

U.S. Geological Survey 2002 Petroleum Resource Assessment of the National Petroleum Reserve in Alaska (NPRA)

A new USGS assessment concludes that NPRA holds significantly greater petroleum resources than previously estimated. Technically recoverable, undiscovered oil beneath the Federal part of NPRA likely ranges between 5.9 and 13.2 billion barrels, with a mean (expected) value of 9.3 billion barrels. An estimated 1.3 to 5.6 billion barrels of those technically recoverable oil resources are economically recoverable at market prices of \$22 to \$30 per barrel. Technically recoverable, undiscovered nonassociated natural gas for the same area likely ranges between 39.1 and 83.2 trillion cubic feet, with a mean (expected) value of 59.7 trillion cubic feet. Economic viability of this gas will depend on the availability of a natural gas pipeline for transport to market.



Figure 1. Map of northern Alaska showing locations and relative sizes of the National Petroleum Reserve in Alaska (NPRA) and the Arctic National Wildlife Refuge (ANWR). ANWR's 1002 Area was evaluated for petroleum potential by the USGS in 1998. The Trans-Alaska Pipeline System (TAPS) and "feeder" pipelines extending east and west of Prudhoe Bay show the extent of existing petroleum infrastructure. Locations of the Alpine and Prudhoe Bay oil fields and the Point Thomson gas and oil accumulation also are shown.

"Whereas there are large seepages of petroleum along the Arctic Coast of Alaska and conditions favorable to the occurrence of valuable petroleum fields on the Arctic Coast . . ." President Warren G. Harding used those words in 1923 to describe the apparent petroleum potential of a tract of land on the western North Slope of Alaska, when he issued a one-page executive order establishing the 23-million acre (36,000 square miles) Naval Petroleum Reserve No. 4. During the following six decades, the U.S. Government conducted two petroleum exploration programs in the reserve, one in the wake of World War II and the second in the wake of the 1970's oil embargo. These programs found only a handful of oil and gas fields, none of them commercial. The name of the reserve was changed to the National Petroleum Reserve in Alaska (NPRA) in 1976 (fig. 1). Four lease sales were held in the 1980's, but only two exploration wells were drilled by industry within the NPRA boundary—one on a Federal lease and another on Native land—and neither resulted in development of petroleum resources.

Following a 10-year hiatus in exploration activity, NPRA again became a focus of interest with the 1996 announcement of the discovery of the Alpine oil field, located just outside NPRA (fig. 1). A Federal lease sale was held in northeastern NPRA in 1999, and a number of exploration wells in that lease sale area were completed by industry during the 2000 and 2001 winter drilling seasons. Five of those wells were announced in 2001 to have encountered oil and gas, and additional wells were drilled during 2002 to delineate those discoveries and to test additional prospects (fig. 2).

The U.S. Geological Survey (USGS) has reexamined the petroleum geology of NPRA and has prepared a new petroleum resource assessment. This new assessment was prompted by (1) the rapidly evolving exploration activity focused on the "Alpine trend," (2) the growing interest in natural gas resources of the Arctic, and (3) the dated perspective of previous resource estimates (the last USGS assessment of NPRA was completed in 1980). Although none of the

data from 3-D seismic surveys or new wells drilled in NPRA since the 1999 lease sale was available for this study, the results nevertheless reflect a comprehensive examination of all public domain data and a consideration of new exploration and development strategies currently being applied on the Alaska North Slope. This new study complements the 1998 assessment of the Arctic National Wildlife Refuge (ANWR), 1002 Area (see USGS Fact Sheet 028-01).

Assessment Project

The NPRA assessment involved nearly 4 years of study by a team of USGS scientists, most of whom also worked on the 1998 ANWR assessment. Research was coordinated with colleagues in other Federal agencies, Alaska State agencies, and several universities. New field studies were conducted, new well and sample data were analyzed, some new geophysical data were acquired, and public technical workshops examining core samples were held. Data and interpretations from previous U.S. Government exploration programs were incorporated. About one-third of the 14,000 line-miles of seismic data collected by the Government between 1974 and 1981 were reprocessed and reinterpreted. Special attention was focused on understanding the more recent oil discoveries immediately east of NPRA and the potential for those productive geologic trends to extend westward beneath NPRA. All information was integrated and used as basic input to the 2002 petroleum assessment.

