North Slope Infrastructure and the ANWR Debate

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Summary

The rich biological resources and wilderness values of northeastern Alaska have been widely known for about 50 years, and the rich energy resource potential has been suspected for much of that time. The future of these resources in the coastal plain of the Arctic National Wildlife Refuge (ANWR) has been debated in Congress for over 40 years. One aspect of the debate in recent years has been proposals to limit the *footprint* of energy development.

The term "footprint" has not been formally defined and the variety of features it might include varies with observers. Yet the word is used regularly in discussions regarding impacts of infrastructure on the natural environment. Without attempting to fix a definition or suggest consensus where it may not exist, this report catalogues the range of features of development that various observers might include in their use of the word, beginning with features that nearly all parties would consider as part of development's footprint. It should be emphasized that the report does not give an overview of the ANWR development/wilderness controversy as a whole, the impacts of development, the portion of the Refuge that might be affected by an acreage limitation, or specific provisions of any legislation. Rather, it seeks to provide an understanding of the terms used only in this aspect of the ANWR debate. As background, the report considers current and planned development at the Alpine complex, the most advanced energy development on the North Slope, and how its lessons might apply to development in the Refuge.

Trends in technology and the emphasis on more compact development could aid in reducing development's footprint. Over the last two decades, the size and number of structures in newly developed areas have gotten smaller or fewer: drill pads are substantially smaller, and support facilities and roads are fewer than in older areas. Some of this reduction occurred because of regulation (e.g., to limit wetlands impacts or reduce waste discharge), but some also occurred because smaller structures are usually cheaper: gravel, water, culverts, waste pits, and so on can all be costly to build, use, and/or maintain. The result is a certain degree of incentive to industry to consolidate and to make structures smaller (or, in the case of waste pits, eliminate them), even in the absence of regulation.

On the other hand, key distinctions between the coastal plain of the Refuge and the coastal plain of currently developed areas are worth noting. Among these differences are the Refuge's more rolling terrain with far less standing water, and its relatively large distance from much of the existing North Slope infrastructure, which could force the building of additional, closer infrastructure to make development more economically practical. These differences, combined with possible constraints on development that might imposed in the 1002 area to limit environmental impacts, should Congress decide to open the area to development, suggest that any generalization about footprints drawn from modern existing developments such as Alpine, although instructive, may be qualified. Ultimately, the presence, distribution, and economic recoverability of any oil will combine with local conditions to determine the significance and impact of any footprint limitation. (For a broader treatment of this issue, see CRS Report RL31278, *Arctic National Wildlife Refuge: Background and Issues*.) This report will not be updated.

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In the debate over energy development in the Arctic National Wildlife Refuge (ANWR), a key issue has been whether the environmental impacts of development can be limited and if so, how. Much of the recent focus of that debate has been on the "footprint" of development, and how to limit the footprint so as to limit the environmental impact of development. The term "footprint" has not been formally defined and the variety of features it might include varies with observers. Without attempting to fix a definition of the word, or suggest consensus where it may not exist, this report catalogues a range of features of development that various observers might include in their use of "footprint." It begins with features that nearly all parties would consider as part of development's footprint, and concludes with those which fewer parties would include. In some cases, it provides illustrations of these features.[1]

When Congress expanded the boundary of the Arctic National Wildlife Refuge (ANWR) in the Alaska National Interest Lands Conservation Act (ANILCA, P.L. 96-487) in 1980, it designated about 8 million acres within the earlier boundaries of the Refuge as wilderness—off-limits to nearly all forms of development. However, in §1002 of ANILCA, Congress required the Department of the Interior (DOI) to prepare a detailed study of the Coastal Plain of the Refuge (now also called the *1002 area*) and to recommend how it should be managed. In §1003, Congress directed that "production of oil and gas from the Arctic National Wildlife Refuge is prohibited and no leasing or other development leading to production of oil and gas from the range shall be undertaken until authorized by an Act of Congress." This provision effectively postponed a decision on development versus wilderness designation of 1.5 million acres of the coastal plain. (See **Figure 1**, showing ANWR and developed areas.)

Interior finished its detailed analysis of oil potential, wildlife resources, impacts, and mitigation measures in April 1987. In this report to Congress (called the *Final Legislative Environmental Impact Statement*, or FLEIS), DOI estimated the chance of recovering economic quantities of oil at 19%, a figure that is very high by industry standards. The report recommended that the entire area be made available for leasing. The report and its recommendation generated controversy, as have virtually all subsequent reports on this topic. In intervening years, estimates of oil potential and industry's enthusiasm have varied, but support for ANWR oil development remains strong among various parties, including many Alaskans. Likewise, opposition to energy development continues to be strong among many observers, based on concern for the area's wildlife and wilderness values.

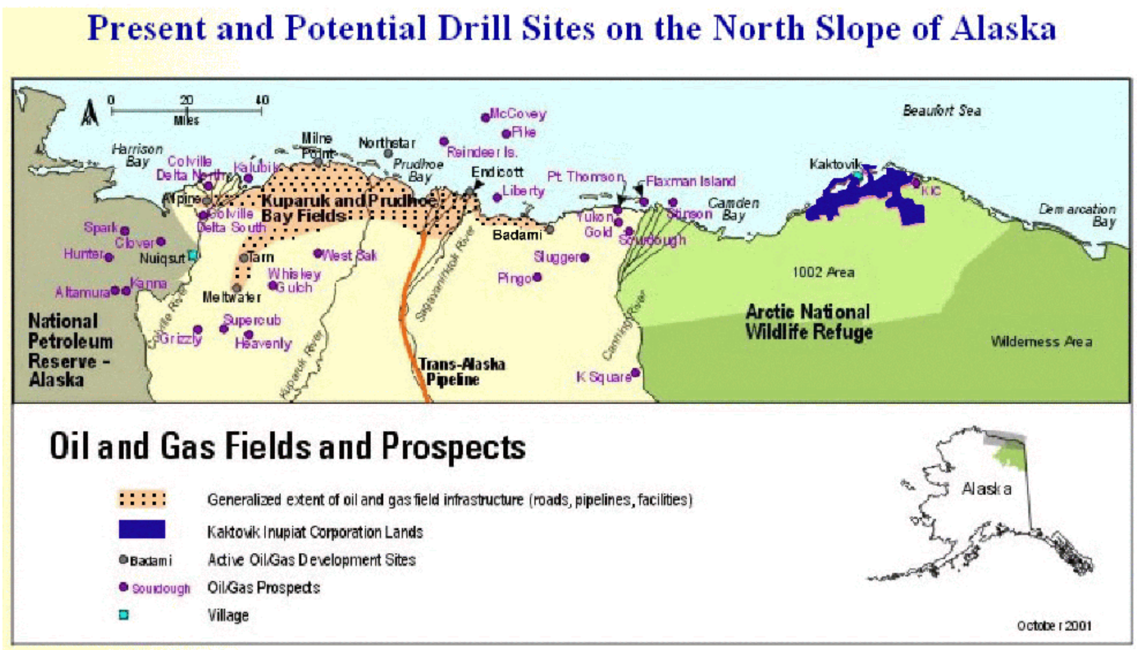
The specific placement and extent of energy infrastructure would be strongly dependent on the location of any oil discoveries, including their distance from other discoveries. But within that context, the trend in North Slope energy development has been toward compactness, reduction in numbers and mileage of roads, centralization or reduction of support facilities, reduction of hazardous wastes, and concentration of exploration and early development activities in winter (when the frozen tundra makes cross-tundra travel possible, and when exploration roads can usually be built from ice). Over the last two decades, the size and number of structures in newly developed areas have gotten smaller or fewer: drill pads are substantially smaller, and support facilities and roads are fewer than in older areas.[2] Some of this reduction occurred because of

