Summary and Conclusions

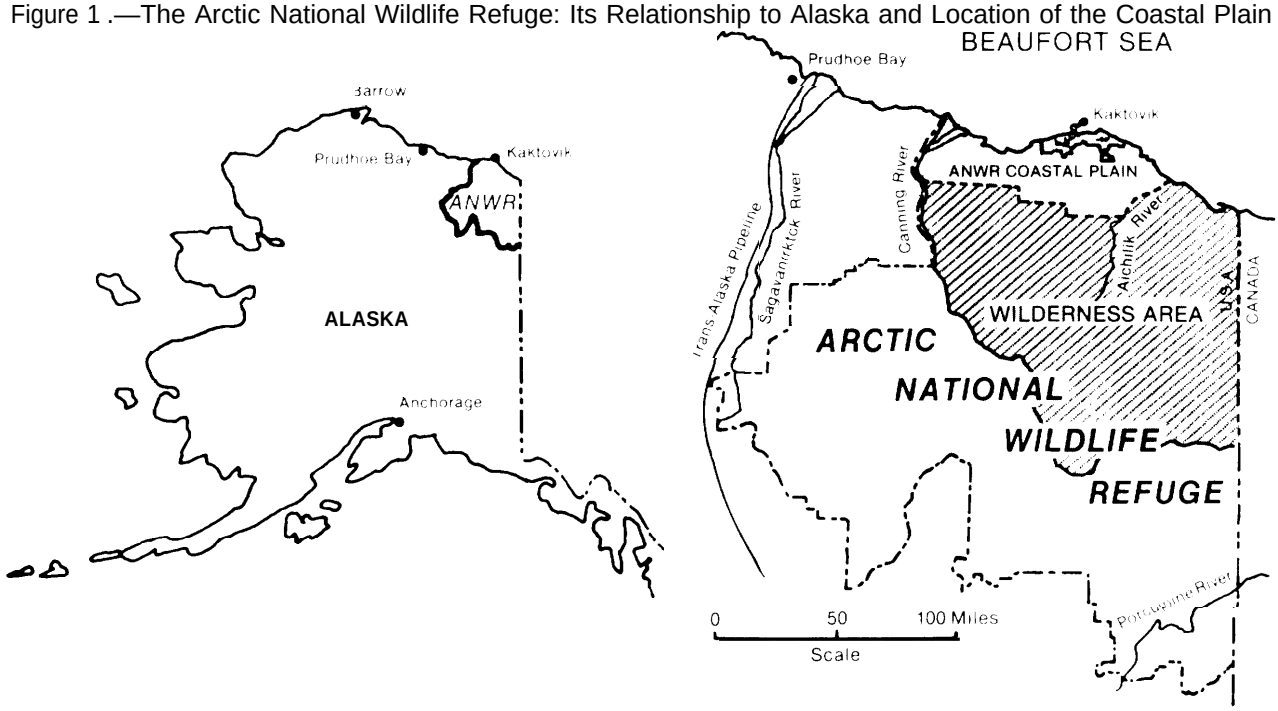
Contents

INTRODUCTION

The coastal plain of the Arctic National Wildlife Refuge (ANWR), in the extreme northeast corner of Alaska (see Figure 1), has become the focal point of a major debate among interest groups seeking either to promote or to block the leasing, exploration, and development of the area for its suspected massive oil resources (see Box A). Those groups opposing the development of ANWR oil resources view the coastal plain as a unique and invaluable Arctic ecosystem and wilderness area. They fear that development will destroy the plain's wilderness character and seriously damage its wildlife and other environmental values in return for a small potential to capture an amount of oil that will make only a temporary dent in the United States' liquid fuels dilemma. They believe that previous North Slope development has damaged the Arctic environment and serves as a warning against expansion of development into the coastal plain.

Pro-development interests view the coastal plain as the most promising remaining area in the United States for finding supergiant oilfields, and they believe that the oil industry can explore and develop the area without significantly compromising its environmental values. In contrast to the views expressed by the environmental groups opposing ANWR development, those favoring ANWR development characterize existing North Slope oil development as a convincing example of sound environmental management

Figure 1 .—The Arctic National Wildlife Refuge: Its Relationship to Alaska and Location of the Coastal Plain



SOURCE: Arctic Slope Regional Corp., "The Arctic National Wildlife Refuge: Its People, Wildlife Resources, and Oil and Gas Potential," revised May 1987.

