The Transmission of Prudhoe Bay Gas to American Markets: A Preliminary Environmental Comparison of the Canadian Arctic Gas Pipeline and the Foothills (Yukon) Pipeline in the Yukon and Northwest Territories

Alaska Highway Pipeline Panel
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Sponsored By
FOOTHILLS PIPE LINES LTD.

ALASKA HIGHWAY PIPELINE PANEL

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MEMBERS:
Mr. I.K. Fox
Mr. W.W. Mair
Dr. I. McTaggart-Cowan
Dr. J.G. Nelson
Mr. C.H. Templeton (Chairman)

June 20, 1977

Foothills Pipe Lines Ltd.
Box 9083
Calgary, Alberta
T2P 2W4

Gentlemen:

Re: The Transmission of Prudhoe Bay Gas to American Markets: A Preliminary Environmental Comparison of the Canadian Arctic Gas Pipeline and the Foothills (Yukon) Pipeline in the Yukon and Northwest Territories

In accordance with our arrangement with you as sponsor of this Panel, we are submitting, herewith, the above mentioned report for your information but not for edit.

We thank you for waiving the provision in our arrangement that we would provide you with our reports four weeks prior to publication. Although we forwarded a draft copy to you June 15, a number of revisions have been made since then.

The report is being forwarded today to the Alaska Highway Pipeline Inquiry and the Environmental Assessment Panel - Alaska Highway Pipeline Proposal and it is our intention to present the report formally at these Inquiries in July.

In addition, we will deposit copies of the report in a number of government and university libraries in accordance with our arrangement that we will "report publicly, all materials and opinions as the studies progress".

Yours truly

ALASKA HIGHWAY PIPELINE PANEL

I.K. Fox

W.W. Mair

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This Panel is sponsored by Foothills Pipe Lines Ltd.

THE ALASKA HIGHWAY PIPELINE PANEL

The Alaska Highway Pipeline Panel was established in August 1976 to study and report on the physical, biological and human environmental implications of construction and operation of the proposed Alaska Highway gas pipeline in the Yukon Territory. The Panel, which is composed of a group of scientists and engineers experienced in northern matters, has taken as its primary role the achievement of a reasonable degree of environmental protection during the planning, implementation, and eventual shutdown of the Alaska Highway gas pipeline. The Panel is sponsored by Foothills Pipe Lines Ltd. under the following goals and terms of reference.

Goals of The Panel

The primary goal of the Panel is to maintain or achieve environmental protection on any projected Alaska Highway gas pipeline route. To achieve this goal, the Panel will:

- determine the nature of the physical, biological, and social environments that might be potentially affected;
- determine the kinds of changes likely to occur and express them publicly;
- advise on what mitigative and control measures should be instituted to achieve environmental protection; and
- advise against construction of a gas pipeline should the Panel decide that mitigative and control measures would not achieve the primary goal.

Terms of Reference

The terms of reference provide for an autonomous panel, in that the members decide what should be studied, what research should be conducted and what conclusions should be drawn. Specifically, these terms of reference include the following:

- The Panel will be free to study in respect of environmental considerations including human and community factors, whatever in its judgement it deems necessary to achieve its goal.
- The Panel will report publicly, all materials and opinions as the studies progress.
- The sponsor does not have the right to preview or edit the reports or opinions of the Panel but shall be provided with such reports or opinions four weeks prior to publication.
- The Panel will submit annually, or semi-annually, a budget for the approval of the sponsor.
- The sponsor or the Panel can terminate the arrangement at any time by giving one month's notice. If the termination is by the Panel, it will deliver all of its findings to the sponsor. If the sponsor terminates the arrangement, the Panel will put its studies into interim report form and deposit them in a library so the information will not be lost. The sponsor will pay for reasonable rundown costs.

Panel Members

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CONTENTS

SUMMARY

We have compared the Alaska Highway and Arctic Gas (circumdelta route) pipeline projects on the basis of the physical, biological and human environmental issues involved. We have concluded that the Alaska Highway project is the strongly preferred route for moving Alaskan gas through Canada north of 60°N.

We have compared only the sections of both routes that lie in the Yukon and NWT because these sections have been the subject of the Federal Government's Inquiries. The Berger Inquiry, for example, considered the environmental and socio-economic aspects (what we call the human environment) of the Arctic Gas and Maple Leaf routes in the Yukon and NWT; and the Lysyk and Hill Inquiries are considering the socio-economic and environmental aspects, respectively of the Alaska Highway route in the Yukon. It seems, therefore, that the Yukon and NWT sections are the ones for which the environmental and socio-economic aspects will be weighed. In any case, little information has been published on environmental impacts for the Alberta and BC portions. We recognize that environmental considerations do not stop at political boundaries; but since we are supplying information leading to a Canadian national decision, we have made no attempt to include the Alaska portion.

We have brought together a number of disciplines and we have tried to be as objective as possible. Many of the opinions expressed are subjective. We have shown how we

arrived at these opinions so that others who weigh the factors differently can form their own opinions. Our aim is to encourage the idea that national discussions must be based on factual information rather than purely emotional considerations.

The two projects in the Yukon and NWT differ considerably in size: the Arctic Gas route is 985 miles long, and the Alaska Highway route 513 miles long. But impacts are not measured by length alone: the type of operations contemplated, and the size of the labor force (5000 personnel for Arctic Gas vs 2300 for Alaska Highway) are also factors. In addition, the sensitivity and quality of the human and natural environments must be considered.

The following paragraphs summarize the major findings and conclusions of the comparison for each of the three environmental categories we studied:

Physical Environment

On the Arctic Gas route, physical environmental problems are substantial in connection with permafrost degradation and thaw settlement of high ice content soils. A chilled pipeline, while reducing permafrost degradation, poses technological and environmental problems which have not been solved. Such problems include frost heave, drainage interruption, and icings. Soil erosion, particularly if planned winter construction proves unfeasible, would be extensive. Sedimentation of streams, the result of extensive borrow operations, would increase tremendously should permafrost degradation become widespread. Potential for accidents in the handling and storage of fuels and toxic substances is high; the effects on water and wildlife would be severe. Ice-fog formation from construction and operation will affect microclimate. Overall, the major problems relate to permafrost.

On the Alaska Highway route, physical environmental problems would result from thaw settlement caused by summer construction and the transmission of gas at above freezing temperatures. Sloping ground with erodible soils would be subject to some erosion. Seismic risk and landslide potential is considerable. Sediment loads in most streams would not increase substantially; a vigorous revegetation program should reduce siltation. Storage and handling of fuels and toxic substances presents the risk of accidental spills with potentially severe effects on water quality and wildlife. Several large lakes such as Kluane and Teslin could be affected because of their close proximity to the pipeline route. Groundwater could become polluted in several communities downslope of the route. Overall, the major problems are permafrost degradation and sedimentation.

In comparing the two routes we found that the Alaska Highway route was substantially preferable to the Arctic Gas route. Permafrost degradation and thaw settlement in excess of one foot would be 3-4 times greater on the Arctic Gas route. Resulting erosion and siltation would degrade the physical environment. Water quality would be more adversely affected by sedimentation on the Arctic Gas route. Other considerations such as frost heave, doubt as to the viability of winter construction, and drainage interruption from a cold pipeline serve to magnify our preference for the Alaska Highway route.

In our detailed quantitative analysis of the physical environment (Table 2), this conclusion translated into a preference ratio of 2:1 for the Alaska Highway route.

Biological Environment

On the Arctic Gas route, the biological environmental impacts relate to mammals, birds, fish and vegetation. Of grave concern is the Porcupine caribou herd which would experience disturbance from aircraft, summer-related construction activities, and compressor station operation. Although the proposed activities on the pipeline right-of-way may not be serious, other development both during and after construction could be serious. This, together with the drastic reduction of Alaskan populations of caribou, increases our concern for the absolute protection of the Porcupine caribou herd. Polar bears and grizzly bears are expected to cause nuisance problems at camps and some animals may be destroyed. Fuel spills, siltation and drainage interruption would degrade aquatic furbearer habitat. Dall's sheep at Mount Goodenough could be disturbed by aircraft and quarrying operations. Nesting rare or endangered birds such as peregrine falcons could be adversely affected by aircraft, as could other raptorial birds that breed along the route. Several hundred thousand snow geese stage on the Yukon coast in fall and on the Mackenzie River islands in spring. Arctic char, grayling and whitefish resources could be affected. Arctic tundra and revegetation success are also of concern. The major problems, however, are with caribou, snow geese and raptors.

On the Alaska Highway route, the major biological problem concerns Dall's sheep: several thousand animals may inhabit the 250 linear miles of range crossed by the pipeline. Grizzly bears will cause nuisance problems and may be shot. Hunting by pipeliners and camp followers is very likely to have an impact on wildlife populations. It would be catastrophic if trophy hunting by workers and greatly increased hunting by locals were allowed along the Dempster highway. Trumpeter swans and bald eagles could be adversely affected by construction-related activities near nesting areas. Salmon, trout, whitefish, and grayling are vulnerable to pollution, erosion and sedimentation. Remedial measures would have to be instituted to prevent degradation of fish habitats. Grassland areas are limited in the Yukon, so the crossing of them is of particular concern.

In comparing the two routes, we found that the Alaska Highway was preferable for three of the four biological components: mammals, birds, and vegetation. For each of these components, preference was primarily based on the unique or critical contributions of the Yukon coast or

Mackenzie Delta to the well-being and long-term stability of key biological species -- the barren-ground caribou calving grounds and the raptor nesting areas of the Yukon coast, the waterfowl nesting and staging areas of the Yukon coast and Mackenzie Delta, and the unique expanse of arctic tundra and its fauna on the Yukon Coastal Plain. There are no similar areas along the Alaska Highway route that provide so much critical habitat for so many key components of the western Canadian Arctic environment. Although sheep are abundant along the Alaska Highway route, it is still clearly preferred over the Arctic Gas route for the parameters addressed in the biological environment.

In our detailed quantitative analysis for the biological environment (Table 3), our conclusion translated into a preference ratio of 1.3:1 for the Alaska Highway route.

Human Environment

The Arctic Gas project could have profound effects on the human environment, particularly on the native population of the Mackenzie Valley because of the traditional nature of communities there. The land claims issue, though external to a pipeline project, poses a substantial problem. There is a clear desire by the people to formally establish their future role in the North through a settlement of these claims. The influx of several thousand southerners over a short period would undoubtedly disrupt traditional living patterns. Increased health problems and higher crime rates would contribute to social problems. In addition, there is some doubt as to the adaptability of the Mackenzie Valley economy to a project of such huge proportions. The existing level of demand for all types of goods and services could be dramatically increased by the demands of pipeline construction. The supply side of the Mackenzie Valley economy is not presently capable of coping with these demands. The wilderness areas of the northern Yukon and the Mackenzie Delta are a part of Canada's natural heritage that will be adversely impacted. If subsequent development were to follow the gas pipeline, this area could be destroyed forever.

The Alaska Highway route will encounter manifold problems as well. The Yukon has traditionally-oriented and somewhat remote communities which will be adversely affected. Social problems with respect to public safety, health, and the way-of-life in these areas will result from a rapid increase in the population. The supply side of the Yukon economy has expanded in accordance with a stable increase in demand and thus a high level of excess capacity does not exist in this economy to respond to project demands. The Yukon economy cannot absorb, without substantial social costs, the demands that would be made on it during the proposed construction period. The northern edge of Kluane National Park would be crossed by the pipeline project at Sheep Mountain. A proposed IBP site at Duke Meadows would also be disturbed. Tourism, mining and other segments of the economy would be adversely affected through labour turnover, increased transportation costs, and inflation.

In comparing the two routes we found human environmental problems with both. But we also found that the problems were different in each project setting. For example, the Arctic Gas route would experience problems in native communities with the influx of workers, whereas the Alaska Highway route would draw many other non-workers to the project area because of ease of access. The more traditional communities of the Mackenzie Valley would experience greater cultural impact than those on the Alaska Highway route. Public safety would be less impaired on the Arctic Gas route because of winter construction and limited access. The Alaska Highway would provide easy access for families of workers, camp followers, and squatters. Trapping and commercial fisheries would not be affected any more by the circum-Delta Arctic Gas route than by the Alaska Highway route. It would be more difficult for government planning and administrative services to respond to local problems and project-induced demands in the Mackenzie Valley than in the southern Yukon. The relatively well-developed transportation sector in the southern Yukon, as compared to that of the Mackenzie Valley, indicates that a regular flow of goods could be maintained there. Tourism is economically important in the Yukon but insignificant in the Mackenzie Valley. The number of pipeline employees in relation to the labour force of each of the regions indicates that adverse economic impacts would be of a smaller order on the Alaska Highway route.

Finally, the Alaska Highway route would have an impact on Kluane National Park, but the impact of the Arctic Gas project on the proposed sanctuaries, parks and IBP sites would be greater.

In our detailed quantitative analysis of the human environment (Table 4), this conclusion translates into a preference ratio of 1.2:1.0 for the Alaska Highway route.

The methodology underlying these findings and conclusions was developed as follows. First, the physical, biological and human environments were divided into their separate parameters (permafrost, snow geese, national parks, etc.). Each parameter was weighted to show its importance in relation to the other parameters in its category. The projects were then studied in the light of their effects on each parameter, the effects were compared, and a preference rating was assigned to each project, parameter by parameter. A scale of 1 to 5 was used, with a "5" assigned to the preferred route, and an equal or lesser rating assigned to the other route. Subjective judgements were made for some parameters in the human environment where time did not allow for detailed studies. The weightings and preference ratings were then multiplied to give Weighted Preference ratings which represent overall preferability.

The following summary table lists the Weighted Preference ratings and preference ratios for both projects.

Table 1. Overall comparison of the routes.

	Weighted Preference	
	Alaska Highway	Arctic Gas
Physical Environment		
Land Component	495	196
Water Component	420	246
Air Component	115	70
Total	1030	512
Preference ratio	2.0	1.0
Biological Environment		
Mammal Component	635	481
Bird Component	590	353
Fish Component	263	281
Vegetation Component	132	104
Total	1620	1219
Preference ratio	1.3	1.0
Human Environment		
Life Patterns Component	882	681
Local Economy Component	590	567
Man-Land Heritage Component	270	246
Infrastructure Component	282	246
Total	2024	1740
Preference ratio	1.2	1.0
ENVIRONMENT		
Total	4674	3471
Preference ratio	1.4	1.0

Clearly, from the point of view of the environmental issues of the projects, the Alaska Highway pipeline is the strongly preferred project by a ratio of 1.4:1.0. However, this preference does not imply unconditional approval of the project. The importance of developing and implementing control systems cannot be overstressed if impacts are to be kept to an acceptable level.

The following tables provide a breakdown of the information in the summary table for all the parameters considered in the comparison.

Table 2. Physical environment comparison summary.

	Relative Importance Weighting	Relative Preference		Weighted Preference	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
LAND COMPONENT					
Permafrost	47	5	1	235	47
Erosion	37	5	2	185	74
Slope stability	15	5	5	75	75
Total	99			495	196
Preference ratio				2.5	1.0
WATER COMPONENT					
Sedimentation	30	5	3	150	90
Water quality	30	5	2	150	60
Groundwater regime	16	5	5	80	80
Surface water regime	8	5	2	40	16
Total	84			420	246
Preference ratio				1.7	1.0
AIR COMPONENT					
Air quality	12	5	4	60	48
Microclimate	11	5	2	55	22
Total	23			115	70
Preference ratio				1.6	1.0
PHYSICAL ENVIRONMENT					
Total				1030	512
Preference ratio				2.0	1.0
OTHER FACTORS					
Seismic risk		2	5		
Frost heave		5	1		
Climatic influence on construction		5	3		
Winter roads		5	2		

Table 3. Biological environment comparison summary.

	Relative Importance Weighting	Relative Preference: Alaska Highway	Relative Preference: Arctic Gas	Weighted Preference: Alaska Highway	Weighted Preference: Arctic Gas
MAMMAL COMPONENT					
Barren-ground caribou	39	5	1	195	39
Dall's sheep	25	2	5	50	125
Grizzly bear	20	5	4	100	80
Polar bear	18	5	4	90	72
Woodland caribou	13	5	4	65	52
Moose	8	5	4	40	32
Wolverine	7	5	5	35	35
Wolf	7	5	4	35	28
Arctic fox	3	5	4	15	12
Aquatic furbearers	2	5	3	10	6
Total	142			635	481
Preference ratio				1.3	1.0
BIRD COMPONENT					
Peregrine falcon	20	5	2	100	40
Gyrfalcon	12	5	2	60	24
Snow geese	12	5	1	60	12
Trumpeter swan	12	4	5	48	60
Whistling swan	12	5	3	60	36
Golden eagle	10	5	4	50	40
Bald eagle	8	4	5	32	40
White-fronted geese	7	5	3	35	21
Brant	7	5	2	35	14
Diving Ducks	6	5	2	30	12
Sandhill crane	6	5	4	30	24
Canada geese	6	5	3	30	18
Dabbling ducks	4	5	3	20	12
Total	122			590	353
Preference ratio				1.7	1.0
FISH COMPONENT					
Arctic char	17	5	3	85	51
Chinook salmon	13	4	5	52	65
Chum salmon	11	4	5	44	55
Dolly varden	7	3	5	21	35
Lake trout	7	3	5	21	35
Whitefish	4	5	5	20	20
Arctic grayling	4	5	5	20	20
Total	63			263	281
Preference ratio				1.0	1.1
VEGETATION COMPONENT					
Arctic tundra	9	5	1	45	9
Grasslands	7	2	5	14	35
Alpine tundra	6	4	5	24	30
Wetlands	4	5	2	20	8
Riparian vegetation	3	5	3	15	9
Pioneer communities	2	5	4	10	8
Boreal forest	1	4	5	4	5
Total	32			132	104
Preference ratio				1.3	1.0
BIOLOGICAL ENVIRONMENT					
Total				1620	1219
Preference ratio				1.3	1.0

Table 4. Human environment comparison summary.

	Relative Importance Weighting	Relative Preference		Weighted Preference	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
LIFE PATTERNS COMPONENT					
Acculturation	42	5	3	210	126
Public Safety	33	4	5	132	165
Public Health	27	5	3	135	81
Cost-of-Living & Incomes	27	5	4	135	108
Subsistence	27	5	3	135*	81*
Employment	15	5	4	75	60
Recreation	12	5	5	60*	60*
Total	183			882	681
Preference ratio				1.3	1.0
LOCAL ECONOMY COMPONENT					
Tourism	25	3	5	75*	125*
Trapping	20	5	4	100	80
Commercial Fishing	20	5	5	100	100
Mining	20	5	5	100*	100*
Planned Land Use	18	5	3	90*	54*
Service & Retail	17	5	4	85*	68*
Forestry	8	5	5	40*	40*
Total	128			590	567
Preference ratio				1.0	1.0
MAN-LAND HERITAGE COMPONENT					
Archaeological and historic sites	18	5	4	90	72
Special areas	17	5	2	85	34
National parks	17	3	5	51	85
Aesthetics	11	4	5	44*	55*
Total	63			270	246
Preference ratio				1.1	1.0
INFRASTRUCTURE COMPONENT					
Planning and administrative services	18	5	3	90	54
Transportation	13	5	4	65	42
Education	13	4	5	42*	65*
Municipal services	9	5	5	45*	45*
Communications	8	5	5	40*	40*
Total	61			282	246
Preference ratio				1.1	1.0
HUMAN ENVIRONMENT					
Total	435			2024	1740
Preference ratio				1.2	1.0

*Parameters where detailed studies were not made for this report; estimates are based on subjective judgements.

INTRODUCTION

This report describes the results of an environmental comparison of the Alaska Highway and Arctic Gas pipeline routes for the movement of Alaskan gas through the Yukon and Northwest Territories. It covers the human, biological, and physical environments along both routes.

To properly analyze the main alternatives so that a complete comparison could be made, we would need to have had the following data.

- The date when Delta gas is needed (not just wanted) by Canada.
- The amount of gas in the Mackenzie Delta sedimentary basin that Canada can and will allow to be removed.
- The method by which offshore gas can be brought to shore in the vicinity of the Mackenzie Delta, and the location where this is to be permitted.
- Environmental data (including data on the human environment) for: the Dempster Highway route, both the Arctic Gas and Alaska Highway routes in Alberta and B.C. to a point where the two routes converge, the Yukon-Tintina Trench route to Watson Lake, and the Yukon-Tintina Trench route to Whitehorse.
- Environmental data (including data on the human environment) for the Alaskan sections of both the Arctic Gas and Alaska Highway routes.
- Canada's long-range plans for providing for future generations of Canadians in terms of hydrocarbons, wilderness, and preservation of the cultural heritage of its native peoples.

This information is not availabe to us and probably not available to anyone; so if the pipeline decision is to be made this summer, it will have to be made without this information.

We realize that the two routes we have compared are not truly comparable in the strictest sense. To begin with we have confined our comparison to the portions of the routes in Canada lying north of 60°N, even though one of the routes crosses twice as much Canadian soil as the other. But the Berger, Lysyk, and Hill Inquiries are all confined to a consideration of these same sections of the routes, so our comparison is consistent with their terms of reference in that regard. We have also confined ourselves to comparing pipelines that are designed to carry Alaskan gas to the "southern 48". With regard to the matter of the "piggy-backing" of Canadian gas onto an American gas pipeline, this involves a whole range of issues -- how much gas there is in the Delta, the cost to Canadians of Delta gas, the dilemma of immediate needs vs the long-term responsibilities to future generations for energy, native claims, and many others. We have not covered these issues in our report but confined ourselves to an environmental comparison of the routes.

Despite the inequalities between the two routes, we felt that a comparison had to be made and therefore we compared the two routes in as quantitative a way as we could. As in other approaches, we combined objective conclusions (those that use facts that are observable or verified) with subjective judgements (those which are based on values, feelings, beliefs). We have shown how we arrived at the figures we reached so that others with a different set of biases will be able to insert their own figures in the tables and come up with their own comparison.

In the northen portion of their route, Arctic Gas proposed a Circum-Delta route and a Cross-Delta route. Although CAGPL preferred the Cross-Delta route we have not considered it because we found it unacceptable. Mr. Justice Berger, by recommending bird and whale sanctuaries in areas crossed by the route, in effect also found it unacceptable. Of course he did not recommend a route across the northern Yukon, so he did not differentiate between the Circum-Delta and the Cross-Delta routes. For the purpose of this comparison, we have used the Circum-Delta route.

We must again stress that the actual amount of environmental impact that takes place if the project goes ahead depends on the quality and extent of administrative control that is exercised by the permittee and the government. Controls would consist of codes, regulations, site-specific restrictions, training and information programs, planning bodies and enforcement officers. This report assumes the same degree of control for each project. In a few instances, the risk of not achieving that degree of control is greater for one project than for the other. In such a case, the comparison of routes would reflect this risk.

The appendix to this report contains the background documentation and analysis of the human, biological and physical environmental features of both routes upon which we relied in making our judgements.

PROJECT DESCRIPTION

Alaska Highway Route:

The proposed routing of the Alaska Highway pipeline (Fig. 1) would generally follow the existing Alyeska oil pipeline and associated haul road south from Prudhoe Bay to Fairbanks. From there, it would generally follow the Alaska Highway across southeastern Alaska and the southern Yukon, across northeastern British Columbia, and south along western Alberta to a point near Calgary where it would divide in two. One line would cross southeastern Alberta and southwestern Saskatchewan, entering the United States near Monchy, Saskatchewan; and the other line would cross southeastern British Columbia, entering the United States near Kingsgate, B.C. Total pipeline length would be about 2754 mi, of which 731 mi would be in Alaska, 513 mi in the Yukon, and 1510 mi in British Columbia, Alberta and Saskatchewan.

Throughout its length, the pipeline will be buried except where above-ground pipe enters compressor and meter station buildings. Right-of-way width will be about 120 ft. Gas temperatures will be below 0°C along all of the pipeline across Alaska but only the northernmost 40 mi in the Yukon will be chilled. South of this, gas temperatures will generally be 20 to 30°C. Pipeline diameter will be 48 in. in the Yukon.

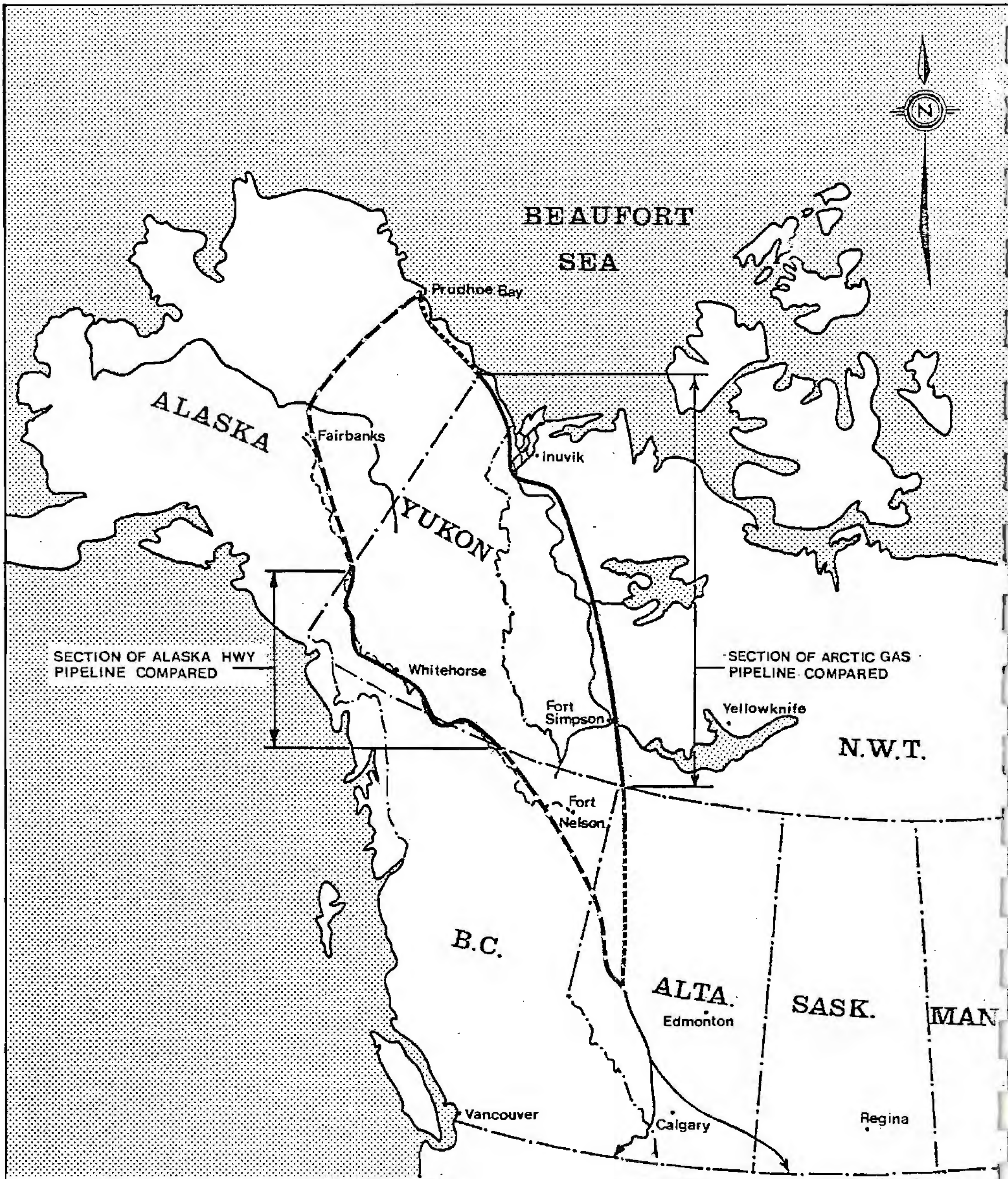

Fig. 1. Location of proposed pipelines to transmit gas from Prudhoe Bay, Alaska to the continental U.S., showing segments compared in Canada north of 60° N.

Clearing of the right-of-way will be carried out year-round. Laying of pipe along the Yukon segment will be done in winter for the northern 110 mi and in summer for the remaining 400 mi. Stockpile sites for pipe, fuel, and other construction materials and equipment will occupy areas varying from 6 to 20 acres and would be located at 30- to 50-mi intervals. Construction camps for about 800 personnel are generally proposed at alternate stockpile sites. Preconstruction and construction activities are scheduled to take about 4 years in total.

Initially, 30 compressor stations would be required, roughly at 75-mi intervals to transmit about 2500 million ft^3 of gas each day along the entire pipeline. Of these, seven stations would be in the Yukon. Each station would cover about 10 acres. If the amount of gas transported is increased to 3400 million ft^3, a total of 60 compressor stations at 40-mi intervals would be required, 13 of them in the Yukon.

Work force requirements during construction would, according to Foothills, peak at about 2300 personnel per year in the Yukon. Once the pipeline is built, about 190 personnel would be needed to maintain and operate it.

Arctic Gas Route:

The routing of the Arctic Gas pipeline we selected for study (Fig. 1) would generally follow the arctic coast of Alaska and the Yukon east from Prudhoe Bay to the Mackenzie Delta, skirt the Delta on the west and south and proceed south along the east side of the Mackenzie River, crossing it near Fort Simpson. From here it would proceed south into Alberta to a point near Calgary where it would divide in two. One line would cross southeastern Alberta and southwestern Saskatchewan, entering the United States near Monchy, Saskatchewan; and the other line would cross southeastern British Columbia, entering the United States near Kingsgate, B.C. Total pipeline length would be about 2465 mi, of which 195 mi would be in Alaska, 985 mi in Canada north of 60°N (135 mi in the Yukon, 850 mi in the Northwest Territories), and 1285 mi in Alberta, Saskatchewan and British Columbia.

Throughout its length, the pipeline will be buried, except where above-ground pipe enters compressor and meter station buildings. Right-of-way width would be about 120 ft. Gas temperatures will be below 0°C along all of the pipeline in Alaska, the Yukon, and all or almost all of the Northwest Territories. Pipeline diameter will be 48 in. across Alaska, the Yukon, and the Northwest Territories.

Clearing of the right-of-way will be carried out by machine, the winter before the pipeline is installed. Laying of the pipe across the Yukon and Northwest Territories sections will be in winter except for crossings of major rivers which would be in summer. Stockpile sites for pipe, fuel, and other construction materials and equipment in northern Canada would be located near two wharf sites along the Yukon coast and at 15 additional wharves at about 50-mi intervals (near compressor stations) along the Mackenzie Valley. The area required for each wharf-stockpile site complex would range from 10 to 20 acres. The pipeline would be constructed in about 75-mi segments with one 800-person camp per segment. Preconstruction and construction activities will be about 5 years in total.

Transmission of 2250 million ft^3 of gas daily from Prudhoe Bay would require 2 compressor stations, 200 mi apart -- 1 in the Yukon and 1 on the southwest side of the Mackenzie Delta. Another 16 compressor stations 50 mi apart would be built along the Mackenzie Valley. This system would have the capacity to handle 4500 million ft^3 of gas daily. During initial construction, an additional 8 compressor station sites (4 in Alaska, 2 in the Yukon, 2 along the west side of the Mackenzie Delta) would be prepared but no compressor equipment installed. All 10 stations between Prudhoe Bay and Travaillant Lake would be required to transmit 4500 million ft^3 of gas daily from Prudhoe Bay.

If this volume is transmitted from Alaska, looping of the Mackenzie Valley pipeline might be required, depending on whether and how much gas from the Mackenzie Delta is transmitted through the same pipeline.

The compressor stations would occupy areas varying in size from 25 to 40 acres depending on the location. Six of the 16 compressor stations along the Mackenzie Valley would have associated airstrips. Most such airstrips would cover an additional 175 acres but one would be 300 acres in size. All stations in the Yukon and along the west side of the Mackenzie Delta would have airstrips, mostly about 100 acres in size but one covering 300 acres.

Work force requirements would peak at about 5000 personnel in the Yukon and Northwest Territories. Once the pipeline is built, about 225 personnel would be needed to operate and maintain it.

APPROACH

Although a great deal of environmental information has been collected by pipeline groups and the government in the last seven years, the information is not in a form that lends itself to ready comparison of alternate routes. What is needed now is to compare the data available, and where data are unavailable make subjective judgements. To make these subjective judgements an interdisciplinary team approach is preferable.

Our approach has been to have a study team analyze environmental parameters and then subject their analysis to the Panel's review as a group. For those parameters on which there were no data available, the Panel members expressed their collective opinions and have indicated them as purely subjective opinions.

The steps through which the studies progressed were as follows:

1) Selection of key environmental parameters.

2) Assignment of Relative Importance Weights to the selected parameters.

3) Determination of a Relative Preference rating for each parameter along both routes.

4) Explanation of the route preference for each parameter and a numerical summation of this as a Weighted Preference.

The details of these steps are shown in the Appendix under the heading "Introduction and Approach".

To accomplish the first step, we began by treating the proposed corridors of the Alaska Highway and Arctic Gas routes in the Yukon and Northwest Territories as an environmental system consisting of three major categories: physical, biological, and human. These categories, in turn, were divided into their major components, such as land, water and air for the physical category. The components were then broken down into parameters, such as permafrost, erosion, and slope instability for the land component of the physical environment category (Fig. 2).

Although the parameters represent only a portion of the total environment, they form a basis for evaluating most of the potential environmental change that could occur along either route.

Some of the parameters were more important than others; this made it necessary to develop a procedure for "weighting" the relative contribution or importance of each parameter. The total environment was assigned 1000 points which were then systematically divided among the parameters using the Delphi technique to "reflect the relative contribution of each parameter to maintain the functioning and stability of the existing natural and social system of the region". First, the 1000 points were divided among the human, biological, and physical environmental categories to express our judgement of the weight that each of these categories should carry in the overall comparison of routes. We assigned 435 points to the human environment, because we judged this to be the most important; 359 to the biological

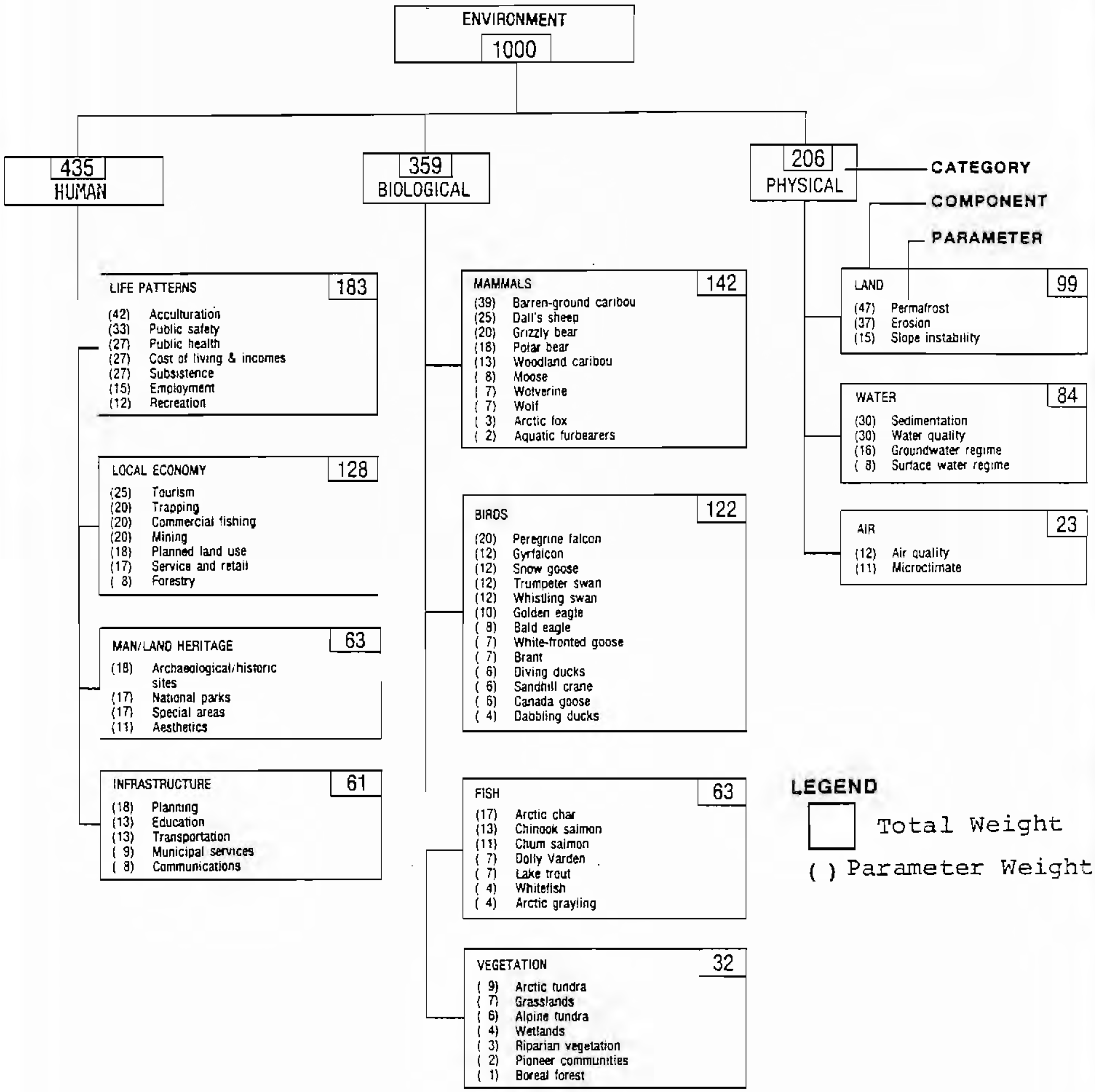

Fig. 2. Organization and Relative Importance Weights of environmental parameters for preliminary environmental comparison--Alaska Highway and Arctic Gas pipeline routes.

environment; and 206 to the physical environment. The 206 points for the physical environment were then divided among its components: land (99), water (84), and air (23). The 99 points for land were in turn divided among the land parameters: permafrost (47), erosion (37), and slope instability (15). Similarly, the Relative Importance Weights for the biological and human categories were divided among their components and parameters.

Although these rankings were established by professionals based on selected criteria, they are value judgements. Reviewers of the comparison may wish to follow the ranking procedures outlined in the appendix and establish their own set of importance rankings.

Following the selection and weighting of environmental parameters, the major potential impacts on the parameters along each route were identified. The routes were then compared, parameter by parameter, and a Relative Preference rating was determined for each parameter. The rating was expressed on a scale from 1 to 5, with the preferred route receiving a "5" and the other route an equal or lesser rating depending on: (1) regional severity of potential impacts (including duration, magnitude, probability and timing), (2) number and nature of site-specific impacts, (3) the ability of controls and mitigative measures to reduce potential impacts, and (4) the magnitude of the difference between the impacts on each route.

It may seem inconsistent <u>not</u> to use a 5:0 ratio in cases where a parameter is not present along one route but present along the other. The reason we did not use a 5:0 ratio is that it unfairly magnifies the difference between the routes in most cases. Although a 5:0 ratio might be appropriate when addressing barren-ground caribou, it does not seem appropriate in the case of polar bears, arctic fox, and salmon. (For example, a ratio of 5:4 in favor of the Alaska Highway is a fair prefence ratio for arctic fox -- even though the species is absent from the Alaska Highway route -- because the Arctic Gas route is not likely to have long-term effects on the species.) We are aware of the apparent inconsistency of the system, but consider it justified for the purposes of this comparison.

The Relative Importance Weights and the Relative Preference ratings were then combined into a Weighted Preference rating for each parameter. The Weighted Preference rating adjusts the preference rating of the parameter, taking into account its importance in relation to the other parameters.

Several points apply to the Weighted Preference ratings. First, the ratings reflect what, in our professional judgement based on available information and the above criteria, is the best route in terms of each of the selected parameters. Second, the ratings reflect relative preference, not relative impact; consequently, high ratings should not be construed to mean acceptability of potential impact or an endorsement of any route. And third, the ratings do not take into account that when the Canadian Government makes a decision on a gas pipeline a key problem will still remain: that of developing a set of controls and mitigative measures together with an organizational mechanism to ensure that the impacts of the project are held to an acceptable level.

PHYSICAL ENVIRONMENT

Changes to the physical environment will result from construction and operation of a northern gas pipeline. These changes can be identified and used as a basis for comparing the potential impacts of alternate pipeline routes on their respective physical environments.

In the following comparison, changes to the physical environment were dealt with in terms of three major components: land, water, and air. The components in turn were divided into nine parameters: for land - permafrost, erosion, and slope stability; for water - sedimentation, water quality, groundwater regime, and surface water regime; and for air - air quality and microclimate. Both projects were examined from the point of view of each of these parameters and a preference rating was determined after reviewing them in the light of several factors: the amount of the physical environment likely to be affected, the number and severity of site-specific problems, and the difficulty of establishing and enforcing effective controls and mitigative measures. Several other factors which would affect preference were also briefly considered: seismic risk, frost heave, climatic influence on construction, and winter roads.

The ratings show that the Alaska Highway route is strongly preferred over the Arctic Gas route.

Land

Land, which was considered to be the most important component of the physical environment for the purposes of this comparison, included a consideration of potential effects on permafrost, erosion, and slope stability. A route comparison based on these parameters indicated that the Alaska Highway route will undergo fewer changes than the Arctic Gas route as a result of pipeline construction and operation. The Alaska Highway route is therefore the preferred route as far as land is concerned. This is primarily due to a decided preference for that route insofar as effects on permafrost are concerned. It is also preferred because fewer erosion problems are likely to occur.

The effects of the pipeline projects on permafrost were compared in terms of their potential to cause significant thaw settlement. Thaw settlement in high ice content soils resulting from right-of-way clearing and grading and from gas transmission at above-freezing temperatures was deemed significant when it exceeded 1 foot, an amount which would begin to disrupt drainage and impede mobility. During construction, permafrost degradation and thaw settlement in excess of 1 foot could occur on 9 percent (48 miles out of 512 miles) of the Alaska Highway route compared to 22 percent (217 miles out of 983 miles) on the Arctic Gas route. During operation, 18 percent (91 miles) of the Alaska Highway route could undergo settlement in excess of 1 foot compared to 26 percent (260 miles) of the Arctic Gas route.

The Arctic Gas route has a vastly greater amount of permafrost of generally higher excess ice content than the Alaska Highway route. Even with a favorable allowance for arctic and winter construction techniques and chilled gas transmission proposed by Arctic Gas (factors which were introduced into the foregoing estimates of thaw settlement), a clear preference still resides with the Alaska Highway route. Moreover, we recognize the risks of dependence on snow road construction on the arctic coast, as outlined by Justice Berger in his final report (Vol. I, pp.22-24) in preventing permafrost degradation and thaw settlement. The possibility of things going wrong on the arctic coast thus creates a decided preference (5:1) for the Alaska Highway route.

In terms of potential for erosion the Alaska Highway route is preferable. The route crosses 247 miles of high and medium erodible soil as compared to 898 miles on the Arctic Gas route, and only 104 miles of frozen ground as compared to 706 miles on the Arctic Gas route. Arctic and winter construction proposed for the Arctic Gas route will expose less mineral soil and provide greater protection to ice-rich ground than the summer construction proposed for the Alaska Highway route. But it is unlikely that these techniques can balance the large differences in erodible soils and frozen ground which exist between the two routes. Slope gradient also influences erosion. The Arctic Gas route is located for the most part along the relatively flat lowlands of the Mackenzie Delta and Valley and crosses only half the length of slopes which may significantly affect erosion potential as the Alaska Highway route. To the extent that a chilled pipeline influences erosion through ponding and channelization of runoff, the Alaska Highway route is preferred because of its much shorter length of chilled gas transmission. Rainfall intensity, a significant factor in erosion, is similar for both routes and no preference can be distinguished, although it is acknowledged that the ground will be snow free and unfrozen for a greater time period annually on the Alaska Highway route.

The preference of the Alaska Highway route in terms of potential for erosion resulted from comparison of the project descriptions and physical factors that influence erosion. As with thaw settlement, however, we recognize the risks of dependence on snow-road construction on the arctic coast. If massive disturbance were to be experienced in the northern Yukon, erosion resulting from such disturbance would outweigh all other considerations affecting erosion.

In view of these considerations, the Alaska Highway route is preferred (5:2) in terms of erosion potential.

Slope stability in unfrozen ground will not be significantly affected by pipeline construction and operation, although it is acknowledged that potential landslide areas exist and must be investigated fully before final route selection, particularly on the Alaska Highway route. Slope instability has, therefore, been compared mainly on the basis of pipeline construction and operation effects on slopes in frozen ground.

Construction of the Alaska Highway pipeline has potential to cause slope instability on just over 2 percent of its length (11 miles out of 513 miles), compared to just under 2 percent (19 miles out of 983 miles) for the Arctic Gas route. Gas transmission at temperatures below 0°C increases stability conditions which prevail within slopes at completion of construction, and these benefits are more pronounced for the Arctic Gas route. Operation will thus reduce potential instability on the Arctic Gas route to just over 1 percent of its length (11 miles out of 983 miles) but will increase potential instability slightly (0.8 miles) on the Alaska Highway route. Since operation will be of longer duration than construction, equal preference (5:5) is given to the routes.

The following table summarizes our comparison of the two routes for the land component of the physical environment.

Table 5. Land component of the physical environment comparison summary.

	Relative Importance Weighting	Relative Preference: Alaska Highway	Relative Preference: Arctic Gas	Weighted Preference: Alaska Highway	Weighted Preference: Arctic Gas
LAND COMPONENT					
Permafrost	47	5	1	235	47
Erosion	37	5	2	185	74
Slope stability	15	5	5	75	75
	99			495	196
Preference Ratio				2.5	1.0

In terms of the land component of the physical environment, the Alaska Highway route is preferred over the Arctic Gas route by 2.5:1.

Water

Water will be less affected by a pipeline project along the Alaska Highway route than along the Arctic Gas route. A comparison of changes expected to occur in three of the water parameters -- sedimentation, water quality and the surface water regime -- indicated a clear preference for the Alaska Highway route. The fourth parameter, groundwater was considered equally affected on each route (it would be affected less on the Arctic Gas route during construction, but more during operation).

Increases in sedimentation are expected to affect a potential 175 miles of rivers and streams with drainage areas of over 10 mi^2 on the Alaska Highway route. By comparison, construction-related sedimentation on the Arctic Gas route could affect up to 211 miles of streams and rivers with drainage areas of over 10 mi^2. No reliable estimate of the amount of sediment was possible for either route; but based on the potential lengths of watercourses affected, a distinct preference rests with the Alaska Highway route.

A further factor in favor of the Alaska Highway route is the extensive borrow extraction from flood plains expected on rivers crossed by the Arctic Gas route with a subsequent increase in sediment. Borrow sites in active floodplains and upslope of active channels have a high potential to contribute sediment, particularly in areas where thermal erosion is possible. This type of problem has been experienced on the Alyeska pipeline and is a potential problem on the Arctic Gas route.

On the basis of these considerations, the Alaska Highway route is preferred (5:3) from the point of view of sedimentation.

Water quality changes will result from the construction of either pipeline project but these will be potentially fewer on the Alaska Highway route. Disposal of wastewater from construction camps will add organic material, nutrients, pathogenic microorganisms and residue to watercourses. Six construction camps planned for the Alaska Highway project will potentially affect water quality in five creeks, two rivers and three lakes. By comparison, 24 construction camps planned for the Arctic Gas route will potentially affect water quality in 12 creeks, 7 rivers, 13 locations on the Mackenzie River, and 2 channels of the Mackenzie Delta. Dilution in the Mackenzie River would be high.

In terms of the storage and transfer of oil, fuel and other toxic materials, together with the potential of these operations to affect wildlife, the Alaska Highway pipeline is preferable. Planned stockpile sites are fewer on the Alaska Highway pipeline (12 vs 19) and will likely be smaller as year-round resupply is possible by the highway. The transfer and storage of toxic materials on the Alaska Highway route will not be carried out as close to water as for the Arctic Gas route where water transport will constitute the major transportation mode. Moreover, regions along the Beaufort Sea coast and the Mackenzie Delta contain sensitive wildlife regions which could be catastrophically affected by major spills of toxic materials.

Thermal pollution due to disposal of heated testing fluids, and leachate from landfills are other sources of change to water quality; but no preference can be made between routes on their account. The Alaska Highway route is preferred in terms of potential adverse effects on water quality due to accidental spills of methanol.

In studies of both the Arctic Gas and Alaska Highway routes, results indicate that impairment of water quality from pipeline construction is not very significant. Most significance stems from the fact that it is the habitat of fish. However, discussions of problems on the Alyeska pipeline with the Alaska Joint Fish and Wildlife Advisory Team on the Alyeska Project lead us to believe that perhaps evidence given in Canada underplays adverse affects at river crossings and perhaps our Relative Preference rating should be higher. If this is the case, greater preference would result for the Alaska Highway route because of the fewer streams crossed. Overall, the Alaska Highway route is preferred (5:2) with respect to water quality.

Changes to the surface water regime on the pipeline projects comprise channel shifting brought about by river or stream crossings, formation of icings induced by gas transmission at temperatures below $0^{\circ}C$, diversion of surface drainage resulting from thaw settlement of permafrost, and alterations in regime initiated by borrow pit operations in river floodplains.

Gas transmission at temperatures below $0^{\circ}C$ is necessary to maintain stability of high excess ice content soils over most of the Arctic Gas route compared to only 40 miles of the Alaska Highway route. This difference in operation, together with the crossing of two to three times the number of drainages and generally longer river crossings, creates a much greater potential for the formation of icings on the Arctic Gas route and is a major factor for giving preference (5:2) to the Alaska Highway route. Thaw settlement and resulting drainage disruption, and borrow from within floodplains also have the potential to create greater changes to the surface water regime on the Arctic Gas route. Only in its potential to affect lakes, does the Alaska Highway route appear to be at a disadvantage compared to the Arctic Gas route. Several large lakes, including Kluane, Teslin, Marsh and Squanga, lie close to the Alaska Highway route and could be affected; no major lakes will be affected on the Arctic Gas route.

Pipeline construction on the Alaska Highway route will have a greater effect on the groundwater regime along the alignment in terms of the potential to affect present users of groundwater. Five Yukon communities immediately downslope (less than 1 mile) of the pipeline presently utilize groundwater for their local water supply and are particularly vulnerable should the groundwater become polluted by fuel or other toxic materials. A further 10 locations utilizing groundwater are downslope of the pipeline by more than 1.5 miles but may still constitute areas of potential impact from groundwater pollution. By comparison, six communities on the Arctic Gas route could potentially have their groundwater affected by pollution, but their present use of the resource is unknown, although it is likely small because of permafrost. Mitigation of a spill by excavation would disturb less permafrost on the Alaska Highway route. However potential groundwater pollution from construction would be less on the Arctic Gas route.

Gas transmission at temperatures below $0^{\circ}C$ will interfere with subsurface flow particularly in discontinuous permafrost where shallow groundwater flow is common and considerable summer flow occurs within the active layer. Subsurface drainage disruption will be greater on the Arctic Gas pipeline which crosses 277 miles of unfrozen ground in the discontinuous permafrost region and transmits gas below $0^{\circ}C$ for almost all of its entire length in the Yukon and Northwest Territories. The Alaska Highway pipeline, on the other hand, will transmit gas at $0^{\circ}C$ for only 40 miles of the widespread permafrost region in the Yukon while crossing less than 28 miles of unfrozen ground.

Methods of preventing drainage disruption caused by the frost bulb wall have been presented by Canadian Arctic Gas Pipeline Limited. However, there is a serious risk in connection with the proper functioning of cross-drainage facilities. Risk is much reduced on the Alaska Highway route where considerably less chilling in unfrozen ground is involved. This is a definite advantage for the Alaska Highway route.

The potential to affect fewer groundwater users during construction is an advantage for the Arctic Gas route. But this is offset by its potential to disrupt more subsurface drainage during operation. Thus, there is no preference (5:5) for either route on the basis of the groundwater regime.

The following table summarizes our comparison of the two routes for the water component of the physical environment.

Table 6. Water component of the physical environment comparison summary.

	Relative Importance Weighting	Relative Preference		Weighted Preference	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
WATER COMPONENT					
Sedimentation	30	5	3	150	90
Water quality	30	5	2	150	60
Groundwater regime	16	5	5	80	80
Surface water regime	8	5	2	40	16
	84			420	246
Preference Ratio				1.7	1.0

In terms of the water component, the Alaska Highway pipeline is preferred over the Arctic Gas pipeline by 1.7:1.

Air

Pipeline construction and operation will have less effect on air quality and microclimate along the Alaska Highway route than along the Arctic Gas route.

Degradation of air quality on a long-term basis will result mainly due to continual emission of nitrogen oxides, carbon monoxide, sulphur oxides, hydrocarbons, and particulates from compressor stations. The Alaska Highway pipeline at full capacity will have 13 compressor stations in the Yukon compared to 22 on the Arctic Gas route when fully developed. Although periods of calm are fewer on the Arctic Gas route, this slightly more favorable condition for dispersion of contaminants does not overcome the nearly two-fold greater source of emission and gives the Alaska Highway route a distinct advantage. Air quality during operation may also be degraded due to the release of hydrocarbons in the event of a pipeline rupture. For an assumed design life of 25 years, 1 rupture is expected on the Alaska Highway pipeline compared to 2 on the Arctic Gas pipeline on the basis of southern pipeline operating experience. These figures however do not include the start up period when ruptures are more frequent. It can be expected that there will be more ruptures where new technology is being used and winter construction techniques are being used. The number of ruptures can be expected to be at least double for Arctic Gas vs the Alaska Highway route. Seismic and frost heave risks add to the expectation of pipeline failures. These topics are addressed later in this section.

During construction of either pipeline, air quality will be affected by contaminants from construction and transportation equipment, from open burning after clearing operations, from landfill sites and from incineration of solid waste. Regionally, the effects on air quality due to these sources of pollution are not expected to be significant and neither route is preferred. Potential site specific impacts on air quality during construction will likely be proportional to length, which gives preference (5:4) to the shorter Alaska Highway route.

Formation of ice fog will be the principal effect on <u>microclimate</u> resulting from pipeline construction and operation. This phenomenon occurs when supersaturated water vapor at temperatures greater than $100^{\circ}C$ is emitted into ambient air temperatures lower than $-30^{\circ}C$. Transportation and construction equipment will produce ice fog during operation. The consequence of ice fog formation from both sources is a reduction in visibility.

Significant reduction of visibility affecting settlements, highways or airports will be less along the Alaska Highway route. Ten compressor stations have the potential to create ice fog which may cause a reduction in visibility on the Alaska Highway, compared to 19 compressor stations on the Arctic Gas route having similar potential to cause a reduction in visibility at airfields at the stations or along the proposed Mackenzie Highway. Moreover, the climate is warmer along the Alaska Highway route and the compressor stations on this line (according to Foothills) apparently emit less water vapor than those on the Arctic Gas route. Both factors reduce ice-fog formation and favor the Alaska Highway route. Thus an overall preference of 5:2 was assigned to the Alaska Highway project for this parameter.

The following table summarizes our comparison of the two routes for the air component of the physical environment.

Table 7. Air component of the physical environment comparison summary.

	Relative Importance Weighting	Relative Preference		Weighted Preference	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
AIR COMPONENT					
Air quality	12	5	4	60	48
Microclimate	11	5	2	55	22
	23			115	70
Preference Ratio				1.6	1.0

In terms of the air component, the Alaska Highway route is preferred over the Arctic Gas route by 1.6:1.

Others Factors Affecting Preference

The physical environment is somewhat unique in that a pipeline project not only may cause changes to land, water and air, but environmental processes may occur which may create hazards to the integrity of the pipeline itself or hinder construction. Such hazards, if they do occur, can have serious implications for other components of the environment. These hazards must be addressed in any comparison of routes.

Seismic risk along the proposed Alaska Highway pipeline is significant. The entire route (513 miles) within the Yukon is in moderate-to-major-damage seismic zoning compared to only 40 percent (393 miles) of the Arctic Gas route. Moreover, the Alaska Highway pipeline will cross terrain susceptible to liquefaction and slope failure during a severe earthquake. Such conditions will not be encountered along the Arctic Gas route as soils within the high seismic risk zone are probably frozen. Although the environmental implications of a seismic-induced gas pipeline rupture are not necessarily severe, seismic considerations clearly favor the Arctic Gas route by 5:2. Special pipeline design can overcome the hazards posed by seismicity, although at considerable additional cost and environmental change (for example, the implications of an above-ground pipeline).

Chilled gas transmission proposed for the Arctic Gas route to control thaw settlement is not without problems as outlined by Justice Berger (Vol. I, pp.18-22). Frost heave, particularly in the unfrozen ground of the discontinuous permafrost zone, presents problems related to design and operation that have yet to be overcome. This unresolved problem of frost heave more adversely affects the Arctic Gas route than the Alaska Highway route within Canada because only carry-over cooling from Alaska affects the Alaska Highway route. On the Alaska Highway route, chilled gas will be transmitted across less than 13 miles of unfrozen, frost-susceptible soils compared to over 156 miles of similar soils on the Arctic Gas route. The Alaska Highway route is therefore substantially preferred over the Arctic Gas route by 5:1.

Special pipeline design may reduce the hazards posed by frost heave, although again at considerable cost and environmental change (for example, the implications of an above-ground pipeline).

