

# SCENARIO STRUCTURE AND RATIONALE

## PETROLEUM DEVELOPMENT IN THE EASTERN ALASKA ARCTIC, IN AND AROUND THE ANWR COASTAL PLAIN

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### SCENARIO ELEMENTS: SUMMARY

The following set of petroleum<sup>1</sup> development scenarios for the Sustainability Project center on, but are not confined to, the "1002 Area" of the Arctic National Wildlife Refuge [ANWR or Refuge].<sup>2</sup> The study area embraces Arctic Alaska east of the western boundary of ANWR,<sup>3</sup> including acreage under state of Alaska jurisdiction immediately offshore of ANWR.

The 40-year scenarios are not offered as predictions, but as "science fiction": stories combining the best available scientific information and a set of fictional assumptions to explore implications of a range of plausible outcomes. In each scenario, the locations and volumes of recoverable oil accumulations in and adjacent to ANWR, and the hypothetical sequence in which they would be discovered and produced, represent only a single run of a Monte Carlo simulation model. This model was based upon probability distributions for the occurrence of recoverable hydrocarbons, estimated by the US Geological Survey and published in 1998.<sup>4</sup> The Scenarios therefore do not purport to be composed of "expected" values, but only to be "plausible" in light of the USGS Assessment. Assumptions on field design and drilling and construction

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<sup>1</sup> "Petroleum" refers to naturally occurring, commercially recoverable fluid hydrocarbons, including crude oil, natural gas, and natural-gas liquids.

<sup>2</sup> The term "1002 Area" is a reference to Section 1002 of the 1980 Alaska National Interest Lands Conservation Act. The Act established ANWR, while section 1002 specified procedures for management and disposition of approximately 1.55 million acres of the Refuge's Arctic Coastal Plain.

<sup>3</sup> The Staines River, the most westerly branch in the Canning River at its Delta.

<sup>4</sup> US Geological Survey Fact Sheet FS-040098, "Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, 1998." The technical appendix to this Assessment — Open File Report 98-34 — was released only in April 1999, and its oil and gas resource estimates for 10 specific geological "plays" were thus not available to us at the time the scenarios were developed

practices are based on the most recent Alaska North Slope operations: Arco's most westerly Alpine development and BP Exploration's [BPX's] easternmost Badami development. The final Scenario hinges on assumptions about continuing trends in technology that reduce future development costs and surface impacts.

There are five scenarios representing successively greater extents of development. They are cumulative across time, each adding on to the prior scenario:

**Scenario 1: Drainage.** This scenario initially assumes continuation of the existing general ban on onshore petroleum leasing or development in the 1002 Area. Scenario 1 anticipates development of petroleum accumulations on onshore and offshore state leases surrounding the northwest corner of ANWR, pursuant to the established movement of oil industry activity eastward on the Arctic Slope from Prudhoe Bay. Scenario 1 assumes that some of these hydrocarbons pools will extend under both state and federal jurisdiction. In order to protect the federal government's royalty interest in such pools, Congress will accommodate limited surface development within ANWR of "borderline" formations. In this scenario, development is limited to a couple drill pads and connecting pipelines with all support facilities located on neighboring state onshore or offshore acreage.

**Scenario 2: ASRC Leases.** This scenario anticipates all activity included in the preceding scenario, plus some leasing and surface operations within the 1002 Area, confined to the Canning Delta, enclaves of Native mineral property near the village of Kaktovik, and intervening acreage north of 70°N. These developments are constructed and operated without any permanent road connection. An off-shore pipeline connects the drillsites to a processing center either on Flaxman Island or onshore state lands west of the Staines River.

**Scenario 3: Roads.** This is a variant of Scenario 2. Instead of ice-roads and an off-shore pipeline, this scenario includes an onshore pipeline corridor, alongside a permanent year-round highway, and other associated surface developments within the 1002 Area.

**Scenario 4: Full 1002 Leasing.** This scenario assumes all activity included in Scenario 3, plus eventual petroleum leasing, exploration and development throughout the 1002 Area. This activity would be subject to restrictions on surface impacts comparable to those that the Department of the Interior currently proposes for the National Petroleum Reserve in Alaska [NPRA].<sup>5</sup> The full leasing scenario includes development and commercial production of natural gas as well as crude oil.

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<sup>5</sup> "NPR-A Sale Plan Carries Heavy Restrictions," Oil & Gas Journal, August 24, 1998 [OR MMS DOCUMENT]

**Scenario 5: Maximum Extent.** This scenario is the same as Scenario 4, except that the spatial impacts modeled include the southeast uplands of the 1002 area where oil and gas prospects are unlikely.

To the extent permitted by public policy, the process of exploration and development in the study area would thus be a direct extension and analogue to the geographic expansion of petroleum activity that has been taking place in Alaska's Central Arctic<sup>6</sup> since crude-oil production began at Prudhoe Bay in 1977. This process is one of simultaneously working more intensively within, stepping out from, bypassing and/or picking up and filling in and between, already producing fields and their existing infrastructure.<sup>7</sup>

#### **LAND STATUS AND RESOURCE ASSESSMENTS**

We have used the following classification of lands, derived from a U.S. Geological Survey [USGS] report, for framing a plausible set of petroleum-development scenarios applicable to ANWR and related areas:

**1. The 1.57 million-acre "1002 Area" of ANWR's coastal plain contains some of the most prospective remaining targets for petroleum development in Arctic Alaska.**

However, federal law currently prohibits exploration, development, or production of hydrocarbons in the entire 1002 Area, including enclaves of private (Alaska Native) lands, pending specific approval by Congress. Geophysical surveys and test drilling have nevertheless taken place within and especially on the margins of ANWR in the past, and a number of exploration wells have been drilled on its perimeter. Data from such sources stand behind recent estimates of hydrocarbons resources published by the USGS. However, the information remains too meager within the 1002 Area itself to make confident location-specific forecasts of potential production or the investment outlay and activity necessary to develop such potentials.