BOX A
THE COASTAL PLAIN OF THE ARCTIC NATIONAL WILDLIFE REFUGE

- Comprises 1.5 million acres of the19-million-acrw Arctic National Wdlife Refuge, established by the Alaska National Interest Lands Conservation Act of 1980 (ANILCA). Known as the "1002 area," a reference to Section 1002(b) of ANILCA, defining the coastal plain
- Located in the extreme northeast corner of Alaska; western edge 60 miles east of Prudhoe Bay, the Nation's largest oilfield; eastern edge 160 miles east of Prudhoe Bay and 30 miles west of the Canadian border
- Climate characterized by long, extremely cold winters and short, cool summers; persistent winds throughout the year; frequent blizzards in winter; precipitation light but frequent
- Not included in the 8 million acres of ANWR desinated as wildemess in 1980, but set aside by Congress for additional study by the Department of the Interior of oil and gas potential and of wildlife resources of the area
- Leasing or other activities leading to oil and gas production must be authorized by the U.S. Congress
- The Department of the Interior released its report in April 1987, recommending orderly oil and gas leasing of the area
- Knowledge of subsurface geology very limited, but located between known petroleum provinces in the United States and Canada, and the petroleum-bearing strata of both maybe present in the refuge
- Considered by the oil industy to be the most promising unexplored area in the United States for discovering supergiant oilfietds
- The Department of the Interior estimates there is a 19 percent chance of finding economically recoverable oil; if any recoverable oil is found, there is likely to be a mean of 3.23 billion barrels.
- Considered by environmentalists to have outstanding wilderness values and to be an especially important habitat for caribou, polar bears; musk oxen, and migrating birds
- The area is **a** prime calving ground for the approximately 200,000 caribou of the Porcupine caribou herd, which is present on the coastal plain from about mid-May to mid-July

Photo credit Arctic Slope Consulting Engineers

Winter on the coastal plain of the Arctic National Wildlife Refuge,

and proof that the Nation can obtain oil from the ANWR coastal plain without unduly disturbing its environmental values.

Through the terms of the legislation that established the Refuge, Congress has the final decision over whether the coastal plain can be leased for oil development. The ongoing congressional debate over the coastal plain's future has been informed by extensive hearing testimony as well as by a variety of analytical reports from executive and congressional branch agencies, industry, academia, and environmental organizations. Much of the testimony and reporting has focused on the potential environmental impacts that development would cause and the nature of the environmental "record" of previous oil development on the Alaskan North Slope.[1]

In this report, the Office of Technology Assessment (OTA) has not attempted to duplicate this information or to produce a complete assessment of all of the issues involved in Congress' decision about ANWR's future. In particular, we **have not** produced an environmental assessment of ANWR oil development. Instead, at the request of the Senate Committee on Energy and Natural Resources, the House Committee on Merchant Marine and Fisheries, and the OTA Technology Assessment Board, we have focused on two issues that will form a part of the congressional decision:

1. The nature of ANWR oilfield technology. To what extent would ANWR development look like existing development on the North Slope? Would the basic technologies and practices be the same or different?
2. ANWR's potential role in Alaskan oil production. How credible are recent projections of large declines in North Slope oil production in the 1990s?

1. Opposing views of the environmental record are presented in: '(Oil in the Arctic: The Environmental Record of Oil Development on Alaska's North Slope," Natural Resources Defense Council, Inc., January 1988; and "Current ANWR Environmental Issues, " The Standard Oil Co., August 1987.

ARCTIC OILFIELD DEVELOPMENT AND TECHNOLOGY

Overview

The technology and practices of Arctic oilfield exploration and development have undergone important changes in the years since the Prudhoe Bay oilfield was discovered and development began (see Box B for a brief description of the process of extracting oil and gas resources). Some important examples of technological changes include improved drilling rig design and operation, improved use of directional drilling (drilling at an angle off the vertical) to allow multiple wells on single gravel "pads" to drain oil from a greater area of the field; improved analytical techniques to design against well damage from permafrost thawing, allowing closer well spacing and thus smaller gravel pads and less coverage of the tundra; and improvements in the use of enhanced oil recovery technologies. These changes in technology and practices stemmed from three sources:

1. the pressure of designing to solve unique Arctic problems and adapting to the harsh Arctic environment,
2. the industry-wide technological changes stemming from the constant drive to improve capabilities and performance and reduce

BOX B
THE OIL Production CYCLE

The extraction of oil resources is commonly divided into three phases: (1) Exploration, (2) Development, and (3) Production. Exploration Includes seismic (acoustic) and other surveys to map the possible underground petroleum reservoirs as well as drilling exploratory wells to confirm the existence and location of an actual oil pool (the pool, or reservoir, is actually a mass of porous rock, with the oil stored in the rock pores)+ If oil is found,[1] further drilling is also necessary to delineate the size and extent of a reservoir and to determine whether it can be economically produced. Exploration is compieted when a decision is made to produce an oilfield or pool. Development is the process of building and installing all of the facilities, machinery and pipelines needed to produce whatever oil is discovered. On the North Slope, development begins with building airfields, roads, drilling pads, and construction camps. This is followed by drilling production wells; building modules containing machinery and processing plants and installing them on the site; building and installing pipelines and flow control equipment; and installing a myriad of machinery to support a complex network through which oil flows from a pool deep beneath the ground to the surface, is processed to yield crude oil and is pumped long distances to terminals for loading on tankers, Production begins when all development is completed and the facilities begin producing oil for the market. The production phase also jncludes maintenance of the facilities and the wells, drilling more wells to keep oil flowing and to keep the underground reservoirs operating smoothly, and installing special equipment for "enhanced oil recovery" to extract the oil left behind by the conventional production wells.

