AN ASSESSMENT OF THE UNDISCOVERED HYDROCARBON POTENTIAL OF THE NATION'S OUTER CONTINENTAL SHELF

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FOREWORD

The results presented in this report represent an estimation of the undiscovered hydrocarbon resource potential of the Outer Continental Shelf of the U.S. It is important to keep in mind that this assessment estimates the natural gas and oil resources that have yet to be discovered and thus are not currently available for production or consumption. The estimates represent potential resources for future development, depending on the economic assumptions and geologic interpretations. The estimation is based on numerous assumptions, and available data at the time of assessment. The new methodology, utilized for this assessment, represents an advancement over previous assessments. The present methodology incorporates many of the recommendations forwarded by the National Academy of Sciences, Association of American State Geologists, and others. The Minerals Management Service appreciates and acknowledges the contributions of these professional groups. However, we understand that alternative interpretations can be made of the same data and, consequently, differing estimates of the resources can be obtained. Thus, any interpretation of these results must be carefully considered in light of assumptions and judgments made. Care must also be used in comparing results of this assessment with the previous assessments of the same areas. Any changes in "risk" factors, whether it is economic or geologic, and modelling assumptions may result in significantly different resource estimates.

ABBREVIATIONS USED

AASG	Association of American State Geologists
API	American Petroleum Institute
Bbbl	Billion Barrels
BOE	Barrels of Oil Equivalent
DIST	Distribution of Possible Field Sizes
EIA/DOE	Energy Information Administration, U.S. Department of Energy
GRASP	Geologic Resource Assessment Program
Mcf	Thousand Cubic Feet
MMS	Minerals Management Service
NAS	National Academy of Sciences
OCS	Outer Continental Shelf
PETRIMES	Petroleum Exploration and Resource Evaluation System
PRESTO	Probabilistic Resource Estimates, Offshore
Tcf	Trillion Cubic Feet
USGS	U.S. Geological Survey

ACKNOWLEDGMENTS

A work of this nature originates from numerous sources. The geologic assessments resulted from a Bureauwide effort by geoscience professionals in the Minerals Management Service Resource Evaluation Program both at headquarters and in the Alaska, Gulf of Mexico/Atlantic, and Pacific regional offices.

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INTRODUCTION

This report presents the results of a multiyear effort by the Department of the Interior's Minerals Management Service (MMS) to assess the undiscovered crude oil and natural gas resources of the Nation's Outer Continental Shelf (OCS) areas. The OCS comprises the submerged offshore lands of the United States. This study was performed concurrently with an effort by the U.S. Geological Survey (USGS) to assess the undiscovered oil and natural gas resources of the onshore areas of the United States and the adjacent waters within the boundaries of the coastal States. The results presented herein reflect information and data available to the MMS as of January 1, 1995.

The current assessment estimates the undiscovered conventionally recoverable oil and natural gas resources located outside of known oil and gas fields on the OCS. The assessment considers recent geophysical, geological, technological, and economic information and uses a play analysis approach of resource appraisal.

Since its formation in 1982, the MMS has completed three systematic assessments of Federal OCS undiscovered oil and natural gas resources. The results of the first such assessment and the methodologies used to develop these estimates were published in 1985 (Cooke, 1985). For the second assessment, the MMS and USGS agreed to conduct a joint reassessment of the United States—both onshore and offshore—to provide the Department of the Interior (DOI), Congress, and other public and private organizations with estimates reflecting consistent timeframes. The results of this first *National Assessment* were published in 1989 (DOI, 1989). The MMS then released more detailed results about the OCS in a separate report (Cooke and Dellagiarino, 1990). Finally, MMS published revised OCS estimates in 1991 to reflect revisions for five OCS areas based upon new information and additional geologic mapping activities (Cooke, 1991). These revised estimates were developed to support the analyses for the 1992-1997 OCS leasing program.

Following the first MMS assessment, a National Academy of Sciences (NAS) panel reviewed MMS's resource assessment and resource estimation methodologies and recommended certain changes for future assessments. Similarly, the NAS panel reviewed the MMS procedures used in the second assessment. Panels from the Association of American State Geologists (AASG), the American Petroleum Institute (API), and the Energy Information Administration of the U.S. Department of Energy (EIA/DOE) also reviewed the second assessment and published recommendations.

To implement these technical recommendations and better address the needs of MMS planners and decisionmakers, the MMS initiated a search for a better methodology in 1991. The objective was to establish a method for assessing resources that maintains the strong points of earlier methodologies, uses the fullest extent of available geological and geophysical data provided by industry and generated by the MMS, and yet allows for flexibility in the application of the geologist’s interpretation.

The available methods of estimating oil and natural gas resources for an area are many and differ significantly. However, these methods can be broadly grouped into two categories: (1) analytical discovery process models and (2) subjective methods. Analytical discovery process models are based on or derived primarily from Arps and Roberts (1958) and from Barouch and Kaufman (1978) methods reviewed by Herbert (1982). These models require information on the number and size of fields or pools discovered in a region. Consequently, discovery process models provide reliable results only in mature areas with a significant number of discoveries. The subjective methods, which vary widely in precision and meticulousness, range from purely geologic analogy and Delphi methods to more rigorous play analysis (White and Gehman, 1979) and probability methods. They rely less on historical records of exploration efforts and discovery records but rely more on descriptive geologic characteristics of a province, basin, or play. The quantities of undiscovered oil and natural gas are then estimated by quantifying reservoir variables and estimating the number of pools expected to be discovered. In this method, a thorough analysis of the subjective probabilities (risks) of occurrence of variables responsible for the formation, migration, trapping, and preservation of hydrocarbons at a play, basin, or province level is critical.

The Petroleum Exploration and Resource Evaluation System (PETRIMES), a probabilistic play analysis (subjective method) model, currently used by the Geological Survey of Canada (Lee and Wang, 1984), was chosen by MMS to be the basic platform for the present assessment of the undiscovered conventionally recoverable resources. Most of the resource assessment models currently used by industry and other government agencies provide estimated resources in aggregated numbers representing total resources as a distribution. However, to support MMS planning and decisionmaking related to OCS exploration and development, a knowledge of the potential number and size of undiscovered pools is essential (Lee and Wang, 1984). Unlike most models reviewed by MMS (including the Probabilistic Resource Estimates, Offshore—PRESTO—model used by MMS in previous assessments), PETRIMES attributes include the assessment and reporting of the:

- number of pools that remain to be discovered;
- size range of the undiscovered pools;
- reservoir characteristics of the undiscovered pools;
- pool size distributions that relate to geologic model; and
- resource data in a manner suitable for economic analyses.

The iterative application of the PETRIMES was viewed as a highly desirable feature because it provided interim feedback to allow the assessors to confirm the geologic concepts envisioned, and, in areas with discovered pools, it allowed for the explicit incorporation of observed play characteristics. The PETRIMES, however, was designed to assess a single commodity play, such as an oil play or a natural gas play. Because OCS plays are, in many cases, mixed plays containing both oil and natural gas pools and because a separate estimation of both liquid (condensates and oil) and natural gas (associated natural gas and nonassociated natural gas) phases is required for an accurate economic evaluation, the MMS modified PETRIMES for OCS resource estimation. The modified version is called the Geologic Resource Assessment Program (GRASP).

Likewise, MMS modified the PRESTO model, used in previous MMS assessments, to accept the GRASP outputs for the number and sizes of pools to determine the economically recoverable resources at the geologic basin level and higher. As an improvement to estimating resources for one or two specific price paths, as done in previous MMS assessments, the current assessment estimates economically recoverable resources over a range of specific fixed prices. These results are then reported as a continuous price-supply curve depicting the resultant price-resource relationships for geologic basins, provinces, or other areas being studied. (See the appendix for price-supply curves for each OCS region/subregion and province.)

This report therefore presents the assessment results and general economic information for each of the Nation's four OCS regions: Alaska, Atlantic, Gulf of Mexico, and Pacific. More detailed information about the geology, assessment methodology, economics, and results on a play level will be published in separate regional assessment reports.

COMMODITIES ASSESSED

The assessed commodities for the OCS include crude oil and natural gas present in conventional reservoirs; unconventional resources (such as clathrates) were not assessed. In this assessment, natural gas present as natural gas caps associated with oil reservoirs, dissolved natural gas present in solution in crude oil, and nonassociated natural gas are reported as natural gas. Condensate, which is the liquid drawn from produced free natural gas, is combined with crude oil in reporting the results of this assessment.

Reserves were not estimated specifically as a part of this assessment. The MMS, however, assesses and publishes reserves estimates annually for fields of the Gulf of Mexico OCS and the Pacific OCS. The reserves estimates in this assessment are obtained from those reports. The amount of oil and natural gas likely to be added to known fields (reserves appreciation) has also been estimated and reported where supportable in this assessment.

Estimates of undiscovered resources are presented in two categories:

- undiscovered conventionally recoverable resources
- undiscovered economically recoverable resources

Undiscovered *conventionally* recoverable resources refer to quantities of hydrocarbon resources expected to be present, as of the date of assessment, in undiscovered pools within a play, using technology and exploration and development efficiency available or reasonably foreseeable at the time of the assessment. No explicit consideration for economic viability was implied in the estimation of the undiscovered conventionally recoverable resources.

Undiscovered *economically* recoverable resources are the portion of undiscovered conventionally recoverable resources that can be explored, developed, and commercially produced at given cost and price considerations using present or reasonably foreseeable

technology. The estimates of economically recoverable resources are presented as continuous curves of resource values corresponding to changing oil/natural gas prices.

LIST OF TERMS

The following is a description of terms used in this report.

Field: An accumulation of hydrocarbons. A field represents an area consisting of a single pool or a group of pools related to the same geological structure/stratigraphic feature.

Hydrocarbon Potential: Quantity of undiscovered hydrocarbons inferred to be present in a play basin, province, or area.

Marginal Probability of Hydrocarbons: An expression, usually a decimal fraction, of the likelihood that an oil/natural gas accumulation may be present in a prospect, play, basin, province, or area.

