
berthing 2, 251
beryllium 217
best available control technology 202, 257
Beverage Container Recycling Advisory Committee 246
bid 263, 289, 290
Biennial Fuels Report 248, 347
Big Lagoon 82, 107
bike lanes 328
bilge pumping 3
biological control 43
biological integrity 218, 220
biological pathogens 66, 67, 71
biological resources 71, 92, 93, 196
biological significance 17, 234, 235
biomagnifying toxins 74
biomass 40, 73, 78, 82, 163, 342, 343
black sand deposits 28
Black skimmer 92
Black turnstones 88
BLM 19, 147, 194, 228
Blue whales 83, 85
bluefin tuna 6
Board of Forestry 29, 250
bocaccio 170
boiler fuel 274, 339
Bolsa Chica 104, 239
bonito 4, 5, 164, 165, 169, 170
bonito (mako) sharks 5
bonuses 272, 289, 290
boron minerals 28
bottom habitats 73, 75, 76
bottom sediments 65, 71, 190
bottom trawling 160
brails 6

Brazoria County, Texas 324
break bulk cargo 152
breakwater 251
breas 119
breeder reactors 336
breeding habitat 90, 91
bridges 116, 147, 221, 252
brine 35-37
brine shrimp 35-37
British Gas Corporation 345
broodstock 21, 31, 33, 36
Brown pelicans 74, 87, 88, 91
brush barriers 12
bryozoans 76
Buchanan Canyon 124
budgetary policies 238
building designs 330
building efficiency standards 330
bunker fuel oil 312
Bureau of Indian Affairs 14, 157
Bureau of Land Management 17, 51, 136, 228, 241
burial locations 132
burial sites 132, 197, 253
buried human remains 121
Business and Transportation Agency 240
business relocation 15
Business, Transportation and Housing Agency 251
businesses 142, 329, 351
butanes 317
butenes 317
Buttonwillow field 319

C

CAA 217
cadmium 66, 70, 74
calcium carbide 318
calcium chloride 28
California Advisory Committee of Salmon and Steelhead 8
California Almanac 150
California Association of Realtors 142
California Building Industry Association 331
California Coast Ranges 51
California Coastal Act 22, 60, 121, 200, 201, 233, 237, 240, 255
California Coastal Commission 16, 134, 192, 205, 216, 233, 238, 240
California Coastal Conservancy 238
California Coastal Zone Conservation Act 233
California Coastal Zone Conservation Plan 240
California Conservation Corps 238
California Current 53-55, 81, 82
California Department of Fish and Game 2, 3, 8, 15, 19, 31, 60, 91, 96, 157, 158, 163, 164, 192, 205, 222, 225
California Department of Transportation 140, 144, 199, 200, 251
California Endangered Species Act 236, 242
California Energy Commission 39, 270, 277, 300, 328, 330, 331, 342, 343, 347, 350
California Energy Plan 248
California Environmental Quality Act 121, 133, 175, 230, 232, 236, 251
California Gull 92
California Historic Landmarks Committee 122
California Ocean Plan 41, 234
California Oil Production 305
California Public Utilities Commission (PUC) 147
California sea lions 81, 85, 88, 89
California Transportation Commission 252
California Undercurrent 53, 55
California Water Atlas 46
Californian province 74
Calistoga, Sonoma County 334
Caltrans 140, 144, 146, 147, 251-253, 329
CALTRANS Noise Manual 140
Cameron Parish, Louisiana 324
Camp Pendelton 48
campgrounds 142, 158
camping 101, 107, 157
Canada 99, 159, 304, 326, 340
canary 164
Cancer antennarius 5
Cancer magister 5, 6, 166
Candida albicans 67
candlefish 12
candles 318
canning 13
canyons 82, 93, 165, 170
Cape Blanco 82
Cape Mendocino 18, 53, 82, 85, 88-90
Cape Mendocino Escarpment 53
capital expenditures 287
Capital Outlay Fund for Public Higher Education 291
car pool lanes 328
car pooling 146
carbon dioxide 64, 66, 308, 309, 311, 335, 339, 344, 348
carbon monoxide 217, 257, 347
carbonate 64
cargos 40, 152
Carpinteria 307, 319
Carquinez Strait 152
Carrizo Plain 332
cars 146, 298, 312, 328, 349, 350
Castle Rock 88
cattle 30, 119, 130, 131
cattle and sheep 30
causeways 221
CDF 16, 29
Central America 82
Central Valley 8, 26, 45, 46, 101, 117, 146, 173, 309
CEQA analysis 133, 134, 136, 137, 140
CEQA review 232, 237, 242
Cermeno 128
CESA 236
cetaceans 82, 85, 224
Chairman of the Council of Economic Advisors 223
Channel Islands 18, 53, 57, 76, 78, 81, 88-91, 123, 125, 162, 164, 167, 168, 170, 222, 228
Channel Islands National Marine Sanctuary Management Plan 222

Channel Islands National Park 228
channel straightening 46
channelization 46, 100, 115, 117
char 345
charter boats 6
Chelonia mydas 90
chemical compounds 309, 316
chemical controls 44
chemical dust inhibitors 188
chemical leakages 158
chemical waste 41
Chemtech 346
Chile 131, 162
chilipepper 169, 170
chillipepper 164
Chilula 12
China 130, 160, 303, 340
chinook salmon 9, 14, 21, 24, 25, 104, 106, 107, 172, 173
chlordane 67, 74
chloride 28, 37, 66, 217
chlorinated pesticides 67
chlorination 342
chlorine 66, 68
chromium 66, 68, 70, 74
Chrysler 348
citrus 30, 110
City of Los Angeles 26, 53, 238
City of Stockton 318
civil liability 219, 235
civil penalties 121, 219
civilian employment 49, 286
clamming 6
clams 6, 13, 67, 72, 103, 105-107, 170-172
Class I railroads 147
Clean Air Act 213, 217, 218, 229
Clean Air Provisions 233, 243
clean up 190, 202, 295
Clean Water Act 31, 39, 41, 45, 190, 194, 218, 221, 229, 230
Clean Water Provisions 234, 244
cliff erosion 47
climate 6, 29, 37, 39, 57, 58, 60, 61, 92, 93, 97, 103, 107, 110, 114, 115, 123-125, 131, 155, 157, 309, 310
climatological data 60
closed cycle system 340-342
Clupea pallasii 163
CO 2, 37, 39, 93, 251, 252, 311
coal 39, 191, 297, 298, 302, 303, 309, 332, 333, 342, 345-349
coal gasification 345, 346
coal gasification mining 346
coal gasifiers 345
Coast Guard 2, 15, 40, 43, 152, 157, 159, 202, 203, 214, 230, 243
Coast Ranges 20, 29, 51, 94-96, 100, 128
Coastal Act 14, 22, 27, 60, 121, 134, 200, 201, 233, 237, 240, 255
Coastal Aqueduct 246
Coastal Commission 16, 27, 121, 134, 154, 192, 205, 216, 233, 238, 240, 249, 255
Coastal Commission Archaeological Guidelines 121
Coastal Conservancy 238, 249
coastal cutthroat trout 8, 21, 25, 106, 107, 119, 172
coastal development 43, 209, 226, 231, 234-237, 241, 242, 246-251, 253, 255
Coastal Development Permits 241, 255
coastal engineering 47, 58
coastal environments 228
coastal planning 134, 228, 229, 237, 238, 244, 246, 247, 251
coastal power generating plants 67
coastal streams 47, 59, 172
coastal waters 1, 3, 15, 54, 59, 61, 216, 229, 234
coastal wetlands 19, 43, 59, 93, 104, 111
coastal zone 1, 2, 14, 22, 27, 28, 35, 43, 47, 48, 55, 58, 65, 81, 134, 216, 217, 233, 237, 240, 241, 249, 255, 334
cockles 13, 103, 171
coho salmon 21, 24, 25, 106, 107, 111, 165, 170
coke 217, 318, 342
coke oven emissions 217
coliform 31, 33, 67, 68
coliform bacteria 31, 33, 68
Colorado 46, 238, 343
Colorado River Aqueduct 46
Colorado River Board 238
Columbia Plateau 125
combustion 69, 308, 344
commerce 14, 66, 144, 146, 169, 212, 217, 223-225, 229, 231, 241
commercial businesses 329
commercial consumers 329
commercial energy users 302
commercial fishing 1, 3, 8, 34, 101, 158, 160, 165, 177, 205, 222, 224, 244
commercial floor space 329
commercial ocean transportation 1
commercial salt production 37
commercial shipping 1, 2, 222
Commission staff 159, 237, 239, 247
common carrier pipelines 147, 283
common carriers 231, 283, 312
Common loon 91
Common murres 88
communication equipment 318
Community Noise Equivalent Level 138, 140
commuter rail 146
commuters 350, 351
compensating for the impact 187
complementary goods 273, 276, 277, 279
compressors 316
computer model 185
computers 185, 329, 331, 332, 352
Conditional Use Permit 254
Congress 16, 23, 41, 212, 213, 215, 219, 222, 224, 226, 289, 323, 324
Congressional approval 213
conservation districts 247
conservation programs 327
Constitution 209, 241
construction sand 28
consumption of imported crude 263
container 1, 2, 152, 246
container storage areas 2

container vessels 1
contaminated surface water 44
contamination from marine vessels 70
Continental Borderland 53, 75
Continental Shelf 53, 55, 57, 65, 75, 80, 87, 89, 164, 212, 217-219, 226, 244, 255, 288, 306
contingency plan 190, 193, 219, 227, 242, 323
Contra Costa County 334
contract prices 261, 323
control technology 202, 217, 257, 347, 348
controlled burning of brushlands 250
Controller 239
convection heating 330
Convention on International Trade in Endangered Species of Wild 228
cooling 39-41, 68, 72, 93, 190, 311, 330, 335, 336
cooling waters 40, 41
copper 66, 68, 70, 352
Cordell Bank 82, 170, 222
cormorants 88
Corporate Average Fuel Economy 328, 349
Corps of Engineers 2, 39, 46, 157, 203, 220-222, 229
corrosive chemicals 349
cosmetics 36
Costa Rica 159
Council of State Governments 141
Council on Environmental Quality Guidelines 215
Councils of Government 144
county governments 2, 233, 239, 254
Covadonga 128
crab pots 3
crab traps 6
crabbing 6
crabs 3, 5, 6, 13, 80, 103, 105, 106, 115, 119, 166, 167, 169-172
Crassostrea gigas 33
crayfish 35
Crescent City 56, 87, 163, 166
Crescent City Harbor 163
criminal 219, 224, 235
crisis 144, 293, 320-323
criteria for impact assessment 188-192, 194, 196, 198-203, 205-207
criteria pollutant 217
critical habitat 223
croaker 4, 73, 163, 169, 170
crops 29, 30, 33, 59, 93, 97, 110, 128, 309, 311
crude oil 1, 41, 111, 112, 115, 147, 150, 154, 253, 259-274, 276, 277, 279-289, 292-295, 297, 298, 302-305, 307, 308, 312, 315-321, 324, 325, 342
crude oil market supply 263
crude oil markets 260, 263, 270, 283
crude oil prices 260-263, 266-268, 274, 280-282, 284-287, 304, 305, 320
crude oil pricing 259, 260, 262
crude oil producers 263, 283
crude oil production 264, 266, 282, 288, 302-305, 315, 318
Crude Oil Windfall Profit Tax 288, 289
cultural heritage 120, 122
Cultural Preserve 249
cultural resource surveys 121
cultural resources 49, 120-122, 132, 133, 196, 197, 253
culverting 46
cumulative effects 59, 176
cumulative impacts 177
currents 31, 47, 53, 55, 71, 81, 104, 110, 112, 123, 126, 163, 203, 204, 351, 352
cyanide 66
CZMA 216, 217, 227, 229