When the oilfields are large, as they are on the North Slope of Alaska: the machinery and facilities are large and extensive; thousands of people are invoived in both development and production; the development resembles a **major industrial** complex; and the process spans at least a few decades.

1, Or gas is found, Often, reservoirs contain both oil and gas, with the gas both in solution in the oil and in a separate "gas cap." On the North Slope, most of the produced gas is reinjected into the reservoir, both to maintain reservoir pressure (which helps the oil to flow) and to avoid having to dispose of the gas by flaring –at current prices, it is not economical to ship the gas to markets.

costs, as well as from fortuitous scientific advances in other industries (such as electronics), and

3. the special urgency to improve efficiency and reduce costs associated with the decline in oil prices beginning in 1981, especiallythe large price drop initiated in December 1985.[2]

OTA believes that the rate of change in Arctic technology and practices likely to be used for ANWR oil development may be more gradual in the future, primarily because some of the pressure for change has lessened. In particular, industry knowledge of how to operate efficiently in the onshore Arctic environment has matured considerably, and further advancement in knowledge should slow from its previous pace. In addition, basic physical conditions on the ANWR coastal plain, while not identical to the current North Slope development area, are quite similar and do not represent a new challenge to industry technology per se. Unless economic or regulatory conditions change, the industry is more likely to deploy systems that have been tried and tested under similar conditions than to take substantial risks in the development of new technologies. Therefore, we conclude that, **in the absence of new pressures,** ANWR **oilfield technology and practices will most likely resemble the technology and practices used at Kuparuk and Endicott, the latest North Slope fields, modified to fit the particular field characteristics encountered.**

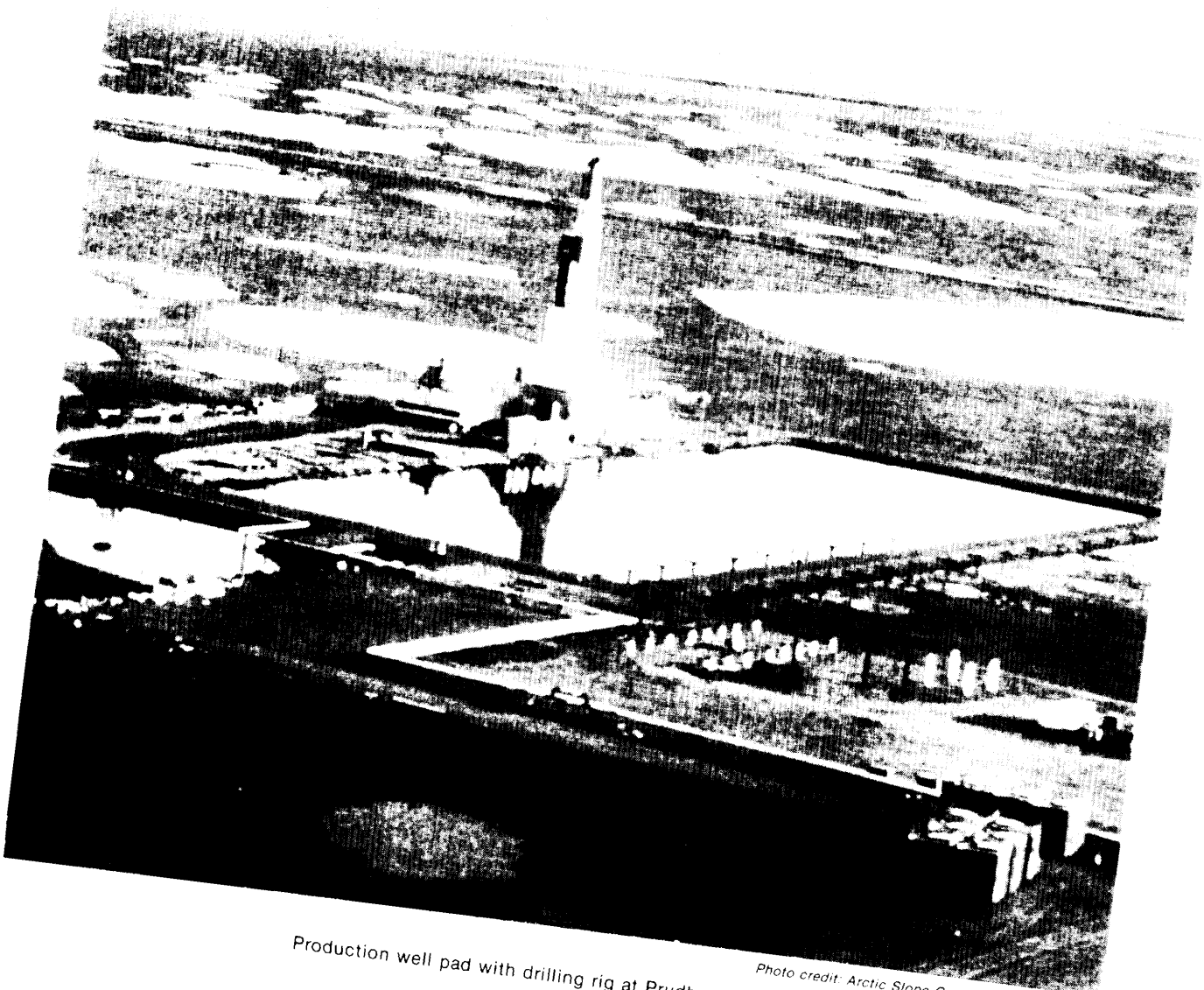
Of course, the constant incentive to lower costs will continue to drive innovation in the industry, and Arctic technology will continue to evolve. Promising areas for technological change include directional drilling, where advances continue to be made in offshore developments such as the North Sea, and enhanced oil recovery, where innovation will be driven by industry desire to boost the economic potential of fields throughout the United States and, on the North Slope, in fields such as West Sak. Also, an additional motivation for technological change could come from mw regulatory pressures. For ANWR oil exploration and development, this pressure could arise from dissatisfaction with current environmental performance at Prudhoe Bay and the other developed North Slope fields, or because the State and Federal authorities seek a higher standard of environmental protection at ANWR because of its status as a wildlife refuge. If this type of pressure arises, the most likely focus for changes in technology and practices would be in the area of waste management and habitat protection.

