CHAPTER 15

Modern human impact in the Arctic

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1. Introduction

Exploration and development of mineral deposits and petroleum have intensified since 1965. However, northern mines including the Klondike and the Alaska-Yukon placer gold fields have operated for years. Oil was discovered at Norman Wells, Northwest Territories in 1920 and a refinery was built in 1936. Petroleum exploration was conducted in northern Alaska in the 1940s and natural gas has been supplied to Point Barrow since 1950. Oil and gas exploration intensified along the Arctic coast of Alaska and near the mouth of the Mackenzie River, Northwest Territories in the mid-1960s. These activities led to the discovery of oil and gas at Prudhoe Bay, Alaska in early 1968 and a year later in the Mackenzie Delta Region. Gas and oil have been discovered throughout the 1970s in the northern Arctic Archipelago as well.

These discoveries in the Low and High Arctic have resulted in the completion of an oil pipeline across Alaska (1974–1977) that has the capacity of pumping two million barrels per day and the initiation of a gas pipeline project (1980–1986) to carry gas (222 million m³) 7700 km from Prudhoe Bay to markets in the United States. A lead and zinc mine was built (1975–1977) at Strathcona Sound, Baffin Island, a lead-zinc mine has been constructed on Little Cornwallis Island, and plans for extracting copper along the Kobuk River, Alaska are being developed.

Ecological research has been closely associated with northern development in both Canada and the United States. In the United States the passage of the National Environmental Policy Act (NEPA) which became law on 1 January, 1970 has stimulated many environmental and ecological studies. This law required that an environmental impact statement be prepared for each project on federal lands, or for any project which involved federal funds where it was perceived that environmental impact would occur. The government of Canada established guidelines for Northern Pipelines in 1970 and these were modified in 1972. While there is no body of law providing for a clear policy on environmental issues, royal commissions dealt with the Mackenzie Valley Pipeline Inquiry (Berger 1977a, b) and the Alaska Highway Pipeline Inquiry (Lysyk et al. 1977). More loosely organized panels such as the Environmental Assessment and Review Process (EARP) have dealt with individual projects, though little emphasis is placed on economic and social issues. A recent workshop on Lancaster Sound (Roots 1980) was held with the intent of providing public input into the decision making process without the need for the expensive and time-consuming special inquiries.

While much of this paper relates to the impact of northern development on vegetation, the impacts are much broader and must include assessments upon terrestrial and marine animals as well as terrain.

Reviews have been prepared on various ecological aspects of northern development and should be consulted for more detail (Andreev 1981; Bliss & Wein 1972a, b; Bliss & Peterson 1975; Bliss 1978; Bliss & Klein 1981; Brown & Grave 1978; Rickard & Brown 1974; Webber & Ives 1978). The Arctic as used here refers to all lands north of the climatic limit of trees. This huge area is subdivided into the Low Arctic (continental mainland), a near complete cover of
vascular plants in which dwarf and low shrubs are prominent, and the High Arctic (arctic islands), where vascular plants typically provide <20% cover (Bliss 1979).

2. Mining

Until the 1970s most mining operations had developed within the boreal forest or taiga. Important gold mining operations are found in Yellowknife, Northwest Territories, in the Yukon and in Alaska; uranium and silver at Great Bear Lake; and lead, zinc, copper and silver at various locations in Alaska and the Yukon Territory. This pattern is changing with the Nanisivik lead – zinc mine on Strathcona Sound, northern Baffin Island, Northwest Territories. This arctic mine went into operation in 1977, is currently producing 150,000 metric tonnes per year and has a life expectancy of about 15 years (Fig. 1). Ore is extracted, concentrated, and stockpiled for shipment in the ice-free season. A portion of the labor force comes from the Inuit settlement at Arctic Bay, 30 km away.

A second lead-zinc mine, Arvik, is under construction on Little Cornwallis Island, about 100 km northwest of Resolute (Fig. 1). This is a very high grade ore; the mine has a life expectancy of about 25 years. Mining is expected to begin in 1982.

