

# **Estimated Oil and Gas Reserves**

## **Pacific Outer Continental Shelf**

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**(as of December 31, 1990)**



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by

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# Contents

	Page
Abstract .....	iv
Introduction .....	1
Definition of Resource and Reserve Terminology .....	1
Methods Used for Estimating Reserves .....	6
Fields Reported .....	6
Studies Conducted .....	10
Field Size Distribution .....	10
Status of Field Development .....	10
Drilling History and Production Rates .....	10
Crude Oil Prices .....	15
Distribution of Reserves by Relative Age of Reservoir Rock .....	15
Conclusions .....	15
References Cited .....	18

## Figures

1. MMS petroleum reserve classification .....	2
2. Wells determined to be producible in accordance with 30 CFR 250.11 .....	3
3. Pacific OCS MMS reserves classification procedure .....	5
4. Recognized discoveries of federally controlled oil and gas fields in the Pacific OCS .....	7
5. Annual estimates of remaining recoverable reserves from known fields .....	8
6. Annual estimates of original recoverable reserves from known fields .....	9
7. Size distribution of oil and gas fields .....	11
8. Annual drilled footage for wells in the Pacific OCS .....	13
9. Annual production rates for the Pacific OCS .....	14
10. Cumulative production for the Pacific OCS .....	14
11. Average daily production rates for the Pacific OCS .....	16
12. Average monthly crude oil price for the Pacific OCS .....	16
13. Remaining reserves and estimated original recoverable reserves (on a BOE basis) by reservoir age group .....	17

## Tables

	Page
1. Proved, unproved, and total oil and gas reserves, Pacific OCS, December 31, 1990 .....	8
2. Annual estimates of original recoverable reserves with source publication numbers .....	9
3. Changes in reported reserves and production, Pacific OCS, December 31, 1990 .....	11
4. Secondary recovery methods used in Pacific OCS fields .....	12
5. Summary of development well borehole status .....	12
6. Annual and cumulative production for the Pacific OCS .....	13
7. Geologic formations within each reservoir age group .....	17

## Abbreviations

ACT ... Actively Drilling	MMS ... Minerals Management Service
API ... American Petroleum Institute	OCS ... Outer Continental Shelf
bbbl ... Barrel of Oil (42 gallons)	OFR ... Open File Report
Bcf ... Billion Cubic Feet of Gas	OFSHR . Offshore
BOE ... Barrels of Oil Equivalent	OSI ... Oil Well Shut-in
CFR ... Code of Federal Regulations	PA ... Plugged and Abandoned
DPP ... Development and Production Plan	PGW ... Producing Gas Well
°F ... Degrees Fahrenheit	POW ... Producing Oil Well
GIW ... Gas Injection Well	psia ... Pounds per Square Inch Absolute
GLO ... Gas Lift Oil Well	SPE ... Society of Petroleum Engineers
GSI ... Gas Well Shut-in	SUSP .. Suspended (includes temporarily abandoned and inactive completions)
Mcf ... Thousand Cubic Feet of Gas	WDW .. Water Disposal Well
MMcf .. Million Cubic Feet of Gas	WIW ... Water Injection Well
Mbbl ... Thousand Barrels of Oil	WSW .. Water Source Well
MMbbl . Million Barrels of Oil	

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**Estimated Oil and Gas Reserves  
Pacific Outer Continental Shelf  
(as of December 31, 1990)**

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By Robert D. Edwards, Scott B. Sorensen, and Harold E. Syme

**Abstract**

Proved reserves of oil\* and gas\*\* in the Pacific Outer Continental Shelf (OCS), offshore California, are estimated to be 923 million barrels of oil and 1,478 billion cubic feet of gas as of December 31, 1990. These reserves are attributed to 13 fields. Original recoverable reserves from these fields are estimated to be 1,418 million barrels of oil and 2,005 billion cubic feet of gas.

Unproved reserves of oil and gas in the Pacific OCS, offshore California, are estimated to be 570 million barrels of oil and 679 billion cubic feet of gas as of December 31, 1990. These reserves are attributed to 25 fields. Original recoverable reserves from these 25 fields are the same as the remaining reserves because these fields have not had any sustained production.

Of the 38 fields, reserve estimates for 31 fields were determined by individual reservoir volumetric studies, while decline-curve and volumetric analyses were used for the remaining seven. At the end of 1990, nine fields were producing.

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\* "Oil," as used in this report, includes crude oil and condensate.

\*\* "Gas," as used in this report, includes associated and nonassociated dry gas.

## Introduction

This report, which supersedes OCS Report MMS 90-0086 (Flynn and Searls, 1990), presents estimates of original recoverable oil and gas reserves, cumulative production through 1990, and estimates of remaining reserves as of December 31, 1990, for the Pacific Outer Continental Shelf (OCS), offshore California. These estimates were completed in June 1991. The annual update of this report is part of a Minerals Management Service (MMS) continuing program to provide a current inventory of oil and gas reserves for the Pacific OCS. The estimates presented here were prepared by petroleum engineers, geologists, geophysicists, and other personnel from the MMS, Pacific OCS Regional Office, Camarillo, California.

## Definition of Resource and Reserve Terminology

The MMS has standardized its definitions of resources (Estimates of Undiscovered Conventional Oil and Gas Resources in the United States - A Part of the Nation's Energy Endowment, U.S. Geological Survey and Minerals Management Service, 1989). The Society of Petroleum Engineers (SPE) has also adopted a standardized set of reserve categories and definitions (1987, p. 577- 578). The definitions used within this report conform with both these sources. Figure 1 shows how resource and reserve definitions are related.

Undiscovered Resources -- Resources estimated from broad geologic knowledge and theory, existing outside of known fields or known accumulations are undis-

covered resources. Undiscovered resources can exist in untested prospects on unleased acreage, or on undrilled leased acreage, or in known fields. In known fields, undiscovered resources occur in undiscovered pools that are controlled by distinctly separate structural features or stratigraphic conditions from the discovered resources (U.S. Geological Survey and Minerals Management Service, 1989).

Discovered Resources -- Once leased acreage is drilled and is determined to contain oil or gas under Code of Federal Regulations (CFR) Title 30, Part 250, Subpart A, Section 11, Determination of Well Producibility (hereinafter referred to as 30 CFR 250.11), the lease is considered to have discovered resources. Discovered resources are the equivalent of identified resources as reported by Dolton and others (1981). Identified resources are resources whose location and quantity are known or are estimated from specific geologic or engineering evidence and include economic, marginally economic, and subeconomic components. Discovered resources can be further characterized as unproved or proved reserves, depending upon evidence of economic viability. The number of wells determined to be producible in accordance with 30 CFR 250.11 is shown in figure 2.

Unproved Reserves -- After a lease qualifies under 30 CFR 250.11, the MMS Field Naming Committee reviews the new producible lease to assign it to an existing field or, if the lease is not associated with an established geologic structure, to a new field. Regardless of where the lease is assigned, the reserves associated with the lease are initially considered to be unproved reserves. Unproved reserves are based on geologic or engineering information similar to that used in estimates of proved reserves; but