Conclusions

1. **The major differences between North Slope and Lower 48 conditions that affect the choice and use of oilfield technologies** are **the very cold weather, the presence of permafrost (ground which is permanently frozen except at the surface, which thaws during the Arctic summer), and the remoteness of the area.** Designs for technologies for operating at sub-zero temperatures draw heavily on advanced concepts in metallurgy, elastomers (elastic substances), lubricants, and fuels. The harsh and extremely cold environment also has demanded development of new survival systems and procedures to assure personnel safety. All drilling rigs and production facilities where people work are enclosed, insulated, and heated. Exterior steel structures are built from a special arctic-grade steel to prevent brittleness at very low temperatures. Most pipelines and flowiines are insulated, either to prevent water from freezing, to avoid increased viscosity of the crude oil, or to avoid permafrost melting. Shut-in flowlines are freeze-protected or evacuated and then filled with inert gas.

2. See U.S. Office of Technology Assessment, U.S. Oil Production: The Effect of Low Oil Prices - Special Report, OTA-E-348, (Washington, DC: U.S. Government Printing Office, August 1987).

3. In evaluating Arctic technology, OTA had to relyprimarilyon industry sources of data; there are few truly "independent" analysts with extensive knowledge of Arctic oilfield technology and production, and analysts in the Alaskan State agencies and Federal agencies such as the Minerals Management Service are also dependent on industry as their primary information source. This comment applies, as well, to our analysis of future North Slope oil production.



Production well pad with drilling rig at Prudhoe Bay.

Photo credit: Arctic Slope Consulting Engineers

To prevent the permafrost from melting and to provide a stable surface during the summer thaw, roads, buildings, pipelines, drilling pads, etc. are built atop thick gravel pads and/or elevated on supports. And because the harshness and remoteness of the North Slope make normal on-site construction methods difficult and expensive, major facilities are built in huge modules in the Lower *48* States, barged to the slope, and installed on prepared foundations.

2. Although the technologies and practices **used on the North Slope today have evolved considerably from those of the early** *'70s* **during the beginning of Prudhoe Bay development, the majority of changes have involved the adaptation of available practices and technologies to a new environment rather than the development of new technologies and practices.** The adaptations address the unique Arctic environment, as described above. Although this conclusion does not negate the importance of what the oil industry has achieved in Alaska – it has made tremendous strides– it is important in projecting future technological development, because it implies that future changes may come more slowly.

3. Most of Prudhoe Bay and the Trans Alaska Pipeline System (TAPS) have been in routine operation for some time. **The industry now believes that it has ascended most of the way up the "Arctic learning curve," that its technologies and practices for Arctic development are mature, efficient, and effective. Therefore, they see little need to change them for ANWR except to modify them to fit specific conditions found on the coastal plain (for example, the size, shape, depth, and location of any oil-bearing reservoirs discovered), and many in the industry foresee little likelihood that the technologies and practices will change significantly for ANWR development.**

4 **Although the ANWR physical environment is not precisely the same as that of Prudhoe Bay and the surrounding area, the differences do not appear to be large.** ANWR has more topographic relief than Prudhoe Bay, producing less standing water but more potential problems with channeling and erosion; there are fewer deep lakes there to serve as sources of fresh water; gravel conditions are about the same; and ANWR contains **a** few more port sites with deeper water near shore. None of the differences appear to challenge industry capabilities per se.