[1] Development advocates have proposed to limit the size of this footprint. The extent to which such legislation might apply to Native lands within the 1002 area is unclear. For treatment of this aspect of the debate, see CRS Report RL31115, *Legal Issues Related to Proposed Drilling for Oil and Gas in the Arctic National Wildlife Refuge (ANWR).*

[2] For a review of advances in arctic petroleum development, see CRS Report RL31022, *Arctic Petroleum Technology Developments*.

regulation (e.g., to limit wetlands impacts or reduce waste discharge), but some also occurred because smaller structures are usually cheaper: gravel, water, culverts, waste pits, and so on can be costly to build, use, and/or maintain. The result is a certain degree of incentive to industry to consolidate and to make structures smaller (or, in the case of waste pits, eliminate them), even in the absence of regulation. Thus the footprint of development in ANWR could be smaller than for comparable earlier development on the North Slope.

Figure 1. North Slope Developed Areas and 1002 Area



Source: Originally obtained from FWS website, http://www.r7.fws.gov/nwr/arctic/devmap.html, in June, 2003, but site has since been modified. Map somewhat modified for clarity in monochrome.

Advances in drilling technologies are a major factor in the size and location of the footprint. Drilling technology has evolved from a single hole straight down into a prospect, to directional, extended reach, horizontal, multilateral, and designer wells. Under very favorable conditions, drill pads can now be located as much as 5 miles in horizontal distance from a target; the current world record for horizontal drilling is 7 miles at two sites, one in China, and the other at the Wytch Farm oil field on the south coast of England. Modern designs permit more efficient production of hydrocarbon reserves, and allow easier connection to production facilities, with fewer pipelines. They also reduce the number of wellheads. Cuttings generated during drilling may be reinjected into special wells for waste disposal rather than the more permanent waste pits used in the past.[3] All of these advances play a role in decreasing the acreage covered by gravel.

However, in considering the extent of needed infrastructure, two crucial influences are worth noting. First, the size and location of infrastructure would depend on where the oil is, and how

[3] For more extensive discussion of these technologies, and for illustrations of types of drilling methods, see CRS Report RL31022, *Arctic Petroleum Technology Developments*, by (name redacted), (name redacted), and Terry Rayno Twyman, previously cited.

much oil can be economically extracted. If oil development were authorized in the 1002 area, and if oil were not found in economically sufficient quantity or quality, only the impacts of exploration would remain.[4] Similarly, if oil were found only in one part, particularly in the west near existing development, the impacts on the eastern portion would be much reduced. Second, distance from other energy development would affect the requirements for new developments. Discoveries in the western portion of the 1002 area might be able to rely on some infrastructure outside of the Refuge. This infrastructure might be some of the facilities which exist already. However, since existing facilities, including permanent roads, are scarce, there might be a demand for new facilities concentrated just outside of the Refuge boundary, across the Canning River. If discoveries were found only farther east in the 1002 area the need for support infrastructure within the Refuge (rather than 100 or more miles to the west) would become more pressing.

This report begins by examining the Alpine complex, an oil field at the extreme western edge of current development, often cited as the North Slope's most advanced oil field. The report reviews the most modern, compact technologies now in use. It is followed by a catalogue of those features that might be considered as part of North Slope development infrastructure. The description includes all of the "oil-related facilities" cited in the FLEIS (p. 99) as being associated with full development, as well as other features or affected areas that are mentioned in discussions of this issue. It refers to issues arising in future reliance on ice technology. The report concludes by identifying physical differences between the 1002 area and the developed areas on the North Slope and discusses how those differences might affect the footprint.

The Alpine Complex: Past and Future

Alpine was originally developed by ArcoAlaska, and is now managed by ConocoPhillips. It began production in November 2000 and the surface area of the oil field was initially estimated at 40,000 acres. It is regarded as an example of environmentally conscientious production and is commonly held as the standard that might be expected if the 1002 area were developed. At the Alpine development, the two gravel pads currently in place are permitted by the Army Corps of Engineers at 36.3 acres for the main pad (also known as *CD-1*) and 10.1 acres for the satellite pad (*CD-2*). (In contrast, drill pads constructed in the 1970s averaged about 44 acres.) The larger pad is the main production pad, and includes a central processing facility, housing, and storage area, along with wellheads. The secondary pad contains only drilling facilities and wellheads; workers there commute from the main pad. Together, the two pads support 112 wells.[5] (See **Figure 2** and **Figure 3**, showing initial phases of Alpine development.) A third pad (*CD-3*) of about 30 acres is planned 6 miles northeast of the main pad. A fourth pad (*CD-4*) in the complex, 4 miles southwest of the main pad is expected to total about 41 acres.[6] (See **Figure 4**, showing plans for Alpine complex expansion.) Three additional pads are planned west of this area, in the National Petroleum Reserve-Alaska (NPR-A).

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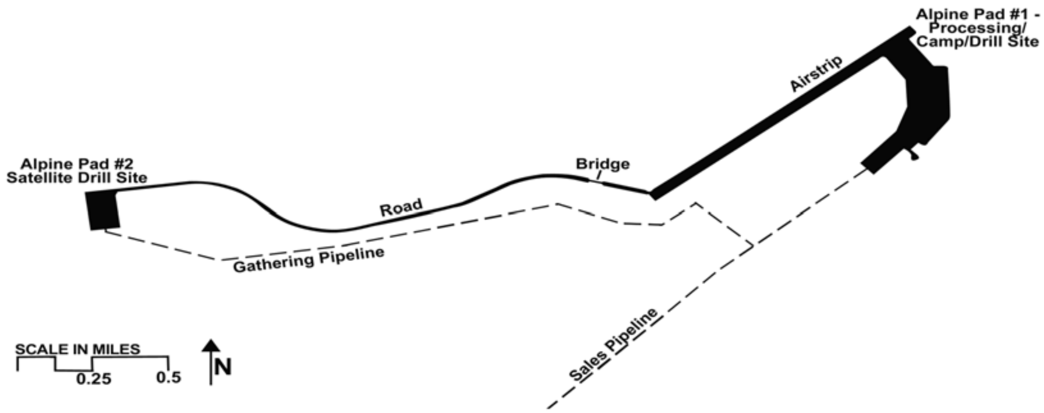
[4] While these impacts are not negligible, they are substantially less than the impacts of development and production.