In keeping with the USGS responsibility for assessing the petroleum potential of all onshore areas and State water areas of the United States, the total area considered in this assessment was extended offshore to the boundary between State and Federal jurisdiction. Thus, in addition to Federal lands of NPRA, this assessment includes resources beneath State waters offshore from NPRA and beneath Native lands within the NPRA boundary (fig. 2). The total assessment area consists of 24.2 million acres, of which 22.5 million acres are Federal and 1.7 million acres are non-Federal (State and Native).

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Figure 2. Map of the National Petroleum Reserve in Alaska (NPRA; boundary shown by yellow line) and surrounding region with locations of seismic lines, wells, oil and gas accumulations, and Native lands. Red line shows the total area assessed in 2002 by the U.S. Geological Survey (USGS), including Federal and Native lands and State offshore areas. USGS seismic grid shows location of those seismic lines reprocessed and reinterpreted for this assessment. The assessment incorporated information on all exploration wells except those in the northeast part of NPRA drilled during 2000 and 2001. Oil fields east of NPRA, including several recently discovered accumulations, are labeled as follows: A, Alpine; F, Fiord; K, Kuparuk River; M, Meltwater; N, Nanuq; and T, Tarn. The map base is a false-color composite Landsat image on which vegetation appears as shades of red, and soil and rock with little or no vegetation appear in shades of green and brown. Deep and clear water appears dark blue to black, and shallow or sediment-laden water appears in lighter shades of blue. Ice is white or bluish white.

Assessment Methodology

The methodology used in this assessment is similar to that used in the earlier USGS assessments of NPRA (1978–80) and ANWR (1987 and 1998). As the initial step of the assessment, twenty-four petroleum plays were defined (fig. 3). A play is a volume of rock that contains similar geological parameters (such as

petroleum charge, reservoir, and trap) that determine petroleum potential. The term “petroleum” is used to include crude oil, natural gas, and natural gas liquids.

For each play, distributions of the number and size of potential petroleum accumulations were estimated on the basis of a probabilistic range of values for certain geological attributes, such as reservoir thickness and porosity. These distributions were restricted to potential accumulations larger than 50 million barrels of in-place oil (MMBO) or 250 billion cubic feet (BCF) of technically recoverable gas, so that the assessment would not be influenced by accumulations smaller than these minimum sizes, which are generally noneconomic on the North Slope.

The resulting distributions were subjected to a geologic risking procedure designed to weigh the likelihood that petroleum charge, reservoir, and trap conditions were sufficient to generate at least the minimum-size accumulation. In turn, a probabilistic estimate of in-place petroleum resources was calculated on the basis of the risked distributions of size and number of potential petroleum accumulations in each play. A recovery factor appropriate to each play was applied to the estimates of in-place petroleum resources to calculate technically recoverable petroleum resources. Typically, only 30% to 50% of in-place oil resources and only 60% to 70% of in-place gas resources are technically recoverable. Estimates for each play were aggregated to calculate total technically recoverable petroleum resources for the entire assessment area and for the Federal area (table 1).

This assessment methodology yields results that include probabilistic expressions of uncertainty. To stress the importance of this uncertainty, results reported

