GAO

July 1993

ARCTIC NATIONAL WILDLIFE REFUGE

An Assessment of Interior's Estimate of an Economically Viable Oil Field

149745

GAO/RCED-93-130

GAO

United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-252603

July 9, 1993

The Honorable George Miller
Chairman, Committee on Natural
   Resources
House of Representatives

Dear Mr. Chairman:

In its April 1991 report entitled Overview of the 1991 Arctic National
Wildlife Refuge Recoverable Petroleum Resource Update, the Department
of the Interior revised its estimate of the likelihood that the coastal plain
of Alaska's Arctic National Wildlife Refuge (ANWR) contains at least one
economically viable oil field. On the basis of a simulated exploration
program model, Interior estimated that there was a 46-percent probability
that ANWR contained such an oil field.[1] This estimate is considerably higher
than its 1987 estimate of 19 percent.

For several years, the Congress has debated the question of whether to
open ANWR to oil and gas exploration drilling and development. Arguments
for opening ANWR point to its petroleum potential and the nation's
increasing reliance on foreign oil sources; arguments against opening it
cite the unique combination of its wildlife habitat and wilderness values,
which could result in the area's designation as wilderness, thereby
precluding development.

You asked us to assess the support for, and accuracy of, Interior's 1991
estimate of ANWR's potential oil resources and the likelihood that oil exists
in economically viable quantities. To do this, we examined the
methodology Interior used and the reasonableness of its key geologic and
economic assumptions.

Results in Brief

While no one really knows how much oil may be in ANWR, we believe that
Interior's estimate of oil resources in ANWR used the best available geologic
and geophysical data for making such an assessment, without having
actual drilling data from the refuge. Overall, we agree with Interior's view
that ANWR's coastal plain may contain a substantial amount of oil.

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[1]Interior's reported probability refers to the chance that oil exists in economically recoverable
quantities in ANWR, not the probability of actually finding oil. The probability that oil exists relates to
the success of an exploratory drilling program that is the same as the simulated exploration program
in Interior's model. The probability of actually finding oil is likely to be different.

Interior used a generally accepted methodology and concluded that there is a 46-percent probability that at least one economically viable oil field exists in ANWR's coastal plain. However, this conclusion does not reflect the uncertainties in a field's development potential that can result from variations in future oil prices or costs. For example, if oil prices are lower than Interior estimated, a larger field is required for economic viability and the probability of such a field existing decreases. Conversely, higher oil prices make smaller fields economically viable and increase the probability that such a field exists.

Cost factors could also influence Interior's estimates in at least two ways. First, Interior assumed that each area in ANWR that was developed would bear the full cost of production facilities and of a pipeline to Pump Station One of the Trans-Alaska Pipeline System. Because each area must independently support all of these costs, a rather large field would be required for economic viability. However, the history of oil production in the North Slope of Alaska shows that when one large economic field is developed, other much smaller fields that are not economically viable by themselves can share facilities or costs with the larger field and become profitable.

Second, if the Congress authorizes development in ANWR, it is likely to require special measures designed to minimize the impact that development may have on ANWR's environment. These measures could prove costly, and the greater cost would increase the field size needed for the development of ANWR to be economically viable. These costs are not fully known and were not factored into Interior's estimates.
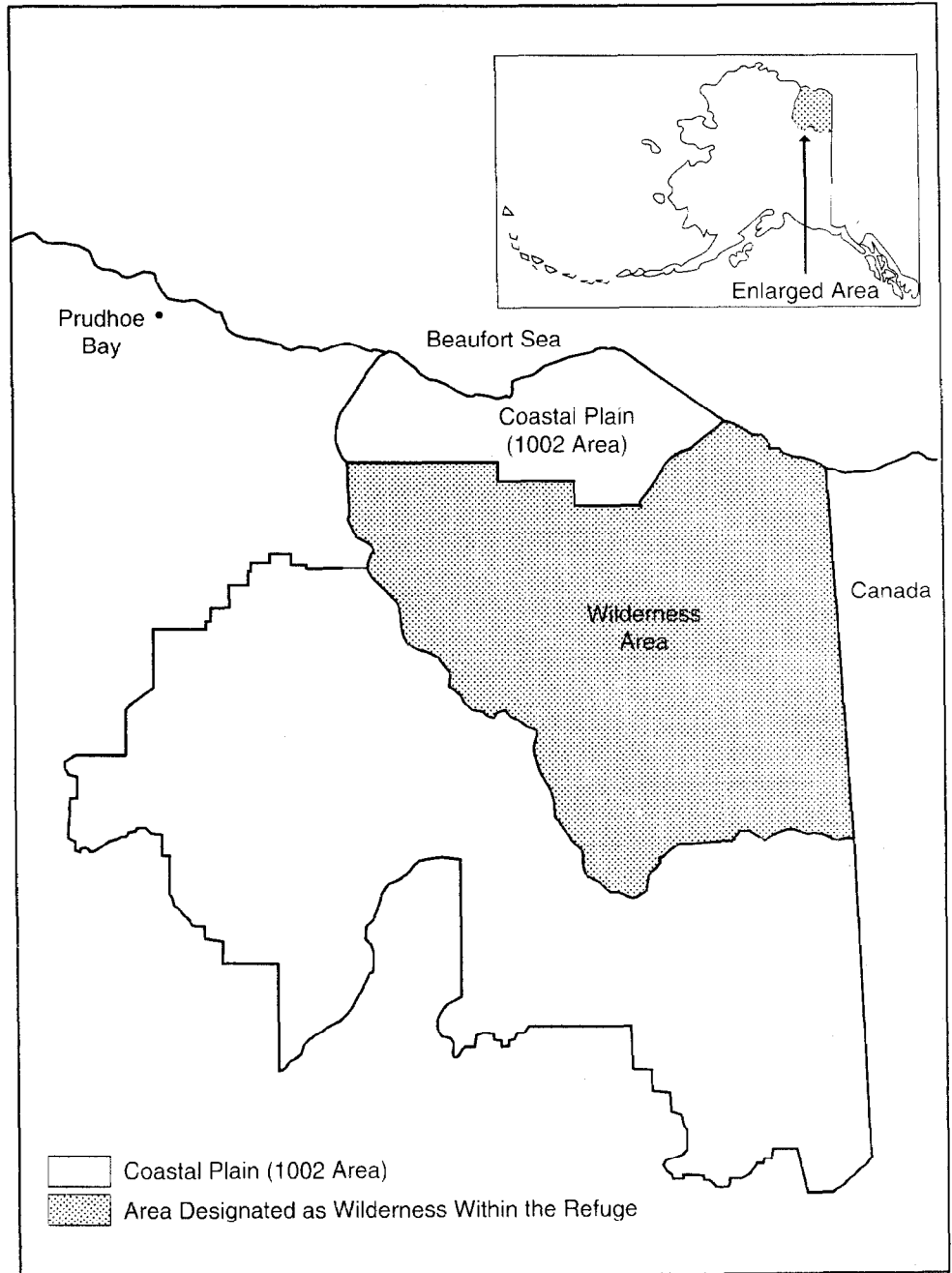
Background

The North Slope of Alaska is the nation's largest single source of domestic crude oil—providing about 25 percent of all oil produced in the United States. However, this supply is declining, and government agencies and industry groups believe that the coastal plain of ANWR contains the largest remaining unexplored prospect for onshore oil fields in the United States.