5. **At least a portion of the environmental effects associated with existing North Slope oil development should not automatically apply to ANWR. The capability now exists for reducing or eliminating some of the impacts reported for early Prudhoe Bay development. Newer North Slope fields such as Kuparuk and Endicott incorporate improvements in environmental management such as reduced requirements for surface usage and gravel, improved handling of oilfield service operations, and more attention to waste management.** These and other improvements are also likely to be used in any ANWR development and, if necessary, regulatory agencies could stipulate use of desirable practices as a condition of development. **Critics, however, have expressed continued serious concerns about several environmental issues because they believe that even the newest operations are still causing significant environmental damage.** Their principal concerns include disposal of resewe pit waste and of other solid and liquid wastes, air pollution, fresh water supply, monitoring of industry activities by resource agencies, and wildlife habitat alteration or destruction. Also, many groups argue that the environment of the ANWR coastal plain deserves greater protection than Prudhoe Bay because the coastal plain is part of a wildlife refuge. **These groups either oppose development outright or conclude that oilfield technologies and practices must change significantly from those used for current North Slope development if environmental values are to be protected properly.** OTA has not evaluated these issues in this report.

6. **If ANWR is leased and commercial quantities of oil are discovered, the period of development and production is not likely to be brief.** Examination of the development cycle of oil regions in the Lower **48** and around Prudhoe Bay shows that the life

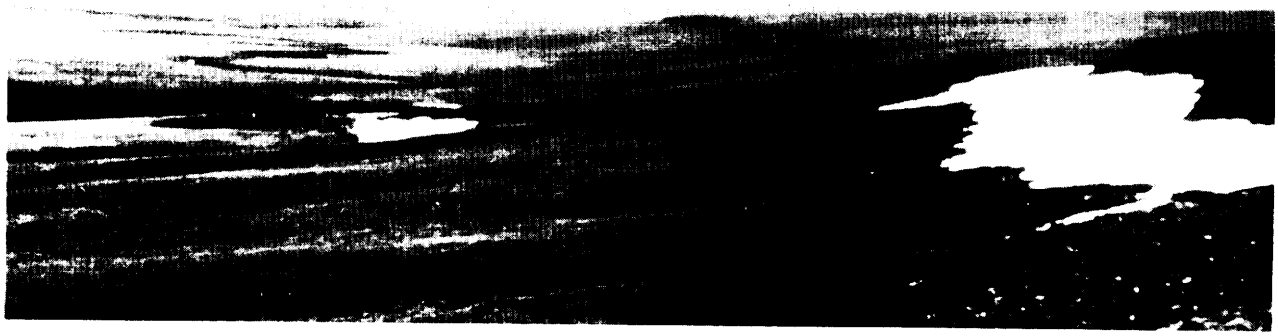


Photo credl(Standard A/aska

The Arctic National Wlldllfe Refuge Coastal Plal n. The terrain is rolling, whereas Prudhoe Bay to the west IS quite flat.

cycles of such regions are long and complex. Development of ANWR is likely to begin with exploration and development of large oilfields. With the development of an extensive infrastructure, however, further development will become economic, and exploration will focus on smaller fields. Also, opportunities for enhanced oil recovery, for the development of fringe areas of the large reservoirs, and for development of smaller reservoirs will extend high activity levels at the larger fields. In the long term, gas resources may be developed. This scenario implies an extensive and elaborate infrastructure, and thus a significant visual impact, coverage of the surface, and accompanying ecosystem impacts for at least 25 to 30 years. Although the industry argues--correctly--that actual coverage of the surface is likely to be less than 1 percent of the coastal plain, the physical coverage would be spread out somewhat like a spiderweb, and some further physical effects, like infiltration of road dust and changes in drainage patterns, will spread out from the land actually covered.

7. The detailed form of any future ANWR oilfield development cannot be predicted. Nevertheless, it is useful to postulate **a hypothetical scenario for the ANWR coastal plain:**

- Two fields would be discovered and developed:
  - one large: 3.0 billion barrels of oil recoverable
  - one small: 0.5 barrels of oil recoverable
- The largefield is one-third the size of the Prudhoe Bay oilfield, and the small field roughly the size of the Endicott oilfield.
- Production from these two ANWR oilfields would total 800,000 bbl/day -or 40 percent of current North Slope oil production.
- Facilities for two ANWR oilfields would include:
  - 800 wells on 14 gravel pads;
  - 3 major and 4 satellite production facilities; and
  - 2 airfields, 2 ports, 2 seawater treatment plants, and one industrial support center.
- Total gravel coverage including pads, roads, etc. is 3,000 to 4,000 acres.
- Total “footprint’ ’-including pipelines and other disturbances – is 5,000 to 7,000 acres.
- Total “sphere of infiuence” –denoting area where some secondary effects occur on certain sensitive species – is 150,000 to 300,000 acres.
- Hypothetical schedule:
  - Exploration - 1991 to 1999
  - Development - 1996 to 2006
  - Production - 2002 to 2030