The Mary River iron ore deposit in northern Baffin Island is a large ore body of high grade (Fig. 1). Ore extraction is in the future, for there are no detailed development plans. Removal of copper and other minerals, as well as the huge coal deposits (estimated reserves <3 trillion metric tonnes) on the North Slope of Arctic Alaska are in the future. These mining operations will be very large and require, in part, development of new transportation and environmental technology.

Mining in the Arctic may be similar in many ways

Fig. 1. Location of pipelines, roads, railways, oil and gas fields, and a few of the mineral deposits in subarctic and arctic North America.

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to that of temperate regions with the exception of the problems associated with temperature. If the permafrost (permanently frozen ground) contains large amounts of ice, special precautions are necessary in the construction of surface facilities (roads, buildings, tailing dumps). Utilization of newer mining techniques (Roy et al. 1973) is essential if the past problems of leachings from tailings entering water bodies are to be avoided. Early plans to dump tailings, high in heavy metals, into Strathcona Sound at the Nanisivik Mine were changed and the tailings are being dumped into a lake that has no outlet to the sea. In this way, marine organisms with already high levels of heavy metals are not subjected to even higher body burdens. There was sufficient lead time following this research to enable the company to change its plans for disposal of tailings. In these high arctic mining locations (Nanisivik, Arviq, Mary River), there is little vegetation and therefore little if any impact on plant cover or land mammals. This is not the situation with most northern oil and gas fields nor future coal mines in the Low Arctic of northern Alaska.

3. Transportation

A transportation system is essential for northern development. Runways and roads are elevated with gravel or other fill in order to provide adequate permafrost insulation as well as to aid wind in snow removal. Road construction in northern Alaska follows guidelines established by the EPA (Lotspeich 1971). The guidelines include placement of insulating fill over undisturbed vegetation, rather than the older practices of bulldozing the vegetation away and then adding gravel. The former practices often lead to permafrost melt and considerable land slumpage. The incorporation of sufficient drainage under elevated roads is essential to prevent upslope ponding of run-off and its potential initiation of permafrost melt and road washout. These problems occurred along the Dalton Highway that parallels the Ayleska Oil Pipeline, especially in the flat Coastal Plain. Control of permafrost degradation beneath roads (Esch 1973) and the control of culvert icings (Gaskin & Stanley 1973) to prevent spring flooding upslope of roads are essential to reduce road maintenance costs and to preserve vegetation. These and other stipulations and their enforcement have resulted in relatively few environmental problems in terms of impeded drainage and permafrost melt relative to the successful operation of the Dalton Highway and the Dempster Highway in the Yukon Territory and Northwest Territories. A detailed, three-year study on roadbed, drainage and side slopes associated with permafrost, road dust and revegetation and restoration along the Dalton Highway indicate that enforcement of environmental regulations is essential for the successful completion of roads in the Arctic and subarctic (Brown & Berg 1980). Knowledge gained from these studies should be incorporated into design and placement practices for culverts and bridges as well as new erosion control and rehabilitation guidelines.

The effect of vehicle and train traffic on the movement of large mammals has been studied in Scandinavia (Klein 1971) and North America (Roby et al. 1976). The results show that animals are turned back by frequent traffic. This can result in reduced use of some rangelands.

Permanent roads in the High Arctic are very difficult to build because of the very limited gravel source in many areas. Consequently, most roads run only from airports to settlements.

4. Petroleum

Within the northern boreal forest and Arctic, most current exploration and development is for oil and gas. During both the exploration and the development and production phases of an oil and/or gas field, much of the environmental concern centers upon terrain disturbance, the maintenance of vegetation and the impact to terrestrial and aquatic animal resources. Interrupted surface drainage, impoundment of water and drainage of wetlands, increased siltation from erosion and increased forest tundra and tundra fires, all modify wildlife habitat as a result of vegetation modification. Of equal or greater concern is the direct impact of people upon wildlife, including fish and waterfowl, through direct access for hunting, fishing and poaching. Large sums of money have been spent by industry and federal agencies to provide inventory and experimental data for the establishment of acceptable limits of ecosystem modification in relation to petroleum development.