ANWR, a 19-million-acre wildlife refuge in northeastern Alaska, was established by the Alaska National Interest Lands Conservation Act of 1980 (ANILCA). The Congress designated a portion of ANWR's coastal plain (approximately 1.5 million acres) as reserved for further study because of its potential significance for oil and gas discoveries. (See fig. 1.) Specifically, section 1002 of ANILCA required Interior to prepare a report to the Congress that (1) identified areas on the coastal plain of ANWR with oil

and gas production potential, (2) estimated the volume of the oil and gas, and (3) recommended whether the Congress should permit further oil and gas exploration and development in ANWR. It also required Interior to use techniques other than drilling wells to evaluate the oil and gas potential of ANWR.

1: ANWR's Coastal Plain

Prudhoe Bay

Beaufort Sea

Enlarged Area

Coastal Plain
(1002 Area)

Canada

Wilderness
Area

Coastal Plain (1002 Area)

Area Designated as Wilderness Within the Refuge

In its April 1987 report (commonly called the 1002 Report), Interior estimated that there was a 19-percent probability that ANWR contained at

least one economically viable oil field. In addition, if such a field was found, it had a 95-percent probability of containing at least 600 million barrels of oil and a 5-percent probability of containing 9.2 billion barrels of oil. On the basis of these findings, Interior concluded that ANWR should be opened for oil and gas exploration and development.

Interior decided to update its projections from the 1987 report because of new and reinterpreted geologic and geophysical data, as well as updated economic data and engineering advances in Alaskan oil production technology. In its 1991 update, Interior used new data, including data from wells drilled near ANWR and revised geologic and geophysical data. It also updated the economic assumptions and statistical models used to estimate the values for the oil resources in ANWR.

On the basis of this effort, Interior reported that the probability of ANWR's containing at least one economically producible oil field had increased to 46 percent. In addition, Interior concluded that if such a field exists in ANWR, there is a 95-percent probability that it contains at least 615 million barrels of oil and a 5-percent probability that it contains at least 8.8 billion barrels of oil. As in its original 1987 report, Interior concluded that ANWR should be opened for oil and gas exploration and development.

New Geologic, Engineering, and Cost Data Used in Interior's 1991 Assessment

New geophysical information was a key factor in Interior's 1991 revised estimates. In September 1988, we noted that Interior needed to utilize certain geologic data to improve its assessment of ANWR.[2] For its 1991 report, Interior used geologic data from three offshore wells drilled near ANWR and gave new consideration to the oil potential of certain rock layers. Interior also incorporated geologic data from one onshore well. It also analyzed new geophysical data and satellite photography of the region.

On the basis of these new and reinterpreted geologic data, Interior changed its conclusions regarding the geology of oil and gas resources located in ANWR. Interior now believes that the coastal plain of ANWR includes a continuation of the North Slope petroleum province. In 1987, Interior had assumed that ANWR was not part of this petroleum province.[3] If ANWR is part of this province, the risks associated with finding oil are

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[2]Federal Land Management: Consideration of Proposed Alaska Land Exchanges Should Be Discontinued (GAO/RCED-88-179, Sept. 29, 1988).

[3]A petroleum province is a region in which a number of oil and gas pools and fields occur in a similar or related geologic environment.

lower. This revised view agrees with the geologic understandings held by the U.S. Geological Survey and some industry experts. Using these new and updated data, Interior identified 9 additional prospects (along with the 26 prospects identified in the 1987 report) and remapped ANWR.

In addition, Interior believes that production costs could be lower than it had assumed in 1987. Interior's 1987 report had assumed that engineering production methods and costs for ANWR would be similar to those for the Kuparuk River oil field—a field that began production in 1981. However, fields that have come into production since the 1987 report (such as the Milne Point and Endicott fields) utilized different engineering methods, which had the effect of reducing costs.

Interior also used information developed by the Department of Energy (DOE) to change its estimates of the cost of production.[4] Interior used a number of DOE's calculations and methods for estimating North Slope development costs in its reassessment of ANWR. To validate some of the engineering aspects of DOE's draft report and to update its own cost and economic data, Interior met with representatives of a number of oil companies producing in Alaska. On the basis of that meeting and the DOE report, Interior revised its model and incorporated new cost information to calculate the minimum economic field size (MEFS)—or the smallest oil field that is considered economically viable—of each prospect in ANWR. Interior also updated tax law information and transportation costs in its model.