Play: A group of pools that share a common history of hydrocarbon generation, migration, reservoir development, and entrapment. A play is classified based on availability of data, stages of hydrocarbon detection and discovery, and degree of confidence in the play concept as established (significant data and discoveries), frontier (limited data and detection), or conceptual (minimal data).

Pool: A discovered or undiscovered accumulation of hydrocarbons, typically within a single stratigraphic interval.

Price-Supply Curves: A plot showing volumes of undiscovered economically recoverable resources at various oil or natural gas prices. As price increases, the amount of economically recoverable resources increases, thus approaching the undiscovered conventionally recoverable resources.

Prospect: A geologic feature having the potential for trapping and accumulating hydrocarbons. (A potential undiscovered pool/field.)

Proved Reserves: Reserves that can be estimated with reasonable expectation to be recoverable with existing technology under current economic conditions, such as prices and costs prevailing at the time of the estimate.

Reserves: Hydrocarbon resources that have already been discovered and may be commercially recoverable under reasonably foreseeable economic scenarios.

Reserves Appreciation: A term synonymous with reserves growth and inferred reserves/indicated reserves. Reserves appreciation refers to the expected increase in estimates

of proved reserves as a consequence of extension of known pools or discovery of new pools within existing fields or through the application of improved recovery techniques.

Resource Endowment: Resources that include undiscovered conventionally recoverable resources, remaining reserves, cumulative production, and reserves appreciation.

Undiscovered Conventionally Recoverable Resources: The portion of the hydrocarbon potential that is producible, using present or reasonably foreseeable technology, without any consideration of economic feasibility.

Undiscovered Economically Recoverable Resources: The portion of the undiscovered conventionally recoverable resources that is economically recoverable under imposed economic scenarios.

Unproved Reserves: Reserves based upon geologic or engineering information similar to that used in estimates of proved reserves, but technical, contractual, economic, or regulatory uncertainties preclude them being classified as proved.

METHODOLOGY

This assessment began with the geologic analyses of the OCS areas using the extensive library of public and proprietary data available to MMS assessors. These data include seismic data and interpretations, well log data and interpretations, petrophysical and geochemical data, geologic maps and cross sections, and resources available to MMS through its Federal regulatory responsibilities for OCS resource management. In cases where data were not available or sparse, geologically analogous areas were studied and the geologic properties of those areas were used. These analyses resulted in the identification of specific geologic plays, which form the basis of this assessment.

For the purpose of the current assessment, the geologic plays are classified into three groups based on the level of exploration and discovery history:

- Established Plays
- Frontier Plays
- Conceptual Plays

Assessing Undiscovered Conventionally Recoverable Resources

The general methodology of assessing oil and natural gas resources for the three types of plays using GRASP is similar. A simplified diagram of the assessment process is presented in figure 1. The basic steps are listed below.

1. Compile play data.

2. Generate prospect (pool) size distribution from probabilistic distribution of reservoir parameters.

3. Generate a number of pools distribution.

4. Determine individual oil, natural gas, and mixed pool sizes by rank.

5. Establish individual pool size rank conditional to discovery data.

6. Generate play potential resources distribution.

In recognition of the differences in the extent of data and information available among the OCS areas (attributable mostly to the degree of past exploration and development activities), some variances in the use of GRASP modules and procedures were incorporated. The frontier and conceptual plays, where available data are sparse and good analogs not identified, are analyzed through the subjective probability method used by GRASP. In this method, individual distributions of input variables are subjectively prepared and, through GRASP, ranked pool size distributions are generated. Most plays in the Alaska OCS and some in the Pacific OCS were analyzed this way. In the case of frontier plays where the assessors feel confident that an analog exists, such as in the Atlantic OCS, the analysts can generate a pool size distribution from the statistical parameters of the appropriately scaled ranked pool size distribution of the analog plays and can estimate the play resources using GRASP.

For established plays, such as in the Gulf of Mexico and in southern California where significant amounts of pool data are available from discovered fields, a pool size distribution curve for a play can be generated from the distribution of discovered pools.

The estimates of undiscovered oil and natural gas resources attributed to basins, provinces, regions, or other areas are derived by statistically aggregating the play level potential resource distributions of the plays of that area.

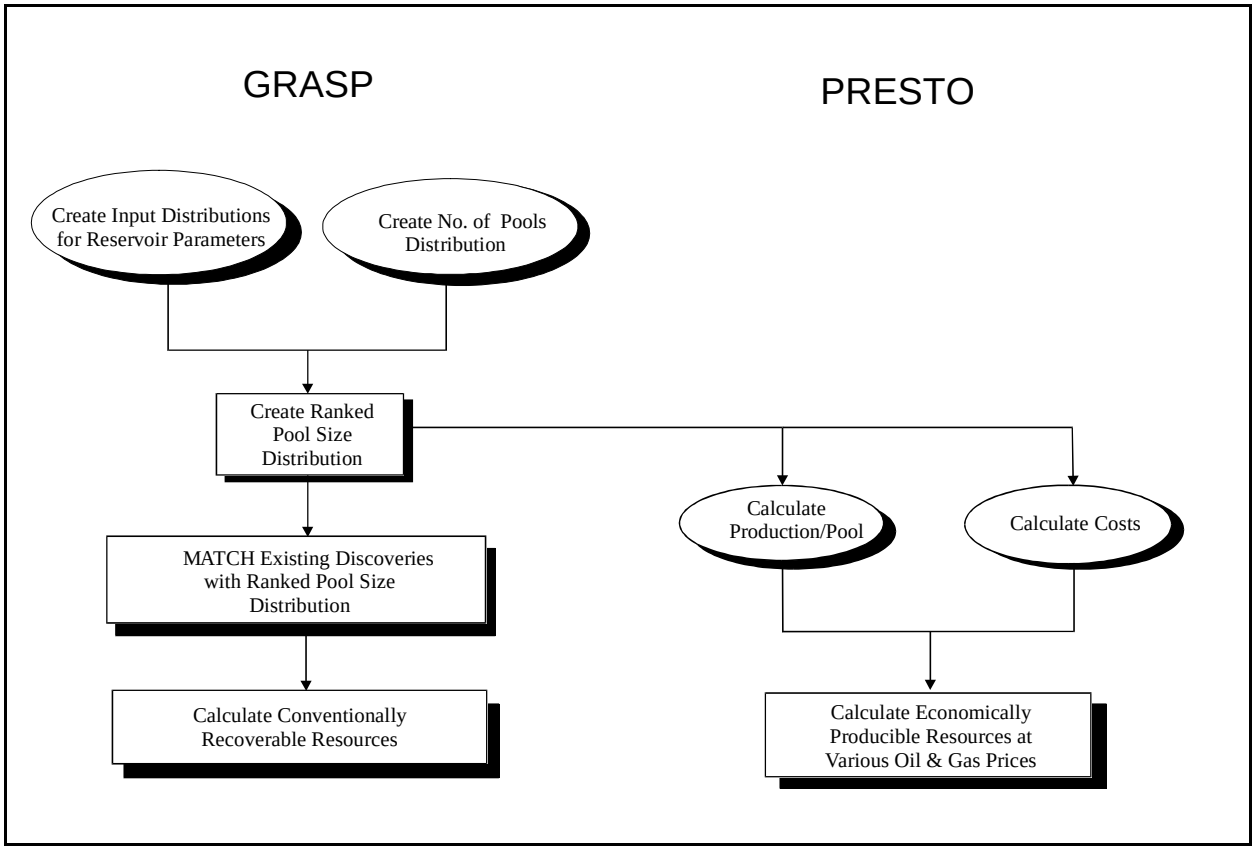


Figure 1. MMS Assessment Process

Assessing Undiscovered Economically Recoverable Resources

The ranked pool size distributions (generated by GRASP) and geologic risk factors are the basic geologic inputs into the PRESTO model. The costs of exploration, development, and transportation, as well as tariffs based upon logical exploration, development, production, and transportation scenarios, were estimated for each OCS region, province, basin, or other operational subarea where activities, costs, or other circumstances warrant. Estimates of economically recoverable resources are then derived for a specific price by (1) subjecting the plays' pool size distribution to multiple computer iterations simulating the drilling of the hydrocarbon prospects associated with the plays; (2) determining which pools and sizes are simulated to be *discovered* on each iteration; and (3) determining a discounted-cash-flow analysis for the plays' *discovered* resources using specified economic parameters. The *resources* that would exceed the economic hurdles are then totaled and become one data point on the price-supply curve. The process is repeated for numerous prices, and a continuous distribution curve is then generated. (For a more detailed description of the PRESTO model's functions, refer to Cooke and Dellagiarino, 1990.)

The Gulf of Mexico, the Atlantic, and certain portions of the Pacific OCS Regions contain *stacked plays* (i.e., plays overlie other plays at different depths). In determining the economic

viability of such plays, assessors needed to consider the concurrent exploration, development, and production of possible pools in these plays. Otherwise, the estimates would be overly conservative. The specific procedures used to evaluate the *stacked plays* will be presented in the regional assessment reports.

The current estimates of undiscovered economically recoverable OCS oil and natural gas resources were developed using the following criteria:

- Flat prices (no real price changes)
- 12-percent discount rate (after tax rate-of-return)
- 12.5-percent or 16.7-percent royalty rate
- 35-percent tax rate
- 3-percent inflation rate
- Cost of exploration, development, and transportation, and tariffs with their associated development scheduling scenarios for each OCS region and portions of regions when conditions warrant
- Natural gas prices related to oil prices at 66 percent of the oil-energy equivalent

LIMITATIONS OF RESOURCE ASSESSMENT

The NAS review panel, which studied the 1987 MMS assessment, succinctly expressed the limitations that every resource assessment must recognize. The limitations, summarized below, also apply to the present assessment (National Research Council, 1991).