4.1 Exploration phase

Much of the early terrain problems of summer road construction, summer seismic activity (Hernandez
1973), and uncontrolled off-road vehicles (Klein 1970) have been minimized through changed seismic operations, use of winter snow and ice-snow road construction and government regulations (Bliss & Wein 1972a; Hernandez 1973; Adam & Hernandez 1977). The successful use of the same winter road for four winters shows that terrain damage (exposed soil, loss of plant cover, permafrost melt) can be reduced, compared with using a new road area each winter (Fig. 2). The potential for thermokarst development (permafrost melt) is much greater within the northern forest where much radiant energy is dissipated as latent heat of evaporation and sensible heat compared with low shrub tundra in the Arctic where the vegetation exerts little influence on energy dissipation (Haag & Bliss 1974a, b). This means that in areas of discontinuous and continuous permafrost, the forest vegetation should be removed so as to leave the peat surface intact. The peat layer is the most significant deterrent to permafrost melt and thermokarst development. The potential for thermokarst development is less in the High Arctic where permafrost temperatures are lower and where ice content is generally less (Babb & Bliss 1974a, b). These more northern lands also have less plant cover and fewer species that can act as pioneers to revegetate surfaces. Therefore, gully erosion is a more serious problem once the surface plant cover and very shallow peat layer is broken (Fig. 3). Soil erosion can result from minor vehicle track surface disturbance or from piling snow at the edge of camp or airstrips that melts rapidly in June.

Fig. 2. Site of a winter snow-ice road after three years of rise. The bare areas are the tops of soil hummocks with the peat layer exposed. Mackenzie Delta area, Northwest Territories, Canada.
Vegetation recovers much more rapidly where winter snow-ice roads and well sites are built on lowlands dominated by sedges and grasses, compared with uplands with cottongrass tussock, low shrub or cushion plant tundra plant communities (Bliss & Wein 1972a; Hernandez 1973; Lawson et al. 1978).

The drilling of exploratory wells in winter permits well completion before spring melt, and, as a result, rigs and the associated camp can often be placed upon wooden piles placed within a gravel pad. The latter is always required in the wet coastal tundra of Alaska and in the Mackenzie Delta of Canada if the well is drilled in spring and summer (Bliss & Klein 1981) (Fig. 4). In areas of ice-rich permafrost, spoil from well and camp sumps melts unless the sumps are filled before summer. Summer melting results in loss of soil volume and this can result in wet sites for several years. In upland sites restoration usually results in less surface disturbance following clean-up (Fig. 5). Plants will naturally reinvade these sites, but succession may be delayed (Bliss & Klein 1981). Well site clean up and sump maintenance often are more difficult in the High Arctic due to the lack of gravel for pads and the loss of soil volume with summer melt (French 1980). The difficulty of establishing a plant cover following clean-up results from reduced plant growth and a relatively small number of species that can serve as pioneers (Bliss 1978).

4.2 Petroleum transport systems: Alyeska Oil Pipeline

Following discovery of the Prudhoe Bay oil and gas
field, the participating oil companies formed the Trans Alaska Pipeline System (TAPS). They planned to build the 1280 km hot oil pipeline from a gravel work pad (Fig. 1) and on an adjacent gravel haul road, having conducted only limited geotechnical and environmental studies. Court injunctions against the project regarding environmental concerns, width of the requested right-of-way, and native land claims delayed the project nearly four years. The U.S. Congress passed the Trans-Alaskan Pipeline Authorization Act in late 1973, in part due to the international pressure of the OPEC oil embargo. The enabling legislation required the Secretary of Interior to see that: (1) native people were hired under the Affirmative Action Program; (2) the government had a strong surveillance role paid for by Alyeska; and (3) an oil spill liability fund was set up including land and sea spills (Roscov 1977).