Interior Used a Generally Accepted Methodology but Did Not Fully Consider Uncertainties of Key Economic and Cost Assumptions
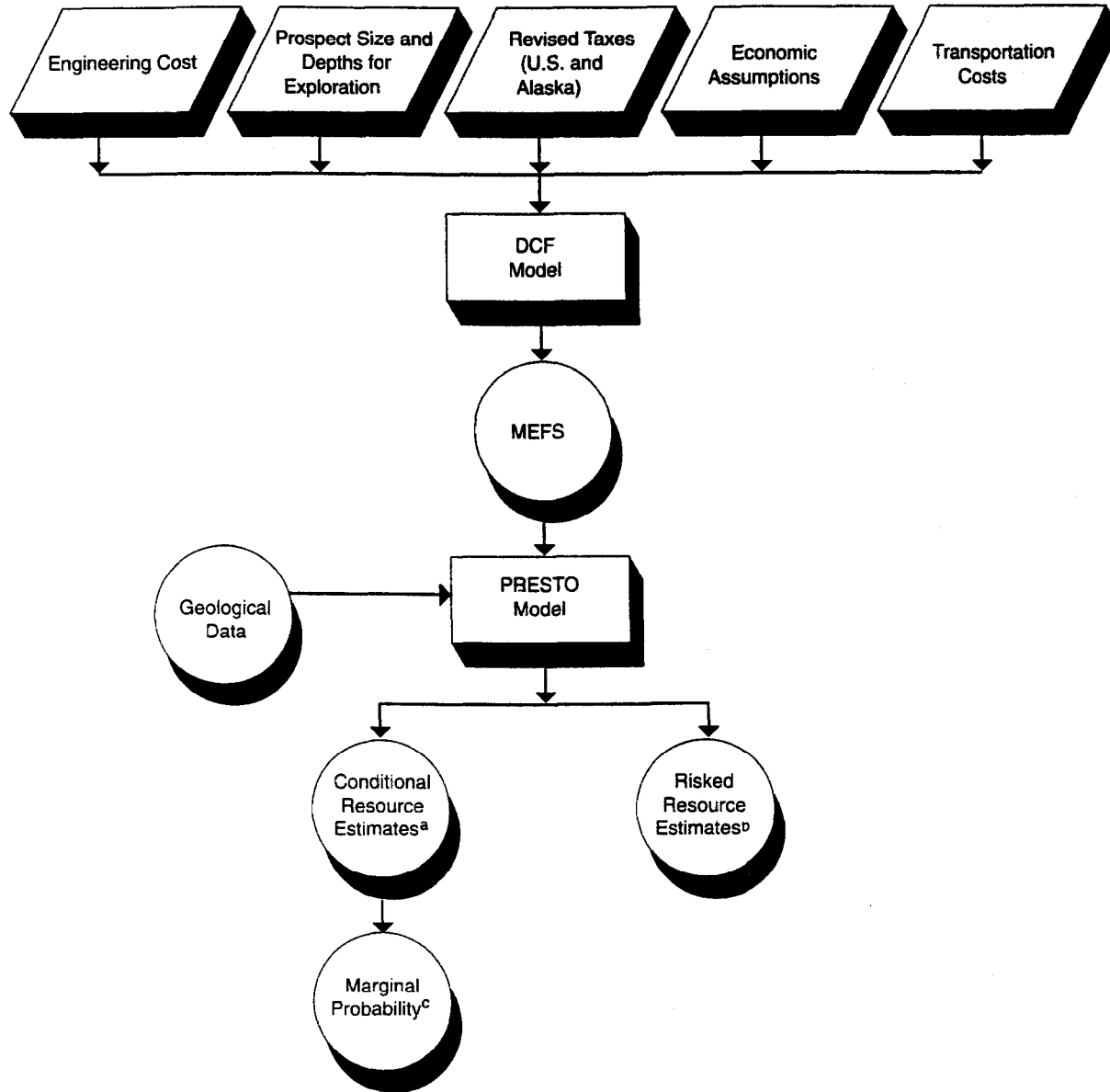
In concluding that there was a 46-percent probability that ANWR contained at least one economically viable oil field, Interior used the same general methodology as it had in 1987: (1) a discounted cash flow (DCF) model to determine the MEFS for each prospect and (2) a computerized simulated exploration program called Probabilistic Resource Estimates-Offshore (PRESTO)—designed to provide a range of estimates of oil in ANWR and the probability that ANWR contains such an economically viable oil field.[5] (See fig. 2 for Interior's modeling process and app. II for a detailed description of our analysis of Interior's methodology and modeling process.) PRESTO is

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[4]DOE's January 1991 report entitled Alaska Oil and Gas—Energy Wealth or Vanishing Opportunity? was prepared for DOE by EG&G Idaho, Inc. We reviewed DOE's report in Trans-Alaska Pipeline: Projections of Long-Term Viability Are Uncertain (GAO/RCED-93-69, Apr. 8, 1993).

[5]Interior identified 35 prospects. At the recommendation of the National Research Council and in accordance with the Minerals Management Service's practices, one additional hypothetical prospect was assumed to help evaluate the possibility of a prospect that Interior could not map using available seismic data.

used and accepted in the petroleum industry as well as in other government agencies for estimating oil resources. However, Interior did not fully consider the uncertainties associated with projecting the potential of ANWR's containing economically viable quantities of oil.

Figure 2: Interior's Modeling Process

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┌──────────────┐  ┌──────────────┐  ┌──────────────┐  ┌──────────────┐  ┌──────────────┐
│ Engineering  │  │Prospect Size │  │Revised Taxes │  │  Economic    │  │Transportation│
│    Cost      │  │ and Depths   │  │  (U.S. and   │  │ Assumptions  │  │    Costs     │
│              │  │for Exploration│  │   Alaska)    │  │              │  │              │
└──────┬───────┘  └──────┬───────┘  └──────┬───────┘  └──────┬───────┘  └──────┬───────┘
       │                 │                 │                 │                 │
       └─────────────────┴────────┬────────┴─────────────────┴─────────────────┘
                                   │
                          ┌────────────────┐
                          │   DCF Model    │
                          └────────┬───────┘
                                   │
                              (  MEFS  )
                                   │
          (Geological Data) ──▶ ┌──────────────┐
                                │ PRESTO Model │
                                └──────┬───────┘
                         ┌─────────────┴─────────────┐
              (Conditional Resource           (Risked Resource
               Estimates[a])                   Estimates[b])
                      │
              (Marginal Probability[c])
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[a]The expected resources in an area that are recoverable, given the condition that at least one prospect is economically viable on ANWR's coastal plain.

[b]Estimates based on the total number of trials, regardless of economic outcome.

[c]The probability that economically recoverable oil exists somewhere on ANWR's coastal plain.

Underlying Assumptions and the Resulting MEFS of the DCF Model

The development of the MEFS is key to Interior's analysis—any change in cost or revenue estimates affects the minimum amount of oil that must be present for each prospect to be economically viable to produce. The MEFS can significantly affect (1) Interior's projections that ANWR contains an economically viable oil field and (2) conditional resource estimates.[6] For example, if the MEFS estimate is high, only large fields can be developed economically; if the estimate is low, small fields can be developed economically.

Using a DCF model, Interior estimated the MEFS for each prospect. Interior used numerous economic, engineering, production, and transportation cost estimates to determine the revenue and costs that development of a prospect would generate over time. These costs and revenues were discounted to the present using a 10-percent real discount rate. Then, by varying the assumed amount of oil in a prospect, Interior determined the minimum amount of resources needed for the prospect to be profitable, given the costs and revenues that depend on those resources—the MEFS. Among its cost assumptions, Interior assumed that each prospect would have to pay all the costs of new production in ANWR, including the costs of a new pipeline to join up with the Trans-Alaska Pipeline (called the stand-alone assumption).