D

Dacron 318
dacthal 67
dairy products 29
dam safety programs 245
dams 12, 23, 39, 46, 47, 58, 100, 114, 117, 118, 173, 221, 245, 246
Davidson Current 55
Davis, California 332
dB 137, 138
dB(A) 138
DDE 91
DDT 69, 74, 91
DDTs 67-71, 74
Dean McIlroy 343
decibels 137, 138
decision theory 184
decrease dependence on oil 323
deep offshore reefs 75
deepwater bottoms 78
Del Mar skull 123
demand for crude oil 260, 271, 273, 274, 276
demography 141, 142
density interfaces 57
Dentalium 12
Department of Agriculture 206, 230
Department of Boating and Waterways 2, 157, 250
Department of Commerce 14, 66, 169, 229
Department of Conservation 246
Department of Energy 267, 277, 324, 325, 343, 346
Department of Finance 8
Department of Fish and Game 2, 3, 5, 8, 15-17, 19, 24-26, 31, 34, 36, 60, 91, 96, 118, 157, 158, 160, 163, 164, 165, 167, 169, 192, 205, 222, 225, 235-237, 241-243
Department of Food and Agriculture 30
Department of Forestry and Fire Protection (CDF) 29, 30, 250
Department of Health Services 31, 140, 199, 200
Department of Interior 80, 163, 164, 168, 170, 214, 225, 227, 228, 288
Department of Motor Vehicles 2, 157, 252
Department of Parks and Recreation 14, 17, 122, 155, 225, 249, 250, 253
Department of the Interior 36, 51, 225
Department of Transportation 140, 144, 146, 147, 155, 199, 200, 202, 230, 251, 351
Department of Water Resources 46, 60, 157, 235, 245
depression 72, 319, 321
derived demand 273
Dermochelys coriacea 90

Desalination Plants 37
desert 26, 27, 30, 45, 124, 143
destruction of habitat 15, 177
detergents 318
developable lands 43
developers 23, 48, 49, 142, 232, 233, 252, 339
development projects 21, 46, 120, 131, 220, 232, 234, 236, 244, 253, 289
Diablo Canyon 39, 336
diatoms 65
dieldrin 67
diesel engines 318
diesel fuels 312, 317
dikes 47, 221
dinoflagellates 31, 171
dioxide gas 335
dioxins 67
dip nets 6, 12, 171
dip netting 167
dipnetting 5
direct and indirect impacts 108, 176
direct space heating 333
Director of Conservation 246
Director of Finance 239, 242, 249
Director of State Planning and Research 251
discharge permits 243
dispensary 316
disposal of sediment 41
disposal permits 244
dissolved oxygen 34, 61, 64, 190, 194
distillates 302, 317
distillates fuels 317
distribution of marine organisms 81
distribution of marine pollution 70
ditches 43, 44
ditching 43
diurnal effects 60
divers 6, 7, 76, 168, 170
diversion 46, 118, 119, 173, 338
diving 6, 9, 74, 78, 157
Division of Mines and Geology 246, 247
Division of Oil and Gas 44, 246, 247, 327
Division of State Lands 238, 239
DOE 267, 286, 324, 343, 346
DOG 202, 246
domestic crude oil supplies 284
domestic production 260, 263-269, 294, 305
domestic sewage 43
domestic supply curve 260, 266, 267, 271
domestic supply patterns 263
Dover sole 158, 160
Dow Chemical 345
drainage 43, 74, 104, 105, 112, 116, 189, 192, 198, 235
draining 43, 74, 100, 108, 114, 115
Drakes Bay 128
dredge spoils 22, 69, 70, 221
dredged channel entrances 47
Dredged material 41, 222
dredging 21, 25, 28, 37, 67, 69, 114-116, 119, 205, 237, 239, 248, 251
drift nets 4, 164, 167
drilling 28, 43, 44, 60, 69, 140, 191, 213, 214, 227, 295, 318, 319, 325-327, 333
drilling activity in state waters 327
drilling fluids 44, 69
dry bulk cargo 152
dry cargo 152
ducks 13, 100, 194
dugongs 224
dumping 41, 66, 67, 69, 70, 100, 115, 221, 229
dunes 21, 47, 93, 95-97, 102, 109, 113
Dungeness crab 6, 102, 104-107, 166, 167
Dungeness crabs 3, 5, 6, 166
duration of impact 176, 177, 198

E

early cultures 124
early man 123
early storage reserve 324
earthquake 58, 181, 228, 247
earthquake preparedness 228, 247
earthquakes 57
East Texas 305
eastern Pacific 74, 159, 164, 166
ecological impacts 71, 72
ecological preservation 17, 231
ecological preserves 242
economic advantage 218
economic impact 49, 287
economic incentives 281
economic sectors 2, 293
economic theory 259, 260, 271, 280
economic value 29, 30
economics 142, 201, 247, 259, 277, 278, 292, 340
economics of oil 259
economies 49, 142, 154, 270, 296, 321
economy 8, 15, 131, 141, 142, 260, 263, 284-288, 293, 295-297, 302, 321, 322, 328, 349
ecosystems 15, 16, 66, 69, 72, 76, 92, 93, 95, 97-103, 108-110, 112-116, 192, 222, 308, 341
education 15, 16, 19-22, 25, 36, 101, 104, 105, 143, 157, 203, 222, 229, 291, 328
educational programs 20, 197, 219, 330
Eel River 10, 27, 44, 106, 107, 119
Eel River Basin 27, 44
EEZ 28
effects of development 92, 110, 112, 117, 119, 132, 141, 173, 194
effects of pollutants 31
eggshell breakage 74
EIR 133, 140, 155, 176, 178, 187, 232
EIS 187, 215, 216, 226
El Segundo 154
electric cars 349, 350
electric transmission lines 47
electric vehicles 349, 350
electrical generation 302
electrodes 318

Elegant tern 92
Elizabeth Tudor 128
Elk Hills Naval Petroleum Reserve 306, 319
Elkhorn Slough 31, 105
Emission Control Technology Division 347, 348
employment 27, 29, 49, 133, 142, 144, 202, 285-288, 293, 294, 322
encircling nets 3, 4
encroachment permit process 253
end product demand 274
endangered species 16, 58, 89-91, 95, 108, 109, 114, 192, 194, 222, 223, 227, 228, 234, 236, 242
Endangered Species Committee 223
endosulfan 67
endrin 67
energy alternative 332, 350, 351
Energy Commission 39, 200, 270, 277, 300, 328, 330, 331, 338, 339, 342, 343, 345, 347, 350, 351
energy consumption 155, 273, 297, 298, 300, 302, 327
energy costs 286, 329, 332
energy crisis 293, 321, 323
energy development 248
energy efficiency 247, 248, 273, 323, 327, 329-331, 344
energy emergencies 248, 323
Energy Information Administration 268, 305, 325
energy needs 101, 248, 278, 293-295, 297-299, 322
energy policy 247, 248, 327
Energy Resources Conservation and Development Commission 238
energy source 297, 303, 349
energy tax credits 332
energy uses 334, 344
enforcement 157, 214, 217-219, 224, 228, 229, 235, 243, 244
engineering 46, 47, 58, 147, 181, 190, 202-204, 225, 247, 252, 352
Engraulis mordax 159
enhanced oil recovery methods 319
enterococcus bacteria 67
environmental analysis 133, 176
environmental assessment 175, 187, 215
environmental costs 294, 295
environmental degradation 22, 44
environmental groups 49, 244
Environmental Health Division 31
environmental impact report 133, 232
environmental impact statement 159, 175, 187, 215, 226
environmental impacts 21, 118, 175, 176, 186, 295, 327, 344-346
environmental protection 44, 45, 60, 140, 217, 219, 223, 229, 232, 243, 247, 256, 279, 347, 348
Environmental Protection Agency 44, 45, 60, 140, 217, 219, 223, 229, 256, 347, 348
Environmental Quality Assessment Act 244
environmental regulations 267, 280
environmental review 214, 230, 233, 236, 244, 246, 249
environmentally sensitive areas 133, 237
enzyme systems 66
EPA 17, 111, 199, 217-222, 229, 256
epidermal tumors 73
Eptatretus 167
equator 53, 55, 87
erosion 21, 30, 41, 43, 47, 51, 59, 60, 65, 73, 93, 96, 97, 108, 112, 115, 117-119, 133, 157, 173, 189, 191, 192, 194, 195, 198, 203, 206, 217, 250, 251
erosion control 21, 157, 195, 217, 250, 251
escarpments 82, 166
estuaries 6, 12, 18, 30, 31, 35, 41, 43, 70, 88, 92, 93, 99, 101-106, 111, 115-117, 164, 172, 173, 191, 192, 219
estuary 12, 13, 17, 19, 40, 90, 101-106, 116, 118, 172, 173, 219, 220, 339, 340
ethane 317
ethanol 342, 343
ethylene 317
euphotic zone 65
Eureka 20, 158-160, 165-168, 170
European influences 13
evaporation ponds 37
evolutionary development 120
Ewing Young 130
Exclusive Economic Zone 159, 212, 224
Executive Officer 239, 249
exhausts 188
existing landscape 136, 137
exoskeletons 65
exploration 28, 126, 128, 140, 213, 217, 227, 240, 264, 267, 271, 280, 305, 306, 319, 323, 325, 326, 327, 334, 345
exploration and development 217, 264, 267, 271, 319, 325-327, 334
exploration plan 213, 227
exploratory drilling 28, 213, 227
exploratory wells 213, 325, 327
explorers 122, 130, 318
exports 154, 282, 305, 324
extinct bison 124
extraction of algin 36
extreme tides 56, 58

F

FAA 140, 230
failure tree 182
Farallon Islands 82, 88, 89, 91, 168, 170
Farallones 85, 88, 222
farming 29, 31, 33, 118, 130, 131, 341
farms 2, 29, 33-35, 40, 242, 295, 333
fault tree analysis 182
Fauna and Flora 228
feather traders 91
fecal wastes 67, 68
federal action 215
federal agencies 46, 121, 140, 166, 215, 223, 225, 250, 323
Federal Aviation Administration 140, 199, 230
Federal Coastal Zone Management Act 233
Federal Energy Regulatory Commission (FERC) 147, 230, 247
Federal Extended Economic Zone (EEZ) 28
federal government 177, 209, 214, 224, 225, 230, 234, 235, 238, 241, 252, 288, 319, 328, 342
Federal Highway Administration 140, 199, 200
federal lands 121, 147, 216, 226, 288
federal law 24, 134, 212