Climatic influence on construction is important for both projects in terms of winter road performance and down-time or worker inefficiency. Adverse winter weather will influence the production rate on both pipelines, but virtually all of the Arctic Gas route involves winter construction and no alternative exists if scheduled winter work is not completed. More problems are also anticipated with winter roads on the Arctic Gas route largely because of the extent of use. Probable lack of snow on the arctic coast, short winter road season from Fort Simpson to the Alberta border, and the heavy dependency on winter road success combine as disadvantages for the Arctic Gas route. Thus, both aspects of climate make the Alaska Highway route preferable (5:3).

Of these other factors affecting preference, that is, seismic risk, frost heave, climate and winter roads, all but seismic risk increase preference for the Alaska Highway route. And although seismic risk may be less on the Arctic Gas route the consequences of pipeline repair after rupture on the arctic coast, particularly in summer, would be severe.

A table has not been drawn up for these factors because we have not assigned Relative Important Weights or Weighted Preference ratings to them.

The tabular summary already suggests a distinct preference for the Alaska Highway route not considering these other factors. But it must be remembered that a great inequality of pipeline length exists between the sections compared. Potential change and impact are somewhat related to length and it is doubtful that as great a difference would exist if the segments compared were of similar length. Nevertheless, a pipeline project on the Alaska Highway route will affect the physical environment less than a similar project on the Arctic Gas route. This is shown in the following table which covers the entire physical environment and its components and parameters. The preference rating for the Alaska Highway route over the Arctic Gas route is, overall, 2:1 for the physical environment.

Table 8. Physical environment comparison summary.

	Relative Importance Weighting	Relative Preference: Alaska Highway	Relative Preference: Arctic Gas	Weighted Preference: Alaska Highway	Weighted Preference: Arctic Gas
LAND COMPONENT					
Permafrost	47	5	1	235	47
Erosion	37	5	2	185	74
Slope stability	15	5	5	75	75
Total	99			495	196
Preference ratio				2.5	1.0
WATER COMPONENT					
Sedimentation	30	5	3	150	90
Water quality	30	5	2	150	60
Groundwater regime	16	5	5	80	80
Surface water regime	8	5	2	40	16
Total	84			420	246
Preference ratio				1.7	1.0
AIR COMPONENT					
Air quality	12	5	4	60	48
Microclimate	11	5	2	55	22
Total	23			115	70
Preference ratio				1.6	1.0
PHYSICAL ENVIRONMENT					
Total				1030	512
Preference ratio				2.0	1.0
OTHER FACTORS					
Seismic risk		2	5		
Frost heave		5	1		
Climatic influence on construction		5	3		
Winter roads		5	2		

BIOLOGICAL ENVIRONMENT

The biological environment affected by the two proposed pipelines contains thousands of species with complex interrelationships; to examine and compare each is impossible. For the purposes of this comparison, therefore, we organized the total biological environment into four major components: mammals, birds, fish and vegetation; and selected 38 species or groups of species as a representative basis on which to compare the relative effects of the two proposed projects on the biological environment. These species were selected because of restricted regional or continental abundance, susceptibility to disturbance, economic value, or special interest. As a result of this comparison, we have concluded that the Alaska Highway pipeline project is preferable to the Arctic Gas route project, particularly for the mammal and bird components of the biological environment.

Mammals

Mammals were considered to be the most important component of the biological environment for the purposes of this comparison. The comparison included an analysis of the potential effects on the following mammal species, listed in decreasing order of relative importance: barren-ground caribou, Dall's sheep, grizzly bear, polar bear, woodland caribou, moose, wolverine, gray wolf, arctic fox, and aquatic furbearers. These species are expected to suffer direct habitat loss and direct and indirect mortality, to evacuate habitat as a result of disturbance, and to undergo behavioral modifications as a result of construction activities. Habitat evacuation during construction could have long-term implications for local populations of species such as Dall's sheep. Compressor station operation and inspection and maintenance activities in critical areas are the major anticipated long-term problems. A comparison based on these mammals indicates a preference for the Alaska Highway route, primarily because of potential long-term implications for the barren-ground caribou herd.

Barren-ground caribou do not occur along the Alaska Highway route in the Yukon. Construction-related activities and, in particular, aircraft traffic on the Yukon coast could disturb traditional caribou movements, interfere with usage of traditional calving areas, or disrupt caribou behavior and social structures during calving and post-calving aggregation. Effects of anticipated increases in hunting pressure and direct mortality on long-term population trends of the herd are unknown but potentially serious. Disturbance due to construction in caribou winter range as well as compressor station operation is expected to be minor. Long-term impacts on the Porcupine caribou herd will ultimately depend on the effectiveness and enforcement of mitigative measures and controls. If these are not completely effective the Arctic Gas project, and subsequent developments stimulated by it, could pose a considerable threat to the survival of the herd. For this reason, the Alaska Highway route is substantially preferred by a ratio of 5:1, based on potential effects on barren-ground caribou.

The only Dall's sheep population adjacent to the Arctic Gas route is the population of 400-600 sheep on Mount Goodenough. Another small population occurs along the Firth River about 15 miles south of the proposed route. Proposed borrow operations near Mount Goodenough could seriously disturb any sheep utilizing nearby slopes, although the extent to which these areas are critical sheep ranges is unknown. There is little potential for disturbance from other sources during construction or operation along the 25 miles of route adjacent to sheep range. In comparison, the Alaska Highway, route has the potential to disturb sheep populations in several areas along the approximately 250 miles of range paralleled by this route. Several thousand sheep may use this range and could be within 5 miles of the project at different times of the year. The operation of three compressor stations and the new access through the

Ibex River valley could have long-term effects on Dall's sheep. Although the Alaska Highway pipeline generally follows an existing transportation corridor and many problems can be eliminated or reduced by proper construction scheduling, effective controls, and facility and route relocations, the greater potential impact on this route makes the Arctic Gas route preferred by a ratio of 5:2.

The Alaska Highway route is considered slightly preferable (5:4) insofar as potential effects on grizzly bears are concerned. Major destruction of denning areas is unlikely on either route. Summer construction on the Alaska Highway route increases the potential for bear problems in camps; however, this problem should be lessened by the generally low grizzly bear population adjacent to the proposed route. Furthermore it can be greatly reduced by fencing camps and burning garbage. Winter construction on the Arctic Gas route, if it proves feasible, considerably reduces the potential for construction-related disturbance. Potential for harassment of bears by aircraft is greater on this route during summer. Although bear populations in the southern Yukon are reduced, effective management is considered more feasible here than in the northern Yukon. This is particularly relevant as the barren-ground grizzly (which is the form occurring on the Yukon coast) is considered endangered.

Polar bears do not occur along the Alaska Highway route in the Yukon but small numbers are found along the Yukon coast in winter. The Yukon coast is not a "core" denning area, but it may be of some importance to a relatively discrete Beaufort Sea population. Polar bears can be expected to investigate winter construction sites if garbage is available. The influx of highly-paid construction workers may increase the demand for hides. Conflicts with denning female bears are considered unlikely. Because bear populations are small and reproductive potential low, any increase in bear mortality is important to long-term population trends, making the Alaska Highway route slightly preferred by a ratio of 5:4.

The Alaska Highway is also slightly preferred (5:4) with reference to woodland caribou. About 100 and 700 miles of woodland caribou range are crossed by the Alaska Highway and Arctic Gas routes, respectively. Summer construction on the Alaska Highway project will minimize disturbance during critical periods, whereas some disturbance by Arctic Gas construction during winter is highly likely. Although woodland caribou populations in the southern Yukon are smaller than along the Arctic Gas route, more information is available on their distribution and management may be easier here.

Moose occupy most wetland areas along both routes, and occur in low densities on the Yukon coast. Summer construction on the Alaska Highway route will cause little disturbance to moose populations and, barring major forest fires, only minor habitat destruction is anticipated. Arctic Gas winter construction is expected to disturb small numbers of moose wintering along the Mackenzie River. Temporary interruptions of seasonal movements in these areas could occur during trenching and pipelaying. Some mitigation is possible by route changes but not by timing within the present construction schedule. The Alaska Highway route is, therefore, slightly preferred by a ratio of 5:4.

The Alaska Highway route is slightly preferable, at 5:4, with reference to gray wolves, although neither route is preferable with respect to wolverines. Effects on denning areas will be minor on both routes for both species. Increased demands for fur of both species are expected along each route. Summer construction and low regional wolf and wolverine populations decrease the likelihood of problems with these species at camps along the Alaska Highway route. The opposite situation will increase potential for these conflicts on the Arctic Gas route. In addition, construction activities in the relatively undisturbed habitat traversed by the Arctic Gas route will duplicate conditions that caused major problems with wolves during construction of the Alyeska pipeline north of the Yukon River.

Arctic foxes occur only on the Arctic Gas route along the Yukon coast. Although several denning areas exist on the Yukon coast, none are known to be in close proximity to the proposed right-of-way. Furthermore, most such sites can be readily identified and avoided. Foxes attracted to camps increase the potential for human exposure to rabies. Long-term effects of aircraft and construction-related disturbance or increased trapping near camps are not expected. Because no long-term effects on arctic fox populations are expected, the Alaska Highway route is only slightly preferred with a ratio of 5:4.

In general, loss of aquatic furbearer habitat resulting from increased siltation and fuel spills during construction will be less extensive and shorter-term on the Alaska Highway route compared to the Arctic Gas route. The wider distribution of ice-rich soils increases the potential for serious siltation problems on the Arctic Gas route. The potential for major fuel spills on the Arctic Gas route is also considerably greater because of the location of stockpile sites and the use of barge transportation. Fall and winter modification of water levels in small streams and lakes will be potentially greater on the Arctic Gas route because of winter construction and possible in-stream gravel removal. Operation of the chilled pipeline could cause disruption of surface drainage over much greater distances on the Arctic Gas route. The larger number and severity of potential problems on the Arctic Gas route, therefore, makes the Alaska Highway route preferred by a ratio of 5:3 insofar as potential effects on aquatic furbearers are concerned.

The overall comparison of the Alaska Highway and Arctic Gas routes for the mammal component is summarized in the following table.

Table 9. Mammal component of the biological environment comparison summary.

	Relative Importance Weighting	Relative Preference		Weighted Preference	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
MAMMAL COMPONENT					
Barren-ground caribou	39	5	1	195	39
Dall's sheep	25	2	5	50	125
Grizzly bear	20	5	4	100	80
Polar bear	18	5	4	90	72
Woodland caribou	13	5	4	65	52
Moose	8	5	4	40	32
Wolverine	7	5	5	35	35
Wolf	7	5	4	35	28
Arctic fox	3	5	4	15	12
Aquatic furbearers	2	5	3	10	6
	142			635	481
Preference Ratio				1.3	1.0

Considering these mammalian species as a group, we believe that the Alaska Highway project will cause less unmitigable impact to mammalian populations than the Arctic Gas project. The Alaska Highway route is therefore preferred. For 8 of the 10 parameters reviewed the relative preferences for one route or the other are not substantial. We believe that there is a potential for serious effects on only two species as a result of these projects: barren-ground caribou and Dall's sheep. The basic decision for a preferred route, therefore, rests primarily on the individual route preferences for these two species.

Although conflicts with Dall's sheep on the Alaska Highway route can be reduced with proper scheduling, effective controls, and route and facility relocation, the same level of reduction in long-term potential impact cannot be expected for barren-ground caribou along the Arctic Gas route.

The Porcupine herd is one of the four largest herds of barren-ground caribou in the world. The importance of this herd has greatly increased due to recent dramatic reductions in the Alaskan Arctic herd. The Porcupine herd has historically been protected, primarily by its inaccessibility to sport hunting and the relative lack of disturbance during critical life history phases. This protection could be destroyed as a result of pipeline construction, subsequent development of access, associated increases in the number of people in critical ranges, and subsequent petroleum developments resulting from construction of this pipeline. The ability of controls and mitigative measures to eliminate all problems associated with these developments is questionable.

In conclusion, the ability to control and mitigate conflicts with populations of Dall's sheep and other species in the southern Yukon and the questionable effectiveness of controls with reference to barren-ground caribou on the Arctic Gas route make the Alaska Highway route preferable from the standpoint of the mammalian component.

Birds

The bird component was considered about 90 percent as important as the mammalian component for the purposes of this comparison. Thirteen species, or groups of species, were included in the comparison: peregrine falcon, gyrfalcon, snow goose, trumpeter swan, whistling swan, golden eagle, bald eagle, white-fronted goose, brant, diving ducks, sandhill crane, Canada goose, and dabbling ducks.

The major potential project-related effects on bird populations include physical destruction of habitat, habitat degradation as a result of disturbance or pollution, and disruption of critical life history activities such as migration, staging or nesting. Improperly scheduled construction activities could have an acute short-term effect on some species and intense disturbance of some critical areas could have long-term population implications. Direct habitat loss is, except for a few critical areas, considered insignificant. Compressor station operation in critical areas is the major anticipated long-term problem. A comparison based on the above parameters indicates that the Alaska Highway route is preferred for 11 of the 13 parameters addressed, primarily because of the major potential problems on the Yukon Coast and the Mackenzie Delta.

No peregrine nests have been reported within the proposed Alaska Highway corridor during the last 10 years; however, further studies are required to verify the birds' current breeding status. Several peregrine nesting areas have been identified within 5 miles of the proposed Arctic Gas routes, including the British Mountains, Campbell Lake, Fort Good Hope and the Norman Range. Many potential problems could be overcome by proper scheduling, effective controls and facility relocation; however, the larger numbers along the Arctic Gas route plus the relatively undisturbed nature of nesting habitat in the British Mountains, make the Alaska Highway route strongly preferred by a ratio of 5:2.

Although gyrfalcons probably breed in the Kluane and Cassiar Mountains, no active sites have been identified within 5 miles of the Alaska Highway route. Because there are no known conflicts within the corridor, the Alaska Highway route is preferred; however, additional surveys must be conducted to verify this conclusion. Several pairs nest within the proposed Arctic Gas corridor on the Yukon coast. No direct habitat destruction is anticipated along the Arctic Gas route, and disturbance from pipeline construction and aircraft can be reduced through effective scheduling and controls. Any activities in this relatively undisturbed area, however, pose risks for the long-term security of the existing gyrfalcon population, and results in a strong preference of 5:2 for the Alaska Highway route.

Small numbers of snow geese and whistling swans stage but do not nest in the southern Yukon. However, none of the areas used for staging are regarded as critically important; the ones identified are small and potential problems can be mitigated. The islands and sandbars of the Mackenzie River on the Arctic Gas route on the other hand are critical spring staging areas for both the western Canadian Arctic snow goose population and about 20,000 Atlantic flyway whistling swans which nest on the outer Mackenzie Delta and Yukon coast. In fall, 150,000-400,000 snow geese gather on the Yukon coast between Alaska and the Mackenzie Delta to feed and rest prior to fall migration. Aircraft disturbance and fuel spills along the Mackenzie River during spring migration, and aircraft disturbance on the Mackenzie Delta and Yukon coast during swan nesting and snow goose fall staging are the major potential conflicts during construction. Compressor station operation could affect some whistling swan nesting habitat and could have long-term effects on the use of the Yukon coast as a fall staging area by snow geese. Although partial mitigation and control is possible, there are few practical alternatives for relocating aircraft access, fuel storage areas, and compressor stations on the Arctic Gas route, making the Alaska Highway route preferred by 5:3 based on potential conflicts with whistling swans, and substantially preferred by 5:1 based on potential conflicts with snow geese.

Trumpeter swans are known to nest occasionally in the southern Yukon and regularly stage at several locations, although there are no nesting records within 5 miles of the proposed route. Small numbers of trumpeter swans probably occur along the Arctic Gas corridor in spring but their nesting status in the Mackenzie Valley-northern Yukon is poorly documented. Although neither route is expected to have a noticeable effect in continental populations, the Arctic Gas route is slightly preferred by a ratio of 5:4.

Golden eagles nest throughout the southern Yukon, particularly the Kluane Mountains. Although potential nesting habitat has been identified in the Alaska Highway corridor, there are no known sites within 5 miles of the proposed route. Golden eagles breed in scattered locations along the Arctic Gas corridor in the northern Yukon and District of Mackenzie. The Richardson Mountains may contain the highest nesting density on the continent. Few nesting areas are close to either route and their high cliff locations facilitate potential conflict avoidance by proper scheduling, controls and facility location. Because of potential conflicts in the British and Richardson Mountains the Alaska Highway route is slightly preferred with a ratio of 5:4.

Although nesting pairs of bald eagles have been reported along the Alaska Highway route in the Yukon, their nesting distribution is poorly documented. Bald eagles are common summer residents in the Mackenzie Valley and Delta and are found occasionally along the Yukon coast. The highest nesting densities along the Arctic Gas corridor are in the Upper Mackenzie Valley south of Fort Simpson. Based on existing information, neither project is expected to have a measureable effect on regional populations, and most potential conflicts on either route can be avoided by proper scheduling and minor route relocations. The Arctic Gas route is, however, slightly preferred at 5:4 because of a greater number of potential conflicts along the Alaska Highway route.

Both white-fronted and Canada geese use the southern Yukon as a spring and fall migration corridor, stopping at Kluane, Marsh and Teslin Lakes. Some of the approximately 25,000-50,000 migrating white-fronts may be the rare and endangered Tule white-fronted goose which nests on the Old Crow Flats. Smaller numbers of Canada geese use the area as a migration corridor; however, nesting has been confirmed at Nisutlin Bay (Teslin Lake) and the Donjek River area. Large numbers of white-fronts and Canada geese use the Mackenzie Valley as a migration corridor. White-fronted geese nest along the Yukon Coast to Alaska, and Blow River delta and Shallow Bay are important fall staging areas. The shortgrass prairie population of Canada geese nests in low densities in the Mackenzie Valley and Delta, which are considered the principal migration and nesting areas for this population of 125,000. Because the Alaska Highway route has fewer opportunities for conflicts over smaller areas, and would potentially conflict with smaller numbers of birds, it is preferred by 5:3 over the Arctic Gas route for both white-fronted geese and Canada geese.

Black brant do not occur on the Alaska Highway corridor in the Yukon. Approximately 6000 - 25,000 migrate along the Yukon coast in spring and fall, and small numbers nest in the outer Mackenzie Delta. Aircraft, watercraft and construction-related disturbance are potential problems during construction; fuel spills on the narrow Yukon coast tidal flats could have longer-term effects on migrating brant. Because of this the Alaska Highway route is strongly preferred for brant, with a ratio of 5:2.

Diving and dabbling ducks occur in wetland complexes along the Alaska Highway corridor during spring and fall migration and nesting; numbers and regional distributions, however, are poorly known. In comparison, the Mackenzie Valley and the Yukon coast are major migration routes for a large number of waterfowl species; and in terms of overall numbers the southern Yukon is comparatively unimportant as a waterfowl migration route. The Mackenzie Delta is one of the major waterfowl production areas of North America, supporting annual nesting populations of 100,000-350,000, and supplying waterfowl to all four North American flyways. The river estuaries, barrier beaches, spits and lagoons of the Yukon coast are important feeding and resting areas during spring and fall migration and during molting. In addition to making a considerable contribution to the fall waterfowl flight, these and other areas of relatively low density nesting habitat have considerable additional value as a reservoir of stable habitat during drought on the prairies.

Aircraft and construction-related disturbance, fuel spills, and compressor station noise could well affect waterfowl populations. The Alaska Highway route has more potential for construction-related disturbance because of the summer construction schedule. Arctic Gas, on the other hand, will have heavy air traffic compared to very little on the Alaska Highway route, will have a considerably larger potential for fuel spills because of the stockpile sites on the river and coast, and will have compressor stations operating in relatively undisturbed staging, nesting and molting areas. Because the Alaska Highway route will potentially affect fewer waterfowl over smaller areas, it is preferred by 5:3 for dabbling ducks and strongly preferred by 5:2 for diving ducks.

Although sandhill cranes nest in and migrate along the proposed Alaska Highway corridor, their main migration corridor follows the Liard River Valley north of the proposed route. The Mackenzie Valley is used by migrating and nesting sandhill cranes, with the major nesting area in the Blow River-Shallow Bay area. Because of potential disturbance and fuel spill problems on the Arctic Gas route, the Alaska Highway route is slightly preferred at 5:4.

The overall comparison has been summarized in the following table.

Table 10. Bird component of the biological environment comparison summary.

	Relative Importance Weighting	Relative Preference: Alaska Highway	Relative Preference: Arctic Gas	Weighted Preference: Alaska Highway	Weighted Preference: Arctic Gas
BIRD COMPONENT					
Peregrine falcon	20	5	2	100	40
Gyrfalcon	12	5	2	60	24
Snow geese	12	5	1	60	12
Trumpeter swan	12	4	5	48	60
Whistling swan	12	5	3	60	36
Golden eagle	10	5	4	50	40
Bald eagle	8	4	5	32	40
White-fronted geese	7	5	3	35	21
Brant	7	5	2	35	14
Diving Ducks	6	5	2	30	12
Sandhill crane	6	5	4	30	24
Canada geese	6	5	3	30	18
Dabbling ducks	4	5	3	20	21
	122			590	353
Preference Ratio				1.7	1.0

As the table indicates, the Alaska Highway route is preferred for 11 of the 13 bird groups examined. It was strongly preferred for five species: peregrine falcon, gyrfalcon, snow goose, brant and diving ducks, primarily because of major potential problems on the Yukon coast and the Mackenzie Delta. These areas also contain the nesting grounds of the potentially threatened buff-breasted sandpiper and Hudsonian godwit. There are no areas of comparable ornithological importance identified along the proposed Alaska Highway corridor in the Southern Yukon. The severity of potential conflicts in these areas and the attendent difficulty in mitigating or controlling problems makes the Alaska Highway the preferred route based on ornithological considerations.

Fish

The fish component, consisting of arctic char, chinook and chum salmon, Dolly Varden, lake trout, whitefish and arctic grayling was considered about half as important as the bird component. Sedimentation at stream crossings was considered to be the major potential source of impact on these fish populations. Project-related effects include sedimentation, destruction or degradation of critical habitats such as overwintering or spawning areas, disruption of critical activities such as migration and spawning, or increased mortality resulting from toxic spills, blasting and sport harvest.

Many of these problems will be acute but short-term during the construction period; disturbed soils should be stabilized within 3 years and most of the silt deposited in streams and rivers will be washed downstream by floods and spring freshets in 1-4 years; however, restoration of lakes will take much longer. Few additional long-term effects are expected during pipeline operation if repair and maintenance activities are properly controlled, although erosion at stream crossings could be a chronic problem in some sensitive areas. A comparison based on this set of parameters indicates there is no real basis for preferring one route over the other in terms of potential effects on fish populations.

Arctic char do not occur along the Alaska Highway route making it the preferred route by a ratio of 5:3 for this species, but char are an extremely important species in the northern Yukon and Northwest territories. The proposed Arctic Gas route crosses 12 streams and rivers and is up-slope of 4 springs known to be spawning-overwintering areas. The major potential problems are sedimentation, flow reduction resulting from excess water use, toxic spills, construction activities, and frostbulbs affecting downslope spawning, overwintering or nearshore feeding areas during operation.

Both chinook and chum salmon are virtually absent from the Arctic Gas route, which is slightly preferred by a ratio of 5:4 for these species. Downstream siltation during construction could potentially degrade an estimated 5 percent of regional habitat used by a maximum of 10 percent of the Yukon drainage chinook spawning population. This could be reduced to approximately 2 percent with proper controls and mitigative measures. Large toxic spills during certain critical periods could affect up to 15 percent of the spawning population. Chum salmon distribution in the corridor is limited to the Kluane region, where downstream siltation could affect up to 10 percent of the regional habitat (5 percent with program controls). The primary spawning areas in the Yukon River mainstream appear to be a considerable distance downstream.

Dolly Varden occur infrequently along the Arctic Gas route which is preferred by a ratio of 5:3. They occur in the Dezadeash, Swift River and Rancheria drainages which are paralleled by the Alaska Highway route for 30-40 miles.

Construction-induced siltation could potentially affect up to 5 percent of the regional habitat; however, this could be reduced to about 2 percent with proper controls.

Most of the lake trout habitat is upslope of the Arctic Gas alignment, making it the preferred route by a ratio of 5:3 because of the limited number of potential conflicts. Lake trout occur in the Yukon, Alsek and Liard drainages along the Alaska Highway route, where the pipeline parallells Kluane, Marsh and Teslin Lakes. These areas support limited, but active sport, commercial and subsistence fisheries, and construction-related sedimentation could affect up to 3-4 percent (2 percent with proper controls) of the available spawning-nursery habitat.

Potential effects on whitefish and grayling populations are about equal and there is no route preference. Approximately 3 percent (2 percent with proper controls) of available whitefish spawning habitat in the Alaska Highway corridor could be affected by construction-related sedimentation, primarily at Kluane, Marsh and Teslin Lakes. In addition, Squanga and Little Teslin Lakes contain two distinct forms of humpback whitefish considered to be of high scientific interest. The Arctic Gas route is upslope of 5 lakes and crosses 6 streams on the Yukon coast, and it also crosses 19 rivers and streams in the Mackenzie Delta-Mackenzie Valley area known to contain whitefish populations. Disruption of the important subsistence fisheries in the Mackenzie Delta region as a result of excessive siltation or large-scale toxic spills is the major concern. In balance, there is no substantial basis for preferring one route over the other.

Arctic grayling occur throughout the Yukon, Alsek and Liard drainages and sport fishing is extensive along the Alaska Highway. Construction-related sedimentation could affect approximately 5 percent of the available grayling habitat in the corridor. This could be reduced by about half with effective controls. Sport fishing for grayling is limited along the Arctic Gas route, but there is a greater potential for habitat degradation as a result of toxic spills during construction, and chronic erosion-siltation and frost bulb problems on the Yukon coast during operation. Thus, neither route is preferable from the point of view of this species.

The overall comparison of the Alaska Highway and Arctic Gas routes for the fish component is summarized in the following table.

Table 11. Fish component of the biological environment comparison summary.

	Relative Importance Weighting	Relative Preference		Weighted Preference	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
FISH COMPONENT					
Arctic char	17	5	3	85	51
Chinook salmon	13	4	5	52	65
Chum salmon	11	4	5	44	55
Dolly varden	7	3	5	21	35
Lake trout	7	3	5	21	35
Whitefish	4	5	5	20	20
Arctic grayling	4	5	5	20	20
	63			263	281
Preference Ratio				1.0	1.1

Although there is a very slight preference for the Arctic Gas route based on potential effects to the individual fish species examined, both routes have the potential for relatively severe short-term effects and some chronic problems. The overall accessibility of the Alaska Highway route to enforce controls and conduct maintenance and repair operations may offset the slight species preference for Arctic Gas, leaving no real basis for preferring one route over the other based on potential effects to fish populations.

Vegetation

The vegetation component of the comparison consisted of seven vegetation types: arctic tundra, grasslands, alpine tundra, wetlands, riparian vegetation, pioneer communities and boreal forest. The vegetation component was assigned about half the Relative Importance Weighting value of fish. The land area required by each project in each vegetation type and the sensitivity of that vegetation type to project-related disturbance were the major basis for assigning route preference.

The Alaska Highway route is preferred for four vegetation types: arctic tundra, wetlands, riparian vegetation and pioneer communities. Arctic tundra is absent along the Alaska Highway route in Canada, and this route is substantially preferred (5:1) because the Arctic Gas route would unavoidably cross much of this unique and sensitive vegetation type. The Alaska Highway route is preferred by a ratio of 5:2 for wetlands because it disturbs much less wetland area and has a much shorter length of chilled pipeline and less potential for frost-bulb related drainage alterations during operation. The Alaska Highway route also disturbs considerably less area of riparian vegetation and slightly less area of pioneer communities, and is therefore preferred by ratios of 5:3 and 5:4 respectively for these parameters.

The Arctic Gas route is preferred by a ratio of 5:2 on the basis of potential effects on grassland communities. Although only a small area of grasslands would be affected along the Alaska Highway, grasslands are rare in the southern Yukon and crossing them is largely unavoidable. The Arctic Gas route is slightly preferred (5:4) on the basis of alpine tundra because it does not cross any of this vegetation, whereas the Alaska Highway route crosses only a few small patches. Even these crossings are avoidable but would necessitate major reroutes.

The Arctic Gas route is slightly preferred by a ratio of 5:4 for boreal forest. Although the Arctic Gas facilities disturb considerably more area, most of the Alaska Highway route construction will be in summer, greatly increasing the possibility of construction-related fires in the southern Yukon.

The overall comparison of the Alaska Highway and Arctic Gas routes for the vegetation component is summarized in the following.

Table 12. Vegetation component of the biological enviroment comparison summary.

	Relative Importance Weighting	Relative Preference		Weighted Preference	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
VEGETATION COMPONENT					
Arctic tundra	9	5	1	45	9
Grasslands	7	2	5	14	35
Alpine tundra	6	4	5	24	30
Wetlands	4	5	2	20	8
Riparian vegetation	3	5	3	15	9
Pioneer communities	2	5	4	10	8
Boreal forest	1	4	5	4	5
	32			132	104
Preference Ratio				1.3	1.0

Overall, the Alaska Highway route is preferred over the Arctic Gas route on the basis of potential effects on vegetation in the Yukon and Northwest Territories. It disturbs less area and the consequences of disturbance are less severe. Soil ice contents and erosion potential are also generally lower in the southern Yukon, and more than compensate for summer construction along much of that route. In particular, the overall route preference is based primarily on the choice between crossing grasslands in the southern Yukon or arctic tundra in the northern Yukon. The area of grassland affected in the southern Yukon is small, and other grasslands would remain uncrossed. The area of arctic tundra crossed, in comparison, is much more extensive, with the right-of-way crossing the entire length of a unique vegetation region of Canada.

In summary, the Alaska Highway route is preferred for three of the four components of the biological environment -- mammals, birds, and vegetation. In each of these preferred components, the preference is primarily based on the unique or critical contributions of the Yukon coast or Mackenzie Delta to the well-being and long-term stability of key biological species -- the barren-ground caribou calving grounds and the raptor nesting areas of the Yukon coast, the waterfowl nesting and staging areas of the Yukon coast and Mackenzie Delta, and the unique expanse of arctic tundra on the Yukon Coastal Plain. Because there are no similar areas along the Alaska Highway route that provide so much critical habitat to so many key components of the western Canadian Arctic environment, the Alaska Highway route is clearly preferred over the Arctic Gas route for the parameters addressed in the biological environment. The results are summarized in the following table.

Table 13. Biological environment comparison summary.

	Relative Importance Weighting	Relative Preference		Weighted Preference	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
MAMMAL COMPONENT					
Barren-ground caribou	39	5	1	195	39
Dall's sheep	25	2	5	50	125
Grizzly bear	20	5	4	100	80
Polar bear	18	5	4	90	72
Woodland caribou	13	5	4	65	52
Moose	8	5	4	40	32
Wolverine	7	5	5	35	35
Wolf	7	5	4	35	28
Arctic fox	3	5	4	15	12
Aquatic furbearers	2	5	3	10	6
Total	142			635	481
Preference ratio				1.3	1.0
BIRD COMPONENT					
Peregrine falcon	20	5	2	100	40
Gyrfalcon	12	5	2	60	24
Snow geese	12	5	1	60	12
Trumpeter swan	12	4	5	48	60
Whistling swan	12	5	3	60	36
Golden eagle	10	5	4	50	40
Bald eagle	8	4	5	32	40
White-fronted geese	7	5	3	35	21
Brant	7	5	2	35	14
Diving Ducks	6	5	2	30	12
Sandhill crane	6	5	4	30	24
Canada geese	6	5	3	30	18
Dabbling ducks	4	5	3	20	12
Total	122			590	353
Preference ratio				1.7	1.0
FISH COMPONENT					
Arctic char	17	5	3	85	51
Chinook salmon	13	4	5	52	65
Chum salmon	11	4	5	44	55
Dolly varden	7	3	5	21	35
Lake trout	7	3	5	21	35
Whitefish	4	5	5	20	20
Arctic grayling	4	5	5	20	20
Total	63			263	281
Preference ratio				1.0	1.1
VEGETATION COMPONENT					
Arctic tundra	9	5	1	45	9
Grasslands	7	2	5	14	35
Alpine tundra	6	4	5	24	30
Wetlands	4	5	2	20	8
Riparian vegetation	3	5	3	15	9
Pioneer communities	2	5	4	10	8
Boreal forest	1	4	5	4	5
Total	32			132	104
Preference ratio				1.3	1.0
BIOLOGICAL ENVIRONMENT					
Total				1620	1219
Preference ratio				1.3	1.0

HUMAN ENVIRONMENT

Changes to the human environment will result from construction and operation of a northern gas pipeline. Many of these changes and stresses can be identified and used as a basis for comparing the Alaska Highway and Arctic Gas projects in Canada north of 60°N.

Initially, 23 social and economic parameters were identified for consideration within four components of the human environment: life patterns, local economy, man/land heritage and infrastructure. Time constraints precluded examination of 11 of the 23 parameters; consequently, data are available to make a factual comparison on only 12 parameters. Although data are not available to make a precise comparison of the effects of the Alaska Highway and Arctic Gas projects on the human environment, there is sufficient information available upon which to base some reliable judgements. The experience with the Alyeska pipeline provides a good indication of the potential impacts associated with a large construction activity and suggests some of the relationships between the size of a well-paid labour force and social and economic impacts. Government data and the Berger hearings provide some insight into the economy and social fabric of the communities that would be impacted along the two routes.

However, there is a paucity of relevant social and economic data for both affected regions. This is true even of the Mackenzie Valley which has been subject to extensive investigations and hearings in connection with pipeline project studies. These limitations mean that the differences between the two routes cannot be precisely measured. Nevertheless, since the Alaskan experience is a recent demonstration of what can happen, a logical basis exists for making a comparison of value to those who must reach decisions.

As a result of this comparison, we have concluded that the Alaska Highway pipeline project is slightly preferable to the Arctic Gas pipeline project from the point of view of changes to the human environment.

Life Patterns

Life Patterns was considered the most important component of the human environment for this comparison. This includes consideration of the potential effects of the Alaska Highway and Arctic Gas projects on the following parameters, listed in decreasing order of importance: acculturation, public safety, public health, cost-of-living and incomes, subsistence, employment, and recreation. A route comparison based upon these parameters indicated that the Alaska Highway route was preferred overall, with the Arctic Gas route being favourable in terms of public safety.

With regard to the acculturation parameter, we are reasonably confident that the construction of a pipeline along the Arctic Gas route has the greater potential for cultural impact given the seemingly more traditional character and relative isolation of the small native communities there compared to the Alaska Highway route. Also, the seemingly more negative perceptions of a pipeline prevailing in the Mackenzie Valley communities lead to a definite preference for the Alaska Highway (5:3).

On public safety, the Alaskan experience suggests to us that offences against property are likely to be the major problem rather than violent crime and the influx of organized crime. Moreover, any organized crime should be easier to control in northern rather than urban southern settings, especially given the expertise of the RCMP. There will be an increase in alcohol-related crimes on either route, particularly where workers associated with the project live or recreate outside field camps. Alaska Highway construction will be year-round whereas Arctic Gas construction will be mainly in winter with workers confined more to the construction camps. However, there will also be a great many activities in summertime in preparation for winter construction on the Arctic Gas project. Poorer access should result in a lesser influx of itinerant workers and families along the Mackenzie Valley. While we envisage a greater impairment of public safety on the Arctic Gas route due to the greater stress anticipated there, the ready access afforded by the highway would result in a greater influx of professional criminals and itinerants to the Alaska Highway route. Thus a preference for the Arctic Gas route of 5:4 seems appropriate.

Public health facilities may be overloaded by both projects. Each applicant says it will look after the health of its staff. Even so, the support subcontractors, suppliers, and families that appear, unplanned as far as the applicant is concerned, could overload existing facilities. We are confident that there is greater potential for impact on public health on the Arctic Gas route. On the basis of the data available, we conclude that the medical facilities and services infrastructure in the Mackenzie Valley is more susceptible to overloading which would result in an impairment of the quality of service available to the local residents.

In addition, given the more traditional character of many Mackenzie Valley native communities, we conclude that the potential for project-induced stress among the resident population and thus the potential for increased mental health problems is greater in the Mackenzie Valley. We thus prefer the Alaska Highway route by a ratio of 5:3.

With regard to cost of living & incomes, neither route appears to possess outstanding advantages. There is a greater potential for increased income benefits on the Arctic Gas project because historically, incomes in the Mackenzie Valley have been much lower than in the southern Yukon. On the other hand, we also anticipate that inflationary pressures will be distinctly greater on the Arctic Gas route because the estimated incoming labour force is about 66% of the 1971 local labour force for the Arctic Gas route as opposed to 22% for the Alaska Highway route. The existence of chain-store organizations such as the Hudson's Bay Co. could help stabilize prices; but where such organizations do not exist, as along the Alaska Highway route, an inflationary pressure could develop which would precipitate rapid price escalation. Nominal income increases of all residents will be offset, to some extent, by a higher local inflation rate. For those people whose incomes are related to project activity, this will be less important. However, many people employed in the less dynamic sectors of the economy will experience a decline in real income during the construction period. This seems most likely to occur for the more remote Mackenzie Valley communities with increased demands on transportation. Thus, we prefer the Alaska Highway route by a ratio of 5:4.

Employment benefits from either project can result from: (1) an expansion of labour force participation, which can be brought about by encouraging people who are not presently members of the labour force to make themselves available for wage employment; and (2) a reduction in the number of unemployed by providing jobs to those already in the labour force. It is the second factor that is of most concern to us. The Arctic Gas work force peaks at 5000 whereas the Alaska Highway work force peaks at 2300 north of 60°N. In view of the size of either work force, we believe that many jobs will be available on either route. There is considerable potential for those already employed to seek alternative employment on the project in either region. The 1971 statistics show a lower participation rate in the labour force for the District of Mackenzie than for the Yukon, probably reflecting the more traditional way of life there. Unemployment rates were also substantially higher in the Yukon than in the District of Mackenzie. The larger total population in corridor settlements along the Alaska Highway route indicates a better ability to respond to project work force requirements. Even though employment opportunities will result from either project, we favour the project offering the greater potential for reduction in unemployment and thus assign a preference ratio of 5:4 to the Alaska Highway project.

Subsistence and recreation are two parameters we have not studied in detail because of insufficient time and a lack of data. Virtually no data exist on food gathering activities along the Alaska Highway route. Indications are, however, that subsistence activities are more widespread in the more traditional native communities on the Mackenzie River. Justice Berger heard considerable evidence on the importance of country food, including whaling, to communities affected by the Arctic Gas project. Subsistence activities, a vital part of life to communities, affect not only their incomes but also their cultures. Our subjective opinion would thus be to assign a preference of 5:3 for the Alaska Highway.

We would distinguish recreation as an activity pursued by residents of an area as distinct from tourism which refers to outsiders coming into an area. Impairment of local areas valued by residents for recreational pursuits is the basis of concern. The recreational preferences and valued recreational resources both present and future are unknown to us for both projects, although there were references made through the Berger Inquiry. The importance of recreation to local peoples and to native peoples in communicating an awareness and appreciation of their setting to their children is of importance. Loss of valued local recreational areas is very significant to those affected but appears inconsequential to outsiders. A definite effort will be needed to protect such areas before any project proceeds. However, at this time we cannot indicate the level to which locations might be impaired or overloaded by the project or project personnel. Thus we cannot indicate a route preference and therefore we have assigned both projects a preference rating of 5.

We can summarize our comparison of the Alaska Highway and Arctic Gas routes for the life patterns component of the human environment in the following table.

Table 14. Life patterns component of human environment comparison summary.

	Relative Importance Weighting	Relative Preference		Weighted Preference	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
LIFE PATTERNS COMPONENT					
Acculturation	42	5	3	210	126
Public Safety	33	4	5	132	165
Public Health	27	5	3	135	81
Cost-of-Living & Incomes	27	5	4	135	108
Subsistence	27	5	3	135*	81*
Employment	15	5	4	75	60
Recreation	12	5	5	60*	60*
	183			882	681
Preference Ratio				1.3	1.0

*Parameters where detailed studies were not made for this report; estimates are based on subjective judgements.

From a consideration of the Life Patterns component of the human environment we would strongly favour the Alaska Highway route for all parameters except public safety.

Local Economy

The local economy was considered the second most important component of the human environment for this comparison. This includes consideration of the potential effects of the Alaska Highway and Arctic Gas projects on the following parameters listed in decreasing order of importance: tourism, trapping, commercial fishing, mining, planned land use, service and retail, and forestry. A route comparison of many of these parameters was not possible to the level of detail we wanted because of time and data constraints. Nevertheless, we believe it may be of value to those confronted with the national decision for us to indicate our subjective opinions on all parameters. A comparison based upon the limited data available indicated no clear preference for either route in terms of local economy.

Trapping is a significant activity to communities on the Arctic Gas route along the Mackenzie Valley, in the Delta and in the northern Yukon. (It should also be noted that carcasses of trapped beaver and muskrat are used extensively as food by community residents.) A small proportion of the Yukon wild fur harvest is taken within the Alaska Highway corridor and short-term impact upon aquatic furbearer populations and consequently harvest could result from any changes to habitat and water levels at critical times of the year. In either region, trappers could be drawn to wage employment on the projects and this could affect the industry locally. Furthermore, pipeline activities in traditional communities and on wild lands will be perceived by trappers to have impact. This perception alone could result in reduced effort and therefore reduced fur returns. Pipeline workers' demand for local souvenir products could result in a short-term increase in demand for fur products. This would be a benefit to the industry provided the long-term viability of the resource is not impaired. Given proper controls on both projects, major impact is not anticipated. Any impact which may occur is expected to be relatively short-term or transitory in nature. The circum-Delta route which we are examining avoids the major concern for the Mackenzie Delta. Either route will require management initiative to avoid adverse trapper-pipeline worker interaction. This will be more of a problem on the Arctic Gas route where trapping is more widespread. Overall, the Alaska Highway route because of its scale warrants a slight preference (5:4) over the Arctic Gas route.

Major impact to commercial fisheries on either route is not anticipated. Commercial yields and the landed value and market value of production are insignificant in both regions. Habitat degradation resulting from pipeline construction is expected to be relatively short-term and limited in extent. Erosion at stream crossings could be a continuing problem, however, and the effects of toxic spills could adversely affect the industry. Also, competition from recreating workers fishing at Kluane and Teslin

Lakes on the Alaska Highway route could have an impact on local fisheries. Demand for salmon at construction camps on the Alaska Highway and char on the Arctic Gas route could be a benefit to the industry. Overall, neither project is regarded as being deleterious to commercial fisheries and thus each route is assigned an equal preference.

We have not studied the following five parameters because of insufficient time, and thus we have been limited to subjective judgements.

Tourism, as distinct from recreation, refers to people from outside a region coming in to recreate. While we have not studied this parameter in detail, it is apparent that tourism is a rapidly growing industry in the Yukon. The number of tourists visiting the Yukon increased 117% between 1971 and 1974. In 1975 revenue from tourism approximated $27 million, a 159% increase over 1970. People are drawn to the Yukon to visit Kluane National Park, view the spectacular scenery, and relive the Klondike gold-rush days. Easy access by the highway and White Pass and Yukon Railway add to the drawing power of the Alaska Highway route. In addition, there is an infrastructure to support the industry. Tourism is much less significant today along the Arctic Gas route and is more wilderness oriented. The importance of this region lies in its value to future generations and to present generations in knowing that extensive tracts of untrammelled wilderness exist.

Pipeline construction, particularly along the Alaska Highway, could displace normal tourism activity. We assume that would-be tourists will not travel to the Yukon to compete with pipeline activities along the railway and highway. This could adversely effect Dawson even though it is isolated from pipeline activity. There is, however, the potential for pipeline workers to replace some of this loss and even the possibility of a short-term boom for the industry. Whether this would subsequently give rise to a substantial drop following construction is uncertain. Winter construction activities on the Arctic Gas project should not affect tourism significantly, although a considerable amount of summer activity is planned as well. On this basis our subjective preference is for the Arctic Gas route by a ratio of 5:3.

The mining parameter of the local economy has not been examined in detail. In 1971, employment in the mining and quarrying sector in the Yukon was about 355 people, while employment for the Northwest Territories was about 420. Most of the mining activity in the N.W.T. is concentrated in the District of Mackenzie. These figures do not include managerial and clerical personnel.

The potential problem from pipeline construction arises from the expected increase in the demand for labour. This could pose a problem in terms of a higher turnover rate for labour in the mining industry. The costs associated with this (hiring, training, loss of output) will be borne by the industry for the duration of the construction period. Given that prices for mining products are established in world markets, and in the absence of any government assistance, attempts by the industry to offset increased production costs will be borne by the industry itself; they will not be able to pass increased costs on to final consumers.

On the basis that the scale of mining activity is fairly comparable in both areas, we expect that labour turnover problems might be of a similar magnitude in both regions, as a result of either pipeline. In addition, pipeline job opportunities may lead to a shift out of mining regardless of the location of the pipeline. Therefore, there seems to be little reason to expect a differential impact on mining resulting from either project and thus an equal preference is assigned.

To evaluate the potential for either project to have an impact on planned land-use requires that there be in existence a plan for the use of the land. There are no detailed inventories of resource potential or plans for preservation or development of lands for either corridor, however. Consequently, the potential for a pipeline project to impair or preclude future options is unknown. Future options would be precluded if a gas pipeline project were to consume available resources such as the Ya-Ya gravel esker in the Mackenzie Delta. Future options would be impaired if a project usurped inherent qualities of a site such as its sustained yield in furs or its potential for tourism development as a scenic lookout, such as Sheep Mountain on the Alaska Highway pipeline route. Considerable land-use activity now occurs particularly along the Arctic Gas route where traditionally hunting, trapping, fishing, and recreation are widespread. Also, communities along both routes consider in an informal sense that they should control a zone around their community as well the resources which that community needs to sustain its viability. In this context, the Alaska Highway route associated with the road is less likely to pre-empt future options than the Arctic Gas route in the northern Yukon and lower Mackenzie Valley. The number of communities on the Arctic Gas route with their land-related aspirations and values are more likely to be adversely affected by the project than those communities closely associated with the Alaska Highway. Squatters along the Alaska Highway or the lack of incorporated communities along the Arctic Gas route can precipitate land-use planning problems from either project. Also, the existing planning mechanisms, though very limited, can respond more easily to the Alaska Highway situation than to Arctic Gas. Thus, a subjective preference of 5:3 favouring the Alaska Highway is assigned.

The <u>service and retail</u> sector of the local economy is particularly sensitive to changes in aggregate disposable income. A sudden increase in demand for the output of this sector would have serious repercussions on the cost of living. The problem is further complicated because transportation is vital to most retail outlets in the North since most commodities are imported. There is a strong possibility that competition for transportation facilities resulting from pipeline construction, will disrupt established patterns of inter-regional trade. Competition for labour adds another constraint to the ability of this sector to cope with a sudden increase in demand. It is questionable whether either project region will be able to respond adequately. There are some differences, however, between the two regions which are useful to note in coming to a route preference opinion and these are as follows.

Project demands for locally provided goods and services are uncertain. Since the Arctic Gas project is larger than the Alaska Highway project, relative to the local economies, the demand for local goods and services could be substantially greater in the District of Mackenzie. It is unlikely that local entrepreneurs would build up sufficient inventories during the summer months to meet the unclear demands of winter construction months.

Transportation is a vital link between southern wholesalers and northern retailers. The Yukon has easy, year-round access to the south via the Alaska Highway and White Pass and Yukon Railway. The District of Mackenzie relies to a large extent on barge service along the Mackenzie River and on winter roads. There is thus a greater potential for diversion of transportation services away from their community resupply role with the Arctic Gas proposal, and this would adversely impact the service and retail sector.

Finally, changes in labour turnover and vacancy rates can arise from either project. People will be drawn from this sector to the higher paid pipeline jobs. This could result in increased wages with resultant inflationary implications. Overall, it is our subjective opinion that the risk of causing stress to the service and retail sector appears greater for the Arctic Gas project and thus we would slightly prefer the Alaska Highway project by a ratio of 5:4.

In 1971 there were about 105 people employed in "forestry and logging" and "wood processing" occupations in the Yukon, compared to 110 in the Northwest Territories. Nearly all of the output from this sector was for local use.

The concern is that project demand for lumber products will create shortages for other would-be users. There is no evidence that one project will be more severe in its impact. In addition, there is no reason to suppose that either project will be "region-specific" in its impacts. Given that project activity may draw labour from the forestry sector for clearing and other preconstruction activities, thus causing turnover problems for that sector, we see little reason to expect differential impacts from either project. However, forestry work is a source of continuing employment that local people easily relate to, and increased project-related demand for materials would be beneficial to the industry. Whereas the Alaska Highway project could reduce local sources of timber near Watson Lake, the Arctic Gas project could reduce sources in the Delta. Overall, the projects could benefit the industry provided lead time is provided for the industry to respond. No overall route preference was assigned.

We can summarize our comparison of the Alaska Highway and Arctic Gas routes for the local economy component of the human enviroment in the following table.

Table 15. Local economy component of the human environment comparison summary.

	Relative Importance Weighting	Relative Preference		Weighted Preference	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
LOCAL ECONOMY COMPONENT					
Tourism	25	3	5	75*	125*
Trapping	20	5	4	100	80
Commercial Fishing	20	5	5	100	100
Mining	20	5	5	100*	100*
Planned Land Use	18	5	3	90*	54*
Service & Retail	17	5	4	85*	68*
Forestry	8	5	5	40*	40*
	128			590	567
Preference Ratio				1.0	1.0

*Parameters where detailed studies were not made for this report; estimates are based on subjective judgements.

From a consideration of the local economy component of the human environment, we have no overall preference for either route. The preference for the Arctic Gas route on tourism is offset by a less favourable rating for the trapping, planned land-use, and service and retail parameters.

Man-Land Heritage

Man-land heritage was considered the third most important component of the human environment for this comparison. It includes the potential effects of both projects on the following parameters listed in decreasing order of importance: archaeological/historic sites, special areas (sanctuaries, reserves, IBP sites), national parks, and aesthetics. A comparison based upon these parameters indicated a preference for the Alaska Highway route because of the unique nature of the northern Yukon.

The density of archaeological and historic sites along either route is very low. There are few known "important" archaeological sites and few highly sensitive areas in either immediate corridor. Significant finds at Old Crow, along the Old Crow River, and on the Firth river are in the region of the Arctic Gas route. While no comparable evidence of early man has been found along the Alaska Highway, the region is highly regarded by archaeologists. Sites on both routes are of equal "value" and the sequences for each area are equally "important". Considerably more archaeological work has been carried out along the Alaska Highway over the years because of easy access than along the Arctic Gas route, although recent surveys have added substantially to the base of information there. Looting of sites and burial areas is a concern for both project areas; however, the more remote setting of the Arctic Gas project poses additional concerns for both archaeological and historic sites such as at Herschel Island. Relics of earlier settlement are more apparent in the northern Yukon than along the Alaska Highway and thus may be more susceptible to scavengers seeking souvenirs of their northern travels. The Mackenzie Valley has considerable historic resources. Most of these are not protected and consequently a potential for damage from project-related activities seems possible. Each project has the potential to contribute to our knowledge of the past through discoveries made in the process of construction -- provided an appropriate effort is made to do so. The village of Old Crow with its traditional way of life and the native communities of the Mackenzie Valley may pose an enticement to project workers to examine them and this could result in impacts to local historical resources. Since the Alaska Highway route has been impacted by construction of the road, we do not anticipate as much impact there as along the Arctic Gas route and thus a preference of 5:4 is assigned to the Alaska Highway route.

In comparing special areas (sanctuaries, reserves, and IBP sites) on both routes two points should be recognized.

First, both the southern Yukon and the northern Yukon-Mackenzie routes contain superb examples of Canada's natural heritage. Second, the main basis for distinguishing between the two corridors in terms of special areas is the national, continental and global significance for wildlife and wilderness, where the latter term basically implies remoteness of large, essentially self-contained ecosystems from the activities and effects of man. The availability of such large areas is decreasing rapidly throughout the world and their national and international significance for learning, culture and management is increasing. In our view, the northern Arctic Gas route poses the greatest threat to such wildlife and wilderness areas, notably the north Yukon coastal area, with its caribou calving grounds and significance for waterfowl. Justice Berger has recognized this forcefully in his report and has recommended a national wilderness park in the region, a whale sanctuary in west Mackenzie Bay, and bird sanctuaries in the Mackenzie Valley and Delta. Special areas along the Alaska Highway route of concern are the Duke Meadows and Sheep Mountain area. We think highly enough of the wildland potential of the northern Yukon to prefer the Alaska Highway to the Arctic Gas route by a ratio of 5:2.

We recognize, however, that when and if Mackenzie Delta gas is developed, options for a pipeline would be along the Dempster Highway or Mackenzie Valley. We have not studied the Dempster Highway route but we are concerned about additional threats to the Porcupine caribou herd's wintering range. This matter will warrant further study.

The Arctic Gas route is preferable in terms of potential impact on <u>national parks</u>. The Alaska Highway route crosses Dall's sheep wintering range at the base of Sheep Mountain in Kluane National Park. National parks are of special public interest as they "....contain significant geographical, geological, biological or historic features as a national heritage for the benefit, education and enjoyment of the people of Canada". Although we have considered the northern Yukon under special areas, we must also recognize that a national park has been proposed for that area as well as a Firth River Territorial Park. We thus prefer the Arctic Gas route by a ratio of 5:3.

Aesthetic impacts of both projects have not been examined in detail. We recognize that either project can impair the corridor environment through increased disturbance of landscapes (visual impacts) and increased noise levels from compressor stations in the vicinity of villages, scenic outlooks, campgrounds, etc. However, since the Alaska Highway route is heavily used by visitors the number of people affected could be significantly more on the Alaska Highway in terms of visual and auditory impact. Aircraft overflights will be more extensive on the Arctic Gas route. Overall, our subjective opinion is to prefer the Arctic Gas route by a ratio of 5:4.

We can summarize our comparison of the Alaska Highway and Arctic Gas routes for the man-land heritage component of the human environment in the following table.

Table 16. Man-land heritage component of the human environment comparison summary.

	Relative Importance Weighting	Relative Preference		Weighted Preference	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
MAN-LAND HERITAGE COMPONENT					
Archaeological and historic sites	18	5	4	90	72
Special areas	17	5	2	85	34
National parks	17	3	5	51	85
Aesthetics	11	4	5	44*	55*
	63			270	246
Preference Ratio				1.1	1.0

*Parameter where detailed studies were not made for this report; estimates are based on subjective judgements.

Based on this consideration of the man-land heritage component of the human environment, we favour the Alaska Highway route because of the unique nature of the northern Yukon and its importance to Canada's northern heritage.

Infrastructure

In this particular comparison, infrastructure was considered the least important component of the human environment. This component includes the potential effects of both projects on the following parameters listed in decreasing order of importance: planning and administrative services, transportation, education, municipal services, and communications. A comparison based on these parameters indicated a preference for the Alaska Highway route generally because planning and administrative services in the southern Yukon can better respond to project demands.

Large-scale project activity, as borne out by the Alyeska experience, results in increased demand for a wide variety of government planning and administrative services. A much expanded government presence and hence public cost will be incurred in this sector as a result of either project. Federal departments will be strained because of land-use planning demands. Territorial and municipal governments will be strained to respond to general demands and particular problems related to education, health, welfare and other services. Since the Arctic Gas project crosses a more remote area, we believe that general administration and the ability to respond to local problems will be more difficult than on the Alaska Highway at places such as Teslin and Haines Junction. Demands related to achievement of a native land claims settlement and subsequent implementation programs are a further complicating difficulty. In light of the Mackenzie Valley setting, we believe that such tasks will be more difficult there for the Arctic Gas project than for the Alaska Highway. We would thus assign a preference of 5:3 favouring the Alaska Highway.

Project activity will place heavy demands upon existing transportation services, thus impairing the quality of service available to local residents. Project demand will also cause local transportation costs to rise. Tariff rates will increase in the private sector and capital and maintenance costs will increase in the public sector. The Arctic Gas project will affect rail, barge, winter road and air transportation whereas the Alaska Highway project will affect the White Pass and Yukon Railway and highway systems. Given the existing infrastructure, we believe the southern Yukon system can respond better to these demands than the Mackenzie Valley system and thus we favour the Alaska Highway route by a ratio of 5:4.

We have not studied the following four parameters in detail because of insufficient time; thus we have been limited to subjective judgements.

Project activity could cause an increase in the demand for educational services in either area, as some workers' families will migrate to the region. We expect that easier access to Yukon communities and the fact that the Alaska Highway project will be primarily a summer operation, may lead to a higher propensity for families to migrate to this region. Winter construction and lack of road access should minimize problems in the lower Mackenzie valley. The degree to which an influx of families will strain the existing educational services will depend on the increase in demand for education relative to the level of excess capacity within the system. Also, curriculum revisions may be demanded in support of new students from a southern educational system. The quality of educational services available to local residents may be impaired because of increased enrollment and operating costs. We are aware that problems did occur in Alaska where some schools were forced to resort to a shift system of teaching. Thus a subjective preference for the Arctic Gas route by a ratio of 6:4 seems appropriate.

The provision of <u>municipal services</u> could be affected by either pipeline proposal. A sudden increase in population will increase demand for local services, including housing. As a result, increased capital and maintenance costs could be incurred. Any expansion of services to meet purely project demands will result in longer term financial obligations to those municipalities. Where present system capacity is not fully utilized, this problem may not arise. The central issue is the number of family units that will be added to existing populations and thus add to the demand for services. Both project will provide facilities and services separate from communities. Thus, the degree of impact in either region is unclear; therefore, we cannot readily justify a preference for either project on the basis of this parameter.