PRESTO'S Underlying Assumptions

Interior entered the MEFS for each prospect, along with detailed geologic and engineering data, into the PRESTO model. PRESTO develops a range of values and a probability distribution for each factor and randomly selects a value for each factor within the range given. PRESTO's analysis results in a probability distribution for the existence of an economically viable oil field as well as a conditional resource estimate.

PRESTO "drills" each prospect to determine whether it contains oil and gas resources. If the prospect contains oil, PRESTO calculates how much, using Interior's estimates of the prospect's size and geology, and how much oil is recoverable. After computing the expected resources,[7] PRESTO determines whether they are large enough to warrant production.

After analyzing all prospects in the area, PRESTO starts another simulated drilling program using randomly selected input values. Each subsequent

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[6]The conditional resource estimate is the amount of oil that may be recovered, assuming at least one MEFS is present in ANWR.

[7]Resources are concentrations of naturally occurring hydrocarbons in or on the earth's crust in such a form that extraction is currently or potentially feasible.

"drilling program" may result in completely different discoveries and resource estimates for the area.[8] PRESTO's estimates are considered conditional resource estimates of the quantities of oil that may be found and developed if at least one economically recoverable prospect is present.

GAO's Analysis of Interior's Conclusions

According to most experts we contacted and our review of Interior's proprietary and public geologic, engineering, and cost data supporting the PRESTO model, Interior's conclusion that ANWR's coastal plain is probably included within the existing North Slope petroleum province is reasonable. However, public interest groups and one oil company disagreed with this assessment because of the lack of well data. Industry and government experts generally found reasonable, or had no basis to question, Interior's range of estimates of future recoverable resources. However, public interest groups disagreed with these estimates because they did not believe that the uncertainty associated with key assumptions—such as future oil prices—was adequately considered.

Several industry experts we contacted believed Interior's conclusions on the 46-percent probability and the size of the MEFS needed to make the development of ANWR economically viable were reasonable. However, other experts, including public interest groups as well as a government agency, and GAO found that changes in key economic assumptions, such as oil prices and interest rates, would significantly affect the estimated size of the MEFS and, in turn, the estimate of recoverable resources in ANWR. In addition, the costs associated with Interior's stand-alone assumption and with potential restrictions that the Congress would probably place on ANWR's development would also affect Interior's conclusions.

DCF Model Does Not Adequately Consider the Uncertainty of Key Economic Assumptions

Interior's DCF model used single-point "best estimates" for most of its economic and cost assumptions, such as oil prices, discount rates, production and development costs, and production rates. Therefore only one MEFS was developed for each prospect. As a result, to the extent that the actual values deviate from the estimates used in the model (deviation is almost certain, given the number of variables included in the model and the uncertainties associated with projecting future oil production in a unique area like ANWR), the outcome—i.e., the MEFS—is no longer valid. For example, the MEFS that Interior developed for each prospect is valid only

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[8]Not all simulated drilling programs will result in economically viable resources. Some simulated programs could result in all the prospects having no resources or being uneconomical for production.

for a single oil price. We believe that to account for the uncertainty associated with making these complex projections, a range of assumptions, resulting in a range of MEFSs, would have been more appropriate.

Effect of Oil Prices on the MEFS

One of the most important assumptions underlying Interior's analysis of the MEFS is the oil price. For its estimates of MEFS values, Interior used the National Energy Strategy (NES) reference case price projections.[9] The reference case is one among several price projections developed for the NES. Recognizing the great uncertainties in projecting future oil prices, the NES projected several oil prices using different scenarios for future oil markets. However, by using the reference case price projections as the only option, Interior implicitly assumed that the reference case price projections presented the "most likely" values for oil prices in the future.

This assumption is not realistic. We examined oil price forecasts from a variety of sources for the period of Interior's evaluation. Compared with these forecasts, Interior's oil prices, although reasonable at the time, are higher than revised lower forecasts available in early 1992. By not addressing the uncertainty in projecting future oil prices and by using only one set of oil prices that are too high for today's market, Interior's analysis resulted in a lower MEFS, which in turn raised the probability that ANWR contained at least one economically viable oil field. Had Interior accounted for the uncertainty of future oil prices by using a range of prices, such as those contained in the NES, its estimate would have shown higher or lower probabilities that ANWR contained economically viable oil fields, depending on the assumed oil price.

In addition, the impact of lower oil prices would have been greater if Interior had recognized the historical differential between the price of North Slope crude oil and imported crude oil used in the NES price projections. Historically, market prices for North Slope crude oil have been, on average, about $1 less than for imported crude oil. A reduction in North Slope oil prices would have lowered Interior's MEFS estimates, though to a smaller degree than lower oil price projections.

To demonstrate the effect of changes in oil price projections and the adjustment for the North Slope price differential on the final MEFS values,

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[9]Among the NES' objectives are achieving balance between the need for energy at reasonable prices and the need for reducing dependence on potentially unreliable energy suppliers. DOE published the strategy in Feb. 1991. As a part of this effort, DOE developed three possible oil price levels—low, mid, and high. Interior used oil prices available from a draft of this report. The NES mid-level prices (in 1990 dollars) range from $16.95 in 1990 to $45.89 in 2030.

we performed a series of sensitivity analyses for these factors using Interior's cash flow model. That is, we replaced Interior's reference case price assumption with alternative prices without changing any other data or relationships in the model—except for correcting minor programming errors. Figure 3 shows the impact of changes in oil prices on the MEFS for one prospect in ANWR. For example, using the NES projection for low-growth oil price and adjusting for the North Slope price differential, the MEFS for one prospect increases from about 408 million barrels to 1.485 billion barrels—a 264-percent increase. Conversely, if higher oil prices were used, a lower MEFS would be needed.