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<sup>6</sup> Central Arctic refers to the territory along the Arctic Coast between the Colville and Canning Rivers. This region, which is mostly under state jurisdiction, contains Prudhoe Bay and virtually all of the existing petroleum investments and production on the North Slope. It is bounded by federal reservations to both the west and east: the National Petroleum Reserve in Alaska [NPRA] just west of the Colville and ANWR just east of the Canning. The westernmost field currently under active development in this region is ARCO's Alpine project in the Colville River delta, which is scheduled to begin production in 2000. The easternmost such development is BP's Badami project, which is about 35 miles west of the Canning River, and began producing in the Summer of 1998.

<sup>7</sup> "North Slope Focus Shifts from Halting Slide to Hiking Output," Oil & Gas Journal, August 24, 1998; "North Slope' Exploration Revival Targeting Satellites Near Giants," Oil & Gas Journal, August 31, 1998.

**2. The "1002 Area" includes about 97,000 acres in the vicinity of Kaktovik, on which the Arctic Slope Regional [Native] Corporation (ASRC) holds mineral title.** ASRC has leased most of this sub-surface estate to BP Exploration and Chevron, which drilled the "KIC" test well east of Barter Island. The surface, owned by Kaktovik Inupiat Corporation, is subject to the current Congressional prohibition against commercial oil and gas activity within the Refuge.

**3. State offshore acreage adjacent to ANWR-- 248 thousand total acres-- consists of a strip extending three miles from the shoreward boundary of the Refuge into the Arctic Ocean.**<sup>8</sup>

On the western end of this strip of submerged state acreage, two wells have been drilled and plugged without any announced commercial discovery. Another well has been drilled, plugged and abandoned on the east end of the study area, on a federal lease just outside the outer jurisdictional boundary and five miles northeast of the KIC well. A few miles north of the outer boundary between state and federal acreage, ten wells have been drilled on federal offshore leases, with two discoveries of potentially commercial resources.

**4. Survey and exploration activity on state lands immediately to the west of ANWR includes six wells within three miles and 19 wells within about 30 miles of the Refuge boundary and at least two announced discoveries of potentially commercial hydrocarbons.**

#### **The USGS ANWR 1002 Area Petroleum Assessment, 1998**

The study team constructed its ANWR petroleum-development Scenarios in the context of the land status and exploration history summarized above. These scenarios thus rest only on geological information that was in the public domain as of May 30, 1998, after release of USGS Fact Sheet FS-040-098, "Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, 1998."<sup>9</sup> While the USGS Assessment has not dictated the substance of the following scenarios, we have used it as an index of the plausibility of their assumptions.

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<sup>8</sup> In general, the inner boundary between federal and state jurisdiction tracks the chain of barrier islands parallel to the coast, and separates a regime of shallow water, frozen to the seabed during much of the year, from a regime of deeper water and moving ice. The outer jurisdictional boundary is typically three miles to the seaward of the inner boundary.

<sup>9</sup> The technical appendix, Open File Report 98-34, was not available at the time these scenarios were prepared.

Neither the present assumptions or future amendments to these assumptions, nor any of our inferences from them, should be treated as *forecasts* of future exploration activity in the study area, or the results of any such activity.

### Land Status and Classification, and Expected Recoverable Resources

The USGS divided its assessment area into four sectors for which its Fact Sheet reported the mean expected number of oil "accumulations"<sup>10</sup> and the volumes of technically recoverable oil by size class of accumulation. These four sectors are distinguished along two intersecting land status and geological dimensions. **Land status** was divided into "federal" jurisdiction (the 1002 Area, *less* ASRC lands) and "non-federal" (state offshore lands, *plus* ASRC mineral inholdings in the 1002 Area). The **geological** dichotomy was along the Marsh Creek Anticline, which separates "undeformed" (horizontal) formations to the north and west, and "deformed" (folded and fragmented) formations to the south and east. The anticline crosses the band of state offshore lands near the village of Kaktovik.

The USGS classification scheme allocates about one-third of the total acreage in the northwest corner of ANWR to the undeformed sector and the remaining two-thirds, including most of the ASRC lands, to the deformed sector. Table 1 below summarizes the USGS assessments of total technically recoverable crude-oil volumes, and volumes in accumulations of 256 million barrels or more, in each of the four sectors of the study area.

**Table 1. Mean Expectations of Technically Recoverable Oil by Land Status and Geological Sector, USGS 1998 ANWR Assessment**

Land Category	Study Area (Acres)	Study Area (Square Miles)	Percentage of Total Area	Technically Recoverable Oil (Million Barrels)	Percentage of Total Oil
Undeformed federal	431,360	674	24.1%	6,420	62.6%
Undeformed non-federal	172,032	269	9.6%	2,330	22.7%
Deformed federal	1,026,640	1,604	57.3%	1,250	12.2%
Deformed non-federal	142,432	223	8.0%	260	2.5%
<b>Total</b>	<b>1,771,464</b>	<b>2,769</b>	<b>100.0%</b>	<b>10,260</b>	<b>100%</b>
	<b>Recoverable Oil per Square Mile</b>	<b>Mean Number</b>	<b>Total Oil in Large Fields*</b>	<b>Oil per Large Field*</b>	<b>Thousand Barrels per</b>

<sup>10</sup> "Accumulation" is not precisely defined geologically or operationally anywhere in the USGS report. The term is used to denote either a pool or a group of adjoining or overlapping pools containing petroleum fluids (crude-oil, natural-gas liquids and/or natural gas), and appears to be equivalent to a "field" in traditional parlance of the American Petroleum Institute [API].