Federal legislation 120, 209, 235
federal offshore fields 306
Federal Register 159
Federal Trade Commission 283
Federal Water Pollution Control Act 218, 235
federal waters 160, 216, 218, 226, 227, 230, 233, 240, 241, 307
feedstocks 273, 274, 315-317
FERC 147, 230
ferries 147
fertilizer 28, 65, 117, 318
fertilizers 30, 114
field crops 29
field storage tanks 312
fill 60, 101, 189, 220, 229, 230, 239, 248, 321, 339
filled lands 43, 239
filling 21, 37, 43, 100, 108, 112, 114-117, 237
fin erosion 73
fin fish 33, 169
Final Notice of Sale 227
finished products 144, 317
fire 21, 27, 29, 30, 49, 94-97, 109, 113, 143, 195, 202, 203, 238, 250, 316, 346
fire fighting equipment 316
fire protection 29, 30, 143, 238, 250
firewood 28, 96
First Eel Ceremony 12
First Salmon Ceremony 12
Fish and Game Code 159, 160, 236, 241
Fish and Game Commission 160, 194, 241, 242
fish farms 40
fish habitat 23, 24, 58, 106, 111, 119
fish populations 8, 23-25, 44, 72, 107, 173
fisheries 3, 6, 8-10, 13, 14, 21, 23, 88, 90-92, 104, 105, 111, 159, 164-166, 169-171, 194, 203, 205, 214, 221, 224, 225, 228, 229, 231, 243-245
fishermen 3, 6, 24, 76, 78, 159, 160, 162, 169-171, 205, 214
fishing grounds 3
fishing industry 2, 242
fishing rights 13, 157
fishing vessels 2, 160, 225
five categories of mitigation 186
flatfish 4, 73, 102, 103, 159, 160, 170
flatfishes 71
flood control 22, 23, 46, 47, 114, 228, 245, 246
flood plain 192
flood protection 45, 46
flood waters 40, 46
Florida 126
flowers 30, 98
fluted points 124
fluted projectile points 124
fog 93, 110, 155
fog belt 155
foliage products 29
Folsom, New Mexico 124
food gathering strategies 123
food technology 36
Ford 323, 348, 349
foreign crude oil 147, 270, 292, 298
foreign imports 263
foreign oil 277, 292, 293, 325
foreign sources of energy 322
foreign vessels 160, 164
forest 15, 17, 18, 20, 29, 30, 92-95, 97, 100, 107-110, 114, 115, 136, 193, 194, 230, 250
Forest Service 17, 29, 109, 136, 194, 230
forestlands 28
forestry 20, 28-30, 68, 115, 194, 238, 250
forests 16, 17, 19, 29, 58, 73, 76, 78, 91, 93-95, 98, 108, 110, 113, 114, 250
formaldehyde 347
Fort Bragg 168, 170, 250
Fort Ross 130, 166
fossil fuel 39, 338, 342
fossil fuel plants 39
fossil shorelines 124
fossils 119, 120
Four Corners Pipeline 150
France 159, 303, 339, 340
Francis Drake 128
Franciscans 130
Fray Andres Urdaneta 126
freeways 48, 140, 192, 201
freon 341, 342
frequency 57, 136, 138, 141, 191, 332
fresh water aquifers 44
Freshwater runoff 68, 73, 74
fruit 318
fruits 29, 94, 98
fuel cell 339, 344, 345
fuel cell stacks 344
fuel economy standards 328
fuel gas 345
fuel use 273, 328, 329
fulmars 87
fur seal 90, 91
fur seals 85, 88, 89, 91
furnaces 316, 330
fusion 336, 337
future crude oil supply patterns 268

G

Galvez 128
gamefish 7, 8
gas prices 302, 326, 332
gas processing 59, 315, 316
Gas Research Institute 345
gasoline 235, 252, 273-276, 278, 279, 286, 289, 292, 298-300, 312, 315-318, 321, 328, 343, 347, 348
gasoline consumption 275, 298, 299, 328
gasoline taxes 292
gastroenteritis 67, 74
geese 13
General Motors 348-350
General Plan 140, 178, 201, 254, 255
General Plan Amendment 201, 254
general plans 27, 60, 251
general public 19, 178, 232, 247

General S. H. Marlette 251
generator 337, 349
geochemical byproducts 333
geologic features 51
geologic hazards 189
geology 39, 51, 58, 107, 181, 189, 192, 195, 198, 228, 239, 246, 247
Geology and Soils 189, 192, 195, 198
geomorphic provinces 51
geomorphology 58
geophysical surveying 213, 326
geophysical surveys 325
geothermal 34, 39, 298, 302, 333-335
geothermal development 335
geothermal energy 302, 333, 334
geothermal fields 39
geothermal plants 39
geothermal power 39, 302
geothermal resources 333-335
geysers 334, 335
geysers field 334
giant kelp 25, 33, 36, 73, 76, 78
giant kelp beds 36
gill net 4, 14, 164, 165
gill nets 6, 13, 163-165
GNP 260, 273, 284, 285, 322
gold 8, 9, 13, 28, 117, 126, 131
Gold Rush 8, 117, 126, 131
Golden Gate 1, 53, 228
Golden Gate National Recreation Area 228
Goleta Slough 128
Gorgonians 76
government action 215, 229
grading 27, 59, 60, 112, 188
grading natural landforms 59
grain alcohol 343
graphics 182
grasslands 16, 21, 30, 97, 101, 113
grave goods 121, 132
gravel 28, 80, 95, 103, 106, 114, 115, 143, 196
Gray Whales 82, 83, 85
grazing 16, 21, 25, 26, 30, 58, 78, 92, 96-98, 106, 114, 115, 118, 119, 128
grazing industry 30
greases 67, 317
Great Alaska Earthquake 58
Great Basin 125
Great Depression 319
Great Plains Plant 343
Great Plains traditions 124
Great Valley 53
grebes 87
Green River oil shale formation 343
green sea anemones 13
green sturgeon 10, 13, 106, 107, 172
grey waters 41
groins 47, 251
Gross State Product (GSP) 329
ground water 58, 100, 189, 191, 235, 245
ground water aquifers 58
ground water recharge 191, 245
groundfish 159, 160
groundwater 43-45, 58-60, 192, 333
groundwater aquifers 45, 59, 60
groundwater basins 44, 59
groundwater quality 58
growers 31, 33-35, 97
growing season 30, 98
Gulf Coast 231, 261, 284, 296
Gulf of California 53
Gulf of the Farallones 85, 88, 222
gulls 87, 88, 97-99

H

habitat 9, 15, 16, 19-24, 28, 44, 47, 58, 59, 66, 68, 71-73, 75, 78, 82, 88, 90-100, 102, 103, 104, 106-115, 117-119, 132, 164, 167, 173, 177, 193-196, 205, 223, 228, 236, 242, 338
habitat areas 47, 59
habitat diversity 75
habitat protection 58, 228
habitat values 94, 177, 196
habitats 15, 16, 18-21, 26, 40, 41, 66, 72, 73, 75, 76, 78, 81, 92, 95, 97, 100, 102, 104, 105, 106, 111, 115, 118, 192, 193, 195, 196, 198
hagfish (slime eels) 5
halibut 4, 7, 33, 103, 158-160, 163, 164, 169, 170
Haliotis 33, 168
handlines 5
handpicking of fish and invertebrates 5
harbor development and management 239
Harbor porpoise 85, 88
Harbor seals 88, 89
harbors 6, 41, 69, 71, 73, 92, 152, 154, 155, 167, 170, 220, 229, 250, 251
hard bottom 193
harpooning 5, 167
harvest by hand 5
harvesting 5, 13, 24, 33, 36, 98, 167, 221, 234
Hawaii 1, 131, 228, 341, 342
Hazardous Substance Cleanup Arbitration panel 244
hazardous wastes 44, 59, 235
Health and Safety Code 44, 233, 236, 256
hearing loss 138
heat 67, 68, 70, 71, 95, 96, 120, 309, 311, 316, 320, 332, 333, 335, 337, 340-342, 344, 349-351
heat exchanger 341, 342
heat output 70
heating oil 274, 286, 312
heating oils 317
heavy crude oil 342
heavy metals 45, 115, 192, 194
heavy mineral black sand deposits 28
helium 335-337, 351, 352
hemispheric wind 60
hepatitis 67, 74
herbicides 59, 68, 114, 115
herring 4, 89, 102, 105-107, 119, 163, 169, 170
hides and tallow 130

High seas drift nets 164
high technology lighting 330
highway construction 252
highways 47, 140, 143, 144, 155, 251, 252, 318
hiking 101, 157
Historic Landmarks 122
historic resources 120, 122, 126, 197, 249
historic sites 121, 133, 157, 197
Historic Sites Act 121
historical 23, 24, 40, 88, 113, 122, 131, 157, 180, 185, 186, 197, 204, 225, 239, 249, 250, 271, 322
historical data 180, 186
historical location of navigable waterways 239
Historical Monuments 157
historical values 24, 225
Hokan 125
Holocene 124, 125
home energy use ratings 331
homebuilders 330
Homo erectus 123
Hondo 307
hook and line 5, 6, 10, 13, 165, 166, 170
hook and lines 3
hoop nets 6, 170
Hoopa Indian Reservation 14
hospitals 140, 188, 352
hot dry rock reservoirs 333
hot springs 333
hotels 14, 157, 158
houses 27, 37
housing 26, 27, 43, 47, 48, 114, 132, 141, 142, 144, 202, 251
housing costs 27
Hueneme 152
human environment 41, 215
human health 31, 41, 66, 67, 74, 110, 184, 221
human health impacts 66, 74
human health impacts of marine pollution 74
Humboldt 10, 13, 18, 21, 23-25, 31, 39, 40, 89, 102, 106, 107, 118, 119, 152, 154, 163, 166, 171, 228, 336
Humboldt Bay 10, 13, 25, 31, 89, 102, 106, 107, 119, 154, 163, 166, 171, 336
Humboldt County 23, 106, 107, 118, 228
Humboldt Redwoods State Park 228
Humpback whales 85, 89
hunting 12, 13, 17, 40, 89, 90, 98, 124, 125, 157, 160
Huntington Beach 154, 292, 307
Hupa 24
hydraulic gold mining 9, 13
hydraulic turbines 338
hydrocarbons 67, 68, 71, 112, 188, 191, 227, 257, 315, 345, 346
Hydroelectric 39, 114, 246, 297, 298, 302, 335, 338-340
hydroelectric dams 39, 114
hydroelectric plants 39, 246
hydroelectric power 39, 297, 302, 338
hydroelectric projects 338
hydrogen 64, 66, 67, 317, 336, 341, 344, 345, 347
hydrogen ion concentration (pH) 64
hydrogen ions 66
hydrogen production 344
hydrology 58, 99, 100, 133, 191
hydroponic agriculture 333
hydropower 297, 302