Figure 3: Example of the Effect of Different Oil Prices on the MEFS for One Prospect in ANWR

8000   MEFS (in millions of barrels)

Oil Prices
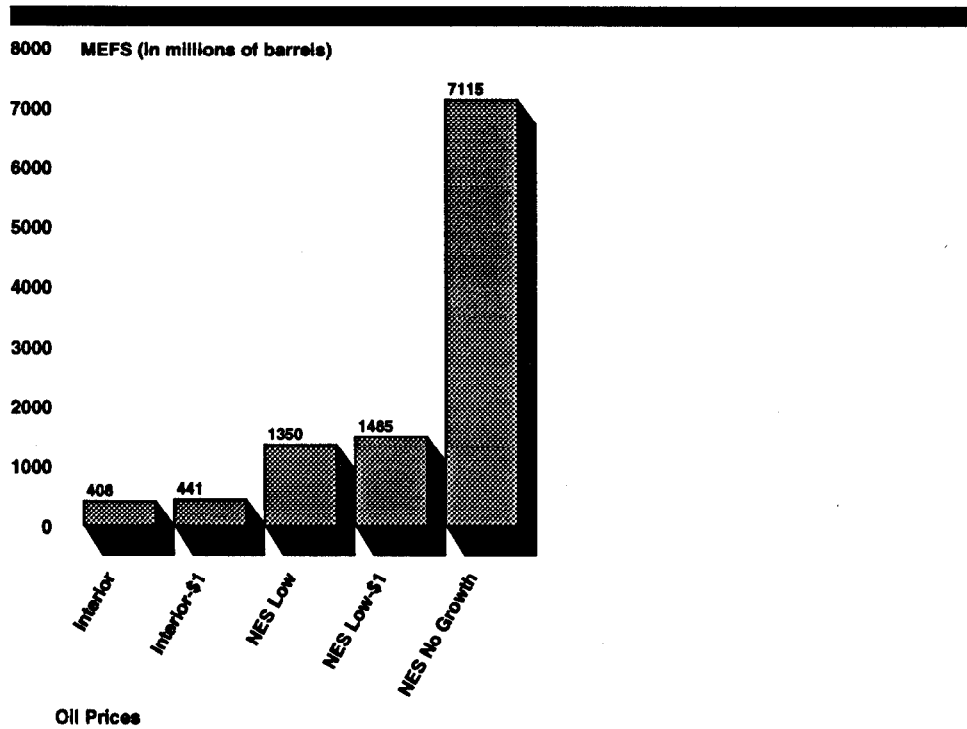
Legend

Interior	=	Interior's baseline estimate ranges from $16.95 in 1990 to $45.89 in 2030 (in 1990 dollars).
Interior-$1	=	Interior's baseline estimate adjusted for $1 price differential.
NES Low	=	NES low-price scenario ranges from $22 in 1990 to $32.95 in 2030 (in 1990 dollars).
NES Low-$1	=	NES low price adjusted for $1 price differential.
NES No Growth	=	No growth in real price of oil after 1990 ($22 in 1990 dollars).

Effect of Discount Rates on the MEFS

Similarly, Interior did not recognize the uncertainty associated with discount rates. Discount rates are used to determine the present value of future revenues and costs from the development and production of oil in ANWR. Interior used a 10-percent real discount rate. According to studies we reviewed and the experts we contacted, there is no consensus on a single discount rate to be used in these types of analyses. We believe that

Interior should have recognized the uncertainty associated with the discount rate and used a range of rates rather than a single-point estimate.

To demonstrate the impact that changes in the discount rate have on the size of the MEFS, we performed a series of sensitivity analyses using a range of rates. For example, a discount rate of 10 percent would result in an MEFS of 408 million barrels of oil; but with a discount rate of 9 percent, an MEFS of 333 million barrels of oil would be needed—about an 18-percent decrease.

Effect of Changes to the MEFS on Resource and Probability Estimates

To demonstrate the effect of changes to the MEFS on Interior's conditional resource estimates and the probability of an economically viable oil field, we reran Interior's PRESTO model using low NES world oil prices and adjusted these prices downward by $1 to account for the North Slope price differential. In addition, we assumed that leasing in ANWR would start in 1995 rather than 1993. Except for correcting Interior's minor data entry errors to PRESTO, we did not make any other changes to the PRESTO model or its assumptions.

Our analysis indicated that changes in the MEFS from lower oil prices reduced the probability that ANWR contained at least one economically viable oil field to a 27-percent probability from Interior's 1991 estimate of a 46-percent probability. However, the estimate of how much oil may be present in ANWR increased somewhat from Interior's projections: The mean estimate of potential economically recoverable oil resources was 3.99 billion barrels, ranging from a 95-percent chance of 1.47 billion barrels, to a 5-percent chance of 9.36 billion barrels. Interior officials told us that they had similar results when they evaluated the effect of lower oil prices on the MEFS and PRESTO.

If we had used higher oil prices than Interior, the probability of ANWR's containing at least one economically viable oil field would have been higher than Interior's projected 46 percent.

Other Factors Could Affect Interior's Estimates

If the costs of developing ANWR increase or decrease, they could also affect the size of the MEFS needed to make the development of ANWR economically viable. For example, if costs are higher than anticipated, the size of the MEFS has to increase. Two such cost factors are the stand-alone assumption and additional costs that the Congress may require to develop a wildlife refuge in an environmentally sound manner.

First, the stand-alone assumption holds that each prospect supports the full cost of production facilities and of building a pipeline to Pump Station One of the Trans-Alaska Pipeline. PRESTO is designed for evaluating offshore oil and gas prospects and assumes that each prospect must support the cost of a separate platform and pipeline to shore unless the model is configured to consider a grouping of discoveries. Because each prospect must independently support all facilities' cost, a rather large MEFS is required. This stand-alone assumption is a conservative means of evaluating the value of a prospect.

However, the history of oil production in the North Slope of Alaska shows that when one large economic field is developed, other much smaller fields that would not be economic by themselves can share facilities or costs with the larger field and become profitable. Thus, we believe that a better resource estimate for ANWR would have recorded the amount of oil found in each exploration simulation run and determined if at least one field could support the infrastructure and pipeline by itself or if a grouping of prospects could support the necessary infrastructure. If such a field or grouping of fields existed, smaller MEFSs than required under the stand-alone assumption could be counted.

Second, congressional approval is required before exploration drilling and development can occur on ANWR's coastal plain. Because ANWR is a wilderness area, the Congress is likely to place restrictions on exploration and development to minimize adverse impacts to the environment. According to an expert we contacted, these restrictions—such as extra time for studying the effects of petroleum activity on the flora and fauna and drilling only in the winter—could add considerably to exploration costs. According to DOE, if well drilling were allowed only during the winter, costs could increase by $20 million to $50 million per well. All of these potential additional costs have the effect of increasing the MEFS and lowering the probability that ANWR contains at least one economically viable field.

Conclusions

We believe that Interior's 1991 estimate of oil resources in ANWR used the best available geologic and geophysical data for making such an assessment without actual drilling data from the refuge. However, we also believe that the DCF model used to develop the MEFS for Interior's projections did not fully consider the uncertainty associated with Interior's underlying economic assumptions—most notably oil prices. Given the uncertainties of future economic variables, such as oil prices and discount

rates, we believe Interior should have developed ranges of MEFS estimates for each prospect and then run its model using the derived field sizes. This would have provided a greater range of values to account for the uncertainty associated with estimating what constitutes an economically viable oil field in ANWR. Nevertheless, we agree with Interior's overall conclusion that ANWR may contain a substantial amount of oil.