	(Thousand Barrels)	of Large Fields*	(Million Barrels)	(Million Barrels)	Square Mile in Large Fields*
Undeformed federal	9,525	6.8	3,970	587	5,890
Undeformed non-federal	8,668	2.8	1,560	567	5,804
Deformed federal	779	2.3	960	414	598
Deformed non-federal	1,168	0.1	220	2,200	989
<b>Total</b>	<b>3,705</b>	<b>12.0</b>	<b>6,710</b>	<b>559</b>	<b>2,423</b>

\* Accumulations of 256 million barrels or more.

### Relative Attractiveness of Study Area Sectors

The undeformed sector, which comprises only 33.7 percent of the study area, accounts for 85.3 percent of the recoverable oil assessment, and thus appears to contain the more attractive exploration targets. The USGS expected 9.6 large<sup>11</sup> crude-oil accumulations to exist in the undeformed sector, and only 2.6 in the much larger deformed sector. Stated differently, for each large oil accumulation expected in the undeformed sector, there existed 98 square miles in that sector. In contrast, each large oil accumulation expected in the deformed sector required 761 square miles in that sector. Likewise, the mean expected volume of recoverable oil per unit area in the undeformed sector is almost nine times the volume of oil expected in an equivalent area within the deformed sector.

The expected concentrations of oil do not differ significantly between the federal and non-federal parts of the undeformed sector, as measured by either the expected number of accumulations per unit area or the volumes of recoverable oil per unit area.<sup>12</sup> Moreover, because the existing stock of geophysical and geological information is much richer on the non-federal than on the federal part of the USGS study area, it is reasonable to infer that:

- Independently of their legal status, the undeformed sectors contain the more promising exploration targets for oil; (the April 1999 USGS Open File Report discloses that the deformed area is substantially more prospective for gas than for oil);
- This assessment is presumably more reliable for the non-federal (i.e., state offshore) part of the undeformed sector than for the federal, because of the richer geophysical

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<sup>11</sup> Here, "large" means 256 million or more technically recoverable barrels.

<sup>12</sup> Despite the contrasting geological characteristics, the USGS did not report a significant difference between the deformed and undeformed sectors in mean size or distribution of sizes of oil accumulations. The mean size of accumulations of 256 million barrels or more is 581 million barrels in the undeformed sector and 488 million barrels in the deformed sector.

- information base and because of the existence of two test wells on the undeformed portion of the offshore state strip;
- Within the federal (i.e., ANWR) part of the undeformed sector, the USGS assessment is most reliable in the northwesterly corner—the Canning River Delta.<sup>13</sup>
  - On balance, the most attractive petroleum exploration targets in the entire study area are likely to be the Canning Delta and its immediate vicinity, both within and outside ANWR.

### **Apparent Pessimism in USGS Assessment of Economically Recoverable Oil Resources**

The USGS assessed the expected volume of "technically recoverable" resources in the total study area at 10.3 billion barrels, with a 95 percent probability the actual value is at least 5.7 billion barrels and a 5 percent probability that it is 16.0 billion barrels or more. Of the expected 10.3 billion technically recoverable barrels, moreover, only 6.8 billion barrels are expected to be found in accumulations containing at least the deemed "minimum commercially recoverable field size" of 512 million barrels.<sup>14</sup>

More notably yet, the USGS estimates that no crude oil from the study area would be "economically recoverable" at a West Coast crude-oil market price of \$15 per barrel or less (1996 dollars), and that only 3.3 billion of the 10.3 billion technically recoverable barrels would be economically recoverable at a price of \$20. After averaging about \$11 in 1998, reported West Coast prices for Alaska North Slope [ANS] crude oil fell to \$9 in early 1999, rebounding to about \$16 in mid-May. Some analysts expect even higher prices over the next year or so.<sup>15</sup>

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<sup>13</sup> The Delta is roughly a right triangle of less than 100,000 acres with its apex at Brownlow Point, bounded on its two legs by zones rich with geological information, including discoveries of at least three hydrocarbons accumulations in six wells on state onshore acreage within about three miles of the ANWR boundary, as well as from the greater geophysical survey data relating to the area.

<sup>14</sup> USGS describes 512 million barrels as a "conservative" threshold of commercial feasibility for the undeformed sector, and notes that "development of fields as small as 150 MMBO recoverable is occurring." The undeformed zone "is relatively confined geographically, so that much smaller accumulations (as small as 100 MMBO) may be commercial if they can be developed jointly with other accumulations or as satellite fields. For the deformed zone, however, "considerable uncertainty exists about using a similar 512-MMBO minimum field size," because the dispersion of development targets deprives them of the benefits of such economies of scale.

<sup>15</sup> Analyst Philip Verleger, usually viewed as an oil-price bear, ". . . can see crude prices rising to the mid-to-upper \$20s by late 1999." Prices may, he believes, "remain high for 12-18 months." [Patrick Crow, "Bullish on Oil," *Oil & Gas Journal*, 3 May 1999, page 52.]

Nevertheless, we are not aware of any mainstream forecasting authorities that now anticipate long-term delivered prices for ANS crude oil greater than \$15.