Either project will increase demands for local communications services and may thus impair the quality of service available to local people. Increased capital, operating and maintenance costs could be incurred depending upon the degree of self-sufficiency planned into either project. Pipeline operating systems should not affect local communications because these systems are dedicated to the project and thus independent. Mail and telegraph systems are federal responsibilities whereas telephones are not. We see little to suggest a differential impact and therefore have no overall route preference.

We can summarize our comparison of the Alaska Highway and Arctic Gas routes for the infrastructure component of the human environment in the following table.

Table 17. Infrastructure component of the human environment comparison summary.

	Relative Importance Weighting	Relative Preference		Weighted Preference	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
INFRASTRUCTURE COMPONENT					
Planning and administrative services	18	5	3	90	54
Transportation	13	5	4	65	42
Education	13	4	5	42*	65*
Municipal services	9	5	5	45*	45*
Communications	8	5	5	40*	40*
	61			282	246
Preference Ratio				1.1	1.0

*Parameters where detailed studies were not made for this report; estimates are based on subjective judgements.

From a consideration of the infrastructure component of the human environment, we favour the Alaska Highway route because the planning and administrative services there, though inadequate, can better respond to project demands than in the case of the Arctic Gas project.

In summary (Table 18), it is evident that the Arctic Gas alternative will have a somewhat less desirable effect upon the human environment in Canada north of 60°N than the Alaska Highway alternative. This conclusion is based upon the following consideration.

The estimated peak labour force associated with the Arctic Gas route is 217 percent of the estimated peak labour force associated with the Alaska Highway route. The larger number of individuals that would be employed on the Arctic Gas route together with the larger amounts of income that they will have to spend will result in a greater adverse effect upon many of the important human environmental parameters. Furthermore, since the communities impacted along the Arctic Gas route are much more traditional in culture than communities impacted along the Alaska Highway route, the problem of social adjustment to the construction program are expected to be much more serious along the Arctic Gas route. The accessibility provided along the Alaska Highway may encourage migration of more socially undesirable individuals than to the construction area of the Arctic Gas alternative. However, we do not consider these factors favouring the Arctic Gas route to offset the other adverse social and economic effects of that route.

Table 18. Human environment comparison summary.

	Relative Importance Weighting	Relative Preference		Weighted Preference	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
LIFE PATTERNS COMPONENT					
Acculturation	42	5	3	210	126
Public Safety	33	4	5	132	165
Public Health	27	5	3	135	81
Cost-of-Living & Incomes	27	5	4	135	108
Subsistence	27	5	3	135*	81*
Employment	15	5	4	75	60
Recreation	12	5	5	60*	60*
Total	183			882	681
Preference ratio				1.3	1.0
LOCAL ECONOMY COMPONENT					
Tourism	25	3	5	75*	125*
Trapping	20	5	4	100	80
Commercial Fishing	20	5	5	100	100
Mining	20	5	5	100*	100*
Planned Land Use	18	5	3	90*	54*
Service & Retail	17	5	4	85*	68*
Forestry	8	5	5	40*	40*
Total	128			590	567
Preference ratio				1.0	1.0
MAN-LAND HERITAGE COMPONENT					
Archaeological and historic sites	18	5	4	90	72
Special areas	17	5	2	85	34
National parks	17	3	5	51	85
Aesthetics	11	4	5	44*	55*
Total	63			270	246
Preference ratio				1.1	1.0
INFRASTRUCTURE COMPONENT					
Planning and administrative services	18	5	3	90	54
Transportation	13	5	4	65	42
Education	13	4	5	42*	65*
Municipal services	9	5	5	45*	45*
Communications	8	5	5	40*	40*
Total	61			282	246
Preference ratio				1.1	1.0
HUMAN ENVIRONMENT					
Total	435			2024	1740
Preference ratio				1.2	1.0

*Parameters where detailed studies were not made for this report; estimates are based on subjective judgements.

CONCLUSIONS

Our analysis has indicated that the potentially larger benefits associated with the size of the Arctic Gas pipeline are more than offset by the larger adverse effects associated with the route.

In addition, the Arctic Gas route has a number of other disadvantages associated with it. Of foremost importance is its very serious potential impact upon the Porcupine Caribou herd, a resource which we believe is of tremendous value not only to the people of the north but to Canadians and Americans as well. We cannot overstate the value we attach to the preservation of that herd and our considered judgement is that the Arctic Gas pipeline would place this herd in serious jeopardy. Also, of great importance is the likely impact of that pipeline upon the traditional cultures of the native people of the Mackenzie Valley.

Beyond these major disadvantages of the Arctic Gas route there are several others which cannot be treated as negligible. Raptor nesting areas could be adversely impacted. The threat of the severe winter climate could prolong the construction period scheduled as it is for the winter months. The greater distance over which gas at temperatures below 0^{o} will be transmitted across unfrozen, frost susceptible soils indicates that frost heave will be a more serious problem along the Arctic Gas route. And finally this route traverses largely an unadulterated landscape and biological environment whereas the Alaska Highway route passes through an area that has already been impacted by a highway and associated development. The pipeline and its construction not only disturbs a previously undisturbed environment but it also makes this environment accessible to many more people, with all of the adverse impacts associated with greater human use of a wild area.

There are advantages associated with the Arctic Gas route which we have carefully weighed. It could provide greater employment opportunities to northerners because of the larger labour force it requires. It does not have the potential impact upon Dall's sheep posed by the Alaska Highway route. Seismic risk is much less. Public safety is not as likely to be as adversely affected because the area it crosses is much less accessible to a criminal element than the Alaska Highway area. Our analyses indicate that while these advantages are noteworthy they do not come near to offsetting the serious comparative disadvantages that we have identified.

<u>BACKGROUND DOCUMENTATION</u>

APPENDIX TO:

The Transmission of Prudhoe Bay Gas to American Markets: A Preliminary Environmental Comparison of the Canadian Arctic Gas Pipeline and the Foothills (Yukon) Pipeline in the Yukon and Northwest Territories

Prepared by:

Interdisciplinary Systems Ltd.

Prepared for:

Alaska Highway Pipeline Panel

May 1977

This Panel is Sponsored by Foothills Pipe Lines Ltd.

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FOREWORD

The individual sections of this appendix present the results of studies carried out to assist the Alaska Highway Pipeline Panel in their preliminary environmental comparison of the proposed Alaska Highway and Arctic Gas pipeline routes in the Yukon and Northwest Territories. These studies were based on the Alaska Highway Pipeline Panel's 1977 "Initial Environmental Evaluation of the Proposed Alaska Highway Gas Pipeline, Yukon Territory", and the project information available for Foothills' (Yukon) revised application of February 1977 for the Alaska Highway route. Information on the Arctic Gas coastal-circumdelta route to the Willowlake River in the Mackenzie Valley was based on the Canadian Arctic Gas filing of 1974, and the section from the Willowlake River to the Alberta border was based on the Canadian Arctic Gas consolidation filing of 1976. Environment Protection Board reports and submissions and testimony to the Berger Commission were used extensively and were supplemented with relevant government and consultant reports and published literature.

Each of the report sections deals with a specific component of the environment: land, water, air, mammals, birds, fish, vegetation, life patterns, local economy, man/land heritage and infrastructure. Each section presents a problem definition, a summary of the potential impacts of either route, and a summary of the relative preference ratings for each key parameter.

Although individual authors are cited for each section, the study was conducted as an interdisciplinary team effort under the guidance of the Panel. The opinions expressed in the individual report sections, however, are those of the individual authors and do not necessarily reflect the views of the Alaska Highway Pipeline Panel.

The study team consisted of:

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INTRODUCTION AND APPROACH

Although the onset of resource development activities in northwestern Canada has made a valuable contribution to the general level of long-term environmental data in the region, a comprehensive set of detailed information required for quantitative assessments and comparisons of alternate gas pipeline proposals is still not available. This effectively limits any comparison of alternate proposals to qualitative estimates of potential impacts that may occur as a result of project construction and operation. This limitation, in turn, requires a systematic procedure that accommodates the available information and the professional judgements of a wide range of specialists assembled and presented in a manner that is meaningful and useful to decision-makers.

Any comparison of alternate projects requires the consideration of a number of aspects of potential environmental impacts, including magnitude, importance, duration, and the types of controls, mitigative measures, and administrative actions required. A comparison of these factors includes both objective conclusions based on fact and professional judgements based on existing levels of project and environmental information. Because of the number of professional judgements required in this comparison it is imperative that they be clearly identified and defined if they are to be of any value in the decision-making process.

Our objective in this comparison approach, therefore, was to develop a systematic framework that would facilitate the identification and definition of potential impacts, incorporate facts and professional judgements related to these impacts, and provide a clear and consistent presentation of the conclusions. This approach contains the following major steps:

1. Selection of key environmental parameters
2. Assignment of Relative Importance Rankings to selected parameters
3. Determination of route preferences for selected parameters
4. Comparison Rating

Parameter Selection

Because of the complex nature of potential environmental changes resulting from a project of this scale we adopted a systematic procedure for refinement of potential problems into discrete and comprehensible units. The breakdown follows the general hierarchical arrangement outlined by Dee et al. (1972) where the total environment is broken into three major categories: physical, biological and human. These categories are in turn divided into major components such as land, water and air for the physical category and finally, the components are separated into major parameters such as permafrost, erosion and slope instability for the land component of the physical environment (Fig. 1).

The selection of environmental parameters is critical to any comparison as these parameters determine the boundaries of concern and to a large degree the nature of the comparison. An almost infinite list of environmental parameters can be considered. Eliminating parameters from the list is equivalent to judging any impact on these parameters as acceptable. Conversely, the inclusion of parameters in the assessment suggests that under some circumstances adverse impact would be unacceptable (Matthews 1975). We used a two-stage selection process for the inclusion of environmental parameters. Preliminary selection was based on the parameter's potential for measureable regional disruption as a result of project activities. Parameters meeting the above criterion and meeting one or more of the following criteria were selected for inclusion in the comparison: 1) limited regional or continental occurrence, 2) restricted regional or continental distribution, 3) sensitivity to disruption, 4) unadaptability to disruption, 5) direct or indirect use by other categories or components of the system and 6) special public or institutional interest.

Relative Importance Ranking

The proposed corridors of the Alaska Highway route and the Arctic Gas route in Canada were considered an

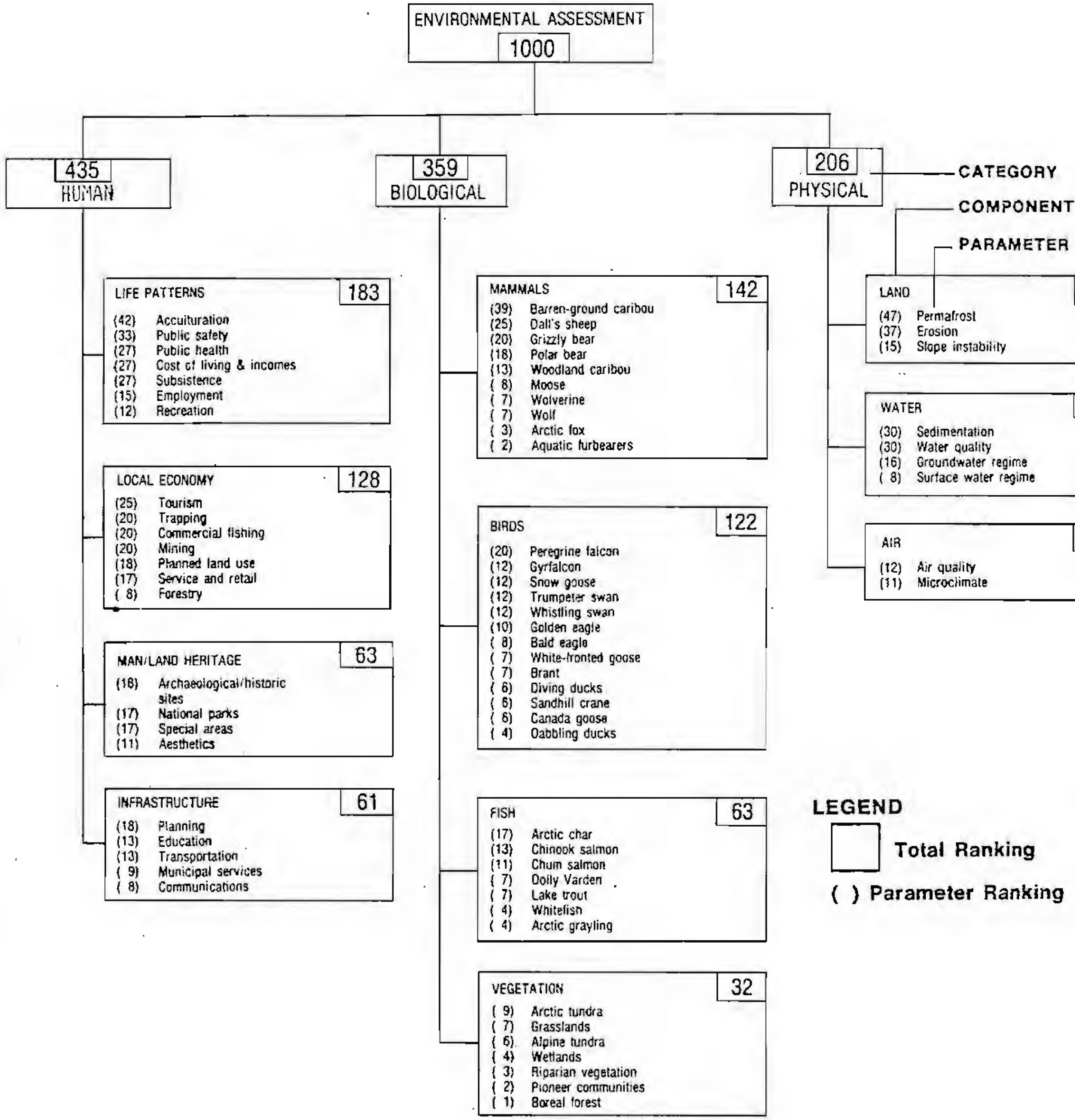

Fig. 1. Organization and Relative Importance Ranking of Environmental Parameters for Preliminary Environmental Comparison — Alaska Highway and Arctic Gas Pipeline Routes.

environmental system consisting of physical, biological and human categories which were sub-divided into major components and parameters (Fig. 1). Two major characteristics of these parameters are emphasized. First, the parameters are a subset of all available environmental parameters and, with proper selection criteria, should reflect the majority of potential environmental changes in the region as a result of pipeline construction and operation. They cannot, however, be expected to reflect total environmental change. Second, because the members of this parameter subset cannot be assumed to make equal contributions to the long-term stability and function of the regional system, a weighting procedure is required to reflect the relative contribution or importance of each parameter.

Relative Importance Rankings were established based as much as possible on scientific information and professional judgments rather than the participant's perceptions of societal value judgments. Although we recognize that no such ranking system can be entirely free of value judgments, the study team's rankings were based on the six criteria outlined in Environmental Parameters and the rankings were defined as "reflecting the relative contribution of each parameter to maintaining the function and stability of the existing natural and social system of the region".

Relative Importance Rankings were assigned using a "ranked-pairwise comparison" in combination with the Delphi process (Dee et al. 1972). The advantages of this technique are that it is systematic in nature, minimizes individual bias, produces consistent comparisons and aids in convergence of judgment.

The basic process is to rank categories first, then components, then parameters. Elements to be compared are ranked according to the selected criteria. Successive pairwise comparisons are then made between contiguous elements to select, for each element pair, the degree of difference in importance. This overall procedure (Dee et al. 1972) consists of the following steps:

Step 1 - Select the evaluation group and explain in detail the weighting concept, criteria and use of ranking and weightings.

Step 2 - Rank the categories, components or parameters that are to be evaluated.

Step 3 - Assign a value of 1 to the first element on the list. Compare the second element with the first to determine how much the second is worth compared to the first. Express this value as a decimal ($0 < X \leq 1$).

Step 4 - Continue these pairwise comparisons until all elements in the list have been evaluated (compare third with second, fourth with third, etc.).

Step 5 - Multiply out percentages and express over a common denominator; average over all individuals in the experiment.

Step 6 - In weighting the categories or components, adjust decimal values from Step 5 if unequal numbers of parameters exist in the parameter groups being evaluated. Adjustment is made by proportioning these decimal values in proportion to the number of parameters included in that grouping.

Step 7 - Multiply the average by the number of units to be distributed to the respective grouping.

Step 8 - Do Steps 2-7 for all categories, components and parameters.

Step 9 - Indicate to the individuals, by controlled feedback, the group result of the weighting procedure.

Step 10 - Repeat as often as necessary to increase reliability of the results.

For a numerical example consider that components A, B, and C have been selected. These components consist of eight parameters, four in A, two in B and two in C.

Step 2 - Relative ranking of components is B, C and A.

Steps 3-4 - Assign weights to components:

B = 1

C = 1/2 the importance of B

A = 1/2 the importance of C

Step 5 - Multiply out percentages and express over common denominator. Assume the average values of all individuals are given below:

B = 1

C = 0.5

A = 0.25

B = 1/1.75 =	0.57
C = 0.5/1.75 =	0.29
A = 0.25/1.75 =	0.14
	1.00

Step 6 - Adjust for unequal number of parameters in each component:

B = 0.57 x 2/8 =	0.14
C = 0.29 x 2/8 =	0.07
A = 0.14 x 4/8 =	0.07
	0.28

Using the new total, the component values are:

B = 0.14/0.28 = 0.50

C = 0.07/0.28 = 0.25

A = 0.07/0.28 = 0.25

1.00

Step 7 - Multiply these adjusted values by the total importance units to be assigned to the group (eg. 20).

B = 20 x 0.5 = 10

C = 20 x 0.25 = 5

A = 2- x 0.25 = 5

Thus importance rankings for components A, B and C are 5, 10, and 5, respectively.

A set of 1000 points was established for assignment during the relative importance ranking of the selected parameters. These points were assigned, using the above methodology in the following manner: the complete study team, together with the Alaska Highway Pipeline Panel, assigned Relative Importance Rankings at the category and component levels, and final category and component rankings reflect the average judgments of these individuals. Finally, individual members of this team ranked parameters within the components covering their respective areas of expertise. The Relative Importance Rankings resulting from this process are illustrated in Fig. 1.

To interpret these Relative Importance Rankings the following points should be considered. First the rankings system produces interval scale rankings which can be combined mathematically with other interval scale numbers and manipulated (Skutsch and Flowerdew 1976). Second, these rankings are the relative importance of each parameter to the other parameters included in the comparison and are not intended to reflect importance relative to all possible environmental parameters. In addition, although the ranking weights are cumulative within the hierarchical structure, the ranking system does not allow for direct comparisons between parameters from different categories since these direct comparisons were never made in establishing rankings. Finally, although these rankings were established by a professional team based on selected criteria, they undoubtedly contain value judgments. Reviewers of the assessment may wish to follow the procedures and establish their own set of importance rankings.

Relative Preference

Following the selection and ranking of environmental parameters, each route was evaluated on the basis of its potential environmental impacts. This consisted of identifying the major potential impacts on each route for each parameter, comparing the differences, and selecting a preferred route. The criteria used in making this selection included: (1) regional severity of potential impacts (including duration, magnitude, probability and timing), (2) number and nature of site-specific impacts, and (3) the ability of controls and mitigative measures to reduce potential problems.

This preferred route was assigned a Relative Preference of 5 and the other route, compared to the preferred route, was assigned a rating of 1 to 5. When both routes were considered equal for a particular parameter they both received a rating of 5. When a parameter occurred along one route but not the other, the project without the parameter automatically received a rating of 5 and the other route was rated relative to this "no impact case" using the above criteria.

Several points should be kept in mind when interpreting the Relative Preference numbers. First, the process is designed to select, based on the above criteria, the best route for each parameter from the two considered in this preliminary comparison. Obviously, there are several other major and minor route and timing options that should be considered in any comprehensive comparison.

Secondly, the Relative Preference number is only intended to reflect a professional judgment, based on the available information, of the preferred route for each selected parameter. Because of the range of criteria used in assigning Relative Preference, the number should not be interpreted as simply a reciprocal of a quantitative summation of potential impacts.

Finally, because the Relative Preference is only designed to select the best from a list of available options, it should not be construed to mean a lack or acceptability of potential impacts. Both routes reviewed in this preliminary comparison have a variety of potential environmental impacts. Once a final route selection is made, the problem of identifying potential impacts and developing a set of controls and mitigative measures to maintain impacts within an acceptable level still remains.

Route Comparison Rating

The clear definition of Relative Importance Rankings and Relative Preference allows the reader to see how the assessment team evaluated individual parameters for each route. The Comparison Rating was subsequently developed to summarize, into a single value for each parameter, these independently developed rankings. This Comparison Rating is defined, therefore, as the Relative Importance Ranking multiplied by the Relative Preference. The combination of these two values into a single Comparison Rating to express route preference has two major advantages. First, the Relative Importance Rankings were developed because of the recognition that individual parameters were not all of equal importance in the regional environment. Combining these rankings with the Relative Preference allows the importance to modify the preference and more accurately reflect the contribution of an individual parameter conclusion to the overall decision. Secondly, this combination into a single value allows the aggregation of parameter conclusions into a Comparison Rating at the component and category level.

The structure of this preliminary comparison follows the general hierarchical structure, in that discussion proceeds from the general category level to the specific components and parameters. An overview summary is provided for each component and each parameter is discussed individually in terms of the potential problems associated with the construction and operation of a gas pipeline, the potential impacts associated with the Alaska Highway and Arctic Gas routes, and a comparison summary.

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Skutsch, Margaret M. and Robin T.N. Flowerdew. 1976. Measurement techniques in environmental impact assessment. Env. Conserv. 3(3):209-217.

The Transmission of Prudhoe Bay Gas to American Markets: A Preliminary Environmental Comparison of the Canadian Arctic Gas Pipeline and the Foothills (Yukon) Pipeline in the Yukon and Northwest Territories

BACKGROUND DOCUMENTATION

LAND

CONTENTS

Hurwitz, L.E. and G.T.S. How. 1977. Land. Pages 13 to 36 in Background documentation. Appendix to The transmission of Prudhoe Bay gas to American markets: A preliminary environmental comparison of the Canadian Arctic Gas pipeline and the Foothills (Yukon) pipeline in the Yukon and Northwest Territories. Alaska Highway Pipeline Panel, Winnipeg. 420 pp.

SUMMARY

The proposed Alaska Highway and Arctic Gas pipeline routes from the Alaska border to the 60th parallel have been compared on the basis of the effects of construction and operation on the three major parameters of the land - permafrost, erosion and slope stability.

The effect of each pipeline project on permafrost was based on the amount of thaw settlement which can result from clearing and grading during construction and from operation of a pipeline at above-freezing temperatures. Potential slope instability was compared on the basis of planned construction activities and gas transmission at above-freezing temperatures. Both permafrost and slope instability were quantifiable; potential erosion from rights-of-way could not be quantified, however, and factors affecting erosion were used as a basis for comparison. Comparison ratings are shown in Table 1.

During construction, permafrost degradation and thaw settlement in excess of one-third of a metre could potentially occur on 9 percent of the Alaska Highway route compared to 22 percent of the Arctic Gas route. During operation, 18 percent of the Alaska Highway route could be so affected compared to 26 percent of the Arctic Gas route. Overall, based upon permafrost considerations, the Alaska Highway route is substantially preferred by a rating of 5 : 1.

Table 1. Summary of land comparison[a] for the Alaska Highway and Arctic Gas pipeline routes in Canada north of the 60th parallel.

	Relative Importance Weighting	Relative Preference[b]		Weighted Preference[c]	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
Permafrost	47	5	1	235	47
Erosion	37	5	2	185	74
Slope stability	15	5	5	75	75
Totals	99			495	196

[a]See Introduction and Approach for detailed discussion of Relative Importance Weightings and Relative Preference ratings.

[b]Relative Preference is based on a scale of 1-5, where the preferred route is assigned a value of 5.

[c]Weighted Preference = Relative Importance Weighting X Relative Preference.

The Alaska Highway route is strongly preferred over the Arctic Gas route based on their respective potentials to increase erosion. The Alaska Highway route traverses only 28 percent as much soils of high and medium erodibility and 15 percent as much frozen ground as traversed by the Arctic Gas route. Although arctic and winter construction proposed for the Arctic Gas route will bare less mineral soil than the largely summer construction of the Alaska Highway route, the erosion potential of soil type and ice-rich ground will remain higher on the Arctic Gas route. Conversely, the Alaska Highway route traverses more steeply sloping terrain which gives it higher erosion potential from the aspect of slope gradient. Overall, the Alaska Highway route is strongly preferred, by a rating of 5 : 2.

Construction on the Alaska Highway route has potential to cause slope instability on just over 2 percent of its length compared to just under 2 percent on the Arctic Gas route. Operation will increase potential instability slightly on the Alaska Highway route but will reduce potential instability on the Arctic Gas route to just over 1 percent of its length. Since operation will be of longer duration than construction, no preference is given to either route.

Overall, the Alaska Highway route is favored by a ratio of about 2.5 : 1 due primarily to major differences in potential effects on permafrost on the two routes.

INTRODUCTION

Within physical environments of northern gas pipelines, parameters identified in the initial environmental evaluation of the Yukon Territory section of the proposed Alaska Highway gas pipeline may be used to compare alternate routes. That evaluation identified permafrost, erosion and slope instability as significant parameters of the land which will change as a result of construction and operation of the pipeline (Hurwitz and How 1977).

This section compares the significant land parameters along the Alaska Highway and the Arctic Gas routes from the Alaska-Yukon border to the 60th parallel. For each parameter we have selected a preferred route and have assigned a preference rating in general accord with criteria outlined in the introduction and approach to this appendix. For permafrost and slope stability we estimated potential changes along each route (Hurwitz and How 1977) and used these as the principal basis for comparison. For erosion, change could not be estimated due to a lack of data but factors affecting erosion were used as indicators to compare erosion potential on each route and provide a basis for preference.

Environmental processes such as seismicity and frost heave which may create hazards to the integrity of a pipeline also are important considerations in any comparison of routes. They are not dealt with in this section however, as we consider them factors related to project design. But they have not been dismissed in the overall comparison. Seismicity and frost heave, together with winter road viability, and climatic influence on construction, are considered in the comparison summary of the physical environment in the report by the Alaska Highway Pipeline Panel.

PERMAFROST

Problem Definition

Construction and operation of a warm pipeline in permafrost areas can lead to permafrost degradation and thaw settlement. Significant thaw settlement or ground subsidence can lead to problems of drainage disruption and erosion, and can impair movement of wildlife across the right-of-way. Extent and amount of thaw settlement are dependent upon permafrost distribution, average excess ice content of the soil and amount and level of surface disturbance (Linell 1973, Strang 1973). Amount and level of surface disturbance are, in turn, dependent upon time and method of construction. Winter construction is known to cause considerably less surface disturbance than summer construction. Use of arctic construction techniques such as snow and ice roads, will further reduce the level of disturbance to the ground surface (Adam 1973, Adam and Hernandez 1977).

Comparison of alternative routes during construction will thus consider their potential to cause significant thaw settlement (i.e. exceeding one-third of a metre) and will be based on permafrost distribution, average excess ice content and timing and method of construction. During operation, transmission temperature of the gas will also be considered.

For the Alaska Highway route permafrost distribution was obtained from Eager and Pryor (1945), and average excess ice content and timing and method of construction were obtained from Foothills Pipe Lines (Yukon) Ltd. (Foothills 1976, 1977). For the Arctic Gas route, permafrost distribution and average excess ice content were obtained from Templeton Engineering Company (1973) and timing and method of construction were obtained from the Arctic Gas project description (CAGPL 1974).

Potential Impact

Alaska Highway Route:

Construction of 179 km of pipeline in the widespread permafrost region will be carried out in winter. In this section, permafrost distribution is 51 percent and the soil has an average excess ice content of 20 percent. Construction of the remaining 646 km of pipeline located in the southern fringe of the permafrost region will be carried out in summer. Permafrost distribution in this southern fringe region is about 13 percent.

During construction, areas equivalent to 36 of 179 km of pipeline right-of-way in the widespread permafrost region and 42 of 646 km in the southern fringe of the permafrost region have potential for significant thaw settlement.

In the widespread permafrost region with 65 km of pipeline operated at a temperature below freezing and 114 km at above freezing, significant thaw settlement could potentially occur along 62 km. In the southern fringe of the permafrost region where the operating temperature is above freezing, 84 km of right-of-way have potential for significant thaw settlement.

Arctic Gas Route:

On the Arctic Gas route, arctic construction techniques will be used along 546 km of pipeline right-of-way located in the continuous permafrost region and along 811 km located in the widespread permafrost region. Winter construction will be used along 225 km in the southern fringe of the permafrost region. Permafrost distribution in the continuous permafrost region is estimated at 98 percent with an average excess ice content of 40 percent. In the widespread permafrost region, permafrost distribution is estimated at 65 percent with an average excess ice content of 20 percent. In the southern fringe region, the permafrost distribution is estimated at 33 percent and average excess ice content is generally less than 20 percent.

During construction, planned to be carried out over three winters, an area equivalent to 161 of 546 km of pipeline right-of-way located in the continuous permafrost region has potential for significant thaw settlement. Significant thaw settlement could also potentially occur along 158 of 811 km of pipeline right-of-way in the widespread permafrost region and along 30 of 225 km of right-of-way in the southern fringe of the permafrost region.

On the Arctic Gas project, the pipeline will be operated at a temperature below freezing to the Northwest Territories-Alberta boundary. During operation, significant thaw settlement could potentially occur along 192 of 546 km of pipeline right-of-way located in the continuous permafrost region, along 190 of 811 km of pipeline right-of-way in the widespread permafrost region and along 36 of 225 km located in the southern fringe region.

Comparison Summary

During construction, thaw settlement could occur along 78 of 825 km on the Alaska Highway route compared to 349 of 1582 km on the Arctic Gas route. The length of potential problem areas along the Alaska Highway route may also be reduced by use of the Alaska Highway for hauling, thus minimizing traffic on the right-of-way. Therefore, the Alaska Highway route is preferred during construction with a preference rating of 5 : 1 for the Arctic Gas route.

During operation, areas equivalent to 146 of 825 km on the Alaska Highway route have potential for thaw settlement compared to 418 of 1582 km on the Arctic Gas route. Areas on the Arctic Gas route are predominantly outside the region of influence of the chilled pipeline. Therefore, during operation, the Alaska Highway route is preferred with a preference rating of 5 : 2 for the Arctic Gas route.

Both construction and operation will thus cause potentially less permafrost degradation and thaw settlement on the Alaska Highway route than on the Arctic Gas route, even with a favorable allowance for arctic and winter construction techniques and chilled gas transmissions proposed by Arctic Gas, factors which were included in the foregoing estimates of thaw settlement. There is also considerable risk that the snow roads proposed by Arctic Gas will not be as effective in preventing thaw settlement as envisaged by the applicant. Therefore, overall, based upon permafrost considerations, the Alaska Highway route is preferred over the Arctic Gas route by a rating of 5 : 1.

EROSION

Problem Definition

Stripping of vegetation, grading and levelling along the pipeline right-of-way, together with similar operations for access road construction and borrow area preparation, will expose underlying soil to forces of erosion. Increase in erosion can lead to increased sediment loads of streams located in watersheds crossed by the pipeline.

Comparison of erosion on the Alaska Highway route to that on the Arctic Gas route is limited to a comparison of potential for erosion from the pipeline rights-of-way only. Roads will be required for access from the Alaska Highway to the pipeline right-of-way just as they are for access from the Mackenzie River to the right-of-way along the Arctic Gas route. Access road location and borrow areas have yet to be defined for the Alaska Highway route however, and a comparison of these contributing sources is not possible at this time.

Even a gross approximation of sediment yields from the rights-of-way is not possible with the level of available data. However, soil type, slope length, slope gradient and rainfall intensity, factors entering into the calculation of sediment yield, together with permafrost occurrence and construction technique, may be used as indicators to compare erosion potential on each route.

Slope gradients and lengths were measured from 1:250,000 scale National Topographic Series maps. Soil types were obtained from Foothills Pipe Lines (Yukon) Ltd. data and Templeton Engineering Company (1973). Rainfall data were obtained from available records (Bruce 1968, Templeton Engineering Company 1973). Permafrost occurrence was obtained from maps and publications (Brown 1967, Eager and Pryor 1945, Templeton Engineering Company 1973). The timing and method of construction were obtained from the project descriptions (Foothills 1976, 1977, CAGPL 1974).

Potential Impact

Alaska Highway Route:

The proposed Alaska Highway route is 825 km long from the Alaska border to the Yukon-British Columbia border near Watson Lake. The route lies entirely in the discontinuous permafrost zone and based on permafrost occurrence (Eager and Pryor 1945), about 167 km would be underlain by frozen soils and 658 km by unfrozen soils. Based on relative erodibility scales (Hurwitz and How 1977), the route crosses 126 km of soils of high erodibility, 272 km of soils of medium erodibility and 427 km of soils of low erodibility. (Relative erodibility was developed from a scale which ranked bedrock as non-erodible (0) and aeolian silts and sands as highly erodible (10). Soils with rankings of 10-8 are considered highly erodible; soils with rankings of 7-4 are considered of medium erodibility; and soils with rankings of 3-0 are considered of low erodibility.)

Approximately 677 km of this route traverses ground which may be considered flat or only gently sloping in respect to its influence on erosion potential. The route traverses 148 km of sloping ground which may significantly affect erosion potential.

The climate in the southern Yukon is considered semi-arid (Kendrew and Kerr 1955). Annual precipitation is generally less than 25 cm and 24-hour, 2-year rainfall intensity is about 2.5 cm (Kendrew and Kerr 1955, Bruce 1968). Rainfall is controlled by topography and tends to be localized. The route, lying leeward of the high Coastal Mountains, is in a rain shadow for 434 km.

Foothills proposed winter construction of 179 km of pipeline east from the Alaska border with the remaining 646 km constructed during summer (Foothills 1977). While winter construction will provide greater protection to the vegetative cover, only 11 percent of the highly erodible soils and 27 percent of the soils of medium erodibility occur within the section to be constructed during winter. About 55 percent of the frozen ground lies within the winter construction section.

Arctic Gas Route:

The proposed Arctic Gas route is 1582 km in length from the Alaska border to the Northwest Territories-Alberta border. The initial 546 km of route is in continuous permafrost, the next 811 km is in widespread permafrost and the last 225 km is in sporadic permafrost. From our estimate of permafrost distribution, about 1136 km would be underlain by frozen soils and 446 km by unfrozen soils. The route traverses 473 km of soils of high erodibility, 973 km of soils of medium erodibility and 136 km of soils of low erodibility.

The Arctic Gas route generally is flat or very gently sloping over approximately 96 percent of its length (1511 km). The remaining 71 km traverse slopes which may significantly affect erosion potential.

Average annual precipitation varies from 31 cm near the Alaska border to approximately 41 cm at the Alberta border, while 1-hour, 2-year rainfall intensity varies from 0.5 cm to 1 cm and 24-hour, 2-year intensity is approximately 2.5 cm (Kendrew and Kerr 1955, Bruce 1968). In general, precipitation increases along the route towards the Alberta border. Topography determines to a great extent local weather patterns but storms tend to track up the Mackenzie River Valley from north to south (Templeton Engineering Company 1973).

CAGPL (1974) propose arctic construction using snow roads and work pads for pipeline spreads in the continuous and widespread permafrost regions (1357 km), and winter construction of the remaining 225 km of pipeline.

Comparison Summary

The length of ground crossed by the Arctic Gas route containing soils of high and medium erodibility exceeds that on the Alaska Highway route by some 3-4 times. The Arctic Gas route also crosses some 6-7 times greater length of frozen ground than the Alaska Highway route. These differences are so great that both factors suggest distinct advantages to the Alaska Highway route in relation to the potential for erosion from the right-of-way. Offsetting these differences to some extent however, is the construction technique proposed for the Arctic Gas route. Arctic and winter construction for the full length of the Arctic Gas route will reduce the exposure of mineral soil and will inhibit thermal erosion. Just how much this reduction will be is unknown but in our judgment it is unlikely to be sufficiently great to balance out the large differences in erodible soils and frozen ground which exist between the routes. As well, the risk is considerable that these measures will not work as well as planned. Thus preference in relation to these factors remains strongly with the Alaska Highway route.

The Alaska Highway route passes through more mountainous terrain, whereas the Arctic Gas route is located along the relatively flat lowlands of the Mackenzie Delta and Valley. Although the Arctic Gas route traverses a greater length of gentle slopes, the Alaska Highway route crosses twice the length of steeper slopes which may significantly affect erosion potential. Using slope gradient as a criterion therefore, preference is give to the Arctic Gas route.

The rainfall intensity of the two routes is quite similar and should not affect their relative erodibility, although it is acknowledged that the ground will be snow free and unfrozen for a greater time period annually on the Alaska Highway route.

Chilling of the gas during operation could affect erosion if pooling and channeling of runoff occurs as a result of an ice bulb around the pipeline. Controls may be designed and constructed to prevent such erosion on either route but slight preference is given the Alaska Highway route because of the shorter length of the chilled portion of the pipeline and the greater probability of the designed controls being effective.

Erosion potential on both routes will decrease after construction as plants recolonize the rights-of-way.

Based upon a summary of the factors affecting erosion, the Alaska Highway route is strongly preferred over the Arctic Gas route by a rating of 5 : 2.

SLOPE STABILITY

Problem Definition

Effects of the proposed pipeline projects on slope stability can be grouped into two classes: effects on slopes in unfrozen ground and effects on slopes in permafrost areas. In areas of unfrozen ground, activities associated with construction of a pipeline and the operation of a warm pipeline will cause little, if any, change in slope stability except at locations where the slopes are modified by cut grading. The proposed extent of cut grading is unknown but it is unlikely that cuts in unfrozen soils will introduce significant lengths of instability on either project. In permafrost areas, however, construction and operation will lead to an increase in the depth of thaw that will change the stability of the thawing slopes.

Factors that affect stability of slopes in permafrost areas include slope inclination, excess ice content of the soil, soil type, and rate and depth of thaw (McRoberts and Morgenstern, 1974). Clearing, grading, ditching and traffic on the right-of-way are construction activities that can cause an increase in heat flow into the ground, thus increasing rate and depth of thaw. The greater the surface disturbance, the greater will be the increase in rate and depth of thaw. Presence of a buried warm pipeline will also cause an increase in rate and depth of thaw.

Comparison of alternate routes during construction considers their potential to cause instability of slopes and is based on extent of construction activities, permafrost distribution, average excess ice content and slope inclination. For the fine-grained soils along the routes in which most instabilities will arise, construction has the potential to cause slopes of 6° or greater to become unstable.

During operation, the operating temperature is also considered in the comparison. Operation of a pipeline at a temperature below $0^{\circ}C$ will reduce instability of slopes within the region of thermal influence of the pipeline. Operation of the pipeline at above $10^{\circ}C$ will lead to a higher rate of depth of thaw. At such temperatures, slopes of 4° or greater have the potential to become unstable.

Comparison for both construction and operation assumes that slopes were permafrost-affected to the same extent as permafrost is distributed along the route. The permafrost distribution along the Alaska Highway route was obtained from Eager and Pryor (1945) and along the Arctic Gas route from Templeton Engineering Company (1973) and Brown (1964).

Potential Impact

Alaska Highway Route:

Of 179 km of pipeline route in the widespread permafrost region, 10 km traverse slopes with inclinations of 6° or greater. Of the remaining 646 km of pipeline route, 93 km traverse slopes of 6° or greater and 114 km traverse slopes of 4° or greater.

During construction, slope instability could potentially occur along 5 of 179 km of right-of-way in the widespread permafrost region and along 12 of 646 km of right-of-way in the southern fringe permafrost region.

In the project description, it is reported that east from MP 40.8 the temperature at discharge will range from 7°c to 29°C. From MPs 0-40.8 the gas will be transmitted at -7°C. During operation at these temperatures the potential slope instability increases to 19 km in 825 km of route.

Arctic Gas Route:

Along the Arctic Gas route, 10 of 546 km in the continuous permafrost region traverse slopes of 6° or greater. Of 811 km of pipeline route in the widespread permafrost region, 29 km traverse slopes of 6° or greater. Of 225 km in the southern fringe permafrost region, 9 km traverse slopes of 4° or greater and 4 km traverse slopes of 6° or greater.

During construction, slope instability could potentially occur along 10 of 546 km in the continuous permafrost region, along 19 of 811 km in the widespread permafrost region and along 1 of 225 km in the southern fringe permafrost region.

Operation of the pipeline at below $0^{o}C$ from the Alaska-Yukon boundary to the Northwest Territories-Alberta boundary will reduce the potential for slope instability to 6 km in the continuous permafrost region, 11 km in the widespread continuous permafrost and 1 km in the southern fringe permafrost region.

Comparison Summary

Construction of the Alaska Highway pipeline has potential to cause 17 km of slope instability in 825 km of route compared to a potential instability of 30 km in 1582 km of line construction on the Arctic Gas project.

Transmission of gas at temperatures below $0^{o}C$ increases stability conditions which prevail within slopes at completion of construction, and these effects are more pronounced for the Arctic Gas route. During operation, the potential length of slope instability is reduced to 18 km of the Arctic Gas route. On the other hand potential slope instability will increase to 19 km along the Alaska Highway route.

To compare overall potential slope instability from both construction and operation requires a somewhat arbitrary weighting related to duration of each event. Since each pipeline will be operated roughly 5 times as long as it takes for construction, conditions prevailing during operation have perhaps a similar influence on slope stability.

On this basis, there is no preference for either route and each is given the preference rating of 5.

The Transmission of Prudhoe Bay Gas to American Markets: A Preliminary Environmental Comparison of the Canadian Arctic Gas Pipeline and the Foothills (Yukon) Pipeline in the Yukon and Northwest Territories

BACKGROUND DOCUMENTATION

WATER

CONTENTS

Adam, K.M. and A.H. Permut. 1977. Water. Pages 37 to 69 in Background documentation. Appendix to The transmission of Prudhoe Bay gas to American markets: A preliminary environmental comparison of the Canadian Arctic Gas pipeline and the Foothills (Yukon) pipeline in the Yukon and Northwest Territories. Alaska Highway Pipeline Panel, Winnipeg. 420 pp.

SUMMARY

Four parameters were used to compare the changes expected to occur in water along the Alaska Highway route to those changes along the Arctic Gas route: sedimentation, water quality, groundwater regime and surface water regime. Sedimentation indicators of change were the amount of sediment and the length of streambed affected. For water quality, indicators of change were oxygen depletion, pathogenic microorganisms, nutrients, and degradation of water quality due to testing fluid, oil, and other toxic substances used during construction and operation. Groundwater indicators of change were the extent of groundwater pollution for downslope users during construction and disruption of subsurface drainage during operation. Surface water indicators were the likelihood of pipeline crossings causing significant change at the time of construction and interference with cross-drainage during operation.

Comparison of effects on water is summarized in Table 1. Sedimentation and water quality were judged to be of equal importance as water parameters, each about twice as important as groundwater regime. The surface-water regime, having been considered separately from sedimentation and water quality, was considered half as important as groundwater regime.

For water, the overall preference is in favor of the Alaska Highway route (420) over the Arctic Gas route (246) on the basis of the total comparison rating. This

Table 1. Summary of water comparison[a] for the Alaska Highway and Arctic Gas pipeline routes in Canada north of the 60th parallel.

	Relative Importance Weighting	Relative Preference[b]		Weighted Preference[c]	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
Sedimentation	30	5	3	150	90
Water quality	30	5	2	150	60
Groundwater regime	16	5	5	80	80
Surface water regime	8	5	2	40	16
Totals	84			420	246

[a]See Introduction and Approach for detailed discussion of Relative Importance Weightings and Relative Preference ratings.

[b]Relative Preference is based on a scale of 1-5, where the preferred route is assigned a value of 5.

[c]Weighted Preference = Relative Importance Weighting X Relative Preference.

results primarily from the moderate preference for the Alaska Highway route for the relatively important parameters of sedimentation and water quality.

Controls can be effective in reducing the change in all parameters. However, it is assumed that controls are equally effective on each route and therefore the preference remains unchanged.

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SEDIMENTATION

Problem Definition

Changes in the sedimentation rate of streams and rivers will result from four basic sources: disturbance of the river bed during excavation and backfilling; local alteration of the natural river bed due to improper restoration of the trench; surface disturbance caused by grading at the right-of-way across the watershed and on the river banks; and, excess spoil left on the cover or within the floodplain as a source of borrow. These sources of sediment result from construction but their adverse effects may not occur until the operation phase (Adam and Permut 1977).

Highest concentrations of suspended sediment will likely occur at the time of trenching and backfilling, but an increase in total amount of sediment introduced to the stream will come from thermal erosion of cleared right-of-way and river banks. Soil types in the river bottom influence the effect of trenching and backfilling while soil types crossed by the right-of-way influence the effect of clearing. Summer construction will expose more mineral soil than winter construction. Arctic construction (using snow roads and workpads) will maintain most of the right-of-way surface mat intact.

Local alteration of the natural river bed due to improper restoration of the trench will not be a general problem, nor will disturbance of the floodplain as a source of borrow. Excess spoil within the floodplain will influence sediment load during high flows when concentrations of sediment are naturally high. Many streams and rivers have a natural sediment barrier such as a marsh or lake to limit the affected distance downstream.

The comparison of increases in sedimentation is based primarily on the potential length of streams and rivers that could be affected by sediment. The amount of increase in sediment on both routes is difficult to predict. Direct comparison of potential amounts of sediment is not possible because the major source of sediment on each route is different. Borrow from within floodplains is directly compared. Consideration is given to the duration of potential sediment sources and the reliability of construction methods.

Potential Impact

Alaska Highway Route:

In the Yukon, the greatest potential for increased sediments resulting from right-of-way grading is between Nisutlin Bay and Logjam Creek. The area east to the Liard River basin may also yield high sediment loads.

White River, Lower Koidern River, Long's Creek, Aishihik River, Greyling Creek, Teslin River and Morley River all may require special attention to limit sediments entering these streams. Several others have a lesser but relatively high potential for large increases in sediment load during and after construction. These include Beaver Creek, Upper Koidern River, Swede Johnson Creek, Glacier Creek, Burwash Creek, Pine Creek, Cracker Creek, Stony Creek and Swift River and its tributaries crossed by the pipeline.

In addition to streams affected by crossings, several lakes and rivers will be affected because they are receiving waters. In particular Kluane River, Kluane Lake, Dezadeash River, Ibex River, Yukon River from Marsh Lake to Lewes Dam, Squanga Lake, Little Teslin Lake, Teslin Lake and Morley River and Lake will be affected.

Overall on the Alaska Highway route up to 280 km of rivers and streams with drainage area over 25 km^2 potentially could be affected by siltation for a period of three years after construction. Little siltation is expected during operation once revegetation programs are complete, except at unknown site specific problem areas (Adam and Permut 1977).

Arctic Gas Route:

Arctic or winter construction is proposed throughout the whole Arctic Gas route north of 60°N. Provided ground cover is maintained particularly where arctic construction is proposed the amounts of sediment reaching streams and rivers from the right-of-way will be minimal. Initiation of thermal erosion on the right-of-way or at stream crossings could become a severe problem. Several such problems at stream crossings were experienced on the Alyeska pipeline (C. Sloan and C. Kay personal communication). Most streams along the coast and lower Mackenzie Valley are in areas of high-ice-content soils. Many of these will have a high potential for large increases in sediment load during and after construction. Considerable restoration effort will be required in these areas. Restoration of drainage during winter construction may be difficult.

In the upper Mackenzie Valley the potential for siltation is high, but streams have low energy and many marshes provide natural settling basins.

Few lakes will be affected by the Arctic Gas route because of its proximity to the arctic coast and the Mackenzie River. The few (13) that have any potential to be affected are small.

Overall the Arctic Gas route could affect with sediment up to 340 km of streams and rivers with drainage area over 25 km^2 for a period of three years after construction. Little siltation is expected during operation once revegetation programs are complete, except at unknown site specific problem areas. However, the more prevalent ice-rich soils along this route increases the chance and effect duration of problem areas.

Comparison Summary

The uncertainty and difficulty in predicting the location and extent of sediment problems and the dissimilar nature of sediment problems on each route makes direct comparison difficult.

The potential length of streams and rivers affected by sediment (280 km on Alaska Highway route and 340 km on Arctic Gas) gives an advantage to the Alaska Highway route. But the amount of sediment is difficult to predict, and the main sources of sediment are different. On the Arctic Gas route thermal erosion is possibly the greatest potential source of sediment. On the Alaska Highway route clearing and grading of the right-of-way is expected to produce the greatest amount of sediment. Arctic Gas' proposed arctic construction in high-ice-content soil areas reduces the complete denudation of the right-of-way, but the risk of thermal erosion is high. The Alaska Highway route has limited areas of high-ice-content soils over a small proportion of the route. But the larger proportion of summer construction will denude much of the right-of-way through the Yukon (MPs 111.4-512.6).

Both pipelines as proposed are buried and all streams and rivers on both routes will be subjected to trenching and backfilling, possible excess spoil within their floodplains, and possible alteration of banks and bottom configuration. More borrow from within floodplains is expected on rivers crossed by Arctic Gas.

Sediment and erosion control methods on denuded graded pipeline rights-of-way have been used for years during summer construction. Pipeline construction (in particular, buried pipeline) in permafrost areas involves new methods and procedures. It is largely because more length of rivers and streams is affected on the Arctic Gas route than on the Alaska Highway route and because the borrow materials are to be taken from within or near flood-plains of rivers by Arctic Gas that a clear preference exists for the Alaska Highway route on the basis of sedimentation. The Alaska Highway route is given a preference rating of 5 and Arctic Gas 3.

WATER QUALITY

Problem Definition

Changes in water quality will result due to the construction of either pipeline project. The disposal of wastewater from construction camps will add organic material, nutrients, pathogenic microorganisms and residue to water-courses. The use of hydrostatic pipeline testing fluid may lead to thermal pollution where warm water is used. Where a methanol-water solution is used, accidental spills could be toxic to aquatic life. Additional toxic effects could result from accidental spills during storage and handling of fuels, oil and other toxic materials. Water quality may also be degraded in a few streams by leachate from landfill sites along the routes.

Thus, the major pipeline-related activities that may affect water quality are: (1) disposal of wastewater from construction camps; (2) use and disposal of hydrostatic pipeline testing fluids; (3) storage and transfer of oil, fuel, and other toxic materials; and (4) landfill site operation.

The effect of oil spills on streams takes several forms. These are obstruction of light passage, interference with reaeration, toxicity to certain fish and aquatic life, hazard to wildlife, destruction of shoreline vegetation, and interference with recreation and water supplies (Nemerow 1971).

Other toxic materials when spilled during storage or transfer may enter and contaminate watercourses or groundwater or both. These toxic substances may include fuels, lubricants, solvents, resins, paints, emulsions (including rubber, which is latex or bituminous based), acids, alkalis, neutral salts (including chrome, iron, ammonium and various metal salts, solutions and sludges) and complex organic compounds (including pesticides and herbicides) (EPS 1976). Potential effects of toxic spills on wildlife are discussed in the respective sections of this volume.

Potential Impact

Alaska Highway Route:

There are 12 proposed stockpile sites between mileposts (MPs) 0-512.6. Between these mileposts, accidental toxic spills at stockpile sites could potentially affect 11 creeks, 9 rivers, and 6 lakes (Adam and Permut 1977). Effects on water bodies due to accidental spills of toxic materials are difficult to predict. These effects would depend on the toxicity and volume of spilled material, flow of the water body, aquatic and terrestrial life present, and location of downstream users.

The most notable potential effects on downstream users will be at Whitehorse. Should large spills of oil occur on the Yukon River the water supply of Whitehorse could be degraded. An accidental spill of toxic material on Teslin Lake could potentially affect the water supply at Teslin. Recreational users of Teslin Lake could also be affected by such a spill.

There are six construction camps proposed for the Yukon portion of the route. Wastewater from camps between MPs 0-512.6 will affect water quality in five creeks, two rivers, and three lakes (Adam and Permut 1977). The creeks will be more severely affected due to lower dilutions than rivers. Sulphur Creek will, in particular, be severely affected by wastewater disposal (Adam and Permut 1977). There will be some oxygen depletion in receiving streams due to the disposal of treated wastewater. Low flows and lack of reaeration will worsen the problem. There will be some nutrients entering receiving streams; however, effects due to these are not expected to be regionally significant. Assuming the wastewater is disinfected before it is discharged there will still be some effect due to pathogenic microorganisms. Not all viruses are killed by conventional disinfection methods. On a regional basis the effects due to pathogenic microorganisms will not be significant. On a local basis some users of Teslin Lake may be affected by these pathogenic microorganisms should they take their water near the camp outfall. If disinfection with chlorine is used there may be some impact on fish due to the toxicity of chlorine. This effect will be most noticeable on small streams where dilution is low. No effect is anticipated on the Kluane River, Teslin Lake or the Rancheria River.

Water will be used as the pipeline testing fluid (Foothills 1977). Pipeline testing will be undertaken during the period between the middle of June to the end of November. Where ground temperature is below 0°C the water will be heated (Foothills 1976). It is anticipated this will be necessary in approximately the first 160 km of the route where there is widespread permafrost. The possibility exists that it may be necessary to use a methanol-water solution for testing in the first 160 km of the route in permafrost areas, or if cold temperatures with little snow cover prevail during testing. This possibility has been addressed (Foothills 1976) in statements to the effect that if temperatures at the top of the pipe are less than 2.2°C (28°F), it will be necessary to implement additional precautions such as pumping heated water "or using a test medium of lower freezing point or adding antifreeze to the water". Effects on water quality due to the disposal of these fluids are difficult to predict, since proposed volumes and disposal sites have not been determined. There is some potential for thermal pollution of streams, or accidental spills of the water-methanol solution between MPs 0-100. Thermal pollution of streams may be easily eliminated by cooling the warm water testing fluid to ambient stream temperature before discharge.

A methanol wash will be run through the pipe after dewatering (Foothills 1976). The volume of methanol to be used will be approximately 443 l/km of pipe (157 Imperial gallons/mile). This value has been linearly extrapolated using cross sectional areas from the value proposed by Foothills (1976) for the 42-inch pipe. Foothills has not stated what the disposal method will be for this methanol wash. The total volume of pure methanol required over the entire length of the route is relatively small. Since the pipe will have been tested before washing, no leaks of methanol from the pipe are expected. There may, however, be accidental spills of methanol during transportation, storage or handling. If sufficiently large spills occurred in watercourses, mortality of fish and other aquatic life could result due to the toxicity of methanol.

There is no information currently available on landfill locations or extent of use. Effects on water quality due to landfill operations will be due to leachate. These effects will include oxygen depletion due to chemical oxygen demand of the leachate, toxic effects due to such constituents as copper, nickel and zinc, and degradation of water quality due to pH changes, hardness changes, residue addition and nutrient addition. Leachate discharge depends on the landfill sites' physical characteristics and geology (American Society of Civil Engineers 1976). Regionally, the effect on water quality due to landfill sites will not be significant.

Arctic Gas Route:

There are 19 proposed stockpile sites along the Arctic Gas route (CAGPL 1974, 1976). Spills of toxic substances could potentially affect water quality in the Beaufort Sea in 2 places, the Mackenzie River in 14 places, 2 additional rivers, 3 creeks, and 2 lakes., The Mackenzie Delta could potentially be affected directly in three locations and by upstream spills. Potential effects on wildlife due to spills of toxic material in these areas are discussed in the respective sections of this volume. An additional effect of toxic spills is the potential degradation of water supplies from rivers near the following communities: Fort McPherson, Little Chicago, Fort Good Hope, Norman Wells, Fort Norman, and Fort Simpson. All stockpile sites north of Fort Simpson will be supplied by barge. Although barge transportation itself poses no great environmental hazards, fuel transfer between barges, storage tanks, and equipment provides the major potential for spills in watercourses (Jacobson 1974). It is expected large quantities of materials such as fuel will be stockpiled due to limited winter access along the Arctic Gas route. This increases the expectation of large spills along the route.

There are 24 camps proposed for the Arctic Gas route in Canada (CAGPL 1974, 1976). Disposal of camp wastewater could potentially affect 12 creeks, 7 rivers plus the Mackenzie River in 13 locations, and 2 channels of the Mackenzie Delta. Effects of wastewater on the Mackenzie River will be insignificant due to large dilution values. The 12 creeks will be potentially most affected due to lower flows. The effects on water quality due to wastewater disposal will be the same as discussed for the Alaska

Highway route. Despite the fact that Arctic Gas construction will be in winter, camp effluent will likely be discharged in the summer since treated effluent will be stored in lagoons (CAGPL 1974). This will eliminate the problems associated with winter discharge such as low flows and lack of reaeration due to ice cover.

A methanol-water testing fluid is proposed for permafrost areas and heated water is proposed in non-permafrost areas during winter pipeline testing (CAGPL 1974). The water-methanol solution is expected to be used as far south as Fort Simpson, that is, on approximately 80 percent of the route. This solution could contain as much as 26 percent methanol by volume (CAGPL 1974). An accidental spill of this solution into a watercourse could be extremely detrimental to aquatic life. McMahon and Cartier (1974) found that "neither char no grayling fry can tolerate exposure to greater than 1 percent methanol for 24 hours and that concentrations of over 2.5 percent are lethal in a much shorter time". They also found that a 24-hour exposure to one percent methanol will damage fish eggs. Before final disposal, the test solution will be reduced in strength to less than one percent methanol by volume using either dilution or continuous distillation (CAGPL 1974). The effects of final disposal should be minor if there is adequate dilution in the receiving stream.