- Estimates of undiscovered oil and natural gas resources are just ESTIMATES.
- Estimates should be viewed as a snapshot at a point in time based on existing data, information, and methodology.
- Although play analysis is universally regarded as the best way to assess petroleum resources, other factors contribute to the uncertainty of the estimation, including (1) the subjective judgment of the analysts and (2) the fact that assessors must make assumptions in estimating the probability of occurrence and magnitude of numerous geologic factors essential for the accumulation of oil and natural gas.
- An assessment is as good as the basic data used. Needed data may be unavailable or may not exist, change constantly, or may be subject to the interpretative skills of the assessors.
- Changing technology, which is difficult to quantify, greatly impacts the resource assessment.
- Actual drilling operations are necessary to confirm the presence of oil or natural gas.
- Specific quantities of oil or natural gas are known only after pools have been produced and depleted.

AREAS ASSESSED

For this assessment, the Nation's OCS is divided into four regions: Alaska, Atlantic, Gulf of Mexico, and Pacific OCS (fig. 2). These regions were subdivided by the regional assessment teams into assessment provinces, defined on geologic affinities, and these provinces were further subdivided into basins or geographic areas.

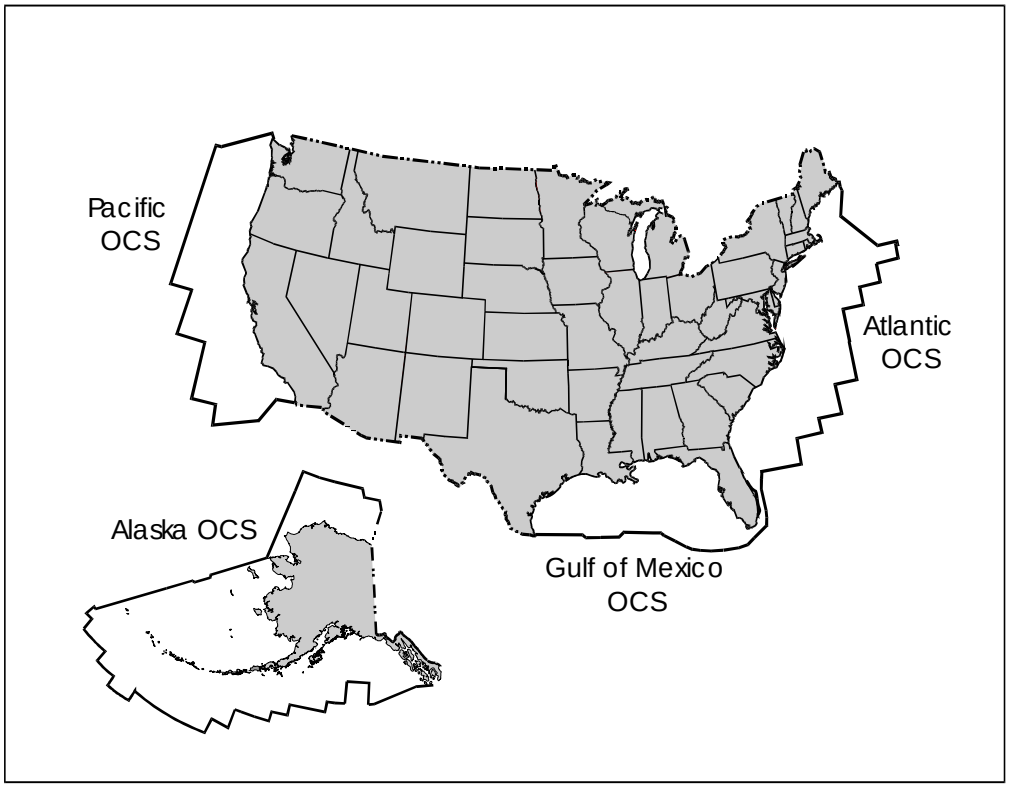


Figure 2. Four OCS Regions of the United States

Alaska OCS

The Alaska OCS Region includes the Arctic, Bering Shelf, and Pacific Margin subregions of the Alaska Federal offshore, a vast area encompassing 17 assessment provinces. Assessment provinces that offer potential for undiscovered conventionally recoverable oil and natural gas resources are confined to the 11 provinces comprising the continental shelves surrounding Alaska (fig. 3). The Arctic subregion includes the Beaufort Shelf, Chukchi Shelf, and Hope Basin assessment provinces. Most of the conventionally recoverable resource potential lies within the Chukchi Shelf and Beaufort Shelf provinces. These lie adjacent to the onshore Arctic Alaska oil and natural gas province. Daily production in this onshore province was about 1.5 million barrels of oil in 1995, and original oil reserves (including cumulative production and proved reserves) were estimated at 16.4 billion barrels. Aside from the onshore Arctic Alaska province, the only other significant production is in State waters of Cook Inlet,

near Anchorage on the Pacific Margin of Alaska. The Bering Shelf subregion includes Norton Basin, Navarin Basin, St. Matthew-Hall Basin, St. George Basin, and North Aleutian Basin assessment provinces. The Pacific Margin subregion includes Shumagin-Kodiak Shelf, Cook Inlet, and Gulf of Alaska Shelf assessment provinces. Within these 11 offshore provinces assessed, oil and natural gas resources were estimated for 74 exploration plays.

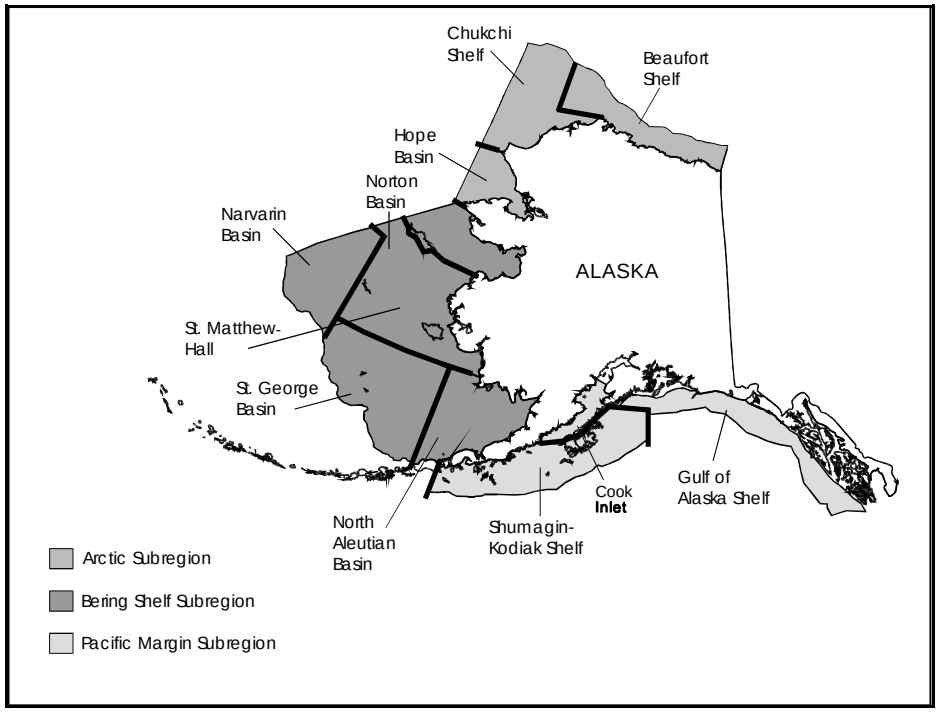


Figure 3. Assessed Provinces of the Alaska OCS

Atlantic OCS

Areas of potential discovery for the Atlantic OCS Region extend from the U.S.-Canada border to the Blake Plateau (fig. 4). Mesozoic strata of Middle Jurassic through Lower Cretaceous age are the only sediments that indicate any significant hydrocarbon potential. Mesozoic Province sediments of Middle Cretaceous age and younger were not assessed because of limited thickness and lack of reservoir quality sands, making these sediments poor hydrocarbon targets. The Southeast Georgia Embayment was also not assessed, owing to the thin, organically lean, and thermally immature sedimentary section. Also, there is an absence of Jurassic source rock in the area. Potential traps are related to folded structures, faults (normal and growth), and permeability pinchouts against nonporous shales, mudstones, evaporites, and carbonates. Eleven plays were identified in the province, all of which are frontier or conceptual, and, therefore, require reservoir and production data from analogs for assessment analysis. The drilling of 49 wells in the province has resulted in a single subeconomic discovery in Upper Jurassic-Lower Cretaceous sediments in the Baltimore Canyon area. Of the 11 plays, 6 conceptual plays were not assessed due to poor petroleum potential, but 2 frontier and 3 conceptual plays were assessed. The region has a greater potential for natural gas discoveries than oil.