**Taken at face value, the USGS assessment implies only a small probability that any crude-oil resources at all will be developed or produced, from or immediately offshore of the ANWR 1002 Area.** In particular, the study seems to rule out the discovery of "Prudhoe-size" accumulations of economically recoverable crude oil, i.e., ultimate reserves on the order of, say, 10 billion barrels. Combined with statements referenced above about the probable geographic distribution of crude-oil accumulations within the study area, it is now reasonable to infer from the USGS assessment that little or no commercially recoverable crude oil will be found and developed on ASRC acreage or elsewhere in the deformed sector.

### **Countervailing Considerations**

Even in the face of these adverse implications of the recent USGS Assessment, the following considerations arguably justify supposing that some development of petroleum resources in or near ANWR is at least a plausible outlook. Using the USGS Assessment as a guide to order-of-magnitude quantities and more-or-less likely discovery locations, we regard the following observations as relevant.

- **Experience over the last 25 years demonstrates that both prices and long-term price expectations are capable of changing dramatically in a very short time.**
- Since ANS crude oil began flowing in 1977, almost all reputable forecasting organizations have *consistently under-forecast ANS production volumes* for any given future year. **Also, forecasters have consistently overestimated the constant-dollar prices necessary to evoke the production volumes that actually occurred.**
- Criteria for "economic recoverability" in the 1998 USGS assessment were based upon technologies of exploration, development, and production, and input prices that prevailed in the mid-1990s. Technical progress in Arctic oil operations since the commencement of production at Prudhoe Bay has steadily reduced average input costs to exploration, development, and production.<sup>16</sup>
- The USGS assumes a minimum economically viable field size of 512 million barrels, which it characterizes as "conservative" in the undeformed zones and other than conservative in the deformed zones. However, the smallest discrete reserves accumulations now being produced in Alaska's Central Arctic are already in the range

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<sup>16</sup> Note that continuing advances in petroleum exploration and extraction technology for the Arctic would not improve the economics of Alaska North Slope hydrocarbons production if they simply mirrored trends that reduced costs and expanded supply globally.

of 100-million barrels or less. The USGS Assessment points out that accumulations as small as 5 million bbl can be developed commercially as “satellites” to larger accumulations with which they share infrastructure investments.

- The USGS Assessment reported a significant potential for natural gas in the eastern portion of the study area. Large natural gas resources remain shut in or undeveloped in Alaska's Central Arctic region to the west and the Mackenzie Delta to the east because of remoteness from markets and high projected transport costs. There is no reason to assume *a priori* that the commercial gas potential of the North Slope, including ANWR, will permanently remain unattractive.
- It is at least plausible to anticipate an ultimate sharing of pipeline access for oil and/or gas between the eastern Alaska Arctic (ANWR and vicinity) and Canada's Beaufort Sea and Mackenzie Delta areas, where substantial reserves have been discovered and confirmed but remain undeveloped or shut-in because of distance from markets or the lack of threshold volumes to justify an export pipeline.<sup>17</sup> Because of transport economies of scale, such facilities sharing could be expected to increase netback values at the point of production in ANWR.
- The persistence with which segments of the oil industry advocate opening ANWR for petroleum exploration and development suggests that a significant part of industry opinion has a more optimistic economic appraisal of the area's petroleum potential than can be inferred from the USGS Assessment. The differences in outlook likely include but need not be limited to those we have listed here.

### **"Least Implausible" Development Scenarios**

The USGS assessment suggests that the least implausible targets of major industry investment in exploration, the least unlikely locations of commercial crude-oil discoveries, and the *least improbable* new locations of economic hydrocarbons production are:

- Onshore ANWR lands of the undeformed geological sector in the Canning River Delta, which are adjacent to Point Thomson and Sourdough discoveries on state leases immediately to the west; and
- State leases on the undeformed geological sector offshore of the Canning River Delta, along Camden Bay, and the federal offshore leases even farther north.

Further exploration, discovery of technically recoverable petroleum, and economic production in this area in the foreseeable future would constitute a direct extension of the industry's fifteen-year eastward movement from Prudhoe Bay. The assumed sequence of petroleum activity for this study is based on the investigators' general understanding of the regional geology and

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<sup>17</sup> Official estimates of recoverable oil and gas reserves discovered in the Mackenzie Delta and Canadian Beaufort Sea through 1997 are about 2 billion barrels of and 24 trillion cubic feet of gas.

economic geography of the North Slope, and the recognition that new activity based on acreage under state jurisdiction might penetrate promising structures within ANWR without requiring direct access to ANWR surface acreage for physical access, staging, or for removal of product.

If the northwest corner of ANWR is exceptionally prospective for commercial crude-oil resources, discoveries and development on adjacent state lease are likely to result in "drainage" of pools that extend under federal lands within ANWR. Such a course of events would threaten a loss of prospective federal royalties and, in turn, materially increase the prospect that Congress would authorize limited exploration and development activity on and especially *under* ANWR in and near the Canning Delta,<sup>18</sup> without agreeing to a general change in federal policy toward the Refuge. This speculation gains particular strength from indications that the Delta itself is outside the prime summer migration and calving range of the Porcupine caribou herd.