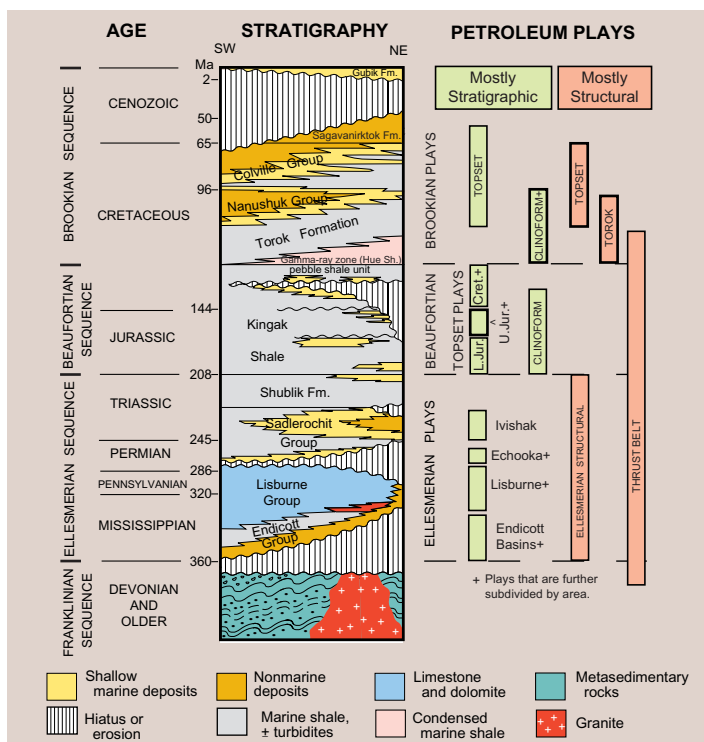


Figure 3. Summary of ages, names, and rock types present in NPRA. Colored bars at right show the stratigraphic position of the 24 petroleum plays evaluated in the 2002 assessment. Note that bars with a “+” symbol indicate multiple plays in different areas. Plays indicated by bold outlines include those with the greatest oil and (or) gas potential, as shown in figures 6 and 8.

here include 95% and 5% probabilities, in addition to mean values. The 95% probability level means that there is a 19 in 20 chance that the amount present will be at least as large as the amount shown; the 5% probability level means that there is a 1 in 20 chance that the amount present will be at least as large as the amount shown. Volumes of petroleum associated with the 95% and 5% probabilities are considered reasonable estimates of minimum and maximum volumes that may be present, and the mean is the average or expected value (fig. 4).

Table 1. U.S. Geological Survey estimates of volumes of technically recoverable oil and nonassociated gas in the NPRA study areas.

OIL	Volume of oil, billions of barrels		
	F ₉₅	Mean	F ₀₅
Entire assessment area ¹	6.7	10.6	15.0
Federal part of NPRA	5.9	9.3	13.2
NONASSOCIATED GAS (gas in gas fields)	Volume of gas, trillions of cubic feet		
	F ₉₅	Mean	F ₀₅
Entire assessment area ¹	40.4	61.4	85.3
Federal part of NPRA	39.1	59.7	83.2

¹ Includes NPRA, Native lands, and adjacent State offshore areas within 3-mile boundary (see figure 2).

Commercial viability of undiscovered oil resources was estimated by considering costs associated with finding, developing, producing, and transporting to market (West Coast of the lower-48 States) the technically recoverable oil resources estimated to be present. The cost functions are calculated in constant 2001 dollars and are based on the expectation that production will repay all operating costs, including taxes and transport to market, and all investment expenditures and will provide an after-tax rate of return of at least 12% on the investment. The economic analysis simulates exploration by assuming that larger accumulations will be discovered early and that these accumulations may be developed depending on their size and location. Any accumulation

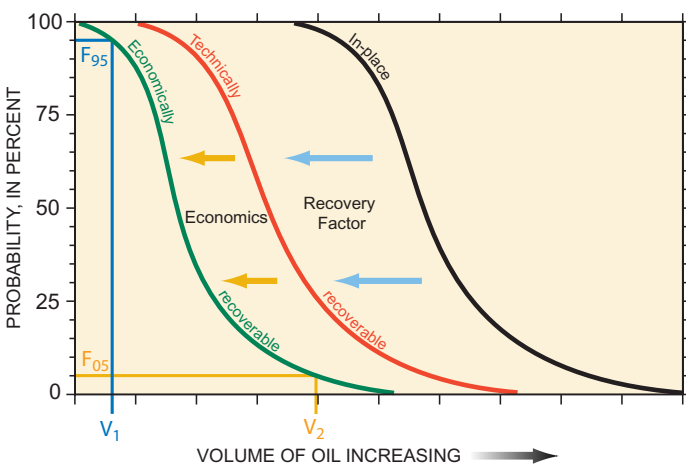


Figure 4. Schematic graph illustrating petroleum volumes and probabilities. Curves represent categories of oil assessment. How one reads this graph is illustrated by the blue and orange lines projected to the curve for economically recoverable oil—in this example, there is a 95% chance (probability F_{95}) of at least volume V_1 of economically recoverable oil, and there is a 5% chance (probability F_{05}) of at least volume V_2 of economically recoverable oil.

large enough to be developed at a specific location will support the costs of constructing processing facilities and extending infrastructure into the area. Smaller accumulations then may become economically viable if they can be developed as satellites to the larger fields. Results of the economic analysis are presented in terms of oil volume as a function of market price.

No analysis of the commercial viability of undiscovered gas resources has been made by the USGS. Such analysis is deferred until plans for a natural gas transportation system are more firmly developed.