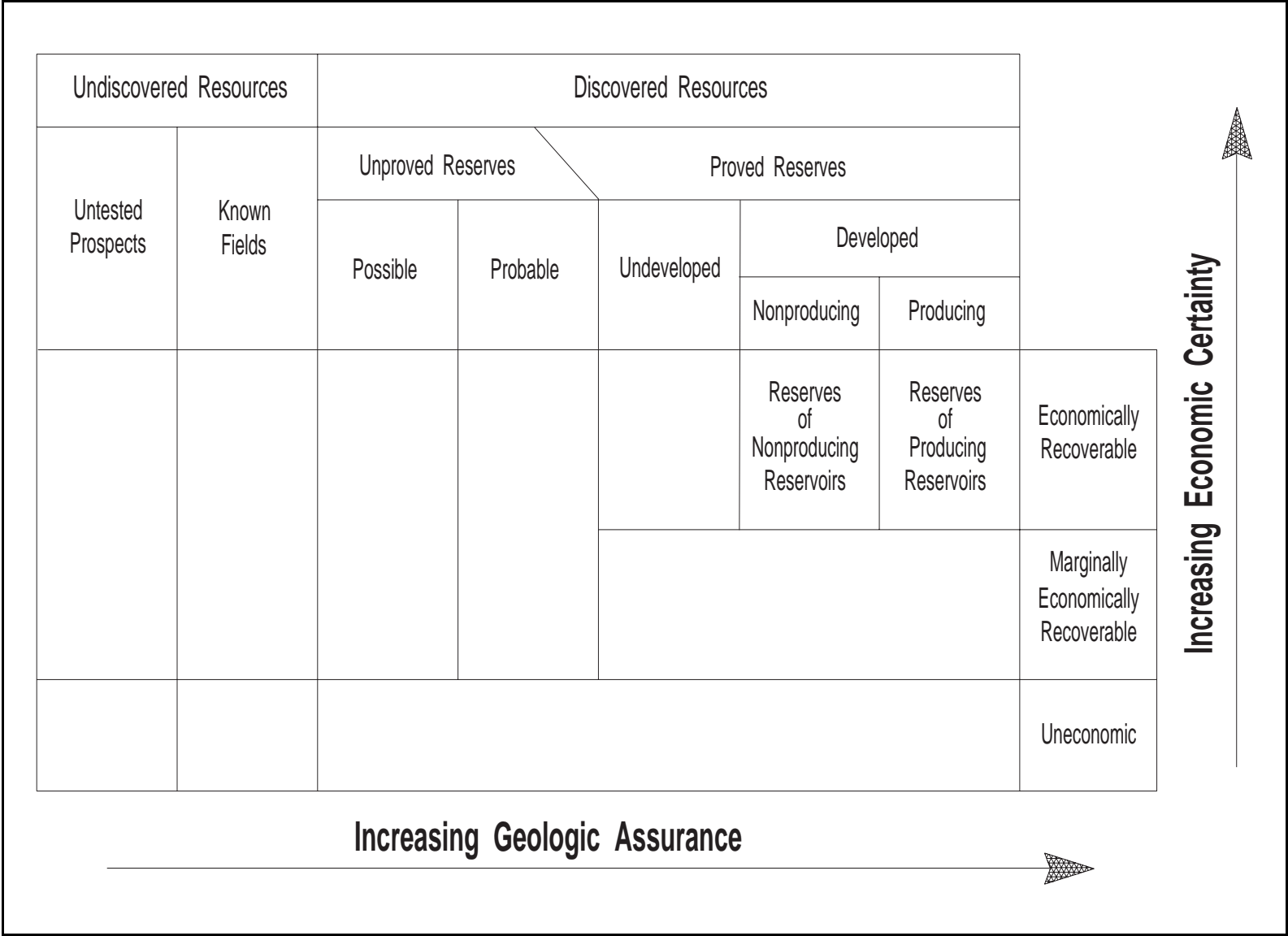


Figure 1. MMS petroleum reserve classification (modified from USGS & MMS, 1989; and SPE, 1987).

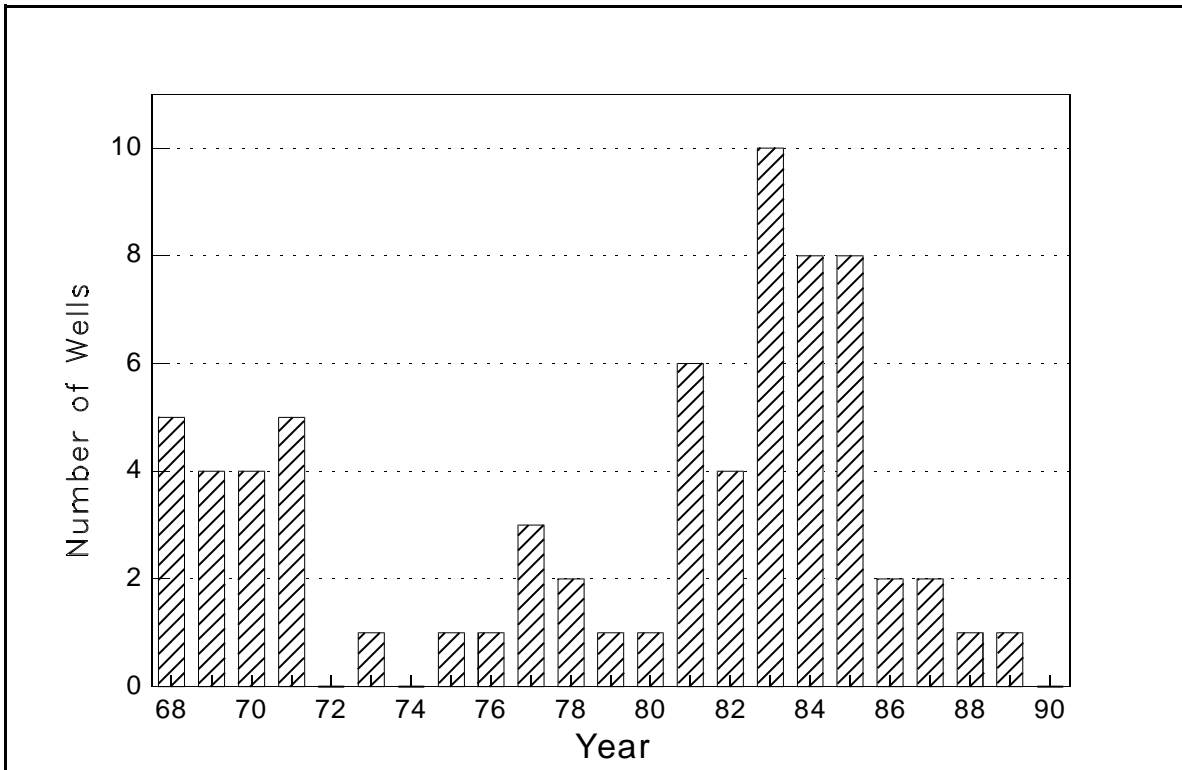


Figure 2. Wells determined to be producible in accordance with 30 CFR 250.11.

technical, contractual, economic, or regulatory uncertainties preclude such reserves being classified as proved.

Unproved reserves may be divided into two subclassifications, possible and probable, which are similarly based on the level of uncertainty.

Unproved Possible Reserves -- "Unproved possible reserves are less certain than unproved probable reserves and can be estimated with a low degree of certainty, which is insufficient to indicate whether they are more likely to be recovered than not. Reservoir characteristics are such that a reasonable doubt exists that the project will be commercial" (SPE, 1987). After a lease qualifies under 30 CFR 250.11, the reserves associated with the lease are initially classified as unproved possible.

Unproved Probable Reserves -- "Unproved probable reserves are less certain than proved reserves and can be estimated with a degree of certainty sufficient to indicate they are more likely to be recovered than not" (SPE, 1987). Reserves in fields for which a schedule leading to a Development and Production Plan (DPP) has been submitted to the MMS have been classified as unproved probable.

Proved Reserves -- "Proved reserves can be estimated with reasonable certainty to be recoverable under current economic conditions, such as prices and costs prevailing at the time of the estimate. Proved reserves must either have facilities that are operational at the time of the estimate to process and transport those reserves to market or a commitment or reasonable expectation to install such facilities in the future" (SPE, 1987).



Proved reserves can be subdivided into undeveloped and developed.

Proved Undeveloped Reserves -- Reserves are classified proved undeveloped when a relatively large expenditure is required to install production and/or transportation facilities, a commitment by the operator is made, and a time frame to commence production is established. Proved undeveloped reserves are reserves expected to be recovered from (1) yet undrilled wells, (2) deepening existing wells, or (3) existing wells for which a relatively large expenditure is required for recompletion.

Proved Developed Reserves -- "Reserves that are expected to be recovered from existing wells (including reserves behind pipe) are classified as proved developed reserves. Reserves are considered developed only after necessary production and transportation equipment have been installed or when the installation costs are relatively minor. Proved developed reserves are subcategorized as producing or non-producing" (SPE, 1987). This distinction is made at the reservoir level and not at the field level.