There is no information currently available on landfill locations or extent of use. Effects on water quality due to landfill operations will be due to leachate.

These effects will be the same as discussed for the Alaska Highway route. Regionally, the effect on water quality due to landfill sites will not be significant.

Comparison Summary

The number of site specific impacts related to accidental spills of toxic materials is compared on a basis of total planned stockpile sites. The Alaska Highway route is preferred on this basis (12 sites vs 19 sites). The toxicity of substances used on both routes is assumed to be similar. A great deal of the material along the Arctic Gas route will be barged to stockpile sites. There is potential for spills in watercourses during the barge-to-shore transfer of such substances as fuels and oils. The Alaska Highway route is preferred in this regard, since material for this route will be trucked in, and transfer of fuels and oils will not occur directly on watercourses. The Alaska Highway route is preferred in terms of the magnitude of spills of such substances as fuels and oils. It is necessary to stockpile large quantities of materials along the Arctic Gas route, whereas, most stockpile sites along the Alaska Highway route can be supplied year-round by the Alaska Highway, and volumes stored should therefore be smaller.

There is significant preference for the Alaska Highway route in terms of the potential effects of toxic spills on wildlife. The Arctic Gas route has very sensitive wildlife regions along the Beaufort Sea coast and in the Mackenzie Delta. Birds and mammals in these regions will also be affected by barge traffic needed to transport material. Site specific impacts due to wastewater disposal are compared in terms of the planned number of construction camps. The Alaska Highway route is preferred in terms of the number of planned construction camps (6 camps vs 24 camps). At peak construction, camps for both routes will be similar size and used for approximately the same length of time. The volumes and strength of camp wastewater are expected to be similar for both routes.

Potential thermal pollution on both routes due to disposal of heated testing fluids can be eliminated by cooling to ambient stream temperatures prior to disposal. Both routes are therefore equally preferred in terms of thermal pollution effects. A methanol-water solution is proposed for the Arctic Gas route. There is a possibility during testing the first 160 km of the Alaska Highway route that it may be necessary to use a methanol-water solution. In terms of toxic effects due to methanol spills and unsupervised disposal, the Alaska Highway route is preferred for two reasons. The first reason is that the use of a methanol-water test solution is a certainty along the Arctic Gas route, but is only a possibility for the Alaska Highway route. The second reason the Alaska Highway route is preferred is that the potential length over which the methanol-water solution may be used is greater along the Arctic Gas route (1365 km vs 160 km).

There may be some local problems due to the use of landfill sites and these will require site specific investigation. Regional problems, however, are not expected to be significant for either route. In terms of effects of landfill sites on water quality there is equal preference for both routes.

Based on the impacts on water quality, the Alaska Highway route is the preferred route with a preference rating of 5 and the relative rating for the Arctic Gas route is 2.

GROUNDWATER

Problem Definition

Construction of a chilled northern gas pipeline can induce changes in the groundwater regime during construction by seepage of spilled fuels and toxic substances and during operation by interferring with subsurface flow. Although groundwater changes in quality can be persistent and affect potential use, the impact on present users of the groundwater resource is considered more serious. Thus, comparison of alternate routes during construction will be based on potential to affect existing use of groundwater supplies.

For operation, comparison of alternate routes will be based on their potential to interfere with existing subsurface drainage. Little interference is expected from a buried pipeline in non-permafrost areas. In continuous permafrost with an active layer depth of about 30 cm (1 foot) (How and Hernandez 1975; and Kerfoot 1972) the effect of a buried chilled pipeline is expected to be minimal. The greatest interference with subsurface flow is anticipated in discontinuous permafrost where shallow groundwater flow is common and considerable summer flow occurs within the active layer. Where permafrost is absent it is assumed there is no potential for groundwater interference. Therefore, the percentage of line length within permafrost is used as the basis of comparison for operation.

The comparison of routes is discussed using the criteria of severity of impact (duration, magnitude, and scheduling) number of site specific conflicts possibility of conflicts mitigability, and access.

Potential Impact

Alaska Highway Route:

Several communities are susceptible to disruption of local water supply by polluted groundwater during the construction period. Those downslope of the pipeline right-of-way or near fuel storage dumps or storage areas of toxic materials are particularly susceptible. Yukon communities downslope of the proposed pipeline route known to utilize groundwater include Destruction Bay, M'Clintock, Johnsons Crossing, Morley River within 0.75 km, and Teslin within 1.5 km. Other areas of potential impact include Beaver Creek, Burwash Flats, Burwash Landing, Porter Creek, McRae, M'Clintock, Marsh Lake, Teslin Lake, Swift River, and a campsite on Big Creek. Groundwater at the historic site of Silver Creek could also be affected (Adam and Permut 1977).

If chilling occurs during operation as originally proposed within the northern Yukon, subsurface drainage disruption will be a potential problem only in the most northerly 66 km. Drainage disruption problems could potentially occur in 24 percent of these 66 km - a length of nearly 16 km.

Arctic Gas Route:

During construction, several communities have potential to have their groundwater affected by pollution, but it is unknown if they utilize this resource. Use is anticipated to be small because of permafrost. In the Yukon, Komakuk is downslope within 1-3 km of the pipeline. In the Northwest Territories, Ft. Good Hope is downslope within 3 km or so as is Norman Wells and Wrigley. Little Chicago and Ft. Norman are more than 5 km away from the pipeline. The only storage area close to a community is at Norman Wells, where it is located downstream of the town and would have virtually no potential to affect the groundwater resource (Environment Protection Board 1974).

During operation, the potential subsurface drainage disruption problem is not serious across the Yukon and around the Delta because of a thin active layer. However, within the Mackenzie Valley the potential for subsurface drainage disruption is substantial. For instance, within a length of 1110 km between Ft. McPherson to 60^{o}N, 595 km are estimated to be permafrost affected. Subsurface drainage disruption can deplete wetlands, contribute to icings, concentrate surface flow and change vegetation patterns.

Comparison Summary

The Alaska Highway route has more potential to affect groundwater users during construction, but the Arctic

Gas route has the greatest potential for subsurface drainage disruption during operation.

During construction, the severity of impact on each route would be about the same if a spill of fuel or toxic substance occurred upslope of a community. Alaska Highway route has the majority of potential site specific impacts (16 as compared to 6 for Arctic Gas). Assuming the occurrence of a spill is a random event, the probability of a conflict with groundwater users is also greater on the Alaska Highway route. Since mitigation of a spill might include excavation of contaminated areas, the Alaska Highway route would be preferred because of the lesser effects of disturbance in areas of less excess ice. Access to undertake mitigation would be best on the Alaska Highway route, although the proximity of this impact to communities could reduce the advantage since airstrips are available at all potentially affected communities on the Arctic Gas route. Overall, however, during construction, the Arctic Gas route is substantially preferred over the Alaska Highway route on the basis of potential groundwater pollution.

During operation, subsurface drainage disruption could potentially occur on at least 595 km of the Arctic Gas route, and on 16 km of the Alaska Highway route. The site-specific severity of subsurface drainage disruption is assumed to be about equal for each route if it occurred. The number of specific sites where conflicts could occur are more on Arctic Gas than on the Alaska Highway route mainly because of the 7-8 fold extra length of chilling. The probability of conflicts per unit length of chilling would be the same, so the Alaska Highway route is favored. Mitigability of subsurface drainage disruption problems can be assumed the same on both lines. But ease of access to mitigate drainage disruption problems is far greater along the Alaska Highway route than along the Arctic Gas route. Thus, overall during the operation phase the preference is substantially in favor of Alaska Highway route.

Duration of impact is an important aspect of comparison. However, in this case the construction impact (groundwater pollution) could linger well into the period of operation. Therefore, the duration of impacts are considered to be about the same in this case.

The advantage of the Arctic Gas route over the Alaska Highway route during construction is offset by the disadvantage during operation. Overall there is no preference for either route on the basis of groundwater and each route is given a preference rating of 5.

SURFACE-WATER REGIME

Problem Definition

Changes in the surface water regime of rivers and streams traversed by a northern pipeline can be induced in several ways including changes to their cross-sectional configuration, shifting of channels both vertically and horizontally, formation of icings induced by the cold pipe, and disruption of local drainage patterns particularly in relatively flat terrain. However, even in steep terrain surface drainage is often concentrated to facilitate water movement through mound breaks.

In permafrost areas settlement along the right-of-way may cause surface waters to be diverted along the pipeline right-of-way. Other changes to the surface water regime can occur at the time of river or stream crossing construction. Channelization or shifting of channels can occur either by man-made diversion or in response to other changes.

Borrow pits within the floodplain can initiate major changes in river regimes. The removal of borrow will create a tendency for the river slope to flatten downstream. Lateral erosion may occur to accomodate meandering and vertical erosion (downcutting) will occur near the borrow area. The initial local increase in gradient at the borrow area will gradually spread over the upstream length. This will also result in downcutting. The final result will depend on local geology (erosion resistant controls) but the tendency will be to return to its former slope although at a lower elevation (Howard 1974). This channel adjustment will entail movement of many cubic metres of material and cause deposition along its channel or its receiving waters.

Another major potential problem relates to the surface-water regime - cold pipe interaction and the possibility of icings developing at river crossings (How 1974). Not enough knowledge exists to predict the location or frequency of this problem. In general, the possibility of icings occurring will be greater in the continuous permafrost zone where springs supply a winter flow.

In this comparison the proposed routes are evaluated on the basis of the total number of drainages greater than 25 km^2 crossed, number of difficult river crossings, number of lakes potentially affected downstream of the right-of-way, potential for disruption of local drainage patterns, potential for regime change from borrow pits within floodplains and potential for icings.

Potential Impact

Alaska Highway Route:

Approximately 65 rivers and streams with drainages greater than 25 km^2 are crossed in the Yukon. In the Yukon River basin the major crossings are the White, Koidern, Donjek, Duke, Slims, Takhini, Yukon, M'Clintock, Teslin and

Swift Rivers plus Nisutlin Bay. In the Alsek River basin only the Aishihik River is considered major and in the Liard Basin within the Yukon only the three crossings of the Rancheria River are considered major.

Crossings range from those in the order of 50 to 100 m such as the Koidern, Takhini, Yukon, M'Clintock, Teslin, Swift, Aishihik, and Rancheria crossings and those in the order of 1 km or more (including floodplains) such as the White, Donjek, Duke and Slims Rivers and Nisutlin Bay. Over the Alaska Highway route 28 rivers and streams crossed have drainage areas over 250 km^2.

A total of 37 named lakes lie within a 30-km wide corridor centered over the proposed pipeline. The major lakes that could be affected are Kluane, Teslin, Marsh and Squanga Lakes. Kluane Lake is paralleled by the proposed pipeline within a relatively short distance for its full length of about 75 km while Teslin Lake is paralleled for about the same distance.

The potential for disruption of local drainage patterns will be greatest where melting of excess ice could occur. This potential exists south to MP 170. Even where chilling occurs, drainage disruption could occur on the outside of the right-of-way where chilling has no effect. Effectiveness of mound breaks over a chilled pipeline is questionable.

The removal of borrow from within the floodplains of rivers along the Alaska Highway route can be minimized because of the prevalence of granular material along the route and the provided access. Few rivers except the White, Donjek, Duke, Silver Creek, and Ibex show potential as borrow sites.

Icing potential is highest wherever chilling takes place. This is between MPs 0-40.8 on the Alaska Highway route. Minor icings elsewhere could occur because of man's activities that change either the hydraulic or thermal regime (Adam and Permut 1977).

Arctic Gas Route:

In the Yukon and Northwest Territories about 125 rivers and streams with drainages greater than 25 km^2 are crossed. Along the Arctic coast drainages greater than 250 km^2 to be crossed include the Malcolm, Firth, Roland, Crow, Trail, Babbage, and Blow Rivers; Rapid Creek; Fish, Willow, and Peel Rivers. In the Mackenzie Valley and down to 60^{o}N, 24 crossings inclusive of two Mackenzie River crossings are across drainages greater than 250 km^2. In total, 35 rivers and streams with drainage areas over 250 km^2 are crossed.

A total of 52 named lakes lie within a 30-km wide corridor centered over the proposed pipeline. No major lakes will be affected. As many as 13 small named lakes could possibly be affected. Many unnamed lakes could be affected.

Potential local drainage disruption problems exist over the majority of the route but particularly where chilling is required. Away from the effects of chilling on the outside of the right-of-way slight settlement could lead to channelization of surface flow and ponding. Facilitating cross-drainage may be difficult.

Borrow from within the floodplains of rivers is proposed for at least 17 sites along the Yukon coast and Mackenzie Delta (Environment Protection Board 1974). This is necessary because of lack of upland borrow sources in this area. Several rivers in the area have abundant supplies of granular material within their floodplains.

Icing potential along the Arctic coast and Mackenzie Valley is high. Low winter flow and freeze-off of the subsurface flow by the cold pipe will be conducive to this problem.

Comparison Summary

The Arctic Gas route crosses more drainages greater than 25 km^2 than the Alaska Highway (approx. 125 vs. 65). More large crossings are also required on the Arctic Gas route, most of them in the permafrost zone. No large crossings on the Alaska Highway route exist where chilling the gas is proposed.

More named lakes exist within a 30-km wide corridor on the Alaska Highway route than on the Arctic Gas route. Chances of lakes being affected appears higher on the Alaska Highway route, particularly Kluane and Teslin Lakes.

Potential for drainage disruption is greater on the Arctic Gas route than on the Alaska Highway route. Chilling to maintain stability of high-excess-ice-content soils is proposed over most of the Arctic Gas route within the Territories, whereas on the Alaska Highway route chilling is proposed only between MP 0-40.8.

Borrow sites from within floodplains are proposed on at least 17 rivers on the Arctic Gas route along the borrow-short northern Yukon coast and Delta. Apparent ample borrow sites and access from the Alaska Highway make the probability of having to locate borrow sites in floodplains remote on the Alaska Highway route.

Potential for formation of icings is much greater on the Arctic Gas route than on the Alaska Highway route. The much greater distance of chilling and the implications of more excess ice on the Arctic Gas route is the reason for preferring the Alaska Highway route on the basis of surface-water regime. Because of a larger number of stream crossings, more crossings within permafrost, borrow from within floodplains and the implications of excess ice and chilling to the surface-water regime, the Arctic Gas route is given a preference rating of 2 relative to the Alaska Highway route.

The Transmission of Prudhoe Bay Gas to American Markets: A Preliminary Environmental Comparison of the Canadian Arctic Gas Pipeline and the Foothills (Yukon) Pipeline in the Yukon and Northwest Territories

BACKGROUND DOCUMENTATION

AIR

CONTENTS

Permut, A.H. and K.M. Adam. 1977. Air. Pages 71 to 90 in Background documentation. Appendix to The transmission of Prudhoe Bay gas to American markets: A preliminary environmental comparison of the Canadian Arctic Gas pipeline and the Foothills (Yukon) pipeline in the Yukon and Northwest Territories. Alaska Highway Pipeline Panel, Winnipeg. 420 pp.

SUMMARY

Air quality and microclimate were the two parameters used to compare effects of the projects on air. Air quality effects were compared in terms of volume and rate of emissions and concentrations of carbon monoxide, sulphur oxides, nitrogen oxides, particulates, unburned hydrocarbons and odor. Effects on microclimate were compared in terms of ice fog formation.

During construction major sources of atmospheric contaminants that will affect air quality are construction and transportation equipment, landfill sites and incinerators. During operation major sources of air pollution will be compressor station operation, compressor station maintenance and pipeline ruptures. Major effect on microclimate will be from construction and transportation equipment and compressor station operation. The Alaska Highway route is slightly preferred in terms of effects on air quality with a preference rating of 5 compared to 4 on the Arctic Gas route (Table 1). The Alaska Highway route is the strongly preferred route in terms of potential effects on microclimate with a preference rating of 5 to 2. The Arctic Gas route will have greater impact on both microclimate and air quality than the Alaska Highway route. For microclimate this is because of colder climate, more winter construction, and a larger number of compressor stations emitting more water vapor. For air quality, this is because of a greater

Table 1. Summary of air comparison[a] for the Alaska Highway and Arctic Gas pipeline routes in Canada north of the 60th parallel.

	Relative Importance Weighting	Relative Preference[b]		Weighted Preference[c]	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
AIR COMPONENT					
Air Quality	12	5	4	60	48
Microclimate	11	5	2	55	22
Totals	23			115	70

[a] See Introduction and Approach for detailed discussion of Relative Importance Weightings and Relative Preference ratings.

[b] Relative Preference is based on a scale of 1-5, where the preferred route is assigned a value of 5.

[c] Weighted Preference = Relative Importance Weighting X Relative Preference.

number of compressor stations each emitting more atmospheric contaminants.

Overall, the Alaska Highway route is preferred over the Arctic Gas route in terms of impact on the air component by a preference ratio of 1.64.

AIR QUALITY

Problem Definition

Project effects will involve changes in concentrations of carbon monoxide (CO); sulphur oxides, primarily sulphur dioxide (SO_2); nitrogen oxides, primarily nitric oxide (NO), and nitrogen dioxide (NO_2); particulate matter; unburned hydrocarbons; and odor.

Meteorological conditions control, to a large extent, ground level concentrations of atmospheric contaminants. Inversion conditions limit the vertical mixing layer thereby causing an increase in ground level concentrations. Wind speeds control the extent of horizontal dispersion. Low wind speeds will contribute towards an increase in ground level concentrations near the source of air pollution emissions.

Potential sources of air pollution related to the pipeline projects are pipeline construction equipment, transportation vehicles, landfill sites and incinerators, compressor station operation and maintenance, and pipeline ruptures.

The two routes were compared on the basis of compressor station capacity for long-term maximum gas throughputs proposed by the applicants. These maximum values were used so the routes could be compared on a "worst case" basis .

Potential Impact

Alaska Highway Route:

Winter construction is expected between mileposts (MPs) 0-111.4. Dispersion due to wind will be poor during the winter months since approximately 26 percent of all winter hours are calm between MPs 0-111.4 (Environment Canada 1969-1975). Based on data from 4 stations along the entire route the mean annual occurrence of calm is 23 percent of all hours. The mean annual wind speed along the route based on data from 4 stations is 9.2 km/h (Environment Canada 1969-1975).

Inversions limit the dispersion of atmospheric contaminants. Based on limited data at Whitehorse and Fort Nelson only, surface-based temperature inversions occur along the Alaska Highway route an annual mean of 39 percent of the time based on two daily readings (Burns 1973).

There will be some burning of non-merchantable timber from clearing operations (Foothills 1976). The major emissions from open burning will be CO, particulates and hydrocarbons. Regionally, changes to air quality due to open burning will not be significant.

The major sources of air pollution from landfill sites are odor, gas production and dust (American Society of Civil Engineers 1976). Regionally, the effects on air quality due to landfill sites are not expected to be significant.

Incineration of solid waste will produce the following emissions: particulates, hydrogen chloride, nitrogen oxides, sulphur oxides, and organic acids (Williamson 1973). The impact on air quality along the pipeline route due to incinerators will not be significant.

Based on the expanded throughput capabilities, there are 13 compressor stations proposed for the Yukon portion of the Alaska Highway route. One of these stations will be 43.27 MW (58,000 hp) with a 1.9 MJ/h gas heater (180 MMBTU/h); 2 stations will be 43.27 MW (58,000 hp); and 10 stations will be 21.63 MW (29,000 hp) (Foothills 1977). When the pipeline capacity is fully developed, these stations will continually emit nitrogen oxides, CO, sulphur oxides, hydrocarbons, and particulates (Federal Power Commission 1976). Ground level concentrations will depend on wind dispersion and the occurrence of inversions. There may be some local problems due to compressor station operation. Routine maintenance can lead to the emission of unburned hydrocarbons during start-up and shut-down of compressors. The effect of these hydrocarbons will be intermittent and should not be significant.

Pipeline ruptures have implications on air quality because of the fumigation of plants by gas and the possibility of fire. However, occurrence of ruptures would be rare and the overall implications to air quality would be small.

Arctic Gas Route:

Annual mean wind speed along the route based on data from 5 stations is 8.4 km/h (Environment Canada 1969-1975). The mean winter occurrence of calm along the route is 27 percent of all hours based on data from 3 stations. The mean annual occurrence of calm along the route is 18 percent of all hours.

Based on data at Inuvik and Norman Wells only, surface-based temperature inversions occur along the Arctic Gas route an annual mean of 41 percent of the time based on two daily readings (Burns 1973).

There will be some burning of nonmerchantable timber from clearing operations (CAGPL 1974). The major emissions from open burning will be CO, particulates and hydrocarbons. Regionally, changes to air quality due to open burning will not be significant.

The major sources of air pollution from landfill sites are odor, gas production and dust (American Society of Civil Engineers 1976). Incineration of solid waste will produce the following emissions: particulates, hydrogen chloride, nitrogen oxides, sulphur oxides, and organic acids (Williamson 1973). The impact on air quality along the Arctic Gas route due to landfill sites and incinerators will not be significant.

Based on possible expansion plans of Arctic Gas, there are 22 compressor stations proposed for the Arctic Gas route (excluding the Richards Island supply line). The proposed compressor stations are sized as follows: 16 stations will be 22.38 MW (30,000 hp) with 12.68 MW (17,000 hp) compressors for cooling; 1 station will be 22.38 MW (30,000 hp) with a 25.36 MW (34,000 hp) compressor for cooling; 2 stations will be 22.38 MW (30,000 hp) with no chilling; and 1 station will be 20.52 MW (27,500 hp) with no chilling (CAGPL 1976). Two additional stations (CA-06 and CA-07) are proposed for increased pumping capacity after the first 5 years of pipeline operation. It is expected these two stations will be 22.38 MW (30,000 hp) with 12.68 MW (17,000 hp) compressors for chilling. It may be necessary for Arctic Gas to increase compression in the Mackenzie Valley when throughput is increased after the first 5 years of operation. It is not known how large additional power requirements will be. These compressor stations will emit the same contaminants as the Alaska Highway stations. Emissions of unburned hydrocarbons due to routine maintenance will likely be the same as for the Alaska Highway route.

The implications of a pipeline rupture along the Arctic Gas route will be similar to those along the Alaska Highway route.

Comparison Summary

Potential site specific conflicts due to construction activities are likely to be proportional to length.

Based on this, the Alaska Highway route is preferred over the Arctic Gas route (825 km vs 1582 km). The severity of impact of construction activity on air quality is expected to be the same for both routes. The Arctic Gas route is the preferred route based on climatic influences on dispersion of atmospheric contaminants. Mean annual wind speeds and the occurrence of inversions appear to be similar for both routes based on limited data. The Arctic Gas route has less periods of calm than the Alaska Highway route (18 percent of all hours versus 23 percent of all hours respectively).

It was assumed for comparative purposes that the emission of atmospheric contaminants from compressor stations will be proportional to power requirements. The two routes were therefore compared on a basis of weighted mean power per station (including any heating and cooling requirements) times the number of stations per route. This methodology gives 30.68 MW per station times 13 stations for the Alaska Highway route, and 33.82 MW per station times 22 stations for the Arctic Gas route. The Alaska Highway route is preferred on this basis (399 MW to 744 MW).

It is difficult to arrive at a preference for either of the routes on the basis of air pollution due to rupture occurrence. The long-term effects on air quality due to pipeline ruptures will be small for both routes. The two routes are therefore given equal preference in terms of air pollution due to rupture occurrence.

Regional effects on air quality due to landfill sites and incinerators are not expected to be significant for either route.

Overall, in terms of effects on air quality, the Alaska Highway route is slightly preferred, with a preference rating of 5 to 4.

MICROCLIMATE

Problem Definition

The effect on microclimate due to the pipeline projects will primarily be an increase in formation of ice fog. Ice fog has, therefore, been selected to represent the effects of the projects on microclimate.

Ice fog is defined as a "reduction in visibility due to large concentrations of solid water particles suspended in air" (Csanady and Wigley 1973). A reduction in visibility affects the operation of transportation equipment, including aircraft, as well as the operation of other equipment such as construction equipment.

Ice fog can be measured in terms of frequency of occurrence and density or visibility reduction. Ice fog is caused by the emission of supersaturated water vapor at temperatures greater than 100°C into ambient air temperatures less than -30°C, and its effect is influenced by the amount of wind ventilation, occurrence of inversions and the volumes of water vapor emitted.

The two routes were evaluated on the basis of ice fog formation during the construction period resulting from the operations of transportation and construction equipment, and during the operation period resulting from the operation of compressor stations. The sizes and numbers of compressor stations are based on compressing requirements for long-term maximum gas throughputs proposed by the applicants. These maximum values were used so the routes could be compared on a "worst case" basis.

Potential Impact

Alaska Highway Route:

There is potential for intermittent, short-term increases in ice fog along the 825-km length of the Alaska Highway route.

The annual mean number of days that the mean minimum temperature is less than -30°C ranges from 32 days at Teslin to 71 days at Beaver Creek. The annual mean number of days that the mean minimum temperature is less than -30°C along the Alaska Highway route is 50 days based on data from 6 stations (Environment Canada 1969-1975).

Mean annual wind speed along the route ranges from 5.6 km/h at Snag to 12.9 km/h at Whitehorse. The mean annual wind speed along the Yukon portion of the route, based on data from 4 stations, is 9.2 km/h (Environment Canada 1969-1975).

Construction activities between mileposts (MPs) 0-111.4 are scheduled for the winter and will, therefore affect ice fog formation. The magnitude of impact cannot be estimated as neither the number and types of machines nor their rate of water vapor emissions is known. Conditions for increased ice fog are expected to occur between MPs 0-

111.4 a mean of 58 days per year. Due to the relatively small area affected at any given time, regional effects will not be significant.

Based on the expanded throughout capabilities, there are 13 compressor stations proposed for the Yukon portion of the Alaska Highway route. One of these stations will be 43.27 MW (58,000 hp) with a 1.9 MJ/h gas heater (180 MMBTU/h); 2 stations will be 43.27 MW (58,000 hp), and 10 stations will be 21.63 MW (29,000 hp) (Foothills 1977). The 43.27 MW compressors will each emit water vapor at a rate of approximately 16,370 kg/h. The 21.63 MW compressors will emit water vapor at a rate of approximately 8180 kg/h. The 1.9 MJ/h heater will emit water vapor at a rate of about 0.20 kg/h. These water vapor emission rates were linearly extrapolated from the rate of 7480 kg/h for a 19.77 MW (26,500 hp) station (Federal Power Commission 1976). Any time meteorological conditions are conducive to formation of ice fog, operation of these compressor stations will contribute to ice fog formation. The extent of change on microclimate due to the operation phase is dependent on winds that provide horizontal mixing and effects of temperature inversions that reduce the depth of the vertical mixing layer. The change to ice fog is also difficult to predict since there is no apparent method to convert water vapor emissions to fog density. The annual mean number of days that the intensity of ice fog may be affected by compressor station operation is 50 days averaged along the Alaska Highway route.

Visibility reduction resulting from ice fog formation due to operation of compressor station FY-7A will be of little consequence. Ice fog formation resulting from operation of stations FY-1A through FY-5A and FY-9A through FY-13A may create hazardous conditions along the Alaska Highway due to intermittent visibility reductions.

Arctic Gas Route:

There is potential for intermittent, short term increases in ice fog along the entire 1582-km length of the Arctic Gas route.

The mean annual days the mean minimum temperature is less than $-30^{\circ}C$ ranges from approximately 69 days near Norman Wells to 91 days near Inuvik. The mean annual days the mean maximum temperature is less than $-30^{\circ}C$ along the entire route is 82 days based on data from 3 stations (Environment Canada 1969-1975).

Mean annual wind speeds along the route range from 7.2 km/h at Inuvik to 10.6 km/h at Norman Wells. The mean annual wind speed along the entire route based on data from 5 stations (Environment Canada 1969-1975) is 8.4 km/h.

It is expected that the entire Arctic Gas route will be built in the winter. Construction activities along the entire route will therefore affect ice fog formation an annual mean of 82 days along the route. The magnitude of impact cannot be estimated as neither the number and types of machines nor their rate of water vapor emissions are known. Due to the relatively small area affected at any given time regional effects will not be significant.

Based on possible expansion plans of Arctic Gas, there are 22 compressor stations proposed for the Arctic Gas route (excluding the Richards Island supply line). The proposed compressor stations are sized as follows: 16 stations will be 22.38 MW (30,000 hp) with 12.68 MW (17,000 hp) compressors for cooling; 1 station will be 22.38 MW (30,000 hp) with a 25.36 MW (34,000 hp) compressor for cooling; 2 stations will be 22.38 MW (30,000 hp) with no chilling; and 1 station will be 20.52 MW (27,500 hp) with no chilling (CAGPL 1976). Two additional stations (CA-06 and CA-07) are proposed for increased pumping capacity after the first 5 years of pipeline operation. It is expected these two stations will be 22.38 MW (30,000 hp) with 12.68 MW (17,000 hp) compressors for chilling. It may be necessary for Arctic Gas to add compressor stations in the Mackenzie Valley when throughput is increased after the first 5 years of operation. It is not known how large additional power requirements will be. The proposed compressor stations will emit 22,700 l of water vapor per hour (CAGPL 1974). This converts to 22,700 kg/h of water vapor. This rate of water vapor emission is considerably greater than the values for Alaska Highway compressor stations of similar size. There is no apparent explanation for this discrepancy. The operation of these compressor stations will contribute to ice fog formation a mean annual of 82 days along the route.

Visibility reduction resulting from ice fog formation due to operation of compressor stations CA-10, M-12 and ME-15 will be of little consequence. Ice fog resulting from the operation of compressor stations CA-05, CA-06, CA-07, CA-08, CA-09, M-03, M-04, M-05, M-11, ME-14, ME-17, and ME-18, may affect visibility at proposed airfields at these stations. This visibility reduction may create hazardous conditions. Ice fog resulting from the operation of compressor stations M-04 through M-11, and ME-13, may affect visibility along the proposed Mackenzie Highway. Ice fog resulting from the operation of station ME-16 may affect visibility along the existing Mackenzie Highway and may create hazardous driving conditions.

Comparison Summary

Dispersion due to wind is essentially the same along both routes. The emissions of water vapor from construction machines are assumed to be equal for both routes. In the comparison of construction effects, the annual number of days when the mean minimum temperature drops below $-30^{o}C$ was considered in conjunction with the number of kilometres wherein winter construction is expected to take place. This ice fog potential works out to 1.044×10^4 kilometre-days for the Alaska Highway route and 1.304×10^5 kilometre-days for the Arctic Gas route. The Alaska Highway route is therefore preferred in terms of construction effects.

Site specific conflicts due to ice fog from compressor stations were compared on the basis of potential visibility reductions having a significant effect. That is, the potential visibility reductions were considered significant when they may affect settlements, highways, or airfields. It is expected there will be site specific conflicts resulting from the operation of 10 compressor stations along the Alaska Highway route, and 19 stations along the Arctic Gas route. The magnitude of impact was compared on the basis of the average number of days when the mean minimum temperature was less than $-30^{o}C$ along the route. There were 50 such days along the Alaska Highway route and 82 along the Arctic Gas route. Dispersion due to wind was found to be essentially the same for both routes. The mean rate of emission of water vapor by compressor stations was found to be 10,070 kg/h per compressor station along the Alaska Highway route, and 22,700 kg/h per compressor station along the Arctic Gas route.

The Alaska Highway route is the strongly preferred route in terms of impact on microclimate with a preference rating of 5 to 2.

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The Transmission of Prudhoe Bay Gas to American Markets: A Preliminary Environmental Comparison of the Canadian Arctic Gas Pipeline and the Foothills (Yukon) Pipeline in the Yukon and Northwest Territories

BACKGROUND DOCUMENTATION

MAMMALS

CONTENTS

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SUMMARY

Eleven mammalian species (barren-ground caribou, Dall's sheep, grizzly bear, polar bear, woodland caribou, moose, wolverine, gray wolf, arctic fox and aquatic fur-bearers) were selected to compare the relative preference of the proposed Alaska Highway and Arctic Gas pipeline projects in the Yukon and Northwest Territories. Species selection and relative importance rankings were based on population status and distribution, sensitivity and adaptability to disturbance, and value to man. Route preference ratings for each species were based on potential severity of anticipated conflicts and relative effectiveness of controls and mitigative measures.

Barren-ground caribou do not occur along the Alaska Highway route and it is overwhelmingly preferred to the Arctic Gas route as far as they are concerned (Table 1). Low-flying aircraft during both construction and operation may disturb caribou primarily during calving and post-calving aggregations. The effects of anticipated increases in hunting pressure and direct mortality during the construction phase on long-term population trends of the Porcupine herd are unknown. A properly constructed and maintained right-of-way should not be an impediment to caribou movements and habitat loss should be minor barring construction-related fires in winter range. Although impact of the proposed Arctic Gas project and ancillary developments on the Porcupine herd of barren-ground caribou could be potentially

Table 1. Summary of mammal comparison[a] for the Alaska Highway and Arctic Gas pipeline routes in Canada north of the 60th parallel.

	Relative Importance Weighting	Relative Preference[b]		Weighted Preference[c]	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
Barren-ground caribou	39	5	1	195	39
Dall's sheep	25	2	5	50	125
Grizzly bear	20	5	4	100	80
Polar bear	18	5	4	90	72
Woodland caribou	13	5	4	65	52
Moose	8	5	4	40	32
Wolverine	7	5	5	35	35
Gray Wolf	7	5	4	35	28
Arctic fox	3	5	4	15	12
Aquatic furbearers	2	5	3	10	6
Totals	142			635	481

[a] See Introduction and Approach for detailed discussion of Relative Importance Weightings and Relative Preference ratings.

[b] Relative Preference is based on a scale of 1-5, where the preferred route is assigned a value of 5.

[c] Weighted Preference = Relative Importance Weighting X Relative Preference.

catastrophic, enforcement of stringent controls and mitigative measures may ensure that there will be no serious, long-term, directly project-related effects on this herd.

The Arctic Gas project is strongly preferred as far as Dall's sheep are concerned. There is little potential for disturbance of sheep along the 40 km where this route is adjacent to sheep range, whereas the Alaska Highway project has the potential to seriously disturb them on the approximately 400 km of Dall's sheep range it parallels. Enforcement of stringent controls on timing and route selection can reduce most construction-related disturbance. Long-term effects will be restricted to local disturbance around three proposed compressor stations. Increased sport-hunting demand, expected primarily during the construction period, is manageable in the southern Yukon. Increased sheep hunting by Natives to supply any market for sheep products created by project-related personnel may be a problem along both routes.

Neither route was considered preferable with respect to grizzly bears. Disturbance of denning areas or denned bears will be infrequent on either route. Summer construction of the Alaska Highway project increases potential for problems with bears at camps, although the magnitude of this problem should be lessened by the smaller size of the southern Yukon grizzly bear population and by adoption of suitable controls. The potential for harassment of bears by aircraft is greater on the Arctic Gas route. Less information for harvest management is available and enforcement of restrictions is less feasible at least in the northern Yukon, balancing the more depleted grizzly bear populations of the southern Yukon. The barren-ground grizzly occurring along the Arctic Gas route has been classified as of indeterminate status.

Polar bears occur only along the Arctic Gas route and impacts here are expected to be minor. Increased demand for polar bear skins may stimulate illegal harvest. Conflicts with dens and foraging male bears in winter and females with young after emergence in spring are unlikely. Small bear populations and a low reproductive potential make any increase in polar bear mortality important to long-term population levels on the Yukon coast.

The Alaska Highway route is slightly preferred with reference to woodland caribou. Summer construction of the Alaska Highway project will minimize disturbance of caribou during critical periods, whereas disturbance in winter by the Arctic Gas project is highly likely. About 150 and 1100 km of caribou range are crossed by the Alaska Highway and Arctic Gas projects, respectively. Woodland caribou populations in the southern Yukon are smaller than along the Arctic Gas route and increased mortality from any source will be more significant here.

The Alaska Highway project is slightly preferable insofar as moose are concerned. Summer construction will minimize disturbance of moose on critical ranges along much of this route, whereas winter disturbance is expected along much of the Arctic Gas route. Fire is more likely to destroy winter ranges along the Alaska Highway route as well as create new moose ranges for the future. Disturbance of moose on critical winter ranges and temporary interruptions of seasonal movements to Mackenzie River islands and possibly along the Yukon coast may occur during construction of the Arctic Gas project.

Neither route is preferable as far as wolverine are concerned, and the Alaska Highway route is preferable with reference to wolves. The summer construction schedule and low populations decrease the probability of problems with these species at camps and dumps along the Alaska Highway route. The opposite situation will increase potential for such conflicts on the Arctic Gas route. Effects on denning will be minor on both routes. Increased demand for the fur of both species is expected along both routes, although the effects may be more significant in the southern Yukon where wolf and wolverine population levels are believed to be lower on the Arctic Gas route. More data for management of these species are believed to be available for the southern Yukon relative at least to the northern Yukon. Aerial harassment will be potentially more serious on the Yukon coast sections of the Arctic Gas route.

Arctic foxes occur only on the Arctic Gas route. No major changes affecting arctic foxes are expected due to the Arctic Gas project. Destruction of denning habitat is a potential problem although preconstruction surveys can prevent serious conflicts. Garbage attracts foxes to camps and increases the potential for human exposure to rabies, although problems with garbage are readily mitigable. Long-term effects of any increased trapping near dumps or disturbance by aircraft and construction activities are not expected.

The Alaska Highway route is preferable with reference to aquatic furbearers. Potential for increased siltation of furbearer habitat is greater on the Arctic Gas route because of the wider distribution of ice-rich soils. Chilling increases potential disruption of surface drainage over a much greater distance on the Arctic Gas route. Modification of water levels in small streams and lakes in fall and winter will be potentially greater on the Arctic Gas route due to winter construction and in-stream gravel removal. Mitigation of these effects is relatively difficult. Although controls can greatly reduce the potential for fuel spills on either route, fuel transportation by barge and the need to store larger volumes of fuel increase the potential for serious spills on the Arctic Gas project.

The comparison indicates that the Alaska Highway project is considered somewhat less likely to cause unmitigable impact to mammals than the Arctic Gas project, and is therefore preferable. Three vulnerable species, the barren-ground caribou, polar bear and arctic fox, are unique to the Arctic Gas route. The data base for management and the infrastructure for dealing with increased wildlife-human conflicts are less adequate in the northern Yukon sections of the Arctic Gas route than along the Alaska Highway route in the southern Yukon. This will compensate somewhat for the generally reduced status of wildlife populations along the Alaska Highway route. Winter construction will increase conflicts with woodland caribou and moose on the Arctic Gas route and Dall's sheep on the Alaska Highway route. These factors all tend to decrease mitigability of impact due to the Arctic Gas project and to increase the likelihood of unexpected conflicts. By far the most serious long-term effect of inadequately controlled and mitigated disturbance, habitat loss and mortality would be on the Porcupine herd of barren-ground caribou. It is because of this potential for destruction of one of the last great caribou herds in North America by the Arctic Gas project and possible associated future developments that the Alaska Highway project is recommended insofar as the mammals are concerned.

INTRODUCTION

The Arctic Gas and Alaska Highway pipeline projects propose to transport natural gas from Prudhoe Bay, Alaska to southern markets through or close to extensive tracts of relatively undeveloped territory. Numerous species, comprising typical nearctic mammalian fauna at these latitudes, are distributed along each alignment (Kucera 1974, Mutch 1977). Eleven mammalian species were selected as parameters on which to evaluate comparative impacts on mammals. This selection was based on literature reviews of species' population status and distribution, susceptibility to disturbance, ability to recover following disturbance, and special importance to man. The selected species, in decreasing relative importance, are: barren-ground caribou, Dall's sheep, grizzly bear, polar bear, woodland caribou, moose, wolverine, gray wolf, arctic fox and aquatic furbearers (beaver and muskrat).

Several criteria were used to evaluate impact: severity (duration, magnitude), likelihood of potential conflicts occurring, number of identifiable site-specific problems, and the relative effectiveness of mitigative measures to reduce potential impacts. Preference ratings were assigned following procedures outlined in the approach section of this report.

Two basic indicators of change, habitat loss and increased mortality, were used. Loss of habitat integrity is a major factor contributing to declines in a mammalian species' long-term welfare in a particular region. Habitat loss can result from either physical destruction or range evacuation as a result of disturbance. Denning areas are particularly prone to destruction. Destruction of ungulate range and aquatic furbearer habitat is generally shorter-term as these areas tend to regenerate through natural processes and to be reoccupied by the original species if other conditions are suitable. Range evacuation, resulting from human disturbance, generally involves short-term habitat loss. Special attention must be given, however, to critical areas such as winter range, calving, lambing or denning areas, rutting grounds, or traditional seasonal migration routes. Relatively short-term disturbances in such areas may have profound, long-term implications for the wildlife population concerned.

A second indicator of deleterious project-related effects is increased mortality. Collisions with vehicles, falling into trenches and injuries as a result of rapid flight may increase direct mortality. Increased demand for harvest of desirable trophy species is expected to result from influxes of project-related staff and visitors and increased publicity surrounding northern frontier areas. This is particularly significant if the wildlife populations concerned are easily taken or already depleted. Repeated disturbance of unhabituated mammals particularly in winter may hasten exhaustion of critical energy reserves, potentially increasing mortality and decreasing birth rates. Serious repetitive disturbance may occur for short intervals where construction occurs in critical seasonal ranges, but is improbable during the operational phase.

BARREN-GROUND CARIBOU (*Rangifer tarandus granti*)

Problem Definition

The Porcupine herd of 90,000 to 110,000 caribou occupies a 220,000 km^2 range primarily in the northern Yukon and northeastern Alaska (Calef and Lortie 1973, Calef 1974). Historically, caribou population declines have followed significant human involvement in an area, due mainly to increased hunting and range destruction, particularly by fire (Bergerud 1974a, Lent 1975). Caribou are sensitive to some human-related disturbance. McCourt et al. (1974) documented minor reactions by caribou to simulated compressor station noise. Low-altitude aircraft produce strong reactions generally decreasing as altitude increases to 300 m (Calef and Lortie 1973, McCourt and Horstman 1974, McCourt et al. 1974, Jakimchuk et al. 1974). Caribou under stress show a greater reaction to aircraft and other forms of disturbance, particularly on the calving grounds and during early winter (Calef et al. 1976). The calving and post-calving seasons may be the most critical periods for them (Bergerud 1976, Calef 1975). Cameron and Whitten (1976) believed construction of the Alyeska pipeline caused caribou to avoid the construction area while work was in progress. Caribou will habituate to many activities unless hunted or harrassed (Calef and Lortie 1973, Bergerud 1974b, McCourt et al. 1974, Calef 1975).

Long-term highway or rail traffic or other disturbances affecting migrations may effectively eliminate portions of previously used range (Espmark 1970, Klein 1971, Bergerud 1974b, Calef 1975, Lent 1975) and artificial barriers may deflect migrations (Miller et al. 1972, Child 1973, Jakimchuk et al. 1974, McCourt et al. 1974).

Caribou in large herds are easily hunted (Bergerud 1974a) although hunted individuals are more alert (Calef 1975). During the fly season caribou, particularly calves, are stressed and subject to stampedes (Calef and Lortie 1973). Stampedes cause injuries and separate calves and mothers (Calef and Lortie 1973, Bergerud 1974b), thus increasing mortality. Caribou regularly travel on roads, increasing probability of collisions with vehicles (Klein 1971, Bergerud 1974b, McCourt et al. 1974).

Potential Impact

Alaska Highway Route:

Sections of this route included in the comparison avoid the distribution of barren-ground caribou.

Arctic Gas Route:

Construction-related activities on the north coast may disturb caribou movements particularly in spring and possibly prevent usage of traditional calving areas and disrupt caribou social structure during calving and post-calving aggregations. Calving and post-calving aggregations along the north coast may be disturbed by low-flying aircraft. Calving coincides with maximum river flow and soil thaw on the Yukon coast, when aerial surveillance needs are greatest (Calef 1975). Construction will cause only minor disturbance of wintering caribou as the route avoids major winter ranges (Jakimchuk et al. 1974, McCourt et al. 1974). Research by McCourt et al. (1974) showed that caribou generally do not react strongly to compressor station noise.

The proposed project will not cause major increases in direct caribou mortality. Low-flying aircraft may initiate stampedes, particularly during fly season on the Yukon coast. Hunting in or from construction camps is not expected, and the creation of new access can be controlled if pipeline facilities are built from snow roads and closed to the public. Publicity surrounding the project and the influx of project-related personnel are expected to increase demand for caribou-hunting privileges (Sprecker 1975, Speller 1976, Lent 1976). The Dempster Highway currently allows hunter access to some caribou migrations and winter ranges (Jakimchuk et al. 1974, Mossop 1976), and sport-hunter success rates are high (Lortie 1974). Residents of northern communities harvest at least 2000 to 5000 caribou annually (Monaghan personal communication to CAGPL 1974).

Information on maximum sustainable harvest from this population is not available, and the herd's capability to withstand increased harvest is unknown.

Habitat destruction as a direct result of the project will be insignificant. Irregular topography, vegetation patterns and winter construction all decrease the potential for habitat loss due to fire. Hernandez (1974) concluded that although numbers of reported fires may increase as a result of the project, the area burned probably would not.

Comparison Summary

Because barren-ground caribou do not occur on the Alaska Highway route, it is preferred insofar as barren-ground caribou are concerned and is assigned a preference rating of 5.

The Porcupine caribou herd may experience significant disturbance along certain sections of the proposed Arctic Gas alignment. Routine survey and maintenance is expected to involve aircraft flights over caribou calving grounds and during post-calving aggregations. Such disturbances may cause stampedes and the separation of calves and dams and, if repeated irregularly, behavioral abnormalities (Geist 1971b,1971c). Most such disturbance can be avoided, however, although control of low-flying aircraft is often difficult. A buried pipeline on a properly maintained right-of-way will create minimum impediments to caribou movement along the right-of-way.

There may be an increased demand for caribou-hunting privileges as a result of the project. Increased hunting is difficult to monitor and control in remote areas. There are insufficient data to predict the effects of any increase in harvest rates together with increased direct mortality on the long-term population trends of this herd.

Impact on the Porcupine caribou herd will ultimately depend on the effectiveness and enforcement of mitigative measures and controls. Calef (1974) concluded that with proper controls caribou populations will not decline as a direct result of the proposed Arctic Gas project. Without adequate safeguards, however, he suggested that the population could decline by as much as 90 percent in 5 to 10 years. Possibly future developments stimulated by the Arctic Gas project in the Porcupine herd's range may pose a considerable threat to the future of this herd.

Based on these considerations the Arctic Gas route was assigned a preference rating of 1 relative to the Alaska Highway route.

DALL'S SHEEP (*Ovis dalli*)

Problem Definition

Dall's sheep annually occupy up to six or seven seasonal home ranges joined by complex travel routes (Geist 1971a). In general, summer ranges are in alpine areas while lower, windswept ranges of frequently restricted area are critical in winter. Lambing (May-June), rutting (November-December) and mineral lick (May-August) ranges are also crucial. Range-use patterns develop ontogenetically and are a band tradition. Sheep do not readily colonize new habitat or former ranges (Geist 1971a).

Sheep which have not been habituated to the presence of humans are sensitive to disturbance, and human incursions may result in range abandonment. Influxes of temporary non-residents into northern areas tends to increase demand for hunting privileges (Sprecker 1975, Lent 1976, Speller 1976). Because many sheep populations are small, and there is no unexploited habitat close to a sheep population under natural conditions (Geist 1971a), any increased mortality or range loss could result in elimination of a population (Geist 1971c, 1975, Dunaway 1971, Hoefs 1975, Mossop 1976). Low-altitude aircraft, particularly helicopters, cause temporary range evacuation and changes in activity patterns (Price 1972, Lenarz 1974, McCourt et al. 1974). Sheep react to helicopters up to 1 km away although this reactivity decreases with increased distance (Price 1972, Reynolds 1974). Infrequent and unpredictable disturbances have the most serious effects, including energy reserve depletion and behavioral disruption (Geist 1971b, 1971c, 1975).

Potential Impact

Alaska Highway Route:

Dall's sheep are found in most alpine areas near the route (Lands Directorate 1973, Foothills 1976b). Several winter ranges are within 5 km of the proposed alignment, particularly at Mount Wallace and adjacent areas between pipeline mileposts (MPs) 135-150. Mount Ingram (MP 250) and the Ibex River valley (MPs 245-260) are an important summer and possibly winter range and travel route, respectively. Lambing, rutting and mineral lick sites are not adequately known in many areas. Sheep wintering near the right-of-way may be disturbed by route preparation and aircraft flights, particularly where the route diverges from the highway. Aircraft and blasting may also disrupt lambing.

Project-related disturbance is expected to cause sheep to withdraw from critical range areas, particularly winter range adjacent to the proposed alignment, during construction. Controls on timing of construction and related activities and on the route selected can prevent most such conflicts. Little habitat destruction is expected during construction. Range loss during operation is expected to be minor. Compressor stations FY-2 (MP 122.6), FY-3 (MP 209.5) and FY-4 (MP 260.8) may disturb sheep occupying adjacent areas during the operational phase.

Some sheep ranges will be made more accessible by the project, particularly in the Ibex River valley. Because Dall's sheep in the Yukon are hunted to a highly disproportionate extent by non-residents (Lortie 1974, 1975, 1976; M. Hoefs personal communication), influxes of pipeline-related personnel may considerably increase demand for hunting privileges. Similarly, disruptive wilderness-use activities may cause temporary habitat loss, potentially contributing to declines in sheep populations, especially if they occur in winter. Even small increases in mortality rates will cause further declines in depleted sheep populations.

Arctic Gas Route:

The only Dall's sheep population adjacent to the route comprises 400-600 sheep on Mount Goodenough, MPs 375-390 (Feist et al. 1974) where the lower slopes are within 1.5 km of the proposed route. Jakimchuk et al. (1974) reported that spruce forest at the base of the mountain was used as winter range. Feist et al. (1974) found little use of these lower slopes, however, indicating that project-related disturbance is unlikely. A small Dall's sheep population is also located near the Firth River about 25 km south of the proposed route (MP 240). In general, Dall's sheep populations and status throughout the area potentially affected by the project are not well known (Ruttan 1976). No compressor stations are planned near sheep ranges (CAGPL 1974) and aircraft are expected to avoid these mountainous areas. Borrow facilities are to be located at the base of Mount Goodenough. Habitat destruction is not expected during construction. No significant disturbance or range loss is foreseen during operation.

Increases in recreational use of sheep ranges are not expected. Only Natives are permitted to hunt sheep in the Richardson Mountains, with a known kill of 41, 22 and 33 sheep by Aklavik residents in 1969, 1970 and 1971 respectively (Jakimchuk et al. 1974). This apparently equals or exceeds recruitment and the sheep population is declining. Demand for trophies and souvenirs by pipeline-related personnel may stimulate this hunting by Natives. Such increases are not easily controlled.

Comparison Summary

The Arctic Gas route is preferred insofar as potential impact on Dall's sheep is concerned and is assigned a preference rating of 5. This route parallels sheep range for about 40 km. There is little apparent potential for disturbance even though these sheep are hunted and habituation to human presence probably would be very difficult. Compressor stations, construction equipment, borrow operations, and aircraft are not expected to significantly disturb sheep on the Arctic Gas route. While hunting of the

Mount Goodenough population is restricted to Natives, demand for salable trophies may stimulate increased sheep hunting. Institution and enforcement of regulations to control any such increases in harvest will be difficult.

The Alaska Highway route parallels sheep ranges for about 400 km and passes through or adjacent to sensitive sheep ranges. Construction equipment, compressor stations and small aircraft have the potential to disturb sheep on this route, although such disturbances are partially mitigable. This route follows an existing highway for much of its length, and sheep are expected to be somewhat habitatuated to these noises. New access to sheep ranges will be created in the Ibex River valley. Increased demand for sheep-hunting privileges is anticipated in all areas near the corridor where sheep hunting is permitted. Increased recreational use of wilderness areas may result in range abandonment. These problems are mitigated somewhat by the fact that information on which to base management decisions is available and controls on hunting and wilderness use are more easily effected along this route than along the Arctic Gas alignment.

On the basis of these considerations the Alaska Highway route has been assigned a preference rating of 2 relative to the Arctic Gas route.

GRIZZLY BEAR (*Ursus arctos*)

Problem Definition

Grizzly bear populations are susceptible to reduction where intensive human land use occurs (Pearson 1975). Human aversion to large predators means legal protection may not prevent extirpation of bears in remote areas (Macpherson 1965, Jonkel 1970a). Grizzlies can habituate to human presence if not hunted (Craighead and Craighead 1972, Pearson 1975). They are sensitive to low-flying aircraft (McCourt et al. 1974, Ruttan 1974a, Schweinsburg 1974a). In wilderness areas bears generally flee from humans although unexpected encounters may result in aggressive reactions (Herrero 1970, Mundy and Flook 1973).

Artificial food sources such as garbage attract bears from as far as 80 km in the Arctic (Hinman 1974), promoting intraspecific aggression and potentially serious threats to human safety made worse by feeding of bears (Stokes 1970, Cole 1972, Craighead and Craighead 1972). Bears without natural wariness of man are menaces and often must be destroyed or removed from the area (Herrero 1970, Cole 1972, Craighead and Craighead 1972, Hinman 1974).

Grizzly bears are desired as trophies, particularly by sports hunters not resident in northern regions (Lortie 1974, 1975, 1976). Influxes of temporary non-residents tend to increase demand for hunting privileges (Sprecker 1975, Lent 1976, Speller 1976). Reproductive potential of northern grizzlies is low (Jakimchuk et al. 1974, Doll et al. 1974, Curatolo and Moore 1974, Pearson 1975) and increased hunting may cause population declines (McIlroy 1972, Pearson 1975).

Disturbance of denned bears (October-April or May), or destruction of scarce denning habitat may drastically affect bear populations (Watson et al. 1973, Harding 1976). Long-term use of snow dens is rare (Ruttan 1974a, Harding 1976). Foraging areas are frequently in river valleys (Ruttan and Wooley 1974, Pearson 1975) and coastal areas (Pearson and Nagy 1976).

Potential Impact

Alaska Highway Route:

Grizzly bears occur mainly in mountainous areas along the route (Lands Directorate 1973, Foothills 1976b). Only small areas of prime foraging habitat on alluvial flats will be destroyed by the right-of-way. Disturbance of foraging bears should have an insignificant effect. Destruction of denning areas is not anticipated as these ranges are remote and inaccessible. Disturbance of bears by aircraft on alpine meadows and alluvial flats is expected to be infrequent.

Attraction of bears to construction camps and dumps in the Yukon is expected particularly if garbage-handling techniques are inadequate. Increased hunting demand is expected due to an influx of project-related personnel. The proposed route follows an existing transportation corridor in the Yukon, and no significant new access to grizzly habitat will be created. Long-term human involvement in the southern Yukon has substantially reduced bear populations there.

Arctic Gas Route:

Grizzly bears are concentrated in valleys and in association with caribou on the Yukon coast and adjacent British and Richardson Mountains in summer (Doll et al. 1974, Ruttan and Wooley 1974, Jakimchuk et al. 1974). They also occur throughout the Mackenzie Valley. Holloway (1970) classified the barren-ground grizzly as being of reduced but indeterminate status. Dens are restricted to stable, well-drained soils in the British and Richardson mountains (Jakimchuk et al. 1974) and were found in uplands well back from the Beaufort Sea on the Tuktoyaktuk Peninsula and Richards Island (Pearson and Nagy 1976, Harding 1976). Bears may den in river valleys on the Yukon coastal plain (A.M. Pearson, personal communication to Kucera 1974) although no den sites are known on or near the proposed right-of-way.

Grizzly bears may be a problem if garbage is available at summer camps and dumps. Increased mortality and harassment of bears are expected near such camps. In remote areas most bears are unaccustomed to man and a selective pressure for shyness has not been in effect for long (Kucera

1974, Krott and Krott 1962 cited by Kucera 1974). Access created by the project may open parts of the Mackenzie Valley to increased sport hunting demand, potentially reducing bear populations there.

Comparison Summary

Summer construction will increase the frequency of problems with bears at Alaska Highway route camps, although such conflicts can be controlled by fencing camps and incinerating garbage. Disturbance of denning areas and denned bears is unlikely. Small areas of lowland foraging habitat will be destroyed, primarily along braided streams. Winter construction will preclude disturbance of foraging bears along streams west of MP 110. Disturbance by aircraft will occur only on alluvial flats and alpine meadows. Increased demand for hunting privileges may result in further depletion of bear populations in the southern Yukon although bear-hunting seasons are restricted in some regions. These problems are mitigated somewhat in the southern Yukon by the fact that data on which to base similar restrictions in other areas are more available, and enforcement is more feasible than in the northern Yukon (Mossop 1976).

With reference to the Arctic Gas project, the proposed winter construction schedule will eliminate most problems with bears at camps. Although there are no known grizzly bear dens near the proposed right-of-way, den destruction and disturbance of denned bears could occur if such dens do in fact occur on or near the alignment and they are not found prior to the start of construction. The probability of such an event occurring is low. Disturbance by aircraft may be significant along the open Yukon coast where control may be difficult. Effects of increased sport-hunting demand may be serious particularly in open areas where bears are vulnerable, or where bear habitat has been made newly accessible, such as parts of the Mackenzie Valley. Shortages of management information, and difficulties in enforcing hunting restrictions make this problem potentially somewhat greater on the Arctic Gas route than on the Alaska Highway project.