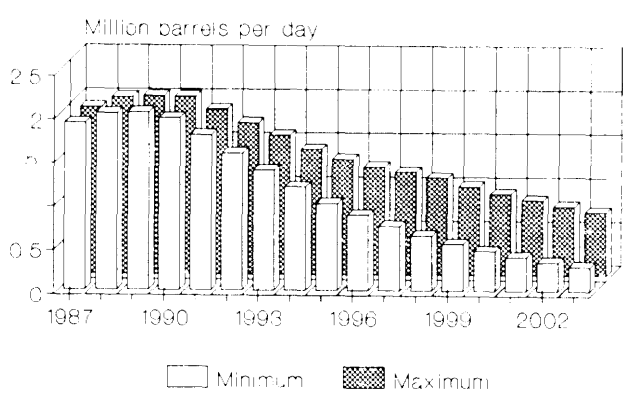
NORTH SLOPE OIL PRODUCTION

Overview

Today, the North Slope of Alaska provides about 2 million barrels per day (mmbd) of oil to the United States, nearly a quarter of total U.S. domestic crude oil production. Most projections of future North Slope production show a marked decline beginning around 1990 to 1991, with production falling to half of current levels or below by the year 2000 (see Figure 2). If production is not to fall, then it must come either from more intensive development of existing fields, from discovered but undeveloped fields, or from undiscovered resources. Based on the available evidence, additional production from more intensive development of existing fields and development of discovered but currently undeveloped fields is unlikely to **reverse the expected decline in North Slope oil production. Production from undiscovered resources is highly uncertain and would likely be more than a decade away even if discoveries were made this year.**

OTA notes, however, that the Prudhoe Bay operators have been able to push back the expected date for the onset of field decline several times, Although it is not clear how a strong production decline can be delayed for much longer, history suggests caution in entirely writing off the possibility.

Figure 2.-Projected TAPS Throughput



SOURCE: Alaska Department of Natural Resources, Division of Oil and Gas.

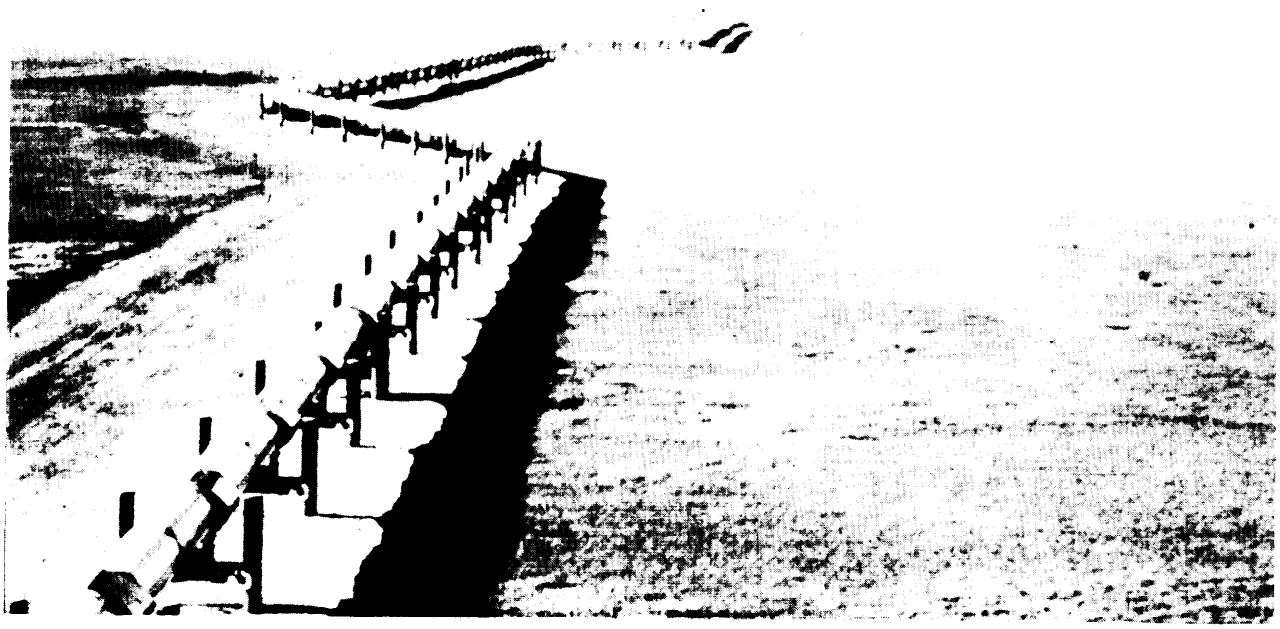
Conclusions

1. The current low oil prices raise the possibility that the oil companies on the North Slope might be foregoing opportunities for adding large increments of production and/or added recovery, waiting for economic conditions to improve. If this were true, then existing forecasts of future North Slope production might be missing the production boost that an improvement in economic conditions could bring about.