Proved Developed Producing Reserves -- Once the first reservoir in a field begins production, the reservoir is considered to contain proved developed producing reserves, and the field is considered on production. If a reservoir had sustained production during the last year, it is considered to contain proved developed producing reserves.

Proved Developed Nonproducing Reserves -- Any developed reservoir in a developed field that has not produced or has not had sustained production during the past year is considered to contain proved developed nonproducing reserves. This

category includes reserves contained in nonproducing reservoirs, contained reserves behind-pipe, and reservoirs awaiting well workovers or transportation facilities. A diagram of the reserves classification procedure is shown in figure 3.

Total Reserves -- Total reserves are the sum of proved and unproved reserves.

Original Recoverable Reserves -- The amount of oil and gas expected to be recovered from the original oil in place or the amount equal to the sum of cumulative production and remaining reserves is considered to be the original recoverable reserves.

Production Data -- The measured volumes of gross hydrocarbons reported to the MMS by Federal lessees and operators. Oil and gas volume measurements and reserves are corrected to reference standard conditions of 60 °F and 14.73 psia. Continuously measured volumes from production platforms or leases are allocated to individual wells and reservoirs on the basis of periodic well tests. These procedures introduce approximations in both production and reserves data by reservoirs and by fields.

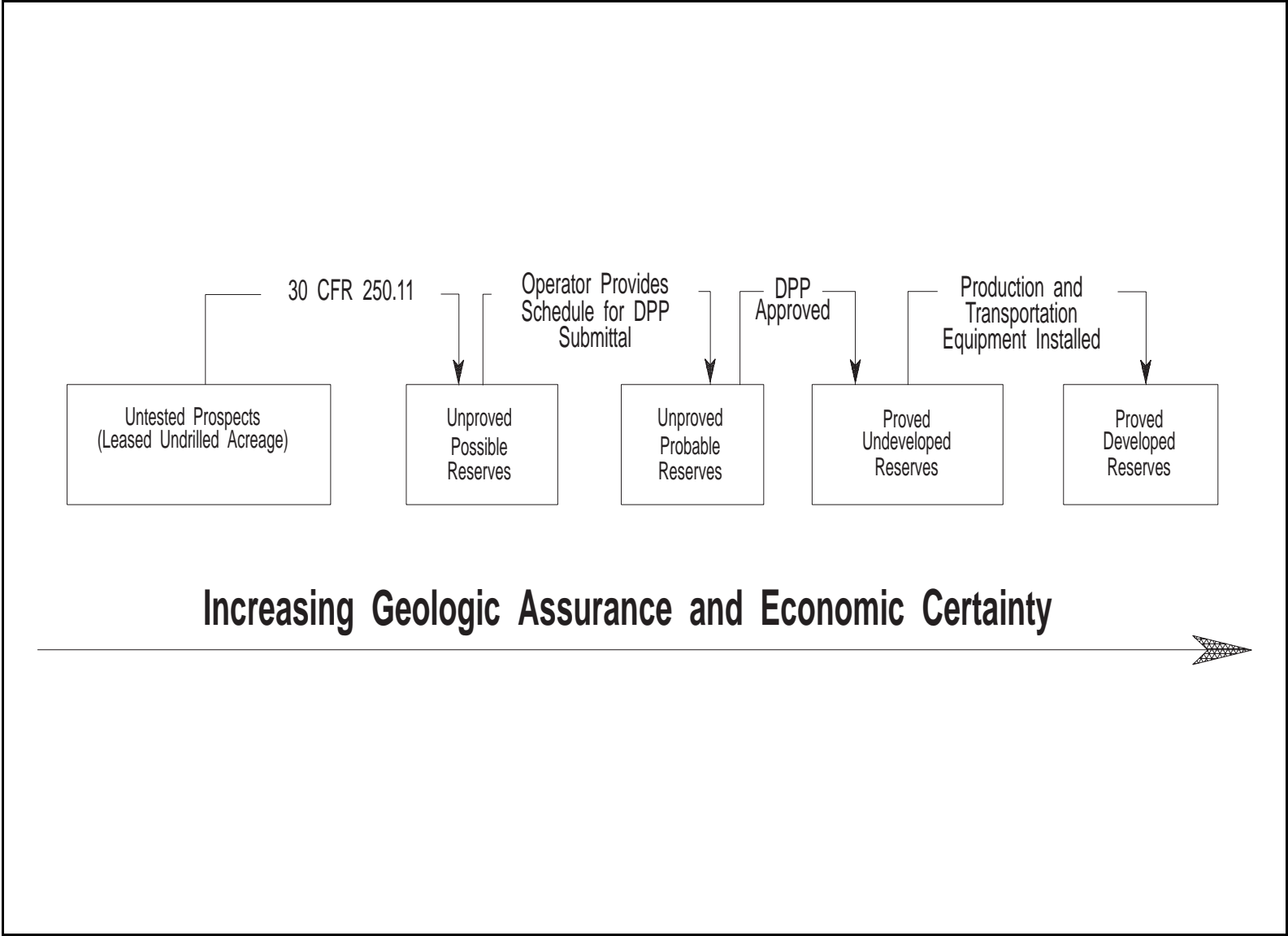


Figure 3. Pacific OCS MMS reserves classification procedure.

## Methods Used for Estimating Reserves

Volumetric calculation -- For the volumetric calculation of reserves, the amount of original oil and gas in place is estimated from the bulk volume of the reservoir as mapped using data from boreholes and seismic profiles. Maps of net oil and gas sand thicknesses are drawn and measured with a planimeter, and the results are converted to bulk volume using the appropriate equations. Rock porosity and the amounts of water, oil, and gas in the pore space are interpreted from well logs and core analyses. The estimated amount of original oil and gas in place is converted to standard conditions by analyses of pressure, volume, and temperature relationships and by the use of standard correlations. The amount of the original oil and gas in place that can be recovered is estimated from information about the reservoir drive-mechanism, spacing of the wells, analog field recovery factors, and API recovery factor equations (Arps and others, 1967, p. 19-20).

Decline-curve analysis -- In the decline curve analysis method, future production is estimated by extrapolating plots of production rates and fluid percentages versus time. The ultimate production is determined by adding past production to predicted future production.

## Fields Reported

As of December 31, 1990, thirty-eight fields in the Pacific OCS (figure 4) are recognized as containing reserves under the established criteria. Two of these fields are gas fields, 27 are oil fields, and

9 are combination oil and gas fields. The number of fields increased by one from the previous report (Flynn and Searls, 1990), and this increase is due to the initial evaluation of a field discovered in 1989.

Thirteen fields were determined to have proved reserves of oil and/or gas. These 13 fields are San Miguel, Point Pedernales, Point Arguello, Pescado, Sacate, Hondo, Dos Cuadras, Pitas Point, Carpinteria Offshore, Santa Clara, Sockeye, Hueneme, and Beta (figure 4, fields 2, 7, 11, 20, 21, 23, 29, 30, 31, 33, 34, 36, and 38). The remaining 25 fields were determined to have unproved reserves of oil and/or gas.

The current Pacific OCS total estimates for proved, unproved, and total reserves of oil and gas are shown in table 1. The totals appear as aggregate numbers to protect the proprietary data used to determine the estimates. Annual estimates of remaining recoverable reserves from Pacific OCS fields are graphically shown in figure 5. Estimates of original recoverable reserves for several individual fields were refined as development drilling continued to delineate the fields. Previous estimates of original recoverable reserves are shown in table 2 by year and source publication. Annual estimates of original recoverable reserves from Pacific OCS fields are shown in figure 6. Differences in reported reserves and production from the previous report (Flynn and Searls, 1990) are summarized in table 3.