I

IATTC 159
Iberia Parish, Louisiana 324
Ice Age 123, 310
illegal reclamation projects 239
Impact Reports 175
imported crudes 260, 268
imports 147, 260, 263, 264, 266, 267, 270, 271, 277, 285, 298, 305, 322-326, 328
income taxes 288, 289
independent crude oil producers 283
independent producers 282, 287, 315
independent refiners 283, 315, 316
Indian Communities 253
Indians 13, 122, 130-132, 253, 318
indirect impacts 108, 176
Indonesia 270
industrial discharges 59
industrial distilled fuels 317
industrial facilities 67, 68, 206
industrial products 36
industrial waste 41
industrial wastes 40
industrial water supply 234
inertial confinement 336, 337
infrastructure 141, 143, 152, 200, 202
injection 41, 60, 243, 324
inland fisheries 8, 166, 170, 171
inns 157
inorganics 66, 316
insecticidal sprays 43
insecticides 317, 318
inspections 214, 227, 235, 244, 252
insulation 111, 199, 309, 318, 330
Internal Revenue Service 281
internal waves 56, 57
international law 2, 212
international negotiations regarding fisheries 228
international oil companies 271
International Pacific Halibut Commission 158, 159
International Pacific Halibut Commission (IPHC) 159
International Thermonuclear Experimental Reactor 337
international trade 228
international treaties 222, 228
Interstate Commerce Commission 146
interstate natural gas pipelines 230
intertidal 7, 12, 15, 37, 43, 73-76, 78, 80, 99, 102, 107, 117, 171, 193
intertidal shores 73, 75
intervention 277, 311
introduced species 97, 118
invertebrates 3, 5, 6, 13, 34, 37, 72, 73, 78, 103-106, 118, 167, 169, 171-173, 196
investment 35, 252, 253, 267, 284, 285, 287, 293, 294, 329, 334, 340, 342, 343

involuntary risks 184, 185
Iowa Department of Transportation 155
IPHC 159
Iraq 320
irrigation 45, 46, 98, 114, 117, 118, 228, 235, 245, 251, 309
Isaac Williams 130

J

Jack mackerel 163
Jackson State Demonstration Forest 250
James Ohio Pattie 130
Japan 1, 123, 159, 168, 303, 323, 335-337, 352
Japanese 37, 163, 328
Japanese cars 328
jeopardy opinion 223
jetties 3, 6, 47, 170, 221
job categories 142
jobs 26, 29, 142-144, 146, 202, 286, 294
John Gilroy 131
John Marsh 131
John Sutter 130
Jones Act 284
Joseph Reddeford Walker 130
Juan Rodrigues Cabrillo 126
Justice Department 281

K

Karuk 24
Kelco Division of Merck and Company 36
Kellog Rust 345
Kelp 7, 15, 21, 25, 26, 33, 36, 37, 73, 75, 76, 78, 80, 90, 168-170, 193, 205
kelp beds 25, 26, 36, 37, 73, 78, 80, 90, 168, 193, 205
kelp canopy 193
kelp harvest 36
Kern River 306, 320
kerosene 317, 318
KGRA 334
kinetic energy 65
King Phillip II 126
King salmon 8
Klamath Mountains 53
Klamath River 10, 12-14, 24, 82, 125
Klamath River Basin 13, 14
Klamath River estuary 13
Klamath-Siskiyou Range 29
Known Geothermal Resource Areas 334
Knox-Nesbit Act 134

L

La Jolla 18, 163, 170
Labor force economics 142
Lacey Act 228
Lagoons 31, 73, 87, 99, 102, 104, 105, 107, 111, 116, 119
lake 10, 19, 39, 60, 101, 104, 107, 125, 146, 242, 324, 334
Lake Tahoe 146
lakes 8, 24, 99, 102, 103, 124, 125, 173, 191, 192, 238
Lakeview Gusher 319
land transportation 47
land use 14, 28, 133, 134, 138, 140, 146, 152, 187, 188, 199, 201, 202, 206, 251, 254, 255, 328
land use impact analysis 133
Land Use Plan (LUP) 134
land use policies 28, 146, 201, 206, 251
landfill 43, 244, 338, 339
landfills 59, 244, 309, 338, 339
landforms 59, 136
landings 6, 47, 158, 163-168, 171
landscape 15, 27, 92, 98, 108, 136, 137, 239
landslides 23, 47, 113, 189
language stocks 125, 126
LaRance Estuary 340
law 2, 22, 24, 40, 41, 44, 46, 134, 152, 157, 212, 221, 224, 225, 228, 234, 247, 253, 255
law enforcement 157, 228
laws 23, 41, 46, 120, 122, 131, 157, 160, 212, 218, 224, 228, 230, 236, 242, 245, 247, 281, 336
LCP 134, 201, 255
lead 27, 66, 68, 70, 74, 78, 109, 110, 112, 113, 177, 178, 182, 187, 201, 202, 217, 233, 236, 267, 285, 293, 294, 311, 322, 326, 344, 346, 350
lead agency 178, 187, 233, 236
lead-acid battery 350
League of Women Voters 30, 146
lease sale 51, 213, 227
lease sites 31
lease-right-of-way 240
leases 31, 33, 36, 147, 150, 213, 214, 226, 239, 240, 305-307, 326
Least terns 87, 90
legal authority 46
legal framework for impact assessment 175
legislature 160, 231, 238-241, 245, 247-249, 251, 253, 349
Lepidochelys olivacea 90
Leslie Salt Company 37
levee work 43
levees 37, 46, 117, 245
levels of marine pollution 69
Levels of Service (LOS) 144
Lewis Air Quality Management Act 256
licensing 157, 220, 230, 247
Lieutenant Governor 239
life cycles 21, 193
light crude oils 312
light oils 317
lighter aboard 154
lighting 309, 330
lime 28
limpets 13, 171
linear nets 4
liquefied petroleum gas 317
liquid bulk cargo 154
liquid hydrocarbons 315, 345, 346
liquid metal fast breeder reactor 336

liquid sodium 336
liquid waste 40, 41, 143
Little Hoover Commission 144
Little River 10
littoral cells 47
livestock 29, 30, 36, 92, 94, 96-98, 117
livestock forage production 30
living species 71
lobster 6, 167, 170
lobsters 5, 7, 76, 166, 167, 169
Local Agency Formation Commission (LAFCO) 134
local and regional impacts 177
Local Coastal Plan 60, 240, 241, 255
Local Coastal Programs 134, 233, 255
Local Coastal Programs (LCPs) 255
Local planning 14, 254
Local Transportation Commissions 144
logging practices 119, 173, 250
Long Beach 1, 43, 47, 152, 154, 290
Long Beach Harbor 154
Long Beach tidelands 290
longline fishing 165
longlines 5, 166
Los Angeles Aqueduct 46
Los Angeles Basin 27, 44, 51, 125, 279, 312
Los Angeles County 73, 154
Los Angeles River 46
Los Padres National Forest 230
Louisiana 288, 296, 305, 324
low pressure wells 338
low probability events 181, 182
low-level radioactive wastes 41
lower atmosphere 60
LPG 289, 292, 317
lubricating oils and greases 317
lumber 2, 29, 131, 250
lumber sheds 2
LUP 134
Lurgi Gesellschaften 345

M

Mackenzie River 123
mackerel 4, 160, 163-165, 169, 170
Macrocystis pyrifera 33, 36, 78
Macrocystis spp. 73
macroeconomic effects 285
macrofossils 119
magnetic bottle 336
magnetic confinement 336, 337
Magnuson Fishery and Conservation Act 159
Magnuson Fishery Conservation and Management Act 224
major action 215
major federal actions 215
major pollution sources 72
major streams 68, 106
makeup 136, 318
Malibu 43
management of public property 209
manatees 224
Manila 126, 128
Manila Galleons 128
manufacturing 14, 142, 273, 274, 279, 287, 318
Mare Island 152
marginal seas 209
mariculture 30, 31, 33, 36, 37, 168, 205, 222, 234, 333-335
mariculture industry 31, 334
Marin 128, 256, 334
Marina del Rey 73, 239
marinas 2, 41, 70, 99, 132
marine biology 19, 74, 192, 193
marine birds 82
marine ecosystem 221
marine ecosystems 16, 66, 72, 101, 341
marine environments 16, 21, 224
Marine Mammal Commission 90, 91, 224
Marine Mammal Protection Act 224, 228
marine mammals 12, 71, 73, 74, 81, 82, 89, 193, 223-225, 227, 229
marine navigation 1
marine organisms 19, 20, 53, 66, 72, 81, 193, 341
marine pollution 66, 67, 69-71, 74
marine protection 221, 229, 230
Marine Protection, Research, and Sanctuaries Act 221
Marine Review Committee 66
marine sanctuaries 221
marine sanctuary provision 222
marine snow 65
marine terminals 40, 147, 152, 154, 237, 240, 315
marine vertebrates 82
marine water quality 61, 66, 75, 190, 194
market areas 27
market imperfections 260, 262, 280
market power 280-282
market squid 162, 167
MARPOL Convention 41
marsh intertidal pools 43
marshlands 43, 114, 117
mass transit 143, 144, 146, 155, 252, 311, 328, 329, 350, 351
matches 318
mathematical abstractions 179
mathematical basis of probability 178
mathematics 178, 179, 182
matrix 119, 184, 209
Mattole 10, 24, 28, 118, 228
Mattole River 118, 228
McAteer-Petris Act 248
medicine 109, 132, 318, 352
melons 29
Mendocino County 23, 37, 89, 94, 95, 106
Mendocino Escarpment 53, 57
mercaptans 315
mercury 66, 68, 70, 74, 217, 351
metamorphism 120
meteorological conditions 257
meteorology and climate 60
methane 309, 317, 339
methanol 277, 278, 341-343, 345, 347-350
methanol production 348

methylmercury 66, 71
Mexican Border 49, 82, 92, 110
Mexican Breeding areas 87
Mexican rule 130
Mexico 1, 53, 57, 82, 90, 103, 123, 124, 126, 130, 131, 168, 288, 304
microcrystalline wax 318
microcrystalline waxes 318
microfossils 119
microscopic algae 33
Middle East 180, 303, 320, 321
Midway-Sunset field 319
Midwest 343
Migratory Bird Treaty Act 228
migratory birds 18, 222, 228
migratory marine birds 82
migratory species 82, 157, 165, 225
military 1, 41, 43, 48, 49, 67, 69, 104, 116, 128, 134, 207, 222, 230, 323, 336
military activities 222
military control 49
military munitions 69
military ship traffic 1
military traffic 207
military waste 41
Millingstone Tradition 125
mineral processing plants 41
mineral resources 28, 238, 246
mineral water 333, 334
Minerals Management Service 51, 213, 226, 288, 325
miners 13
Mini-Otec 341
minimizing impacts 187
mining 9, 13, 19, 21, 28, 68, 95, 97, 108, 117, 118, 173, 226, 246, 247, 346
Mining and Geology 246
Mining and Geology Board 246
Minke whales 83
missiles 48
missions 128, 130
Mississippi Canyon block 194 305
Mitigation Monitoring 187, 232
mitigation monitoring plans 187
mitigation of impacts 186
mitigations 158, 175, 178, 186-190, 192-195, 197-202, 204-207, 226
MMS 180, 213, 214, 218, 226, 227, 288, 325
mobile emission sources 233
modeling 185, 186, 257, 310, 337
models 58, 136, 179, 185, 186, 310, 350
Modoc Plateau 125
monitoring networks 235
monitoring program 187, 192, 195, 200, 232, 235
Monte Carlo method 186
Monterey Bay 6, 18, 90, 105, 117, 160, 162, 163, 222
Monterey County 23, 30, 87, 93, 108
Montrose Chemical Company 70
monuments 157
Morro Bay 5, 31, 74, 87, 96, 105, 160, 166, 167
mosquito abatement 43, 44
Mosquito and Vector Control Association 44
mosquito control 43, 44
Mosquito fish 35, 43, 115
mosquito larvicide 44
mosquitoes 43
motels 157
motor oils 317
multiple event probabilities 181
municipal outfalls 67, 69, 70, 72-74
municipal runoff 45
municipal wastewater discharges 67
municipal wastewater treatment plants 67
munitions 41, 69
murrelet 88, 91, 93, 94
murres 88
mussels 13, 31, 33, 67, 71, 76, 103, 105, 107, 170, 171
Mytilus edulis 33