Assessment Results

Oil.—The total quantity of undiscovered, technically recoverable oil within the entire assessment area is estimated to range between 6.7 and 15.0 billion barrels (BBO) (95% and 5% probability), with a mean value of 10.6 BBO. The quantity of undiscovered, technically recoverable oil beneath Federal lands in NPRA (excluding State and Native areas) is estimated to range between 5.9 and 13.2 BBO (95% and 5% probability), with a mean value of 9.3 BBO (table 1).

As illustrated in figure 5, most oil accumulations are expected to be of moderate size, on the order of 30 to 250 million barrels (MMBO) each, and large accumulations like Prudhoe Bay (ultimate recovery approximately 13 BBO) are not expected to occur. This conclusion is consistent with the fact that numerous exploration wells previously drilled in NPRA and in adjacent State and Federal waters tested prospects that were geologically similar to Prudhoe Bay, without success. Significantly, figure 5 shows that NPRA is expected to contain many accumulations in the size range commonly developed as “stand alone” or satellite fields on the central Alaska North Slope in recent years. For comparison, announced estimates of ultimate recoveries from recently discovered fields shown in figure 2 include 429 MMBO for Alpine, 70 MMBO for Tarn, 50 MMBO for Meltwater, 50 MMBO for Fiord, and 40 MMBO for Nanuq.

Quantities of technically recoverable oil are not expected to be uniformly distributed throughout NPRA. This is illustrated by accumulation-size histograms and maps for the four plays estimated to hold the greatest oil potential in NPRA (fig. 6). Based on the mean estimate, about 80% of the technically recoverable oil resources are likely to occur in northern NPRA within plays that are westward continuations of the geologic trends that host Alpine, Fiord, Tarn, Meltwater, and Nanuq oil pools, just east of NPRA (fig. 2).

The economic analysis of undiscovered resources is particularly important in an area as large as NPRA, because some of the oil resources may be far from existing infrastructure. Figure 7 summarizes oil volume as a function of market price based on accumulation-size distributions associated with the mean, 95%, and 5% probability estimates of technically recoverable oil. Over a range of market prices between \$22 and \$30 per barrel, between 1.3 and 5.6 BBO are estimated to be economically recoverable from the Federal part of the study area on the basis of the mean estimate of technically recoverable oil volumes (fig. 7).

Gas.—Significant volumes of natural gas also are estimated to occur in NPRA. Although North Slope gas is currently noncommercial for lack of a transportation system, it is of growing interest because of recent discussions and proposals of gas pipeline construction. The total quantity of undiscovered, technically recoverable nonassociated gas within the entire assessment area is estimated to range between 40.4 and 85.3 trillion cubic feet (TCF) (95% and 5% probability), with a mean value of 61.4 TCF. The quantity of

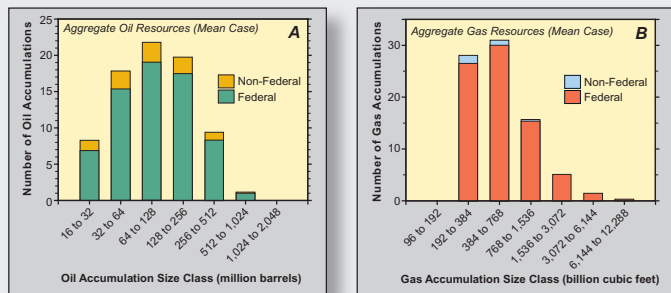


Figure 5. Histograms showing the expected (mean) numbers of oil and nonassociated gas accumulations estimated to exist in various size categories of technically recoverable resources in the 2002 U.S. Geological Survey assessment of NPRA. Each histogram bar is divided into Federal and non-Federal portions. Left sides of histograms appear truncated because of minimum accumulation sizes considered in the assessments. A, Expected (mean) numbers of oil accumulations, read as follows: It is estimated that the assessment area contains approximately 10 accumulations containing between 256 and 512 million barrels of technically recoverable oil; 8 of those accumulations are under Federal jurisdiction and 2 are non-Federal. B, Expected (mean) numbers of nonassociated gas accumulations, read as follows: It is estimated that the assessment area contains approximately 15 accumulations containing between 768 and 1,536 billion cubic feet of technically recoverable gas; 14 of those accumulations are under Federal jurisdiction and 1 is non-Federal.

undiscovered, technically recoverable nonassociated gas beneath Federal lands in NPRA (excluding State and Native areas) is estimated to range between 39.1 and 83.2 TCF (95% and 5% probability), with a mean value of 59.7 TCF (table 1).