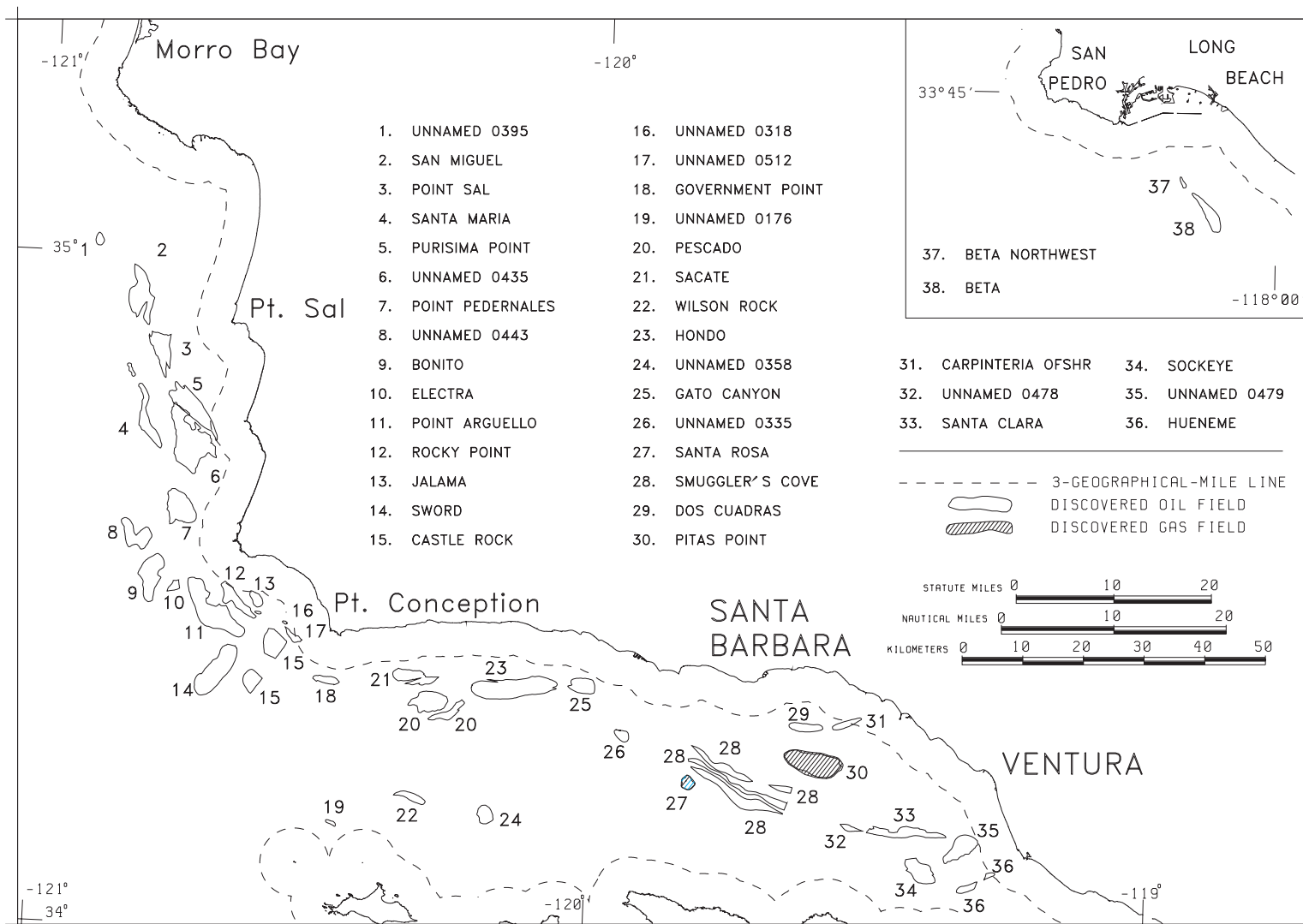


Figure 4. Recognized discoveries of federally controlled oil and gas fields in the Pacific OCS. (Dashed lines indicate 3-geographical-mile boundary between State and Federal waters.)

Table 1. Proved, unproved, and total oil and gas reserves for Pacific OCS, December 31, 1990.

Reserves	Number of Fields	Original Recoverable Reserves		Cumulative Production		Annual Production		Remaining Reserves	
		Oil (MMbbl)	Gas (Bcf)	Oil (MMbbl)	Gas (Bcf)	Oil (MMbbl)	Gas (Bcf)	Oil (MMbbl)	Gas (Bcf)
Proved Reserves	13	1,418	2,005	494	528	30	50	923	1,478
Unproved Reserves	25	570	679	0	0	0	0	570	679
Total Reserves	38	1,988	2,684	494	528	30	50	1,493	2,157

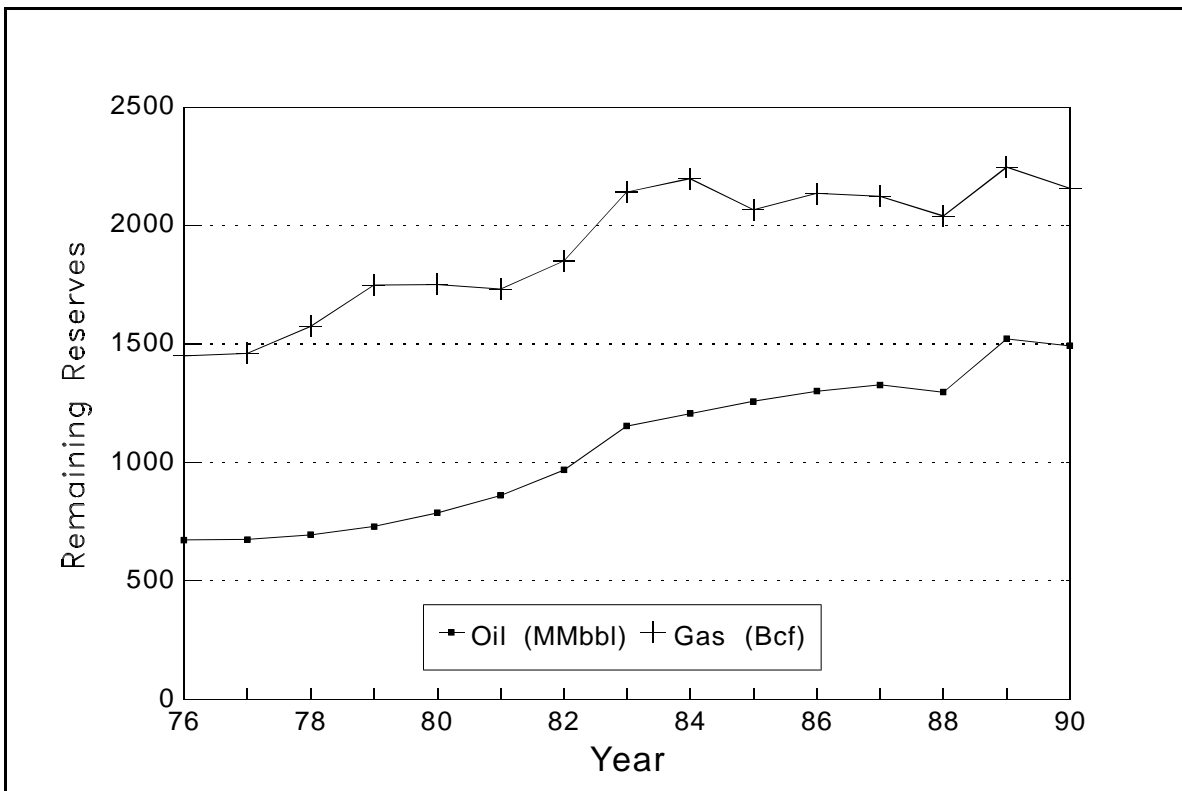


Figure 5. Annual estimates of remaining recoverable reserves from known fields.

Table 2. Annual estimates of original recoverable reserves with source publication numbers.