Agency Comments

Interior provided written comments on a draft of this report. Interior agreed that the scope and objectives of its analysis were very narrow. Interior also pointed out that in a subsequent analysis of potential revenues from ANWR that was performed for the Office of Management and Budget and forwarded to the Congress, it did account for the uncertainties of key economic assumptions. (See app. III.)
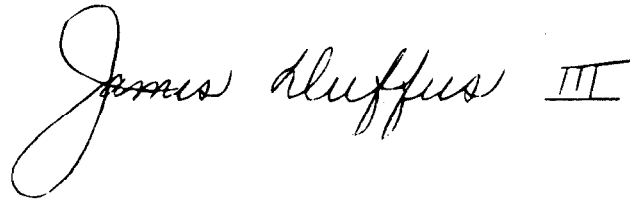
To assess Interior's 1991 report, we analyzed the logic of Interior's models and major assumptions, including economic, geologic, engineering, and cost factors, and also obtained the views of a number of experts, including state and federal officials, industry consultants, and representatives of oil companies on the North Slope, industry organizations, and public interest groups.

Our work was conducted from November 1991 through March 1993 in accordance with generally accepted government auditing standards. A complete discussion of our scope and methodology is contained in appendix I. Appendix II provides our analysis of Interior's methodology.

Unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after the date of this letter. At that time, we will send copies to the Secretary of the Interior; the Director, Office of Management and Budget; Alaska state officials; and other interested parties. We will also make copies available to others on request.

Please contact me at (202) 512-7756 if you or your staff have any questions. Major contributors to this report are listed in appendix IV.

Sincerely yours,

James Duffus III
Director, Natural Resources
  Management Issues

Contents

Abbreviations

ANILCA	Alaska National Interest Lands Conservation Act
ANWR	Arctic National Wildlife Refuge
BLM	Bureau of Land Management
DCF	Discounted Cash Flow
DOE	Department of Energy
MEFS	Minimum Economic Field Size
GAO	General Accounting Office
NES	National Energy Strategy
PRESTO	Probabilistic Resource Estimates-Offshore
USGS	U.S. Geological Survey

Objectives, Scope, and Methodology

On January 9, 1992, the Chairman, House Committee on Interior and Insular Affairs (now the Committee on Natural Resources), asked us to assess the accuracy of and support for the Department of the Interior's 1991 estimate of the potential amount of oil resources in the Arctic National Wildlife Refuge (ANWR) and the likelihood that ANWR contains oil in economically viable quantities. This estimate appears in Interior's April 1991 report entitled Overview of the 1991 Arctic National Wildlife Refuge Recoverable Petroleum Resource Update. To address these issues, we examined the methodology and the reasonableness of key geologic and economic assumptions Interior used to arrive at its estimates.

To assess the reasonableness of Interior's principal geologic assumption that the coastal plain of ANWR should be considered part of the North Slope petroleum province, we conducted an extensive literature search and interviewed Bureau of Land Management (BLM) officials in Anchorage, Alaska. We also interviewed U.S. Geological Survey (USGS) officials in Menlo Park, California; officials of the American Association of Petroleum Geologists in Tulsa, Oklahoma; and the Chairman of the National Research Council's Committee on Undiscovered Oil and Gas Resources, in Norman, Oklahoma. We also reviewed and analyzed geologic and geophysical data from Interior's BLM and Minerals Management Service, which were used to support the assumption.

To assess the reasonableness of Interior's modeling process, we analyzed Interior's discounted cash flow (DCF) and Probabilistic Resource Estimates-Offshore (PRESTO) models. We reviewed the models' logic and documentation as well as their economic, geologic, and cost assumptions. We met with BLM officials in Anchorage, Alaska, and Washington, D.C. We also interviewed USGS officials in Menlo Park, California; officials of the American Association of Petroleum Geologists in Tulsa, Oklahoma; and the Chairman of the National Research Council's Committee on Undiscovered Oil and Gas Resources, in Norman, Oklahoma. We also ran aspects of the models to determine their sensitivity to changing data entries. In addition, we made changes in the data entries in both models to correct errors made by Interior. The changes and results of those analyses are described in appendix II.

To assess the reasonableness of the key geologic, economic, engineering, and cost assumptions Interior used to evaluate the estimates and probability that oil existed in economically viable quantities in ANWR's coastal plain, we obtained the assumptions used for the models and reviewed these assumptions in detail. In addition, we developed a survey

instrument that presented Interior's assumptions and/or calculated values for ANWR and asked those surveyed to assess the reasonableness of those assumptions for five parameters: (1) resource estimates, (2) exploration and/or development costs, (3) operating costs, (4) taxation costs, and (5) transportation costs.[1] Those surveyed included oil companies with operations on the North Slope, federal and state agencies, consultants, professional organizations, and public interest groups. When respondents found an assumption to be unreasonable, we asked them to provide us with documentation explaining their view. The survey instrument was detailed and long, and we did not expect any single respondent to have information or knowledge about all, or even most, of the sections of the survey instrument. Respondents were instructed to reply to only the parts or sections for which they had sufficient knowledge to assess the reasonableness of the assumptions and/or calculated values.

The following is a list of the 29 organizations and individuals that we surveyed:

Federal Agencies

Bureau of Land Management
U.S. Geological Survey
Minerals Management Service

State of Alaska

Department of Natural Resources
Department of Revenue
Oil and Gas Conservation Commission

Oil Companies

Amerada Hess Corp.
ARCO Alaska, Inc.
BP Exploration (Alaska), Inc.
Chevron Producing Company
Conoco, Inc.
Exxon Corporation
Marathon Oil Company
Mobil Corporation
Phillips Petroleum Company

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[1]This was done in conjunction with a survey instrument for a separate but related review we conducted of a Department of Energy report that had concluded that unless a major new oil field was discovered and developed, the Trans-Alaska Pipeline System would most likely shut down in the year 2009. DOE's conclusion was evaluated in our report entitled Trans-Alaska Pipeline: Projections of Long-Term Viability Are Uncertain (GAO/RCED-93-69, Apr. 8, 1993).

	Shell Oil Company
	Texaco, Inc.
	Unocal Corporation

Industry Organizations/Consultants	American Association of Petroleum Geologists
	Society of Petroleum Engineers
	Three independent industry consultants

Public Interest Groups	Alaska Coalition
	National Audubon Society
	National Wildlife Federation
	Natural Resources Defense Council
	Trustees for Alaska
	Wilderness Society

Eleven responses to our survey specifically addressed Interior's ANWR estimates: 4 oil companies, 1 federal agency, 1 state agency, 4 industry organizations/consultants, and 1 consolidated response representing 6 of the 7-public interest groups.