As illustrated in figure 5, most gas accumulations are expected to range between about 200 and 1,500 billion cubic feet (BCF) each. For comparison, the gas cap at the Prudhoe Bay oil field (fig. 1) contains more than 23,000 BCF, the Point Thomson gas and oil accumulation (fig. 1) may contain more than 6,000 BCF, and a recently announced discovery in the Mackenzie River delta of Canada (about

150 miles east of the U.S.–Canada border) is estimated to contain 200 to 300 BCF recoverable reserves. Quantities of technically recoverable gas are most abundant in central and southern NPRA, as illustrated by accumulation-size histograms and maps for the four plays estimated to hold the greatest gas potential in NPRA (fig. 8).

Comparison With Previous NPRA Assessments

Of the prior assessments of NPRA oil and gas resources, only the USGS assessments of 1978–80 can be reliably compared to the current assessment because a common assessment methodology and well-documented assumptions and data were used. The current assessment shows an overall increase in estimated technically recoverable oil and gas resources when compared to the 1980 assessment (table 2). The increase in estimated oil resources has resulted in large part from incorporation of information available from recent, nearby oil discoveries, mostly in a play (fig. 6A) that was not previously known to exist in NPRA. The increase in estimated gas resources has resulted from a combination of factors, including a better understanding of regional thermal-maturity patterns and timing of trap formation relative to hydrocarbon generation and improved models of reservoir development.

Comparison with the ANWR 1002 Area Assessment

The volumes of undiscovered, technically recoverable oil estimated for NPRA in this assessment are similar to the volumes estimated for the ANWR study area in 1998 (table 3). The estimates for the Federal part of NPRA are: mean 9.3 BBO, range 5.9 to 13.2 BBO (95% and 5% probabilities). The estimates for the Federal part of ANWR are: mean 7.7 BBO, range 4.3 to 11.8 BBO (95% and 5% probabilities). The similarities between these estimates may be misleading, however, because of differences in accumulation sizes (the ANWR study area is estimated to contain more accumulations in larger size classes) and differences in assessment area (the NPRA study area is more than 12 times larger than the ANWR study area). Results of the economic analysis help clarify the comparisons between the estimates for NPRA and ANWR, because key components of the analysis include: (1) the largest accumulation sizes estimated to be present, (2) the number of accumulations in various size classes,

Table 2. Comparison of the 1980 and 2002 assessments of NPRA by the U.S. Geological Survey. Volumes are technically recoverable oil and gas.

	Oil, billions of barrels			Gas, trillions of ft ³		
	F ₉₅	Mean	F ₀₅	F ₉₅	Mean	F ₀₅
1980 Assessment ¹	0.3	2.1	5.4	1.8	8.5	20.4
2002 Assessment ²	5.9	9.3	13.2	39.1	59.7	83.2

¹ Includes entire NPRA as Native selections had not been made. Does not include State offshore areas. Reported gas resources are total gas (non-associated and associated).
² Includes only the Federal part of the NPRA; Native lands and adjacent State offshore areas are excluded (see figure 2). Gas resources are non-associated gas only.