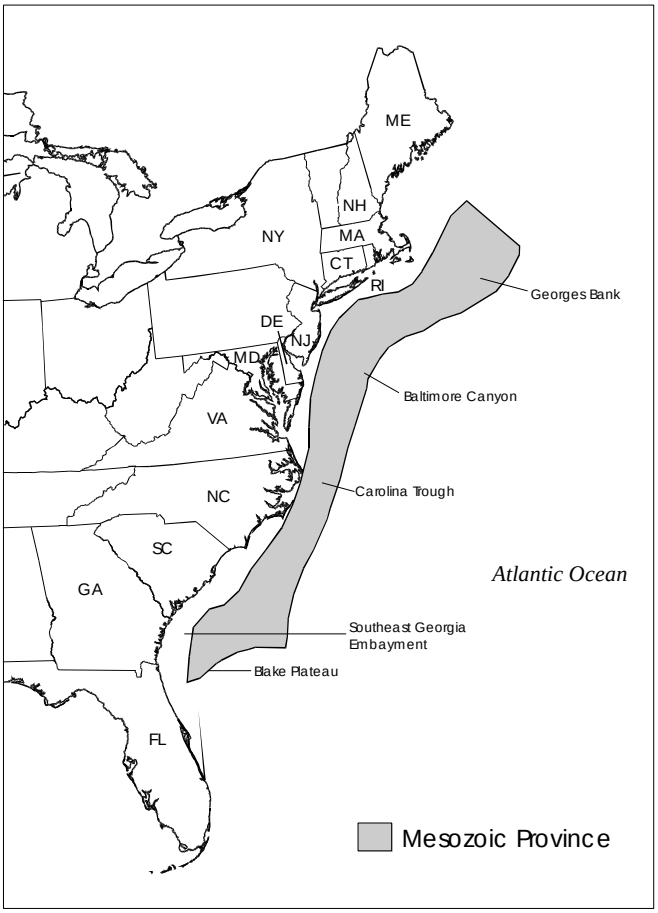


Figure 4. Assessed Provinces of the Atlantic in OCS

Gulf of Mexico OCS

In the Gulf of Mexico OCS Region, the Texas and Louisiana shelf (fig. 5) and slope are characterized by massive amounts of clastic materials (silts, clays, and sands) that were deposited largely during the Cenozoic. In the eastern Gulf of Mexico, the continental margin is dominated by a thick accumulation of carbonate rock and evaporite deposits of the Mesozoic. These two distinct sedimentary environments provided the basis for the two provinces of the Gulf of Mexico OCS Region, the Cenozoic Province and the Mesozoic Province. Sixty-one individual plays within the Gulf of Mexico OCS have been defined and described, with 57 of these having been formally assessed. Two conceptual Mesozoic plays were not assessed due to low potential, and two Cenozoic established plays were not assessed due to limited occurrence.

Initially, exploration in the region targeted oil, but recent discoveries have tended to be predominately natural gas. This mixture of hydrocarbon types is reflected in the predicted volumes of oil and natural gas. As of January 1, 1995, there were 876 proved fields—157 fields were classified as oil and 719 as natural gas. Included in this number are the 133 fields

that are depleted and abandoned. In addition, there are 77 unproved active fields (Melancon et al., 1995). The Cenozoic Province covers an area from the U.S.-Mexico maritime boundary to the Federal waters of offshore Florida. The 50 assessed plays of the province (48 established, 1 frontier, and 1 conceptual) have been defined by geologic age and depositional environment (Lore and Batchelder, 1995). In the Cenozoic Province, 867 proved fields have been discovered. The Mesozoic Province extends from the Mississippi, Alabama, and Florida State-Federal boundaries to the vicinity of the U.S. international boundary with Cuba and the Bahamas. Approximately 125 offshore wells have been drilled to test the Mesozoic plays in the Gulf of Mexico since exploration began in the early 1960's. Of the nine plays of this province, seven were assessed (two established, four frontier, and one conceptual). The others were believed to have little potential for hydrocarbon accumulations. The province has a greater potential for additional natural gas discoveries to the northwest and greater potential for oil off of southwest Florida.

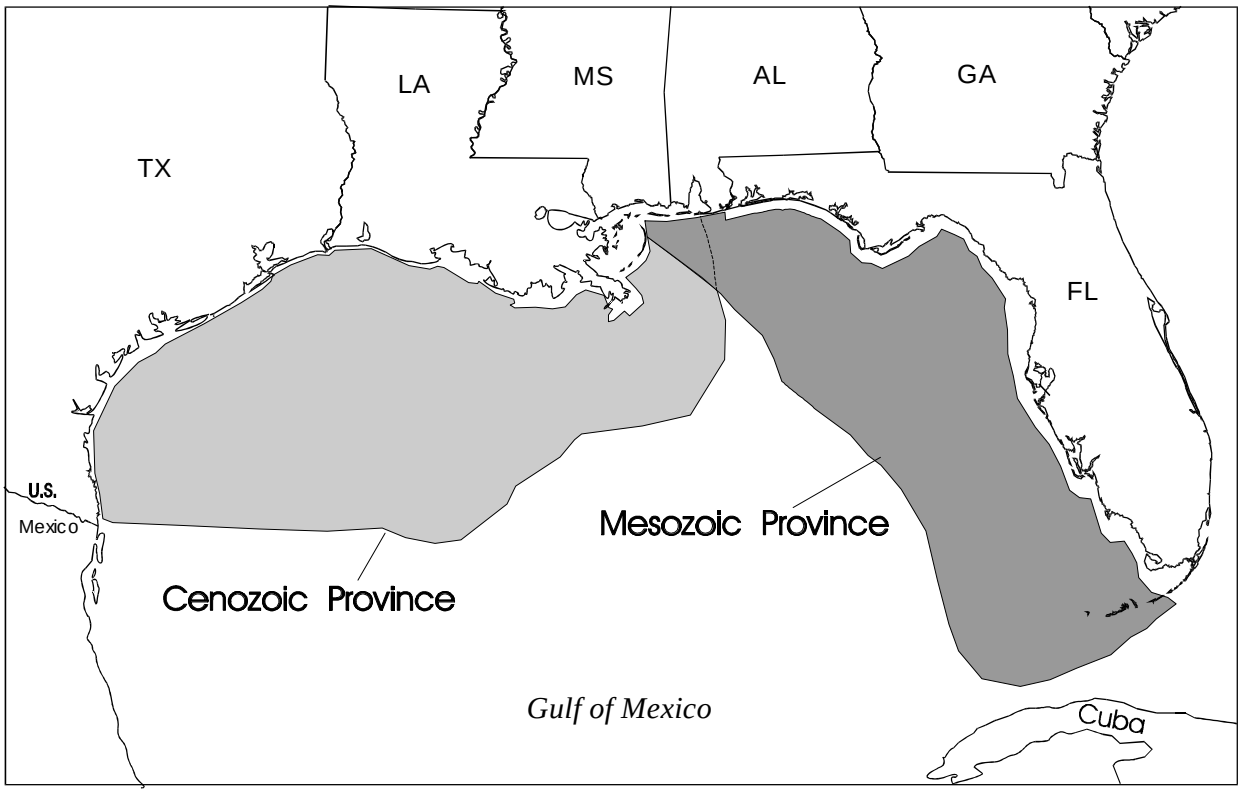


Figure 5. Assessed Provinces of the Gulf of Mexico OCS

Pacific OCS

The Pacific OCS Region includes the Federal offshore of the States of Washington, Oregon, and California, encompassing six assessment provinces in an area of complex geology along a tectonically active crustal margin (fig. 6). Cenozoic deposition, volcanism, folding, and faulting have created environments favorable to the generation, accumulation, and entrapment

of hydrocarbons. The Pacific Northwest Province is composed of a thick sequence of shelf sediments above an active convergent tectonic margin. Its geologic history for the last 20-30 million years is quite distinct from the remainder of the Pacific OCS Region, which has during that time changed from a convergent to a transverse tectonic margin. The five provinces composing the central and southern Pacific OCS Region include basins that vary in water depth from shallow (less than 500 feet deep) to deep (greater than 3,000 feet deep). Many of these basins include thick sequences of siliceous shales, which are a prolific source as well as reservoir for hydrocarbons. Included within this region are the Santa Barbara - Ventura and Los Angeles Basins, which include some of the thickest sequences of Cenozoic sediments and the greatest concentration of hydrocarbon deposits (on a per cubic-mile basis) anywhere in the world. In the southern California OCS proven hydrocarbon accumulations have been discovered in 38 fields.

Within the six assessment provinces, 50 plays were defined. Of these, 46 were assessed, but insufficient information was available to assess the remaining 4 plays. However, the existing information suggests they are not important contributors to the Pacific regional resource endowment.

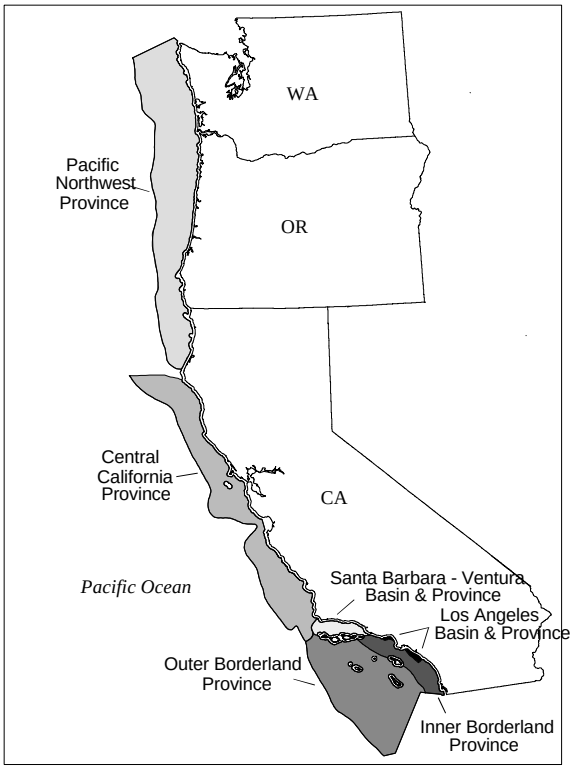


Figure 6. Assessed Provinces of the Pacific OCS

ASSESSMENT RESULTS

Estimates of the undiscovered conventionally recoverable oil and natural gas resources for the OCS resulting from this MMS assessment are presented in table 1 for the four OCS regions and total OCS. The estimates reflect the geologic data and information available to MMS as of January 1, 1995.