The deformed zone of the 1002 Area seems much less promising for major new exploration activity or for discovery of economically recoverable hydrocarbons. This is particularly the case absent or prior to any industry decision regarding "commercialization" of natural gas from

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<sup>18</sup> The significance of possible "drainage" of oil on federal lands from wells on state land arises from the common-law "Rule of Capture," which governs ownership of oil and gas. Ownership of produced petroleum is determined by the ownership and location of the well that brings it to the surface, rather than by the ownership of the lands under which it may have resided prior to production. Where an oil pool straddles the boundary between state and federal lands, therefore, all of the oil produced from a well drilled under authority of a state mineral lease normally belongs to the operator(s) of that well. Royalties from producing the pool would go to the state under these circumstances. This would be the case even if a significant part of the produced oil had earlier resided under federal acreage and was subsequently "sucked up" by the state-authorized well, thereby permanently depriving the federal government of royalties and other leasing revenues from the resource. It should be noted that this rule does not authorize a driller to direct its wells beneath property not owned or leased by it in order to drain oil from under that property.

To protect its interest in the potential revenue from such pools, the federal government would normally lease the affected acreage on its own side of the boundary, so a federal lessee could "sever" the resource from the ground on federal property, and thereby confirm the federal government's claim to the oil (or more precisely, its royalty interest in the oil). If all the resources in question (including resources on federal lands) were under state of Alaska "conservation" jurisdiction, the affected parties could be expected to join in a "unit agreement" approved by the Alaska Oil and Gas Conservation Commission, whereby they would operate the entire pool essentially as a tenancy in common, and allocate rights and obligations in the unit to the various parties according to their respective holdings in acreage covering the pool. However, the legal prohibition on leasing or production of hydrocarbons in ANWR now deprives the federal government of either of the two means of assuring itself of a revenue share proportionate to its acreage position.

Prudhoe Bay and other gas sources in Arctic Alaska.<sup>19</sup> It is in this sequence of declining practical and political attractiveness that the investigators have stratified the scenarios.

## **DRILLING AND CONSTRUCTION PRACTICE**

The various Scenarios assume that field practices will continue to reflect recent trends in Arctic Alaska, wherein the land area occupied or altered, and the mass of material introduced, employed, and removed from development sites, has steadily declined. Surface impacts of development per unit of production will not in any case exceed those characterizing the most recent (1996-99) ANS operations at Arco's most westerly "Alpine" development and BPX's easternmost "Badami" development. Salient features include —

- Directional and horizontal drilling and well completion, and the shrinking of wellsite and support-function "footprints," mean that 20 wells on a single 5-to-10-acre surface pad are now capable of draining oil reservoirs under a 6-10,000 acre surface area.
- Muds and cuttings from such sites can be injected into subsurface formations, rather than discharged into lakes and streams, or accumulated in holding structures and exported from the site.
- Three-phase (oil, gas, water) pipelines are (or within the time scale contemplated in these scenarios, will be) capable of consolidating hydrocarbons processing functions at a single location for wellsites within a radius up to 25 miles.
- No gravel or other permanent roads are (or within the time scale contemplated in these scenarios, will be) technically indispensable for equipping, servicing or supplying such wellsites or processing centers, or for the construction and servicing of pipelines.<sup>20</sup>
- Pipelines are (or within the time scale contemplated in these scenarios, will be) capable of placement by directional drilling and operated underground for sufficient distances to span the width of most river crossings in Arctic Alaska.

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<sup>19</sup> By "commercialization" we mean the transport and sale of natural gas from Arctic Alaska either as pipeline gas, LNG, other liquid fuel products. Depending upon their design, transport and conversion facilities from Prudhoe Bay and nearby accumulations are likely create a viable market for natural gas produced from (say) Point Thomson, ANWR, and/or Canada's Mackenzie Delta. Moreover, to the extent that a gas-commercialization project is subject to economies of scale, its economic viability is likely to depend upon aggregating the largest feasible supply. (See Arlon R. Tussing and Samuel A. Van Vactor, *Viability of Natural Gas Projects for Northeast Asia: Fundamental Principles and Practical Considerations*, at Fourth International Conference on Northeast Asian Natural-Gas Pipelines, Ulaanbaatar, Mongolia, 16-18 August, 1998)

<sup>20</sup> Choices typically exist between aviation, permanent roads, and ice routes for establishing and servicing new wells and other facilities in Arctic Alaska. The balance of costs among these options in each instance will differ according to local conditions and, above all, the distance from the established service infrastructure. Clearly, however, the trend is toward smaller and more self-contained modules or enclaves for new development sites, and consequent reductions in road construction, gravel requirements, and in the use of automobiles and trucks to move personnel and materials.

- Pipelines can be placed and maintained for reaches of 25 miles or more under shallow Arctic waters and on Arctic barrier islands such as those that define much of the inner of the two boundaries between federal and state jurisdiction offshore of ANWR, albeit at materially higher costs than across tundra.

It is reasonable to assume that industry operators will in general prefer as more economical those practices which minimize land-use and materials requirements, such as for gravel, steel or cement pads as roads and as bases or footings for structures. Temporary or quasi-permanent ice structures increasingly serve as substitutes in many of these applications.

We also assume that location of permanent roads, airfields, staging areas, or personnel accommodations at or adjacent to production sites will not be primarily the result of technical or economic necessity or the preferences of operators. **Rather, we anticipate that such scenario elements, if incorporated, will be chosen to serve non-petroleum development or social objectives, and will often reflect the preferences of parties other than oil and gas operators.**

#### **DETAILED SEQUENCE OF ACTIVITIES AND EVENTS**

Investment, production, and revenue assumptions in all Scenarios will build upon the most recent projections for Arctic Alaska of responsible Alaska state agencies, which do not assume any hydrocarbons investment, employment, production or revenues originating east of the Canning River. These projections serve as the base from which the scenarios cumulate values for Scenarios 1, 2, 3 and 4.