   Although low oil prices have affected the level of investment in new development on the North Slope, in general the large producing fields continue to be developed intensively. Despite the low prices, we could not identify any development opportunities being foregone that would make a large difference in future North Slope production. Thus, **higher oil prices may slow but are unlikely to stop the expected declines in North Slope oil production.**

2. Prospects for enhanced oil recovery (beyond that already in place or scheduled) in the discovered fields are good, but the increments of recovery and production from the available enhanced oil recovery (EOR) technologies will be small and will accrue over a long period. In other words, **there are no available or readily foreseeable technologies that promise to "turn around" expectations of declining production at Prudhoe Bay and other North Slope fields.** Table 1 describes the conditions affecting oil recovery in the discovered North Slope fields; Figure 3 shows the location of these fields,

3. Aside from additional recovery from the producing fields, increments of production must come from discovered but non-producing fields or from the undiscovered resource base.



Phofo credit .4merican Pefroleum Institute

A quarter of the United States' domestic production of crude oil flows through the Trans Alaska Pipeline System (TAPS)

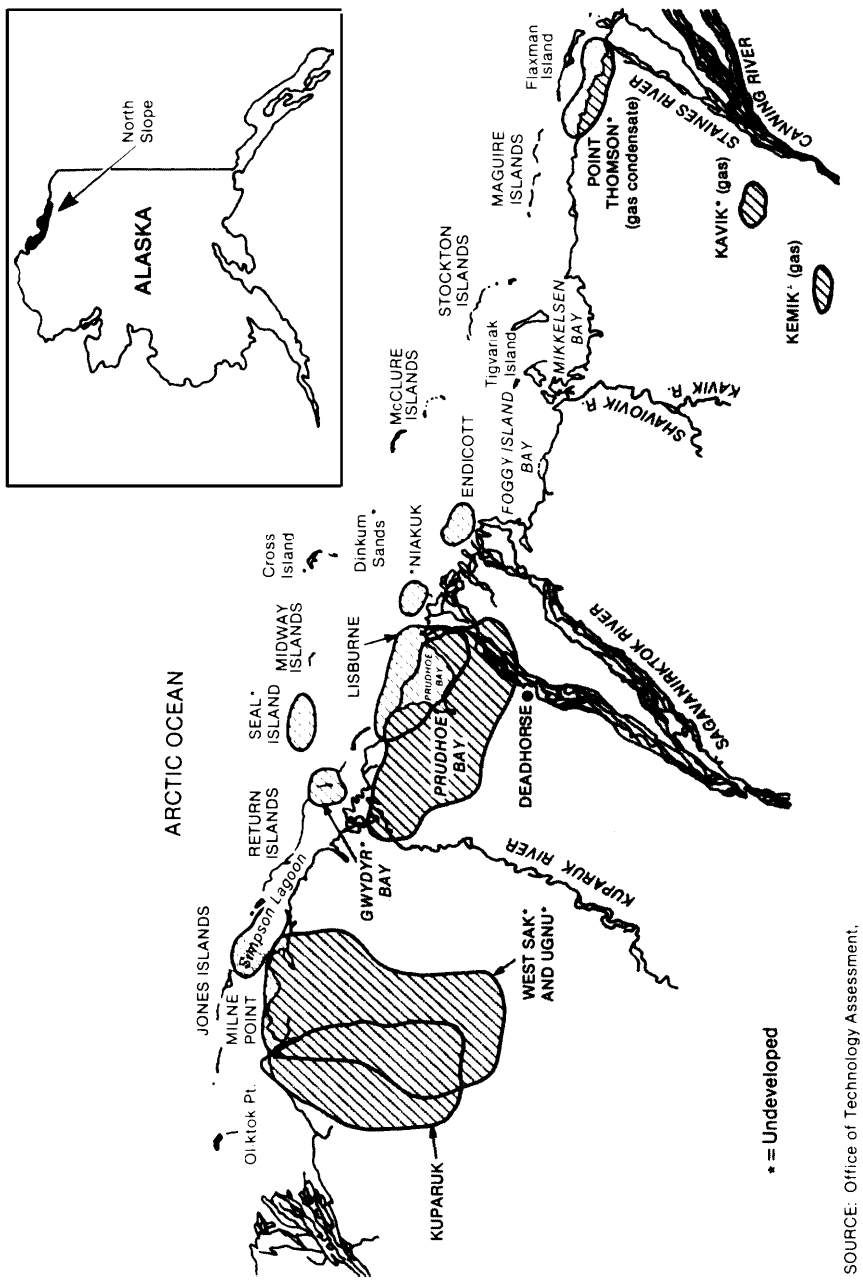


Figure 3.—North Slope Oilfields

SOURCE: Office of Technology Assessment.

a. The discovered but non-producing fields **do not have large volumes of recoverable resources** and cannot be expected to reverse the impending decline in oil flow through the Trans Alaska Pipeline System (TAPS).

b Although the West Sak field contains large in-place resources (at least 15 billion barrels), there are, as yet, no available technologies that can economically recover more than a small fraction of these resources. ARCO, the majority owner of this field, plans to begin a pilot drilling program soon, and hopes eventually to produce a few hundred thousand barrels per day from West Sak. Given the substantial technical problems remaining, however, large scale oil production from West Sak must be viewed as highly uncertain.