[5] "ConocoPhillips plans five new Alpine satellite pads, signs MOU for EIS." *Petroleum News*. vol. 9, no. 9, (Jan. 27, 2003).

[6] Rose Ragsdale, "Phillips looks to develop Alpine satellites, seeks state OK on sites." *Alaska Oil & Gas Reporter*. (Feb. 5, 2002.)

Figure 2. Initial Layout of Alpine Oil Field



Source: ARCO Alaska, Incorporated. Permit Application to U.S. Army District Engineer, Alaska, Permit No. 2-960874, Colville River 18. Jan. 22 and 24, 1998. Map somewhat simplified for clarity in monochrome.

Figure 3. Early Development of Alpine Oil Field

Source: Photo by Pamela A. Miller, Arctic Connections (used with permission). Photo taken from northeast (top right corner of map in **Figure 2**).

Notes: Arrows indicate the following features:

1—Main (sales) pipeline carrying crude oil south and then east to Kuparuk;

2—Alpine (main) pad #1 (CD-1);

3—Airstrip;

4—Connecting road;

5—Alpine Satellite Pad (CD-2).

The current airfield for the Alpine complex (permitted at 35.7 acres and about 1 mile long) doubles as part of the road connecting the first two drill pads. In summer, access to Alpine is by aircraft only, with 6 to 8 aircraft, including large cargo planes, arriving daily.[7] A second airfield is planned as part of CD-3. It is expected to be 1.1 miles long and occupy 17.1 acres.[8] Since there would be no dormitory facilities at this pad, workers would be based at the main Alpine pad, and would use ice roads or small planes for daily operational access. Reliance on aircraft for summer transport reduces or sometimes eliminates the need for connecting roads.

The current connector road in the Alpine complex is over 2 miles long and covers 14.6 acres. Along with the airfield, it links the first two pads in the complex. However, "the frequency of air traffic is higher than was anticipated during the permitting of Alpine..., and the safe joint use of the airstrip has become increasingly difficult."[9] Added development would place increased demands on the airfield. The conflict with increasing vehicular traffic means that "any alternative that increases use across this section of road may require a separate road that would allow separate and discrete use by rolling stock and fixed wing traffic."[10] No road is planned at this time to connect the main Alpine pad to CD-3, although a 0.1 mile road (0.6 acres) would connect the drill pad to its own airstrip, and a raised pipeline would transport oil from the pad to the processing facility on the main pad.[11] A second road of 3.8 miles with a 32 foot wide driving surface is being planned to connect CD-4, south of the main pad.[12] A permit application estimates that the footprint of this road would be approximately 26.6 acres.[13] ConocoPhillips plans an additional 3 satellite pads in the complex, in the NPR-A, connected by a bridge across the Colville River to the main pad, via a gravel access road over 20 miles long (see **Figure 4**). At the first two Alpine pads, the permit issued by the Army Corps of Engineers provided for 1.7 acres of culverts, bridges, and stream crossings.

[7] W. Wayt Gibbs, "The Arctic Oil and Wildlife Refuge," *Scientific American* (May 2001), p. 68.

[8] Phillips Alaska, Inc. *Colville River Unit Satellite Development CD North Draft Plan of Operations* (July 31, 2001).

[9] "Supporting Documentation for Alpine Satellite Development Program. Preliminary Alternatives and Environmental Conditions. Final." CononcoPhillips and Anadarko (February 2003). p. 12.

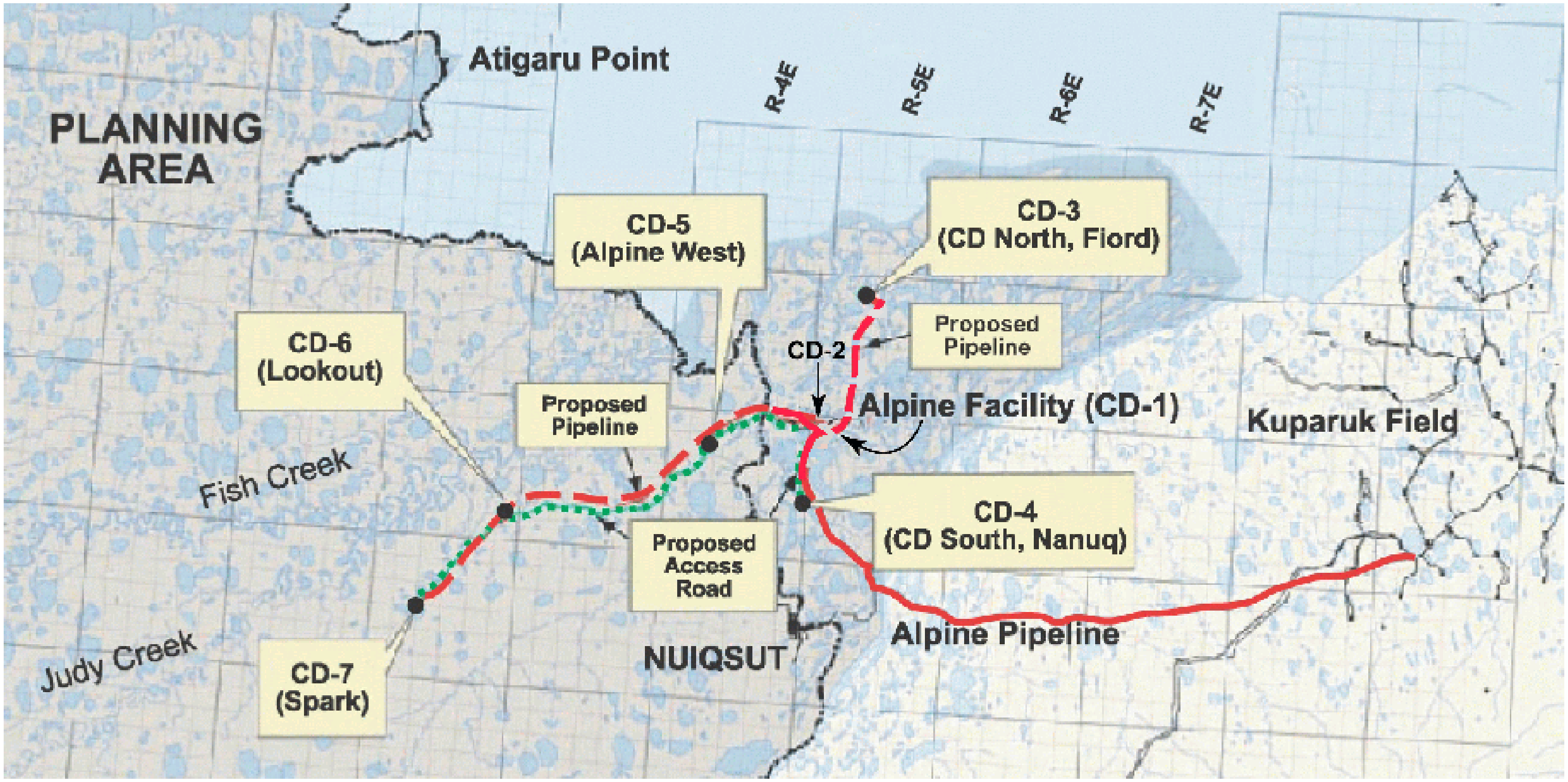
[10] Ibid.