Table 1. Estimates of Undiscovered Conventionally Recoverable Resources for the OCS [1]

[Tcf = trillion cubic feet; Bbbl = billion barrels; BOE = barrels of oil equivalent]

Region/Subregion	Natural Gas (Tcf)			Oil (Bbbl)			BOE (Bbbl)		
	Low	High	Mean	Low	High	Mean	Low	High	Mean
Alaska	**58**	**229.5**	**125.9**	**16.9**	**33.6**	**24.3**	**28.7**	**70.6**	**46.7**
Arctic	38.0	201.1	99.4	14.7	31.2	22.0	22.5	63.3	39.6
Bering Shelf	7.0	38.6	18.8	0.4	1.8	0.9	1.6	8.6	4.3
Pacific Margin	2.1	18.3	7.7	0.7	2.5	1.4	1.1	5.5	2.8
Atlantic	**15.9**	**43.4**	**27.5**	**1.3**	**3.7**	**2.3**	**4.5**	**10.7**	**7.2**
Gulf of Mexico	**82.3**	**110.3**	**95.7**	**6.0**	**11.1**	**8.3**	**21.2**	**30.0**	**25.4**
Pacific	**15.2**	**23.2**	**18.9**	**9.0**	**12.6**	**10.7**	**11.8**	**16.6**	**14.1**
Total OCS [2]	**186.3**	**369.2**	**268.0**	**37.1**	**55.3**	**45.6**	**72.9**	**117.0**	**93.4**

[1] *Low* and *High* values refer to those estimates which occur at the 95th and 5th percentiles, respectively, on a cumulative distribution curve (see figure A-2): The "Mean" value is the arithmetric average of all values in the distribution.

[2] *Low* and *High* values are not additive to reach the "Total" values; only "Mean" values are additive.

Table 2. Estimates of Mean Undiscovered Economically Recoverable Resources for the OCS (at $18 per barrel of oil and $2.11 per Mcf natural gas)

[Mcf = thousand cubic feet; Tcf = trillion cubic feet; Bbbl = billion barrels]

Region/Subregion	Natural Gas (Tcf)	Oil (Bbbl)
Alaska	**1.1**	**3.8**
Arctic	0.2	3.4
Bering Shelf	0.9	Negligible
Pacific Margin	Negligible	0.3
Atlantic	**5.2**	**0.4**
Gulf of Mexico	**57.9**	**4.9**
Pacific	**8.3**	**5.3**
Total OCS	**72.5**	**14.4**

Table 2 presents estimates of the mean undiscovered economically recoverable oil and natural gas resources for the four OCS regions based upon the mean resource estimate at prices of $18 per barrel for oil and $2.11 per thousand cubic feet (Mcf) of natural gas.

Estimates of these resources for the geologic provinces assessed within each OCS region as well as a price-supply curve for each region and province are presented in the appendix. Results for individual plays and basins will be presented in regional reports to be released separately. The regional reports will also include more detail on the provinces and region-level estimates.

Figure 7 presents the range of undiscovered conventionally recoverable oil resources for each of the regions as well as the total OCS. Figure 8 presents the mean estimates of undiscovered conventionally recoverable oil resources with indicators reflecting the relative portion of these resources that would be considered *economically recoverable* at specific prices.

Figure 9 shows the range of undiscovered conventionally recoverable natural gas resources for each of the regions as well as the total OCS. Figure 10 presents the mean estimates of undiscovered conventionally recoverable natural gas resources with indicators reflecting the relative portion of these resources that would be considered *economically recoverable* at specific prices. (Note: the natural gas prices used in fig. 10 and the oil prices used in fig. 8 are *paired prices* and the resultant "economically recoverable" quantities of oil and natural gas are *co-existent resources* that is oil resource estimates at $18 per barrel and natural gas resource estimates at $2.11 per Mcf are directly related.)

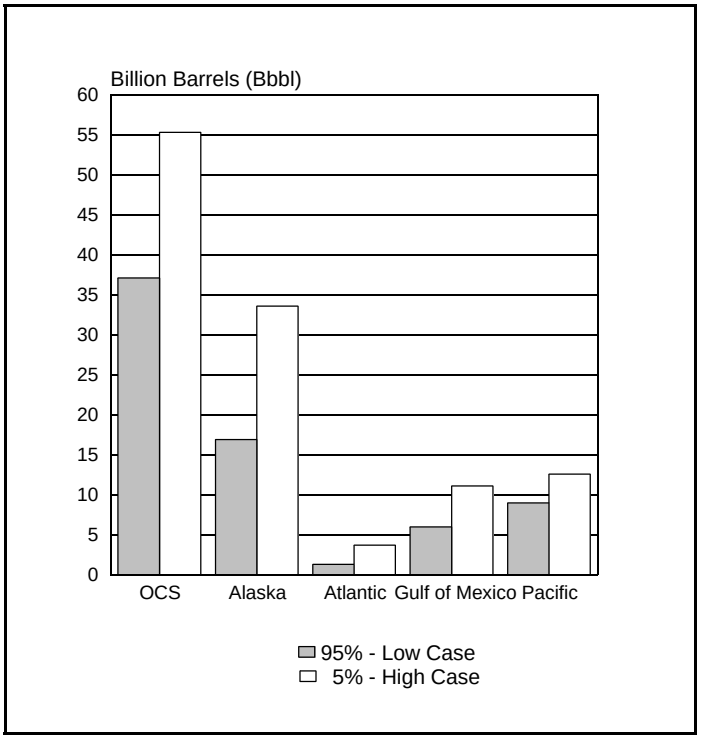


Figure 7. Undiscovered Conventionally Recoverable Oil Resources -- Low and High Resource Case

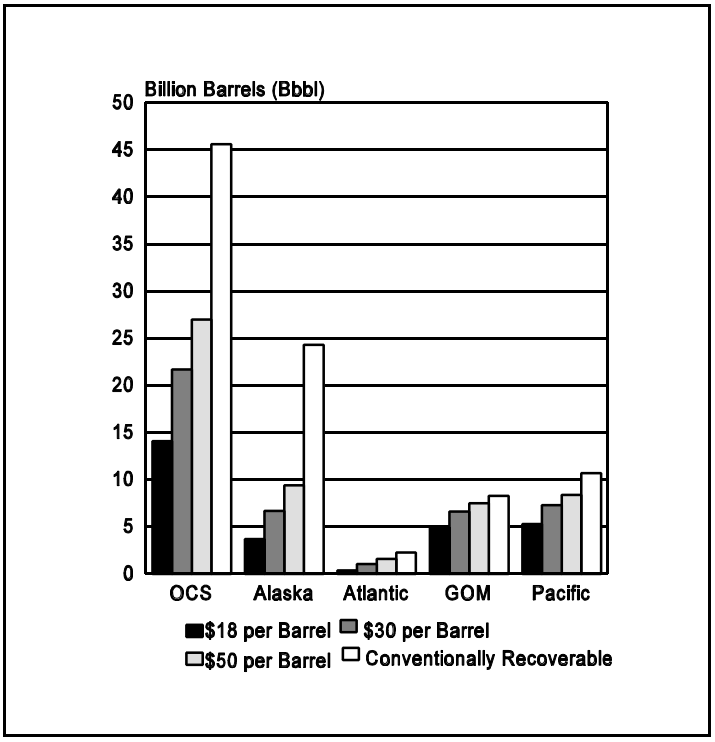


Figure 8. Undiscovered Conventionally Recoverable Oil Resources -- Mean Resource Case

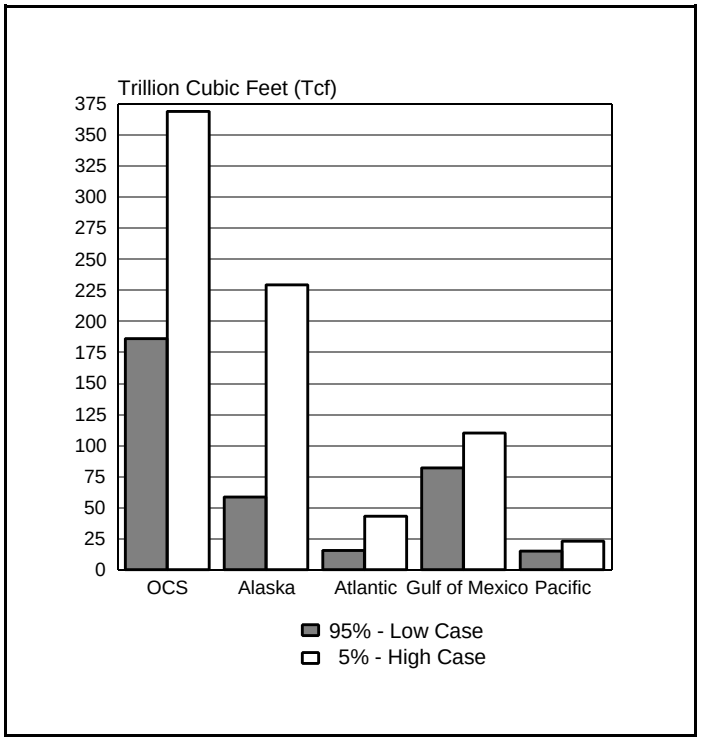


Figure 9. Undiscovered Conventionally Recoverable Natural Gas Resources -- Low and High Resource Case

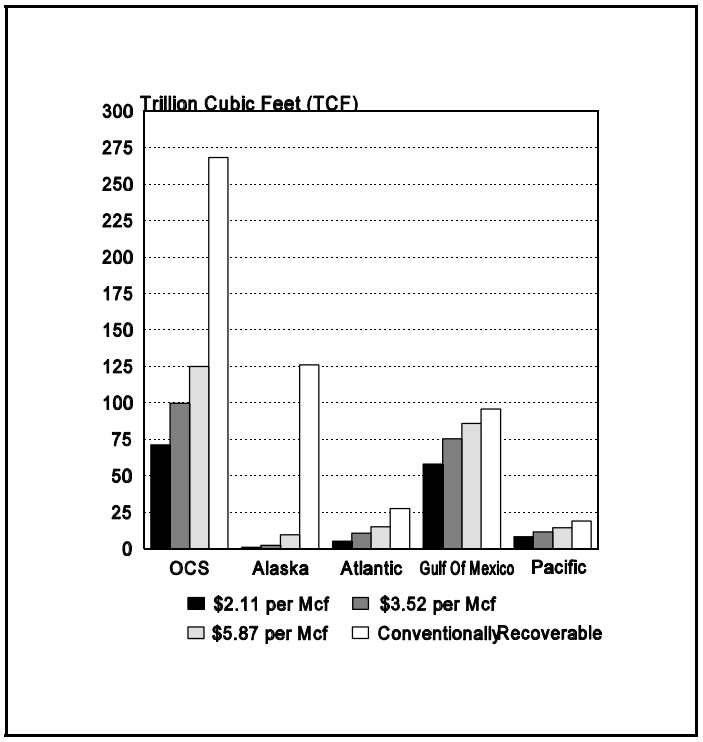


Figure 10. Undiscovered Conventionally Recoverable Natural Gas Resources -- Mean Resource Case

RESERVES AND RESERVES APPRECIATION

Estimates of the oil and natural gas reserves for the OCS are presented by region in table 3 for three categories: (1) proved reserves, (2) unproved reserves, and (3) reserves appreciation. The cumulative production from existing and depleted fields is also presented.