#### **Scenario 1: Drainage of Pools Underlying the ANWR Border**

We anticipate that industry will continue to extend and interpolate exploration, development and production in the Central Arctic, on the same pattern that has prevailed since the mid-1980s.<sup>21</sup> For purposes of this study, we assume that, beginning in **Year 1**, petroleum development commences in the vicinity of the Canning River Delta on state onshore acreage immediately west of ANWR, and on state offshore acreage immediately north of ANWR. Activity outside ANWR involves 5-acre offshore island drill pads, and a three-phase undersea pipeline along the

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<sup>21</sup> “Alaskan North Slope Operators Shift Focus from Stemming Decline to Hiking Production,” Oil & Gas Journal, August 24, 1998, and “North Slope’s Exploration Revival Targeting Satellites Near Giants,” Oil & Gas Journal, August 24, 1998. Also, Arlon R. Tussing and Linda Leask, “The Changing Oil Industry: Will it Affect Oil Prices?” University of Alaska-Anchorage, Institute of Social and Economic Research, Fiscal Policy Papers, May 1999

Arctic barrier islands that constitute the inner state-federal jurisdictional. This pipeline will connect the drillsites to a processing center either on Flaxman Island or onshore state lands west of the Staines River. These facilities will be constructed and equipped entirely without support from, of alteration of, the onshore surface of ANWR.

In this scenario, four oil and gas accumulations straddle the boundary between ANWR and state offshore or onshore acreage. These accumulations are initially developed exclusively from wells on state leases, but wells drilled on state acreage outside the Refuge boundaries are expected to drain pools that extend under it.<sup>22</sup> The operators of these leases would inform the appropriate state and federal agencies that one or more of the pools from which they intend to produce crude oil extend(s) onshore under ANWR, and that some wells completed entirely within the offshore lease areas may be expected to drain federal resources. The various parties would thereupon negotiate an interim agreement under which the Interior Department yielded oil and gas conservation jurisdiction over the structures influenced by these wells to the Alaska Oil and Gas Conservation Commission [AOGCC]. We assume that the federal Government agrees not to take any action that interferes with the planned offshore development, in return for an imputed royalty interest in a negotiated proportion of the oil produced from the designated pools. For royalty and tax purposes, this oil will be treated as if it were produced from onshore federal mineral leases under otherwise applicable laws.

In **Year 3**, this Scenario assumes that Congress authorizes **limited petroleum-related surface activity within ANWR in connection with "drainage" sales along the Refuge boundaries**, for the purpose of protecting the federal royalty interest in oil and gas occurring in such pools. Actual development and production under this provision would occur only in the extreme northwest corner of ANWR — essentially within the Canning River Delta as shown on the map of "ANWR Development Scenario No. 1." Two additional borderline accumulations are developed from wells on the Canning River Delta within ANWR.

The assumed legislation would also authorize the Interior Department to **issue permits for seismic surveys** in the undeformed sector of the 1002 Area up to ten kilometers from its northern and western boundaries, and farther if necessary to delineate oil or gas pools that might straddle the Refuge boundary. It also authorizes the Interior Department to **lease 1002 Area acreage that is subject to or threatened with drainage** from production on non-federal

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<sup>22</sup> Field development of pools extending under ANWR from onshore state acreage west of the Staines River commences in **Year 1**. Field development of pools extending under ANWR from offshore state acreage North of the Canning River Delta commences in **Year 2**.

lands. All such leases would be issued competitively, and Alaska would receive 50 percent of leasing proceeds from them.<sup>23</sup> The legislation would also permit drilling of wells and construction of pipelines within the 1002 Area, to the extent they are necessary in order to produce and conserve such resources. Permanent roads, drill pads and processing or service sites of greater than 20 acres, and facilities for overnight lodging of personnel, other than for safety, security or environmental-protection, would still be prohibited within the 1002 Area without specific Congressional approval.

The Interior Department subsequently authorizes directional drilling under ANWR. to produce crude oil from ANWR acreage at the existing drillpads on state leases to the west and north of the Canning Delta. It also authorizes drilling from two well sites within ANWR, and onshore pipelines to connect these wells with processing facilities on state land west of the Canning River.<sup>24</sup>

Production under this scenario is sustained through the end of the 40 year period.<sup>25</sup>

### **Scenario 2: Leasing of ASRC Holdings, the Canning Delta, and North of 70°**

Scenario 2 continues this hypothetical chain of events and extends the scope of development. In reaction to exploration success in and adjacent to the northwest corner of ANWR and seemingly minimal wildlife impacts associated with these operations, Scenario 2 assumes additional legislation authorizing partial opening of additional ANWR acreage to oil and gas activity. Specifically, in **Year 5**, Congress permits renewed seismic exploration, followed by

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<sup>23</sup> This arrangement waives the present statutory requirement for competitive leasing of onshore public lands that the acreage to be leased be on the "known geological structure ['KGS'] of a producing well." Under the legislation permitting ANWR leases, Alaska would receive only the 50 percent of bonus, rental, and royalty proceeds that other states receive from onshore federal leases, as opposed to the 90 percent share established in the Alaska Statehood Act.

<sup>24</sup> Additional seismic surveys covering the strip 10 kilometers within boundaries of ANWR on the Canning Delta are completed by **Year 4**; directional development drilling under ANWR commences from off-Refuge sites in Year 4 and from sites in the Canning River Delta in **Year 5**.