[11] *Colville River Unit Satellite Development CD North Draft Plan of Operations*. Phillips Alaska, Inc. (July 31, 2001).

[12] Rose Ragsdale, "Phillips looks to develop Alpine satellites, seeks state OK on sites." *Alaska Oil & Gas Reporter* (Feb. 5, 2002). Also, *Colville River Unit Satellite Development CD South Draft Plan of Operations*. Phillips Alaska, Inc. (July 31, 2001). p. 7.

[13] *Colville River Unit Satellite Development CD South Draft Plan of Operations*. Phillips Alaska, Inc. (July 31, 2001).

Figure 4. Proposed Expansion of Alpine Complex



Source: BLM website, http://www.alpine-satellites-eis.com/alpeis.nsf/?Open, under "Learn about the Alpine Satellite Development Plan," viewed on August 13, 2003.

Notes: Solid (red) line indicates existing pipeline; dashed (red) line shows proposed pipelines. Dotted (green) line shows proposed roads. Irregular splotches mark the area's numerous lakes. Map modified slightly for clarity in monochrome.

Pipelines, whether for crude oil, diesel fuel, fiber optics, electrical conduits, water, or natural gas, are raised on support arms, typically 5 to 10 feet above the tundra. (See **Figure 5**, showing pipeline and gravel mine.) At the Alpine complex, these Vertical Support Members (VSMs) are spaced 35 to 55 feet apart. Up to 450 VSMs, providing ground clearance of at least 5 feet, were planned in the initial phase at the Alpine complex for pipelines within the field.[14] The bases of these supports must be protected from sinking into the tundra; this requires sinking the VSM into the stable layer of permafrost, disturbing a few square feet of tundra.

Figure 5. Nuiqsut Gravel Mine and Pipeline

Source: Photo by Joel Bennett © 2003 (used with permission). Arrows added and photo modified slightly for clarity in monochrome.

Notes: Gravel mine indicated by large arrow; pipeline carries oil from Alpine main pad (CD-1) to Kuparuk field, where it is sent on to TAPS. Small arrows indicate some of the pipeline supports.

For the initial phase of development, the Corps of Engineers issued a permit to Nuiqsut Contractors for a 150-acre gravel mine (see **Figure 5**). Some portion of the gravel was to meet needs in the nearby Native village of Nuiqsut. A new marine facility was not required for construction at the Alpine complex. Instead, barges were used in August 1999 to transport 15 modules of heavy equipment through the Bering Strait to the Kuparuk complex (see **Figure 1**) on the North Slope for the initial development of the Alpine complex. These modules, totaling nearly

[14] U.S. Army Corps of Engineers. *Permit Evaluation and Decision Document.* Application Number 2-960874. Waterway Number: Colville River 18. (Feb. 13, 1998). p. 3.

12,000 tons, were held at Kuparuk until March 2000, when they were transported via ice road[15] on the frozen Beaufort Sea and then inland via ice road to the Alpine development.[16]

Fresh water used for ice construction at Alpine comes from lakes (accessed with state permits) and is hauled by truck to the appropriate site. These specially designed trucks hold 4,200 to 10,500 gallons. Water for human use comes via pipes from lakes near the main pad. Currently, ConocoPhillips has "no plans to change the current processes for water withdrawal or ice road construction for CD-3 or CD-4 or any of the proposed National Petroleum Reserve Alaska (NPR-A) satellites."[17]

Another important factor affecting footprint at the Alpine complex is the ability to use extended reach drilling (ERD) or horizontal drilling to reach oil at some distance from the wellhead.[18] "All of Alpine's wells, [both] producers and injectors, are horizontal, with the well angled to pass horizontally through the producing reservoir. Horizontal footages within the reservoir range from 3,000 feet to 6,000 feet, with one 6,000 foot horizontal section and three wells with horizontal sections more than 5,000 feet in length [from the wellhead]."[19]

In sum, the initial phases of development of a field whose surface extent was estimated at 40,000 acres directly disturbed about 250 acres, plus an undetermined area indirectly affected (see discussion below). Developers were also able to rely on some support from facilities for staging in the Kuparuk field. As oil prospects nearby have improved, the size of development infrastructure has continued to increase.

Recent developments in Alaska suggest that for economic reasons, access to the Alpine area may not remain roadless indefinitely. The Alaska Department of Transportation and Public Facilities is beginning to study a project to build industrial roads to support the state's oil, gas, and mining industries, where lack of adequate transportation in remote areas is a significant handicap to development. A department spokesman said that "it found the best investment returns would come from transportation improvements for North Slope oil and gas: a four-stage project, involving roads and a bridge across the Colville River [into the NPR-A] to provide all-season access."[20] The project would provide a gravel road link from the Dalton Highway (which parallels TAPS) near Pump Station 2, west and then north to a permanent bridge crossing the Colville River and linking (a) the village of Nuiqsut (through a planned road to be funded by the Bureau of Indian Affairs), (b) planned roads for development of the NPR-A west of the Colville River,

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[15] Ice roads and pads are created by special trucks that spray increasing layers of fresh water (sometimes mixed with chipped ice) on the tundra, gradually building up a thick ice layer capable of supporting large trucks, exploratory drill rigs, etc. The structures usually last only one winter, but under certain circumstances can be protected from summer heat for use in a second season.

[16] A. John Whitehead, Vice President, Western North Slope Business Unit, ConocoPhillips. Letter of May 30, 2003, to author.

[17] Ibid.

[18] ERD wells have horizontal displacement of at least 2 to 5 times the vertical depth, regardless of the angle of bend in the drill path. A horizontal well is, technically, one that reaches a certain depth and then turns at a 90 degree angle to reach a geological structure. While the terms differ technically, *ERD* will be used in this paper to include both types of wells, unless otherwise indicated.

[19] Kristen Nelson, "Drilling in the fast lane: Alpine drilling passes million-foot drilling mark on 69th well," *Petroleum News* (June 8, 2003), citing remarks of Mike Alvord, Alpine drilling team leader.

[20] Kristen Nelson, "Building resource roads," *Petroleum News* (April 27, 2003), p. 1, citing comments by Mike McKinnon, senior planner, Alaska Department of Transportation and Public Facilities.

and (c) the western edges of the existing road system supporting the Tarn and Meltwater fields, which are satellites connected to the road network at the Kuparuk oil field (and from there to the Prudhoe Bay fields).[21]

The Components of Infrastructure

This section catalogues features which have been considered in discussions on the footprint of development. It is primarily a description of the features *per se*, rather than their environmental impacts. Features at the beginning of the catalogue tend to be mentioned as forming part of development's footprint more frequently than features at the end.