N

NAAQS 188, 217
NASA 333
National Ambient Air Quality Standards (NAAQS) 188, 217
national defense 212
national economy 260, 322
National Energy Laboratory of Hawaii 341
National Energy Plan 324
National Environmental Policy Act 120, 175, 214, 226
National Estuary Program 219
National Historic Preservation Act 120, 121, 225, 249, 250
National Marine Fisheries Service 159, 194, 214, 224, 229
National Ocean Service 229
National Oceanic and Atmospheric Administration 66, 222, 223, 229
National Park Service 14, 17, 21, 157, 222, 228
national parks 119, 157
National Petroleum Council 269
National Pollution Discharge Elimination System 41, 60, 221
National Recreation Area 17, 19, 228
National Register 121, 198, 225
National Register of Historic Places 121, 198, 225
National Weather Service 229
national wildlife refuges 18, 19, 228
Native American 8, 10, 12, 13, 24, 121, 122, 125, 126, 131-133, 157, 196, 197, 236, 253
Native American Fisheries 8
Native American fishing rights 157
Native American Heritage Commission 121, 122, 253
Native American human burials 236
Native American religious practices 121, 122
Native American Remains 236
Native Americans 1, 8, 10, 12-14, 107, 122, 131, 132, 197, 198
native fish 44
native species 15, 35, 97, 108, 114, 118, 189, 194, 195
natural disasters 118, 185
natural gas 67, 230, 240, 273, 277, 278, 297-299, 302-304, 312, 315, 316, 319, 323, 339, 342, 344, 345, 347, 348
natural gas fields 312
natural gas liquids 297, 302-304

natural lighting 330
Natural Preserve 17, 249
natural resources 15, 20, 28, 67, 154, 220, 250, 293
natural seeps 69, 119, 318
nature appreciation 157
Nauru 341
nautical charts 229
Navidad 126
navigable rivers 238
navigable waters 212, 219-221, 229, 230
navigation 1, 3, 19, 49, 117, 128, 155, 157, 212, 229-231, 234, 238, 250
navigation facilities 1
navigational aids 2
navy 17, 48, 230, 332, 341
negative declaration (ND) 232
nekton 72
NEPA 108, 120, 121, 175-178, 186, 187, 214-216, 226, 227, 230, 236, 249
Nereocystis 76
Nereocystis luetkeana 76
nesting 37, 47, 87, 88, 90, 98-100, 193, 195
net profit shares 213
nets 3-6, 12, 36, 49, 126, 132, 163, 164, 167, 170, 171
neurotoxins 31
New England 130
New Mexico 124, 288
New Orleans 128
New Source Review 257
New Spain 126, 128
New York 141, 142
newsprint 152
NHPA 121
Nicaragua 159
nickel 66, 350
nickel iron batteries 350
Nikolai Rezanov 130
nineteenth century 46, 239
nitrate 65, 66
nitrogen 65, 110, 188, 217, 316, 347, 351
nitrogen dioxide 217
nitrogen oxides 188, 347
nitrous oxides 257
NMFS 89, 167, 169, 224, 229
NOAA 17, 103, 111, 112, 217, 222, 224, 229
noise 47-49, 133, 137, 138, 140, 141, 152, 176, 177, 185, 195, 199, 207, 252, 328
nonassociated gas 315
noncompliance 121, 218
nonhazardous waste 235, 243
Nonpoint Source Program 235
nonpoint sources 67, 69, 71, 73, 220
North Coast 13, 18, 19, 29, 45, 46, 58, 97, 100, 106, 118, 244, 250
North Coast Range 18
North Pacific 53, 55, 126
North Pacific Gyre 53
North Pacific Ocean 53
Northern anchovy (Engraulis mordax) 159
Northern elephant seals 81, 85, 89
Northern France 340
Northern fulmars 87
Northern fur seals 85, 88, 89
Northern sea lion 91
Notice of Sale 226, 227
NOx 188
NPDES 41, 60, 190, 220, 235
nuclear 39, 184, 297, 298, 302, 303, 311, 332, 333, 335, 336, 338, 340, 349
nuclear electric power 297, 302, 303
nuclear fission 335
nuclear generators 39
nuclear plants 39, 335, 336, 338
nuclear power 184, 297, 298, 303, 311, 332, 333, 335, 336
nuclear power plants 335, 336
nuclear research 336
nursery 29, 30, 73, 76, 102, 104-107, 111, 117, 205, 250
nutrient concentrations 61, 65
nutrients 31, 35, 54, 55, 65-68, 71, 73, 76, 81, 109, 220, 341
nutrients in the ocean 65
nuts 12, 29, 94, 98, 125
nylon 318

O

Oakland 47, 152
objectionable odors 188
Occidental Petroleum 271
ocean climate 61
ocean discharges 190
ocean dumping 41, 66, 69, 70, 221, 229
Ocean Dumping Act 221, 229
ocean farming 31
ocean floor topography 239
ocean outfalls 27
Ocean Plan 41, 234, 235
ocean waters 41, 221, 234
Oceanside Harbor 47
OCS 216, 217, 244, 270, 288, 306, 325
octane 343
octopus 171
Off-Highway Vehicle Park 249
Office of Historic Preservation 121, 225, 249, 253
Office of Historic Preservation Guidelines 121
Office of Land Conservation 246, 247
Office of Marine and Estuarine Protection 219
Office of Noise Control 140, 199
Office of Oceanic and Atmospheric Research 229
Office of Planning and Research 251
offshore development 214, 232, 244
offshore fields 306
offshore oil and gas 67, 69, 70, 78, 212, 214, 222, 226, 228, 239, 240, 244, 297, 325
offshore oil and gas leasing 228, 240
offshore Oil Spill Pollution Fund 214
OHP 249, 250
oil and gas development 137, 212, 226, 289, 292
oil and gas effects 140
oil and gas extraction 27

oil and gas projects 136, 140, 155, 226, 297
oil and gas reservoirs 315
oil and gas resources 232, 325
oil and gas taxes 288
oil depletion allowance 281
oil development 1, 143, 292-294
oil gravity 262
oil imports 147, 277, 285, 298, 324, 328
oil market 261, 263, 268, 283, 289
oil price declines 285, 296
oil price shocks 284, 296
oil production platforms 41
oil refinery refuse 69
oil shale 342, 343
oil shale deposits 343
oil spill 69, 112, 196, 214, 227, 230, 236, 237, 240, 242, 295
oil spill contingency plan 227
oil spills 3, 73, 74, 90, 99, 110-112, 132, 154, 158, 185, 237
oil tankers 154
oil transportation ports 230
Oklahoma 288, 296, 305
old growth forests 91
olephins 316
Oncorhynchus kisutch 165
Oncorhynchus tshawytscha 165
onshore transport 47
onshore water resources 191, 195
Opah 164
OPEC 260, 263, 265, 270-272, 280, 281, 303, 304, 307, 320, 322
open markets 259
open space 14, 16, 27, 37, 48, 122, 247, 254
Open Space Subvention Program 247
open system 340
OPR 46, 251
Orange County 26, 146, 154
orbital circulation 57
ore 28
Oregon 5, 35, 87, 88, 92, 93, 108, 113, 126, 131, 165, 166, 225, 228, 243
Oregon Border 5, 88, 92, 93, 113, 166
Oregonian province 74
Organic compounds 66-68
Organic substances 67
Organophosphates 44
Orlon 318
Orthophosphate 65
osmosis 37
OTEC 340-342
OTEC 1 341
Outer Continental Shelf 212, 217-219, 226, 244, 255, 288, 306
Outer Continental Shelf Lands Act 212, 217, 218, 226
outfall 41, 67-69, 73
outfall pipe 67
outfalls 27, 40, 41, 67, 69-74
overcrowding 15, 119
overdrafting of groundwater aquifers 59
overgrazing 117, 119
oversight authority 239, 243
oysters 13, 31, 33, 105, 107, 119
ozone 61, 110, 188, 195, 257, 347, 353

P

Pacific Fisheries Management Council 14, 225
Pacific Fishery Management Council 158-160
Pacific flat oysters 13
Pacific Flyway 87, 99
Pacific Gas and Electric Company 345
Pacific Halibut 158, 159
Pacific herring 89, 102, 105-107, 119, 163
Pacific lamprey 12, 107
Pacific mackerel 163
Pacific Marine Fisheries Commission 166, 225
Pacific Northwest 45
Pacific Ocean shrimp 160
Pacific oyster 33
Pacific Rim 142
paint 68, 318
Pajaro 87
paleontological resources 119, 120
paleontologists 119, 197
paleontology 119
Palos Verdes 26, 73
Panama 159
Panulirus interruptus 167
paper mills 41
paraffin waxes 318
paraffins 316
Paralichthys californicus 164
paralytic shellfish poisoning (PSP) 31
park and ride 329
parkland 49
particulate matter 65, 66, 68, 188, 217
particulates 66, 68, 69, 71, 73, 188, 257
party boats 6, 169
passenger vessels 1
passive solar heating 330
pathogens 66, 67, 71, 74
paving 100, 112, 116, 318
PCBs 67-71, 74
Pecho Rock 76
penalties 121, 218, 219, 224
Peninsula Commute Service 146
Peninsular Ranges 29, 51
Pennsylvania 318
pentachlorophenol 67
Penutian 125
perch 7, 13, 103, 105, 118
permit processing 232
Permit Streamlining Act 232, 233
permits 41, 45, 60, 121, 154, 157, 168, 169, 220, 222, 224, 235, 241, 243, 244, 246, 252, 253, 255, 256
Persian Gulf 263, 321, 323
personal income 142
Peru 57, 87, 162
pesticides 30, 44, 45, 59, 67, 68, 114, 115
petrochemical feedstocks 273, 274
petrochemical plants 312, 315-317
petroleum coke 342
petroleum industry 280, 281, 283, 286-289, 292, 294, 296, 312, 317, 326