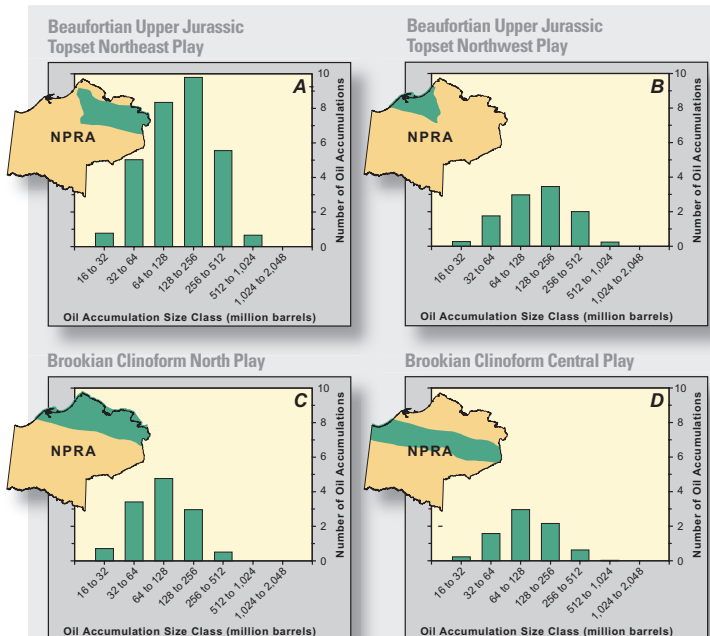


Figure 6. Maps of petroleum plays with histograms showing the expected (mean) numbers of undiscovered petroleum accumulations estimated to exist in various size categories of technically recoverable oil resources in the four plays estimated to hold the greatest oil potential in NPRA. About 80% of the technically recoverable oil resources, on the basis of the mean estimate, are thought to occur in northern NPRA within these four plays. These plays are westward continuations of geologic trends that host the Alpine and Fiord oil pools (A, B) and the Tarn, Meltwater, and Nanuq oil pools (C, D), just east of NPRA (fig. 2).