Original Recoverable Reserves			
Year	Publication	Oil (MMbbl)	Gas (Bcf)
1976	OFR 78-387	829	1,530
1977	OFR 79-345	843	1,546
1978	OFR 80-477	875	1,665
1979	OFR 80-1042	920	1,845
1980	OFR 81-623	988	1,853
1981	OFR 82-37	1,082	1,847
1982	OFR 83-559	1,217	1,983
1983	OFR 84-0024	1,433	2,298
1984	MMS 85-0041	1,515	2,400
1985	MMS 86-0066	1,599	2,334
1986	MMS 87-0045	1,670	2,461
1987	MMS 88-0047	1,727	2,501
1988	MMS 89-0085	1,729	2,467
1989	MMS 90-0086	1,987	2,723
1990	MMS 91-0087	1,988	2,684

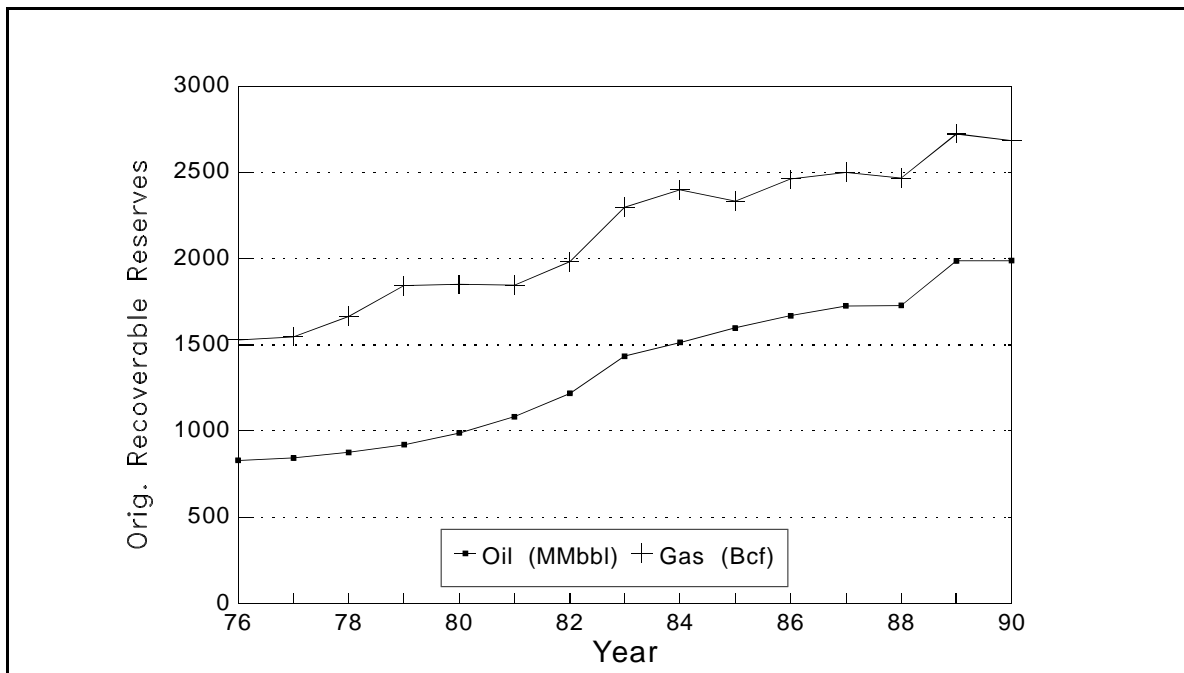


Figure 6. Annual estimates of original recoverable reserves from known fields.

## Studies Conducted

Reserve estimates for seven of the producing fields were conducted from volumetric calculations and decline-curve analyses: Hondo, Dos Cuadras, Pitas Point, Carpinteria Offshore, Santa Clara, Hueneme, and Beta (figure 4, fields 23, 29, 30, 31, 33, 36, and 38).

Individual reservoirs in each field were grouped for volumetric calculations, while decline-curve analyses were made on lease-by-lease and platform bases. The 31 remaining fields were studied on a reservoir-by-reservoir basis, and the reserve estimates were determined solely by the volumetric calculation method.

## Field Size Distribution

Figure 7 shows the field size distribution based on current estimated original recoverable reserves for 36 oil and gas fields and 2 gas fields. For convenience of comparison, gas reserves are expressed in terms of barrels of oil equivalent on the basis of equivalent heating values (5,620 cubic feet of gas has the approximate heating value of one barrel of oil), herein after referred to as BOE.

## Status of Field Development

As of December 31, 1990, five of the fields in the Pacific OCS have completed their primary drilling programs: Dos Cuadras, Pitas Point, Carpinteria Offshore, Hueneme, and Beta (figure 4, fields 29, 30, 31, 36, and 38). Of the 38 recognized fields, nine were producing in December: Dos Cuadras, Pitas Point, Carpi-

neria Offshore, Santa Clara, Sockeye, Hueneme, and Beta (figure 4, fields 7, 23, 29, 30, 31, 33, 34, 36, and 38). Additional exploratory and delineation wells are anticipated in many of the remaining fields to further define productive limits and optimize oil and gas recovery.

Five producing oil and gas fields in the Pacific OCS are undergoing fluid injection: Hondo, Dos Cuadras, Santa Clara, Hueneme, and Beta (figure 4, fields 23, 29, 33, 36, and 38). Recovery beyond primary production is occurring or can be anticipated (table 4). One field, Hondo, is undergoing gas injection for reservoir pressure maintenance. One field, Dos Cuadras, was undergoing polymer injection. Polymer injection at the field ceased in August 1990. Five fields, Hondo, Santa Clara, Dos Cuadras, Hueneme, and Beta, are undergoing water injection.

## Drilling History and Production Rates

There were 329 exploratory wells and 707 development wells spudded by year-end. For the first year since 1963, no exploratory wells were drilled in the Pacific OCS. Table 5 shows the yearend summary of the borehole status for all development wells. Drilled footage by year for all wells in the Pacific OCS is displayed in figure 8.

Annual oil and gas production through 1990 is shown in table 6 and figure 9. Cumulative production through 1990 is shown in table 6 and figure 10. Average daily production rates for each month during 1990 are shown in figure 11.

Table 3. Changes in reported reserves and production, Pacific OCS, December 31, 1990.

Production and Reserves	Oil	Gas
	(MMbbl)	(Bcf)
Original Recoverable Reserves:		
Estimated as of 12/31/90 (MMS 91-0087)	1,988	2,684
Estimated as of 12/31/89 (MMS 90-0086)	1,987	2,723
Change	+1	-39
Cumulative Production:		
Through 1990	494	528
Through 1989	464	478
Proved Reserves:		
Estimated as of 12/31/90 (MMS 91-0087)	923	1,478
Estimated as of 12/31/89 (MMS 90-0086)	951	1,515
Change	-28	-37
Total Reserves:		
Estimated as of 12/31/90 (MMS 91-0087)	1,493	2,157
Estimated as of 12/31/89 (MMS 90-0086)	1,523	2,246
Change	-30	-89