Gravel Structures

Gravel Drill Pads

In 1987, the FLEIS in its full development scenario assumed that 50 to 60 pads, averaging 20-32 acres each, would be built; these would cover 1,200 to 1,600 acres (FLEIS, p. 99). Now, 26 years later, the projected average pad size compares well with the 29 acre average of the first 4 Alpine pads, but it seems unlikely that as many as 50 to 60 pads would be needed in a contemporary scenario. The FLEIS (p. 86) noted that the maximum extended reach for drilling then was somewhat over 2 miles if the oil reservoir was deep enough. In contrast, modern Extended Reach Drilling (ERD) under optimum conditions can reach more than twice that distance, and in actual practice on the North Slope has reached 3.78 miles at one wellhead. Consequently, assuming the same full development scenario posited in the FLEIS, fewer than 50 pads might be needed. (See modern drill pads in **Figure 3**.)

Airfields

Two large (130 acres each) and two small (30 acres each) airfields were contemplated in the FLEIS (p. 99) in a full development scenario. Under the Alpine model (with its airfield that would have been considered small in the FLEIS), for equivalent discoveries, more airfields would be likely to be built than the four that were envisaged in the full development scenario in the FLEIS, since each complex would need its own airfield(s). (See airfield in **Figure 2** and **Figure 3**.) The reliance on multiple airfields could be reduced, but at the cost of additional roads linking more pads to fewer airfields.

Connector Roads in Drill Site Complex

Gravel roads connect drill pads in a complex. These roads may be as thick as 6.5 feet of gravel above the surface of the tundra.[22] Gravel connector roads could lower costs over the long haul

[21] Kristen Nelson, "Building resource roads," *Petroleum News*, (April 27, 2003). Anchorage, Alaska. p. 1. Also, Patricia Jones, "BIA road project progressing in Nuiqsut," *Petroleum News* (Sept. 29, 2002), Anchorage, Alaska,. p. 1. It is unclear why the proposed state road would not continue north on a short spur to link directly with CD-4, the southernmost pad now being developed in the Alpine complex. However, by linking westward to roads in the NPR-A, some of which are planned as part of the Alpine complex, an all-weather gravel road to the Alpine complex might be achieved, albeit though a circuitous route.

once production begins (though development may be continuing on the same pad) since they would obviate the need for annual construction of some of the ice roads used for winter transport of heavy equipment and might reduce the number of airfields that would be needed for summer travel. (See connector road in **Figure 2** and **Figure 3**.)

Stream Crossings, Culverts, and Bridges

A variety of structures must be built to manage water or to cross streams in the arctic environment. In the arctic spring, as rivers and ponds swell with melting runoff, and water drains slowly across the tundra, culverts are needed to prevent the creation of impoundments on the upper side of the road that might threaten the road itself. In addition, main pipelines must be designed to cross over or under streams and rivers, and bridges may be needed to carry traffic across major rivers.

In its full development scenario, the FLEIS (p. 99) estimated that a maximum of 25 major river or stream crossings could be required. It noted (p. 92) that "bridges and culverts would be designed and constructed to provide cross drainage for roads in a manner that prevents erosion or adverse effects on the fisheries." For similar discoveries, a modern scenario would require similar precautions, but to the extent that fewer miles of roads are constructed, then fewer bridges and culverts would need to be constructed. The number of stream crossings for a main pipeline (carrying crude oil from all of the 1002 area fields to TAPS) could be expected to be similar in a modern scenario, but (assuming the same hypothetical discoveries) the infield pipelines would likely be reduced, because fewer drill pads are needed in a modern scenario to produce the same amount of oil.

Major Roads Connecting Complexes or Existing Developments

In the exploration and development phases, ice roads not only reduce environmental impacts, they also reduce costs, relative to building gravel roads and pads at each new prospect which may—or may not—contain oil. However, once a find is confirmed, gravel drill pads are put in place and (as is occurring at the Alpine complex), gravel roads may also be put in place to link some if not all of the gravel pads. If a pad in a complex is not linked by a road to other facilities in the same complex, an airfield may be required at the unlinked pads, as at CD-3 in the northern part of the Alpine complex. All-weather gravel roads serve to reduce the number of flights, as well as demands on fresh water for ice roads each winter when heavy equipment must be transported.[23] (See **Figure 6**, showing road with 2 trucks.)

(...continued)

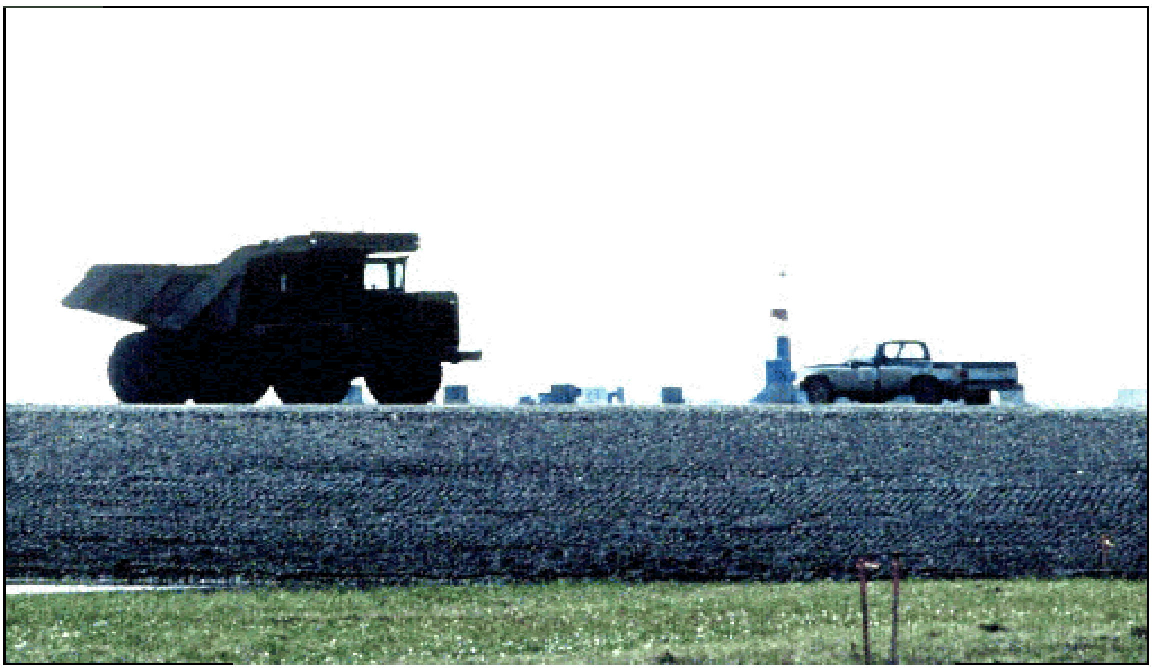
[22] National Research Council, *Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope* (Washington DC: March 2003), p. 108. (Hereafter referred to as NRC Report.)