Based on these considerations the Alaska Highway route is slightly preferred by a ratio of 5 to 4.

POLAR BEAR (*Ursus maritimus*)

Problem Definition

Polar bear populations have been severely reduced by over-hunting in once-secure circumpolar wilderness areas. By classification of the International Union for the Conservation of Nature and Natural Resources polar bears are "depleted" world wide (Holloway 1970) although populations in Canada are believed to be relatively secure. Natives hunt small numbers in the Beaufort Sea area (Smith and Jonkel 1975, Stirling et al. 1975).

Although adaptable to some forms of human contact, polar bears are sensitive to disturbance in established coastal or landfast-ice foraging zones (Jonkel and Kolenosky 1969 cited in Jonkel 1970b, Watson et al. 1973). Beaufort Sea bears summer on drifting pack ice and return to the mainland in September and October as this ice drifts to land. Pregnant females den in river valleys and near bluffs or slopes with deep snow, or on landfast ice (Lentfer 1972, Jonkel et al. 1972, Stirling et al. 1975, Moore and Quimby 1975). Heavy vehicle operation could disturb denning bears (Moore and Quimby 1975). If such disturbances caused den evacuation they would probably result in death of the young and could affect local population levels. Polar bear populations are small and the species has a very low reproductive potential (Banfield 1974b, Stirling et al. 1975).

Garbage and intentional feeding attracts foraging bears to winter camps, potentially resulting in increased intraspecific aggression, susceptibility to hunting, removal of dangerous animals, and threats to human safety (Jonkel 1970a, Schweinsburg 1974a).

Large-scale oil and fuel spills in Arctic waters may affect polar bears and their prey, particularly by causing bears to lose buoyancy and suffer from exposure (Lentfer 1972, Stirling 1976).

Potential Impacts

Alaska Highway Route:

Sections of this route included in the comparison avoid the distribution of polar bears.

Arctic Gas Route:

Polar bears occur along the Yukon coast in winter. Construction activities could disturb any bears denning near the route. Detection of occupied dens is very difficult in winter, and avoiding dens during construction is largely a matter of chance (Moore and Quimby 1975). The Alaskan and Yukon north coasts are not "core" polar bear denning areas and few bears are known to den there (Harington 1968, Moore and Quimby 1975, Stirling et al. 1975, Stirling 1976). Although Moore and Quimby (1975) suggested that the western

Beaufort Sea coast may be a significant reproductive denning area for a relatively discrete Beaufort Sea bear population, it is unlikely that the right-of-way will encounter polar bear dens.

Polar bears will investigate coastal garbage dumps and camps during winter if refuse is available or bears are fed. Nuisance animals may be shot or removed to another area. Investigation of man-polar bear conflicts has become a major task for Northwest Territories Fish and Wildlife officers in the Mackenzie Delta area (Simmons 1976). Demand for polar bear skins may increase due to the influx of highly-paid, pipeline-related personnel. This may contribute to increased poaching, potentially causing declines in bear populations, including those made more accessible by temporary project facilities during construction, and any which may have congregated near camps.

Increased barge traffic along the Yukon coast poses the threat of oil spills at sea and coastal staging areas. Such spills could render large areas uninhabitable for bears. No significant impacts on bears are expected in the operational phase.

Comparison Summary

Because polar bears do not occur on the Alaska Highway route, it is preferred insofar as polar bears are concerned and is assigned a preference rating of 5.

Encounters with polar bear dens are considered unlikely during winter construction on the Yukon coast. Inadequate data make the probability and long-term effects of such disturbances difficult to predict. Illegal polar bear hunting may occur in response to increased demand for polar bear pelts as a result of the project. These problems are difficult to mitigate. Removal of nuisance animals and possible intraspecific aggression at dumps may increase polar bear mortality and lead to threats to human safety. Low reproductive potential means that increased mortality may be reflected in lower polar bear populations in the Beaufort Sea for some time to come. Disturbance of foraging male bears along the coast in winter or of females following emergence from the dens in spring will not be critical. Future industrial development along the coast as a result of the proposed project may have long-term, deleterious effects on bear populations.

On the basis of these considerations the Arctic Gas route has been assigned a preference rating of 4 relative to the Alaska Highway route.

WOODLAND CARIBOU (*Rangifer tarandus caribou*)

Problem Definition

Woodland caribou population declines have followed human settlement in North America, due primarily to increased mortality and habitat loss (Bergerud 1974a, 1971). Woodland caribou are sensitive to human contact and flee when approached (Oosenbrug 1976), although motionless objects and familiar phenomena elicit little reaction from caribou (Bergerud 1974a, 1976). Although Bergerud (1976) reported that disturbance by hunting or aircraft during winter did not significantly alter natality, repeated disturbance or forced evacuation from critical winter ranges would be expected to hasten depletion of limited energy supplies and potentially decrease calf birth weights and survival potential (Geist 1971b, 1971c). If data from Calef and Lortie (1973), McCourt and Horstman (1974) and Calef et al. (1976) on barren-ground caribou can be extrapolated to woodland caribou in open areas, aircraft at less than 300 m altitude will cause significant disturbance. Woodland caribou seasonal migrations are often altitudinal and do not occur in massive aggregations. Barriers and human activity on the right-of-way may disrupt migration locally. At present woodland caribou are hunted by both sport and domestic hunters in the Mackenzie Valley and southern Yukon. Although data from the southern Yukon (Lortie 1974, 1975, 1976) indicate that caribou are not prime targets of non-resident sport hunters, influxes of temporary non-residents tends to result in a generally increased demand for sport-hunting privileges (Sprecker 1975, Lent 1976, Speller 1976).

Potential Impact

Alaska Highway Route:

Most mountainous areas adjacent to the route in the Yukon probably support small woodland caribou populations (Lands Directorate 1973, Foothills 1976b). Hoefs (1975) estimated woodland caribou populations in the Yukon at 10,000 to 20,000 although regional caribou distributions are unknown.

Habitat destruction by the project will be insignificant unless fire destroys winter range. Hernandez (1977) indicated that the project could increase the potential for major fires if construction occurred in a "bad" fire year. Disturbance will be temporary and insignificant unless caribou are forced from winter ranges. Winter construction is not scheduled in known caribou ranges, although route preparation may be undertaken in winter. Disturbance by aircraft will be limited to caribou on alpine meadows.

Pipeline-related increases in hunting demand are expected, although caribou are not prime targets of non-resident hunters and new access to caribou ranges will not be created. Given their very low recruitment (Oosenbrug 1976), however, any increase in mortality is critical to the integrity of woodland caribou populations in the southern Yukon.

Arctic Gas Route:

Widespread, low-density woodland caribou populations are found in the Mackenzie Valley (Watson et al. 1973, Ruttan and Wooley 1974, Ruttan 1976). Their range extends from Alberta to tree line east of the Mackenzie River and to Arctic Red River on the west. There are no known population concentrations near the right-of-way (Watson et al. 1973), although important year-round ranges will be crossed in the Redknife and Ebbutt Hills and near Travaillant Lake. Other herds are believed to be sparsely distributed along the pipeline corridor.

Project-related increases in hunting demand by non-residents are expected, as well as new access to caribou ranges along the corridor in the upper Mackenzie Valley.

Disturbance effects will be minimal unless caribou are forced from winter ranges. Protective cover should decrease effects of aircraft noise. Little disturbance is expected during operation. Habitat destruction will be insignificant in either phase unless project-related fire destroys winter range. Hernandez (1974) expected an increase in the number of fires but not in the area burned as a result of the project.

Comparison Summary

The Alaska Highway route is preferred insofar as woodland caribou are concerned and is assigned a preference rating of 5. Although the absolute increase in caribou hunting demand is expected to be small, any increase in hunting is important due to the small size and apparently reduced viability of caribou populations in the southern Yukon. However, some information on which to base management regulations is available and regulation of caribou hunting is potentially possible in the southern Yukon where caribou hunting is already prohibited in certain areas. The summer construction schedule will reduce the potential for winter disturbance in most areas to those effects which accompany route preparation. Identifiable conflicts may be mitigable by timing and alignment changes. Woodland caribou populations occur along about 150 km of the route. About one-half of these caribou ranges are adjacent to the Alaska Highway, and caribou in these areas may be somewhat habituated to disturbance accompanying aircraft and vehicular traffic. Habitat destruction along the right-of-way will not be critical unless project-related fire destroys winter ranges. The probability of such an event in a "bad" fire year is high.

Winter disturbance of woodland caribou is highly probable as a result of the winter construction schedule, and may be mitigable only by major timing changes. Little habituation to low-flying aircraft is anticipated to have occurred in most areas. Any interference with migration will be local. Scattered woodland caribou populations are believed to occur along about 1100 km of the route. Habitat destruction will be minor unless project-related fire destroys winter ranges, of which the probability is low. Effective caribou management may be more difficult on the proposed Arctic Gas alignment due to inadequate information and difficulties of enforcement, particularly in remote areas.

Based on these considerations the Arctic Gas route was assigned a preference rating of 4 relative to the Alaska Highway route.

MOOSE (*Alces alces*)

Problem Definition

Moose are commonly a species of disturbed areas, occupying primarily riparian and deciduous upland areas in winter and early spring, and wetlands and deciduous woodlands in summer and fall (des Meules 1964, Watson et al. 1973, Peek et al. 1976). Seasonal movements may be lateral or altitudinal (Edwards and Ritcey 1956, Goddard 1970). Winter range tends to be restricted by excessive snow, although availability of other seasonal ranges generally does not limit moose populations (Watson et al. 1973). Disruption of climax communities by fire or other agents often creates new moose habitat, although the short-term effects of winter range loss can be serious.

Moose tolerate many human activities (Geist 1963). McCourt et al. (1974) observed strong reactions to aircraft flying at under 60 m altitude but only a slight response to those flying at over 200 m altitude. Jakimchuk et al. (1974) suggested that moose are more easily disturbed by aircraft during late winter and in deep snow conditions, potentially exacerbating already-negative energy balances at these times (Geist 1971b, 1971c, Watson et al. 1973, Peek et al. 1976).

Moose are susceptible to hunting by humans (Geist 1963). Influxes of temporary non-residents frequently increase demand for hunting privileges (Sprecker 1975, Speller 1976, Lent 1976). Moose productivity and populations are lower in northern areas than in southern, increasing susceptibility to overhunting (Jakimchuk et al. 1974, Hoefs 1975). Geist (1971a) considered moose capable of colonizing new ranges but Goddard (1970) found that locally overhunted areas were not invaded by moose from nearby, unhunted regions. Moose are primarily unsociable and solitary except during and after the rut (Geist 1963, Houston 1974).

Potential Impact

Alaska Highway Route:

Moose occupy most wetland areas along the route (Lands Directorate 1973, Foothills 1976b). Data on regional populations and harvests are largely unavailable.

Disturbance by aircraft will generally be minor. Winter construction and route preparation in occupied winter ranges will disturb moose in areas adjacent to the right-of-way. Although some such disturbance will occur in summer the effects will not be critical. Large-scale destruction of critical habitat is unlikely unless extensive areas of riparian vegetation are cleared or forest fires destroy winter range. Hernandez (1977) indicated that the project could increase the potential for major fires if construction occurred in a "bad" fire season. Such fires in mature forest will probably create favorable moose habitat for the future. Increased hunting demand as a result of the project is anticipated, although moose are not prime targets of non-resident hunters in the Yukon (Lortie 1974, 1975, 1976; M. Hoefs personal communication). Hoefs (1975) inferred that increased moose hunting in the southern Yukon may deplete moose stocks there.

Arctic Gas Route:

Moose are found along the entire route although densities are especially low on the Yukon north slope (Prescott et al. 1973). Moose on the coastal plain tend to be found in riparian willow patches, although they generally winter in the foothills to the south (Roseneau and Stern 1974, Doll et al. 1974, Ruttan 1974d). Moose are common in the Mackenzie Valley where local areas in river valleys, floodplains and Mackenzie River islands are prime winter ranges (Watson et al. 1973, Prescott et al. 1973, Ruttan 1974d, Ruttan 1976). Right-of-way clearing or borrow operations in riparian vegetation could cause severe reductions in local habitat availability. The Alyeska project destroyed considerable amounts of critical riparian moose habitat on the Alaskan north coast (J. Hemming personal communication). Hernandez (1974) concluded that although numbers of reported fires may increase as a result of the project, the area burned probably would not, thus making both short- and long-term effects of project-related fires relatively minor. Moose will be vulnerable to disturbance in winter wherever project-related activities occur in their ranges in winter.

Normal seasonal migrations may be disturbed for short periods during construction, primarily by trenching and pipe-laying activities. Moose wintering particularly on Mackenzie River islands and possibly in valleys on the Alaska (and presumably Yukon) north coasts undertake seasonal migrations believed to cross the proposed alignment (Watson et al. 1973, Roseneau and Stern 1974, Ruttan 1976).

Increased demand for moose hunting is expected due to project-related influxes of non-resident personnel into the northern Yukon and Mackenzie Valley. Moose are an important resource for northern peoples and have been effectively extirpated from areas surrounding many northern communities (Jakimchuk et al. 1974).

Comparison Summary

The Alaska Highway route is preferred insofar as moose are concerned and is assigned a preference rating of 5. Disturbance of moose on winter ranges along this route will be decreased by the scheduled summer construction on most of the route. Some disturbance on winter ranges will accompany route preparation activities, although they will be somewhat mitigable by route and timing changes. Little disturbance is expected when summer range is crossed.

Little interference with seasonal movements is expected. The Alaska Highway generally does not encounter moose habitat between MPs 90-350. A "bad" fire season during construction may destroy moose winter ranges, but also create significant areas of new moose browse for the future. The route will not create significant new access to moose ranges. Increased non-resident sport hunting is anticipated. Should controls on sport-hunting prove advisable a data base for management is more readily available and restrictions probably more easily implemented and enforced in the southern Yukon than in the northern Yukon (Mossop 1976).

The winter construction schedule proposed by Arctic Gas is expected to result in disturbance of small numbers of moose wintering along the right-of-way, particularly near the Mackenzie River. Mitigation may be possible by route changes in some cases, but not by timing within the present schedule. Minor, temporary interruptions of seasonal movements may also occur during trenching and pipe-laying in these same areas. Essentially the entire Arctic Gas route traverses moose habitat, although it is marginal on most of the Yukon coast. Effects of increased hunting may be significant along the Arctic Gas route, particularly where new access is created in the upper Mackenzie Valley. Any increased hunting in such areas, particularly by holders of General Hunting Licences, is difficult to control and could cause depletion of local populations. Information for management of moose along much of the route is relatively unavailable and enforcement of regulations difficult relative to most of the southern Yukon. Project-related fires are not expected to increase either winter range loss or creation of future moose habitat over present rates.

Based on these considerations the Arctic Gas route was assigned a preference rating of 4 relative to the Alaska Highway route.

GRAY WOLF (*Canis lupus*)

Problem Definition

Wolves have been extirpated over much of the species' range but are not endangered in northern Canada (Mech 1970). Versatility as predators and presumed awareness of prey conditions over wide areas render local disturbance or prey population changes relatively unimportant (Mech 1970, Voigt et al. 1976). Denning areas are very susceptible to disruption. They are established in April or May in dry, stable soils and are abandoned by August (Jordan et al. 1967, Mech 1970). Although wolves may abandon disturbed dens, they are ordinarily reused in successive years (Joslin 1967, Mech 1970, Cottrell 1975). In some areas wolf populations may be limited by availability of suitable den sites.

The greatest potential impact on wolves will result from increased contact with man. Aversion to large predators frequently mandates extirpation of wolves by man. Wolf fur is a popular garment trim and influxes of project-related personnel may stimulate demand for increased wolf harvest. Wolf populations may be reduced particularly where new access is created, although their high reproductive potential makes widespread or long-term eradication difficult (Mech 1970). Harassment by aircraft in open areas often results in exhaustion or death. Wolves will habituate to aircraft unless hunted or harassed by them (Burkholder 1959, Mech 1970).

Unhunted wolves tolerate human activities, feeding at dumps and approaching occupied dwellings closely (Rausch 1967, van Ballenberghe et al. 1975, Voigt et al. 1976, Grace 1976). Their willingness to accept handouts increases the threat of rabies to workers (US Department of Interior 1976). A no-hunting corridor concentrated wolves along the Alyeska pipeline corridor, causing increased problems with wolves in camps (J. Hemming personal communication). Wolves range most widely in winter (Mech 1970) and camps and dumps are expected to attract wolves over the greatest distances at this time.

Potential Impact

Alaska Highway Route:

Detailed information on wolf distribution in the Yukon is generally lacking. Wolves are assumed to be present where significant ungulate populations are found in relatively undeveloped areas. Most reported wolf harvest adjacent to the route occurs west of MP 100 (R. Archibald personal communication). Wolves are believed to den near Kloo Lake and Michie Creek, MPs 165-170 and 310-320, respectively (Foothills 1976b) and in and near Kluane National Park and Sanctuary (Cottrell 1975).

The most important disturbance of wolves that may occur is of their denning areas. In zones of extensive permafrost or swamp suitable den sites may be scarce. Den searches during location surveys can prevent most potential conflicts at den sites. Construction is scheduled for the early denning period only in the Beaver Creek to Duke River sections, although right-of-way preparation in other sections may be underway during this period. Cover and rough terrain will protect wolves from aircraft harassment along most of the route.

Demand for wolf fur is expected to increase over an area larger than the proposed corridor. About 2 percent of the current Yukon wolf harvest is obtained within 15 km of the proposed alignment (Hoefs 1975, M. Hoefs personal communication, R. Archibald personal communication). Increased harvest effort could deplete the already-reduced wolf populations in the southern Yukon. No major new access to wolf ranges will be created by the project.

Wolves frequently follow ungulates into alpine valleys and lowlands in winter (Cowan 1947). This increases the potential for problems at camps during winter construction in the Beaver Creek to Duke River section and wherever route preparation and other activities are undertaken in winter. Problems at camps and dumps are readily mitigable, however.

Arctic Gas Route:

Wolf distribution near the proposed route is poorly known. Wolves occur on the Yukon coast and Mackenzie

Delta (Ruttan and Wooley 1974, Ruttan 1974b, Jakimchuk et al. 1974, Doll et al. 1974) and are expected to occur along the route wherever significant ungulate populations are present (Ruttan and Wooley 1974).

Some disturbance of dens may occur although Ruttan (1974b) found no wolf dens near the proposed alignment on the Yukon coast. Suitable denning areas may be uncommon in this region. Extraction of borrow material may destroy such areas unless den sites are identified during route location surveys and subsequently avoided. Construction later than early April may disturb denned wolves. Wolves will be particularly vulnerable to aircraft harassment on the open coastal plain.

Large numbers of project-related in-migrants may increase demand for wolf pelts, possibly stimulating harvesting effort. The proposed winter construction schedule increases the possibility of investigations by wolves in camps, with corresponding increases in wolf-human contacts. Although appropriate controls can be expected to mitigate many such difficulties, wolves proved to be a serious problem in camps and along the right-of-way during construction of the Alyeska pipeline in northern Alaska (J. Hemming personal communication).

Comparison Summary

The Alaska Highway route is preferred insofar as wolves are concerned and is assigned a preference rating of

5. No significant new access to wolf ranges will be created by the Alaska Highway project. Wolves are hunted along much of the route and are expected to be extremely wary of man, lessening the magnitude of any problems at camps and dumps. Summer construction should decrease the potential for problems with wolves at Alaska Highway camps. Such problems can be readily mitigated by fencing camps and incinerating garbage. Disturbance of denning areas along the right-of-way and in or near sources of borrow material can be avoided by undertaking pre-alignment surveys. Increased demand for wolf fur as a result of influxes of project-related personnel is expected to stimulate wolf harvest. This is important in view of the already-depleted wolf populations in much of the southern Yukon. Relatively more data on wildlife are available in the southern than the northern Yukon (Mossop 1976), and any management of wolves made necessary by the project should be more easily effected in the more southern areas.

On the Arctic Gas route the winter construction schedule will increase the potential for serious problems with wolves at camps and along the right-of-way although some of these are mitigable. This problem could be exacerbated by the relatively higher populations of wolves believed to occur along this route. Lack of cover in tundra increases vulnerability of wolves to harassment by aircraft. The anticipated increase in demand for wolf fur is expected to increase harvest effort. Data on which to base management are relatively unavailable, at least in the northern Yukon (Mossop 1976) and any management and enforcement of hunting and anti-harassment regulations will be difficult in remote areas. Disturbance of denning areas along the right-of-way or near sources of borrow material can be avoided by undertaking pre-alignment surveys.

Based on these considerations the Arctic Gas route was assigned a preference rating of 4 relative to the Alaska Highway route.

WOLVERINE (*Gulo gulo*)

Problem Definition

Extirpation of wolverines over much of the species' range has followed human settlement, although wolverine populations in remote northern and mountainous areas of Canada are believed to be relatively secure (Rausch and Pearson 1972, van Zyll de Jong 1975). Van Zyll de Jong (1975) proposed three reasons for this decline: excessive human predation, caribou population declines, and wolf-control programs. The wolverine is a scavenger-omnivore-predator with low population densities, and removal of a few individuals can greatly reduce or eliminate populations over a wide area. Wolverines are affected by major changes in distribution or abundance of large ungulates, as well as predators which provide them with carrion. Large home ranges and high mobility enable them to avoid local disturbance and to follow shifts in the distribution of food sources.

Wolverines have a low reproductive potential (Wright and Rausch 1955, Rausch and Pearson 1972). Young are born in snow dens in later winter and early spring. If disturbed, females may relocate their cubs prior to normal den abandonment in April or May (Pulliainen 1968, Rausch and Pearson 1972).

Wolverines can coexist with humans if given protection from hunting and habitat destruction. They frequently take advantage of human activities and are considered nuisances and menaces on traplines. Garbage attracts wolverines to camps where they may be trapped or destroyed as real or imagined threats to humans. They may be disturbed by low-flying aircraft (Burkholder 1962), and high visibility in winter increases vulnerability to harassment. Wolverine fur is a desirable garment trim and wolverines are sought as trophies by some sport hunters.

Potential Impact

Alaska Highway Route:

Although accurate distributional data are lacking, fur harvest records show that wolverines occur in areas adjacent to the proposed route over much of its length (R. Archibald personal communication). Summer distribution is expected to be primarily alpine and subalpine. They have probably been extirpated near settled areas along the Alaska Highway.

A major concern is the potentially increased demand for wolverine fur and trophies due to influxes of project-related personnel. This demand may increase harvest pressure and tend to expand the recently increasing Yukon wolverine harvest. At present about 6 percent of the Yukon's reported wolverine harvest is obtained within 15 km of the proposed alignment (Hoefs 1975, M. Hoefs personal communication, R. Archibald personal communication). The primary effect of increased trapping would be wolverine population reductions or extirpation along much of the route.

Wolverine mortality is also expected to increase due to man-wolverine contacts during construction. Problems at camps and dumps will be decreased by the summer construction schedule along most of the route although winter route-clearing camps may experience problems with wolverines. Late summer-early spring preparation of the right-of-way and permanent facility sites may occasionally destroy or disturb wolverine dens.

Very little habitat loss is anticipated during any phase of the project.

Arctic Gas Route:

Although details of distribution are unknown, wolverine are believed to occur along the entire route. Kucera (1973) recorded wolverine at Travaillant Lake. The entire Northwest Territories has recently exported fewer than 100 wolverine pelts annually (Kucera 1974). Most wolverines are trapped incidentally and pelts used locally (Novakowski 1975).

The major impact of the proposed project on wolverines will be increased human contact and consequently increased mortality. The winter construction schedule increases the likelihood of wolverines coming into contact with any poorly managed dumps and camps. Current scheduling should prevent clearing operations from threatening dens.

Influxes of project-related personnel may increase demand for wolverine harvest. Long-term effects of increased harvest are unknown although population reduction or extirpation in accessible areas is probable. Their high visibility increases vulnerability of wolverines to aircraft harassment particularly in winter on the Yukon coast.

Very little habitat loss is anticipated during any phase of the project.

Comparison Summary

Neither route is preferred insofar as wolverines are concerned. Most construction on the Alaska Highway route is scheduled for summer when wolverines are least likely to be in valleys, reducing the potential for conflicts at camps. Although some problems with wolverines may occur at winter camps during route clearing, they should be readily mitigable. Late winter-early spring route clearing may destroy a small number of dens. The route follows an existing transportation corridor and will not create significant new access. Wolverine populations are believed to be reduced or absent over extensive sections of the Alaska Highway project corridor, reducing potential for man-wolverine contacts but increasing the significance of increased harvest. Because relatively more data on wildlife are available for the southern than the northern Yukon (Mossop 1976), any management of wolverine made necessary by the project should be more easily effected here. Habitat loss is not expected, barring major forest fires, although wolverines may temporarily abandon areas adjacent to the right-of-way during construction. Rugged terrain will minimize aerial harassment.

Camps and dumps on the Arctic Gas route may experience frequent investigations by wolverines because of the winter construction schedule, although many such problems are generally mitigable. Wolverine harvest may increase as a result of the project due to greater demand for wolverine fur, possibly depleting wolverine populations. The route crosses primarily undeveloped territory, bringing human incursions to areas where wolverine populations are expected to approach carrying capacity. Very few data on which to base any wolverine management programs made necessary by the project are available and enforcement of any harvest restrictions could be difficult. Very little habitat loss is anticipated barring major forest fires, although areas near the alignment may be temporarily abandoned during construction. Aerial harassment may be significant in areas lacking protective cover, particularly the Yukon coast.

Based on these considerations both routes were assigned Relative Preference ratings of 5.

ARCTIC FOX (*Alopex lagopus*)

Problem Definition

Arctic foxes are found on much of Canada's arctic tundra and are economically important furbearers (Kucera 1974, Hoefs 1975). They have large home ranges on sea ice and land and their versatility as predators decreases susceptibility to disturbance except when denning in spring and summer, at which time territories are defended (Macpherson 1969, Ruttan 1974b). Destruction of dens or denning habitat can have serious effects on fox populations. The availability of good den sites (eskers, moraines and similar areas) may limit fox populations and in many tundra areas the same sites may be reused for centuries (Macpherson 1969, Ruttan 1974b, Ruttan and Wooley 1974). Foxes cannot dig new dens in spring and must utilize existing burrows (Macpherson 1969). Where gravel availability is limited these same areas may also be prime sources of borrow material. Dens are easily crushed by heavy equipment even in winter (Ruttan 1974b, Quimby and Snarski 1974).

Foxes are attracted to garbage dumps, particularly in winter, thereby increasing local vulnerability to trapping. Feeding attracts foxes into camps bringing a potential rabies hazard (Quimby and Snarsky 1974, J. Hemming personal communication). Foxes react strongly to humans only if approached closely and hungry foxes do not fear humans. They may avoid low flying aircraft or simply show watchful curiosity (Ruttan 1974b). Nearby operation of heavy equipment or use of explosives may cause den abandonment (Watson et al. 1973).

Arctic fox populations are generally resistant to overtrapping. They experience periodic population fluctuations in apparent response to changes in prey species abundance (Macpherson 1969, 1970). High reproductive potential promotes recovery from population reductions due to natural causes, overtrapping or over-reliance on temporary local food abundance (e.g. garbage).

Potential Impacts

Alaska Highway Route

Sections of this route included in the comparison avoid the distribution of arctic fox.

Arctic Gas Route:

Arctic foxes are found on the Yukon coast and Mackenzie Delta (Ruttan 1974b, Schweinsburg 1974a). Kucera (1974), using the habitat classification of Nolan et al. (1973), found that the Arctic Gas route crossed 82 km of Class 1 (most important) habitat, 70 km of Class 2 and 116 km of Class 3 habitat on the Yukon coastal plain. Several denning areas exist between the Alaska-Yukon boundary and the Blow River, including areas near Clarence Lagoon, alluvial fans of the Malcolm and Firth Rivers and the region between the Firth and Spring Rivers (Ruttan 1974b). Most occupied dens found by Ruttan (1974b) were not near the proposed alignment. Borrow material will be collected in many of the same general areas that have been identified as denning ranges (CAGPL 1974); however, locations of fox dens can be readily identified and avoided (Macpherson 1969). The potential for den destruction will be restricted to the construction phase unless maintenance of the line requires extensive amounts of gravel. Den abandonment may result if heavy equipment is operated nearby or if human investigation of dens occurs.

Foxes are expected to congregate at camps and garbage dumps if food is available, particularly if there is a no-hunting corridor along the right-of-way. Without such a corridor, harvest of these fox concentrations by hunters and trappers may increase, but probably without long-term effects. Restricting garbage availability is a feasible control for such problems. Little disturbance is expected due to human presence.

Comparison Summary

Because Arctic foxes do not occur on the Alaska Highway route, it is preferred insofar as arctic foxes are concerned and is assigned a preference rating of 5.

There are no serious long-term threats to arctic foxes along the Arctic Gas route. One potential problem is destruction of denning habitat, primarily by borrow operations. Extensive loss of the available denning habitat is not anticipated, and effects of borrow operations on fox populations should be minor if pre-construction surveys are undertaken and borrow areas chosen to avoid such conflicts. Any fox concentrations near camps as a result of garbage availability may be exposed to greater harvest effort but no long-term or widespread declines in arctic fox populations are anticipated due to their high reproductive capacity. The incidence of rabies in the fox population may increase if they concentrate near camps, and feeding of foxes will increase the potential for human exposure to this disease. Right-of-way vegetational changes may promote locally increased small-mammal populations, changing local arctic fox distribution patterns in summer. Little disturbance by aircraft, humans or equipment is anticipated.

Based on these considerations the Arctic Gas route was assigned a preferencing rating of 4 relative to the Alaska Highway route.

AQUATIC FURBEARERS - (Beaver *Castor canadensis*)
(Muskrat *Ondatra zibethicus*)

Problem Definition

Beaver require water about 1.5-4.5 m deep (Dennington and Johnson 1974), and muskrats require a depth of about 1-3.5 m (Stevens 1955). Both species are highly sensitive to abnormal water level fluctuations and alterations to drainage patterns, particularly in late summer, autumn and winter. By late summer their lodges or bank burrows and the food reserves of beaver (Aleksiuk 1970) are established and subsequent water-level changes will freeze or flood them out and also expose muskrat to increased mink (*Mustela vison*) predation (Ruttan 1974c). Silt sometimes renders aquatic furbearer habitat unusable, particularly in headwater streams and lakes. Large forest fires increase siltation, destroy riparian vegetation and alter drainage regimes (Watson et al. 1973, Wooley 1974). Spills of fuel and toxic chemicals and discharges of sewage and testing solutions can cause habitat loss and direct mortality (Wragg 1954, Watson et al. 1973). Recolonization of these areas requires several years in northern regions particularly if aquatic vegetation has been destroyed (Stevens 1955). Beaver and muskrat productivity is relatively low in northern areas (Stevens 1955, Brenner 1964, Aleksiuk 1970). Beaver are easily overtrapped but muskrats are not, due to their rapid natural turnover and an apparent tendency for population fluctuations (Watson et al. 1973).

Potential Impact

Alaska Highway Route:

Beaver and/or muskrat are present in most wetlands along the route, particularly in the Beaver Creek-White River (MPs 0-44) and Koidern River-Pickhandle Lake (MPs 45-58) areas, and the Swift, Rancheria and Liard river basins (Lands Directorate 1973, Foothills 1976b). Trenching will cause temporary siltation in furbearer streams and water-bodies, particularly east of Nisutlin Bay between MPs 375-512 (Adam and Permut 1977a). Floodplain borrow activities will be unnecessary along this route. Chemical, fuel and sewage discharges into streams and marshes will be inevitable, although the probability of large spills is generally small. Several stockpile sites where spills are most likely to occur have been identified (Adam and Permut 1977a). The project may increase the forest fire hazard if construction occurs in a "bad" fire season (Hernandez 1977). Significant fall and winter water-level fluctuations will be restricted to specific streams and marshes where construction problems are experienced or alterations in drainage patterns occur.

Minor increases in trapping may occur in some areas, particularly if local residents employed on winter route-clearing do not return to their homes on their days off. In recent years about 7 and 1 percent respectively of the Yukon's reported beaver and muskrat harvest has originated within 15 km of the Alaska Highway (Hoefs 1975, R. Archibald personal communication).

Arctic Gas Route:

Beaver and muskrat are widely distributed along the entire Mackenzie Valley (Watson et al. 1973, Dennington and Johnson 1974). Small streams in the south and central portions of the Mackenzie Valley are more utilized by beaver than those in the lower valley (Dennington and Johnson 1974). Good muskrat habitat is found between Arctic Red River and Travaillant Lake but populations in other areas are apparently small and scattered (Ruttan and Wooley 1974).

Aquatic furbearer habitat may be destroyed by large discharges of oil and chemicals. Construction activity in furbearer streams during fall and winter will occasionally alter normal drainage patterns and water levels in inter-connecting lake systems, particularly if in-stream borrow operations are undertaken (Howard 1974). The cold pipe may initiate ice-bulb formation, potentially interrupting subsurface drainage during operation (How 1974). Worst-case oil spills would be of relatively local significance for beaver and less serious for muskrat (Kucera 1974). Streams on the Yukon coast and lower Mackenzie Valley may experience significant increases in sediment load during construction and for some time thereafter due to thermal erosion in high ice-content soils (Howard 1974, Adam and Permut 1977b). The upper Mackenzie Valley has relatively high siltation potential although winter construction can be an effective mitigative measure (Adam and Permut 1977b). Probability of large, uncontrolled forest fires as a result of the project is small (Hernandez 1974).

Aquatic furbearers are important to Mackenzie Valley residents although this importance has apparently declined somewhat in recent years (Ruttan and Wooley 1974, Wooley 1974, Commission Counsel 1976). Furbearer population reductions could affect local subsistence economies. Trapping may increase if new access is created particularly within the regular trapping radii of villages or if human population shifts occur (Dennington and Johnson 1974). Employment of local residents on the project could decrease trapping effort, at least temporarily.

Comparison Summary

The Alaska Highway route is preferred insofar as aquatic furbearers are concerned and is assigned a preference rating of 5. In general, habitat loss during construction will be less extensive and shorter-term on this route than on the Arctic Gas route. Siltation as a result of thermal erosion will be comparatively less as ice-rich soils are uncommon. Minimizing removal of surface vegetation during summer construction can mitigate erosion. In-stream and floodplain dredging for borrow material is not anticipated. Any major oil and fuel spills will probably be restricted to storage depots where appropriate mitigative measures can be taken and contingency plans developed to minimize any effects. Volumes of fuel stored in these depots will probably be smaller than those on the Arctic Gas route as year-round fuel supply is feasible.

Greater increases in siltation of small streams are expected during construction on the Arctic Gas route. These increases will be more difficult to mitigate than on the Alaska Highway route due primarily to differences in soil types and construction techniques (Adam and Permut 1977b). Modification of drainage patterns and water levels is expected to be greater on this route due to the winter construction schedule and the predominance of high-ice-content soils. This will be exacerbated by any in-stream gravel removal, particularly on the Arctic coast. Potential for pipeline-related icing and consequent alterations of drainage patterns is greater on this project as chilling will occur over a longer section of the route. Any oil and fuel spills have the potential to be larger as greater volumes of these materials will be stored to overcome problems of supply and access. Spills in more northern areas can be more damaging to natural systems. Appropriate mitigative measures can be taken and contingency plans developed to minimize the effects of any such spills. Fuel will be barged to areas north of Fort Simpson, increasing the probability of large spills from such sources.

Based on these considerations the Arctic Gas route was assigned a preference of rating of 3 relative to the Alaska Highway route.

The Transmission of Prudhoe Bay Gas to American Markets: A Preliminary Environmental Comparison of the Canadian Arctic Gas Pipeline and the Foothills (Yukon) Pipeline in the Yukon and Northwest Territories

BACKGROUND DOCUMENTATION

BIRDS

CONTENTS

Schmidt, R.K. 1977. Birds. Pages 159 to 231 in Background documentation. Appendix to The transmission of Prudhoe Bay gas to American markets: A preliminary environmental comparison of the Canadian Arctic Gas pipeline and the Foothills (Yukon) pipeline in the Yukon and Northwest Territories. Alaska Highway Pipeline Panel, Winnipeg. 420 pp.

SUMMARY

The proposed Arctic Gas and Alaska Highway pipeline projects were compared with respect to their potential for affecting bird populations that occur along each route. The purpose of the comparison was to identify the route likely to have the least impact on selected species. The comparison was limited to those species considered sensitive or unlikely to adapt to disturbance, those known to be vulnerable because of their population status or distribution, and those used by man. They include, in order of their relative importance, peregrine falcon, gyrfalcon, lesser snow goose, trumpeter swan, whistling swan, golden eagle, bald eagle, white-fronted goose, brant, diving ducks, sandhill crane, Canada goose, and dabbling ducks. In all cases, the assigned preferences for the two projects reflect (1) the numbers of birds and amount of important habitat likely to be affected, (2) numbers and expected severity of potential conflicts, (3) the nature of anticipated impacts, and (4) the estimated level of difficulty required to effectively mitigate potential impacts.

The outcome of the comparison is summarized in Table 1. The Alaska Highway route was given preferred status for 11 of the 13 species (or groups of species in the case of ducks); hence, that route is preferred overall by a large margin. Arctic Gas was the preferred route for bald eagles and trumpeter swans. Aside from bald eagles and

Table 1. Summary of bird comparison[a] for the Alaska Highway and Arctic Gas pipeline routes in Canada north of the 60th parallel.

	Relative Importance Weighting	Relative Preference[b]		Weighted Preference[c]	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
Peregrine falcon	20	5	2	100	40
Gyrfalcon	12	5	2	60	24
Snow goose	12	5	1	60	12
Trumpeter swan	12	4	5	48	60
Whistling Swan	12	5	3	60	36
Golden eagle	10	5	4	50	40
Bald eagle	8	4	5	32	40
White-fronted goose	7	5	3	35	21
Brant	7	5	2	35	14
Diving ducks	6	5	2	30	12
Sandhill crane	6	5	4	30	24
Canada goose	6	5	3	30	18
Dabbling ducks	4	5	3	20	12
Totals	122			590	363

[a]See Introduction and Approach for detailed discussion of Relative Importance Weightings and Relative Preference ratings.

[b]Relative Preference is based on a scale of 1-5, where the preferred route is assigned a value of 5.

[c]Weighted Preference = Relative Importance Weighting X Relative Preference.

trumpeter swans, Arctic Gas was considered the greater threat to bird populations both in terms of potential severity of impact and difficulty involved in avoiding conflicts. This is partly because the Arctic Gas route is longer (1583 versus 826 km) than its Alaska Highway counterpart. More important, the mode of supply transport and access (barge and aircraft) proposed by Arctic Gas jeopardizes more critical waterfowl habitat and raptor nests than the rail-highway mode adopted by Alaska Highway. In addition, the Mackenzie Valley-Yukon coast (Arctic Gas) is recognized as an extremely important migration route and breeding area for most waterfowl whereas the southern Yukon (Alaska Highway) is not. The Arctic Gas route also traverses large amounts of undeveloped terrain attractive to breeding falcons and golden eagles; the Alaska Highway route follows an existing highway corridor. These factors together outweigh the detrimental effects of summer construction proposed by the Alaska Highway project (construction on Arctic Gas is scheduled for winter), and are responsible for the low preference rating given to Arctic Gas.

INTRODUCTION

The proposed Alaska Highway and Arctic Gas pipeline projects included in this comparison will affect birds along the two routes. Potential effects on bird populations were evaluated using existing environmental studies and information from the literature. The projects were compared on the basis of these assessments and a preferred route selected.

Since consideration of all species present in the project areas would be impractical, analysis was confined to the following key species, listed in order of relative importance: peregrine falcon, gyrfalcon, lesser snow goose, trumpeter swan, whistling swan, golden eagle, bald eagle, white-fronted goose, brant, diving ducks (Aythyinae), sandhill crane, Canada goose and dabbling ducks (Anatinae). Criteria used to select species and assign relative importance weightings were population status and distribution, sensitivity to disturbance, adaptability after disturbance, and degree of use by people.

Each route was evaluated according to the numbers and probable severity of potential impacts on birds caused by different project activities. The number of potential impacts is based on the number of major problem areas or "red flags" identified in previous assessments, principally Environment Protection Board's "Environmental Atlas" (EPB 1974) and Schmidt (1977). A subjective estimate was made of the likelihood that a particular project event would result in a measureable reduction of regional or continental populations through direct mortality, habitat degradation or disruption of normal behavior. Severity of impact, therefore, reflects the number of birds likely to be affected within the project corridor over a given period of time.

Although the projects are similar in many respects, there are some important differences relevant to potential impacts on birds. On the Alaska Highway project, materials, men and equipment will be transported to construction sites by existing railroads and highways. Arctic Gas will use barges to transport fuel and equipment to stockpile sites along the Mackenzie River and Arctic coast; additional access in and out of camps and other facilities will be provided by aircraft. Because access is limited on the Arctic Gas route, large amounts of fuel and other materials will be stockpiled in advance of construction. In the case of Alaska Highway, fuel and supplies will be brought in as needed, thereby eliminating the need for storing large volumes of fuel and other materials. In addition, most construction work on the Mackenzie Valley-Yukon coast is scheduled to take place in winter whereas construction for much of the Alaska Highway project will occur in summer.

Other factors have a direct bearing on how amenable the two projects are to direct comparison. There is considerably more information available on the distribution and ecology of birds in the Mackenzie Valley-Yukon coast region than there is for the southern Yukon, hence many of the conclusions reached in this report are conditional on there being further ornithological investigations along the Alaska Highway route. A similar situation exists with regard to project descriptions: information on location of borrow pits, granular material requirements and batch plants must be made available for the Alaska Highway project before any final route comparison can be made.

PEREGRINE FALCON (*Falco peregrinus*)

Problem Definition

Two races of peregrine falcon, *F.p. anatum* and *F.p. tundrius*, breed in boreal and tundra regions of the Yukon and District of Mackenzie. The peregrine is regarded as an endangered species (U.S. Department of Interior 1973); Fyfe et al. (1976) reports that populations of both races have continued to decline since 1970. Peregrines normally nest on ledges of high cliffs or cutbanks but may build aeries in trees or on the ground (Godfrey 1966, Hickey 1942). They usually arrive on breeding grounds in late April to mid-May and remain until 1 September or early October. The breeding season extends from about 1 June to 31 August in the western Canadian arctic (Godfrey 1966, Jacobson 1974).

Peregrine falcons are sensitive to disturbance caused by human activity, although there is considerable individual variation in the response of nesting pairs. Noise and activity from construction projects have caused some birds to abandon aeries (Herren 1969, Herbert and Herbert 1969); other pairs have shown remarkable tolerance to such disturbance (Hickey 1942). Close approach of people appears to be the most serious disturbance in causing birds to abandon nests (Hickey 1942, Herbert and Herbert 1965, Snow 1972, Campbell and Davies 1973). Passage of fixed-wing aircraft over nests is evidently less disruptive to breeding falcons than approach of helicopters (Campbell and Davies 1973, White 1969). Other events that may affect breeding peregrines adversely are noise from blasting, compressor stations and heavy construction, physical destruction of nest sites, and shooting of territorial adults. In general, any activities that cause birds to leave nests, especially during egg-laying and incubation, will increase the chances that eggs or young will be lost. Given the precarious status of peregrines in North America and the limited availability of nest sites, any activities that result in increased mortality of the birds or desertion of traditional aeries must be avoided.

Potential Impact

Alaska Highway Route:

No active aeries have been recorded within the proposed Alaska Highway corridor although four sites within 5 km of the route were identified as having particularly good potential for nesting. If peregrines are found to nest at each site they would be affected by surveillance aircraft, construction activities, and human presence. No compressor stations appear to be in conflict with any potential site. Possible effects associated with borrow operations cannot be determined until locations of those sites are known. In general, any assessment of potential impacts at this time must be regarded as tentative, owing to the lack of data on peregrine distribution within the proposed corridor. Site-specific surveys must be conducted before a final assessment can be made.

Arctic Gas Route:

Gunn (1975) reported 2-3 peregrine nests within 5 km of prime coastal routes and another 7 nests within 5 km of the prime route from the Mackenzie Delta south. He stated that wherever an active aerie lies within 4 km of the pipeline or compressor station, the alignment and station should be moved. Although specific nest site locations are not given, it appears that several sites along the Arctic Gas route are vulnerable to human activity at camps, at borrow pits and other summer-construction facilities and to noise from compressors during pipeline operation; these may also be affected by frequent passage of aircraft during the construction period.

Comparison Summary

No active peregrine aeries have been found within 80 km of the proposed Alaska Highway pipeline route, although several potential nesting areas have been identified (Schmidt 1977). On the Arctic Gas route, several known nests are vulnerable to disturbance from pipeline activities. Gunn (1975) stated that in two cases, relocation of the pipeline and compressor stations is an impractical means of reducing potential conflicts. Winter construction is scheduled near all aeries, which will eliminate most construction-related impacts, although construction of support facilities will take place during summer. Disturbance from compressor noise can be minimized by installing mufflers if the stations in question cannot be moved and problems caused by aircraft can be reduced by instituting flight corridors and minimum altitude restrictions that avoid occupied nests. The fact remains, however, that there are more opportunities for conflicts on the Arctic Gas route than on the Alaska Highway route, where no occupied nest sites have yet been identified. The greater frequency of aircraft flights during construction and the presence of compressor stations near known aeries in the Mackenzie Valley-northern Yukon indicate that potential impacts caused by the Arctic Gas project will be more severe and difficult to mitigate. In addition, the Arctic Gas route conflicts with both races whereas Alaska Highway would affect only *F.p. anatum*, assuming they nest there in the first place.

In conclusion, the Alaska Highway route is preferred because existing information indicates there are no known peregrine nests within the proposed corridor; however, surveys are required along the route before this preference can be validated. Conflicts identified on the Arctic Gas route can probably be reduced through mitigation. But because opportunities for impacts on known nests still exist on Arctic Gas, that route is given a less preferred rating of 2.

GYRFALCON (*Falco rusticolus*)

Problem Definition

Gyrfalcons inhabit arctic tundra ranges of North America and Eurasia, extending south into boreal forest ranges (Godfrey 1966) and are thought to be endangered in Canada (Holloway 1970). They prefer to nest in high cliffs, although other sites such as trees are sometimes used (Cade 1960, Irving 1960).

Gyrfalcons are shy and sensitive to disturbance when nesting and may leave aeries when approached by people (R. Fyfe in Hickey 1969a). Because of their early breeding any activity that forces adults off nests may lead to mortality of eggs through chilling (Platt 1975). Platt (1975) reported that passage of helicopters within 150 m of occupied nests caused one of four incubating birds to leave the eggs for a short period of time. Other studies have indicated that gyrfalcons exhibit little reaction to overflights of fixed-wing aircraft but are disturbed by low-level approach of helicopters (F. Beebe in Jacobson 1974). Presumably, other noise and activity associated with pipeline construction and operation (blasting, compressor noise, borrow operations) would also disrupt gyrfalcons nesting nearby but data on the effects of such interactions are lacking.

Potential Impact

Alaska Highway Route:

Gyrfalcons are probably common breeders in the Kluane and Cassiar mountains of the southern Yukon (D. Mossop personal communication) but no positive nesting records exist within the proposed corridor. Observations of birds in mid-summer at Donjek River (Drury 1953), Kluane Lake and Slims River valley (Hoefs 1973) and Burwash uplands suggests gyrfalcons may nest near the route. At present, the gyrfalcon must be considered a "potential" breeder within 5 km of the proposed alignment. Best potential sites are located at Pickhandle Lake, Ibex River valley, Pine Lake and Rancheria River valley. Of these, the latter three sites are subject to disturbance from summer construction, where approach of people and loud noise from blasting and other activities could force adults to leave young or eggs unprotected. Potential nest sites at Pickhandle Lake are far enough from the route to be unaffected by winter construction activity. Movement of surveillance aircraft may cause minor disruption of normal nest site behavior but this should not have any effect on nesting success. Compressor stations will not influence birds at any of the above sites.

Arctic Gas Route:

Gyrfalcons breed in the Richardson and British Mountains (Campbell and Davies 1973, Platt 1975); Campbell and Davies (1973) reported 18 nests in Richardson Mountains in 1972. Adults begin nesting in late winter, probably in late February or early March, and remain at aeries until July or August (Brown and Amadon 1968, Campbell and Davies 1973).

Active gyrfalcon aeries occur within 5 km of the proposed route (Gunn 1975). These are vulnerable to disturbance from aircraft during construction, and to disturbance from construction activity and human presence; several sites could be adversely affected by noise from compressor stations.

Comparison Summary

The Alaska Highway route is preferred because no potential conflicts with nesting gyrfalcons are anticipated within the proposed corridor. The Arctic Gas project is potentially in conflict with several aeries, largely as a result of aircraft disturbance and construction activity. Even though potential impacts would be reduced through proper mitigative measures, the fact that aeries exist near the Arctic Gas route makes it impossible to guarantee gyrfalcons will not be adversely affected. If existing information for the Alaska Highway corridor is correct, gyrfalcons will not be affected by project activities; however, surveys along that route are needed before such a conclusion can be confirmed.

In summary, then, the Arctic Gas route offers more risks to gyrfalcons than the Alaska Highway route, even though many of the potential impacts can be effectively mitigated. Because of this, Arctic Gas is given a rating of 2 compared to the preferred 5 rating for Alaska Highway.

LESSER SNOW GOOSE (*Chen caerulescens*)

Problem Definition

Lesser snow geese nest in colonies through much of the western and central Canadian Arctic and on the Hudson Bay lowlands as far south as James Bay (Cooch 1961). They are an important species for sport and subsistence hunting and are known to be extremely sensitive to disturbance at particular stages of their life cycle. Staging snow geese will readily flush at the approach of aircraft (Salter and Davis 1974) and will avoid noise and activity associated with compressor stations, drilling rigs, and major construction (Barry and Spencer 1976, Wiseley 1974). Pollution of staging areas with fuel or other toxic materials can affect snow goose populations by forcing them to abandon key habitats during critical periods of their life cycle.

Potential Impact

Alaska Highway Route:

The Yukon River valley and Shakwak trench lie along spring and fall migration routes of snow geese that breed on Wrangel Island off the northeast coast of Siberia. Bellrose (1976) indicates that between 100,000 and 250,000 pass over the southern Yukon in spring; return migration in fall involves 1,000-10,000 birds. Existing data indicate small numbers of snow geese stage at a few sites along the proposed route. Soper (1951) reported that medium-sized flocks have been observed at Kluane Lake (particularly the northwest end), Marsh Lake, Teslin Lake and Nisutlin Bay during migration. Flocks of snow geese numbering up to 100 have been sighted at the mouth of Slims River in May 1970-71 (Hoefs 1973). Snow geese do not breed along the Alaska Highway route.

Disturbance of staging snow geese by activities associated with construction are anticipated at four sites. Fuel spills at Duke River and Teslin Lake stockpile sites could foul Kluane River and Teslin Lake shorelines, making them unsuitable for staging for one or more years. Passing aircraft during pipeline operation may flush groups of staging snows, but surveillance flights will not be frequent enough for this to have any detrimental effect on staging populations. Compressor station noise is not expected to cause problems at any of the above sites.

Arctic Gas Route:

Islands and sandbars near open water in Mackenzie River are important staging areas for spring migrants (Campbell and Shepard 1973). Important areas are located between Norman Wells and Thunder River where up to 92,500 geese have been observed in a single day (Campbell and Shepard 1973). These same areas are rarely used during fall migration, except in years when flocks are forced to abandon coastal staging areas prematurely (Barry 1967).

From late August to mid-September as many as 160,000 to 400,000 snow geese gather along the Yukon coast between Alaska and the Mackenzie Delta (Koski and Gollop 1974) where they feed and rest until late-September or early October or until snow and freezing temperatures trigger southward migration.

Potential conflicts with staging snow geese have been identified at about 25 different sites over approximately 950 km (55 percent) of the proposed route. Most problems will occur during construction as a result of aircraft disturbance and possible fuel spills at wharves or stockpile sites along the Mackenzie River. Snow geese will not be affected by construction activities per se because work in all areas is scheduled for winter; however, approximately 10 km^2 of habitat on the Yukon coast will be degraded by the pipeline right-of-way. Summer construction activities at camps and support facilities along the north slope may cause geese to avoid or abandon nearby staging sites. Noise from compressor stations will affect staging geese at several sites during pipeline operation.

Comparison Summary

The Alaska Highway route is preferred because no critical snow goose staging areas appear to exist within the proposed corridor. The few use areas that have been identified are not extensive and support small numbers of geese for short periods in spring and fall. Because most potential conflicts are confined to a few small areas, mitigation should be relatively easy by scheduling construction to avoid staging areas during spring and fall. Presence of surveillance aircraft during pipeline operation will have little effect on staging snow geese. This can be reduced by routing flights away from concentration areas, most of which lie at least one kilometer from the proposed alignment. Minor relocations of two stockpile sites will greatly reduce the likelihood of habitat degradation from pollution.

Potential conflicts along the Arctic Gas route are likely to be more severe in terms of numbers of snow geese affected. In addition, there are many more opportunities for conflicts over a greater area in Mackenzie River-Yukon coast areas than in the southern Yukon. The most serious potential problems are aircraft disturbance and the possibility of fuel spills during pipeline construction, both of which would be difficult to mitigate because there are few alternatives for relocating aircraft access or fuel storage/handling areas away from sensitive areas. Thus, regardless of safeguard measures adopted to reduce the incidence of spills and disturbance by aircraft, supply barges and air traffic must still have to use depots and air strips located along the Mackenzie River and Yukon coast, both of which are critical staging areas for snow geese. A similar situation exists with the proposed compressor stations and camps in Mackenzie Valley-North Slope regions. Problems caused by compressor noise and human activities can be alleviated somewhat through facility relocation, but the most favourable form of mitigation -- avoiding the Mackenzie Valley-North Slope area altogether -- is not a realistic option. Even with institution of mitigative measures at conflict sites identified to date, the chances of something going wrong are considerably greater on the Arctic Gas route because (a) there are more problem areas that require protective measures, and (b) the opportunities for major impact on continental populations of snow geese are much greater than on the Alaska Highway route. Therefore, the Arctic Gas route is given a low preference rating of 1 compared to 5 for Alaska Highway.

TRUMPETER SWAN (*Olor buccinator*)

Problem Definition

The trumpeter swan, while still relatively uncommon, is no longer regarded as an endangered species. According to Bellrose (1976) the population is on the increase and numbered about 4000 birds in 1968. The center of their breeding range is in western North America, principally south-central Alaska, northern Alberta and northwestern United States (Godfrey 1966, Bellrose 1976).

Nesting trumpeter swans are intolerant of man-caused disturbance and have been known to desert nests when closely approached by people (Van Wormer 1972, Andersson 1973), thereby exposing eggs to predators or inclement weather. Swans are also vulnerable during molting and staging when uninterrupted feeding and resting are essential for building energy reserves needed for breeding and migration. Pollution of critical habitats with fuel and other contaminants, or disruption of normal activities by aircraft and construction activity could cause swans to avoid or abandon these areas and result in reduced breeding success and increased mortality during migration.

Potential Impact

Alaska Highway Route:

Trumpeter swans are known to breed in the southern Yukon, although no recent nesting records have been obtained within 5 km of the proposed Alaska Highway pipeline route (D. Mossop personal communication). Trumpeter swans are among the first waterfowl to arrive on northern breeding grounds. D. Mossop (personal communication) observed flocks of up to 200-300 swans staging in the outlets of large lakes in the southern Yukon during the first 2 weeks in April. The most important areas are the outlets of Marsh, Kluane and Teslin Lakes and the mudflats at the mouth of Slims River.

Areas along the Alaska Highway route where trumpeter swans have been observed during the breeding season are wetlands around Pickhandle Lake, in the Donjek River area, Rancheria River valley (Veronica Lake) and Dodo Lakes (Foothills 1976b). All are regarded as potential breeding areas and are subject to disturbance from pipeline activities, as are the four known staging areas at Marsh, Teslin and Kluane Lakes, and Slims River.

Pipeline-related events that have potential to affect staging swans are construction and associated human activities, aircraft overflights and fuel spills. Four potential breeding areas are susceptible to aircraft disturbance -- two of these would be affected by fuel spills at stockpile sites and three are vulnerable to actual construction disturbances.

Arctic Gas Route:

Small numbers of trumpeter swans probably occur along the proposed Arctic Gas corridor in spring, but timing and location of concentration areas have not been documented. The breeding status of trumpeter swans in the Mackenzie Valley-northern Yukon is also poorly known -- only one nest and one brood have been reported along the Arctic Gas route, both in the Mackenzie Delta area (Campbell 1973b). It appears from available information that the Arctic Gas project will have a negligible effect on trumpeter swans, largely because the project lies outside important swan use areas. It is clear, however, that further studies of trumpeter swan distribution in the Mackenzie Valley and Delta are needed before this conclusion can be confirmed.

Comparison Summary

Information on the distribution of trumpeter swans in the Mackenzie Valley and northern Yukon appears to be incomplete, a situation that probably reflects difficulties in differentiating trumpeter swans from whistling swans during surveys along the Arctic Gas route. Without more data it is virtually impossible to make a full comparison between the two routes with regard to trumpeter swans. This lack of data applies as well to the southern Yukon, where breeding areas have yet to be accurately determined.