The MMS estimates for proved oil and natural gas reserves for the OCS are revised annually and are reported for individual fields in MMS publications, most recently *Estimated Proved Oil and Natural Gas Reserves, Gulf of Mexico, December 31, 1994* OCS Report MMS 95-0050 (Melancon et al., 1995) and *Estimated Oil and Natural Gas Reserves, Pacific Outer Continental Shelf (as of December 31, 1994)* OCS Report MMS 95-0062 (Sorenson et al., 1995).

Estimates of unproved reserves are published annually for the Pacific OCS Region. However, due to the changing status of field development in the Gulf of Mexico, unproved reserves (of oil and natural gas) as of January 1, 1995, were estimated specifically as part of this assessment. Similarly, although the Alaska OCS Region has no proved reserves, five unproven fields were studied as part of this assessment, and estimates of unproved oil and natural gas reserves are reported (table 3).

Reserves appreciation reflects an observed historical trend to increase estimates of proved reserves for oil and natural gas fields as development of the fields proceeds and production occurs. Several factors are generally cited as contributors to this appreciation (although downward revisions are sometimes encountered), including discovery of previously undetected pools, improved recovery techniques, technological advances, enhanced economic returns, and similar factors—although observed and documented—that are difficult to quantify. Nevertheless, reserves appreciation is increasingly recognized as an important component of resource assessments, particularly for mature producing regions.

An estimate of reserves appreciation to the year 2020 was developed for the Gulf of Mexico OCS fields as a part of this assessment, and the results are included in table 3. Because of the relatively few fields and the lack of a long production history for Pacific OCS fields, reserves appreciation could not be estimated. Also, due to different geologic, physiographic, and economic conditions, the Gulf of Mexico estimates could not be applied to the Pacific OCS Region. (The specific methodology and data used in estimating the Gulf of Mexico OCS reserves appreciation will be discussed in the Gulf of Mexico regional assessment report.)

Table 3. Estimates of OCS Oil and Natural Gas Reserves and Production as of January 1, 1995

[Bbbl = billion barrels; Tcf = trillion cubic feet]

Reserve Category	Alaska	Atlantic	Gulf of Mexico	Pacific
Remaining Proved Reserves:				
Oil (Bbbl)	0.0	0.0	2.5	0.7
Gas (Tcf)	0.0	0.0	29.3	1.6
Unproved Reserves:				
Oil (Bbbl)	0.4	0.0	0.9	0.6
Gas (Tcf)	0.7	0.0	4.7	0.8
Reserves Appreciation:				
Oil (Bbbl)	0.0	0.0	2.2	Not
Gas (Tcf)	0.0	0.0	32.7	Estimated
1994 Production:				
Oil (Bbbl)	0.0	0.0	0.31	0.06
Gas (Tcf)	0.0	0.0	4.8	0.05
Cumulative Production:				
Oil (Bbbl)	0.0	0.0	9.3	0.7
Gas (Tcf)	0.0	0.0	112.6	0.7

TOTAL OCS POTENTIAL

The total oil and natural gas endowment for the Nation's OCS as of January 1, 1995—comprising estimates (mean) of undiscovered resources, remaining proved reserves, unproved reserves, and reserves appreciation—is presented in table 4 and figures 11 and 12. Individual region endowments are presented in figures 13-16. Although summarized in tables and charts, the estimates for each category should be viewed differently because of the relative uncertainties pertaining to (1) the existence and the estimated quantities of undiscovered conventionally recoverable oil and natural gas resources in the lightly explored OCS areas and (2) the amounts that may eventually become economically viable under future economic realities. The estimates of unproved reserves and reserves appreciation also have a degree of uncertainty incorporated. Even proved reserves have some uncertainties associated with the estimation process.

Technological advances in hydrocarbon exploration and development are sure to occur in the future, yet the nature of advancement is extremely hard to predict and its impact difficult to estimate. However, past experience indicates most technological breakthroughs occur during high cost scenarios and impact the exploration and development by lowering the cost and sometimes by improving the chance of success.

For the purpose of this assessment, recent technological advances in gathering, processing, and interpreting seismic data contributed to the identification and mapping of geological plays and development of geologic parameters used to model the plays. Similarly, recent technological advances in offshore drilling and development operations were incorporated through the assumptions associated with the costs of these activities. However, no attempt was made to determine an empirical relationship between the future technological advancements and the estimated undiscovered resources. It is believed, however, any technological advances in the future will significantly affect the portion of the undiscovered conventionally recoverable resources, which will then be viewed as the economically recoverable resources. The estimates of undiscovered economically recoverable resources may be higher if the finding risks are reduced.

Table 4. Total OCS Oil and Natural Gas Conventionally Recoverable Resources and Reserves Potential

[Bbbl = billion barrels; Tcf = trillion cubic feet]

Category	Oil (Bbbl)			Gas (Tcf)		
	Low	High	Mean	Low	High	Mean
Undiscovered Conventionally Recoverable Resources	37.1	55.3	45.6	186.3	369.2	268.0
Proved Reserves	—	—	3.2	—	—	30.9
Unproved Reserves	—	—	1.9	—	—	6.2
Reserves Appreciation	—	—	2.2	—	—	32.7

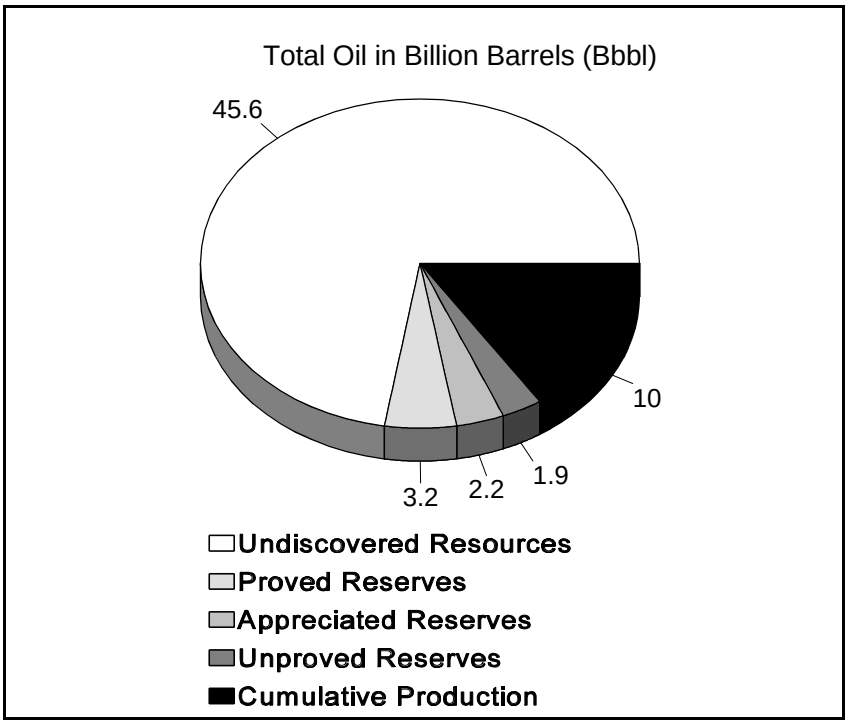


Figure 11. Total OCS Oil

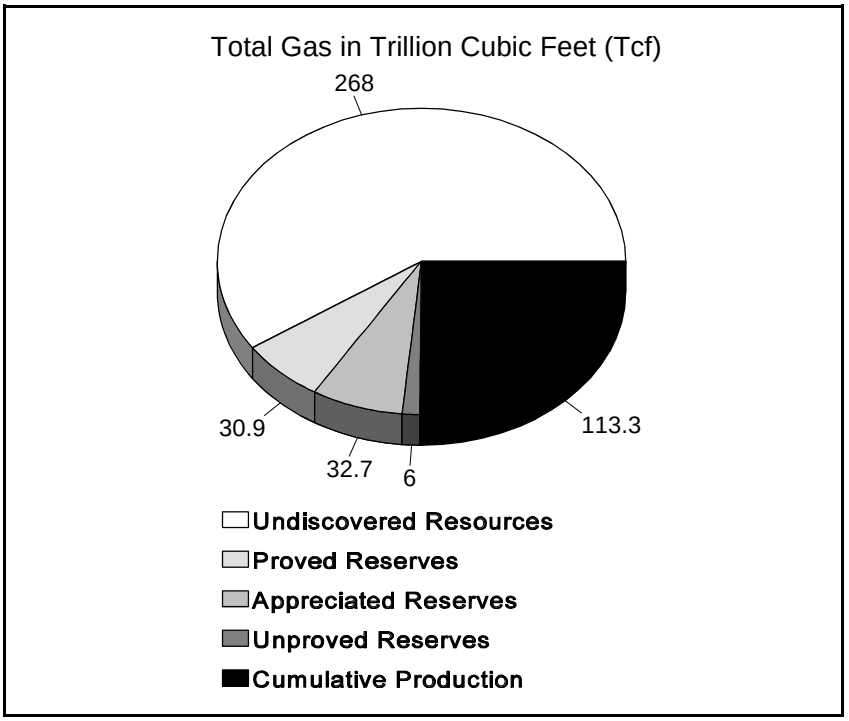
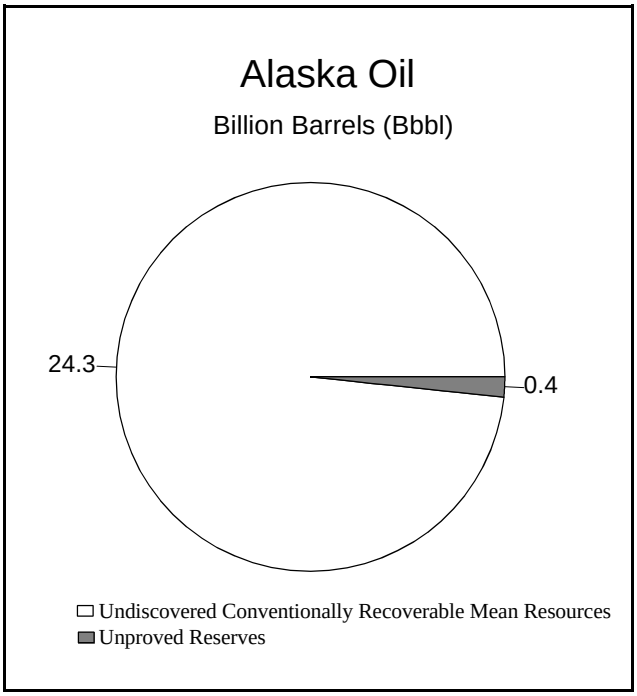