<sup>25</sup> Projections for relevant variables under the various scenarios, such as exploration and development investment, oil and gas production and value, state and local revenue, population and employment, extend over a scenario period of 40 years. However, on the basis of experience from the Lower 48 that commercial hydrocarbons production, once commenced, will continue for 100 years or more in specific accumulations, and certainly in the study area as a whole. See, David B. Hatcher and Arlon R. Tussing, "Prospects for Alaska's North Slope Oil Fields and the Fiscal Implications for the North Slope Borough," Seattle: ARTA Inc. for Societe Generale, 1995. Adapted as, "Long Reserve Lives Sustain Prospect for Independents in Lower 48," Oil and Gas Journal, 24 November 1997.

onshore oil and gas leasing, exploration and development drilling, attendant onshore surface activity (including construction), and production of hydrocarbons, on the following additional portions of the 1002 Area:

- The remainder of the Canning River Delta, as shown on Map 2;
- Mineral inholdings of the Arctic Slope Regional Corporation [ASRC];<sup>26</sup>
- Intervening ANWR acreage north of latitude 70° N, such as along Camden Bay; plus
- Any additional acreage that is prospectively subject to drainage either from non-federal acreage from federal acreage in the preceding categories.

On the basis of this authority, we assume that three additional commercial hydrocarbons deposits are discovered, developed and produced in the Canning River Delta area. Petroleum discoveries with a higher proportion of natural gas, subsequently occur in the eastern portion of the 1002 Area on lands whose mineral estate is held by ASRC and on adjacent federal acreage leased under the legislation's drainage provisions. Discoveries and developments that occur under this scenario include a (hypothetical) major accumulation of oil and gas southeast of Kaktovik, based on discoveries from ASRC acreage and ultimately involving both ASRC and federal mineral properties.

In this scenario, oil from developments in the eastern part of the 1002 Area are transported from the area by means of an offshore pipeline. Gas remains undeveloped.

### **Scenario 3: Roads and On-shore Facilities**

In this scenario, a new east-to-west pipeline corridor and a parallel all-weather highway are built across ANWR to facilitate development and marketing of hydrocarbons from wells on and near the ASRC inholdings. The scenario assumes that the legislation authorizing development of ASRC lands also authorizes:

1. An onshore oil-and-gas pipeline corridor from the Kaktovik area; (in place of the offshore pipeline assumed in Scenario 2, this corridor would become the chief route for removal or transit of oil from or across the Refuge+;
2. A parallel year-round highway extending from the eastern fields and Kaktovik, to the western boundary of ANWR (connecting with petroleum transport facilities and the North Slope haul road, respectively, near Prudhoe Bay);

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<sup>26</sup> ASRC is a for-profit Alaska Native regional corporation established under the Alaska Native Claims Settlement Act of 1981 [ANCSA].

3. a state-owned jet-capable regional airport near Kaktovik; and
4. associated Kaktovik Inupiat Corporation-owned industrial, commercial and transient-accommodation facilities adjacent to the airport.

These developments are not motivated by technical or economic necessity or preferences of the operators. Rather, we assume these facilities are chosen and sited to serve regional social and economic objectives, as well as to allay concerns about the marine environment.

#### **Scenario 4: Gas Commercialization and Leasing Throughout the 1002 Area**

In Scenarios 1 through 3, any natural gas discovered in the course of oil and gas exploration and development not used on ANS leases continued to be reinjected or (in the case of nonassociated gas) shut in. Scenario 4, however, introduces commercialization of gas along with leasing throughout the 1002 Area.

In **Year 5**, ANS gas producers, other private investors, the State of Alaska, and ASRC will also agree upon a "commercialization" system<sup>27</sup> and associated financial arrangements for natural gas produced at Prudhoe Bay and other accumulations in the Central Arctic. To capture potential economies of scale, this system would be designed to gather natural gas produced from Point Thomson and other sources east of Prudhoe Bay, including ANWR and perhaps as far east as Canada's Mackenzie Delta.<sup>28,29</sup> Accordingly, Scenario 4 involves development and commercial production of natural gas in the ANWR study area, chiefly in the disturbed sector south and east of Kaktovik.

However, we assume that natural gas production and sale from ANWR is deemed to be economically marginal. Under the fiscal incentive arrangements negotiated by state government, we assume that separate arrangements and accounts would be established for facilities and

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<sup>27</sup> Examples of such a gas-commercialization system include (1) transport of gas by pipeline from a hub near Prudhoe Bay to an LNG terminal on Prince William Sound, Cook Inlet, or the Chukchi Sea; or (2) conversion to hydrocarbon (i.e., naphtha or diesel) or oxygenate (e.g., methanol or MTBE) liquids on the North Slope for transport through the existing TAPS oil pipeline. Alaska State law permits negotiation of unconventional fiscal (tax, royalty, etc.) arrangements as incentives for investment in such a system.

<sup>28</sup> Conceivably, this corridor could be the vehicle for shipment of oil or gas produced in Canada to processing or export facilities in the Prudhoe Bay area, or for oil or gas produced in the eastern Alaska Arctic to processing or transport facilities in Canada.

<sup>29</sup> We assume that agreement is reached on a system and financing in **Year 5**, and that the facilities could be in service to receive gas by **Year 12**.

operation of the commercialization project east of the Canning River. Natural gas production from this sector might be physically substantial, but should not be expected to produce significant economic rent for the state, the North Slope Borough or for ASRC in the form of royalties, or production and property taxes.<sup>30</sup>

New legislation in **Year 10** permits the search for and production of smaller, more elusive, and previously sub-marginal oil and gas accumulations throughout the 1002 Area. This added activity would occur under the assumption that, and only after such time as:

- Virtually the entire stock of "technically recoverable" oil and gas in pools of 64 million barrels<sup>31</sup> or more within the 1002 Area and the adjacent state offshore acreage is capable of being extracted profitably, even if expected energy prices remained materially below those that prevailed during the 1990s; and
- Demonstrated advances in petroleum development and production technique are capable of reducing incremental surface disturbance and artificial cover, and other predictable environmental impacts attendant on this process, to levels deemed compatible with the Refuge, and are otherwise politically acceptable.