petroleum markets 320, 321
petroleum operations 226
petroleum products 1, 41, 69, 115, 147, 154, 274, 275, 277, 279, 285, 286, 297, 300, 302, 318, 320, 324, 331, 336
petroleum refining 287
petroleum resources 273, 292, 295, 297, 307
petroleum stocks 317
petroleum waxes 317, 318
PFMC 14, 159, 165, 167
pH 64-66, 110, 190, 192
phalaropes 87
pharmaceuticals 15, 36
phenols 67
Philippine Islands 126
Philippines 1
phosphate 65, 66
phosphorite 28
phosphorus 65
photochemical oxidants 217
photovoltaic effect 332
phthalate esters 67
Phyllospadix 26, 76
physical oceanography 53, 61, 75, 203
phytoplankton 31, 54, 65, 72, 81, 102
picnicking 157
piers 3, 6, 28, 47, 170, 221, 319
Pilot whales 85, 88
pine nuts 12
pine trees 95
pinnipeds 85, 88, 89, 224
Pioneer Canyon 170
pipeline 26, 41, 45, 48, 69, 133, 141, 147, 150, 177, 181, 185, 189, 194, 197-199, 202, 203, 213, 240, 246, 283, 289, 312, 315, 316, 339
pipeline access 213, 316
pipeline ruptures 69
pipelines 26, 39, 47, 108, 132, 136, 143, 144, 147, 150, 155, 198, 230, 231, 239, 253, 283, 312, 315
Pismo clams 6, 171
pitch 131, 138
plankton 36, 57, 65, 72, 81, 99, 341
Planning and Conservation League 146
plastics 41, 57, 66, 71, 274, 318
platform 136, 137, 141, 152
platforms 28, 41, 136, 137, 155, 199, 227, 230, 295
playas 124
pleasure boat fleets 2
pleistocene 124
pluvial lakes 124, 125
poaching 167, 171
Point Arena 27, 53, 106, 126
Point Arguello 6, 51, 87, 160
Point Conception 5-7, 53-55, 61, 74, 75, 82, 85, 90, 104, 105, 165, 166, 168, 169
Point La Jolla 170
Point Lobos 91
Point Magu 48
Point Pedernales 306, 307
Point Reyes 85, 87, 89, 126, 228
Point Reyes National Seashore 228
Point Saint George 89
point sources 67, 71, 219
Point St. George 82, 85, 88, 89
Points of Historical Interest 122, 250
Poland 160
Polar bears 224
police 15, 27, 143, 209, 238
police power 209, 238
political instability 321
pollutants 3, 31, 45, 53, 55, 60, 61, 66-71, 74, 91, 115, 117, 185, 217, 219, 220, 230, 256, 257, 295, 333
pollute 3, 59
polluted air 142
pollution control 218, 221, 233-235, 243, 244, 256
pollution detection 235
pollution impacts 72
pollution of coastal streams 59
pollution risks 295
pollution transport 60
polychlorinated biphenyls (PCBs) 67
polymetallic sulphide nodules 28
polynuclear aromatic hydrocarbons 67
pooling 146, 213
Popular Science 343, 344
porpoises 88, 224
port facilities 2, 3, 48
Port Master Plans 134
Port of Humboldt Bay 154
Porter-Cologne Water Quality Control Act 234
Portland cement 28
ports 1, 2, 43, 48, 131, 134, 147, 152, 158, 168, 180, 230, 284
posted prices 260, 261
potable water 27, 44
Potential Impacts 186, 188-190, 192-194, 197-202, 204-207, 232
pots 3, 5, 12, 170
power generating stations 68
power generation 184, 311, 336, 338, 342, 344, 352
power plant 40, 41, 70-73, 184, 247, 248, 339, 344
power plant cooling waters 40, 41
power production 39, 331
powerhouse 338
Powerplant and Industrial Fuel Use Act 273
prawns 4, 5, 166
predation by dogs, cats 90
predatory birds 90
prehistoric resources 122
presentation of results 182
President Carter 324
President Ford 323
President of the United States 323
President Reagan 327
Presidio in San Francisco 49
presidios 128
pressurized water reactors 335
prevailing winds 53
prevention of significant deterioration 256
price 29, 158, 163, 259-263, 266-269, 271-274, 276-281, 283-289, 292, 296, 304, 305, 320, 321, 325, 326, 330, 332, 343, 348
prices of substitutes 260
primary and secondary drinking water standards 60

primary energy producers 303
primary petrochemicals 316, 317
Prince Island 91
Prince William Sound 295
private property 15, 233
probability 119, 175, 178-182, 184, 185
probability and risk assessment in environmental documents 178
probability calculation 180
probability interactions 181
probable reserves 307, 308
projected noise level 140
propane 316, 317
propene 317
proposed notice 226, 227
Proposition 116, 146
Proposition 20, 240
proprietary lands 231
proprietary pipeline system 289
proprietary status 312
proven reserves 271, 307, 308, 325
PSP 31
public and social services 143
public education 222
public finance/economics 201
public mass transit 328, 350
Public Resources Code 121, 122, 187, 231-233, 236, 237, 239, 255
public revenue 288
public safety 113, 143, 200, 328
public services 27, 43, 133, 141, 200
Public Trust Doctrine 231, 238
Public Utilities Commission 146, 147, 247, 253
PUC 146, 147, 253
pueblos 128, 130
Puerto Rico 162
pulp mills 40
pumped-storage 338
pumping stations 295, 312
pumps 312, 316, 341
purse seine 4
purse seines 6

R

radar sites 48
radioactive elements 66
radioactive particles 67
radioactive waste 41, 336
radionuclides 217
rail operations 140
Rail Transportation Bond Act 146
railroad stations 48
railroad systems 147
railroad tank cars 312
railroads 47, 48, 143, 144, 146, 147, 155
rain 45, 58, 68, 81, 110, 195
rainfall 45, 46, 58, 60, 61, 70, 92, 93, 99, 103, 105-107, 110, 308
rainwater 40, 58, 68
Rance River 339, 340
ranchos 130
random walk 186
rangeland resources 250
rangelands 29, 30, 92
rare and endangered species 114, 194, 234
rare-earth metal 28
rayon 318
Razor clams 13
reactors 316, 335-337
real estate 43, 331
real estate industry 331
Real GNP 284, 285
recession 321
recirculation ditches 43, 44
recreation 14-17, 19, 21, 28, 46, 92, 93, 117, 122, 133, 155, 157, 158, 177, 201, 206, 222, 225, 228, 231, 233, 234, 238, 239, 249, 250, 253, 311, 338
recreation areas 157
recreational areas 91, 228
recreational boating 1, 2
recreational fishing 6, 8, 169
rectifying the impact 187
recycling 41, 244, 246, 252
Red Bluff 125
reduce private automobile use 328
reducing or eliminating the impact 187
redwood 29, 58, 92-94, 108, 112, 113, 228
redwood forests 58, 93, 94, 113
Redwood National Park 228
reefs 3, 18, 73, 75, 76, 78, 80, 193
refined products 154, 273, 289, 305, 312, 317, 318
refineries 1, 154, 295, 298, 312, 315-317
refinery 68, 69, 154, 188, 195, 316, 317, 319
refining 154, 273, 280-282, 286, 287, 289, 294, 295, 312, 315-318
reformulated gasolines 348
refuges 18, 19, 228, 242
Regional Transportation Planning Agencies 144
Regional Water Quality Control Board 191, 238
Regional Water Quality Control Boards 60, 244
Registered Environmental Assessors 245
registration of environmental assessors 244
regulatory intervention 277
regulatory process 138, 209
regulatory setting 60, 120, 134, 140
religious beliefs 123
religious heritage 14
reproductive failures 74
reptiles 15, 96, 99, 100, 104, 105, 241
Republic of Korea 160
Research and Sanctuaries Act 229, 230
reserves1 7-20, 67, 104, 169, 249, 267, 270, 271, 295, 305, 307, 308, 321-326, 345
residential 1, 16, 27, 44, 59, 67, 68, 96, 97, 106, 108, 112, 114, 115, 122, 138, 158, 177, 254, 277, 278, 284, 299, 302, 309, 327, 330, 332
residential development 1, 16, 27, 96, 106
residential sewage 67
residential subdivisions 59, 108

residential users of energy 302
residential uses 27
residues 44, 317
Resources Agency 237-240, 246, 249, 250
responsible agencies 227, 233
Responsible Agency 187
restaurants 10, 34, 157
restoration of fisheries 228
restoration programs 21, 26, 228
restored wetlands 43
retention basins 192, 195
revegetate 189, 198
Rhinoceros auklets 87, 88
Richmond 152
rideshare 329
ridesharing 328, 329
rights of navigation 212
rights-of-way 48, 194, 249
riparian vegetation 46, 58, 100, 114, 115, 196
Rivers and Harbors Act 229
Rivers and Harbors Appropriations Act 220
Riverside Counties 256
roads 27, 97, 113, 131, 132, 251
Roaring Forties 53
rock crabs 5, 6, 166, 167, 171
rock scallops 6, 7, 33, 171
rockfish 4, 5, 7, 13, 159, 160, 163-166, 169, 170
Rockies 123, 325
roe 9, 10, 34, 163, 168
roosting sites 47
Rotterdam 261
royalties 213, 226, 288-290, 292, 293
Ruddy turnstones 88
Russia 130, 336, 340
Russian America 130
Russian merchants 130
Russians 130
rust preventives 318
RWQCB 60, 190

S

sablefish 5, 160, 165, 166
Sacramento River 8, 117, 172
Sacramento Valley 125, 128, 312, 319
sacred sites 121
safety 20, 44, 70, 113, 133, 143, 152, 157, 181, 182, 184, 195, 200, 203, 214, 215, 233, 236, 237, 242, 245, 246, 252, 256, 315, 325, 328, 336, 344, 349
safety standards 214
sales tax 289
Salinas River 44, 87, 105
Salinas River Basin 44
salinity 10, 31, 61, 66, 78, 81, 92, 96, 99, 102, 104, 114-116, 190
salmon 5, 8, 9, 12-14, 21, 24, 25, 34, 35, 103-107, 111, 118, 119, 159, 165, 166, 169, 170, 171-173
salmonella 67
salmonids 8, 9, 34, 172
salt 16, 36, 37, 39, 92, 97, 99, 101, 102, 104-106, 108, 118, 172, 316, 324, 339
salt (sodium chloride) 37
salt industry 37, 39
salt pond systems 37
salt ponds 36, 37, 39
salt production 36, 37, 101
salvage program 197
Samoa 162
San Andreas 53
San Andreas Fault 53
San Bernardino 256
San Diego Bay 37, 48, 90, 126
San Diego County 23, 95, 101, 103, 107, 116
San Diego Gas and Electric Company 90
San Diego Interagency Water Quality Panel 66
San Francisco Bay 1, 8, 9, 16, 18, 19, 22, 27, 36, 37, 39, 41, 43, 46, 48, 53, 61, 69, 70, 82, 89, 92, 102, 105-108, 110, 117, 125, 130, 144, 154, 160, 163, 166, 168, 239, 248, 249
San Francisco Bay Area 9, 18, 22, 43, 46, 69, 107, 110, 117, 125, 144
San Francisco Bay Conservation and Development Commission 39, 248
San Francisco Bay Plan 248
San Gorgino Pass 331
San Joaquin Valley 117, 118, 125, 128, 306, 308, 312, 315, 319, 326
San Luis Obispo 30, 39, 49, 76, 102, 105, 117, 154, 246, 332-334
San Mateo 154, 256
San Miguel 53, 88, 89, 91, 126
San Miguel Island 89, 91, 126
San Nicolas 36, 53, 90
San Nicolas Island 36, 90
San Pablo 18, 37, 51, 106, 152
San Pedro 1, 2, 152, 162-164, 166-168
San Pedro Bay 1
sand movement 47, 97, 203, 204
sand supply 47, 237
sanddabs 169
sanderlings 87, 88
sanitary landfills 59, 338, 339
Santa Ana 104, 128
Santa Barbara 2, 26-28, 30, 31, 36, 37, 53, 76, 78, 87-89, 91, 101, 105, 128, 136, 147, 152, 154, 160, 164, 165, 167, 168, 222, 230, 246, 312, 319
Santa Barbara Channel 2, 31, 78, 87, 136, 160, 167, 222
Santa Barbara Channel Islands 222
Santa Barbara County 26, 28, 37, 101, 105, 128, 154
Santa Barbara Island 89, 91
Santa Fe 130
Santa Maria Basin 27, 44, 136
Santa Maria Valley 319
Santa Monica Bay 45, 238
Santa Monica Estuary Project 219
Santa Monica Visitor and Convention Bureau 14
Santisima Trinidad 128
sardines 4, 163
satellite launching 48
Saudi Arabia 272, 303, 304, 307, 325
Saudi crude oil 261