[23] State and industry planning for remote fields west of Prudhoe Bay suggest that for marginal fields, proximity to all-weather gravel roads can help in making a marginally profitable lease more profitable by lowering long term access costs. This factor could be important in ANWR, since the westernmost boundary of the 1002 area is roughly 30 miles east of Badami, the easternmost producing field to date—and which was recently shut down for its marginal economics. (See map, **Figure 1**.) Thus gravel roads may be a factor in deciding whether to develop some marginal fields.

Exploration Roads

Ice roads and ice pads are the norm in current exploration technology, although in some cases gravel structures must be used. For example, in the state lands south of current developments, between the Colville and Canning Rivers, a new area is being opened for lease sales by the Alaska Department of Natural Resources. This area is in the foothills of the Brooks Range, and has a topography more similar to the rolling hills common in the 1002 area than to the areas that have been developed to date near the coast. Among these hills, ice roads and ice pads have proven potentially unsafe or difficult to construct. State regulations for the area require that exploration activities must use ice roads and ice pads, but exceptions "including the use of gravel, may also be granted on a site specific basis, if it is determined, after consulting with [the Alaska Department of Fish and Game], that no feasible and prudent alternatives exist for constructing an exploration road or pad."[24]

Figure 6. North Slope Gravel Road



Source: FWS file photo; modified slightly for clarity in monochrome.

Notes: Roads on North Slope constructed to a height of at least 5 feet to maintain stability of permafrost.

Marine Facilities: Ports, Causeways, and Seawater Treatment Facilities

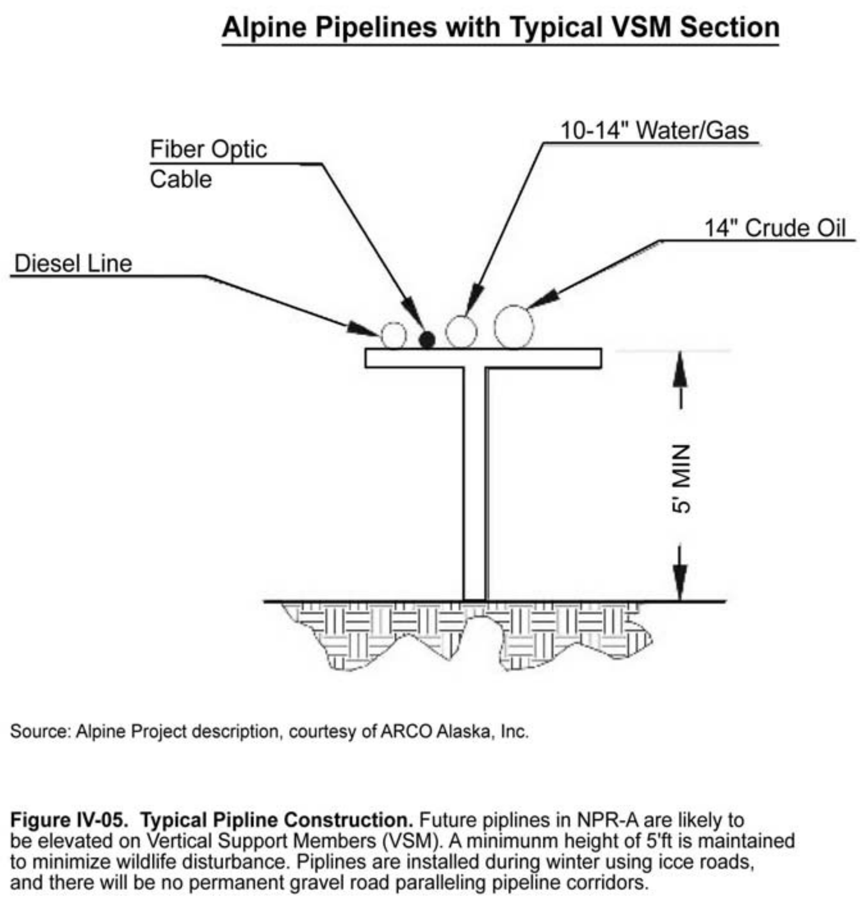
In 1987, the FLEIS (p. 89) contemplated two marine facilities in a full development scenario; these were estimated to cover 200 acres (p. 99). Camden Bay and Pokok Lagoon were considered possible sites, since surveys suggested that dredging would not be necessary at those locations in order to bring in summer barges carrying heavy equipment. Because heavy cargo arrives during

[24] Alaska Department of Natural Resources, Division of Oil and Gas, Chapter 7, *Mitigation Measures North Slope Foothills Areawide Oil and Gas Lease Sale 2003*, p. 3. (Available at http://www.dog.dnr.state.ak.us/oil/ on April 23, 2003).

only a few weeks in the arctic summer, the facility must include docks for several barges, and gravel pads to store off-loaded cargo.[25] The marine facility might also require its own temporary camp and support facilities, depending on its distance from other facilities. A port capable of receiving barges already exists at Kaktovik, a Native village on Barter Island along the coast of ANWR. New construction might be avoided if arrangements can be made to use or modify this facility—an option not analyzed by the FLEIS.

Marine facilities would probably also include plants (possibly supported on barges) to treat seawater for use in production to maintain pressure in an oil field; causeways would link such facilities to the shore.[26] A saltwater treatment plant is now located at end of the 2.5 mile long West Dock on a barge in relatively shallow water. Raised insulated pipes then carry water from the treatment facility to production facilities (see above). Between 1996 and 2001, North Slope operations used an average of 46 million gallons per day of treated seawater.[27]

Figure 7. Cross-Section of Vertical Support Members for Pipelines



Source: BLM website, http://denali.ak.blm.gov/nwnpra/index.html, Figure IV-05. Caption retained from original document. Viewed on August 13, 2003.

[25] The three causeways (West Dock, East Dock, and Endicott) now in current developed areas on the North Slope total 7.7 miles, and occupy 227 acres as measured at mean sea level (NRC Report, p. 310).

[26] Water produced from an oil field may also be used for re-injection if it is available.

[27] NRC Report, p. 78.

Other Structures

Infield Pipeline Supports

Infield pipelines, besides collecting crude oil produced from wells, also supply natural gas and water for injection to maintain pressure in the oil field, support communications equipment, supply diesel fuel for transportation, and provide electric power and water for human use. (See **Figure 5** and **Figure 7**, showing infield pipeline and supports.) They are grouped together so that a number of the various kinds of pipelines rest on the same Vertical Support Members (VSMs), often with space to spare so that other pipelines can be added at a later date. The diameters of these pipelines vary with function, ranging from a few inches (fiber optic cable) to 14 inches (crude oil or water and gas, with diameters possible for larger finds).[28] Infield pipelines, with their supports, would link development complexes to a larger *main pipeline* (see below) which would carry crude oil over much longer distances from within the 1002 area to existing main pipelines and ultimately to TAPS. Whether for infield lines or for main lines, the very small cross-sectional areas of the bases for the support arms would take up only a small fraction of the total gravel footprint that might be expected from ANWR development, as well as a small fraction of the area under the pipeline.