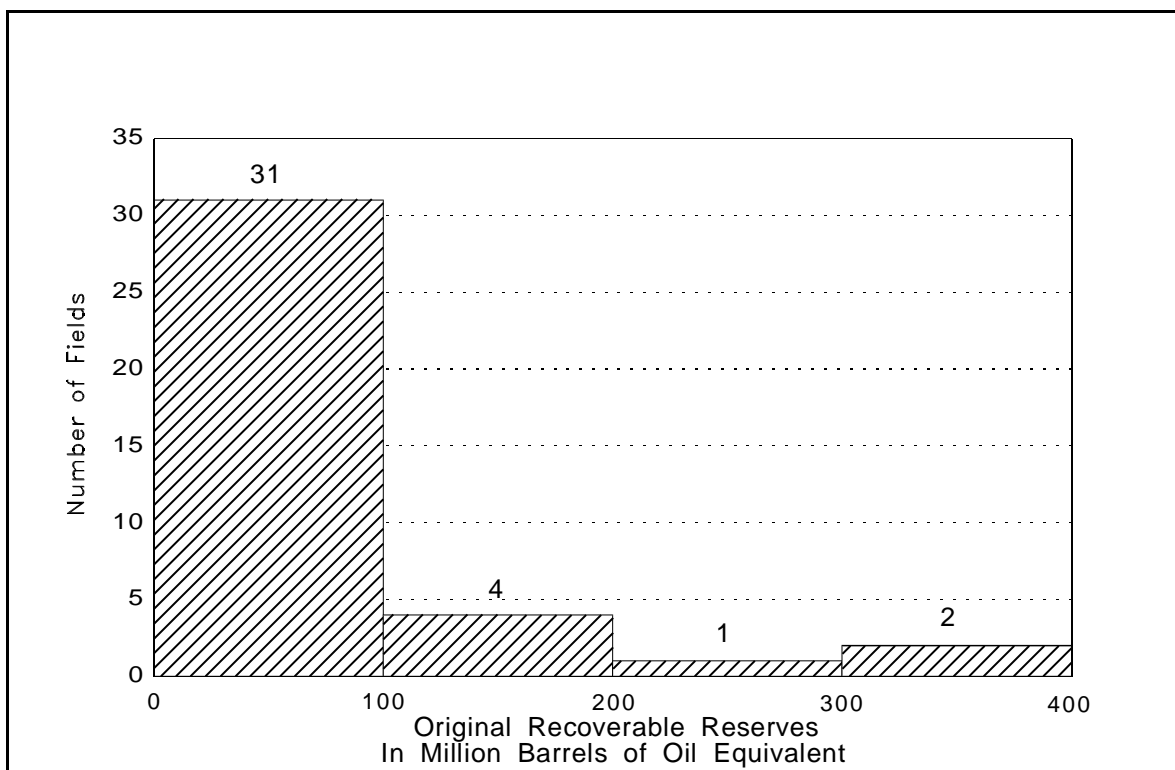


Figure 7. Size distribution of oil and gas fields.



Table 4. Secondary recovery methods used in Pacific OCS fields.

Field Type	Polymer Flood	Active Water Injection	Active Gas Injection
Oil	Dos Cuadras	Beta Dos Cuadras Hueneme	
Oil & Gas		Hondo Santa Clara	Hondo

Table 5. Summary of development well borehole status.

Platform Name	POW	GLO	PGW	OSI	GSI	GIW	WIW	WDW	WSW	SUSP	PA	Total	ACT
A	42	0	0	5	0	0	2	1	0	0	15	65	0
B	39	0	0	5	0	0	4	0	0	0	21	69	0
C	22	0	0	1	0	0	5	0	0	0	0	28	0
Edith	15	0	0	3	0	0	0	0	0	2	1	21	0
Ellen	28	0	1	3	1	1	22	1	3	0	7	67	0
Eureka	28	0	0	0	0	0	14	1	0	0	1	44	0
Gail	11	2	0	1	0	0	0	0	0	0	0	14	0
Gilda	39	0	2	2	3	0	14	0	0	2	6	68	0
Gina	7	0	0	0	0	0	5	0	0	0	2	14	0
Grace	0	17	0	4	3	0	0	0	0	3	7	34	0
Habitat	1	0	14	0	2	0	0	0	0	3	1	21	0
Harvest	0	0	0	8	0	0	0	0	0	11	0	19	0
Henry	22	0	0	1	0	0	0	0	0	0	2	25	0
Hermosa	0	0	0	11	0	0	0	0	0	1	0	12	0
Hidalgo	0	0	0	6	0	0	0	0	0	1	0	7	0
Hillhouse	16	25	0	4	0	0	1	0	0	0	4	50	0
Hogan	6	9	0	16	0	2	0	3	0	0	14	50	0
Hondo	11	11	0	2	0	2	1	1	0	0	9	37	0
Houchin	14	9	0	9	0	0	0	0	0	1	10	43	0
Irene	9	4	0	3	0	0	0	0	0	1	2	19	1
Total	310	77	17	84	9	5	68	7	3	25	102	707	1

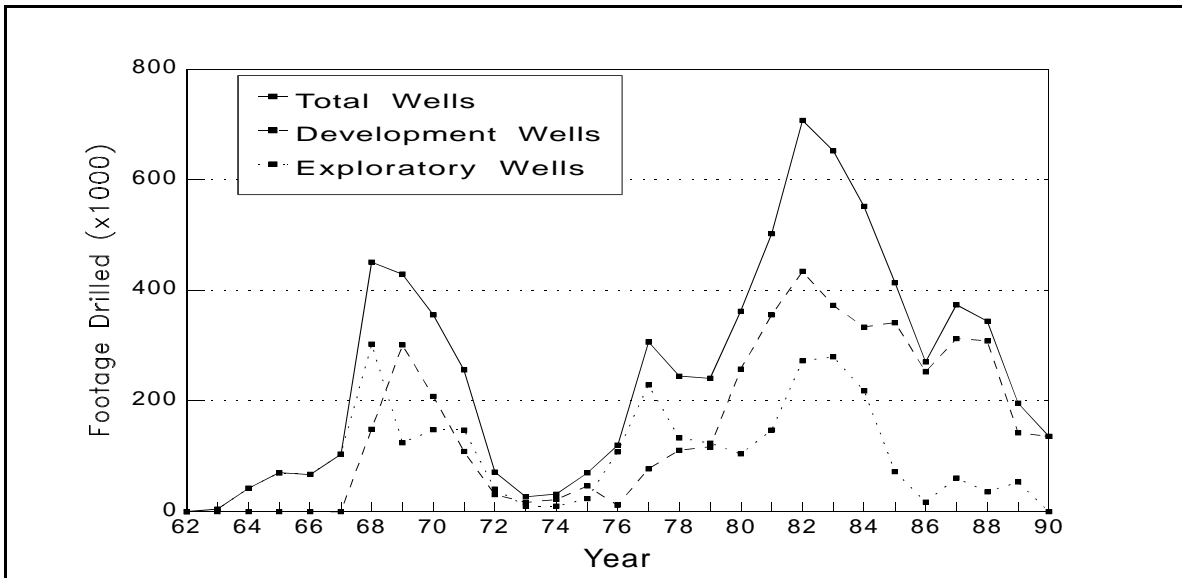


Figure 8. Annual drilled footage for wells in the Pacific OCS.

Table 6. Annual and cumulative production for the Pacific OCS.

Year	Annual Oil (bbl)	Cumulative Oil (bbl)	Annual Gas (Mcf)	Cumulative Gas (Mcf)
1968	2,076,160	2,076,160	1,237,180	1,237,180
1969	9,942,733	12,018,893	6,016,485	7,253,665
1970	25,035,171	37,054,064	13,757,148	21,010,813
1971	31,103,681	68,157,745	17,853,055	38,863,868
1972	22,562,566	90,720,311	12,546,915	51,410,783
1973	18,818,026	109,538,337	9,157,714	60,568,497
1974	16,784,100	126,322,437	7,234,937	67,803,434
1975	15,434,507	141,756,944	5,978,959	73,782,393
1976	13,977,436	155,734,380	5,533,258	79,315,651
1977	12,258,013	167,992,393	5,366,181	84,681,832
1978	11,979,674	179,972,067	5,193,985	89,875,817
1979	10,971,013	190,943,080	5,430,689	95,306,506
1980	10,118,614	201,061,694	5,771,792	101,078,298
1981	19,619,670	220,681,364	12,769,110	113,847,408
1982	28,471,665	249,153,029	17,814,958	131,662,366
1983	30,558,866	279,711,895	23,923,258	155,585,624
1984	30,500,506	310,212,401	45,912,435	201,498,059
1985	29,673,649	339,886,050	63,523,094	265,021,153
1986	28,779,936	368,665,986	57,989,035	323,010,188
1987	31,284,618	399,950,604	54,874,298	377,884,486
1988	31,529,776	431,480,380	49,132,759	427,017,245
1989	33,067,789	464,548,169	50,872,623	477,889,868
1990	29,885,271	494,310,184	49,950,216	527,796,524