SCAG 45, 144, 328
SCAQMD 256
SCCWRP 66, 69
school lands 238, 239, 246
schools 4, 19-21, 27, 105, 140, 143, 166, 200
Science Applications International Corporation 53
Scientific American 336, 340, 342, 346-348
scientific research 15, 104, 222, 224
Scomber japonicus 163
scoop nets 12
scoters 87, 88
scuba divers 76, 170
Sculpin 169
Sea bass 4, 103, 169
Sea Grant Program 20, 229
Sea gull eggs 13
sea level height 55
Sea lion 12, 91
Sea lions 12, 15, 81, 85, 88, 89, 224, 229
Sea of Cortez 87
Sea otters 74, 78, 88-90, 164, 171, 224
sea traffic 155
sea turtles 90
sea urchin 167
sea urchins 6, 25, 26, 33, 76, 78, 168
sea vegetable harvesting 36
sea walls 221
seabirds 81, 82, 87, 88, 91, 164, 193
seafloor habitats 66
seafood 30, 33, 74
Seal Beach 43, 104
seals 12, 15, 71, 81, 82, 85, 88, 89, 91, 97, 224, 229
seamounts 82, 170
seaports 143
seasonal jobs 143
seaweed 13, 35, 163
Sebastes 164
Secretary for Resources 238
Secretary of Commerce 217, 223-225
Secretary of Environmental Affairs 243
Secretary of the Interior 223-226
Section 102 215
Section 106 121, 225, 250
sediment load 22, 65, 114
sedimentary basins 27
sedimentation 21, 22, 24, 60, 73, 115, 117-119, 133, 173, 195
Sei whales 83
seining 12, 160, 166
seismic exploration activity 326
seismic survey 325
seismology surveys 228
selenium 66
senate 41, 121, 122, 240, 241, 243, 247, 249
Senate Bill 297 121
septic tanks 43
service industries 142
set back 189, 308
settlers 13, 131
settling basins 47
sewage 1, 25, 27, 40, 41, 43, 45, 66-69, 74, 115, 116, 118, 142, 143, 200, 219, 221, 239, 240, 251
sewage disposal 1, 27, 40, 41, 66, 115, 239
sewer 27, 41, 45, 68, 134, 143
sewers 27, 40, 45, 68, 70, 221
shallow subtidal reefs 75, 78
shampoo 318
shark 4, 164, 165
sharks 5, 6, 105, 164, 165
sheep 30, 131
Shell Corporation 345
shellfish 31, 33, 71, 73, 74, 168, 169, 171, 234
shellfish growers 31
shellfish harvesting 234
shellfish industry 31
Shelter Cove 53
ship repair facilities 48
ship traffic 1, 70
shipbuilding 2
shipping industry 1, 2
shipping safety 152
shipwrecks 40, 68, 132
shipyards 1, 2
shorebirds 39, 87, 88, 98, 114
shorefront access plans 217
shorelands 216
shoreline structures 47
short line railroads 147
Shoshone 125
shrimp 3, 4, 9, 10, 33, 35-37, 102-107, 158, 160, 335
shrublands 16, 30, 113
Sierra Madre Mountains 51
significance levels 178
significant environmental effects 175, 232
significant impacts 173, 178, 188
Significant Lands Inventory 201, 237
silicon 65, 333
siltation 22, 27, 59, 76, 78, 118, 119, 338
silver 8, 34, 66, 74, 97, 119, 126, 130, 159, 165
silver deposits 126
silver salmon 119
SIP 217, 218
Siskyone 10
Sitka 93, 94, 112, 130
skiffs 2, 170
Skipjack tuna 162, 165
slavery 131
SLC 17
slime eels 5
sloughs 31, 106, 107, 119
sludge 43, 68, 235
sludge discharge 68
slumping 43, 203
smog 68, 132
smudge oil 317
snorkel 7
Snowy plovers 87, 91
SO2 188, 195
soaps 36
social acceptability 184

social organization 123
social services 143
society 15, 17, 23, 28, 92, 131, 142, 143, 184, 194, 295, 326
Society of Exploration Geophysicists 326
socioeconomics 133, 141
sockeye fields 307
sockeye salmon 12
soft bottom 73, 78
soil characteristics 58
soil erosion 59, 93, 189
solar 37, 39, 40, 61, 330, 332, 333, 340, 344
solar cells 333
solar collector farms 333
solar energy 40, 332, 333, 340
solar evaporation 37
solar power 39, 332, 333
solar radiation 332, 340
solar technology 344
soldiers 128, 130
solid waste 27, 200, 235, 244, 338, 339, 346
Solid Waste Disposal Program 235
solvents 317
Sonoma 18, 39, 256, 334
Sonoma County 334
Sooty shearwaters 87
sound 137, 138, 140, 141, 224, 227, 233, 244, 245, 292, 295, 333
sound barriers 141
Sources of marine pollution 67
South Africa 303
South America 90, 126, 128
South Belridge 305, 320
South Coast Air Basin 256
South Elwood 307
Southeast California 125
Southern Alaska 130
Southern California Association of Governments 14, 66, 144
Southern California Borderland 5, 53, 55, 57, 61, 70, 75, 80-83, 85, 90, 160, 163, 164, 167
Southern California Coastal Water Research Project 66, 69
Southern California Countercurrent 53
Southern California Eddy 53-55
Southern California Edison 345, 350
southern hemisphere 57, 82, 87
Southern Pacific 147
Southern Sea Otter 82, 90
Southern Sea Otter Recovery Plan 90
Soviet Union 160, 336
space exploration 345
space heating and cooling 330
space shuttle 48
Spanish California 130
Spanish contact 122
spawning 36, 102, 105-107, 111, 114, 119, 162-164, 167, 168, 171-173, 196, 234
spawning habitat 164
Speaker of the Assembly 240
spearguns 7
special biological significance 17, 234, 235
special interest groups 232
specialty crops 30
species diversity 15, 43, 75, 76, 78, 80, 109, 110
specific Plan 254
Spheres of Influence 134
spill contingency plans 230
spilled chemicals 190, 193
Spiny lobsters 5
spoils 22, 69, 70, 221
sponges 75
sport fisheries 105, 169, 228
sport fishermen 6, 76, 169-171
sports arenas 157
spot market 261, 323
spot prawns 5
spot prices 260-263
SPR 323-325
spray oils 317
squid 4, 6, 160, 162, 163, 167, 169-171
St. Augustine, Florida 126
St. George Reef 82
Staphylococcus 67
State agricultural production 30
State Beach 249
State Beaches 17, 157
State Board of Forestry 250
State Department of Transportation 146
State Forest Tree Nursery Program 250
State Forests 17, 250
State Geologist 247
state governments 141, 223
State Historic Preservation Offices 121, 225
State Historic Preservation Programs 225
State Historical Unit 249
State Implementation Plans (SIP) 217
State Landmarks Program 250
State lands 2, 40, 44, 51, 122, 134, 150, 201, 212, 231, 237-240, 246, 288, 325
State Lands Commission 2, 40, 44, 51, 134, 150, 201, 231, 237-240, 246, 325
State law 44, 152, 221, 224, 255
State Legislature 249, 251, 253
State Mussel Watch Program 235
State of California 120, 159, 209, 224
State Park 17, 119, 155, 228, 249
State Park and Recreation Commission 249
State Park System 155, 249
State Preserves 155
State Rail Plan 147
State Recreation Area 249
State Recreation Areas 157
State Reserve 17, 249
State Supreme Court 253
State tidelands 27, 292, 325
State tidelands oil and gas 292
State Transportation Improvement Program (STIP) 252
State Water Project 46, 118, 157, 173, 245, 246
State Water Resources Control Board 41, 46, 66, 234, 238, 243
State waters 118, 327
State Wilderness 249
statehood 16, 131, 231, 238
statistical data 182

statistics 141, 158, 165, 169, 178, 311
statutes 2, 46, 121, 236, 253
steam 39, 320, 332-335, 338, 341
steel products 152
Steelhead 8, 9, 12, 13, 21, 24, 25, 34, 103, 105-107, 111, 116-119, 170, 172, 173
STIP 252
Stockton 152, 318
storage 2, 45, 46, 58, 96, 103, 136, 141, 155, 200, 235, 243, 312, 316, 317, 324, 338, 344, 352
storage tanks 136, 235, 243, 312
storm drains 45, 68, 70
storm sewers 40, 453
Storm-petrels 88
Straits of Hormuz 321
Strategic Petroleum Reserve 321, 323
straw oil 317
Streambed Alteration Agreement 242
streamflow 58, 115, 192
Streams 1, 8, 21, 23, 25, 41, 45-47, 58-60, 65, 68, 70, 81, 92, 99, 100, 102, 105, 106, 114, 116-119, 125, 170, 172, 173, 191, 192, 245
Streptococcus 67
stripper wells 305
Strongylocentrotus franciscanus 168
Sturgeon 8, 10, 12, 13, 21, 25, 34, 103, 104, 106, 107, 169, 170, 172, 173
subarctic 53, 55, 61, 75, 81
subarctic water 55, 61
subdivision map approval 255
submarine transit lanes 49
submarines 48, 49
submerged lands 136, 212, 231, 237-239, 255
Submerged Lands Act 212
substation 316
substitute goods 276, 277
subtidal environments 76
subtidal reefs 75, 76, 78
Suisun Bay 106, 118, 152
Suisun Marsh Protection Plan 248
sulfate 66
sulfates 61
sulfur 110, 217, 257, 312, 316
sulfur dioxide 217, 257
summerland field 319
sun belt 155, 332
superfund 244, 279
superfund list 244
supply and demand 259-261, 263, 266-268, 277, 280, 281, 286
supply boats 155
supply curve 260, 263, 266-268, 271, 272
surf fish 12, 13
surf scoters 88
Surf smelt 6, 169, 170
surface and ground water quality 235
surface impoundments 235, 244
surface mining 246, 247
Surface Mining and Reclamation Act 247
surface water development 45
surfbirds 88
surfing 74, 157
Surfperch 104, 169, 170
surveillance and monitoring programs 235
Sutil Island 89
swamp 238
swells 56, 57
swimming 5, 74, 157
switching services 147
swordfish 5, 6, 164, 167, 168, 170
synfuels 342
synthetic fibers 318
synthetic fuels 342-344
synthetic natural gas 342, 344
synthetic pollutants 67
synthetic rubber 318