Main Pipelines

In 1987, the FLEIS full development scenario (p. 99) assumed that the main oil pipeline that would collect oil from the various fields in the 1002 area for shipment to TAPS would be elevated (for caribou passage), run generally east-west, extend 100 miles inside the 1002 area, and occupy about 610 acres within the 1002 area, based on a 50 foot width for a right of way.[29] It would include two to three pump stations, with one or two stations inside the Refuge and the others between the Refuge boundary and the start of the TAPS pipeline. Each pump station was expected to require a roughly 7-acre gravel pad for "pumping, oil storage, power, pipeline equipment and repair and communications facilities, [as well as] living quarters for about 30 people, and environmental support systems ..." (FLEIS, p. 91). The extent to which the pump station pads or the right of way could be reduced with modern technology is unclear, since the size of a pipeline itself would be partly a function of the volume of oil flowing through it. However, it is possible that the 50 foot right of way for the pipeline would no longer be necessary.

Gravel Mines

Gravel, whether for pads, airfields, causeways, or roads, is mined from nearby sources such as river beds and, more recently, upland sites. In 2001, 24 open pit gravel mines occupied 6,364 acres (average pit: 265 acres) on the North Slope.[30] About 10 to 15 gravel mines were considered necessary for full development in the FLEIS; they were estimated to occupy 500-750 acres total.

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[28] See **Figure 7**. The FLEIS (p.89) estimated a range of 8-24 inches for infield pipeline diameters.

[29] In effect, the FLEIS considered the "footprint" of the pipeline to be the full 50 foot width of the right of way times its length, rather than the area occupied by the bases of the VSMs; no figure was given for the area occupied by the supports. In addition, the FLEIS assumed another 50 foot right of way for a transportation corridor. However, modern technologies might not require such a corridor; see "Major Roads," above.

[30] NRC Report, p. 65.

The mine at the Alpine complex (**Figure 5**, above) occupies 150 acres, falling between the current average size and the smaller gravel mines contemplated in the FLEIS. Some portion of the gravel from this mine was to meet needs in the village of Nuiqsut, and the size of the permitted mine may have been designed to allow the expansion of the Alpine development to some of the additional satellite pads and associated connector roads now in the planning phases.[31] It is not known what size of gravel mine would have been required to construct only the original two pads at Alpine. In the 1002 area, consolidation of gravel mines might be considered desirable; this might be accomplished by digging fewer or deeper pits, as at Alpine. However, consolidation would result in hauling gravel over longer distances, and possibly constructing more roads. The FLEIS (p.111) noted that effects of gravel extraction can be reduced by using gravel from exposed and unvegetated bars along streams that are not fish-bearing or from gravel terraces adjacent to river beds.

Water Impoundments

In 1987, the FLEIS stated that the use of desalinated seawater "might not be economically feasible for ice roads and airstrips" (p. 88). To avoid construction of gravel roads during most exploration, operations using ice technology have expanded since 1987, and exploration requires far more water than was contemplated then. A year's supply of fresh water for exploration camp use would typically be about 360,000 gallons. In addition, 1 to 1.5 million gallons are needed for an ice road 1 mile long, 30-35 feet wide, and 6 inches thick.[32] In the winter of 2001-2002, ConocoPhillips alone built more than 100 miles of ice roads for exploration on the North Slope.[33] This effort would have required over 100 million gallons of fresh water.

In the past, when freshwater has been needed for ice construction or for camp use in some of the developed areas, and could not be readily obtained from deep lakes, water impoundments were sometimes created in the tundra to supply additional water. One method for creating these impoundments is to excavate gravel mines in the flood plain of a stream or river, and then to wait for spring floods to overflow the stream, fill the excavated pits, and recede, leaving an artificial deep lake.[34] While an attempt is made to avoid fish-bearing streams or to use higher ground, these artificial deep lakes may provide overwintering fish habitat where none existed, and become attractive to food fish such as grayling or arctic char—an effect some would consider beneficial.

Other Types of Affected Areas

In this category are features which were not mentioned in the FLEIS list of "oil-related facilities" (p. 99). In one case, the technology did not exist in 1987. In other cases, the features are described here because environmental, scientific, or Native groups have argued that development's footprint should include not only areas covered by gravel, or the features described above, but also other areas that may be affected by development. At this point, the term shades into the environmental

[31] Not all of the gravel in the complex will be taken from this source, however, since the CD-North Draft Plan of Operations proposed to obtain the necessary 462 thousand cubic yards of fill from either of two other sources.

[32] BLM, cited in NRC Report, p. 63.

[33] A. John Whitehead, Vice President, Western North Slope Business Unit, ConocoPhillips. Letter of May 30, 2003 to author.

[34] Normally, the gravel excavated in this process would be used for construction elsewhere.

effects of development taken as a whole. The most commonly mentioned of these affected areas are included below.

Multi-Season Insulated Ice Pads

Tundra vegetation which has been covered by ice roads or pads generally recovers within a season or two if the ice is allowed to melt and the area is not subsequently covered with a gravel structure. As a result, ice covered areas are rarely considered to be part of development's footprint. However, to prolong the season for drilling and eliminate the time required for mobilizing and demobilizing heavy equipment as well as allow more time for technologically advanced drilling, pads are sometimes insulated and preserved over the summer so that they can be used during a second winter. (See CRS Report RL31022 for more on advanced drilling technologies.) Where this occurs, vegetation around the edge of the insulated pads is sometimes killed by being simultaneously thawed and blocked from sunlight. In addition, some decrease in plant life has been observed two years after such pads were allowed to melt.[35]

Adjacent Areas Affected by Human Presence

The cumulative effects of oil development on the North Slope have been recently and extensively reported by the National Research Council (NRC) of the National Academies of Science and of Engineering and the Institute of Medicine in *Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope*.[36] A number of the environmental effects described in the NRC report bear on the footprint debate. While many of these effects have been described above, a few of the remaining effects will be mentioned briefly here. (For details, consult the NRC report citations below.) The NRC noted that the data were more complete or clear for some effects than others.[37] In some cases the effects were minor, in others substantial. In some instances, there was an absence of quantitative data. Examples of the effects of existing development noted in the NRC report included:

- changes in air quality, considered by NRC to be partly a result of long-range transportation of some pollutants, and partly due to locally produced smog, but with largely unknown effects due to lack of long term monitoring (p. 117);
- effects on water flows due to gravel mining in rivers, but diminishing with movement of mining to upland areas; interruption of water flows where culverts are inadequate or poorly located (p. 118);
- effects of clouds of dust, which may kill all vegetation within 16 feet of heavily traveled roads; modern techniques can result in fewer effects than older roads, but still produce dust (p. 124-126); and
- effects of existing development on caribou cows with young calves (whose general avoidance of development interferes with free movement between

[35] NRC Report, p. 140-141.

[36] National Research Council. *Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope* (Washington DC: March 2003), 452 p.

[37] The NRC Report noted a wide variety of effects of development, both harmful and beneficial, and ecological as well as economic. The effects listed in this report sample only those which can be construed as related to development's footprint in the natural environment.

> feeding and insect-relief areas); effects stretch out 1.2 to 2.5 miles around pads and roads. (p. 176).