Figure 12. Total OCS Natural Gas



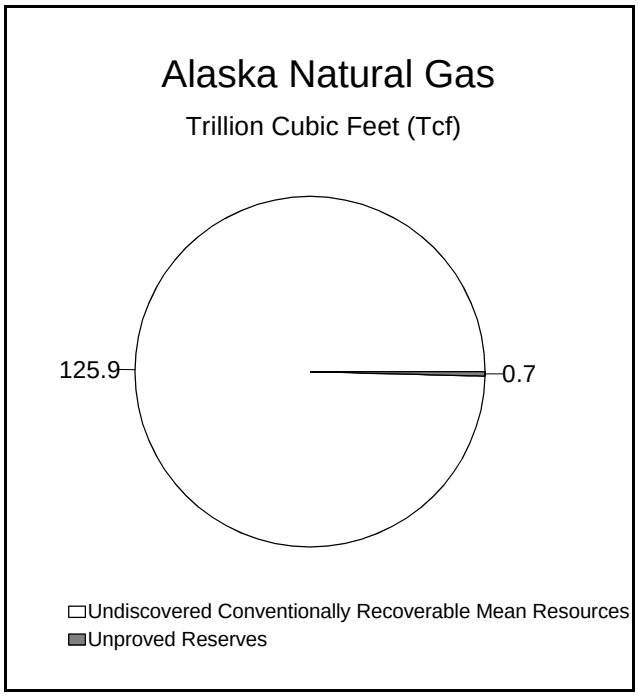
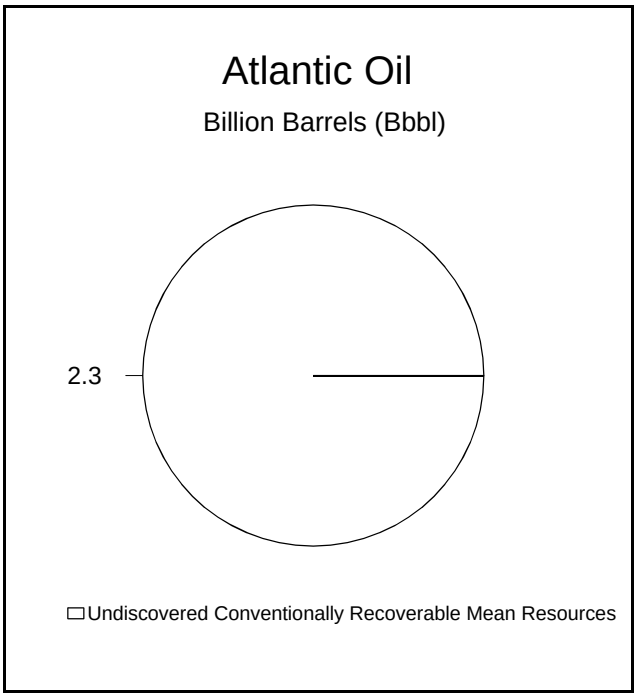


Figure 13. Alaska OCS Resources and Reserves



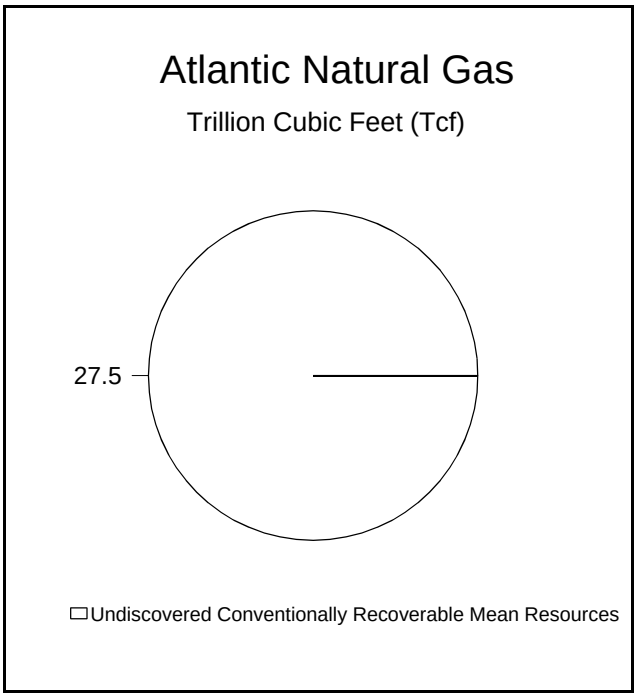
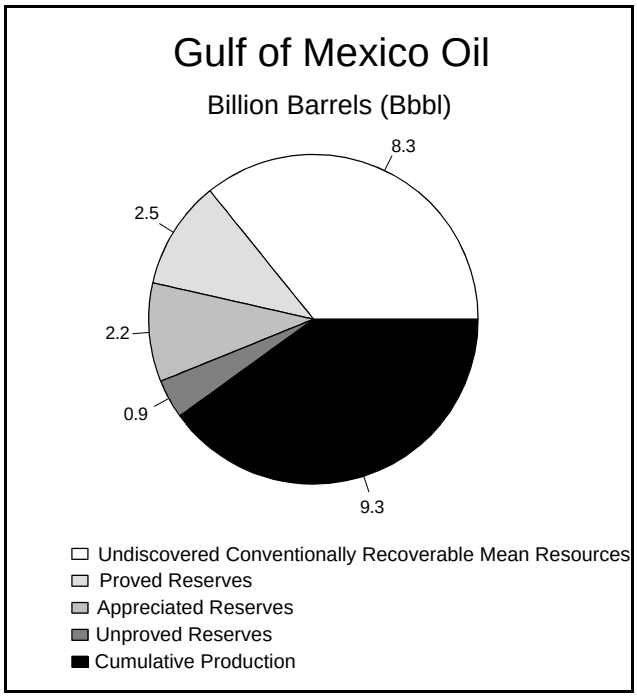


Figure 14. Atlantic OCS Resources



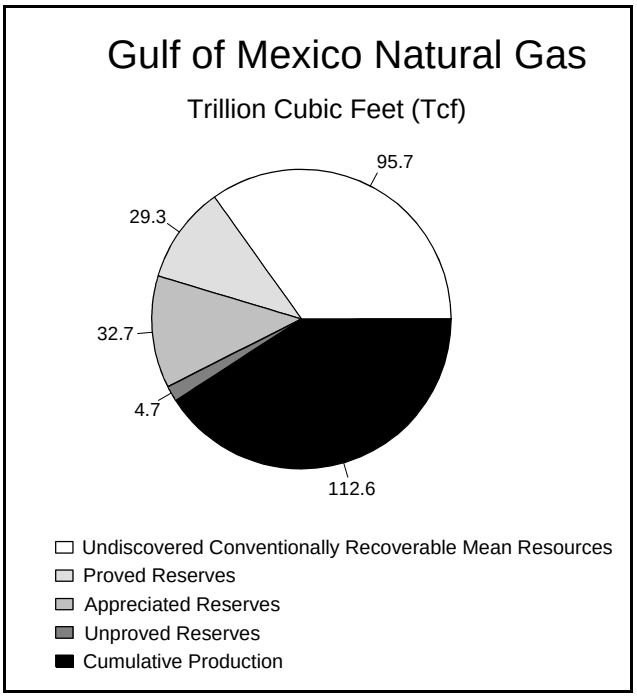
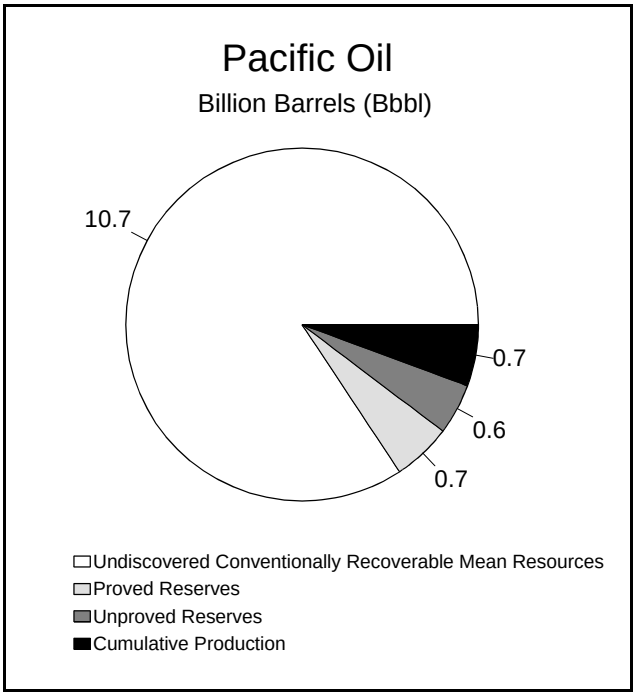