It seems reasonable to assume, however, that very few trumpeter swans inhabit regions along the Arctic Gas route, because major nesting ranges in the north are located farther west in Alaska. The Alaska Highway route, on the other hand, includes known staging areas, lies directly along a major migration flyway, and probably supports small numbers of swan nests. Pipeline activities potentially will have greater adverse effect on trumpeter swans along the Alaska Highway route than on the Arctic Gas route, even though neither project is expected to have a noticeable effect on continental populations. Thus, Arctic Gas is given a preferred rating of 5, with Alaska Highway rated slightly lower at 4.

WHISTLING SWAN (*Olor columbianus*)

The continental population of whistling swans has increased steadily from about 78,000 in the 1950's to about 133,000 in the early 1970's (Bellrose 1976). Their breeding range in Canada is confined largely to arctic tundra from Baffin Island to the northern Yukon.

Whistling swans are extremely conspicuous and vulnerable to disturbance. Nesting swans will abandon nests when closely approached by people whereas molting adults and brood flocks have been known to avoid areas where construction and other disturbance activities are taking place (Barry and Spencer 1976). Whistling swans are less sensitive to aircraft but may leave nests or staging areas if repeatedly disturbed (Andersson 1973, Jacobson 1974). River islands and sandbars near open water are regarded as critical staging habitats during spring (Jacobson 1974). Fuel spills in these areas could foul shorelines and associated vegetation, making them unsuitable for feeding and resting. In general, activities that disrupt nests or broods or interrupt molting or staging patterns could reduce productivity and survival in swan populations.

Potential Impact

Alaska Highway Route:

Whistling swans do not breed within the proposed pipeline corridor, although several thousand occur there during migration, particularly in spring (D. Mossop personal communication). Migrating swans have been observed in the corridor at the outlets of Kluane and Marsh Lakes (including adjacent segments of Yukon and M'Clintock Rivers), Nisutlin Bay, the Squanga-Little Teslin Lake area, and Teslin River near Johnsons Crossing.

The Alaska Highway pipeline will have no direct impact on nesting swans; conflicts with staging flocks are anticipated at only five sites. The chief source of conflict is construction-related activity, including movement of people and equipment as well as noise, which could disturb staging swans at all five areas. Only two areas (Squanga Lake and the outlet of Teslin Lake) are vulnerable to pollution from spills at stockpile sites. Presence of aircraft during pipeline operation in spring and fall will cause only short-term disruption of staging flocks.

Arctic Gas Route:

Whistling swans are common breeding residents of the Mackenzie Delta and Yukon coast. Midsummer populations in these areas, including non-breeders, have been estimated at about 20,000-22,000 (Barry 1971, Campbell and Weber 1973). Major spring concentrations of staging swans gather on river islands and sand bars from Norman Wells to Arctic Red River, with largest numbers occurring near Fort Good Hope and Little Chicago (Salter 1974a, Campbell and Shepard

1973). Nesting densities are highest in northern parts of the delta and at Blow River-Shallow Bay and Babbage River delta on the Yukon coast, although a few pairs are found in boreal regions south to Great Bear Lake (Jacobson 1974, Campbell and Weber 1974). Most non-breeders summer in outer Mackenzie delta and at Malcolm and Firth River deltas. Swans migrate east along the Yukon coast and southeast through the Mackenzie Valley to Little Chicago and the Brackett Lake area from late August to late September or early October (Campbell 1973a, Salter 1974b). Koski (1975) reported that 259-680 birds were observed in migration on the Yukon coast from late August to late September 1973, whereas 478-1968 passed through the Mackenzie Valley during the same period. Bellrose (1976) indicates 30,000-60,000 migrate through the lower Mackenzie Valley; only 500-4900 follow upper Mackenzie and Yukon coast routes.

Approximately 1240 km (78 percent) of the Arctic Gas corridor crosses swan breeding or staging areas. The potential for aircraft disturbance of staging birds during the construction phase is of particular concern because frequent flights will be required along the Mackenzie River-Yukon coast to provide access to pipeline facilities. Virtually all important staging areas, primarily those along the lower Mackenzie, are vulnerable to pollution, whereas only a few sites designated as breeding habitat are likely to be so affected. Disturbance from compressor stations may occur at four sites used for staging. Actual pipeline construction, which will take place in winter, will not disturb swans although an insignificant amount of nesting habitat may be lost through clearing of the proposed right-of-way. Construction-related disturbance, however, is anticipated at camps and other support facilities during summer.

Comparison Summary

Opportunities for pipeline-related conflicts and resulting effects on whistling swan populations are considerably greater on the Arctic Gas than on the Alaska Highway project; therefore, Alaska Highway is given the preferred rating of 5. Potential conflicts with whistling swans in the southern Yukon could occur at a few, widely separated sites and would affect only staging flocks. Through careful construction scheduling and proper placement of camps and stockpile sites, most anticipated conflicts can be avoided. Presence of aircraft during pipeline surveillance will cause temporary and largely avoidable conflicts with staging flocks. In general, protective measures should be relatively easy to achieve and will prevent pipeline construction and operation from having any measureable effects on swan populations.

Arctic Gas has more potential problems because the proposed route crosses or parallels critical staging and breeding areas over much of its length in the Yukon and Northwest Territories. Pollution of important staging areas is more likely to occur on the Arctic Gas route because fuel handling sites are located adjacent to and upstream from important swan-use areas and because fuel will be transported to wharves or stockpile sites via Mackenzie River, thus increasing the danger of fuel spills during transfer operations. Because alternative access is not available, relocation of fuel handling and transport away from Mackenzie River is not a mitigative option. Safeguard measures instituted at fuel storage and handling sites are not expected to be as effective as relocating problem sites. Similar difficulties are expected with regard to aircraft disturbance during construction in terms of effort required to achieve fail-safe migitation. Planes and helicopters will have to use airstrips along the North Slope and in the Mackenzie Valley which means that regardless of altitude and corridor restrictions, a certain amount of air traffic is bound to pass over staging areas used by swans. Such problems will not occur on the Alaska Highway route. Minor, short-term disruption of staging activities by surveillance aircraft is anticipated on both projects.

In conclusion, the chances of pipeline activities having detrimental effects on whistling swan populations are significantly greater on the Arctic Gas route than on the Alaska Highway route both before and after mitigation. Therefore, Arctic Gas is given a preference rating of 3.

GOLDEN EAGLE (*Aquila chrysaetos*)

Problem Definition

Golden eagles in North America are largely confined to western mountain ranges. They arrive on northern breeding areas during April and May and nest in cliffs or other high places usually overlooking tundra. Egg-laying and incubation probably begin in April and birds remain at the aerie until the young fledge in late July or early August (Campbell and Davies 1973, Jacobson 1974).

Olendorff and Stoddart (1974) suggested that availability of nest sites could limit populations of golden eagles; therefore destruction or degradation of nesting habitat could have an adverse effect on northern eagle populations. Nesting golden eagles are especially intolerant of human intrusion and have been known to abandon aeries when approached by people (Camenzind 1969, Whitfield et al. 1969, Spofford 1971). As with other raptorial species, golden eagles exhibit considerable variation in response to disturbance. Whereas some readily desert eggs or young, others return to aeries in disturbed areas and successfully raise young over several years (Nelson in Hickey 1969). Golden eagles appear to be little affected by aircraft overflights.

Potential Impact

Alaska Highway Route:

Godfrey (1966) states that golden eagles breed in the Kluane Mountains and are widely distributed through the southern Yukon. Several nests and large numbers of adults have been observed in Kluane Range between the Donjek and Slims Rivers (Hoefs 1973, Theberge 1974, Banfield 1953, Foothills 1976b); there is one active aerie at Haeckel Hill near Whitehorse (D. Mossop personal communication). Soper (1951) reported golden eagles near Teslin Lake and Teslin River.

No golden eagle aeries have been identified within 5 km of the proposed Alaska Highway route, which may reflect a lack of knowledge on breeding distribution rather than an actual absence of active nests. Sites that appear suitable for nesting and that should be surveyed before any final recommendations are made are cliffs adjacent to Pickhandle Lake, Ibex River, Pine Lake and Rancheria River. Based on existing information, no known problems or problem areas that require mitigation have been identified.

Arctic Gas Route:

Golden eagles are fairly common breeders on the north slope of Yukon Territory along the lower Mackenzie and in mountainous terrain adjacent to the delta. The Richardson Mountains appear to be the most important areas used by golden eagles in summer. Campbell and Weber (1973) reported highest eagle densities in mountain tundra habitats and lowest in the south Mackenzie Delta and at Blow River-Shallow Bay. Beebe (in Jacobson 1974) estimated that the Richardson Mountains may contain the highest densities of nesting golden eagles in North America.

The most serious conflicts are anticipated in the British-Richardson Mountains where compressor stations or summer construction sites lie within 5 km of active aeries. To date, there are several known nests that may be affected if pipeline work occurs there during the period of nest occupancy. Passage of aircraft during construction and operation phase could disrupt nesting golden eagles if aeries are closely and directly approached; otherwise, aircraft should have little impact on breeding pairs.

Comparison Summary

Neither project is likely to have a measureable impact on populations of golden eagles, largely because aeries tend to be in cliffs and are not in direct conflict with pipeline right-of-way activities. A small number of active aeries are threatened by the Arctic Gas project and most of the events likely to affect eagles at these sites can be mitigated. Current plans for winter construction in Mackenzie Valley-Yukon coast areas will eliminate many conflicts associated with actual building of the pipeline.

Effects of compressor noise can be reduced by moving problem stations or, if that proves impractical, by muffling emitted noise. Problems caused by aircraft can be overcome by restricting flights to designated corridors and by instituting minimum altitude restrictions.

The main difference between the Arctic Gas and Alaska Highway routes is that no known conflicts with golden eagles exist along the Alaska Highway route, although additional study is required to confirm the presence or absence of nesting golden eagles within the proposed corridor. If one assumes, however, that investigations done to date are correct in indicating no active nests near the Alaska Highway route, then that route must be given a preferred rating of 5. Arctic Gas is somewhat less preferable, largely because known potential for conflict exists in the British and Richardson Mountains, and is assigned a rating of 4.

BALD EAGLE (*Haliaeetus leucocephalus*)

Problem Definition

The breeding range of bald eagles generally coincides with the distribution of forest habitats. They occur throughout central Canada from Newfoundland to the British Columbia coast and north to the Mackenzie Delta and Alaska-Yukon border; nests are usually situated in trees near larger bodies of water (Godfrey 1966).

Nesting bald eagles may be adversely affected by right-of-way clearing, aircraft, human intrusion, noise and construction activities; however responses of individual pairs are often difficult to predict. Some pairs have been known to suffer losses of production because of human activities more than a kilometer away (Juenemann 1972 in Snow 1973). Others have tolerated people at very close range with no subsequent reduction in productivity (Grier 1969). Such inconsistencies of reaction suggest that site-specific investigations are required for each pair that could be potentially affected by pipeline projects.

Potential Impacts

Alaska Highway Route:

Breeding pairs have recently been reported along the proposed Alaska Highway route near Squanga Lake, Swift

River (Foothills 1976b) and along Meister River (D. Mossop personal communication). Birds have been recorded at Kluane Lake, along Yukon River and at Ibex River. Soper (1951) reported a nest with fledging young at Johnsons Crossing in July 1950.

It is unlikely that all currently active aeries have been discovered along the Alaska Highway route where few ornithological studies have been undertaken that relate specifically to the proposed pipeline area. What evidence is available from the southern Yukon (Foothills 1976b) indicates there are two aeries that may be situated within 5 km of the proposed Alaska Highway pipeline. Both will be affected by disturbance from aircraft and construction activities and are vulnerable to habitat destruction from right-of-way development. Eagles nesting at the Swift River may be affected indirectly if spilled fuel enters Swift River via Logjam Creek, thereby reducing the availability of prey. Noise from compressor station FY-6 may discourage nesting along adjacent segments of the Swift River.

Arctic Gas Route:

Bald eagles are common summer residents in the Mackenzie Valley and Delta and are occasionally found along the Yukon coast (Porsild 1943, Salter et al. 1974). They normally arrive in the Mackenzie Valley from late April to early May. Nesting densities are highest along upper reaches of the Mackenzie River south of Fort Simpson, although Schweinsburg (1974a) recorded one nest in the Moose Channel area, Mackenzie Delta. Greatest numbers of nests occur along larger lakes near the Alberta border (Salter 1974c, Schaafsma 1975). In most years, bald eagles leave arctic and boreal ranges by late September-early October (Jacobson 1974).

As in the case of the Alaska Highway route, additional surveys should be conducted to provide more complete account of the breeding distribution of bald eagles nesting along the Arctic Gas route. According to existing information, it is possible that one active aerie (near Moose Channel) is located within 5 km of the Arctic Gas route; however, the current status of that site is not known. Other aeries in the Mackenzie Valley area and especially those south of Fort Simpson (Trout and Bistcho Lake region) are situated at least 11 km from the proposed route and should not be affected by project activities.

<u>Comparison Summary</u>

It appears there is greater potential for conflicts with bald eagles on the Alaska Highway route than the Arctic Gas route, hence the latter route is preferred. However, neither project is expected to have a measureable effect on regional populations. Activities likely to reduce local production or increase mortality along either route can be reduced through project scheduling, regulation of aircraft flight paths and minor route relocations. Compared to Arctic Gas, then, Alaska Highway is only slightly less preferred and is given a rating of 4.

WHITE-FRONTED GOOSE (*Anser albifrons*)

Problem Definition

The breeding range of white-fronted geese in Canada extends across the arctic mainland from the west shore of Hudson Bay to the Alaska border (Godfrey 1966). Whitefronts nest on the tundra, along lakes and streams, on islands or in river deltas; they often nest in colonies (Godfrey 1966). Recent estimates indicate there are approximately 240,000 white-fronted geese in North America (Bellrose 1976).

Whitefronts, like other species of geese, are susceptible to disturbance from activities associated with pipeline construction and maintenance. Fuel spills, aircraft overflights and construction activities in spring staging areas could disrupt feeding-resting activities which in turn could deplete energy reserves and result in reduced production. Similar disturbance on breeding grounds could lead to loss of eggs through nest abandonment (Jacobson 1974). In fall, construction-related activities at staging areas could trigger premature southward migration and increase the likelihood of mortality en route to wintering grounds.

Potential Impact

Alaska Highway Route:

According to Soper (1951), small flocks of white-fronted geese migrate through the southern Yukon, stopping at Teslin and Marsh Lakes. Hoefs (1973) observed six birds in Duke River delta on 6 May 1971. Whitefronts, possibly of the rare Tule race (*A.a. gambelli*) which nests at Old Crow Flats, are also known to stop at Burwash Flats, Kluane Lake (Foothills 1976b). From 26,000 to 50,000 birds are believed to migrate over the southern Yukon to breeding grounds in western and central Alaska (Bellrose 1976). They do not nest in the southern Yukon.

Because very few whitefronts stop in the southern Yukon during spring and fall, pipeline-related events there should have no measureable effect on populations migrating along the Alaska Highway route. Staging whitefronts could be affected by fuel and toxic material spills at two sites. Aircraft and construction activity could disrupt geese at three sites, whereas noise from compressor stations during pipeline operation will be an impacting factor at one site. In all cases, however, only small numbers of birds would be subject to any of the above disturbances, hence pipeline activities will have no measurable effect on regional or continental populations.

Arctic Gas Route:

White-fronted geese arrive in the Mackenzie valley during late May or early June on their way to breeding grounds on the arctic tundra (Dzubin et al. 1964, Godfrey 1966). Flocks commonly stage at island and sand bar habitats on Mackenzie River from Norman Wells to Arctic Red River, but estimates of staging populations are not available. Nesting occurs in low densities on the Yukon coast from the Mackenzie Delta to Alaska (Dzubin et al. 1964).

Fall migration begins in early August and continues until late September. Koski (1975) stated that whitefronts probably do not stop during their eastward fall migration along the Yukon coast until they reach the Mackenzie Delta, where an estimated 25,000 and 22,000 birds were observed, primarily on the outer delta, in 1973 and 1974, respectively. According to Koski (1975), Shallow Bay and Blow River delta are also important fall staging areas. Southward migration through the Mackenzie Valley occurs in September, with some birds stopping at lakes and river islands along the way (Salter 1974b, Barry 1967). According to Bellrose (1976), 51,000-100,000 whitefronts may migrate through the Mackenzie Valley while 26,000-50,000 pass along the North Slope between Alaska and Mackenzie Delta.

Potential conflicts with spring-staging geese are anticipated at river islands, lakes and deltas between Blow River and Fort Norman. Within this area (860 linear kilometers), almost all important staging sites are identified as being susceptible to pollution from fuel spills at wharves and stockpile sites along the Mackenzie River. The possibility that supply aircraft will drive geese away from staging areas, either temporarily or for the entire spring staging period, exists at sites along the Mackenzie River from Norman Wells to Arctic Red River. Noise from compressor stations is considered likely to affect staging geese at three sites. Pipeline construction along the proposed right-of-way is scheduled for winter, hence associated activities should not conflict with staging white-fronts.

Only 10 km^2 of approximately 300 km^2 of coastal range between the British Mountains and Arctic Ocean will be degraded by development of the pipeline right-of-way. Construction work, which is scheduled for winter, will not affect nesting geese; and other disturbances such as aircraft, compressor noise and pollution should affect a small percentage of the geese that breed in the western Arctic.

Comparison Summary

The Alaska Highway route is clearly preferable to the Arctic Gas route with respect to white-fronted geese. Data on population distribution clearly indicates that the Mackenzie Valley and Yukon coast are used more extensively and by more birds than the southern Yukon. The number of potential conflicts is also considerably greater on the Arctic Gas route. Mitigation in the southern Yukon can be achieved relatively easily because whitefronts use a few, widely separated areas within the proposed corridor, primarily during spring migration. Proper location of two stockpile sites, and reduction of construction and aircraft activity near staging areas during spring-fall use period will eliminate most problems.

Potential conflicts will be more difficult to prevent along the Arctic Gas route. There are opportunities for problems over extensive areas of the Mackenzie Valley-Yukon coast and the majority of these cannot be absolutely avoided by relocation of pipeline facilities because few areas for alternative alignment away from whitefront habitats exist on the Arctic Gas route. Potential disturbance from aircraft can be greatly reduced by instituting flight corridors and minimum altitude restrictions; disturbance caused by compressor noise can be eliminated or at least minimized through minor relocations or by using noise abatement devices.

The most serious potential problem would be a major fuel spill into the Mackenzie River before thaw, which could degrade key staging sites over several years. The likelihood of such an event can be reduced, but not entirely eliminated, by instituting proper safeguards at stockpile sites located on the river or its tributaries. Spills from barges or wharves during the summer transport period would be of less concern owing to the diluting effect of an open

Mackenzie River and the accelerated rate of breakdown of toxic substances. In addition, summer construction work at pipeline facilities along the North Slope segment will affect small numbers of nesting pairs, possibly causing some nest abandonment and loss of offspring; however, such losses would not be expected to cause noticeable reductions of regional breeding populations.

In conclusion, the greater difficulties anticipated along the Mackenzie Valley-Yukon coast are responsible for the lower preference rating of 3 assigned to the Arctic Gas project.

BRANT (*Branta bernicla nigricans*)

Problem Definition

The Pacific brant nests in colonies in low-lying coastal habitats from Cape Bathurst west to the southwest coast of Alaska. Bellrose (1976) indicates the population has remained fairly stable (approximately 140,000 birds) since 1951.

Brant nests are extremely susceptible to destruction from flooding and predation (King 1970, Einarsen 1965, Barry 1967), hence activities that disturb nesting birds will jeopardize the breeding success of local populations. Investigations along the arctic coast have shown that brant will readily flush and abandon nests when approached by people or aircraft (Jones and Jones 1966, Einarsen 1965, Gollop et al. 1974). In migration, they gather in quiet bays and lagoons, making them vulnerable to disturbance from humans, aircraft, watercraft, pollution and construction activities at nearby borrow pits and stockpile sites (Jacobson 1974). On northern breeding ranges, brant are dependent on brant grass (*Carex subspathacea*) for food. Destruction of this sedge through pollution or excavation would undoubtedly have an adverse effect on breeding success of brant.

Potential Impacts

Alaska Highway Route:

No conflicts are anticipated because brant do not breed or stage within the proposed pipeline corridor.

Arctic Gas Route:

Brant are present only on the Arctic Gas route. They are found primarily in coastal areas during migration and breeding. Bellrose (1976) indicates that 6000-25,000 brant migrate along the Yukon coast in spring and fall with peak movements occurring in early June (McEwen 1958, Schweinsburg 1974a) and again in late August. Migration almost always follows the shoreline and rarely extends inland more than 90-180 m, although offshore movements are fairly common (Bent 1925, Gollop and Davis 1974a).

Only a small percentage of the Pacific Flyway population nests in the western Canadian Arctic. Slaney (1974) estimated the total population in the Mackenzie Delta at 200 individuals in 1973. Elsewhere, nests have been found in the mouth of Blow River (R.W. Campbell in Jacobson 1974), the Barrier Islands (Slaney 1974), Kendall Island (Smith et al. 1964) and on islands offshore from Firth River delta (Gollop et al. 1974). Schweinsburg (1974a) estimated 1.5 brant/km^2 inhabit coastal areas between Prudhoe Bay and Blow River.

Approximately 200 km of coastal habitat is vulnerable to pipeline-related activities that could affect nesting or staging brant. Brant are susceptible to disturbance from aircraft during construction and operation over this entire area. Other site-specific problems that require mitigation have been identified for three sites; causes of disturbance include watercraft, human presence, and pollution.

Comparison Summary

The Alaska Highway route is clearly favored over the Arctic Gas route because brant do not occur in the southern Yukon. Most conflicts anticipated along the Yukon coast (Arctic Gas route) can be reduced in severity by locating pipeline facilities away from the coastline and tidal flats, which are critical brant feeding and resting areas, and by scheduling aircraft and boat traffic to avoid occupied nest colonies and staging areas. The most serious potential problem is the possibility of fuel spills offshore along the Yukon coast which could foul stands of brant grass (*Carex subspathacea*) that make up the bulk of the brant diet in the western Canadian Arctic. Widespread pollution of tidal flats could render staging and molting habitats unsuitable to brant for several years. Mitigative measures, of course, would lower the chances of such spills occurring, but prevention cannot be absolutely guaranteed. Therefore, the Arctic Gas route is given a moderately low preference rating of 2 compared to 5 for Alaska Highway.

DIVING DUCKS (Aythyinae)

Problem Definition

Representative species of this large and diverse subfamily of waterfowl breed throughout Canada in grassland, boreal forest and arctic tundra habitats. For purposes of convenience, diving ducks have been divided into two major but rather arbitrarily defined groups - freshwater ducks and sea ducks. Freshwater divers include species such as canvas-back (*Aythya valisineria*), redhead (*A. americana*), greater (*A. marila*) and lesser scaup (*A. affinis*), ring-necked duck (*A. collaris*), goldeneye (*Bucephala clangula*, *B. islandica*), bufflehead (*B. albeola*) and common merganser (*Mergus merganser*), which occur on inland lakes, marshes and streams during breeding and post-breeding seasons. The harlequin duck (*Histrionicus histrionicus*) and red-breasted merganser (*M. serrator*) are also included in this group even though much of their life cycle is spent in marine habitats. Sea ducks consist of those species that are largely dependent on coastal areas even though many species may nest in inland, freshwater habitats. Representatives of this group are the scoters *Melanitta deglandi*, *M. perspicillata*, *M. nigra*), eiders (*Somateria mollissima*, *S. spectabilis*) and oldsquaw (*Clangula hyemalis*).

Aircraft take-offs, landings and low level flights in areas used by diving ducks have the greatest potential for disturbance, especially during brood and molt periods when ducks are relatively helpless (Jacobson 1974; Schweinsburg 1974a,b). Possible adverse effects caused by aircraft include abandonment of productive habitats, reduced survival of young and molting adults, and reduced nesting success. Construction-related activity (human presence, water and land traffic) along rights-of-way and around support facilities and work sites located near waterfowl use areas could have similar effects. Clearing of rights-of-way and pollution of waterbodies through accidental spills could degrade duck habitats or at least make them unattractive for several years.

Potential Impact

Alaska Highway Route:

The freshwater diver most frequently observed in the southern Yukon is the greater scaup. Barrow's goldeneye, bufflehead, harlequin duck and common merganser, all of which probably nest near rivers, lakes and marshes along the proposed pipeline route, are also common in the southern Yukon (Hoefs 1973, Bellrose 1976). Other species that breed regularly in the area include lesser scaup, common goldeneye, canvasback and red-breasted merganser (Godfrey 1966, Bellrose 1976). Numbers and regional distribution of these species in southern parts of the Yukon are poorly known. White-winged and surf scoters are the only sea ducks known to nest along the proposed corridor, the former being most abundant (Hoefs 1973). Oldsquaws and black scoters have been recorded but probably do not breed in the area (Hoefs 1973, Bellrose 1976).

Important breeding areas within the proposed pipeline corridor are Kluane, Pine, Marsh and Sulphur Lakes, wetlands near Pickhandle Lake, Donjek River, Squanga Lake-Michie Creek, Kloo Lake, Nisutlin Bay, the confluence of Smart and Swift Rivers, Rancheria River valley and Dodo Lakes. These areas plus Kluane River, Little Teslin Lake, Teslin River and Lake and Morley Bay are also used for staging by migrating divers.

Opportunities for conflicts caused by surveillance aircraft during pipeline operation exist at an estimated 15 sites, although such disturbance should not have a measurable effect on the status of regional populations. Construction-related activities (human presence, movement of equipment) could have an impact on breeding/staging birds at 11 sites. Fuel and toxic material spills and noise from compressor stations will have less impact in terms of number of sites affected, but the effects of such disturbance are likely to last longer than those anticipated during construction.

Arctic Gas Route:

Twenty species of diving ducks have been recorded in the Mackenzie Valley Delta, and on the Yukon coast (Jacobson 1974). Of these, 17 species occur as breeders, 3 as casual visitors. The most abundant freshwater species are lesser and greater scaup, which comprised over 50 percent of all waterfowl observed in the Mackenzie Valley and were among the most common species in the Mackenzie Delta and on the Yukon coast during 1972 (Davis 1974). Campbell and Weber (1973) estimated approximately 51,000 scaup used the Mackenzie Delta in 1972. Canvasback also nest in the Mackenzie Valley and Delta but in low numbers; bufflehead and common goldeneye are widely distributed and breed in low densities along the Mackenzie River valley, whereas red-breasted mergansers occur along the arctic coast and to a lesser extent in boreal habitats. Other species such as Barrow's goldeneye, ring-necked ducks, common mergansers and redheads are confined to upper reaches of the Mackenzie; ruddy ducks occur as transients. Surveys conducted by the US Fish and Wildlife Service in 1973 showed that the stratum from Norman Wells to Inuvik had the highest brood index recorded in the Northwest Territories (Bellrose 1976).

Freshwater divers, with scaup dominant, arrive in the Mackenzie Valley between mid-May and early June and gather on thawed ponds or open stretches of the Mackenzie River in the vicinity of islands. Other major spring concentration sites include the Brackett Lake wetlands, Mackay Creek area and Ramparts River area (Davis 1974). Southward migration through the Mackenzie Valley begins in mid-August and continues until early October.

The most common sea ducks along the Arctic Gas route are eiders, scoters, and oldsquaw. The common eider occurs in very large numbers (approximately 1,100,000) in migration along the Beaufort Sea coast. They nest in small colonies on low-lying tundra of the Yukon coast and molt in nearby lagoons and bays, although they do not appear to form large concentrations between the Alaska border and the Mackenzie Delta. Migration is generally westward along the Arctic coast and occurs from about the first of July (pre-molt) to October (post-molt migration). Scoters (white-winged, surf and black) nest near inland waters but spend most of the year along seacoasts. White-winged scoters are most common of the three and stop in large numbers along the Mackenzie River during spring migration. Both surf and white-winged scoters nest in highest densities in coastal habitats along the proposed route but black scoters are rare in the area. Large numbers of scoters molt offshore from the Yukon coast and are especially abundant around Herschel Island (Gollop and Davis 1974b). Migration from molting areas begins in late August and early September and continues until early October, when most birds have left northern ranges. Oldsquaws, like eiders and scoters, migrate, nest and molt in greatest densities along the Yukon coast; a few reach breeding areas via inland drainages including Mackenzie River.

Approximately 1220 km (77 percent) of the proposed Arctic Gas route parallels or crosses areas used for staging; areas designated as breeding habitat are present along an estimated 760 km (48 percent) of the route. About 35 different sites regarded as important for nesting or staging are vulnerable to disturbance from low-flying aircraft. Fuel or toxic material spills at wharves, campsites and stockpile sites along the Mackenzie River and Yukon coast threaten many important waterfowl areas, while noise from compressor stations is likely to conflict with diving ducks at staging sites, especially along the upper Mackenzie River. Movement of boats and barges along the Arctic coast could disturb large flocks of sea ducks molting or staging near Herschel Island. Actual construction work along the proposed right-of-way will be a significant impact factor if work is carried out in winter as scheduled. The only effects of construction will be a minor loss of potential nesting habitat caused by trenching and movement of equipment along the pipeline alignment, and disturbance caused by summer construction activity at camps, compressor stations and other support facilities.

Comparison Summary

The Mackenzie Valley and Yukon coast are major migration routes for many diving duck species. Roe (1976) stated that ..."in terms of overall numbers, fall staging areas in the southern Yukon are used much less (by waterfowl) than those in southern Mackenzie District. Also these numbers suggest that the southern Yukon is comparatively unimportant as a waterfowl migration route".

There are also major differences between the two routes with regard to the severity of potential impacts.

Air traffic during construction will be much heavier on Arctic Gas than Alaska Highway; aircraft on the latter project will be used only for surveillance during pipeline operation. In addition, most stockpile sites along the Mackenzie River and Yukon coast will be supplied by barge, thus increasing the probability of major fuel spills occurring in marine and riverine habitats used for breeding, molting or staging. Pollution of waterbodies is less likely on the Alaska Highway project because stockpile sites will be supplied via the Alaska Highway. However, diving ducks on the Arctic Gas route will be less susceptible to disturbance from most construction-related activities (aside from outright destruction of breeding habitat along rights-of-way which is inevitable on both routes) because work there will take place in winter. Most duck-use areas along the Alaska Highway route lie within summer construction zones.

If proper mitigative measures are applied where project events are expected to conflict with diving ducks, no measureable reductions of populations will occur on either route. However, more effort will be required to achieve effective mitigation on the Arctic Gas project because of the large number and variety of potential conflicts identified along that route. Consequently, one must assume that the probability of control measures not being absolutely effective in mitigating potential conflicts is also greater for Arctic Gas. For these reasons, the Alaska Highway route is preferred over Arctic Gas, which is given a relatively low preference rating of 2.

SANDHILL CRANE (*Grus canadensis*)

Problem Definition

Sandhill cranes are wary and extremely sensitive to disturbance when breeding or staging. Approach of aircraft or people on foot will cause breeding cranes to leave nests or to flush from staging sites. Presence of people and equipment near traditional stopover areas could cause migrating cranes to avoid or leave these sites, but such effects should not persist beyond the period of construction. Compressor noise, movement or aircraft and pollution may also cause cranes to avoid suitable breeding or staging habitats.

Potential Impact

Alaska Highway Route:

Sandhill cranes are not known to breed in the southern Yukon (Godfrey 1966, D. Mossop personal communication) and only one pair (near Pickhandle Lake) has been recorded within the proposed pipeline corridor during the breeding season. Small numbers of migrants have been seen in spring at several sites between Kluane Lake and the Alaska border. According to D. Mossop (personal communication) the major migration route for cranes in the Yukon follows the Liard River valley located approximately 13 km east of the proposed route, and along the Yukon River.

Staging cranes are likely to be affected by surveillance aircraft at four sites during pipeline operation. Conflicts caused by construction activity and presence of people are anticipated at two sites, while fuel and toxic material spills at stockpile sites should have little if any effect on staging habitats. Disturbance from aircraft will be confined to the operation period over most of the route and will not be frequent enough to have anything but a short-term disruptive effect in staging flocks.

Arctic Gas Route:

Sandhill cranes probably breed throughout the District of Mackenzie (Godfrey 1966). Migrating cranes have been observed in the Mackenzie Valley from Fort Simpson to the Delta and along the Yukon coast in both spring and fall. Small numbers of cranes (flocks smaller than 50) have been observed staging at Fort Simpson (Salter 1974a) and on islands in the Mackenzie River between Norman Wells and Little Chicago (Campbell and Weber 1973, Salter et al. 1974).

Campbell (1973b) recorded four active nests and three broods in the Mackenzie Delta during summer 1972. He reported that crane densities in the Delta in 1972 ranged from 0.23/100 km^2 (upland tundra) to 39/100 km^2 (north delta wetlands); at Blow River and Shallow Bay densities were about 18/100 km^2. Southward migration of cranes through the Mackenzie Valley takes place from mid-August to mid-September.

Major fuel or toxic material spills at wharves and stockpile sites along Mackenzie River and Delta could result in extensive pollution of downstream islands, mudflats and sand bars used by cranes during spring and fall migration. Of special concern are island-sand bar habitats between Norman Wells and Little Chicago. Spills from the stockpile site at coastal MP 360 will pollute areas identified as nesting range in western Mackenzie Delta. Cranes are also vulnerable to disturbance from aircraft along the Yukon coast and in the Mackenzie Valley and Delta. Noise from compressor stations could affect staging or breeding cranes at only a few sites. No impacts caused by construction activity are anticipated along the route as long as work is carried out in winter as proposed.

Comparison Summary

Available information suggests that conflicts will be more numerous and widespread on the Arctic Gas than on the Alaska Highway route, although neither project is likely to result in any measureable reduction of regional populations. For these reasons, Alaska Highway is preferred over Arctic Gas.

Most potential impacts can be avoided along both routes if proper mitigative measures are taken. However, the chances that conflicts will occur are considerably greater for Arctic Gas, simply because there are more problem sites that require mitigation and supervision. Therefore, Arctic Gas is given a rating of 4, slightly less preferable than Alaska Highway.

CANADA GOOSE (*Branta canadensis*)

Problem Definition

At least 11 different races and 12 distinct populations of Canada geese are recognized in North America and virtually all of these have increased substantially in the last 20 years. Bellrose (1976) states that in 1974, the continental population was estimated at over 2 million birds. The Alaskan and Shortgrass Prairie populations, which occur along the two proposed pipeline routes, number about 250,000 and 125,000 geese, respectively.

Human activity and equipment and noise during construction in nesting areas may result in abandonment of nests and subsequent loss of eggs through predation or chilling. Similarly, disturbance of birds during staging or molting can break up family groups and place molting and staging flocks under stress. Canada geese are particularly vulnerable during spring staging when available feeding and resting areas are confined to a few open water areas. Aircraft disturbance and pollution at these sites could force pre-nesting birds into unsuitable habitats which in turn could reduce breeding success by delaying nest initiation and depleting energy reserves. Noise and activity around compressor stations could cause geese to avoid nearby staging, molting and nesting areas for as long as a pipeline remains in use. Presence of aircraft during pipeline operation will have minor, short-lived effects on staging flocks but should have virtually no adverse impact on nesting birds.

Potential Impact

Alaska Highway Route:

The breeding status of Canada geese (presumably of the Alaskan population) in the southern Yukon is not well known. Nesting has been confirmed in two areas: Nisutlin Bay and wetlands in the vicinity of Donjek River. Areas having high potential for breeding include wetlands and lakes in the Pickhandle Lake and Squanga Lake-Michie Creek areas. Important stop-over points during spring and fall migration include grassy shorelines of Kluane Lake (particularly at the north end), Marsh Lake (outlet area), Little Atlin, Little Teslin and Teslin Lakes, and Morley and Nisutlin bays. Teslin Lake serves as an important migration flyway.

Surveillance aircraft during operation are likely to temporarily disrupt goose staging activity, but should have no adverse effects on populations. Clearing and construction of the pipeline will destroy a small amount of potential breeding habitat but related activities could conflict with staging geese at four sites and with nesting and brood-rearing birds at one site. One staging area (Kluane River) and one breeding area (Donjek River) lie downstream from proposed stockpile sites and are therefore vulnerable to pollution. Fuel spills at the stockpile site at Teslin Lake are not likely to have a measureable effect on staging geese even though some shorelines used in spring and fall could be fouled. Noise from two compressor stations could drive birds away from staging areas or discourage them from landing, effects that may persist as long as the pipeline is in use. In general, Canada geese will be affected by the project should not suffer noticeable production or regional population losses as a result of pipeline construction or operation.

Arctic Gas Route:

Canada geese of the Shortgrass Prairie Population (Grieb 1970) nest in low densities along the Mackenzie Valley and Delta (Smith 1956-1962, Smith and Matlock 1963, Smith and Jensen 1964, Smith and Wellein 1965, Wellein and Jensen 1966, Godfrey 1966). According to Bellrose (1976) the Mackenzie River, including the Delta, serves as a principal breeding ground and migration route for this population which numbers approximately 125,000 birds. During spring migration which lasts from about early May to early June (Irving 1960), Canada geese often stop at islands and sand-bars en route to nesting grounds (Jacobson 1974).

Site-specific distribution and numbers of nesting birds in Mackenzie River-Yukon coast areas is not well documented. Density estimates for treeless parts of the Delta and coastal tundra east of the Delta are 0.01-0.25/km^2 and 0.015-0.2/km^2, respectively (Jacobson 1974). Approximately 300 Canada geese used the Delta in 1972 (Campbell and Shepard 1973); Davis (1974) estimated 0.046 geese/km^2 on transects between Alberta and Arctic Red River. Nesting and molting Canada geese have also been reported at Herschel Island (Slaney 1974, Dixon 1943, Brooks 1915). In general, Canada geese prefer to nest inland rather than along barren coasts (Jacobson 1974). There are no known molting areas of major importance along the proposed route. Fall migration through the Mackenzie Valley takes place from about early August to early October; some birds stop at river islands and lakes on the way, but most proceed nonstop to southern staging grounds (Campbell 1973a).

Available information indicates that the Yukon coast from the Alaska border to the Mackenzie Delta receives very little use by breeding or staging Canada geese. While project events may affect geese in this region (13 potential conflict areas have been identified, most of which are vulnerable to aircraft disturbance or pollution), they should not have any measureable impact on the status of the Shortgrass Prairie Population. More serious problems are anticipated in Mackenzie Valley and Delta areas which are used by large numbers of geese, especially for staging in spring. Fuel spills from wharves and stockpile sites along the Mackenzie River could foul critical staging habitat; presence of aircraft during construction is an impact factor at more than 20 specific sites regarded as important to staging Canada geese. Compressor stations are likely to affect staging geese at fewer than five sites.

Potential conflicts with nesting and molting birds cannot be determined on a site-specific basis because no key breeding areas have been specifically identified. Canada geese are known to nest in low densities throughout the route area, so one must assume that breeding birds will be affected to some extent by project activities; however, the project is not likely to have any major adverse impact on breeding success of the population. Persistent disturbance of spring-staging geese by supply aircraft or pollution of staging habitats could ultimately lead to lowered nesting success caused by stress and depleted energy reserves.

Comparison Summary

The Alaska Highway route is preferred because there are fewer opportunities for conflict over a smaller area than on the Arctic Gas route. In addition the data, while incomplete in many respects, indicate that comparatively few Canada geese stage along the proposed route and that breeding is restricted to a few, local areas (D. Mossop personal communication), many of which are located more than 5 km from the alignment. Potential conflicts that have been identified can be avoided by scheduling construction so that key use areas are not disturbed when geese are present, by placing stockpile sites and compressors such that spills and noise will not affect important wetlands.

Problems identified on the Arctic Gas route will be more difficult to solve partly because there are more opportunities for conflict over extensive areas compared to the Alaska Highway route. Another factor which makes

Arctic Gas less preferred, is that effective mitigation will be difficult to guarantee because limited access makes it impossible to completely avoid most problem areas by means of route relocation or adopting alternate methods of servicing camps and pipeline facilities. Therefore, Arctic Gas is given a preference rating of 3.

DABBLING DUCKS (Anatinae)

Problem Definition

Arctic and boreal forest regions of Canada are secondary production centers for dabbling ducks compared to the prairie and parkland habitats to the south. Northern ranges are important, however, in that they provide stable, relatively undisturbed habitat conditions over large areas and therefore support large numbers of ducks at low densities. This region is particularly important in years when production on the prairies is reduced because of drought. At such times, the North serves as a production reservoir and tends to buffer losses sustained on southern ranges.

As in the case of diving ducks, dabbling ducks may be adversely affected by activities associated with large scale developments such as pipeline projects. Construction activity, human presence, compressor noise and aircraft are likely to disrupt normal activities of dabbling ducks during staging, nesting, brood rearing and molt periods. Disturbance at close range or over extended periods could drive ducks out of favorable habitats or away from nests thereby resulting in production losses, abnormal expenditure of energy or severe stress, all of which could lead to reduction of regional populations. Some physical degradation of breeding or staging habitat will accompany right-of-way construction, especially where rights-of-way crosses undisturbed terrain. Fuel spills and alteration of natural drainage patterns may render traditional nesting, molting or staging areas uninhabitable longer than one year and could result in loss of nests, young and possibly adults.

Potential Impacts

Alaska Highway Route:

Six species of dabbling ducks breed in the southern Yukon, with mallards (*Anas platyrhynchos*) and green-winged teal (*A. carolinensis*) present in larger numbers than American wigeon (*A. americana*), blue-winged teal (*A. discors*) and shovelers (*A. clypeata*). Pintails (*A. acuta*) are common as migrants but apparently breed there in low densities. Arrival on breeding grounds occurs from mid-April to mid-May (Bellrose 1976); mallards, and pintails arrive somewhat earlier than the other species.

Drury (1953) stated that shovelers nest at Pine and Sulphur Lakes and that the Pickhandle Lake area is important breeding range for mallards and green-winged teal. Other nesting areas within the proposed pipeline corridor include the Enger Lakes-Dry Creek wetlands, marshes and ponds adjacent to Donjek River, Kloo Lake, Mendenhall River, Smart-Swift River junction, Rancheria River valley, the Squanga Lake-Michie Creek wetland complex, Nisutlin Bay (Teslin Lake) and lakes north of Swan Lake (Foothills 1976b). Key staging areas are at Pickhandle Lake, Donjek River wetlands, shores of Kluane Lake and Kluane River, Marsh Lake, Squanga and Little Teslin Lakes, Teslin River and Morley and Nisutlin Bays (Schmidt 1977).

Within the proposed corridor area, disturbance caused by human interference and pipeline construction could have an adverse impact on dabblers at 11 sites considered important for breeding or staging. Approach of aircraft during operation is expected to have a negligible effect on dabbling ducks during all seasons. Noise from compressor stations should not have any effect on nesting or staging dabblers, whereas seven waterfowl-use areas are vulnerable to pollution.

Arctic Gas Route:

Nine species of dabbling ducks have been recorded in Mackenzie Valley-Yukon coast areas. Species that occur as breeding residents are mallards, pintails, American wigeon, green-winged teal, blue-winged teal and shovelers. Of these, blue-winged teal nest in southern parts of the Mackenzie Valley as far north as Great Slave Lake whereas pintails, American wigeon and some green-winged teal breed along the Yukon coast and in Mackenzie Valley and Delta areas. Other dabblers are largely confined to Mackenzie River and Delta portions of the route.

The Mackenzie Valley is an important spring migration route for dabbling ducks from mid-May to early June.

Important staging areas used include river islands between Norman Wells and Arctic Red River, and wetlands at Brackett Lake-Mackay Creek and Ramparts River areas (Davis 1974, Campbell and Shepard 1973). Estimated breeding densities for all dabblers are 0.04-0.2/km^2 in boreal forest habitats with higher densities (0.3-2.0/km^2) occurring in Brackett Lake-Mackay Creek and Ramparts areas (Davis 1974). The Mackenzie Delta is an important mid-summer concentration area (Campbell and Weber 1973). Lakes and marine shores on the Yukon coast appear to be important molting areas for unsuccessful nesters and non-breeders (Bartonek 1969, Gollop and Davis 1974a,b). Fall migration along the Yukon coast and south through the Mackenzie Valley takes place from mid-August to mid-Octber (Gollop and Davis 1974a, Salter 1974b), with pintails by far the most abundant in coastal areas and lower Mackenzie Valley, including the Delta (Gollop and Davis 1974a, Campbell 1973a).

The potential for impacts resulting from the pipeline project exists over most of the route from Fort Simpson to the Alaska border. Areas where conflicts are likely to occur are essentially the same as those identified for diving ducks except in the case of watercraft which should not affect dabbling ducks. With regard to other project components, the possibility of fuel or toxic material spills threatens 17 breeding/staging areas, while aircraft and compressor noise are considered potential impacting agents at more than 30 sites used for staging.

Comparison Summary

The proposed Arctic Gas route lies along a major migration corridor used by thousands of dabbling ducks (Campbell and Shepard 1973). In comparison, the Alaska Highway route appears to be much less important during migration, although this may reflect differences in the information available for the two routes -- data on waterfowl are considerably more detailed for Arctic Gas than Alaska Highway.

The amount of breeding and staging habitat that coincides with the two pipeline routes is much greater for Arctic Gas than for Alaska Highway. Thus, on the Arctic Gas route more dabbling duck habitat is likely to be degraded by right-of-way development and made less attractive because of aircraft and construction-related disturbance.

There are also more opportunities for conflicts on the Arctic Gas project than on the Alaska Highway project. In the first place, Mackenzie Valley-Yukon coast areas support larger numbers of breeding and staging ducks than the southern Yukon (Roe 1976, Bellrose 1976), therefore pipeline-related disturbances on Arctic Gas will affect a greater portion of continental populations than Alaska Highway. The two projects also differ in methods of transporting fuel and materials to camps and storage facilities. On Arctic Gas, supplies will be brought in by barges and aircraft during construction. On the Alaska Highway project, railroads and highways will be used to transport most fuel, people and equipment to work sites, which should produce fewer opportunities for impact on dabbling duck habitats and populations than water-air transport. However, the effects of actual construction will be more severe on the Alaska Highway project because most work will take place in summer whereas winter construction is scheduled on Arctic Gas.

In general, mitigation of potential conflicts resulting from construction activity will be more difficult to achieve for Alaska Highway, but problems of aircraft disturbance, pollution and compressor station noise will require greater mitigative effort for Arctic Gas. Overall, Arctic Gas has more potential for impact in need of mitigation than Alaska Highway, hence the latter route is preferred. A preference rating of 3 is assigned to Arctic Gas.

The Transmission of Prudhoe Bay Gas to American Markets: A Preliminary Environmental Comparison of the Canadian Arctic Gas Pipeline and the Foothills (Yukon) Pipeline in the Yukon and Northwest Territories

BACKGROUND DOCUMENTATION

FISH

CONTENTS

Hayden, W. 1977. Fish. Pages 233 to 274 in Background documentation. Appendix to The transmission of Prudhoe Bay gas to American markets: A preliminary environmental comparison of the Canadian Arctic Gas pipeline and the Foothills (Yukon) pipeline in the Yukon and Northwest Territories. Alaska Highway Pipeline Panel, Winnipeg. 420 pp.

SUMMARY

The proposed Alaska Highway and Arctic Gas pipelines were compared with respect to their potential for affecting seven selected species of fish: arctic char, chinook and chum salmon, Dolly Varden, lake trout, whitefish, and arctic grayling. The magnitude, duration, and mitigability of potential effects was considered in determining route preference.

Arctic char are absent from the Alaska Highway route in Canada, so this route was preferred (Table 1). Along the North Slope and west Delta regions of the Arctic Gas route the potential for chronic siltation and the possibility of dewatering downslope spawning and overwintering areas make this route less preferred for arctic char.

Both chinook and chum salmon are virtually absent from the Arctic Gas route, making it the preferred route for both species. Because of the relatively limited numbers of these species expected to be vulnerable to impact along the Alaska Highway route and because of their relatively low use within this corridor, this route is only slightly less preferred for salmon.

Dolly Varden occur infrequently along the Arctic Gas route, making it the preferred route for this species. The Alaska Highway route parallels several drainages inhabited by Dolly Varden, thus affording greater chance for interaction. The species is also more abundant here, and

Table 1. Summary of fish comparison[a] for the Alaska Highway and Arctic Gas pipeline routes in Canada north of the 60th parallel.

	Relative Importance Weighting	Relative Preference[b]		Weighted Preference[c]	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
FISH COMPONENT					
Arctic char	17	5	3	85	51
Chinook salmon	13	4	5	52	65
Chum salmon	11	4	5	44	55
Dolly Varden	7	3	5	21	35
Lake Trout	7	3	5	21	35
Whitefish	4	5	5	20	20
Arctic grayling	4	5	5	20	20
Totals	63			263	281

[a] See Introduction and Approach for detailed discussion of Relative Importance Weightings and Relative Preference ratings.

[b] Relative Preference is based on a scale of 1-5, where the preferred route is assigned a value of 5.

[c] Weighted Preference = Relative Importance Weighting X Relative Preference.

more harvested by man. For these reasons, the Alaska Highway route is less preferred for Dolly Varden.

There are few locations along the Arctic Gas route where interactions will occur between the project and lake trout; therefore, this route is the preferred one for this species. The Alaska Highway project has a higher potential for causing disturbance to lake trout because of the long distances over which it parallels lake shorelines; therefore, this route is less preferred relative to this species.

Interaction with whitefish along the Alaska Highway route is likely along paralleled lakeshores of Kluane, Marsh, and Teslin Lakes. Unique whitefish populations could be seriously disturbed at two small lakes (Squanga and Little Teslin Lakes) near this alignment. The Arctic Gas project could interfere with important subsistence fishing for whitefish by residents of Fort McPherson and Arctic Red River in the lower Mackenzie River Valley. Relative to whitefish neither route is preferable because potential problems are about equal.

Predominant summer construction of the Alaska Highway project is expected to affect arctic grayling nursery and feeding habitat. Construction-related interference with sport fishing is also likely along this route. Along the Arctic Gas route toxic spills and conflicts with subsistence fishing are more likely to occur than along the Alaska Highway project route. Ice-rich soils may cause chronic siltation problems on the Arctic Gas route. Both routes were assigned equal preference ratings based on their potential effects to grayling.

In conclusion, this comparison shows a slight preference for the Arctic Gas route relative to effects on fish. This preference may result largely from the fact that more of the compared species are found along the Alaska Highway route. The balance of preference could go to either project depending on the adequacy of controls which will, in turn, depend on site-specific investigations before construction. Assuming such controls were equally effective for both projects, characteristics of the projects' physical settings which control such factors as ease of access for emergency repairs could be the key factors in determining which is the preferable route relative to impact on fish.

INTRODUCTION

The construction and operation of either the Alaska Highway pipeline or the Arctic Gas pipeline will affect fish populations in waterbodies associated with these developments. To compare effects of these pipelines on fish populations, seven major fish species were selected: arctic char, chinook salmon, chum salmon, Dolly Varden, lake trout, whitefish, and arctic grayling. These species were chosen because they have the most specific environmental requirements and are thus more vulnerable to disturbance, and because they are of the greatest harvest use and value. Not all these species are found on both proposed routes, but their importance weightings reflect their relative importance in northwestern Canada generally, rather than on specific project routes.

The primary impacts of both proposed projects considered in this comparison were the same for all species, and included: degradation of habitat and direct mortality to fish and fish eggs, disruption of sensitive fish activities, disturbance of unique or special fish situations, and construction - fish harvest conflicts.

Habitat degradation will result from erosion of the cleared right-of-way and from stream crossings silting downstream areas. Siltation is of greatest concern where fish utilize redds for spawning, because silt could smother eggs and alevins (newly hatched eggs prior to emergence from the gravel as fry). Toxic spills could affect fish habitat as well as cause direct mortality to fish and eggs. Degradation of stream habitat by siltation and toxic spills would, except for chronic erosion problems, be of shorter duration than similar impacts to lake habitats because of the clearing and cleansing action of flowing waters.

Sensitive fish activities most vulnerable to impact are migration and spawning, both of which may have critical time constraints. Overwintering habitat most sensitive to disturbance is that limited to stream pools or spring areas. These sensitive fish activities could be interferred with if pipeline crossings are inappropriately located, or if construction activity is inappropriately timed.

Unique fish situations require special consideration since they are often of high scientific interest and value. Examples include unusual or isolated fish populations. Project-caused disruptions in these areas could result in considerable impact, and these areas are best avoided if special mitigative procedures cannot be designed to avoid disruptions.

Construction-fish harvest conflicts depend largely on the location and timing of construction and the location of ancillary facilities. Protection of subsistence, commercial and sport fisheries will require a thorough identification of fishing sites.

The highest common level of information available for the addressed species in each project corridor was used to compare routes. Species distribution was outlined, the size or relative size of populations was estimated where possible, and the amount and importance of harvest was also considered. Project aspects that would most severely affect each species were identified, and potential effects and their duration were compared between projects. Preference values were assigned based on the procedures outlined in the Introduction and Approach section.

ARCTIC CHAR (*Salvelinus alpinus*)

Problem Definition

Arctic char has the most northerly distribution of any freshwater fish and is abundant in arctic coastal rivers (Scott and Crossman 1973, McPhail and Lindsey 1970). They are highly valued by both sport and subsistence fishermen, and are being harvested more and more in arctic commercial fisheries (Glova and McCart 1974, Scott and Crossman 1973).

Anadromous char move to the sea in spring and return to freshwater in fall. This sea run is not associated with spawning but is apparently a feeding migration that mature adults may not undergo in the season prior to spawning (Johnson 1975, Craig and McCart 1975). Spawning populations are of several age-classes, and mature fish probably do not spawn in consecutive years (Johnson 1975, Craig and McCart 1975). Fall spawning occurs in gravel-bottomed, freshwater lakes and rivers with permanent flows. Eggs incubate in redds overwinter and fry emerge from the gravel during spring break-up (Scott and Crossman 1973). Young arctic char spend 5-8 years in freshwater before their first migration to the sea (Johnson 1975).

The most sensitive period of anadromous arctic char life history is during winter when fish and incubating eggs are present in restricted overwintering and spawning areas (Craig and McCart 1975). During this period actions that interrupt water flow or degrade water quality would cause severe impact to char populations. Interruption of spring or fall migrations, and toxic spills and siltation in coastal feeding areas would also cause serious impact, though less severe because entire populations would not be subjected to impact at these times.

Potential Impact

Alaska Highway Route:

No arctic char are found in this pipeline corridor within Canada, thus this route presents no potential impact to char populations.

Arctic Gas Route:

This route will cross 12 streams and rivers on the north slope and Delta drainages (Craig Creek, Fish Creek, Malcolm River, Firth River, stream 1000, Spring River, Crow River, Trail River, Babbage River, Blow River, Big Fish River and Rat River) from which arctic char have been reported (McCart et al. 1974). The alignment will also be upslope of four springs known to be spawning or overwintering areas for char (Jones 1976). Fish Creek, Firth River, Babbage River, Big Fish River and Rat River all serve as migration routes to major upstream spawning areas (Craig and McCart 1974). Anadromous char utilize the nearshore area of the Beaufort Sea coast during summer for feeding, while pre-smolt juveniles and perhaps spawners of the year remain in freshwater during this period (Craig and McCart 1975).

Dewatering of char spawning and overwinter areas would cause severe impact to the fish and incubating eggs. Dewatering could occur during construction as a result of water withdrawal for camp, snow-road and pipe-testing uses. During operation of the pipeline, dewatering of downslope areas could be caused by the buried, chilled pipeline and associated frostbulb affecting aquifer flow. There is high potential for dewatering downslope areas on the Firth River delta where a spring and downstream river pool contain char spawning beds and overwinter populations.

Short-term interference with char migrations could be caused by inappropriately timed in-stream activity during construction or repair operations. Chronic delay or blockage of spring char migrations could also be caused by ice dams resulting from frostbulb effects during pipeline operation. These situations would cause greatest impact in major char rivers (Fish Creek, Firth River, Babbage River, Big Fish Creek and Rat River).

Toxic spills and habitat degradation via organic wastes and siltation could cause severe impact to near shore feeding populations and downslope spawning and overwintering areas. Toxic spills could originate from fuel storage sites, maintenance areas, or methanol used in pipe testing; organic wastes could originate from construction camps. These effects would be short-term in nature. Silt would originate from erosion of the right-of-way, and from trenching and borrow activity. This problem could be persistent if disturbed terrain is not stabilized. A major wharfing and storage site is planned at the mouth of Fish Creek at Komakuk Beach. Fuel and methanol will be distributed along the entire alignment during construction. Construction camps are planned near Fish Creek, Babbage River and Blow River and compressor station construction camps are planned near Malcolm River, Babbage River and Rat River. Borrow activity is planned near Craig Creek, Fish Creek, Malcolm River, Firth River, Spring River, Big Fish River and Rat River.

Interference with domestic char fishing could occur at the mouths of Fish Creek, Malcolm River, Babbage River, Rat River and near Shingle Point (Northern Environment Foundation 1976) by wharfing and stockpiling activities near harvest areas, or by siltation and toxic spills originating from the alignment upstream of the harvest areas. These effects would occur during the construction period.