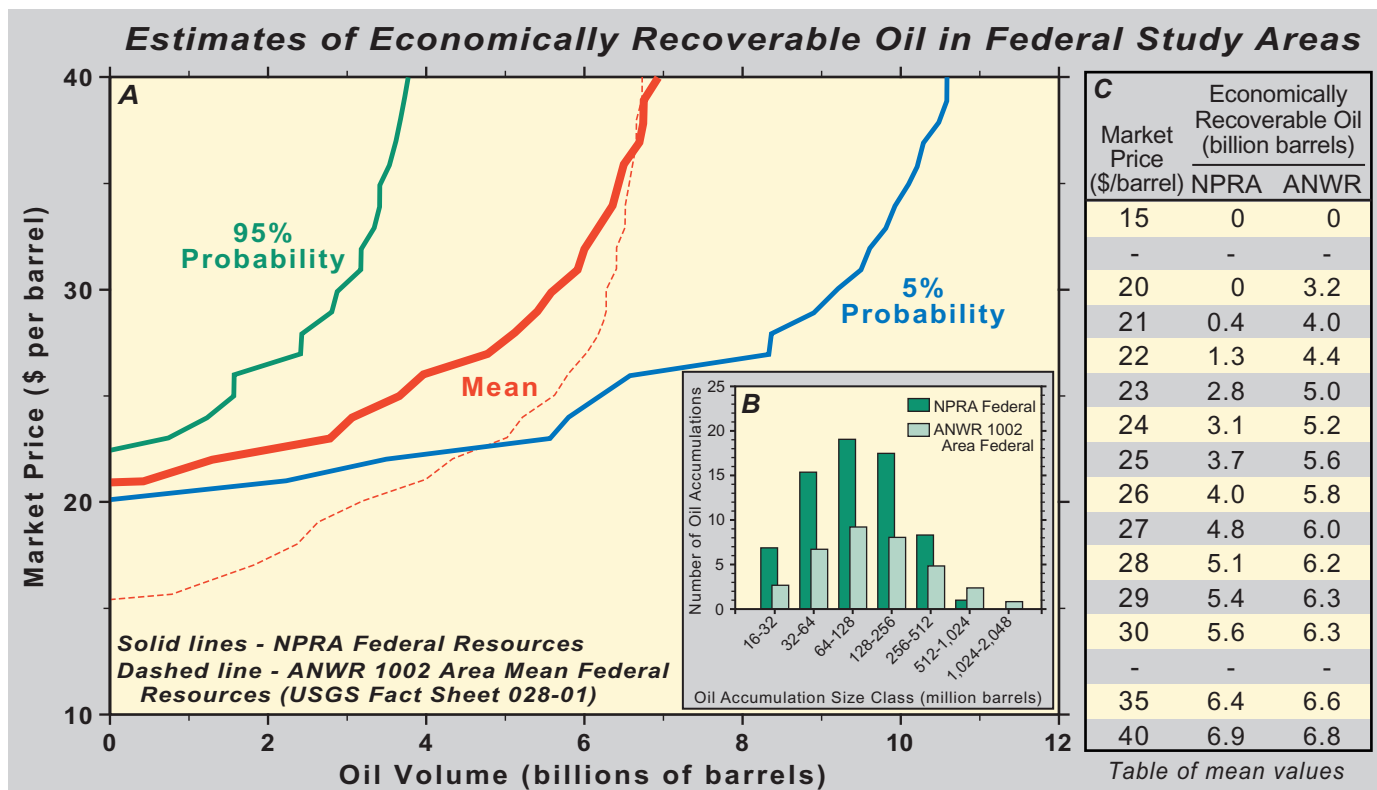


Figure 7. Summary of the 2002 U.S. Geological Survey (USGS) estimate of economically recoverable oil that may occur beneath the Federal part of NPRA. A, Graph relating market price to the volume of oil estimated to be profitably recoverable. The three curves are based on estimates of technically recoverable oil volumes at the mean (expected) value, and at the 95% (F_{95}) and 5% (F_{05}) probabilities. The 95% probability level means that there is a 19 in 20 chance that the amount economically recoverable will be at least as large as the amount shown; the 5% probability level means that there is a 1 in 20 chance that the amount economically recoverable will be at least as large as the amount shown. Included are the costs of finding, developing, producing, and transporting oil to market (West Coast of the lower-48 States) based on a 12% after-tax return on investment, all calculated in constant 2001 dollars. The chart is read as follows: At a market price of \$25 per barrel, there is a 95% probability of at least 1.6 billion barrels of economically recoverable oil and a 5% probability of at least 6.2 billion barrels. The mean or expected value is at least 3.7 billion barrels of economically recoverable oil. So that estimates of economically recoverable oil for the NPRA can be compared with those for the ANWR 1002 Area, the graph shows the mean curve (dashed line) from the 1998 USGS assessment of ANWR Federal lands, which was calculated in constant 1996 dollars. B, Histograms showing the expected (mean) numbers of oil accumulations estimated to exist in various size categories of technically recoverable oil resources in the 2002 USGS assessment of NPRA (dark green) and in the 1998 USGS assessment of ANWR (light green). Note that each size class is twice as big as the next smaller size class. The ANWR area is estimated to contain more accumulations in the largest two size classes shown, whereas the NPRA area is estimated to contain more accumulations in all the smaller size classes. C, Table of economically recoverable oil resources estimated to occur in the Federal parts of NPRA and ANWR assessment areas at various market prices. Values are based on the mean curves shown in A. NPRA results are calculated in constant 2001 dollars, whereas ANWR results are calculated in constant 1996 dollars.

Table 3. Comparison of the 1998 ANWR and 2002 NPRA U.S. Geological Survey assessments. Volumes are technically recoverable oil.

	Oil, billions of barrels			Size of area (Million acres)
	F_{95}	Me	F_{05}	
ENTIRE AREA ¹				
ANWR 1002 Area	5.7	10.4	16.0	1.9
NPRA	6.7	10.6	15.0	24.2
FEDERAL AREA				
ANWR 1002 Area	4.3	7.7	11.8	1.5
NPRA	5.9	9.3	13.2	22.5

¹ Includes Federal and Native lands and State offshore areas.

and (3) distance from existing infrastructure. A direct comparison of results based on the mean estimates of technically recoverable oil (fig. 7) shows that a larger volume of oil is economically recoverable at market prices below \$35 per barrel in the ANWR study area. At market prices above \$35 per barrel, estimates of economically recoverable oil for the two areas are similar.

Summary

In anticipation of the need for scientific support for policy decisions and because the perspective of the 1980 USGS assessment of NPRA is two decades old, the USGS has completed a new assessment of undiscovered petroleum resources in NPRA. This comprehensive study was conducted by a team of USGS scientists with contributions on some technical issues from colleagues in other agencies and at universities. The study included evaluation of all available public data and previous interpretations, as well