c. As for the undiscovered resources, recent exploration on the North Slope and offshore has been extremely disappointing. Afthough new **large discoveries cannot be ruled out, the prospects for such discoveries seem to have dimmed considerably.**

4 The industry appears to have made significant strides in controlling and reducing oilfield costs over the past few years. Part of the reduced costs are associated with reduced prices for basic oilfield services, and these lower prices are unlikely to be sustained for more than a few years. Part, however, appears to be the result of improved practices and design, and this should be sustained permanently. The industry now appears to be able to bring new fields on line and develop older fields more intensively at lower breakeven oil prices than just a few years ago. To the extent that production projections are

Table 1 .—Summary Field Data

Field	Remaining recoverable oil-1 /88	Estimated recoverable gas-1 /88	Recovery factor	Daily 011 production	Present EOR	Factors limiting production
Prudhoe Bay	4,100-6,000 million barrels	23 trillion cubic feet	42-45% of original in-place resources	1,550,000 barrels per day	Waterflood, miscible gas injection infill and horizontal drilling	Although a good performer, production will ultimately be limited by residual 011 saturation to waterflood
Kuparuk	600-1 100 million barrels	600 billion cubic feet	Approximately 30% of original in-place resources	300,000 barrels per day	Waterflood, mlsctble gas injection	Faulting, thin pay, and residual 011 saturation waterflood
Lisburne	280-580 million barrels	900 billion cubic feet	7-22% of original in-place resources	50,000 barrels per day	Small waterflood pilot is being tested	Difficulty of producing fractured limestone reservoir, low porosity and permeability
Endicott	270-445 million barrels	800 billion cubic feet	**35%** of original In-place resources	100,000 barrels per day	Waterflood	Faulting, gas handling ability in future
Milne Point	O-95 million barrels	None	Approximately 33% of original In-place resources	N/A: currently shut-in due to low price of oil	Waterflooding	Extensive faulting
West Sak	O-1 ,200 million barrels	None	O-5% of original In-place resources	N/A	Test only of heated waterflood	Poor (shaly) rock, unconsolldated. fine-gralned sand, VISCOUS, low temperature 011
Seal 'Island'	0-300 million barrels	?	Approximately 33%	N/A	N/A	7
Niakuk	55-75 million barrels	'?	Approximately 33%	N/A	N/A	?
Point Thomson	350 million barrels condensate (light grawty hydrocarbons)	5 trllion cubic feet	7	NIA	N/A	7

SOURCE Off Ice of Technology Assessment 1988

based on older costs, they maybe pessimistic. Also, because reserve projections and production rates are oil price dependent, higher oil prices in the mid to late 1990s could be expected to stimulate additional production. Thus, **the more optimistic of the current projections for North Slope production over the next** 15 **to** *20* **years are more likely to be accurate, especially if higher oil prices prevail. However, even the optimistic projections still foresee a large decline in the flow of oil through TAPS during the next decade and a half.**

5 The oil industry has over time tended to be overly pessimistic about prospects for future oil production, not only in Alaska but for the United States as a whole. Projections for the onset of decline in Prudhoe Bay production, for example, have been pushed back a number of times. And U.S. production, although down substantially since the oil price drop of 1985-1986, has not fallen nearly as severely as the industry had predicted immediately following the price drop. Although OTA could not identify a likely means to maintain North Slope production at levels much higher than the "high" curve in Figure 2, OTA is reluctant to totally rule out this possibility.

6. Estimates of the resource potential of ANWR are highly speculative, given that they are not based on extensive drilling data. 001's "best guess" of AlNWR's economically recoverable resources is based on available geologic and geophysical data and on a number of economic assumptions. Several factors lead OTA to conclude that **DOI's estimate of the likelihood of finding economically recoverable quantities of oil in ANWR may be conservative.** These factors are: 1) In its analysis, DOI assumed that the costs to develop ANWR will be similar to costs as detailed in the 1981 National Petroleum Council report on the Arctic. The oil companies have reduced their costs substantially since 1981, and these reductions do not appear to have been captured by the DOI assessment;4 *2)* DOI did not include the possibility that ANWR oil could be developed with two or three moderate-sized fields, even though no single field exceeds the minimum economic field size for a stand-alone field; and 3) Smaller potential oil prospects were not included in DOI's analysis. Even though these smaller prospects are not large enough to develop alone, some would likely be developed in association with a large prospect.

7. Many groups have either misinterpreted or misused DOI's estimate of ANWR'S economically recoverable resource potential. What DOI has concluded is that there is an 81 percent chance that no economically recoverable oil will be found in ANWR, but if ANWR contains any recoverable oil, a mean of 3.23 billion barrels is likely to exist. Estimates will change with acquisition of additional data, but geologic conditions for finding oil in ANWR are favorable, and industry considers a 19 percent probability of finding economically recoverable oil in any region to be good odds.

4. **Although some of the cost reduction may not be permanent, OTA believes that much of the savings will be retained even if drilling activity levels pick up.**