While the project was under litigation, the company determined that 680 km of pipe needed to be elevated due to high ice content of the permafrost from the original plan to elevate 220 km of the pipeline. The 120 cm diameter pipe was redesigned to be placed on highly engineered steel support members with ammonia heat exchangers to prevent heat transfer to the supports set into the permafrost. The original plan was for a wooden beam design. Culverts, bridges and low-water crossings (stream fords) were used to permit free passage of fish (Fig. 6). The original 280 designated fish streams that the pipeline crossed were eventually increased to 450 fish streams (Hubbard 1980a). Because there were limited data from fish surveys prior to construction, the enforcing agency biologist could demand culverts or bridges on streams not previously designated as having fish. With little or no recourse, the company was required to add the additional crossings for fish. Similar concerns arose with regard to elevating the pipeline or using a 'special-bury' of 'sagbend' section of pipe to allow large animals to cross. The pipeline company provided 556 official and 268 additional unofficial crossings for moose, bison and caribou (Hubbard
1980a). Survey studies since completion of the line indicate that moose freely cross under the pipeline (Van Ballenberghe 1978) and that caribou generally cross the pipeline, but that female caribou with calves tend to avoid the haul road, pipeline and adjacent rangeland more than the male caribou (Roby et al. 1976). Many biologists who have studied wildlife along the pipeline and road believe that frequent road traffic and work crews along the road are a greater deterrent to wildlife than is the passive pipeline (Fig. 7). A section of the oil pipeline and a 25 cm diameter gas pipeline, 230 km in length, were constructed from snow pads rather than a gravel pad. Two years following construction, the tundra shows little disturbance except where Betula and Salix shrubs occur (Bliss personal observation, Johnson 1981). This method of pipeline construction has great advantages for terrain and vegetation, where gravel roads are not essential for future maintenance. This is especially important for gas pipelines that can be buried and the gas refrigerated to maintain permafrost integrity.

A major component of project planning and construction costs is related to land restoration. Pipeline construction, roads, gravel and rock removal (material sites) resulted in surface disturbance to about 12,000 ha. Much of this required revegetation. Alyeska spent considerable money developing seed mixes and fertilizer mixes for each of the four designated climatic regions (arctic tundra, alpine, Brooks Range and interior). Seeding was done most economically by fixed-wing planes although hydroseeding by truck was also used. Mulching was applied in special sites (Hubbard 1980b). The reports to date
indicate that revegetation through seeding has been reasonably successful in most regions, the most difficult being the wet coastal tundra (Brown & Berg 1980; Johnson 1981).

Some of the most successful species for revegetation in the forest-tundra and Low Arctic include: arctared creeping red fescue, boreal creeping red fescue, nugget Kentucky bluegrass, meadow foxtail and engmo timothy as northern varieties of agronomic species. The native grasses Calamagrostis canadensis and Arctagrostis latifolia are also used in seed mixes and generally replace most agronomic species within 2–4 years (Youkkin 1976; Bliss 1978; Hubbard 1980b). In the High Arctic, climatic conditions are so severe that it appears that only native species can be used. The most successful ones are Arctagrostis latifolia in the southern islands and Aleopecurus alpinus and Phippsia algida in the northern islands (Bliss 1978).

An oil pipeline from Norman Wells, Northwest Territories to Zama, Alberta is in the planning stages. The 32 cm diameter pipeline, 866 km in length would parallel the Mackenzie River much of the way. Esso Resources Canada Ltd. and Interprovincial Pipe Lines (N.W.) Ltd. have issued an Environmental Impact Statement which has been reviewed by The Norman Wells Environmental Assessment Panel. The Panel has recommended that the project not proceed until 1982 at the earliest in order to deal with project deficiencies. These include potential problems of scour around artificial islands in the river, contingency plans for oil spills in ice-covered water, oil-leak detection capability, disposal of toxic and hazardous materials, pipeline integrity in discontinuous permafrost and revegetation and erosion control plans. Other concerns relate to economic and social issues relative to native peoples. All of these issues have been presented in the other pipeline projects in Alaska and Canada.