On these premises, Congress would authorize the Interior Department to permit leasing exploration, development, and production on acreage that is believed to contain the bulk of the expected technically recoverable oil and gas resources, elsewhere on the ANWR coastal plain. However, in implementing this authority, we assume that the Interior Department's leasing and permitting activity will be conditioned on the ability to operate without intolerable adverse foreseeable location-specific surface impacts.<sup>32</sup> Such activity would thus not necessarily require or imply leasing of the entire ANWR Coastal Plain, or imply either actual drilling or petroleum-related construction on more than a very small (less than one percent) of the leased acreage. The pending leasing and production proposal for NPRA is a prototype for such a program.<sup>33</sup>

Under Scenario 4 the Interior Department would lease ANWR acreage holding one half of the expected unleased recoverable oil and gas in five such sales at four-year intervals. We anticipate that such a staged leasing program for the 1002 Area would enable a search for and

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<sup>30</sup> ASRC would, however, seek to profit through its direct investment in the commercialization project. The North Slope Borough could expect enlargement of its property-tax base associated with new pipelines and processing facilities built within the Borough, west of ANWR.

<sup>31</sup> Figures include natural gas in thermal equivalents of crude oil.

<sup>32</sup> For example, activity of personnel and equipment in times and places of concentrated caribou calving.

<sup>33</sup> "NPR-A Sale Plan Carries Heavy Restrictions," Oil & Gas Journal, August 24, 1998.

development of successively more elusive, smaller, or more difficult accumulations of hydrocarbons east of the Canning River, recapitulating the process that has been under way in the Central Arctic since the mid-1980s. This scenario implies that, through Year 40, the Interior Department and ASRC together will ultimately lease about 50 percent of the total Area 1002 acreage, containing about 80 percent of the technically recoverable oil and gas resources.<sup>34</sup>

Extrapolation of technical progress in North Slope hydrocarbons exploration since 1977 suggests that after Year 10, and almost certainly by Year 20:

- Advances in remote sensing, geophysical analysis, and 3-dimension imaging will permit the more exact identification, location and quantification of hydrocarbon deposits prior to drilling.
- More nearly precise directional drilling and advances in recovery technique will result in quantum reductions in unit oil and gas extraction costs, and improvement in ultimate recovery rates as a proportion of original oil and gas in place.
- Advances in transport, drilling, hydrocarbons processing, pipeline and other construction techniques will result in further quantum reductions in necessary surface disturbances and artificial cover in new development area — probably to no more than 0.1 percent of total operating areas.<sup>35</sup>
- The combined impact of these advances is likely to imply a reduction of the minimum commercial field size to no more than 32 million barrels of oil equivalent, consistent with variable production costs of no more than \$1 per barrel (oil) and no more than 25 cents per million btu (gas).<sup>36</sup>

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<sup>34</sup> We assume that the Interior Department conducts five sales at four-year intervals in **Years 10 through 26**, each offering for lease 10 percent of the remaining unleased acreage in the undeformed and deformed sectors respectively. The acreage offering for lease in each sale will contain 16 percent of the total number of accumulations remaining undiscovered as of **Year 10** from the expected numbers of accumulations by land status and size of accumulation in the 1998 USGS Assessment. During each four-year period beginning in **Year 10**, the largest half of the remaining leased but undiscovered accumulations will be discovered and development will commence.

<sup>35</sup> Areas covered by structures or gravel have declined from about 2 percent of total operating areas at Prudhoe Bay and Kuparuk in the late 1970s and early 1980s to about 0.5 percent at Alpine and Badami in the late 1990s.

<sup>36</sup> These parameters apply only to now-conventional oil and gas from onshore and shallow offshore Arctic deposits such as the USGS now classifies as technically recoverable — i.e., those "petroleum" resources accessible with mid-1990s technology. By the late 2010s, technically or even economically recoverable hydrocarbons resources of the region may include now sub-marginal heavy crudes (e.g., Ugnu and much of West Sak), subsea and permafrost-zone methane hydrates, kerogens in various geological environments, and/or hydrocarbons of any kind found below 50 kilometers of the earth's crust. However, speculations about the local or global economics and environmental implications of exploiting such materials is beyond the scope of this project.

It is plausible to anticipate that, during the remainder of the study period,

- Virtually the entire stock of "technically recoverable" oil and gas within the 1002 Area and the adjacent state offshore acreage is capable of being discovered and economically produced, even if energy-price expectations and actual prices were materially below those of the 1990s.
- The incremental surface disturbance, artificial cover,<sup>37</sup> and surface or atmospheric waste discharges associated with this process would be negligible.

**These scenarios do *not* assume or imply, however, that any set of anticipated technical advances can put an end to controversy about the desirability of petroleum-industry or other commercial activity in ANWR, including construction of infrastructure and increases in the human presence in, or air traffic over, currently de-facto wilderness areas.**

#### **Scenario 5: Maximum Extent**

This scenario is the same as Scenario 4, except that the spatial impacts modeled are the full extent of the 1002 area, including the southeast uplands where oil and gas prospects are least likely.

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<sup>37</sup> Gravel, pavement and structures.