Figure 15. Gulf of Mexico OCS Resources and Reserves



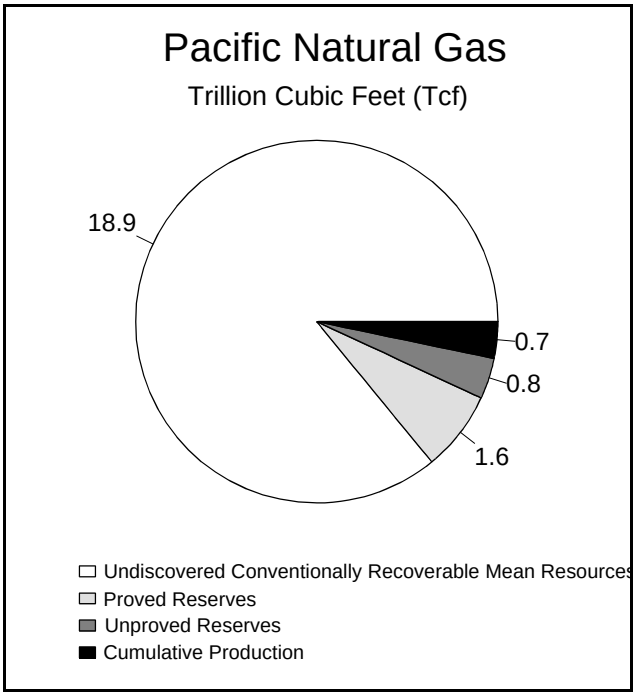


Figure 16. Pacific OCS Resources and Reserves

COMPARISON WITH PREVIOUS ASSESSMENTS

Conclusions drawn from direct comparisons of this assessment with previous assessments of undiscovered oil and natural gas resources on the OCS may be misleading because of the numerous changes in assessment methodology and models employed.

Previous MMS assessments of undiscovered oil and natural gas resources were performed to address specific OCS policy and regulatory decisions facing MMS officials, and they generally focused upon estimating *economically recoverable* resources. The results of these *assessments* were published as a means of informing industry and the general public of the basis of MMS analyses and decisions. The 1987 assessment was the first attempt by MMS to address the *undiscovered resource base* (as defined in the subsequent publications), but the assessment was based upon the prospect-oriented database and PRESTO model used by MMS for its economics-oriented decisions. The MMS attempted to compensate for this problem by creating *field size distributions* from mapped prospects to estimate resources associated with small fields. This methodology was labeled DIST, referring to DISTributions of possible field sizes. (See Cooke and Dellagiarino, 1990, for a complete discussion of DIST.) The MMS methodologies used in the 1987 assessment were reviewed by NAS, AASG, API, and EIA/DOE. These reviews surmised that estimates of undiscovered oil and natural gas resources were conservative—attributable generally to the prospect-oriented databases and modeling factors (particularly risking procedures) that contained ingrained economic characterizations. Hence, many of the review recommendations addressed this perceived problem.

The decision to use the geologic play as the basis for this assessment and the development of the GRASP model by MMS were made in acknowledgment of the shortcomings of previous assessments in reflecting the full extent of the recoverable oil and natural gas resources that may exist on the OCS. In view of these changes, geologic inputs incorporated significantly larger numbers of prospects and pools than previous assessments to reflect data coverage gaps, stratigraphic traps, and other possible exclusions by previous MMS assessments. This generally produced *upward pressure* on the magnitude of the estimates of overall undiscovered oil and natural gas resources. These vastly different geologic inputs also impacted the risking procedures used by MMS—the result being much higher probabilities for occurrence of oil and natural gas within the geologic plays being assessed (this, too, produced *upward pressure* on the overall estimates of much of the OCS). Finally, the MMS has thoroughly reviewed most of the geologic provinces and basins on the OCS since the last assessment including the acquisition of geological, geophysical, and engineering data and information resulting from interim industry exploration and development activities. Extensive new mapping and data analyses have also been incorporated, supporting more optimistic analyses in some areas and more pessimistic analyses in others.

In summary, MMS incorporated numerous changes into this assessment to better reflect the full extent of the recoverable oil and natural gas resources yet-to-be-discovered on the OCS resulting in generally higher estimates (as expected) for most areas. However, MMS is not able to quantify the relative portion of the change in estimates attributable to the modeling

changes or interim geologic data and information analyses associated with ongoing OCS activities or geologic interpretation changes.

As stated, incorporation of the recommendations of NAS, AASG, API, and EIA/DOE addressing the *resource base* portion of previous assessments tended to result in higher estimates. However, MMS changes to address recommendations for estimating undiscovered economically recoverable resources tended to produce lower proportions of the undiscovered resource accumulations to be considered *economically recoverable* at stated prices. The major changes in economic parameters that produced these *downward pressures* generally were made to reflect economic parameters industry practices associated with exploring, developing, and producing oil and natural gas in OCS areas. These major changes were (1) including costs for exploration and delineation drilling versus previous exclusions of those costs, (2) use of a 12-percent after-tax rate of return discount factor versus previous 6-8-10 percent range, and (3) use of constant oil and natural gas prices versus the previous practice of *starting prices* with real price growth. Additionally, modeling changes associated with the timing of future exploration, development, and production activities impacted economic analyses, generally producing more conservative estimates. For this report, no attempt has been made to quantify the incremental changes associated with each of these factors although future technical publications on this topic are being considered.

With these changes in mind, a general comparison of 1987 and 1995 assessment results is given in figure 17. It is apparent that the considerable increase in the Alaska OCS Region's undiscovered conventionally recoverable oil and natural gas resources was the primary factor in the significant increase in overall OCS *conventionally recoverable estimates.* This increase, however, is mostly attributable to the use of the GRASP methodology, which allows for the inclusion of unmapped prospects and possible stratigraphic fields—which NAS, AASG, and other reviewers had professed that the previous MMS assessments had excluded. Additional seismic mapping activities in the Alaska OCS Region's two most promising provinces (the Arctic subregion accounts for nearly 90 percent of the Region's undiscovered conventionally recoverable resources) and adjustments to the MMS

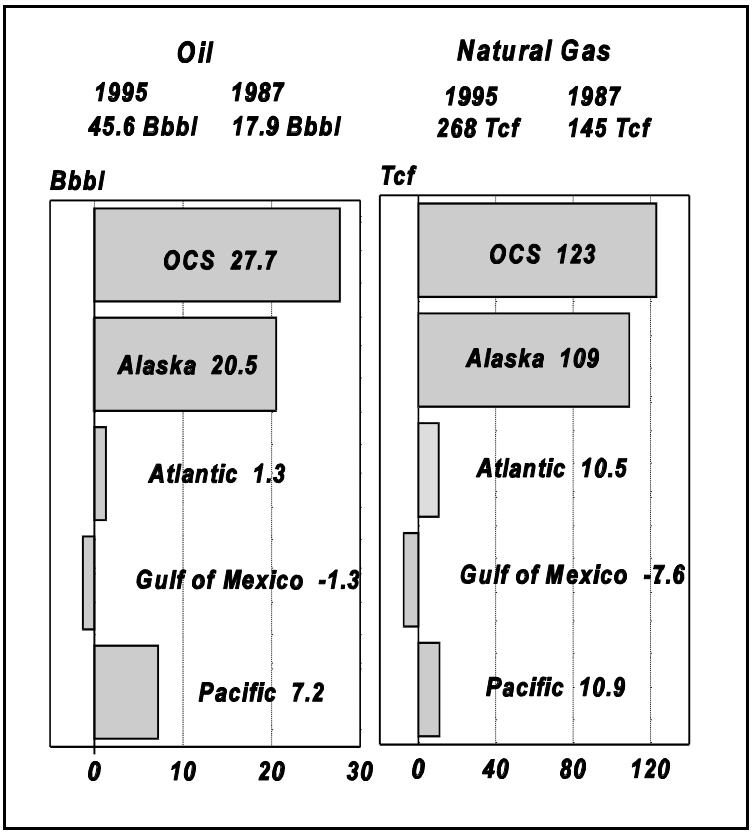


Figure 17. Changes in Mean Estimates of OCS Undiscovered Conventionally Recoverable Resources from the 1987 and 1995 Assessment

techniques for determining *risk* (also recommended by NAS and others) also contributed to the higher estimates. Finally, it is important to know that the significant quantities of the Alaska OCS Region's undiscovered conventionally recoverable natural gas resources are thought to exist as *associated and dissolved* natural gas (i.e., natural gas that is found as a gas cap in contact with or dissolved in oil accumulations). Hence, these natural gas resources are attainable only if the oil accumulations occur within the projected geologic formations under the conditions as modeled.

Pacific OCS Region and Atlantic OCS Region results also reflect the expected upward revisions resulting from the inclusion of previously unmapped and possible stratigraphic prospects and risking procedure changes. The Pacific OCS Region results were also positively influenced by recent geologic information suggesting a more widespread occurrence of the prolific Monterey horizon than previously assessed.

At first glance, the Gulf of Mexico OCS Region appears to have been assessed as slightly less optimistic than previous assessments. However, two factors are important considerations to counter this viewpoint:

1. Since the 1987 assessment, nearly 2 1/2 billion barrels of oil and 40 trillion cubic feet (Tcf) of natural gas have been produced—only 1 billion barrels and 13 Tcf of which were not replaced by resources in the undiscovered categories or from unproven reserves.

2. Similarly, nearly 1 billion barrels of oil and 4.7 Tcf of natural gas currently considered as unproven reserves were most likely assessed as undiscovered resources in the previous assessment.

Comparisons of the economically recoverable resources between the assessments may prove even more misleading because the higher estimates for the undiscovered conventionally recoverable resources would seem to lead to higher levels of economically recoverable resources. However, the changes in economic parameters employed tended to counter these effects.

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