While there will always be environmental, social and economic concerns in relation to large northern projects, it is evident that companies, regional and

Fig. 6. Placement of culverts in main stream channel with a side water 'U'-shaped channel dug to permit fish to move upstream in water flowing at a lower velocity. Along the Dalton Highway adjacent to the Alyeska Pipeline, Alaska.
federal governments are working together to reduce their impacts to acceptable levels. The Alyeska pipeline created a great deal of environmental concern before and during its construction. However after oil began to flow through the pipeline in June, 1977 to the tanker port at Valdez, many environmental issues seemed to subside with the exception of completing restoration, including revegetation. There were a few places of permafrost melt along the right-of-way, and some concerns remain regarding animal crossings. Taken as a whole, most ecologists who have driven the pipeline route agree that there are far fewer environmental scars than anticipated and certainly far fewer than occur with comparable huge projects in temperate America, a clear indication that industry can construct projects with minimal environmental impact in the Arctic, provided environmental regulations are followed.

4.3 Arctic gas pipelines

To date, three arctic gas pipelines have been planned, with one of them under construction at this writing. Two systems are on the continent and the third, still under review, is the Arctic Pilot Project on Melville Island, Northwest Territories.

The Canadian Arctic Gas Pipeline System was designed to carry natural gas from Prudhoe Bay, Alaska to the gas fields of the Mackenzie Delta and then south along the Mackenzie River to Alberta. Geotechnical and ecological research costing more than $40 million was conducted from 1970–1975. The consortium of companies filed an application in 1974 to construct the pipeline and the Mackenzie Valley Pipeline Inquiry held public meetings from March, 1975–October, 1976 and a report was released in May, 1977. Justice Berger (1977a, b) re-
commended against the pipeline largely on the basis that it would take more than one winter to construct the arctic portion and therefore the company would seek to extend construction into the summer and that this would be environmentally unacceptable.

Other major issues were concerns for ice build-up around the refrigerated, buried pipeline in regions of discontinuous permafrost and concerns for native people and their land claim settlement. The Federal Government of Canada rejected the project on the basis of these geotechnical, environmental and social concerns. This project was planned as a fully buried pipeline to carry refrigerated gas in permafrost terrain. Further the project was designed to be built from winter snow–ice roads to lessen the impact on terrain and vegetation. In that way, no permanent road would have remained upon completion of the pipeline and its associated problems of revegetation over gravel, and vehicle traffic with its potential for deflecting animals attempting to cross the road. A greater general concern with roads is their direct access for increased pressure on hunting and fishing. A detailed summary on the two pipeline proposals with a critique on the Berger Inquiry and its findings is presented by Peacock (1977).

A counter proposal for a gas pipeline paralleling the oil pipeline to Fairbanks and the running southeast adjacent to the Alcan Highway was approved following the Lysyk Inquiry (Lysyk et al. 1977) although that Inquiry pointed out many deficiencies in the project and the need to settle land claims of native people in the Yukon Territory. In spite of these concerns and the lack of a land claim settlement, the Canadian Federal Government approved the project and construction in Canada began the fall of 1980. Financing for the Alaskan portion is not yet finalized and approval hearings have not been held. It was anticipated that construction in Alaska of the Alaska Highway Pipeline would begin in 1982 with completion expected in 1986–1988. If constructed as planned, the pipeline will be 7700 km in length, transport 222 million m³ of gas per day and cost $34.5 billion in 1981 dollars. This will be the largest and most expensive construction job ever undertaken.

Detailed plans are being developed for site restoration, including revegetation using some native species in the original seed mixes. The intent is to encourage reestablishment of native vegetation. Other ecological issues being addressed are maintaining fish populations in streams and minimizing disruptions to wildlife and bird populations during construction. A buried gas pipeline has the advantage of not modifying the free movement of mammals, but the adjacent Alcan Highway is an effective barrier to at least some species.

By comparison the proposed gas pipeline and icebreaker tanker project on Melville Island is small, yet very significant for what is planned. The pipeline would transport gas from the Drake Point Gas Field through a 546 cm diameter buried pipeline, 160 km to Bridport Inlet on the south coast. A liquidation plant would be built and the gas transported in icebreaker tankers to eastern Canada.