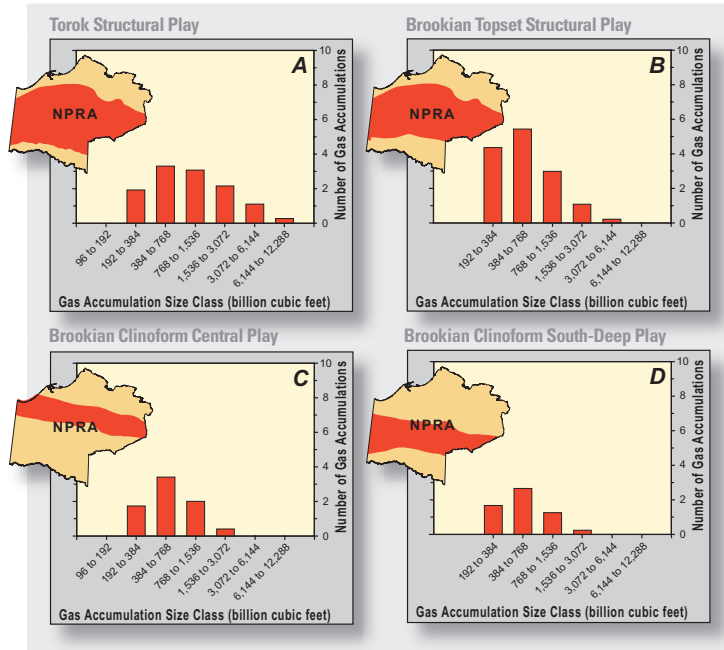


Figure 8. Maps of petroleum plays with histograms showing the expected (mean) numbers of undiscovered petroleum accumulations estimated to exist in various size categories of technically recoverable gas resources in the four plays estimated to hold the greatest gas potential in NPR. About 60% of the technically recoverable gas resources, on the basis of the mean estimate, are thought to occur in central and southern NPR within these four plays.

as new data stemming from field and laboratory analyses. The assessment was conducted using a methodology similar to that used in previous USGS assessments in NPR and ANWR.

This new assessment concludes that the volume of technically recoverable, undiscovered oil beneath Federal lands in NPR ranges between 5.9 and 13.2 billion barrels (95% and 5% probabilities), with a mean (expected) value of 9.3 billion barrels. Most of the oil is estimated to occur in the northern third of NPR, to be distributed among several plays, and to occur in accumulations of moderate size. It is unlikely that a Prudhoe Bay-size accumulation occurs in NPR. Over a range of market prices between \$22 and \$30 per barrel, between 1.3 and 5.6 billion barrels of oil are estimated to be economically recoverable, on the basis of the mean estimate of technically recoverable oil volumes.

Estimates of technically recoverable, undiscovered nonassociated natural gas resources for the same area range between 39.1 and 83.2 trillion cubic feet (95% and 5% probabilities), with a mean (expected) value of 59.7 trillion cubic feet. The economic viability of these natural gas resources will depend on the availability of a pipeline to transport the gas to market.

The amounts of oil and gas estimated for the NPR area are significantly greater than USGS estimates made in 1980. The increase in estimated oil resources is largely the result of the recognition of new plays based on oil accumulations recently discovered just east of NPR. Increased gas estimates result from improved understanding of thermal maturity, reservoir development, and timing of trap development relative to hydrocarbon generation.

The amount of technically recoverable oil estimated for NPR is similar to that estimated for the ANWR study area. However, economic analysis—

which takes into consideration differences in accumulation sizes, the number of accumulations of various size, and proximity of those accumulations to infrastructure—shows that for market prices below \$35 per barrel, a larger volume of oil will be economic in the ANWR area.

The USGS is solely responsible for the input and results of the 2002 petroleum assessment of NPR. The USGS acknowledges the cooperation of the U.S. Fish and Wildlife Service, Bureau of Land Management, Minerals Management Service, Alaska Department of Natural Resources (Geological and Geophysical Surveys and Division of Oil and Gas), and Alaska Oil and Gas Conservation Commission. The USGS provides the Federal Government with scientific information and analyses related to natural resource issues. USGS research provides a scientific basis for policy discussions regarding land, water, biological, energy, and mineral resources management, environmental quality, and economic and strategic policy.

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Explanation of Some Terms

Charge. Conditions of petroleum generation and migration adequate for an accumulation of the minimum size considered in the assessment.

Reservoir. Occurrence of reservoir rocks of sufficient quantity and quality to permit containment of petroleum in volumes sufficient for an accumulation of the minimum size.

Trap. Occurrence of those structures, pinch-outs, permeability changes, and similar features necessary for the entrapment and sealing of petroleum in an accumulation of the minimum size.

In-place resources. Volume of petroleum contained in accumulations of at least 50 MMBOE, without regard to recoverability.

Technically recoverable resources. Volume of petroleum representing that proportion of assessed in-place resources that may be recoverable using current recovery technology, without regard to cost.

Economically recoverable resources. Volume of technically recoverable petroleum for which the costs of discovery, development, production, and transport, including a return to capital, can be recovered at a given market price.

Associated gas. Natural gas in oil accumulations.

Nonassociated gas. Natural gas in gas accumulations.

95% probability level. Refers to a 19 in 20 chance that the amount present will be at least as large as the amount shown.

5% probability level. Refers to a 1 in 20 chance that the amount present will be at least as large as the amount shown.

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See also *Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, 1998, Including Economic Analysis* (USGS Fact Sheet 028-01).

This fact sheet and any updates to it are available online at:

<http://geopubs.wr.usgs.gov/fact-sheet/fs045-02/>