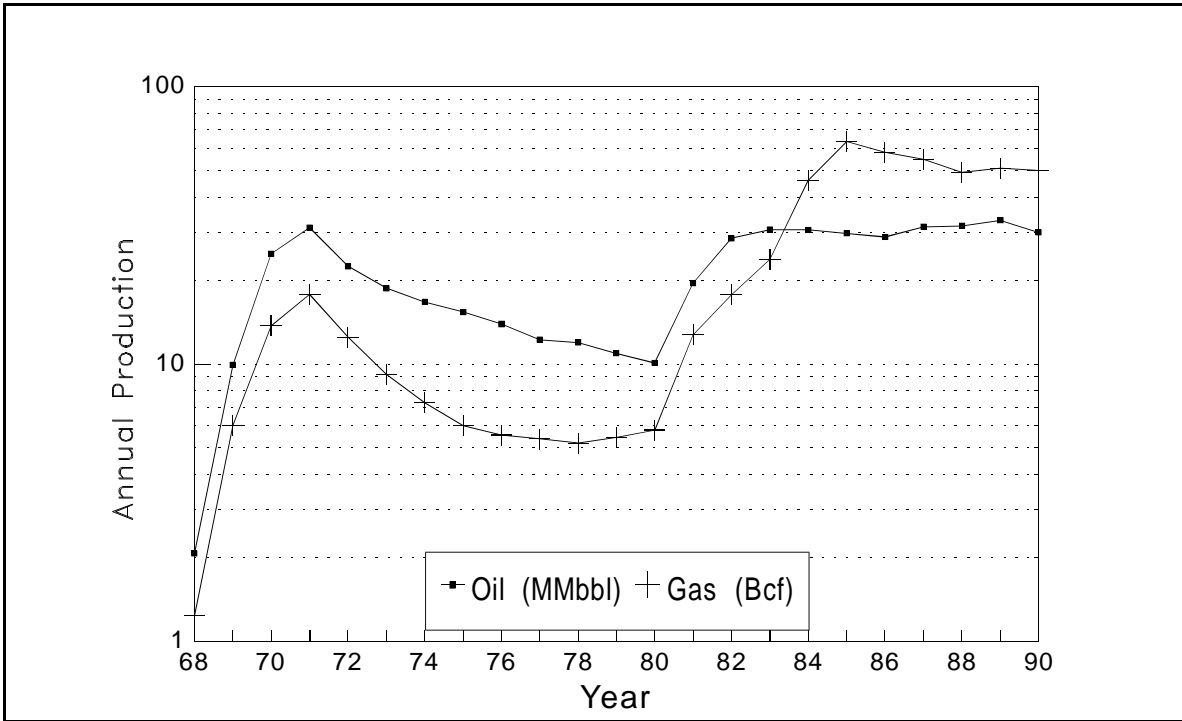


Figure 9. Annual production rates for the Pacific OCS.

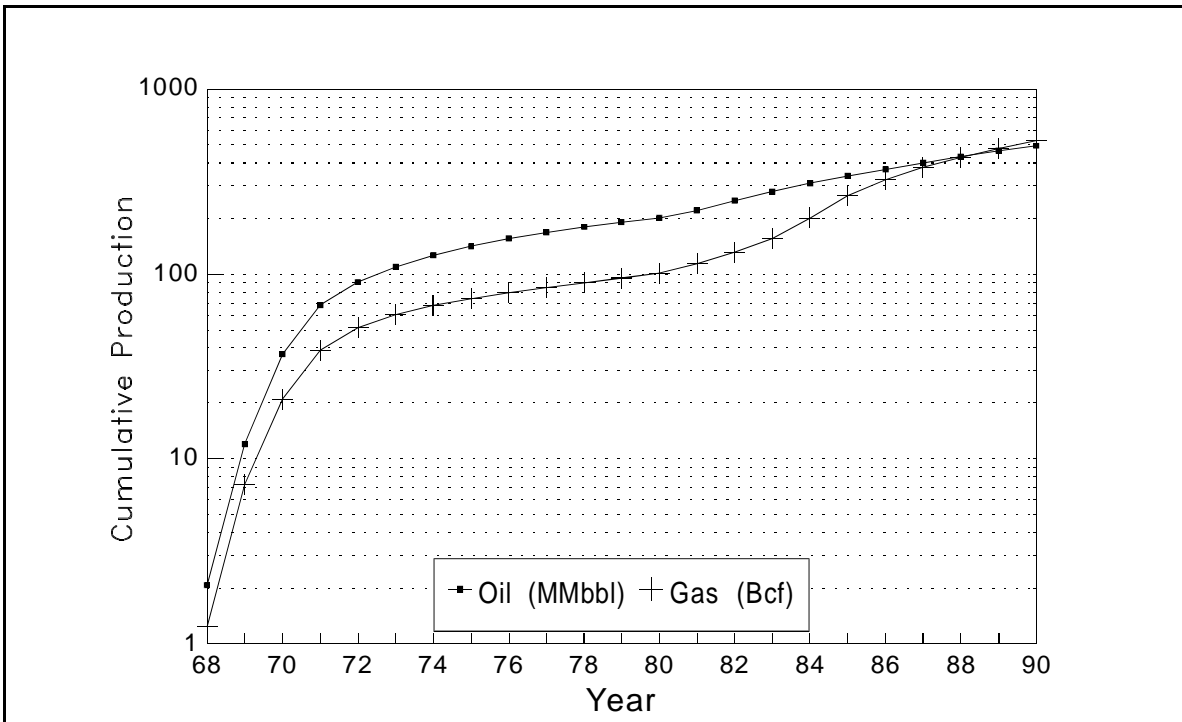


Figure 10. Cumulative production for the Pacific OCS.

## Crude Oil Prices

Figure 12 shows the price for Pacific OCS crude oil (average 19 °API) for each month during 1990. The price of West Texas Intermediate crude oil (38 °API) is shown for comparison. After a general decline during the first six months of 1990, average crude oil prices rose to a yearly high level of \$26.41 per barrel in October 1990. A total of 13 lessees sold Pacific OCS crude oil during the year, with the four largest firms accounting for over 80% of all sales.

recoverable unproved reserves in 25 known oil and gas fields in the Pacific OCS are estimated to be 570 million barrels of oil and 679 billion cubic feet of gas. Nine oil and/or gas fields being produced by 17 platforms have yielded 494 million barrels of oil and 528 billion cubic feet of gas since the first Pacific OCS platform began production in 1968.

## Distribution of Reserves by Relative Age of Reservoir Rock

The reserves of the Pacific OCS can be divided into three groups based on the relative age of the reservoirs in which they exist. The three age groups of reservoir rocks are (1) Pre-Monterey: rocks older than the Monterey Formation (early Miocene age and older), (2) Monterey: rocks of the Monterey Formation (Miocene age), and (3) Post-Monterey: rocks younger than the Monterey Formation (late Miocene age and younger).

The distribution of remaining reserves and estimated original recoverable reserves in BOE is illustrated in table 7 and figure 13.

## Conclusions

As of December 31, 1990, the remaining recoverable proved reserves in 13 known oil and gas fields in the Pacific OCS are estimated at 923 million barrels of oil and 1,478 billion cubic feet of gas. Remaining