We also conducted our own detailed economic and geologic analyses of other North Slope oil fields and their operating conditions to assess the data used in Interior's models. To evaluate Interior's assumptions on oil prices, we obtained oil price forecasts from recognized economic forecasters for 1990 and 1992 and adjusted them to the same dollar value. To assess the price differential between North Slope oil and imported oil, we interviewed officials from DOE, the state of Alaska, and independent industry consultants. Following their suggestions, we estimated the historic price differential between North Slope oil and the world market price of oil delivered to the lower 48 states. To evaluate the reasonableness of the interest and discount rates used by Interior, we used the results of our survey instrument, published data, and discussions with various experts.

To discuss various aspects of Interior's 1991 report and exploration/production operations on the North Slope of Alaska, we met with numerous officials from government, industry, and public interest groups. They included Interior officials in Washington, D.C., and Anchorage, Alaska; DOE officials in Washington, D.C.; state of Alaska officials from the Departments of Natural Resources and of Revenue, and

the Alaska Oil and Gas Conservation Commission; officials from ARCO Alaska, Inc., BP Exploration (Alaska), Inc., Conoco, Inc., Alyeska Pipeline Service Company, and the Trustees for Alaska, in Alaska; and the Natural Resources Defense Council and the Alaska Coalition in Washington, D.C. We also observed operations at the following North Slope fields: Prudhoe Bay, Kuparuk River, Milne Point, and Endicott. Our work was conducted from November 1991 through March 1993 in accordance with generally accepted government auditing standards.

GAO's Analysis of Interior's Methodology and Results

In October 1990, Interior ran its PRESTO model,[1] which calculated the conditional resource estimates for the 1002 area of ANWR, the probability of an economically viable prospect, and the risked resource estimates for ANWR. The conditional resource estimates evaluated the numerical distribution of simulated discoveries that were economic. The risked resource estimates evaluated the distribution of all the simulated drilling. In April 1991, Interior published the conditional mean resource estimate (3,559 million barrels) and the probability of economic success (46 percent). Although not published in Interior's April 1991 report, the conditional range of economically recoverable oil resources ranged from 615 million barrels at the 95-percent probability level, to 8,797 million barrels at the 5-percent probability level. We evaluated Interior's estimation procedure in two steps. First, we reviewed the model and economic assumptions that Interior used to calculate the MEFS. And second, we reviewed the PRESTO model and the assumptions used to calculate the conditional mean resource estimate and probability that an economically viable field exists.

Review of MEFS Estimation Methodology

The MEFS is key to Interior's resource estimation methodology. Interior used a DCF model to estimate the minimum amount of oil that must be present for each prospect to be economically viable to develop. Interior estimated an MEFS for 35 prospects (and 1 "dummy" prospect) using numerous geologic, engineering, cost, and economic assumptions. The estimated MEFS was then used in the PRESTO model to estimate the resources present in ANWR as well as the probability that an economically viable field exists. The MEFS estimate can significantly affect Interior's estimate of the oil present in ANWR. If, for example, the MEFS is set too high, only large fields would be considered economically viable for development, resulting in a lower estimate of the total resources present in ANWR.

To review the MEFS estimate, we obtained the DCF model that Interior had used to calculate the MEFS. Except for a programming error, we found the model to be generally acceptable for estimating the MEFS.[2] The error resulted in overestimating the MEFS by about 5 percent.

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[1]Interior used the PRESTO III version of its model. GAO's review and analysis used this version as well. For simplicity, PRESTO III is referred to as "PRESTO" throughout this report.

[2]Interior's estimates include exploration and delineation costs. However, Interior recognizes that from an economic perspective, the costs of the exploratory wells are sunk costs. Sunk costs should not influence the decision to continue to develop the oil field. Excluding these sunk costs would slightly lower Interior's MEFS estimate.

However, Interior did not appropriately address the uncertainty of key economic assumptions, such as oil prices and interest rates used in MEFS estimates. In addition, Interior did not adjust the NES oil prices for price differentials that have historically existed between North Slope crude oil and crude oil imports that are used as the bench mark for calculating the NES price projections.

To demonstrate the impact of changes in these assumptions on MEFS estimates, we used Interior's model—making no change other than to correct the model for the programming error—and performed a series of sensitivity analyses on the key economic variables using one prospect as an example.

Review of Resource Estimation (PRESTO Model) Methodology

To review Interior's conditional resource estimation methodology, we reviewed Interior's PRESTO model and its underlying assumptions. We found a number of minor data entry errors, which we documented and brought to the attention of Interior; those errors caused Interior's estimate of oil resources in ANWR to be higher than it should have been on the basis of the other assumptions.

PRESTO "drills" each prospect (35 prospects and 1 "dummy" prospect) to determine whether the prospect contains oil and gas resources. If the prospect contains oil, PRESTO calculates how much, using Interior's estimates of the size of the prospect, its geology, and the amount of oil that can be recovered. After computing the expected resources, PRESTO will determine if they are large enough to warrant production. If PRESTO determines that the resources for the prospect exceed the MEFS, the estimated resource values are stored in the computer for later use. If the estimated resources are less than the minimum amount required for economically viable production, PRESTO sets the resources for that prospect to zero.

After analyzing all prospects in the area, PRESTO starts another simulated drilling program using randomly selected values.[3] Each subsequent "drilling program" may result in completely different discoveries and resource estimates for the area.[4] Interior ran its model to simulate 1,000 drilling

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[3]Interior's drilling program is based on a 36-well program—one well in each prospect. The model resulted in a marginal probability of 46 percent. If the number of wells changes, the marginal probability will be different.

[4]Not all simulated drilling programs will result in economically viable resources. Some simulated programs could result in all the prospects having no resources or being uneconomical for production.

programs and generate 1,000 resource estimates for ANWR. The zero
estimates were eliminated, and the range of positive estimates sorted,
ranked, and divided into 99 percentiles, which were used to arrive at the
low, mean, and high estimates of the probability of finding commercial
quantities of oil. PRESTO's estimates are considered conditional resource
estimates of the quantities of oil that may be found and developed if at
least one economically recoverable prospect is present.[5]

Results of GAO's Analysis

Making no changes in the models other than to correct the identified data
entry errors, we reran PRESTO and found that the range of resources
became 582 million barrels at the 95-percent probability level and
8,383 million barrels at the 5-percent probability level; the conditional
mean estimate became 3,517 million barrels; and the probability became
47 percent. Table II.1 shows some of Interior's estimates and the results of
Interior's model after we corrected the model's input data.