Much of this terrain has little vegetation, except the sedge-moss meadows in the Sabine Lowland. Most of the area is classified as polar desert or polar semi-desert (Bliss 1979). With limited plant cover, there is limited ability to control sheet and gully erosion with other than mechanical means. Where fine-textured soils occur on the Christopher Shale Formation, active layer detachment slides (mud slumps) are found. These result from soil saturation with summer rain or following snowmelt. The upper portion of the permafrost is normally ice-rich (Babb & Bliss 1974a). With limited vegetation to hold the soils, massive slumps occur (Hamilton & Bliss 1979).

The lack of construction gravel in many of these northwestern islands, the general lack of vegetation, and the abundance of natural sheet and gully erosion resulting from snowmelt and summer rains are probably the most serious terrain-vegetation problems (Babb & Bliss 1974a, b; Babb 1977; Hamilton & Bliss 1979).

4.4 Petroleum spills and fire

Limited diesel fuel spills occurred next to the Alaska Haul Road during construction when trucks turned over due to slippery roads. Small oil spills have occurred since completion of the line. In all cases, much of the diesel fuel or crude oil was cleaned up, the surface lightly burned in winter to remove the residue and fertilizer added to promote regrowth of native vegetation. It appears that resident and seeded plant species respond most significantly to phosphorus fertilizer (McKendrick & Mitchell 1978b).

The impact of crude oil on native vegetation has been studied near the treeline and in three sites within the Low Arctic near Inuvik and Tuktoyaktuk, Northwest Territories (Wein & Bliss 1973a; Freed-
5. Human impact on tundra vegetation, USSR

The limited papers available show that considerable research is under way in the USSR to determine the impact of industrial development on vegetation, soils and permafrost (Andreyev 1981; Brown & Grave 1978; Matveyeva 1979; Druzhinina & Zharkova 1979; Yurtsev & Korobkov 1979). Revegetation of gold mine tailings requires 8–10 years, vehicle tracks require 3–4 years for initial species and 40–50 years for sedge hummocks to develop (Andreyev 1981). At the Vorkuta Industrial Center (67°N, 64°E), grasses develop rapidly after soil disturbance (Poa pratensis, P. alpigena, Festuca ovina, Agrostis borealis, Calamagrostis lapponica, Alopecurus pratensis) and the sedge Eriophorum scheuchzeri. These are invaded by Salix glauca, S. phyllicifolia, S. lanata and Betula nana, forming a willow grass–moss community (Druzhinina & Zharkova 1979). At Kresty in Western Taimir (71°N, 89°E), Matveyeva (1979) reported on the successional sequence of species following disturbance and listed 11 species, of the 27 species commonly found in disturbed soils, that are favored for rehabilitation. The list includes five grass species. At the settlement of Yanrakynnot on the Chukchi Peninsula (65°N, 17°W), Yurtsev & Korobkov (1979) list numerous species in disturbed soils. Important species include Arctagrostis arundinacea, A. latifolia, Poa arctica, Phippsia algida, Descurainia sophiodes and Artemisia tiliis.

Where fire is common in the forest–tundra, fire induced tundra dominated by low shrubs (Betula, Salix) and sedges (Eriophorum, Carex) develop (Belyi 1974).

6. Conclusion

From this review, it should be evident that a considerable amount of information has been learned in the past 10–15 years regarding the use of ecological data in lessening the impact of human influence in the Arctic. Through detailed studies prior to completion of industrial plans, ecological information can be used to help locate the least-damaging routing of roads, pipelines and the positioning of even towns and industrial facilities. In all northern countries, ecologists within the government agencies and industrial concerns are learning to work together in ways that are saving construction and maintenance costs. While
much remains to be learned in lessening harmful environment impacts as new mining and petroleum complexes are developed, we have come a considerable way in maintaining wildlife, vegetation and intact permafrost in these cold stressed environments.

References


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