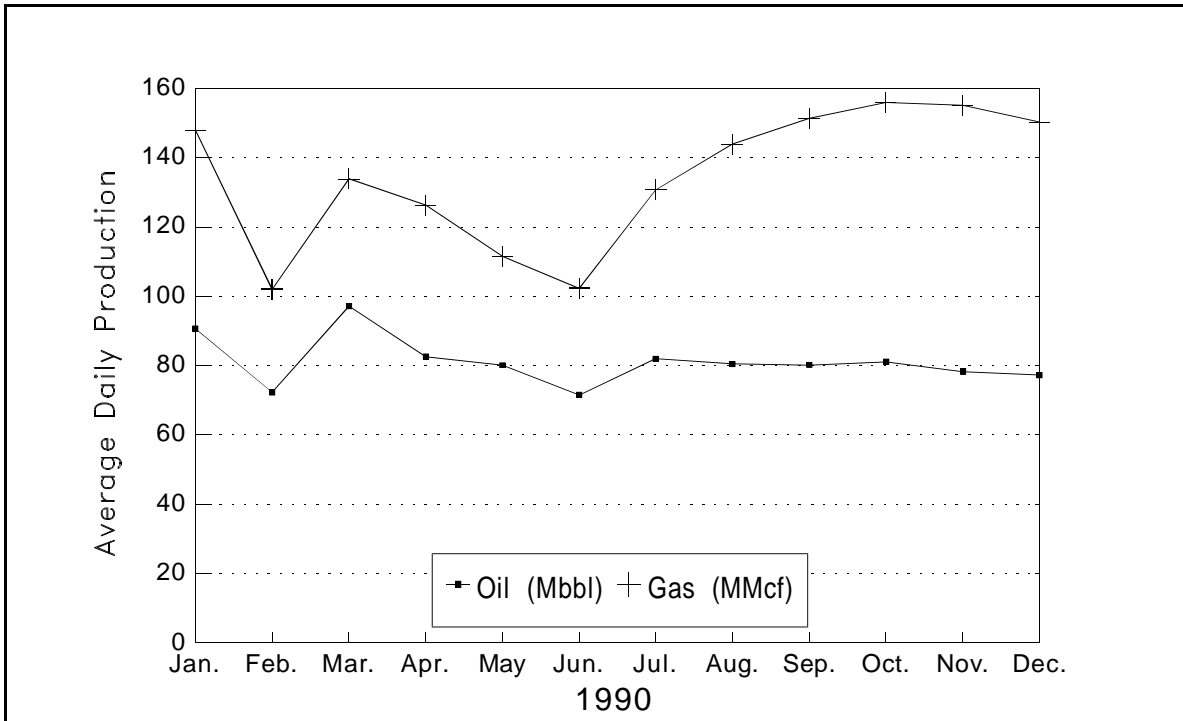


Figure 11. Average daily production rates for the Pacific OCS.

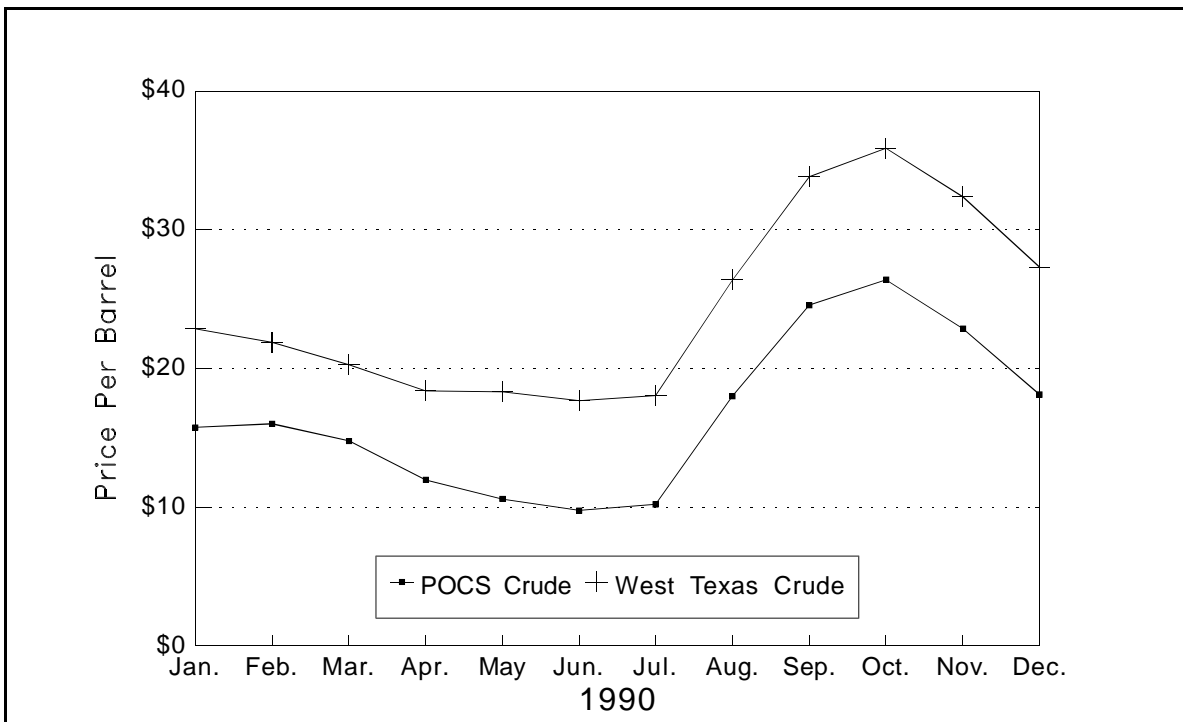


Figure 12. Average monthly crude oil price for the Pacific OCS.

Table 7. Geologic formations within each reservoir age group.

Reservoir Age Group	Geologic Formations	Remaining Reserves* (MMbbl)	Estimated Original Recoverable Reserves* (MMbbl)
Post-Monterey	Pico, Puente, Repetto, Santa Margarita, Sisquoc	185	586
Monterey	Monterey	1,492	1,657
Pre-Monterey	Point Sal, Vaqueros, Topanga, Hueneme, Sespe/Alegria, Gaviota, Sacate, Camino Cielo, Jalama	200	222

\*Barrels of oil equivalent

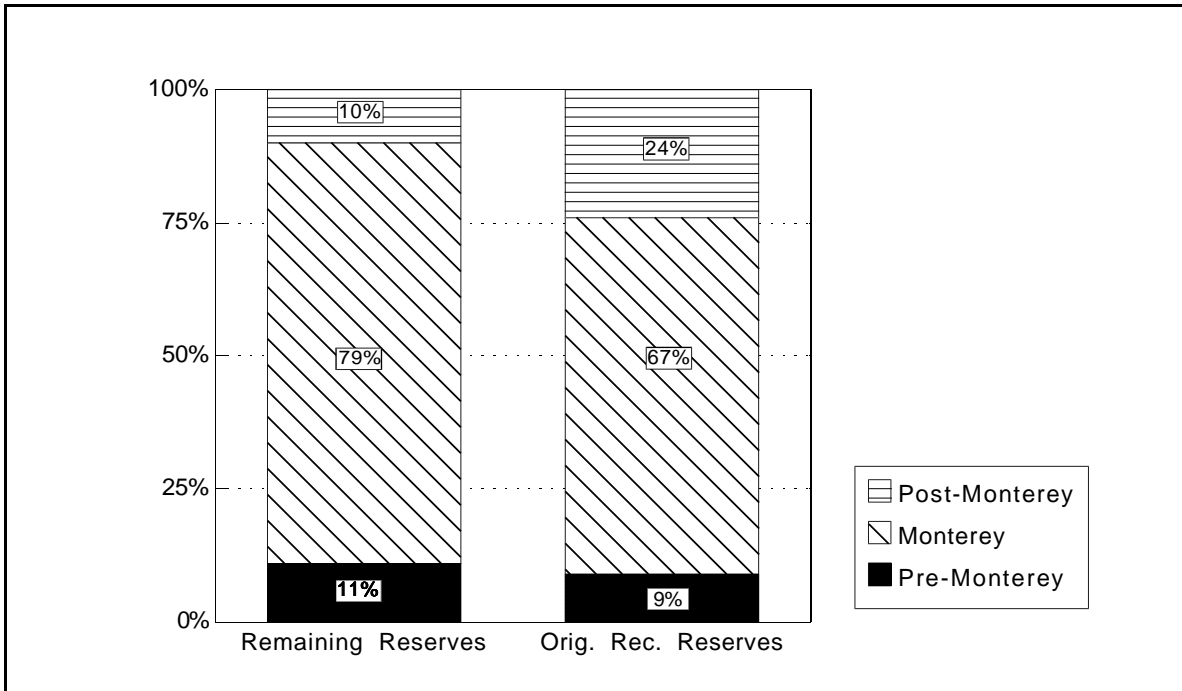


Figure 13. Remaining reserves and estimated original recoverable reserves (on a BOE basis) by reservoir age group.

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.