Table II.1: Interior's 1991 Conditional and Risked Resource Estimates, and GAO's Corrected Conditional and Risked Resource Estimates, by Probability Level for ANWR

Barrels in millions

Percentile	Interior's conditional	Interior's risked	GAO-corrected conditional	GAO-corrected risked
95th	615	0	582	0
85th	1,011	0	1,019	0
65th	1,865	0	2,022	0
45th	3,117	536	3,057	557
25th	4,787	2,504	4,672	2,649
5th	8,797	7,235	8,383	6,895
Mean	3,559	1,633	3,517	1,650

Note: The resource estimates shown are generated by the PRESTO III model. Conditional resource estimates are based on trials for which the prospect had oil and the prospect's barrel of oil equivalent size exceeded the minimum economic field size. Risked resource estimates are based on the total number of trials, regardless of economic outcome.

Sources: Interior and GAO analyses.

To demonstrate the uncertainty associated with a key economic
assumption—oil prices—we reran Interior's models. Using the corrected
MEFS DCF model, we entered a low 1990 NES world oil price forecast and
subtracted $1 from forecast prices to account for the historic differential
between world crude oil prices and Alaska North Slope crude oil prices
paid in the U.S. Gulf Coast refinery market, allowing the computer to

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[5]In particular, the probability relates to the success of an exploratory drilling program that is the same
as the simulated exploration program in Interior's model.

calculate nominal future prices. We also changed the year of leasing to 1995, because no legislation has yet been passed to authorize leasing in 1993, and it may take 2 years to prepare for such a sale. No other factors in the MEFS model were changed.

We then calculated, prospect by prospect, the MEFS on the basis of these changed conditions. The resultant MEFSs were used in the PRESTO model. We reran PRESTO, which computed the conditional range of economically recoverable resources to be 1,474 million barrels at the 95-percent probability level and 9,355 million barrels at the 5-percent probability level; the conditional mean estimate was 3,994 million barrels; and the probability that an economically viable field existed was 27 percent. Table II.2 lists the distributions by percentile calculated by our model run using low NES oil prices and our correction of Interior's input errors. The conditional mean estimate is higher in this case because the MEFS was increased, thus deleting many smaller discoveries from the distribution and causing the remaining discoveries to be larger. Since the discovered fields are fewer, the probability that an economically viable field exists is smaller.

Table II.2: GAO Example of the Effect of Low NES Oil Price on PRESTO Resource Estimates for ANWR

Barrels in millions

Percentile	Conditional	Risked
95th	1,474	0
85th	1,643	0
65th	2,330	0
45th	3,426	0
25th	5,036	1,524
5th	9,355	5,948
Mean	3,994	1,074

Note: The resource estimates shown are generated by the PRESTO III model. Conditional resource estimates are based on trials for which the prospect had oil and the prospect's barrel of oil equivalent size exceeded the minimum economic field size. Risked resource estimates are based on the total number of trials, regardless of economic outcome.

Source: GAO analyses.

Comments From the Department of the Interior

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

MAY 28 1993

Mr. James Duffus III
Director, Natural Resources
  Management Issues
General Accounting Office
Washington, D.C. 20548

Dear Mr. Duffus:

This letter transmits our comments on the General Accounting Office (GAO) draft report entitled "ARCTIC NATIONAL WILDLIFE REFUGE: Estimate of Finding An Economically Viable Oil Field Is Uncertain" (GAO/RCED-93-130). The report assesses the Department of the Interior's (DOI) 1991 estimate of the Arctic National Wildlife Refuge's (ANWR) potential petroleum resources, compared to a 1987 DOI analysis, and the likelihood that an oil field exists in economically viable quantities.

The GAO's principal criticism of the DOI analysis is that it did not account for all possible risks and uncertainties. The DOI and the Bureau of Land Management (BLM) agree that the scope and the objective of the analysis was very narrow. It was only meant to answer the following question: "Given the changes in geologic knowledge of the North Slope, the costs in exploration, development and production, and price expectations, how will these changes impact the original estimates of probability and petroleum resources published in the April 1987 report?" The 1991 updated analysis was very explicit in establishing the conditions and variables that were used to form the basis for the revised 46 percent probability that ANWR contains at least one economically viable oil field. As the GAO knew at the time of its study, the DOI had performed a subsequent analysis to estimate potential revenues from ANWR. This revenue analysis did account for the uncertainties regarding prices and costs and eliminated the assumption requiring each field to be capable of being economic on a stand alone basis. The revenue analysis was performed for the Office of Management and Budget (OMB) and the OMB forwarded the results to Congress.

Sincerely,

Assistant Secretary, Land and
Minerals Management

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Glossary

1002 Area	That portion of the coastal plain of ANWR identified in ANILCA for future determination of oil and gas leasing or wilderness designation.
Conditional Resource Estimates	The amount of oil that may be recovered, assuming at least one MEFS is present in ANWR.
Discounted Cash Flow	A method of determining current value of an investment after considering the costs and revenues that may be generated over time by the investment, discounting the future value of money to the present.
Marginal Probability	The probability of occurrence of economically recoverable oil somewhere in the 1002 area.
Mean Estimate	The arithmetic average of all estimates.
Minimum Economic Field Size	The smallest amount of oil contained in a geologic prospect or prospects needed to ensure profitable production.
Percentile	The specific 100th part of a mathematical distribution.
Petroleum Province	A region in which a number of oil and gas pools and fields occur in a similar or related geologic environment.
Petroleum Reserves	Specific accumulations of oil whose location, quality, and quantity are estimated from geologic evidence and are legally and economically extractable at the time of determination.
Petroleum Resources	Concentrations of naturally occurring hydrocarbons in or on the earth's crust in such a form that extraction is currently or potentially feasible.
Potentially Economically Recoverable Resources	The portion of hydrocarbon resources that can be physically and economically extracted from the earth at a profit without regard to legal or environmental considerations.

Potentially Recoverable Resources	The portion of hydrocarbon resources that can be physically extracted from the earth at a profit without regard to legal or environmental considerations.
PRESTO	An acronym for Probabilistic Resource Estimates-Offshore, a computer model developed by the U.S. Minerals Management Service to statistically estimate through probability analysis the amounts of potential economically recoverable petroleum resources in an offshore leasing area.
Probability	The mathematical chance of a specific outcome.
Prospect	Commercial deposits of oil and gas found underground in the pore spaces of various kinds of rocks.
Risk	Estimates based on the total numbers of trials, regardless of economic outcome.

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