Visual "Footprint"

In terms of the footprint debate, the relative significance of the visual effect including its human impacts, constitutes a major bone of contention between development opponents and advocates. Development advocates stress the decreasing size of some of the items described above, growth in a caribou herd in the developed area, responses to cleaning up any oil spills and other environmental protections. They particularly argue that future development effects cannot be judged in terms of the effects of past development (now over 30 years old in some places) because advances in technology are reducing environmental impacts, and many structures are smaller or less numerous than they would have been with older technology. (Implicitly, they define footprint as a much narrower term that does not include visual impacts.)

Development opponents stress their view that development's "footprint" should include more than those features commonly mentioned by development advocates.[38] When pipelines, gravel roads, bridges, and gravel pads rise several feet above the surrounding area in a treeless environment, set wherever possible so as to avoid disturbing water flows (i.e., usually on higher ground), their visual impact can be felt for miles. In addition, seismic exploration, especially with modern methods requiring close spacing of tests across the tundra, results in dense networks of trails "producing a serious accumulating visual effect."[39] The NRC (p. 239) commented:

> The common practice of describing the effects of particular projects in terms of the area directly disturbed by roads, pads, pipelines, and other facilities ignores the spreading character of oil development on the North Slope and the consequences of this to wildland values. All of these effects result in the erosion of wildland values over an area far exceeding the area directly affected.

A Look to the Future: Reliance on Ice Technology

Current North Slope exploration and development rely on ice technology, as described above. But if current warming trends continue, use of this technology appears to be at risk in northern Alaska, whether in ANWR or elsewhere. The state now permits industry to engage in oil exploration and ice construction on the North Slope when the top 12 inches of tundra are frozen and snow cover reaches 6 inches; cross-tundra travel and ice construction must cease once these conditions no longer prevail in spring.[40] Warmer winters have caused ice road use to drop from 200 days 20 years ago to the 2002 level of 103 days per year.[41] As a result of the constraint on

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[38] The website of the Alaska Wilderness League, http://www.alaskawild.org/pressroom.html (viewed on October 6, 2003) for example, describes this approach to the issue. Maps of North Slope development created by wilderness supporters sometimes make no distinction between roads and pipelines, suggesting that they view these structures as equally affecting the footprint, as they would define it. See, for example "Broken Promises: the Reality of Big Oil in America's Arctic" by The Wilderness Society (Washington, DC, 2003), p. 5.

[39] NRC Report, p. 154.

[40] Federal law, regulation, or lease stipulations could ultimately set different standards for the 1002 area.

[41] U.S. Dept. of the Interior, Bureau of Land Management. *Environmental Assessment National Petroleum Reserve-Alaska (NPR-A) Exploratory Drilling Program Puviaq #1 and #2 Exploration Wells, ConocoPhillips Alaska*. (December 2002). p. 4-22. See also Kristen Nelson, "Building resource roads," *Petroleum News*. April 27, 2003. (continued...)

exploration, the U.S. Department of Energy, the State of Alaska, three petroleum companies, and Yale University will fund a study to develop a model that might result in this standard being modified to determine whether seismic exploration can occur safely at a lower standard.[42] However, according to the NRC Report (p. 154), the current standard "is not based on scientific evidence. The variations in snow depth and density across the North Slope are not considered in the establishment of opening dates for seismic exploration each year, and 15 cm (6 in.) of snow is not sufficient to protect the tundra in many areas of the North Slope."

Distinct Aspects of the 1002 Area

With respect to infrastructure needs, the 1002 area is distinct in two important respects from current development. The first is its terrain. The 1002 area is made up largely of low rolling hills with braided rivers containing gravel bars. While the terrain *per se* would present no unusual difficulties for oil development, it presents some relatively new challenges due the natural environment of the North Slope. Modern arctic exploration and development methods rely heavily on ice technologies not only in the exploration phase but also in the development and production phases when winter ice roads substitute for gravel roads under certain conditions. Freshwater supplies are essential to this technology.

However, the flat terrain of developed areas to the west (where there are numerous ponds to serve as water sources) is characteristic of only part of the 1002 area, chiefly south of Kaktovik, and to a lesser extent near the mouth of the Canning River; elsewhere in the 1002 area the topography is more rolling. Small thaw lakes, like those that are nearly ubiquitous in developed areas to the west, are concentrated only in those very flat areas. Nearly all of the lakes are less than 640 acres and most are less than 6 feet deep, and freeze solid during winter (making them impractical as resources for ice road construction).[43] Consequently, fresh water is not as readily available as in currently developed areas, although impoundments might be constructed.

Moreover, regardless of water supply, ice technology is reportedly considered impractical in hilly terrain (a common condition in the 1002 area).[44] Reduced water supplies, together with hilly terrain less favorable to ice technology, pose a problem if industry were to rely on ice technology to reduce development's footprint in the 1002 area.

The second distinctive characteristic is the distance of the 1002 area from major existing infrastructure.[45] The need for new infrastructure would depend substantially on whether existing

(...continued)

Anchorage, Alaska. p. 1. Also, Department of Energy Press Release, "DOE Joins Alaska in Replacing 30-Year Old 'Ad-Hoc' Rule with Science-Based Model for Protecting Tundra." June 3, 2003. (Available October 6, 2003, at http://www.energy.gov/engine/content.do; search for "tundra.")

[42] Department of Energy Press Release, "DOE Joins Alaska in Replacing 30-Year Old 'Ad-Hoc' Rule with Science-Based Model for Protecting Tundra." June 3, 2003. (Available June 4, 2003, at http://www.energy.gov/HQPress/releases03/junpr/pr03121_v.htm.)

[43] U.S. Dept. of the Interior, Fish and Wildlife Service. *Final Report Baseline Study of the Fish, Wildlife, and Their Habitats* Vol. 1 (December 1986), p. 30.

[44] Kristen Nelson, "Building resource roads," *Petroleum News* (April 27, 2003). p. 1.

[45] As noted above, this report does not address whether a footprint limitation might apply to Native lands in the Refuge. If there were such a limitation, worded to apply only to federal lands but not Native lands, infrastructure might be preferentially located on Native land, possibly resulting in a substantial development footprint that technically stayed (continued...)

facilities could serve new areas, or whether operational costs were best controlled by building new facilities close by. For example, the nearest dock serving industry is at Endicott (roughly 40 miles west of the far western edge of the 1002 area). The closest current onshore oil field with a gravel road is over 20 miles west of the boundary at Badami, a field that was recently closed due to poor economics. In contrast, the Alpine complex was able to use West Dock and the large Kuparuk development as a staging area and for some of its support needs. Additionally, as described above, a permanent road into the general area (if not to the main pad at Alpine) has drawn support as a means of improving economic prospects for the NPR-A.

(Congressional readers please note that the figures in this report may be viewed in color on the CRS Web page at http://www.crs.gov/. Enter the report number in the box shown in the upper right of the Web page.)

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within a legislative limit. See CRS Report RL31278 and CRS Report RL31115, cited above.