T

Tahiti 342
Tahoe Conservancy 238
tank farms 2, 295
tank trucks 283, 312, 315
tanker accidents 69
tanker traffic 1, 154
tankers 1, 3, 154, 180, 181, 284, 312, 315
tanks 21, 33, 34, 43, 136, 154, 235, 243, 312, 316
target range 48
tax laws 281
tax revenue 288, 289
TBT 68
technical regulations 279
Tehachapi Mountains 39
Tehachapi Pass 331
Tennessee Eastman Corporation Coal Gasification Plant 345
terminal trackage 147
terrestrial & freshwater biology 194
territorial seas 212
territorial waters 2, 209
Texaco 283, 345
Texaco-Getty merger 283
Texas 144, 288, 296, 305, 308, 324
Texas Transportation Institute 144
The Geysers 334, 335
thermocline 61, 64, 81, 340, 341
thermoclines 57
thermonuclear 336, 337
Thomas Larkin 131
threatened and endangered species 58, 89, 108, 222, 223, 228, 242
Three Mile Island 336
thresher sharks 5, 164, 165
Thunnus alalunga 166
Thunnus albacares 166
tidal currents 55, 112
tidal energy 339, 340
tidal flushing 43, 102
tidal marshes 37, 118
tidal power plant 339
tide and submerged lands 136, 231, 237-239

tide lands 239
tidelands 27, 28, 47, 255, 290, 292, 307, 325
tides 12, 13, 37, 55, 56, 58, 75, 76, 99, 101, 107, 112, 339, 340
Tijuana, Mexico 123
timber 13, 28, 29, 92-94, 106, 112, 113, 117, 118, 173
timber harvesting 13
timber industry 29
timberland 29
tin 66, 68, 70, 74, 351
tokamak 337
Tolowa 10, 107
Tomales Bay 31, 106, 163, 164
toothed whales 83, 85
topography 15, 18, 29, 30, 55, 58, 60, 82, 115, 140, 189, 195, 205, 239, 331
tourism 14, 27, 133, 155, 158, 201, 206
towers 316, 332
toxaphene 67
toxic discharges 243
toxic Pits Cleanup 235
toxic Substances Monitoring Program 235
toxic wastes 59
toxics 41, 220, 234, 245
toxins 31, 74
trace metals 66-72, 316
trachurus symmetricus 163
tractor fuel 317
trade 1, 12, 35, 36, 53, 126, 128, 130, 142, 146, 228, 283, 285
trade Winds 53
traders 91, 130, 131
traffic 1-3, 27, 70, 133, 137, 138, 142, 144, 146, 152, 154, 155, 171, 180, 185, 193, 200, 205, 207, 230, 237, 252, 253, 328, 329, 350
traffic congestion 144, 252, 350
traffic separation schemes 152
trammel nets 4, 163
transit incentives 188
transmission lines 47, 338
transport toxic waste 192
transport vessels 2, 152
transportation Laboratory 140, 252
Transverse Ranges 51
trappers 130
traps 3, 5, 6, 166, 167, 170, 192, 205
trawl 3, 205
trawler 3
trawls 3, 4, 160
treasure 40, 128
treasury 214, 288
trespass 15
tributary 24, 25, 40, 45, 119
tributyltin 66, 68, 70, 71, 73
Trinidad 18, 85, 87, 89, 128, 166
trinidad Head 18, 85, 89, 166
trolling 5, 165, 166
trout 8, 9, 12, 21, 24, 25, 34, 103, 105-107, 116, 119, 171, 172
truck 152, 155, 252, 334
trucking 253
trucks 138, 154, 283, 298, 312, 315, 327, 348, 349
trunk line 283
trunk lines 150, 312
tsunamis 56-58, 189, 204
tufted Puffin 91
tulare Lake 125
tuna 4, 6, 158-160, 162, 165, 166, 170, 225
tungsten 28
tungsten ore 28
turbidity 65, 66, 73, 76, 118, 190, 192, 194, 205
turbine 332, 333, 336, 339-341
typical Mitigations 188-190, 192-194, 197-202, 204-207

U

U.S. Army Corps of Engineers 2, 203
U.S. Coast Guard 15, 43, 152, 159, 203, 214, 230
U.S. Dept. of Transportation 146
U.S. Fish and Wildlife Service 2, 8, 17, 113, 154, 157, 205, 224, 227
U.S. flag carriers 284
U.S. Geological Survey 78, 226, 228, 235
U.S. Supreme Court 209
U.S. Synthetic Fuels Corporation 342
U.S. Treasury 288
U.S. Waters 224, 225, 230
U.S. windpower 331
U.S.S.R. 303, 304
unamuno 128
underground aquifers 58
underground injection wells 243
underground reservoirs 41
underground storage 235, 243
underground Storage Tank Program 235
undersea banks 57
underwater earthquakes 57
unemployment 142, 143, 284, 285, 288, 296, 322
unemployment claims 288
unemployment rate 284
unit trains 315
upwelling 54, 55, 61, 65, 81, 82, 165
urban area 142
urban development 58, 99, 109
urban runoff 59, 116
urban streams and fisheries 245
urban uses 152
urbanization 18, 28, 30, 45, 47, 58, 95, 96, 100, 108, 114, 117
urbanized areas 43, 45
urchin fishery 6
USFS 147
USFWS 12-14, 90
Utah 343
Uto-Aztecan stock 125

V

vacancy rates 142
vacuum chamber 340, 341
van pool 188
vandalism 236

vandenberg 105, 230
Vandenberg Air Force Base 105, 230
vanpooling 329
vector control district 44
vegetable coatings 318
vegetables 29, 30
venison 12
Ventura 27, 28, 30, 39, 43, 147, 154, 171, 230, 312, 319
Ventura County 154, 319
vertical integration 280, 281
vessel discharge 67
vessel safety 157
vibrio 67
Viceroy Antonio de Mendoza 126
viewer reactions 136
village and burial sites 253
vinyl chloride 217
viscous crude oil 312
visual 15, 27, 47, 136, 137, 198, 199, 340
visual blight 15, 136
visual intrusion 27
visual qualities 47
visual quality 136, 199
Vizcaino 128
volatile products 317
voluntary risks 184, 185

W

wading birds 39, 98
walruses 224
Walter Colton 131
Warren-Alquist State Energy Resources Conservation and Development 247
Washington clams 6
Waste Discharge Requirements 235
waste disposal 41, 142, 235, 244, 338, 342
waste management 143, 200, 234, 238, 243, 244
waste to fuel 338
waste treatment 68, 143
waste water 25, 316
waste water treatment 316
waste-to-energy conversion 244
wastewater discharges 31, 67, 68
water circulation 47, 102, 114, 115
water clarity 31
water column 4, 64, 65, 71, 72, 80, 164, 166, 190, 205
water conservation 245
water development 45, 46
water pollution 27, 59, 99, 115, 158, 218, 221, 235, 243
Water Pollution Control Act (Clean Water Act) 218, 235
water quality 24-26, 31, 34, 58, 60, 61, 66, 69, 75, 93, 114, 115, 117, 132, 177, 190-192, 194, 205, 219, 220, 234, 235, 238, 243-245
water quality control 60, 191, 219, 234, 238, 244
Water Quality Control Plan for Ocean Waters of California 234
water resources 41, 45, 46, 58, 60, 66, 157, 191, 192, 195, 200, 234, 235, 238, 239, 243-246
Water Resources Control Board 41, 46, 66, 200, 234, 238, 239, 243, 244
Water Resources Development Bond Act 246
water rights 46, 243, 244
water storage 45, 46
water storage capacity 46
water supply 45, 46, 59, 200, 202, 234, 245, 246
water vapor 110, 308, 309
waterfowl 23, 39, 98, 104, 111, 114
watershed protection 28
waterways 2, 8, 19, 24, 46, 93, 106, 107, 114, 157, 173, 216, 221, 231, 238-240, 250
wave action 31, 47, 78, 92, 203
waves 47, 53, 55-58, 65, 71, 80, 81, 137, 341
weapons research 337
weed killers 318
Weeks Island Salt Mine 324
weirs 12
welfare 143, 152, 184, 217, 221, 238
wellhead 268, 289, 312
wells 28, 34, 44, 100, 192, 213, 243, 266, 305-307, 315, 319, 325-327, 333, 338
West Coast 9, 37, 48, 126, 128, 154, 261-263, 270, 281, 282, 284, 321, 325
West Hackberry Salt Dome 324
Western California 29
Western gulls 88
Western Oregon 126
Western Pluvial Lakes Tradition 125
Western Salt Company 37
Western snowy plover 91
wetland areas 134, 229
wetland environments 58
wetlands 2, 16, 18, 19, 21, 22, 25, 43, 59, 87, 93, 98, 99, 102-104, 111, 112, 117, 124, 125, 158, 193, 196, 230, 239
whale watching 157
whales 12, 82, 83, 85, 88-90, 224, 229
wharfs 221
white croaker 4, 73, 163, 169, 170
White Ibis 91
White pelican 91
White sturgeon 10, 12, 21, 34, 172
wide variety of food 36
Widow rockfish 4, 164
Wildlife Conservation Board 24, 242
wildlife habitat 22-24, 28, 92, 98-100, 104, 108, 112, 195, 228, 338
wildlife resources 59, 227, 241, 242
William Hartnell 130
Wilmington field 306, 307, 319
wind 39, 40, 47, 55-57, 60, 93, 96, 97, 109, 185, 186, 188, 204, 331, 332
wind erosion 96, 97
wind fetch 57
wind generating fields 39
wind power 39, 331, 332
wind turbines 332
wind waves 56, 57
Windfall Profits Tax 281
windmills 331, 352

windplant 331
windplants 331, 332
Wiyot 10
wollastonite 28
wood products industries 29
woodlands 16, 21, 30, 92, 94-96, 98
workers 142, 144, 202, 294, 336, 337
world crude oil demand 271
world energy production 302
world oil markets 263, 303, 320, 324
Wyoming 343

X

X-rays 337
Xiphias gladius 164

Y

yachts 2
Yankees 130
Yellowfin tuna 158, 159, 162, 166
Yuha Desert 124
Yukian 125
Yurok 10, 12, 14, 24

Z

zinc 66, 68, 70
zones of convergence 57
zoning amendment 254
zoning ordinances 27, 122, 255
zooplankton 72, 81, 115, 172
zoos 157