Most of the potential effects can be minimized with adequate design and controls, but several would be very difficult to mitigate. Although several methods have been proposed to deal with possible frost-bulb blockage of subsurface flows none of the methods are proven techniques. Containment and clean-up of toxic spills would be very difficult in flowing water. It may be impossible in flowing water under ice. Finally erosion of the right-of-way may lead to chronic siltation of North Slope streams and rivers because of the fine-grained, ice-rich soils of this area. Erosion control may necessitate extensive repair activities along the right-of-way during the sensitive non-winter period.

Comparison Summary

Since arctic char are not present along the Alaska Highway corridor it is the preferred route relative to this species.

Major problems that would affect arctic char could occur along the Yukon/NWT North Slope area of the Arctic Gas corridor. Sub-surface water flow to spawning and over-wintering areas downslope of the alignment could be impeded or blocked by the frost-bulb created by a buried, chilled pipeline in the Firth River area. Mitigation proposed for this potential situation involves untried methods that may not work, thus creating the possibility of long-term impact. Toxic spills into flowing water, especially under ice may prove impossible to contain and clean up. This danger can be considered short-term impact, but nonmitigability of this situation makes it a serious concern. Finally, chronic erosion and siltation from the North Slope right-of-way could lead to extensive repair activities during the sensitive non-winter period. These problems make the Arctic Gas route less preferred (3) than the Alaska Highway route (5).

CHINOOK SALMON (*Oncorhynchus tshawytscha*)

Problem Definition

Chinook salmon are found throughout most of the Yukon River drainage. They are of major importance to subsistence and commercial fisheries of the Yukon River (Brock 1976) and offer high potential for sport fisheries in some areas.

Mature chinook salmon migrate from the sea into freshwater rivers during summer to spawn in headwater regions. They exhibit a strong homing tendency to parental spawning streams. Adults die following spawning and the eggs incubate in redds overwinter. Juveniles remain in freshwater for 2-3 years and return to the sea as smolts (Scott and Crossman 1973).

The most sensitive freshwater aspects of chinook salmon life history are spawning and incubation of eggs, emergence of fry from the gravel, and availability of space and food for juveniles (McNeil 1969). Migration is also an essential phase of their life history.

Interference with spawning migrations could occur during the construction period if in-stream construction activities are improperly timed. Downstream migration of smolts could be impeded by ice-dams caused by frostbulb of a chilled pipeline. Toxic spills during migration or egg incubation could cause severe impact to local populations, directly via mortality and indirectly by adversely affecting the food supply available to juvenile chinook salmon. Siltation could degrade spawning beds and smother eggs.

Potential Impact

Alaska Highway Route:

In the upper Yukon River drainage seven waterbodies to be crossed by the pipeline (Takhini, Yukon, McClintock, Teslin, Morley, and Swift Rivers, and Nisutlin Bay) are known migration routes and two (Ibex River and Wolf Creek) are suspected migration routes (Beak 1977, Brown et al. 1976, Brock 1976, Clemens et al. 1968). If chinook salmon ascend the White River drainage to the project zone, five waterbodies that may be chinook migration and spawning areas (White, Koidern, Donjek and Duke Rivers, and Swede Johnson Creek) would be crossed and one river (Kluane River) would be closely paralleled (Beak 1977, Lands Directorate 1973, Wynne-Edwards 1947). However, it is questionable whether chinook salmon now occur in the corridor area of the White River drainage.

Brock (1976) estimated that the chinook salmon population of the Yukon River upstream of Dawson was 36,700 fish in 1974. If this estimate represents the average upper Yukon chinook salmon spawning population, the relative use of waterbodies within the corridor can be summarized as in Table 2. Spawning areas in the upper Yukon are reported

Table 2. Relative use by chinook salmon of upper Yukon River waterbodies in pipeline corridor.

Waterbodies in corridor used by chinook salmon	Spawning areas relative to PLC[1]	Estimated numbers of fish	References and (explanation)	Percentage of upper Yukon river drainage chinook salmon population (36,700)
Takhini River	US[2]	165	Brown et al. 1976 (highest count made in 1975)	0.4
Yukon River (above Whitehorse)	US DS[3]	450 450	Brown et al. 1976 (1966-1975 average of fish counted through Whitehorse Fishway)	1.2 1.2
M'Clintock River	US	225[4]	(Author's estimate of 1/2 the fish upstream of Whitehorse Fishway)	0.6
Teslin River	DS US	2000- 5000	NBCYD[6] 1973 (estimates from technical report)	5.4- 13.6
Nisutlin Bay	?	1000-[5] 2000	NBCYD 1973 (of Teslin River estimate above)	2.7- 5.4
Morley River	DS	200-[5] 500	NBCYD 1973 (of Teslin River estimate above)	0.5 1.4
Swift River	US	100-[5] 300	NBCYD 1973 (of Teslin River estimate above)	0.3- 0.8

(1) PLC = pipeline crossing
(2) US = upstream
(3) DS = downstream
(4) Originating from Yukon River
(5) Originating from Teslin River
(6) NBCYD = Northern British Columbia and Yukon Division

upstream of proposed pipeline crossings of the Takhini, Yukon, McClintock and Swift Rivers, and at or downstream of proposed pipeline crossings of the Yukon, Teslin and Morley Rivers (Lands Directorate 1973). Migration and spawning has not been documented in the Ibex River, and it is questionable if chinook salmon still use Wolf Creek (Brown et al. 1976).

Inappropriately timed in-stream activity could interfere with a maximum of about 9 percent (3300 fish) of the estimated Yukon chinook salmon spawning population migrating to spawning beds during construction of the pipeline crossings. Toxic spills could affect a maximum of about 15 percent (5600 fish) of this population if the spills were massive or continuous during migrations in Takhini, Yukon and Teslin Rivers. Downstream siltation from construction activity could degrade an estimated 5 percent of available habitat (Hayden 1977) used by a maximum of about 10 percent of the spawning population (3700 fish).

Mitigation of these sources of impact appears possible and practical. Interference with spawning migrations can be avoided by appropriate scheduling of in-stream construction. Chance of toxic spills can be lessened by following the silt location and procedural recommendations made in the Initial Environmental Evaluation (Hayden 1977), and the proposed predominance of summer construction will enhance containment and clean-up of spills. Degradation of chinook salmon habitat by siltation cannot be avoided, but can be reduced by as much as one half with controls (Hayden

1977). Natural restoration of silted habitat should occur within 1-4 years (Hayden 1977) unless erosion of the right-of-way and stream banks is chronic, but ease of access to the right-of-way would facilitate repair and restoration that may be required.

Arctic Gas Route:

Chinook salmon are not found along this alignment thus no impact to this species will occur.

Comparison Summary

Since chinook salmon are absent from the Arctic Gas corridor it is the preferred route for this species and is given a preference rating of 5.

An estimated 36,700 chinook salmon utilize the Yukon River for spawning upstream of Dawson. Fifteen percent (5600) of these salmon may utilize waters within the Alaska Highway pipeline corridor. Inappropriately timed instream construction activity could interfere with spawning migrations of an estimated 3300 chinook salmon. The chance of toxic spills can be lessened by proper location of sites and careful construction procedure. Construction activity could cause degradation of 5 percent of available habitat used by an estimated 3700 chinook salmon. Degradation of this habitat will be of short duration if erosion and siltation are properly controlled.

Because of the limited number of chinook salmon vulnerable to impact along the Alaska Highway route, the anticipated short-term nature and mitigability of potential impacts, and because of the ease of access for right-of-way repair, a preference rating of 4 is given this route.

CHUM SALMON (*Oncorhynchus keta*)

Problem Definition

Chum salmon are distributed throughout the Yukon River system almost to its headwaters and in limited numbers in North Slope drainages and the Mackenzie River drainage. They are of considerable importance in commercial and subsistence catches in the Yukon, but are caught only incidentally in the Mackenzie River drainage (McPhail and Lindsay 1970).

Mature chum salmon (ages 3-5) migrate from the sea into freshwater rivers during summer to spawn. Spawning occurs from July to October depending on the distance of spawning sites from the sea (McPhail and Lindsey 1970). Eggs incubate in redds overwinter and fry emerge from the gravel in spring and immediately start their downstream migration to the sea (Scott and Crossman 1973).

The most sensitive freshwater phase of chum salmon life history is the survival of eggs and alevins (McNeil 1969). As with chinook salmon the spawning migration and the quality of spawning habitat are also important.

Potential Impact

Alaska Highway Route:

Estimates of the chum salmon spawning population of the Yukon River upstream of Dawson were approximately

31,000 during 1974 (Brock 1976) and approximately 40,000 during 1973 (Sweitzer 1974). Sweitzer (1974) reported chum salmon favor the Yukon mainstem and White River system within the southern Yukon for spawning. Brock (1976) identified spawning areas in the Yukon River downstream of Carmacks. Fisheries Service (Northern British Columbia and Yukon Division 1973) indicate chum salmon spawn in the lower Teslin River to Roaring Bull Rapids, approximately 100 km downstream of Teslin Lake. Clemens et al. (1968) however, reported chum salmon in Teslin Lake. The presence of chum salmon in the Yukon River mainstem upstream of Lake Laberge outlet has not been confirmed nor have chum salmon been observed in the Whitehorse fishway (Brown et al. 1976). Sweitzer (1974) identified spawning areas in Kluane River near Kluane Lake, and spawning is suspected along the shore of Kluane Lake and near the mouth of Christmas Creek (O. Sweitzer, personal communication). Within the White River drainage 300-500 chum salmon were observed in Kluane River near Kluane Lake in 1974 (Brock 1976). Beak (1977) found evidence of chum salmon spawning in Duke River. Chum salmon have also been observed in the White River near the proposed pipeline crossing (O. Sweitzer, personal communication).

Chum salmon are only commercially harvested from the Yukon River between Dawson City and Tatchum Creek (Environment Canada 1973). Brock (1976) reported the commercial catch to be 3010 fish in 1974; 1590 fish were harvested by subsistence fishermen from this area and 32 were taken in the Kluane River subsistence fishery in 1974 (Brock 1976). The latter is likely an underestimate of average harvest since Sweitzer (1974) reported "a few hundred" fish taken each year from Kluane River and Kluane Lake.

Potential for impact to chum salmon may be limited to the Kluane region of the Alaska Highway corridor. Migration and spawning could be delayed or disrupted at the White, Donjek, Duke, and possibly the Koidern Rivers by inappropriately timed in-stream activities. The proximity of the proposed stockpile site at Duke River provides potential for introduction of toxic materials to both this river and Kluane River. Possible toxic spills, siltation, and general construction activity in the Kluane River area may interfere with subsistence harvests of chum salmon. Siltation resulting from construction may degrade up to 10 percent of available habitat in these waters (Hayden 1977).

Interaction between chum salmon and pipeline construction cannot be entirely avoided. The size and probable difficulty of construction of the White and Donjek River crossings will lead to some interference with migration and spawning, but the degree of interference can be limited by construction controls. Mitigation will be more difficult at the Koidern River because the alignment parallels this drainage and crosses the river several times. Extensive care would be required to protect chum salmon in the Klaune area from the effects of toxic spills because of the difficulty of containment of spills on granular soils, and because of the possibility of contaminating groundwater that may flow to spawning areas. Degradation of chum salmon habitat by siltation can be reduced by as much as one-half with controls (Hayden 1977). Natural restoration of silted habitat should occur within 1-4 years (Hayden 1977) unless erosion of the right-of-way and stream banks is chronic, but ease of access to the right-of-way would facilitate the repair and restoration that may be required.

Arctic Gas Route:

Chum salmon have been reported from the Mackenzie River drainage in the Mackenzie Delta, Great Bear Lake, Great Slave Lake and Slave River (Keleher 1972, McPhail and Lindsey 1970). They occur in very low numbers in this drainage and are caught only incidentally (McPhail and Lindsey 1970). No spawning areas have been identified along this route. Because of the very limited numbers of chum salmon and their incidental harvest here, little or no effect on the species is expected.

Comparison Summary

Since chum salmon occur very infrequently along the Arctic Gas alignment and because they are of virtually no importance in harvest in the Mackenzie River drainage, the Arctic Gas route is preferred and given a preference rating of 5.

In the southern Yukon Territory the main chum salmon spawning areas are a considerable distance downstream of the Alaska Highway Pipeline route. Distribution of chum salmon within this pipeline corridor may be limited to the Kluane region. Project effects on these fish can be limited by adequate controls, but additional problems caused by granular soils, the paralleling drainages, and the contamination of possible groundwater flow to spawning areas will be more difficult to mitigate. Because of the limited abundance and distribution of chum salmon along the Alaska Highway pipeline corridor, the relative effectiveness of controls, and the ease of access for right-of-way repair, this route is given a preference rating of 4.

DOLLY VARDEN (*Salvelinus malma*)

Problem Definition

Dolly Varden are a fall-spawning, redd-building species with both anadromous and non-anadromous populations. They have been reported from the Mackenzie, Liard, Yukon and Alsek drainages (McPhail and Lindsey 1970; Lindsey, personal communication), and where abundant are harvested in sport and subsistence fisheries.

Spawners of non-anadromous populations move from lakes to permanent-water streams during summer. Eggs incubate overwinter and juveniles remain in permanent water nursery streams for several years (McPhail and Lindsey 1970).

The most sensitive aspects of non-anadromous Dolly Varden life history are spawning, egg incubation and juvenile nursery/feeding. Dewatering of, and siltation and spills of toxic materials to these areas could cause severe impact.

Potential Impact

Alaska Highway Route:

Dolly Varden are reported in tributary streams of Dezadeash Lake (Lindsey, personal communication) and thus may be expected throughout the Dezadeash drainage. McPhail and Lindsey (1958) report Dolly Varden in Swan Lake of the Swift River drainage. R. Bodaly (personal communication) has collected Dolly Varden from Daughney Lake, which is a headwater lake of the Rancheria drainage, and Beak (1977) collected them from the upper Rancheria and Little Rancheria Rivers. Specific spawning sites and migration routes along the Alaska Highway alignment are unknown, but the usual spawning habitat is in summer in clear water, gravel-bottomed, permanent-water rivers.

Information on the relative abundance of Dolly Varden is not available, but harvest of this species appears limited in the Yukon Territory. Sport harvest and some subsistence harvest is likely in the Rancheria and Alsek drainages.

All three drainages with Dolly Varden (Dezadeash, Swift and Rancheria) within the Yukon Territory are paralleled by the proposed alignment for 50-65 km each and many of their tributaries are crossed by the alignment. These situations increase the likelihood of habitat degradation and also increase the chance of mortality to fish resulting from toxic spills. Siltation could degrade an estimated 5 percent of Dolly Varden stream habitat but this habitat should be naturally restored in 1-4 years (Hayden 1977). Proposed stockpile sites and compressor stations in these drainages represent additional sources of siltation and toxic spills. Disruption of spawning or migration could occur if in-stream construction activity is inappropriately timed.

It is more difficult to limit siltation and toxic spills where the route parallels river drainages. Because of the pattern of regional topography, major rerouting may only relocate the situation to another river drainage, and construction of additional access roads would be required. However the degree of impact can be lessened by following recommendations made in the Initial Environmental Evaluation. With adequate controls degradation of Dolly Varden habitat can be decreased by as much as one-half (Hayden 1977). Detailed inspection and evaluation of stream crossings prior to final route alignment in the paralleled drainages is necessary to avoid excavation of spawning beds.

Arctic Gas Route:

Dolly Varden are reported in the Big Fish River of the Beaufort Sea drainage (Stein et al. 1973), Peel River, Little Smith Creek and a tributary of Blackwater River of the Mackenzie River drainage (Griffiths et al. 1974). In some locations they may have been confused with landlocked arctic char.

Population estimates are not available, but relative abundance and use of water bodies by Dolly Varden along this alignment are much less than along the Alaska Highway alignment. Dolly Varden are probably caught occasionally in subsistence nets, but their importance is incidental. There is no known sport harvest of this species in the Mackenzie

Valley or along the Yukon coast. Therefore the effect of this project on Dolly Varden is expected to be minimal.

Comparison Summary

Potential impacts on Dolly Varden will be less for Arctic Gas than for the Alaska Highway project because Dolly Varden are infrequent on the Arctic Gas alignment and little harvest occurs. The Arctic Gas route is therefore preferred relative to this species.

Along the Alaska Highway route Dolly Varden are found in three river drainages each paralleled by the alignment for 50-65 km. These situations increase the likelihood of species disruption by the pipeline project, but may be unavoidable. Adequate controls can limit impact, but inspection of stream crossing sites is necessary to permit avoidance of spawning sites in the final alignment. These points lower the preference rating of this route for Dolly Varden to a 3 relative to the Arctic Gas route.

LAKE TROUT (*Salvelinus namaycush*)

Problem Definition

Lake trout are distributed throughout northern Canada and are of considerable value in sport, subsistence and commercial harvests.

Their usual habitat is clear, deep lakes, but during summer they are often found feeding in large rivers (McPhail and Lindsey 1970). Spawning occurs in lakes during fall. Redds are not used, rather eggs are shed along lake-shores usually over rubble bottom and hatching occurs the following spring. Juveniles remain in nearshore areas for several years (Scott and Crossman 1973).

Spawning and egg incubation are the most sensitive aspects of lake trout life history. During fall and winter siltation and toxic spills to spawning areas could cause severe impact.

Potential Impact

Alaska Highway Route:

In the Yukon drainage lake trout are found in Caribou Lake, Coal Lake, Cowley Lake, Fish Lake, Kluane Lake, Marsh Lake, Swift River and Swan Lake, Taye Lake, Teslin Lake and Nisutlin Bay, and Yukon River within the pipeline corridor (Griffiths et al. 1974, C.C. Lindsey personal communication). Within the corridor in the Alsek drainage lake trout are found in Aishihik Lake, Kloo Lake, and Pine Lake (Griffiths et al. 1974), and in lakes near Watson Lake in the Liard drainage (Foothills 1976b). Many of these locations are upslope of the alignment and would not be affected by pipeline construction. Areas where the route parallels shorelines of Kluane, Marsh and Teslin Lakes for a considerable distance are of major concern. Siltation here could degrade approximately 100 km of lake trout spawning habitat, which represents an estimated 3-4 percent of lake trout habitat downslope of the route within the corridor (Hayden 1977). Toxic spills in these areas could increase mortality of incubating eggs, lake trout fry and juveniles. Siltation could cause long-term effects because of the lack of flowing water in lakes to cleanse the substrate of silt. Interference with subsistence and commercial harvests could occur at Kluane and Teslin Lakes during the construction period, and similar short-term interference with sport harvest may occur at all the lakes mentioned above.

With adequate controls the amount of silt entering these waters can be limited; thus the effects of siltation could be reduced by as much as one-half (Hayden 1977). The remaining siltation that would occur could leave long-term effects, for restoration would require natural processes. Toxic spills into shoreline areas could cause severe impact to lake trout young-of-the-year or fry, but older fish could more successfully move from the area. Containment and clean-up of toxic spills would be more successful in non-flowing waters. Ease of access to the right-of-way would facilitate repair, contingency, and restoration activities that may be required. Interference with harvest could be limited by proper siting of construction facilities, and would be a short-term conflict.

Arctic Gas Route:

Lake trout are found in lake "105", Travaillant Lake, Thunder River, Yeltea Lake, Carcajou Ridge Lake, Brackett River, River Between The Mountains and Trout Lake within the Arctic Gas corridor (McCart et al. 1974). Most of these locations are upslope of the alignment and would not be affected by siltation or toxic spills originating from the alignment. Lake trout present in the Mackenzie River mainsteam are vulnerable to toxic spills, but restricted concentrations of fish are unlikely here except, perhaps, at tributary mouths where lake trout may feed or overwinter. Little sport harvest occurs within the corridor, and according to the Variation Order of the Northwest Territories Fishery Regulations (Environment Canada 1976) there is no commercial fishing for lake trout within the Arctic Gas corridor.

Most lake trout waters within the Arctic Gas corridor are upslope of the alignment and would not be affected by the project. Winter construction will further limit interaction with these species. For these reasons the potential impact to lake trout is limited along the Arctic Gas route.

Comparison Summary

Because of the few locations where interaction with lake trout will occur and because of proposed winter construction the Arctic Gas route is given a preference rating of 5.

Because of the many kilometres of downslope lakeshore to be paralleled, and the potential of long-term effects from siltation, this route is less preferred relative to lake trout and is given a preference rating of 3.

WHITEFISH (*Coregonus clupeaformis* and *C. nasus*)

Problem Definition

Both humpback and broad whitefish are considered together in this comparison. Both species are harvested in subsistence fishing and are important in commercial catches.

Whitefish are usually considered lake dwellers but are often found in large rivers. Near marine areas they are often anadromous. Whitefish spawn in fall over hard, stony and sandy bottom; redds are not built, and eggs hatch in the spring (Scott and Crossman 1973). Juveniles use lakeshore areas and tributary mouths as nursery/feeding sites.

The most sensitive period for whitefish is during spawning and egg incubation in late fall and winter. At these times siltation and toxic spills to spawning areas could cause severe impact.

Potential Impact

Alaska Highway Route:

Whitefish are found in Kluane, Marsh, Teslin and Swan lakes, and in Takhini, Yukon and Morley rivers (Griffiths et al. 1974, McPhail and Lindsey 1958). Kluane, Marsh and Teslin lakes are closely paralleled for approximately 100 km where pipeline-related siltation and toxic spills could degrade whitefish habitat and cause direct mortality to both fish and fish eggs. Crossings of Takhini, Yukon and Morley Rivers could also degrade river habitat of whitefish. At Swan and Teslin Lakes construction of compressor stations and operation of stockpile sites could cause additional siltation and toxic spills in these waters. It is estimated that 3 percent of whitefish habitat downslope of the route within the corridor could be degraded by siltation. Duration of this effect should be relatively short-term in rivers, but may be long-term in lake habitats (Hayden 1977). Interference with harvest could occur at Kluane, Marsh and Teslin Lakes during the construction period.

Two distinct forms of humpback whitefish (*Coregonus clupeaformis* complex) occur in Squanga and Little Teslin Lakes near Johnsons Crossing (C.C. Lindsey, personal communication). These situations are of high scientific interest and value, and are currently being studied. Because of the small size of these lakes, siltation or toxic spills in them could cause severe, long-term damage to their unique whitefish populations.

As with lake trout, the amount of silt entering waters can be limited by as much as one-half (Hayden 1977). Effects of siltation to whitefish habitat in lakes could have long-term persistence, but in rivers the silt should be washed away within a few years. Toxic spills into lake shoreline areas could cause severe impact to whitefish fry and young-of-the-year, but older fish could successfully move from the area. Containment and clean-up of toxic spills would be more successful in non-flowing water. Ease of access to the right-of-way would facilitate repair, contingency, and restoration activities that may be required. Interference with harvest could be limited by proper siting of construction facilities, and would be a short-term conflict. Rerouting of the alignment away from Squanga and Little Teslin Lakes could eliminate the potential of damaging the unique whitefish populations there.

Arctic Gas Route:

Across the Yukon coast whitefish have been reported in five lakes downslope of and six streams crossed by the proposed alignment (McCart et al. 1974). In the Delta region, the Rat, Peel and Mackenzie Rivers, which serve as whitefish habitat and migration routes, will be crossed by the alignment. On the east side of the Mackenzie Valley to the 60th parallel at least 16 streams and rivers from which whitefish have been reported will be crossed by the alignment (Griffiths et al. 1974), and 6 of the larger rivers may provide whitefish spawning and overwintering habitat. The Delta region is the most important subsistence fishing area in the Mackenzie Valley. Subsistence fish harvest from Fort McPherson and Arctic Red River was estimated to be 450,000 pounds in 1972 (Withler 1975) of which the majority was whitefish. Much of this catch is taken from the upper Delta and the Peel and Mackenzie Rivers downstream of the alignment. Commercial whitefish quotas of 55,000 pounds were set in 1976/77 for the upper Delta region (Environment Canada

1976), but little or no commercial fishing occurs near the proposed alignment.

Pipeline activities (barging, stockpiles, borrow sites, mainline construction) could all adversely affect whitefish by siltation or toxic spills. This could be particularly critical in late summer when many whitefish move upstream to spawning areas. Barging and wharfing activities may also interfere with fish harvest activities near the mouths of Big Fish Creek and Rat River in the Peel River near Fort McPherson, and in the Mackenzie River near Arctic Red River. South of the Delta on the east side of the Mackenzie River main sources of impact to whitefish would be siltation from borrow sites and the right-of-way, and toxic spills from fuel storage sites. Most of these problems would be relatively short-term and would occur at Mackenzie River tributary mouths and in the river mainstem since in this region the whitefish lakes are upslope of the proposed alignment.

The potential problems associated with siltation will be largely reduced because of the planned predominance of winter construction along the Arctic Gas route. Summer crossings of the Peel River and Mackenzie River near Arctic Red River will add silt to already silt-laden waters, but toxic spills here could be particularly damaging if they were to coincide with fish migrations. Scheduling of construction activities could limit this danger. Perhaps the greater danger in the upper Delta-lower Mackenzie region would be interference with domestic harvest by barging and wharfing. This is of particular concern because of the importance of domestic fishing to residents of Fort McPherson and Arctic Red River. Remuneration to fishermen may be the only possible form of mitigation.

Comparison Summary

The two major potential conflicts with whitefish populations presented by the Alaska Highway route are the dangers of the alignment paralleling lakeshore areas for approximately 100 km, and the possibility of disrupting unique whitefish populations of high scientific interest at Squanga and Little Teslin Lakes.

Serious short-term disruption of important subsistence whitefish fishing is possible in the upper Delta region. Toxic spills in this area could be particularly damaging if they were to coincide with whitefish migrations.

Because of these offsetting conflicts no preference is given either route and both routes are assigned a rating of 5.

ARCTIC GRAYLING (*Thymallus articus*)

Problem Definition

Arctic grayling are ubiquitous throughout both project regions. Where accessible, grayling are sought in sport harvest and in some areas they are harvested in subsistence fishing.

Grayling spawn in early spring following migration from permanent water overwintering areas to small, often intermittent, clear water streams. Redds are not built, rather the eggs settle in interstices of the substrate. Hatching usually occurs in about 2 weeks and the fry remain in the spawning streams through most of the open water period. Emigration from spawning streams occurs first with adults, next with juveniles and finally with young-of-the-year (Craig and Poulin 1974).

The most serious potential conflicts with grayling populations are habitat degradation and interference with migration. Habitat degradation may be caused by erosion and siltation from the right-of-way and pipeline crossings, and by toxic spills. Interference with fish movement could result from inappropriately timed in-stream construction activities and channel restrictions caused by ice bridges, culverts, and frostbulb-created ice dams.

Potential Impact

Alaska Highway Route:

Arctic grayling are found throughout the Yukon, Alsek and Liard drainages. Spawning is likely in most of the small, clear streams crossed by the pipeline, and overwintering probably occurs in the larger rivers and downslope lakes. Sport fishing for grayling is extensive along the Alaska Highway and some subsistence fishing may occur near Indian settlements along the route.

It is unlikely that spawning migrations will be affected since instream activity would be unlikely during spring spate. Spawning and egg incubation could be disrupted in spring and early summer during construction in the many small streams crossed by the alignment in the southern Yukon. Summer construction could cause degradation of grayling nursery and feeding habitat via siltation. Hayden (1977) estimated that about 5 percent of available habitat could be thus degraded, but suggested this estimate could be low because small streams were under-represented in this assessment. Summer construction activities could cause short-term interference with sport fishing in waters downslope of the alignment.

Adequate scheduling of in-stream construction activities could lessen impact to grayling migration, spawning, and egg incubation. To do this migration routes and high-use spawning areas need to be identified. Degradation of grayling habitat can be reduced by as much as one-half, and natural restoration of this habitat should occur in 1-4 years (Hayden 1977). Ease of access to the right-of-way would facilitate repair, contingency, and restoration activities that may be required.

Arctic Gas Route:

Arctic grayling are found in most Yukon coastal streams, in tributaries of the Mackenzie Delta and in most tributaries on the east side of the Mackenzie River. Grayling are less abundant south of Fort Simpson to the 60th parallel. Spawning occurs in most small tributaries and overwintering occurs in the Mackenzie mainstem, and in larger tributaries, lakes, and groundwater areas of other tributaries. Sport fishing for grayling is very limited throughout this corridor, but subsistence fishing is extensive in the middle and upper Mackenzie regions.

The major sources of siltation will be from the disturbed right-of-way, and stream crossings. Winter construction will limit erosion from the right-of-way and most stream crossings, but tundra soils along the Yukon coast and ice-rich soils in the Mackenzie Valley may be difficult to stabilize, and thus may be a chronic source of siltation. Dewatering of downslope overwintering areas may persist through pipeline operation if ice damming is caused by frostbulb effects in smaller streams with winter flow.

Barging and wharfing operations may conflict with subsistence fishing at tributary mouths. Methanol used to hydrostatically test the pipeline presents an additional possible source of toxic spills to grayling habitat.

Ice-dam formation can be minimized by deeper burial of the pipe at streams with winter flow. Interference with harvest and occurrence of toxic spills can be lessened by careful control of construction-related operations and adequate contingency plans for containment and clean-up of toxic spills. Instability of ice-rich soils may lead to persistent erosion and siltation problems which would be difficult to repair because of difficult access.

Comparison Summary

Along the Alaska Highway route there is a greater likelihood of construction interferring with grayling migration, spawning, and feeding because of summer construction. This scheduling will also allow more short-term siltation. Conflicts with sport fishing are much more likely here.

On the Arctic Gas route erosion-siltation problems may be chronic in areas of ice-rich soils. Toxic spills are more likely here, as is interference with subsistence fishing.

Effects to grayling potentially caused by both projects are considered equal and neither is preferred over the other; thus both are given a preference rating of 5.

The Transmission of Prudhoe Bay Gas to American Markets: A Preliminary Environmental Comparison of the Canadian Arctic Gas Pipeline and the Foothills (Yukon) Pipeline in the Yukon and Northwest Territories

BACKGROUND DOCUMENTATION

VEGETATION

CONTENTS

Hernandez, H. 1977. Vegetation. Pages 275 to 305 in Background documentation. Appendix to The transmission of Prudhoe Bay gas to American markets: A preliminary environmental comparison of the Canadian Arctic Gas pipeline and the Foothills (Yukon) pipeline in the Yukon and Northwest Territories. Alaska Highway Pipeline Panel, Winnipeg. 420 pp.

SUMMARY

The proposed Alaska Highway and Arctic Gas pipeline projects were compared with respect to their potential for affecting seven types of vegetation: arctic tundra, grasslands, alpine tundra, wetlands, riparian vegetation, pioneer communities, and boreal forest. These include all of the vegetation along both routes, although some only occur along one of the routes. Preference was based on land area affected by each project in each vegetation type combined with an evaluation of the susceptibility of each type to disturbance from project activities.

The Alaska Highway route is preferred over the Arctic Gas route for four of the seven vegetation types (Table 1): arctic tundra, wetlands, riparian vegetation, and pioneer communities. One of these preferences results from the absence of arctic tundra along the Alaska Highway route. The Arctic Gas route is preferred for the other three types (Table 1): grasslands and alpine tundra, neither of which is crossed by this route; and boreal forest.

For arctic tundra, the Alaska Highway route is substantially preferred over the Arctic Gas route because the Alaska Highway route does not cross this sensitive and unique type of vegetation whereas Arctic Gas would unavoidably cross much of it.

For grasslands, the Arctic Gas route is strongly preferred because grasslands are absent in the northern

Table 1. Summary of vegetation comparison[a] for the Alaska Highway and Arctic Gas pipeline routes in Canada north of the 60th parallel.

	Relative Importance Weighting	Relative Preference[b]		Weighted Preference[c]	
		Alaska Highway	Arctic Gas	Alaska Highway	Arctic Gas
Arctic tundra	9	5	1	45	9
Grasslands	7	2	5	14	35
Alpine tundra	6	4	5	24	30
Wetlands	4	5	2	20	8
Riparian vegetation	3	5	3	15	9
Pioneer communities	2	5	4	10	8
Boreal forest	1	4	5	4	5
Totals	32			132	104

[a]See Introduction and Approach for detailed discussion of Relative Importance Weightings and Relative Preference ratings.

[b]Relative Preference is based on a scale of 1-5, where the preferred route is assigned a value of 5.

[c]Weighted Preference = Relative Importance Weighting X Relative Preference.

Yukon. Although only a small area of grasslands would be affected along the Alaska Highway, grasslands are rare in the southern Yukon and their crossing is unavoidable.

For alpine tundra, the Arctic Gas route is only slightly preferred. Although the Arctic Gas route does not cross any alpine tundra, the few patches crossed by the other route are small and their crossings could be avoided.

For wetlands, the Alaska Highway route is strongly preferred over the Arctic Gas route. It disturbs much less wetland area and has a much shorter length of chilled pipeline across wetlands.

For riparian vegetation, the Alaska Highway pipeline is preferred. It disturbs fewer riverbank areas, largely because wharves are not needed for access to the southern Yukon whereas they are needed along the Mackenzie River Valley.

For pioneer communities the Alaska Highway pipeline is slightly preferred over the Arctic Gas pipeline because it disturbs less of this vegetation.

For boreal forest, the Arctic Gas route is slightly preferred. Although it disturbs more area, much of the Alaska Highway pipeline construction would be in summer, increasing the possibility of fire.

In conclusion, this comparison shows a preference for the Alaska Highway route over the Arctic Gas route in terms of effects on vegetation. For the four vegetation types crossed by both routes, the Alaska Highway route is preferred. It disturbs less area and the consequences of disturbance are less severe. Soil ice contents and erosion potential are lower, and more than compensate for summer construction along much of the route, especially since construction across most wetlands will be in winter along both routes. For the remaining three types, grasslands and alpine tundra are crossed by the Alaska Highway route and arctic tundra by the Arctic Gas route. Areas of alpine tundra affected are small and largely avoidable. Given a choice between crossing grasslands in the southern Yukon and crossing arctic tundra in the northern Yukon, the choice is overwhelmingly for crossing grasslands and avoiding arctic tundra. The area of grassland affected is small; other grasslands would remain uncrossed, and recovery would follow. The area of arctic tundra crossed by the Arctic Gas route, however, is much more extensive, and forms part of a unique region of Canada which would be crossed for its entire length.

INTRODUCTION

The vegetation of the Yukon Territory and District of Mackenzie, Northwest Territories consists of numerous plant communities which vary in species composition, abundance, distribution, sensitivity to disturbance from construction activities, and ability to recover following such disturbance. Vegetation reduces erosion and, in permafrost areas, helps insulate underlying permafrost. All plant communities provide habitat for wildlife and some are directly used by man. Ground activities associated with construction of a pipeline off existing permanent roads or gravel pads will affect vegetation.

Most of the 826-km proposed route of the Alaska Highway pipeline in the Yukon between Beaver Creek and Watson Lake is forested. Exceptions are non-wooded wetlands, grasslands, and shrubland openings in forests, alpine tundra above treeline in mountains, and recently burned or cleared areas. The route of the proposed Arctic Gas pipeline in the Northwest Territories crosses similar forested areas with non-forest openings for about 1300 km. In addition, however, it crosses almost 275 km of tundra beyond the northern limit of treeline along the northwestern edge of the Mackenzie Delta and the Yukon Coastal Plain.

The vegetation crossed by these two pipeline proposals was grouped into seven vegetation types: arctic tundra, alpine tundra, grasslands, wetlands, riparian vegetation, pioneer communities, and boreal forest.

APPROACH

Route preference was based on the land requirements of each project in each vegetation type combined with an evaluation of the susceptibility of each type to disturbance from project activities.

Arctic Gas Route

Alignment of the coastal-circumdelta and Mackenzie Valley segment to the Willowlake River (MP 590) was based on the original Canadian Arctic Gas Pipeline Limited application (CAGPL 1974) and the segment south of MP 590 on the consolidation filing (CAGPL 1976). Length of route in each vegetation type was determined from the Environment Protection Board's environmental atlas (EPB 1974).

Land requirements per unit distance were determined from data in Hernandez (1974: Table 9) for land requirements, excluding river crossings and communications towers, along the Arctic Gas route north of 60°N to Prudhoe Bay originally applied for. In tundra areas these land requirements were 4.84 ha/km of which 0.31 ha/km were estimated to be borrow pits. In forest regions, land requirements were almost 6.10 ha/km, of which 0.49 ha/km were estimated to be borrow pits.

Alaska Highway Route

Alignment of the Yukon segment was based on alignment sheets and strip maps provided by Foothills Pipe Lines (Yukon) Ltd. (Foothills 1976a, 1977). Length of route across each vegetation type in the Yukon had been determined previously (Hernandez 1977).

Land requirements per unit distance in the Yukon were 3.80 ha/km (Hernandez 1977, Foothills 1976a,b). This does not include borrow pits. Borrow requirements for this project are likely to be less than those of Arctic Gas, because of smaller compressor stations. Nevertheless, lacking an estimate of borrow needs in the Yukon segment, they were assumed to be the same as for Arctic Gas in forested areas (0.40 ha/km) since the southern Yukon is within the boreal forest. Thus, total land requirements were estimated to be 4.29 ha/km.

For riparian vegetation, the number of rivers crossed was determined along each route from 1:250,000 scale maps. Major river crossings were assumed to require 0.8 ha on each side (60 m wide by 150 m deep); minor crossings 0.2 ha on each side (36 m wide by 30 m deep).

Problem Definition

All ground activities associated with construction of a pipeline off existing permanent roads or gravel pads will directly affect vegetation. In forested areas, the initial disturbance will result from clearing rights-of-way for subsequent use and travel. In non-forest areas, overland travel will be the initial source of vegetation disturbance. On both forest and non-forest land, some areas will also be subjected to additional disturbance. The ground surface will be dug up by grading operations, ditching, river crossings and borrow activities. At other sites, vegetation will also be covered by gravel pads for compressor stations, permanent roads, wharves, and similar long-term facilities.

Following pipeline construction, stable areas which were only temporarily disturbed could be colonized naturally by pioneer species depending on such site conditions as site stability, climate, time and severity of disturbance, survival of plant parts, availability of seed, and the right-of-way vegetation management approach adopted by the pipeline company.

Construction activities, especially in summer, have the potential for starting fires which could affect adjacent vegetation, and fires originating elsewhere could threaten project activities.

During operation of the pipeline, vegetation could be affected in several ways. Construction of pipelines and their associated roads across wetlands in other areas has altered drainage resulting in dead trees and other changes in vegetation. Operation of the chilled pipeline could aggravate this situation in wetlands and may have similar effects in other areas. Emergency repairs requiring overland traffic, especially in summer, will have more immediate effects on vegetation, most likely on recovering pioneer communities. Operating compressor stations will also be emitting water vapour, nitrogen oxides and sulphur oxides. The latter emissions will have some effect on vegetation, but ground concentrations and the area affected during the life of the project cannot now be evaluated.

ARCTIC TUNDRA

Potential Impact

Alaska Highway Route:

The Alaska Highway route does not cross arctic tundra.

Arctic Gas Route:

Almost 275 km (Table 2) are crossed between the Alaska-Yukon boundary (MP 195) and MP 375 on the west side of the Mackenzie Delta. This section of the route will also include 4 compressor stations and their associated air-strips, 3 stockpile sites, and 15 river borrow operations. Total area affected is about 1300 ha (Table 2).

Arctic tundra consists of wet sedge meadows, cottongrass tussock communities, and low shrub-heath communities (Hernandez 1974). Permafrost is continuous and ice rich. Once disturbed, such as by winter seismic lines, thaw settlement begins and continues for several years until the active layer is completely within consolidated material (How and Hernandez 1975). For a given level of disturbance, thaw settlement is greater on the Yukon Coastal Plain than elsewhere along the pipeline route (How and Hernandez 1975). Natural recolonization of disturbed sites is not extensive until such sites are stable (How and Hernandez 1975, Lambert

Table 2. Comparison of length of route (L) and land requirements (A)[a] in each vegetation type crossed by the proposed Arctic Gas and Alaska Highway pipeline routes in Canada north of 60^{o}N latitude.

Vegetation Type	Arctic Gas Route		Alaska Highway Route	
	L(km)	A(ha)	L(km)	A(ha)
Arctic tundra	274	1326	0	0
Alpine tundra	0	0	5	28[b]
Grasslands	0	0	3	10[b]
Pioneer communities	114	695	97[c]	566[c]
Riparian vegetation	-	208[e]	-	94[d]
Wetlands	207	1262	56	240
Boreal forest	987	6016	665[c]	2705[c]
TOTAL	1582	9507	826	3643

[a]See text for discussion on how the following numbers were derived: Unless otherwise stated, land requirements are:

4.84 ha/km for Arctic Gas project across tundra region.
6.095 ha/km for Arctic Gas project across forest regions.
4.29 ha/km for Alaska Highway pipeline Yukon Segment.

[b]Taken from Hernandez (1977)

[c]Length of route along existing rights-of-way (150 km of northern 209 km) is counted as boreal forest not pioneer communities since right-of-way would have to be widened by about 4 times and would involve disturbing more forest than pioneer areas. Land requirements, however, were altered by adding 150 ha to the value calculated across recent burns and by subtracting 150 ha from boreal forest.

[d]Estimated by assuming 1.6 ha for major and 0.4 ha for other river crossings.

[e]Includes 120 ha for wharves; remainder calculated as for d, above.

1976) and is more effective where mineral soil is exposed than where organic soil is exposed (Hernandez 1973a, b; 1974, Lambert 1976). Exposure of mineral soil, however, leads to more severe disturbances since peat acts to delay the onset of thaw because of high moisture content and lower conductivity (Haag and Bliss 1974). All impacts discussed in the general problem definition will affect arctic tundra and will have greater effects than elsewhere because of high ice contents. Fire, however, is not as great a problem in this vegetation type although tundra fires do occur (Wein 1976).

This region of the pipeline route has been relatively undisturbed in comparison to tundra areas east of the Mackenzie Delta and construction of the pipeline would affect the entire unit of Herbaceous Coastal Tundra in Canada which is part of this parameter (Hernandez 1974).

Comparison Summary

The Alaska Highway pipeline does not cross arctic tundra and is the preferred route (Table 1). In comparison, the Arctic Gas route crosses 274 km of arctic tundra and affects 1326 ha (Table 2). Overall the Arctic Gas route is much less preferred (1 vs 5) because of amount of area disturbed, the unique nature of the vegetation, the unavoidability of disturbing it by any routing across the Yukon Coastal Plain, and the relative severity of disturbance and slower rates of recovery in this region in comparison to other areas affected. Winter construction will reduce the effects on arctic tundra but if construction across the Yukon Coastal Plain cannot be accomplished off winter roads in one winter, the consequences of summer construction would be severe.

GRASSLANDS

Potential Impact

Alaska Highway Route:

Grasslands are only crossed by the Alaska Highway pipeline (Table 2). These grasslands are rare and localized in the southern Yukon and generally only occur west of Whitehorse. Grassland areas crossed include: Duke Meadows (MP 110), probably the largest single valley grassland in the southern Yukon (Lands Directorate 1973); southern and western aspects of Sheep Mountain, part of critical Dall's sheep winter range (Hoefs et al. 1975), and the drier portions of the Slims River delta, which is easily disturbed (Johnson and Raup 1964, Douglas 1974). These major grassland areas were estimated to cover at least 1000 ha (Hernandez 1977) but other smaller areas also occur. Once disturbed, portions of these grasslands were considered slow to recover (e.g. Hoefs et al. (1975) for Sheep Mountain).

Only the pipeline right-of-way itself will affect grasslands since no other project facilities are proposed for known grassland areas.

Arctic Gas Route:

The Arctic Gas route does not cross grasslands.

Comparison Summary

Arctic Gas is the preferred route for grasslands. Although the Alaska Highway pipeline will only affect 10 ha of grasslands, this small area represents 1 percent of the existing major grasslands in the region (Hernandez 1977). In addition, the crossings of Duke Meadows and the base of Sheep Mountain are unavoidable but that of Slims River delta is avoidable (Hernandez 1977). These two reasons, combined with summer construction, the susceptibility to disturbance, and slow recovery of disturbed grasslands in the project area make the Arctic Gas pipeline much preferred (5 vs 2) over the Alaska Highway pipeline for grasslands.

ALPINE TUNDRA

Potential Impact

Alaska Highway Route:

Alpine tundra occurs above treeline on mountain tops along both routes but is only crossed for 5 km in the southern Yukon (Table 2). In addition to the crossings near MP 260 and MP 445, compressor station FY-4 and about 2 km of permanent access road leading to it along the right-of-way are located on alpine tundra. Total area disturbed is 28 ha (Hernandez 1977). Once alpine tundra is disturbed, recovery can take a long time, of the order of centuries (Billings 1973).

Arctic Gas Route:

The Arctic Gas route does not cross alpine tundra.

Comparison Summary

For alpine tundra, Arctic Gas is slightly preferred (5 vs 4) over the Alaska Highway route. Only 28 ha of alpine tundra would be affected, leaving intact adjacent entire examples of similar alpine tundra. Much of the disturbance of alpine tundra is also avoidable if the pipeline route is changed to follow the Alaska Highway around Whitehorse instead of crossing the mountains (Hernandez 1977).

WETLANDS

Potential Impact

Wetland communities occur along both routes. They consist of non-wooded areas containing wet soils and include shallow open water areas, marshes, swamps, wooded or non-wooded bogs and open, sparsely wooded fens (Zoltai et al. 1974). Wetlands are easily disturbed by summer construction activities but when frozen they can easily support vehicle traffic. In addition to actual construction activities, wetlands will be affected by alteration of surface and sub-surface drainage. Pipelines and the associated corduroy roads used to build them have blocked normal water flows and raised the water table on the upslope side, significantly reducing growth and killing trees in north-central Minnesota (Boelter and Close 1974). In northern Ontario a road built across a wetland resulted in the conversion of a treed peatland to an open bog in about 20 years (Jeglum 1975). The frost bulb which will result wherever the pipelines are chilled could similarly act as a dam interrupting drainage (How 1974).

Alaska Highway Route:

Almost 60 km of wetlands will be crossed by the proposed Alaska Highway pipeline in the Yukon (Table 2). About 35 km occur north of the Duke River. Total wetland area affected is about 240 ha (Table 2). The portion of the Alaska Highway pipeline north of the Duke River (MP 110) is planned for winter construction the remainder for summer construction (Foothills 1977).

Chilling of the proposed Alaska Highway pipeline is currently planned for only the northern 65 km, of which about 25 km are across wetlands.

Arctic Gas Route:

Almost 210 km of wetlands are crossed by the proposed alignment of the Arctic Gas pipeline along the Mackenzie Delta and valley (Table 2). Wetlands occur almost continuously south of the Willowlake River (MP 600), but about 70 km also occur north of here. A few small scattered patches of wetlands are crossed along the Mackenzie Valley but most of these 70 km lie around the Mackenzie Delta. Total wetland area affected is about 1270 ha (Table 2). Winter pipeline construction is planned for the entire route. Summer activities are scheduled only at specific sites such as wharves, camps, stockpile sites and compressor stations on gravel pads.

The last point of chilling of the Arctic Gas pipeline has not yet been determined (Mackenzie Valley Pipeline Inquiry 1976: Vol. 201). Previously, chilling was to have ceased at the compressor station near Fort Simpson. Unless heated, the gas would remain below 0°C for about 225 km more, to around the Northwest Territories-Alberta boundary.

How (1974) recommended that the pipeline be operated at above freezing temperatures from about the Willowlake River south. This would free about 140 km of wetlands from frost bulb effects.

Comparison Summary

Overall, the Alaska Highway pipeline is preferred (5 vs 2) over the Arctic Gas pipeline for potential effects on wetlands. It crosses a much shorter length of wetlands (56 vs 207 km) and disturbs much less area and has a much shorter length of chilled pipeline across wetlands. Summer construction along parts of the Alaska Highway pipeline would only take place across a few small, scattered wetlands, many of which are avoidable (Hernandez 1977). Only about 25 km of wetlands would be crossed by chilled portions of the Alaska Highway pipeline whereas over 200 km would be crossed by chilled portions of the Arctic Gas pipeline, assuming the last compressor station with chillers to be at Fort Simpson.

RIPARIAN VEGETATION

Potential Impact

Riparian vegetation lines and helps stabilize watercourses along both pipeline routes. It will be affected by all river crossing activities, especially clearing, grading and cutting of riverbanks. Riparian vegetation is generally more productive than adjacent areas, even in tundra regions.

Alaska Highway Route:

About 94 ha of riparian vegetation will be affected by river crossings along the Alaska Highway pipeline (Table 2). Most will be built in summer. The proximity of the Alaska Highway along most of the route in the Yukon will allow access across large rivers. Some camps and stockpile sites are located near watercourses and could affect up to 16 ha of riparian vegetation but this could be prevented by maintaining such facilities a minimum of 450 m from bodies of water (Hernandez 1977).

Arctic Gas Route:

Almost 210 ha of riparian vegetation will be affected along the Arctic Gas pipeline (Table 2). Of these, about 90 ha will be by river crossings and the remainder by the construction of wharves along the Mackenzie River for the offloading of equipment and supplies (CAGPL 1974, 1976).

Winter construction will allow the crossing of rivers but riverbanks will have to be graded to permit vehicle passage. Major river crossings will be built in summer.

Comparison Summary

Overall, the Alaska Highway pipeline is preferred (5 vs 3) over the Arctic Gas pipeline for effects on riparian vegetation. Although both would affect similar areas from crossing rivers, Arctic Gas would also require an additional 120 ha for wharves. These would not be needed on the Alaska Highway pipeline. The presence of the Alaska Highway along most of the pipeline in the Yukon would provide access for construction equipment and supplies.

Summer construction of river crossings generally has a greater initial effect than winter construction. However, the Arctic Gas route has a greater abundance of ice-rich permafrost and both routes would require extensive grading and cutting of riverbanks, thereby exposing soils, irrespective of the time of year of construction.

PIONEER COMMUNITIES

Potential Impact

Pioneer communities occur along both routes, mostly on recent burns, but also on other recently disturbed sites. Although adapted to growing on disturbed sites, pioneer species are sensitive to secondary disturbances. All potential impacts discussed previously in the problem definition will affect pioneer communities.

Alaska Highway Route:

Almost 100 km of the Alaska Highway pipeline across the southern Yukon will cross recently burned areas (Table 2). Most of these recent burns lie around Whitehorse and in the Rancheria River valley. About 150 of the northern 200 km of the proposed pipeline alignment in the Yukon lie on or within a few metres of existing abandoned rights-of-way such as those of the Haines military oil pipeline (Hernandez 1977). This would disturb an additional 150 ha of pioneer communities, for a total of 566 ha (Table 2).

Alignments along existing rights-of-way are generally preferable to clearing new areas in the southern Yukon because of the low regional erosion potential and general stability of the area (Hernandez 1977). Nevertheless, specific proposed alignments along existing rights-of-way would still have to be examined and evaluated to see if they were suitable.

The northern 180 km of the pipeline will be constructed in winter the remainder in summer. Summer construction across pioneer communities will be more severe in its effects than winter construction.

Arctic Gas Route:

About 114 km of recent burns will be crossed by the Arctic Gas pipeline in the Northwest Territories, affecting almost 700 ha (Table 2). Most of these occur near Little Chicago, Fort Good Hope, Chick Lake, Ochre River and Willowlake River. Few, if any, portions of the alignment parallel existing cleared rights-of-way for significant distances.

Permafrost is widespread or continuous north of Great Bear River, with excess ice generally 10-15 percent with local occurrence of up to 50 percent (How 1974). Thermokarst subsidence becomes significant after disturbances in this area (How 1974) with some recent burns resulting in flow slides in the region (Strang 1973). Winter construction will reduce the severity of disturbance from construction activities on pioneer communities.

Comparison Summary

Overall, the Alaska Highway pipeline is slightly preferred (5 vs 4) over the Arctic Gas pipeline for effects on pioneer communities. It disturbs less area; permafrost is less common and ice contents are lower, even though much of the line would be built in summer.

Based on available data, Arctic Gas crosses a slightly greater length of pioneer communities but disturbs a more extensive area (Table 2).

Winter construction is generally preferable to summer construction for reducing effects on vegetation. This is especially so across sensitive areas such as pioneer communities. Where permafrost is present along those portions of the Alaska Highway pipeline route to be built in summer, ice contents are low (Hurwitz and How 1977) so disturbance will be less severe. Winter construction across pioneer communities in the northern Mackenzie River valley will still affect the communities because ice contents are relatively high and instabilities may have resulted from the recent burn which created them.

BOREAL FOREST

Potential Impact

Boreal forest communities occur along both projects. All of the impacts discussed in the Problem Definition section will affect boreal forest. In addition, fire is an integral part of boreal forest regions and plant communities of the boreal forest are adapted to and rejuvenated by fire. Fire also occurs in tundra regions, although it is neither as common nor as extensive as in forests (Wein 1976). Fire susceptibility varies along both pipeline routes depending on climate, site moisture conditions and consumable biomass. Wetlands and tundra communities generally have a lower susceptibility than forest communities.

The incidence of fire is variable throughout both project areas. More fires are reported as caused by men or unknown factors than by lightning but at least 75 percent of the area burned results from lightning-caused fires (Departmental Statistics Division 1973-75, Barney 1971). Most fires occur in the summer months (June, July and August). Data indicate that the chances for a 'bad' fire year are about 1 in 4 (Rowe et al. 1974, Hernandez 1974, 1977).

Fires which start elsewhere can threaten project activities and facilities. Construction activities themselves also have a potential for starting fires which could affect other areas. During operation of the pipeline, the likelihood of project-caused fires will be reduced but not eliminated. Fires could result from pipe rupture or maintenance activities. In addition, fires which start elsewhere could threaten permanent project facilities.

Alaska Highway Route:

About 80 percent of the 825-km proposed Alaska Highway pipeline route crosses boreal forest types (Table 2). White and black spruce, occasionally with aspen and birch, dominate the route west of Whitehorse; lodgepole pine become abundant east of Whitehorse (Hernandez 1977, Raup 1945a,b; Raup and Denny 1950). Lodgepole pine and aspen often overtop the initial pioneer communities and spruce become dominant if the interval between fires is sufficiently long. Construction of about 80 percent the Alaska Highway pipeline will be in summer, increasing the possibility of fire. Clearing of the right-of-way is proposed to be year-round.

Arctic Gas Route:

About 60 percent of the almost 1600-km Arctic Gas route crosses boreal forest communities (Table 2). Forest-tundra grows between Norman Wells and Inuvik where permafrost is widespread or continuous; boreal forest grows south of Norman Wells and occurrence of permafrost decreases to the south (Hernandez 1974, Forest Management Institute

1974, 1975). Black and white spruce dominate forests in the Mackenzie Valley with lodgepole pine and jack pine appearing in the southern end of the route. Fire has played an important role in determining the patterns and composition of these boreal forest communities (Hernandez 1974, Rowe et al. 1974). Winter construction will reduce the likelihood of project caused fires but numerous summer activities will take place at wharves, camps, and stockpile sites. Clearing will be restricted to the winter.

Comparison Summary

Overall, there is a slight preference for the Arctic Gas route for effects on boreal forest (5 vs 4). Regarding area affected, the Alaska Highway route is slightly preferred. It crosses 300 km less boreal forest and disturbs 3300 ha less land. In addition, the Arctic Gas route has a greater extent of underlying permafrost. Winter clearing and construction, especially the use of winter roads, would reduce the effects on vegetation and permafrost terrain (Adam and Hernandez 1977) but not eliminate them.

For fire implications, however, the Arctic Gas pipeline is preferred over the Alaska Highway pipeline, chiefly because pipeline construction will be in winter rather than in summer as is the case for almost 80 percent of the Alaska Highway pipeline. Summer activities, however, will still be associated with both pipelines at locations used for wharves, camps and stockpile sites and both projects will also carry out final site selection and evaluation programs in summer.

In view of these two factors, as well as the abundance and distribution of boreal forest along both routes, the Arctic Gas route is slightly preferred because most clearing and construction activities will be in winter when the risk of fire is low.

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THE HUMAN ENVIRONMENT - OVERVIEW

A comprehensive comparison of the potential for socio-economic impact on the Alaska Highway and Arctic Gas routes is not possible at this time. Several factors militate against such a comparison. The first of these relates to the time constraints under which not only a comparison but also an initial evaluation of the Alaska Highway route, which is an essential component of any comparison, was done.

Originally 23 social and economic parameters were identified for consideration in an initial evaluation of the Alaska Highway route. Due to time constraints, however, it proved necessary to restrict consideration to only 12 selected parameters. Consequently any attempt at a comparison of the socio-economic impact on the two routes must be restricted to this short list of selected parameters.

The second factor militating against a comprehensive comparison relates to the strategy adopted in the initial evaluation of socio-economic impact on the Alaska Highway route. For the most part that strategy involved examining the Alaska experience with construction of the trans-Alaska pipeline for the selected parameters and then on the basis of limited setting data making a judgement respecting the applicability of that experience to the Yukon setting. Consequently any comparison which can be made is not so much a direct comparison between the two routes based on an appraisal of comparable indicator data for each social or economic parameter as it is a comparison of judgements respecting the applicability of the Alaskan experience to the respective project settings.

The third factor militating against a comprehensive comparison is the paucity of relevant social and economic data for both the southern Yukon and Mackenzie Valley settings. We were particularly surprised to discover this for the Mackenzie Valley setting given the extensive investigations that have been carried out there pursuant to project applications and the subsequent hearings conducted with respect to that route. We found relevant indicator data lacking in the limited socio-economic background studies of the area and although the proceedings of the pipeline inquiry are replete with judgements respecting the potential for social and economic impact we found corroborative data in support of these judgements generally lacking. Also, several areas of potential social and economic impact seem not to have been seriously considered or not considered at all in the Mackenzie Valley appraisals.

In view of the above it is clear that the discussion which follows, though referred to as a comparison, must be regarded at best as a preliminary appraisal of the relative applicability of the Alaskan experience with construction of the trans-Alaska pipeline to the respective project settings. Further, the appraisal as indicated earlier is restricted to a consideration of a short list of selected social and economic parameters.

In our view, if there is a general conclusion to be drawn respecting the potential for socio-economic impact in the two proposed project settings, it is that construction and to a lesser extent operation of a gas pipeline will have a considerable socio-economic impact regardless of the route chosen. The limited information available suggests that while there are some noteworthy differences between the two project settings, the overall sensitivity to and potential for impact in the two settings is comparable. Setting differences serve only to exacerbate different social and economic impacts.

The Transmission of Prudhoe Bay Gas to American Markets: A Preliminary Environmental Comparison of the Canadian Arctic Gas Pipeline and the Foothills (Yukon) Pipeline in the Yukon and Northwest Territories

BACKGROUND DOCUMENTATION

LIFE PATTERNS

CONTENTS

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SUMMARY[1]

For the life patterns component of the human environment we examined the following parameters; acculturation, public health, public safety, incomes and cost-of-living, and employment opportunities. Although we concluded that the Alaska Highway route was preferable from a life patterns perspective, it is not conspicuously so. We are reasonably confident that the construction of a pipeline along the Arctic Gas route has a greater potential for cultural impact given the seemingly more traditional character and relative isolation of the small native communities there compared to southern Yukon and the seemingly more negative perceptions of a pipeline project prevailing in Mackenzie Valley communities. We are also reasonably confident that there is greater potential for impact on public health in the Mackenzie Valley. On the basis of the limited indicator data available, we concluded that the medical facilities and services infrastructure in the Mackenzie Valley are more susceptible to overloading which would result in an impairment of the quality of service available to local residents. Also, given the more traditional character of many Mackenzie Valley native communities, we concluded that the potential for project-induced stress among the resident population and thus the potential for increased mental health problems is greater in the Mackenzie Valley.

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[1]See also "Human Environment--Overview", pages 331-333.

The relative preferability of the two routes with respect to their potential for impact on public safety is less clear. On the one hand we envisage a greater impairment of public safety in Mackenzie Valley due to the greater stress anticipated there, while on the other given the more ready access afforded by a highway we anticipate a greater influx of professional criminals and itinerants to southern Yukon. The above considered we have concluded that the Arctic Gas route is marginally preferable with respect to public safety considerations.

Neither route appears to possess outstanding advantages with respect to incomes and cost of living considerations. While there appears to be greater potential for increased income benefits in Mackenzie Valley District, given that historically incomes there have been much lower than incomes in Yukon Territory, there also appears to be a reasonable basis for anticipating a greater increase in the cost of living in Mackenzie Valley as a result of project activity. It is not inconceivable that any gains in nominal income which might be realized could be more than offset for large portions of the population by cost-of-living increases. We expect though, that the smaller scale of the Alaska Highway project and the relatively more developed Yukon economy will permit greater real income increases to be realized in this region. The Alaska Highway route is regarded as being preferable.

Neither project we concluded has a readily demonstrable advantage in terms of employment opportunities. In arriving at this conclusion we have assumed that employment opportunity advantages only accrue from expanding labor force participation or decreasing unemployment rates. On the basis of the very limited data available, some of which are quite dated, it would appear that whereas there is greater opportunity to expand participation in the labor force of Mackenzie District there is greater opportunity to affect the unemployment rate in Yukon Territory.

Regional differences in labor skills and willingness to participate in the project labor force considerations aside, both projects are capable of employing all unemployed and presently non-participating members of the labor forces of the respective regions. The duration of employment on the Arctic Gas route would be slightly greater but overall, the long-term impact of both projects for local residents will be minimal.

ACCULTURATION

Problem Definition

Large-scale northern development projects possess potential for overwhelming native peoples, disrupting the social and economic fabric of their communities, exerting tremendous pressures on prevailing value systems, and otherwise eroding their culture.

We feel that the nature and magnitude of a major development project's impact on native peoples depended in large measure on the way in which the development is perceived, the degree to which the people voluntarily, and involuntarily, interact with it and the extent to which it introduces values and lifestyles in marked contrast to or conflict with existing values and lifestyles.

The more "traditional" the value system and lifestyle, we have assumed, the greater will be the potential for impact. If the assumption is correct, the relative potential of the two projects for impact may best be determined by appraising the relative "traditionality" of native peoples in the two project settings. Essentially this is what we have attempted to do.

Potential Impact

As a result of extensive hearings related to construction of an Arctic Gas pipeline, the following was concluded: "The common position of the Native People of the Northwest Territory and Northern Yukon (Old Crow) is that before any Mackenzie Valley pipeline is approved their land claims must be settled (Commission Counsel 1976a). Commission Counsel (1976a) further concluded that this was not a view restricted to native organizations but rather one widely embraced by native peoples throughout the proposed Arctic Gas project area.

In their summary of fundamental recommendations, the Council for Yukon Indians (CYI) stated "That no pipeline be constructed until the Land Claims of Yukon Indian People have been settled and implemented" (CYI 1976a).

The community hearings conducted as part of the Mackenzie Valley Pipeline Inquiry clearly indicate that native people in the Mackenzie Valley view the proposed pipeline project negatively and consequently are opposed to it. It is not possible to ascertain the precise number who hold this view, however. It is even less clear at this time how native peoples residing in communities along the proposed Alaska Highway corridor regard a pipeline project.

Commission Counsel (1976a) stressed the importance of being cognizant of peoples' perceptions in appraising impact, noting "A distinction can usefully be made between 'actual' interference with native resources and 'perceived' interference. Even if evidence has been insufficient to establish definitely whether, for example, seismic activities have seriously threatened the animal populations upon which native people depend, the fact that such harm is perceived to have occurred has been sufficient to produce widespread anxiety and altered attitudes towards the resource base in native communities. Disregard for this anxiety aggravates the native peoples' sense of being unable to control their own lives. In many areas what is perceived as a problem is a problem." We suggest this statement is equally applicable to perceptions of social impact, like those voiced by Old Crow residents in the CYI submission to the Mackenzie Valley Pipeline Inquiry (CYI 1976b).

The limited data available to us clearly indicate that native peoples of the Northwest Territories are more "traditional" in orientation. Language serves as one useful indicator of this.

As indicated in our initial evaluation of the Alaska Highway corridor (England and Johnston 1977), the use of native languages has declined markedly in Yukon Territory during the last three decades (Statistics Canada 1951, 1961, 1971a). For example, census data show a 28 percent decline between 1951-71 in the number of Yukon residents reporting a native language as their mother tongue. Also, 1971 census data show only 425 persons in all of Yukon Territory as using a native language as the primary language of the home, 41 percent of the number reporting a native language as their mother tongue.

In contrast, census data show a 44 percent increase between 1951-71 in the number of persons in Northwest Territories reporting a native language as their mother tongue.

In addition, 13,500 persons are reported as using a native language as the primary language of the home, 85 percent of the number reporting a native language as their mother tongue.

The apparent contrast in resiliency of native languages in the two project settings may be explained by a variety of factors. Among those which appear most obvious to us are the differences in setting access and consequently differences in exposure to outside influences, and the differences in the proportion of the total setting population comprised of native peoples.

Alaska Highway corridor communities are without question much more accessible than all Mackenzie Valley communities with the possible exception of Fort Simpson which is located at road's end. As a consequence, the native peoples of the Alaska Highway corridor have been subjected to much more outside influence and are accustomed to travelling quite readily and at a relatively small cost to quasi-urban settings like Whitehorse. Travel is much more costly for residents of Mackenzie Valley villages. Mackenzie Valley communities where outside influence is most manifest - Inuvik, Fort Simpson, Hay River - are located far from the predominantly native settlements of Fort Macpherson, Fort Good Hope, Fort Norman and Arctic Red River.

Also, in the majority of Mackenzie Valley settlements, the population is overwhelmingly native. This is again in sharp contrast to the situation in most Alaska Highway corridor settlements (Table 1). It seems logical

Table 1. Proportion of corridor community populations comprised of native peoples.

	Total Population 1971	Percent Native
Corridor Settlements (Arctic Gas)		
Aklavik	660[a]	76[b]
Fort Macpherson	841	89
Arctic Red River	95	89
Fort Good Hope	375	93
Norman Wells	363	23
Fort Norman	260	84
Wrigley	191	83
Fort Simpson	1004	45
Sub total	3789	69
Non-corridor Settlements (Arctic Gas)[c]		
Inuvik	3249	48[d]
Hay River	3004	23
Sub total	6253	36
TOTAL	10,042	48
Corridor Settlements (Alaska Highway)		
Beaver Creek	120[e]	4[e]
Burwash Landing	67	82
Haines Junction	183	48
Whitehorse	11,217	7
Teslin	340	54
Upper Liard	219	89
Watson Lake	553	17
TOTAL	12,699	11

[a]Source: Gemini North (1974a, p.113).

[b]Source: Gemini North (1974a, p446).

[c]The non-corridor settlements shown are settlements which though they lie outside a 20 mile wide corridor along the proposed pipeline right-of-way will be subject to impact from staging, transportation, personnel movement and project management activities.

[d]Gemini North (1974a, p.446) cites as the source for this estimate 1971 NWT government community population data. Elsewhere, however, Gemini North (1974a, p.191) indentifies the 1971 Eskimo, treaty Indian and non-treaty Indian population of Inuvik as 969 or about 30 percent of the total population. A northern manpower survey program in the Yukon and Northwest Territories 1969-71 (DIAND undated) shows the Eskimo, treaty and non-treaty Indian population of Inuvik as only 662. We cannot reconcile these data.

[e]Source: Thibault (1975).

to assume that communities which have remained relatively more isolated from outside influence and are overwhelmingly comprised of native peoples with "traditional" values and lifestyles are better able to maintain more a "traditional" cultural orientation.

This is not to suggest that the native cultures of Mackenzie Valley have not undergone change in response to influences from without, for they have. Commission Counsel (1976a) in addressing the potential impact of a pipeline in the Mackenzie Valley corridor notes, however, "the evidence also suggests, and the community hearings establish that native people sustain and hold fact to many values and activities they regard as traditional".

The 1971 population of Mackenzie Valley corridor communities likely to be most directly affected by pipeline activity (this excludes such centres as Inuvik, Hay River and Yellowknife) was 3789 compared to 12,699 in the Alaska Highway corridor. Further, of the 3789 persons residing in the 8 Mackenzie Valley corridor communities apt to be most adversely affected, 69 percent were native peoples and almost 80 percent of these people lived in communities where they comprised at least three-quarters of the population (Table 1).

In contrast, only about 11 percent of the population residing in the 7 Alaska Highway Corridor communities was native and only about 17 percent of these people lived in communities where they comprised three-quarters or more of the population.

Comparison Summary

On the basis of the foregoing we conclude that the potential for adverse impact on the culture of native peoples is higher in the Arctic Gas than in the Alaska Highway corridor.

As already indicated, this evaluation does not take into account native peoples' perceptions of a pipeline project in either setting. Our conclusion, therefore, must be regarded as highly speculative, based as it is upon a somewhat superficial appraisal of relative ease of access, setting and exposure of native communities to outside influences, the proportion of corridor community population comprised of native peoples, and the seeming resiliency of native languages. Nonetheless, given the noteworthly differences in the two settings with respect to these factors, we have concluded that the Alaska Highway route is to be preferred over the Arctic Gas route.

PUBLIC SAFETY

Problem Definition

Large-scale project activity will contribute to an increase in crime rates and consequently an impairment of public safety. The Fairbanks experience with respect to Alyeska project activity clearly bears this out as reported by the Fairbanks North Star Borough Impact Information Center (IIC 1975,1976). With a sudden and large-scale increase in economic activity, such as that which characterized construction of the trans-Alaska pipeline and will characterize these gas pipeline projects, populations increase, the number of prey available to resident criminals increases, non-resident criminals are attracted to the area and life becomes more stressful for many residents. These and other factors contribute to an increase in crime.

Fairbanksans witnessed a significant increase in crime rates during construction of the trans-Alaska pipeline, particularly an increased rate of property crimes under the criminal code. There was also an increase in the incidence of violent crime. Our appraisal of Fairbanks crime rates in general and violent crime rates in particular, however, was that the increases were less than might have been anticipated given the magnitude of the population increases which accompanied Alyeska project activity -- a conclusion, we might add, only recently reached in Alaska as a result of a statewide criminal justice survey (IIC 1977).

The crime situation in Fairbanks was aggravated by a loss of local law enforcement personnel to pipeline security jobs.

Potential Impact

Commission Counsel (1976a) for the Mackenzie Valley Pipeline Inquiry anticipates increased crime to be more of a problem in what are termed the "action communities". These are the larger ethnically mixed communities of the Mackenzie Valley where growth is expected to be more sudden and dramatic as a result of project activity: Inuvik, Norman Wells, Fort Simpson and Hay River. The problems anticipated are summarized as follows: "In advance of, and until well after the period of pipeline construction, the action communities will experience rapid population increases, inflation, pressures on housing and services, lack of recreation facilities, increased cash income, increased alcohol consumption and heightened racial tension. Southerners may bring with them new problems associated with organized and more sophisticated crime" (Commission Counsel 1976a).

That increased crime does not seem to be perceived as a potential problem in the smaller native communities of the Mackenzie Valley may be an oversight on the part of Commission Counsel. It is interesting to note, for example, that Alaskans were surprised to discover from a recently completed statewide criminal justice survey that during the height of pipeline activity in 1975, crime was much more prevalent in the small rural Alaskan communities than in Fairbanks or Anchorage (IIC 1977). Robbery (property crime) and assault (violent crime) were found to be particularly prevalent in rural Alaskan communities.

In our initial evaluation of the Alaska highway pipeline project (England and Johnston 1977) we concluded that not only would that project give rise to an increase in the rate of property crimes such as Fairbanks experienced but also an increase in the rate of violent crime. Our conclusion that violent crime rates would also increase was based on the assumption that the prevailing high rate of violent crime in Yukon Territory is a valid indicator of the potential for increased violence.

We would suggest that the same conclusion applies to Northwest Territories, the only provincial or territorial jurisdiction in Canada where crime rates, both property and violent, are comparable to or exceed those prevailing in Yukon Territory. Property crime rates (per 100,000) in Yukon and Northwest Territories are 10,762 and 8240 respectively while violent crime rates are 2904 and 4513 respectively.

Since the RCMP assume responsibility for law enforcement in both Yukon Territory and Northwest Territories no serious problem in maintaining police personnel is anticipated in either area.

Impairment of public safety due to increased traffic and incidence of impaired driving is anticipated in

Yukon Territory and is expected to be most prevalent in Whitehorse and Haines Junction areas. Accidents and related injuries will be much less likely in Northwest Territories where many smaller corridor communities are not serviced by roads.

We anticipate that more itinerants seeking jobs and excitement will be attracted to Yukon Territory generally and Whitehorse in particular than to Mackenzie Valley communities given that Yukon communities are accessible by auto, bus, boat, train and air. Most of the communities in the Mackenzie Valley are serviced only by air and consequently much less accessible and more costly to reach.

To the degree that increased stress contributes to an increase in crime rates we would anticipate more crime in Mackenzie Valley. This conclusion is based on the assumption that the more an activity is alien to the residents' experience and the more those involved in the activity hold values and attitudes markedly different from those of local residents, the more stressful will be the situation for local residents. As indicated in the acculturation and public health (mental health) discussions of this volume, we feel that a greater potential for stress exists in the less acculturated villages of the Mackenzie Valley.

Comparison Summary

Crime rates will increase as a result of either project. Prevailing violent crime rates in both settings are high and may be expected to increase as a consequence of project activity. Although most communities in Yukon Territory are more accessible and consequently likely to experience a higher influx of itinerants during project activity, the population of Mackenzie Valley is apt to manifest more stress in response to project activity. In balance we conclude that neither route has outstanding advantages in terms of public safety. We would suggest, however, that the more ready access to the southern Yukon and the presence within the corridor of a large center, Whitehorse, could give rise to a slightly higher increase in crime rates than is likely to occur in Mackenzie Valley communities. As a consequence we conclude that from the perspective of public safety, the Arctic Gas route is slightly preferable to the Alaska Highway route.

PUBLIC HEALTH

Problem Definition

Large-scale project activity, as shown by the Alaskan experience, has the potential for impairing health and the quality of health service available to local residents (IIC 1974-1976). Increased stress resulting from Alyeska project activity affected mental health in Fairbanks and such effects have been predicted as a result of pipeline construction activity in northern Canada (Kehoe 1976). The increased incidence of injuries associated with construction activity as well as an increase in population also resulted in increased demand for medical services in Alaska. Demand at times exceeded existing capacity.

In appraising the relative potential of the proposed Arctic Gas and Alaska Highway pipeline projects for impact on public health, two indicators were used: capacity of existing hospital facilities relative to potential project demands, and potential for an increase in stress and consequently mental health problems.

Potential Impact

The potential impact of a gas pipeline on local health and health service delivery in Mackenzie Valley communities was addressed only briefly by Canadian Arctic

Gas Pipeline Limited (CAGPL 1974, Gemini North 1974a). In its assessment of the CAGPL application, the Federal government Pipeline Application Assessment Group (PAAG) noted "While the Applicant does not acknowledge that pressure would be placed on the health-care delivery system during pipeline construction and operation, it is reasonable to expect such pressures despite the fact that his work force should be a healthy population" (PAAG 1974, p.110).

The CAGPL assessment relies heavily on assumptions respecting the potential for fairly ready expansion of existing Northwest Territories medical facilities such as hospitals to cope with special project requirements and takes for granted that all necessary precautions, such as evacuation of injured project personnel to medical facilities in the south, will be taken to ensure that local facilities are not overburdened. We consider it ill advised to accept such expressions of intent at face value.

The potential for increased demand resulting from a simple increase in population received only passing consideration in the CAGPL application (CAGPL 1974) as did the potential for increased demand from local residents due to increased stress and social disruption resulting from project activity.

In addressing potential impact of the Alaska Highway pipeline project on public health we assumed that many of the changes in Fairbanksans' health and health service delivery in Fairbanks which characterized construction of the trans-Alaska pipeline will prevail in Yukon Territory generally and Whitehorse in particular. We see no reason not to assume that these same impacts will apply in the Northwest Territories. Indeed, there are some noteworthy differences in the projects and project settings which lead us to conclude that the potential for impact in the Arctic Gas project setting may be greater than in the Alaska Highway project setting. We consider differences in hospital capacity and medical staff complement in relation to size of project work force to be one such indicator.

There are five hospitals in Northwest Territories communities located within or close to the proposed Arctic Gas pipeline corridor. These hospitals with a combined capacity of 276 bed spaces and a total staff complement of 27 doctors vary greatly in size (Wood 1976). Inuvik General Hospital and Stanton Yellowknife Hospital are the largest and best equipped of the 5 hospitals with 129 and 78 bed spaces respectively (75 percent of the total bed capacity). These two hospitals also have about 74 percent of the medical doctor complement on their staffs. St. Ann's Hospital (Fort Smith), H.H. Williams Memorial Hospital (Hay River) and the Fort Simpson Hospital are small hospitals with a combined capacity of 69 beds (25 percent of the total bed capacity) and a total staff complement of 7 doctors (26 percent of the total number of hospital staff doctors). Clearly the vast majority of injured workers evacuated from pipeline construction spreads to hospitals within the Northwest Territory will be referred to Inuvik and Yellowknife hospital facilities. The potential for overloading these facilities and thus impairing the quality of service available to local residents is obviously greater than in Yukon Territory.

The combined capacity of the two major Northwest Territories hospitals is only about 36 percent greater than the capacity of Whitehorse General. At the same time the number of doctors on staff at these two hospitals is only 20 compared to 22 for Whitehorse General.

From information prepared by CAGPL (1974) we estimate the peak construction work force for the Arctic Gas pipeline project, north of 60°, at about 5000 or about 2.78 times the peak labor force estimated for Foothills' (1976) Alaska Highway project (1800).

In our initial evaluation of the impact of the Alaska Highway pipeline project on health, the impact of the Alyeska project on mental health in Fairbanks was reviewed and considered applicable to the southern Yukon. Again we see no reason for not assuming these same problems will apply in the Mackenzie Valley setting. Indeed, given the seemingly pronounced cultural differences between the southern Yukon and Mackenzie Valley project settings, we would venture to suggest that mental health problems are likely to be more pronounced in the latter setting. We base this comparative assessment on the fact that native peoples in Mackenzie Valley communities appear more "traditional" in orientation and their culture "less" modified (but certainly not unmodified) than is the case in Alaska Highway native communities. Consequently a major pipeline project and the attendent change associated with it would be more alien and stressful to Mackenzie Valley residents than to Alaska Highway corridor residents.

Alaska Highway corridor residents have a history of being confronted by large-scale development activity; and due to their relatively long-term residence in larger centers like Whitehorse and in communities bordering a major road, they have had regular contact with outside influences. This is not to minimize the real potential for increased stress in Alaska Highway communities, however. Rather, it is simply a recognition of the difference in degree of stress that may well result from a major project undertaking.

Comparison Summary

We consider that public health in the Mackenzie Valley setting is more susceptible to impact. In our judgement, the probability of Mackenzie Valley hospital facilities being overburdened is greater, and as a consequence the quality of service available to residents impaired. Also, given the seemingly more traditional orientation of native peoples of the Mackenzie Valley and their more limited exposure to outside influences, we would suggest that a pipeline project could induce more stress among them and consequently give rise to more mental health problems in Mackenzie Valley communities.

Consequently, we consider the Alaska Highway route preferable with respect to public health considerations.

COST OF LIVING AND INCOMES

Problem Definition

On the basis of Alaskan experience, it is reasonable to assume that both the Alaska Highway and Arctic Gas pipeline projects could increase the rate of inflation (raise the cost of living) in their respective regions. By doing so, the projects would tend to offset increases in nominal incomes that were realized by local residents. The problem, then, is to assess the extent to which each project could affect real incomes in either region.

The inflationary impetus will result from a marked increase in aggregate demand during the proposed construction periods. For example, prices of consumer goods are expected to rise in response to the increased demands of migrant labor, at least until such time as local retailers can increase the capacity of their stores, given that existing capacity is insufficient. One component in this expansion of capacity would be capital to expand floor and hence storage space for commodities. But if the costs of capital expansion must be recovered over the construction period, since demand will decline after that time, consumer prices will rise, reflecting the costs of expansion. The alternative is not to expand capacity, in which case prices may rise reflecting shortages of goods rather than increased costs.

In the event that the flow of consumer goods is augmented, though, there will be an increased demand for transportation services, since these are a vital input to northern retailers. Recalling that pipeline construction will be competing with local retailers for similar types of transportation services (indeed, there will be more competition for the inputs, capital and labor, within the transportation sector), further price increases are probable. Similar lines of thought apply to other sectors of the economy, with the common underlying theme that increased demand for intermediate inputs such as capital, labor and transportation, will be reflected in higher consumer prices.

The relative importance of inputs to each sector and the ultimate level of demand for the outputs will, generally speaking, determine price increases during pipeline construction. For example we have identified expansion of capacity and transportation as important elements in the supply of consumer goods. However, in a sector such as accomodation, the relevant decision is whether or not high capital costs, inherent to this industry, can be recovered over the period of pipeline construction. If the level of demand warrants, the supply of housing will expand and prices will rise in order that costs can be recovered over a short period of time. On the other hand, if there is increased demand for housing but not enough to justify many new housing projects, prices of existing accomodation will rise, reflecting the shortage.

The demand for labor will also be reflected in final prices. For example, pipeline construction is expected to draw off local, skilled construction workers from their traditional pursuits in favour of working on the pipeline. The relative shortage of workers for non-pipeline projects will result in a commensurate rise in the costs of these projects. The same may be said of trucking firms competing for labor in response to the increased demand for their services.

Little can be concluded by discussing the inflation rate by itself; the importance of the inflation rate over a given period of time is found by deleting this rate from the change in nominal incomes over the same period of time. Only in this way can the change in real incomes be established. That is, a change in real income denotes a net change in welfare, or purchasing power, for a given period of time.

Some idea of the change in real incomes for Alaskan non-agricultural wage and salary earners over the 2-year period 1974-75, is given as follows. Weighted by 1974 average monthly employment figures, about 19.8 percent of Alaskan non-agricultural wage and salary earners enjoyed a real income increase of at least 10 percent, while about 46.8 percent incurred a loss of real income. Weighted by 1975 average monthly employment figures, about 28 percent of the Alaskan non-agricultural wage and salary earners enjoyed a real income increase of at least 10 percent, while about 41.2 percent incurred a loss of real income (calculated from

Alaska Dept. of Labor 1975a, 1976a,b). We believe that much of the Alaskan inflation, and consequently the changes in real incomes, was attributable to demands made by the Alyeska project. For example, direct employment on the Alyeska pipeline peaked at about 23,460 people which represents about 20 percent of the 1971 Alaska labor force (Alaska Dept. of Labor 1975b). A project of this magnitude would, no doubt, induce important side effects such as inflation in the local economy.

Potential Impact

In this section we have assumed that the scale of the two projects being compared (measured by employment data) relative to the size of the labor forces of the regions where they occur, will be a significant determinant of inflation. This assumption ignores possibilities for significant differences between the economies of the two regions. Such differences may be: 1) capacity utilization rates of existing businesses, 2) speeds of response of the output of each sector to a rapid increase in demand, and 3) increasing costs to local businesses from meeting the increased demand. (In other words, the supply side of both markets is assumed to behave in a similar fashion in response to a rapid increase in demand).

Therefore, differences in potential demands from either project are assumed to be the source of differences in inflation rates between the two regions. As stated above, inflation is assumed to be a direct function of the number of workers employed by each project relative to the size of the labor force in each region.

The Alaska Highway pipeline, essentially a 5-year project, has most of its activities concentrated between October of the first year and October of the third year of construction. If data provided by Foothills are accurate, employment does not drop below about 800 people during the two years of heaviest construction (Foothills 1976). Two peak employment periods occur, about 1700 during the summer of the second year and about 1800 during the summer of the third year. Peak employment of 1800 represents about 22 percent of the 1971 Yukon labor force (Statistics Canada 1971b). This is roughly equivalent to the peak manpower requirements of the Alyeska project relative to the Alaska labor force. Our best guess, given the above, is that impacts similar to those which occurred in Alaska could occur in the Yukon. That is, while a portion of the labor force will make substantial gains in real incomes, many will incur a loss due to the fact that inflation will increase faster than their nominal incomes.

Arctic Gas construction is projected to take place over a 4-year period with its heaviest activities occurring in the winter. Manpower requirements in the District of Mackenzie (ie. north of 60°) are estimated to peak at about 4000 during the first winter of heavy construction and about 5000 during the second winter. Peak employment of 5000 represents about 67 percent of the 1971 labor force in the District of Mackenzie (CAGPL 1974, Statistics Canada 1971b).

It is evident that manpower requirements for the Arctic Gas proposal represent a substantially larger proportion of the local labor force than manpower requirements for the Alaska Highway project (67 percent compared to 22 percent). Linking this to the assumption that there is a functional relationship between inflation and the ratio of manpower requirements to local labor force, we suggest that inflation will be more severe under the Arctic Gas proposal.

Given the above, the question as to whether or not nominal incomes will increase more in the District of Mackenzie and thus militate against the more severe inflationary impact remains. Table 1 establishes that in 1970, income distribution was more concentrated among the lower income earners in the District of Mackenzie. If this differential persists today, one could expect pipeline construction to offer greater nominal income changes to those in the District of Mackenzie, assuming no significant interregional migration.

Differences in nominal income changes, in the advent of a pipeline, will depend on differences in the ability and inclination of local people to work in the more dynamic sectors of the economy during pipeline construction. In Alaska, these wage-leading sectors were business services, trucking and warehousing, water transportation, "other" transportation, contract construction, and eating-and-drinking places. (This is based on data from the Alaska

Table 1. Incomes of males who worked in 1970, Yukon Territory and District of Mackenzie, by percentage distribution.[a]

	<$1000	$1000 - $1999	$2000 - $3999	$4000 - $4999	$5000 - $5999	$6000 - $6999
Yukon	7.3	5.4	10.1	5.3	5.4	6.9
Mackenzie	13.2	8.0	12.0	5.3	5.7	6.1

	$7000 - $7999	$8000 - $9999	$10,000 - $14,999	>$15,000
Yukon	7.3	18.5	27.2	6.7
Mackenzie	7.6	16.3	20.9	4.9

[a]Statistics Canada (1971b).

Department of Labor 1975b and 1976b). If we consider that the ability of local residents to gain pipeline employment is similar in both regions, and that the inclination of local residents to seek pipeline employment is a direct function of the income to be gained, and if we accept that there is presently a higher concentration of lower income earners in the District of Mackenzie one would expect a stronger response to pipeline employment from this area. Coupled with the fact that there will be a greater demand for manpower (for a shorter time period) on the Arctic Gas project, we expect a greater increase in nominal incomes to accrue in this area.

Comparison Summary

Recalling that over 40 percent of the Alaska labor force incurred a loss of real income, we feel that the potential for inflation is the primary concern. Our feelings as to the potential difference in the inflaction rates from these projects are fairly well established in the above text, where we indicated that the scale of the Mackenzie Valley proposal relative to that local economy by far exceeds the scale of the Alaska Highway proposal relative to the Yukon economy; the potential demands and hence inflationary pressure would seem to be greater for the Mackenzie Valley pipeline. Therefore, we slightly prefer the Alaska Highway route.

EMPLOYMENT

Problem Definition

We expect that short-term employment opportunities will be made available to residents in the Yukon Territory or the District of Mackenzie should either proposal be approved. However, it would be quixotic to suppose that either project will be a panacea for unemployment problems in either region, due to the relatively short construction period and the seasonal nature of employment on either project. The employment benefits that do accrue, both during and after construction, should be measured by the change in the unemployment rate of local residents.

We expect that the rapid increase in the demand for labour for either project may impose additional costs on local businesses. These costs may be reflected in increased turnover rates for labour, with higher training costs and lost output.

Because labour force surveys are not done in the North, little statistical information is available for a comparison of the two regions. For example, the most recent and reliable unemployment data are from the 1971 Census which put unemployment rates in the District of Mackenzie at 4.2 percent and 4.4 percent for males and females respectively, and in the Yukon, at 6.3 percent and 7.2 percent (Statistics Canada 1971c). However, when one considers that these 6-year-old figures were based on whether or not an individual was employed during the last week of May, the possibilities for definitive conclusions in the present context are limited.

We did not use information published by Gemini North (1974a) due to the statistical methods they employed. In comparison with labour force surveys conducted by Statistics Canada, the material published by Gemini North was, in our opinion, misleading.

According to Palmer and St. Pierre (1974), "...there is no system to assess on a continuing basis the size and status of the labour force in the N.W.T." This has been borne out by our experience; yet despite the lack of statistical data, we have attempted to outline the theoretical issues of employment impacts in each region. Our conclusions are based on 1971 Census data; but it must be remembered that we view these data with some skepticism in the present context.

Potential Impact

From 1971 Census data, we know that the labour forces of the Yukon Territory and District of Mackenzie each numbered about 8250 that year. A significant difference was found in the participation rates, however: 68.6 percent for the Yukon Territory and 58.1 percent for the District of Mackenzie (Statistics Canada, 1971c). The lower participation rate in the District of Mackenzie could imply that a pipeline built through that area might have a stronger effect in expanding the labour force than would the Alaska Highway pipeline in the Yukon. This would depend, though, on differences in the inclination and ability of residents in both areas to seek employment during construction.

We believe that sufficient demand for labour will be generated by either project to affect favourably, in a small way, the unemployment rates of local residents in either region during the construction period. Indeed, there is a possibility that interregional migration of labour may affect the unemployment rate of one region should a pipeline be built through a neighbouring region. We suspect that there will be little difference in employment impacts between the two proposals, both during and after construction.

We do not anticipate a significant difference in the potential for labour turnover problems resulting from either project. Based on the Alaska experience, and assuming no offsetting policies, we believe that these problems may be prevalent in both regions. It is reasonable to suppose that labour turnover could be inhibited by local firms offering more competitive wage scales. However, this would tend to be inflationary to the extent that wage rates are reflected in higher prices for consumer goods. It could also reduce the return to capital when some products are sold at world prices (such as the output of the mining industry) in other than local markets.

Comparison Summary

In view of the lack of available information, we have no real basis for predicting the differences in employment impacts to be generated by either project. We have assumed that there will be similar relative effects on the unemployment rates resulting from either project, which might favour the Alaska Highway proposal if 1971 Census data is accurate and relevant today. On the other hand, the potential for expansion of the labour force in the District of Mackenzie seems greater, again if 1971 Census data is relevant, which would tend to favour the Arctic Gas proposal. In addition, we believe that local labour markets may be disrupted to an equal extent in either region. In view of the above we regard neither project as preferable to the other.

The Transmission of Prudhoe Bay Gas to American Markets:
A Preliminary Environmental Comparison of the Canadian
Arctic Gas Pipeline and the Foothills (Yukon) Pipeline
in the Yukon and Northwest Territories

BACKGROUND DOCUMENTATION

LOCAL ECONOMY

CONTENTS

England, R.E. 1977. Local Economy. Pages 371 to 381 *in* Background documentation. Appendix *to* The transmission of Prudhoe Bay gas to American markets: A preliminary environmental comparison of the Canadian Arctic Gas pipeline and the Foothills (Yukon) pipeline in the Yukon and Northwest Territories. Alaska Highway Pipeline Panel, Winnipeg. 420 pp.

SUMMARY[1]

For the Local Economy component of the human environment only two parameters were examined: trapping and commercial fisheries. In both instances major impact is not anticipated and those impacts considered possible are regarded as short-term or transitory in nature. With respect to impact on furbearer populations and consequently harvest potential, particularly for aquatic furbearers, the Alaska Highway route appears slightly preferrable. Neither project is regarded as potentially deleterious to commercial fisheries.

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[1]See also "Human Environment--Overview", pages 331-333.

TRAPPING

Problem Definition

The concern with respect to trapping is for potential long-term impact of a pipeline on furbearer populations and consequently harvest potential. This is only likely to occur in areas where traplines are actually crossed by a pipeline or where furbearer habitat within the general vicinity of a pipeline is somehow altered, e.g. water flows and levels downstream of a pipeline are affected.

Although many may tend to regard trapping as a relatively insignificant activity in economic terms, there remains a strong emotional as well as economic attachment to this activity in many northern native communities. Commission Counsel (1976a) for the Mackenzie Valley Pipeline Inquiry summarized their findings with respect to this emotional attachment as follows: "Native people are not as completely dependent on the land and its resources, as in traditional times. Yet many who testified before the inquiry still spoke of the land as something vital to their cultural identity and economic welfare - as their "bank"." It is primarily because of this strong emotional attachment that impact upon furbearers and consequently trapping is of concern here.

Potential Impact

Information provided by Yukon Game Branch personnel (Archibald personal communication) indicates that 63 traplines are crossed by or lie wholly or partially within the proposed Alaska Highway pipeline corridor. In 1973-74, an estimated 3192 pelts with a gross value of about $41,550 were harvested from these traplines. At best we are able to determine that the above production was taken by about 25 trappers.

We know neither the number of trappers utilizing, nor the harvest from a 20-mile-wide corridor along the proposed Arctic Gas pipeline alignment. At best we can focus attention on trapping activity in those communities within or close to the proposed pipeline right-of-way: Aklavik, Fort Macpherson, Arctic Red River, Fort Good Hope, Fort Norman, Wrigley and Fort Simpson.

Fewer native people in the Mackenzie Valley communities trap now than in the recent past. As a consequence, the number of furbearers harvested has declined considerably. Gross revenue from trapping has only been maintained at former levels due to the current strong market, particularly the market for long fur (PAAG 1974). Data available for trapping activity and harvest in Yukon Territory would indicate that the same general observations attain there (Hoefs 1975, Tanner 1966).

Estimates of 1972-73 gross revenue to trappers residing in the Mackenzie Valley communities mentioned above vary. Gemini North (1974b) estimated the 1972-73 gross revenue to trappers in the aforementioned communities at $220,467. Bissett (1974) on the other hand estimated gross revenue from local fur sales at $207,633 but provided no estimate of 1972-73 revenue from export fur sales. In 1970-71, however, 33 percent of the total trapping revenue in these communities was derived from export fur sales. If this same ratio prevailed in 1972-73 the total trapping revenue in these communities could have been about $276,000.

There were an estimated 419 trappers in the aforementioned communities in 1972-73. Of these about 82 met one or both of the following criteria. They had a gross return from trapping in excess of $1000, or spent 2 or more months on the trapline (Bissett 1974). These 419 and 82 trappers would represent about 46 percent and 9 percent respectively of the total 1971 male population 15-65 years of age in these communities.

In the Mammals section of the initial evaluation of the Alaska Highway pipeline corridor (Mutch 1977) and in the Mammals section of this report the potential for pipeline impact on acquatic furbearers is discussed. It is concluded that the potential for impact on aquatic furbearers, the staple species of the trapping industry, is greater in the Mackenzie Valley than along the Alaska Highway corridor. If impact is more likely and of potentially greater magnitude in the Mackenzie Valley, there is greater potential for impact on trapper harvest. For the most part impact on furbearer habitat will be transitory and little long-term impairment is anticipated.

Comparison Summary

We conclude that a greater potential for short-term impact on trapper harvest exists along the Arctic Gas route. However, no major long-term impairment of staple furbearer habitat and populations and consequently harvest potential is expected on either the Alaska Highway or Arctic Gas routes. Native people along the Mackenzie Valley nonetheless appear to perceive a potential for greater impact, and the importance of these perceptions cannot be ignored. We therefore feel that the Alaska Highway route is slightly preferable.

COMMERCIAL FISHERIES

Problem Definition

Commercial fisheries provide one of the few sources of earned income in many mid-northern communities, particularly native communities. As one proceeds into the far north or remote areas, however, transportation costs tend to render commercial fishing activity uneconomic. Consequently, northern contexts far removed from the market, commercial fishing for other than local markets is uncommon. Where commercial fisheries do exist, the potential for project impact on them deserves attention nonetheless.

The primary concerns with respect to project impact are long-term degradation of fish habitat and large-scale reduction of fish populations. Project activity which leads to high and sustained levels of siltation of major spawning areas, interrupts spawning runs, or exposes populations to toxic chemicals is of particular concern.

Potential Impact

Commercial fishing harvest in both the Mackenzie Valley and Alaska Highway settings is small. In Yukon Territory the estimated 1973 commercial harvest from waters within the effect zone of the proposed pipeline was 53,600 pounds (Yukon Territorial Government undated).

The only commercial fishery within the potential effect zone of the proposed Arctic Gas pipeline, and one which has had a very checkered history, is located in the Mackenzie Delta. In 1972, the harvest from this fishery was probably less than 5000 pounds but has been as high as 63,998 pounds (Barlishen and Webber 1973).

Virtually all the commercial production in Yukon Territory is sold locally. This is generally true for the Mackenzie Delta production also. The year when 63,998 pounds of whitefish were harvested from the Delta, however, fishermen delivered their production to Menzies Fish Company Limited which exported it to Edmonton along with char production from their Herschel Island and northern Yukon coast fisheries.

Due to the limited nature of Yukon commercial fisheries and the transitory nature of impact from siltation, we concluded with respect to those fisheries, that construction of a pipeline did not constitute a serious problem. Similarly we foresee no serious long-term impact on commercial fisheries of the Mackenzie Delta due to siltation. The fish populations commercially harvested in the Delta are far removed from the pipeline corridor. The only potential source of impact envisaged for the commercially harvested fish populations of the Delta would be from a fuel or toxic chemical spill carried into the Delta from an upstream stockpile or work site. Given the distance of the harvest area from the pipeline right-of-way, however, there would probably be ample time to clean up a spill (if not in winter) before it reached the commercial fishing area.

Comparison Summary

We see neither project as having a greater potential for impact than the other on commercial fisheries.

We would add a note of caution, however. These conclusions apply to commercial fisheries only. Domestic or subsistence fisheries have not been addressed.

The Transmission of Prudhoe Bay Gas to American Markets: A Preliminary Environmental Comparison of the Canadian Arctic Gas Pipeline and the Foothills (Yukon) Pipeline in the Yukon and Northwest Territories

BACKGROUND DOCUMENTATION

MAN/LAND

CONTENTS

Will, G. 1977. Man/Land: Archaeological-Historic Sites. Pages 387 to 394 in Background documentation. Appendix to The transmission of Prudhoe Bay gas to American markets: A preliminary environmental comparison of the Canadian Arctic Gas pipeline and the Foothills (Yukon) pipeline in the Yukon and Northwest Territories. Alaska Highway Pipeline Panel, Winnipeg. 420 pp.

Hernandez, H. 1977. Man/Land: National Parks. Pages 395 to 396 in Background documentation. Appendix to The transmission of Prudhoe Bay gas to American markets: A preliminary environmental comparison of the Canadian Arctic Gas pipeline and the Foothills (Yukon) pipeline in the Yukon and Northwest Territories. Alaska Highway Pipeline Panel, Winnipeg. 420 pp.

Hernandez, H. 1977. Man/Land: Special Areas. Pages 397 to 402 in Background documentation. Appendix to The transmission of Prudhoe Bay gas to American markets: A preliminary environmental comparison of the Canadian Arctic Gas pipeline and the Foothills (Yukon) pipeline in the Yukon and Northwest Territories. Alaska Highway Pipeline Panel, Winnipeg. 420 pp.

SUMMARY[1]

For the Man-Land Heritage component of the human environment three parameters were examined. These were: archaeological and historic sites, special areas (ecological reserves and wildlife sanctuaries), and national parks.

The Alaska Highway route is regarded as being only slightly preferable to the Arctic Gas route with respect to potential impact on archaeological and historic sites. This conclusion was based on the following considerations: site density is very low on both routes, there are few known "important" sites and few sensitive areas on either route, sites on both routes are of equal "value", and the sequences for each area equally "important". The factors favoring the Alaska Highway route are primarily related to the following: the Alaska Highway route has already been impacted by construction of the highway; and the area is more readily accessible, thus facilitating monitoring and salvage should sites be revealed during the progress of construction.

Both routes would affect important proposed and designated special areas. Overall, however, the Alaska Highway route is preferred. Route preference hinged on the potential for impact on the Duke Meadows and Sheep Mountain sites of the southern Yukon vs the Firth River-North Slope area of the northern Yukon crossed by the Arctic Gas route. The latter was considered more critical and consequently the Alaska Highway route was favored.

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[1] See also "Human Environment--Overview", pages 331-333.

The Arctic Gas route is preferred for potential impact on national parks since it does not cross any parks. The Alaska Highway route, however, crosses Dall's sheep wintering range at the base of Sheep Mountain in Kluane National Park. Although the northern Yukon has been considered under special areas, a national park is also under consideration here.

ARCHAEOLOGICAL-HISTORIC SITES

Problem Definition

Both routes cross territory formerly occupied by the predecessors of Indians, Inuit, or both. This past occupation is recorded in archaeological sites scattered throughout the region. Some of these sites may date to 30,000 years ago, the initial occupation of the New World. Later sites relate to the development of native cultures on this continent while more modern sites record the arrival of Europeans and their activities for the past few hundred years.

Archaeological sites are very fragile and are non-renewable resources. It is probable that a number of archaeological sites will be encountered along either right-of-way, and it is imperative that every effort be made to preserve this archaeological record. Where pipeline construction activities conflict with archaeological sites, data concerning the past are invariably lost unless mitigative procedures are brought into effect. The types of potential conflict, their degree of destructiveness, and the mitigative procedures designed to eliminate or reduce potential impacts have been previously described (Doyle 1974). In addition to potential negative impacts, however, pipeline construction also contains some positive aspects related to the archaeological resource. Potential new site discoveries and subsequent archaeological investigations resulting from pipeline construction could greatly add to our knowledge of the prehistory of northwestern North America.

Neither of the two routes appears to directly affect historic sites such as forts and trading posts, abandoned settlements, buildings from the Gold Rush, or historic routes and trails. These historic sites are well-documented and their locations known. The potential effects on prehistoric archaeological sites, therefore, will form the basis of this route comparison. Route comparison criteria include: number of sites in the pipeline corridor, number of major site-specific concerns (known sites directly affected), amount of prior disturbance, and accessibility of endangered sites for salvage operations (effectiveness of mitigative procedures).

Potential Impact

Alaska Highway Route:

No Early Man sites are known within the proposed corridor but some have been found nearby. The first well-documented complex, the Kluane Complex (MacNeish 1964), was first recorded at the Gladstone site on Kluane Lake. MacNeish regards this as a manifestation of the Old Cordilleran Tradition common throughout northwestern North America and is dated to around 8000 BC.

The next period of occupation is called the Champagne Phase by MacNeish (1964) and represents a manifestation of the Northern Plano or Agate Basin Complex (Millar 1968). This was a bison hunting culture dated to before 5000 BC and is believed to represent an expansion from the plains.

The Northwest Microblade Tradition is also a ubiquitous tradition in northwestern North America. In the Yukon it is known as the Little Arm Phase (MacNeish 1964) and dates from 6000 to 2500 BC. There then seems to be an abrupt hiatus probably reflecting a rapid environmental change. The next phase, the Taye Lake Phase, seems to represent an entirely new population because of the great differences in its artifact assemblage. The Taye Lake Phase at about 2500 BC marks the beginning of a cultural sequence leading up to the ethnographic Athapascan populations and ending only with European contact.

There are approximately 66 known prehistoric archaeological sites reported in the proposed corridor between the Yukon-Alaska border and the 60th parallel: 33 from the Alaska border to Kloo Lake, 33 between Kloo Lake and Whitehorse, and 10 from Whitehorse to Watson Lake (Will 1977).

Many of these sites have been previously impacted and/or excavated during or following construction of the Alaska Highway. Since the pipeline generally parallels the highway closely throughout much of its route, many sites likely to be encountered during pipeline construction were discovered during highway construction. A few small sites were destroyed and there have been archaeological excavations at about 10 others. The route crosses little unexplored territory and in any case the presence of the highway facilitates any necessary archaeological salvage activities from reconnaissance through excavation.

Human population density in the area prehistorically was likely always low (1 individual per 10 km^2) so sites are both rare and scattered. It is unlikely that more than 20 previously unknown archaeological sites would be encountered during construction of the pipeline. Of the known sites only two or three appear to be in danger of direct impact from pipeline construction and it is relatively simple to avoid or excavate them. As Morlan (1975: 7628) pointed out in his testimony before the Berger Inquiry, of the 400 known prehistoric sites in the Yukon only a few dozen warrant protection or intensive excavation. Very few sites along the Alaska Highway route meet Cinq-Mars' (1974:28) criteria establishing a site as important enough to protect or excavate. Only some of the sites from Kluane Lake and the Aishihik-Dezadeash Valley confluence meet even one of the criteria. Most of the other sites are small surface scatters of undiagnostic material which, if encountered, can be rapidly dealt with using conventional archaeological recovery techniques.

Arctic Gas Route:

There is some convincing evidence that Early Man was present in northwestern North America as early as 30,000 years ago. A very old find was made at Old Crow Flats (Harrington and Irving 1967; Harrington 1970; Irving 1968, 1971; Irving and Harrington 1973). If other sites of similar antiquity are found within the Mackenzie Corridor there will be little doubt that it was used as a major migration route for Early Man into the New World.

Certainly the corridor was used as a migration route for hunters in later times. A date of 15,000 years before present is given to an occupation at Fisherman Lake (Millar 1968). The first identified cultural tradition for the area is the Old Cordilleran known widely from northwestern North America. It is manifested at Engigstciak at the northern extreme of the corridor (MacNeish 1964) and from Fisherman Lake at the southern end (Millar 1968) but is absent to date from the corridor itself.

The first well-identified tradition in the corridor is the Northern Plano (MacNeish 1964) or Agate Basin Complex (Millar 1968). There are numerous type sites in the Barren Grounds, Yukon, Alaska, and in the Mackenzie Corridor. It is dated to the period before 5000 BC and represents an intrusion of Plains bison hunters.

The next tradition, the Northwest Microblade Tradition (MacNeish 1964), is very widespread with a great deal of local variability. It has been found in several corridor sites including Franklin Tanks (MacNeish 1955, 1964) and Fisherman Lake (Millar 1968). It has been dated to between 3000 BC and 1 BC.

The next period saw the beginning of ancestral Athapascan culture. Sites dating to this period are: Whirl Lake (Gordon 1973) and Fisherman Lake (Millar 1968). This cultural sequence continues until ethnographic times. Most of the sites in the corridor date to this time period.

The Mackenzie Delta area has a somewhat different prehistory than the corridor. The earliest dated material (3500 BC) is known as the Mackenzie Blade Industry (Gordon 1974). The British Mountain Tradition (MacNeish 1964) is slightly later and is found west of the Delta. The Arctic Small Tool Tradition (Irving 1968) represents the first occupation of the Delta itself. It has been dated from 3000 to 1000 BC and resembles the Northwest Microblade Tradition. It seems to have originated in the Bering Strait area. Later peoples lived along the river and utilized the caribou. They came originally from Alaska along the Arctic coast around 500 BC and remained until AD 1000 being replaced then by the ancestors of the present-day Mackenzie Eskimos.

Approximately 200 recorded archaeological sites have been reported along the Arctic Gas route: 58 from the Arctic Coast to Fort Good Hope (MacNeish 1953, 1956, Gordon 1971, McGhee 1971, Millar 1973, 1974, Cinq-Mars 1974, Clark 1973, Losey 1974), 130 from Fort Good Hope to Willowlake River (MacNeish 1953, 1954, Millar 1973, 1974; Losey 1974, Fedirchuk and Dice 1972, Goshorn and Hilderman 1972, Janes 1974), and 10 sites from the Willow Lake River to the 60th parallel (MacNeish 1954, Millar 1973, Losey 1974). Site density in the corridor is generally very low and many of the above sites are some distance from the proposed right-of-way.

Few sites meet Cinq-Mars' (1974:28) criteria for being "important". There are a few known large, stratified sites which are culturally important, very complex, and which require total protection: Engigstciak, Klo-Kut, Old Chief, Rat Indian Creek, Kittigazuit and Kopuk (Cinq-Mars 1974:24). "With two exceptions -- the Fisherman Lake area with its impressive site clustering and its possible early cultural manifestations, and the Lower Delta, with its large prehistoric Eskimo settlements -- the Mackenzie Valley portion of the Corridor has yielded little in terms of extensive and/or diagnostic prehistoric artifacts" (Cinq-Mars 1974:2).

Although much of the proposed route has been surveyed archaeologically, especially in priority areas such as river mouths and lake shores, most of the route is still unexplored often simply because of inaccessibility. Any type of archaeological work is hindered by the logistical problems of dealing with the inhospitable terrain (muskeg, permafrost, lakes, etc.) and the difficulty of supporting remote operations because of transportation difficulties.

Comparison Summary

Of the 66 known sites in southwest Yukon only a few are in danger of being affected by pipeline construction activities. The very low site density for the area indicates that the potential for impacting unknown sites is also extremely low. Very few important sites are known and these can readily be avoided. Many sites were previously disturbed during construction of the Alaska Highway which closely parallels much of the Alaska Highway pipeline route. The proximity of the highway also facilitates all archaeological activities from reconnaissance to salvage excavation.

In the Mackenzie Valley corridor, site density is also very low, few sites are likely to be encountered, there are few "important" sites, and there are few sensitive areas. Sites in the case of either route are of equal "value" and the cultural sequences for each area are equally "important"

The Arctic Gas route is longer than the Alaska Highway route in the area compared. There is more construction activity associated with it; there are more compressor stations, stockpile sites and camps; and there is more potential to adversely effect the archaeological resource. Logistically, the Alaska Highway route is also favored because the proximity of the highway along much of the pipeline route facilitates archaeological reconnaissance and salvage operations. For these reasons the Alaska Highway route is slightly preferred.

NATIONAL PARKS

Potential Impact

Several areas in the Yukon Territories and Northwest Territories have previously been designated as national parks. Others are under consideration for such designation in the future. These areas represent significant or unique areas worthy of preservation.

Alaska Highway Route:

The Alaska Highway route will cross Kluane National Park for about 25 km at the south end of Kluane Lake. The portion of Kluane National Park affected lies at the base of Sheep Mountain just inside the northern boundary of the park. Sheep Mountain represents one of the special areas within Kluane National Park and contains critical winter range for up to 200 Dall's sheep (Hoefs et al. 1975). This crossing is unavoidable because Sheep Mountain rises directly from Kluane Lake at this point.

Arctic Gas Route:

The Arctic Gas route will not affect Nahanni National Park in the Northwest Territories but it will cross part of the northern Yukon which has been proposed as a national park (Parks Canada in Commission Counsel 1976b).

Comparison Summary

For national parks, the Arctic Gas route is preferred because it does not cross any existing parks whereas the Alaska Highway route will infringe on the existing Kluane National Park. The Arctic Gas crossing of the northern Yukon is considered under special areas.

SPECIAL AREAS

Problem Definition

Numerous areas of the Yukon and Northwest Territories, have already been designated or have been proposed for future designation as ecological reserves or wildlife sanctuaries. These areas are of special public interest, limited in occurrence, restricted in distribution or representative examples of the various natural regions of Canada. Both proposed pipeline routes cross or pass close to several of these special areas.

The compatibility of industrial activities within an ecological reserve or wildlife sanctuary varies with the industrial activity and the reason for which a site is considered special and worthy of preservation. In some cases entire reserves or sanctuaries require prohibition of activities; in other cases only key areas within a larger reserve or sanctuary require the highest degree of protection.

Comparison of the two projects will be based on examination of the numbers and types of proposed project activities within a designated or proposed ecological reserve or wildlife sanctuary, the sensitivity and level of protection considered compatible with the area affected and the feasibility and ease with which such conflicts could be avoided.

Potential Impact

Alaska Highway Route:

The region beside the proposed Alaska Highway pipeline route in the Yukon contains the Kluane Game Sanctuary and six proposed ecological reserves (Beckel 1975): Koidern River area (Pickhandle Lake), Klutlan Glacier area (between the White and Donjek Rivers south of the Alaska Highway), Duke Meadows (at the Duke River), Sheep Mountain-Mount Wallace (at the southern end of Kluane Lake), Mount Archibald-Decoeli area (between the Jarvis and Dezadeash Rivers), and Wolf Lake (in the northern Cassiar Mountains). The proposed alignment crosses the Kluane Game Sanctuary and four of the proposed ecological reserves: Klutlan Glacier area, Duke Meadows, Sheep Mountain-Mount Wallace, and Mount Archibald-Decoeli.

The proposed alignment generally parallels and lies outside the northern boundary of the Klutlan Glacier area (MPs 45-48, 59-87). This site is entered, however, every time the pipeline comes to the south side of the Alaska Highway (MPs 62-69 and 72-79). About 90 ha in the area could be affected (0.02 percent). In addition a stockpile site at MP 70 lies just outside the site beside a lake complex.

The southern tip of Duke Meadows is crossed at pipeline MP 110 for about 2.5 km. The total area disturbed will be about 10 ha (out of 2500). About half this 10-ha area is grassland. A stockpile site is proposed on the west shore of Duke River.

The entire pipeline between MPs 136-154 lies within the northern boundary of the Sheep Mountain-Mount Wallace site. Most of the alignment lies only a few hundred metres within the site but between MPs 136-138, 146-148 and 150-154 it lies about 1.5 km inside the area. The area disturbed would be about 120 ha (0.3 percent of the site), part of it crosses the bottom of critical Dall's sheep winter range. Effects on sheep will also result if construction activities occur in winter.

Much of the Mount Archibald-Decoeli area lies about 6 km south of the proposed pipeline alignment between MPs 173-180 but the northwest corner of the site is crossed between MPs 170-173. The 12 ha which would be disturbed are not important grizzly bear habitat.

The proposed pipeline alignment MPs 45-185 generally parallels the northern boundary of the Kluane Game Sanctuary, falling within it whenever the pipeline lies south of the Alaska Highway pipeline: MPs 45-57, 63-69, 73-79, 91-109 and 112-172. Compressor station FY-2 (MP 123) lies just within the sanctuary. A stockpile site at MP 70, a stockpile and camp at MP 90 and a stockpile at MP 110 lie just outside the sanctuary but a stockpile site and camp at MP 161 lie about 3 km inside it.

Arctic Gas Route:

The region along the proposed Arctic Gas pipeline route contains five proposed ecological reserves (Beckel 1975): Firth River, Canoe Lake, Rat River, Brackett Lake and River, and Ebbutt Hills. In addition four areas have also been proposed as wildlife sanctuaries: Yukon North Slope (Canadian portion of Arctic International Wildlife Range), Mackenzie Bay White Whale and Bird Sanctuary, Mount Goodenough Dall Sheep Range and Mackenzie River Islands (staging areas) (Commission Counsel 1976b). The pipeline alignment considered in this study would directly cross four of the proposed ecological reserves: Firth River, Rat River, Brackett Lake and River, and Ebbutt Hills and the Canadian Arctic Wildlife Range. In addition, the proposed Mackenzie Bay White Whale and Bird Sanctuary would be directly affected by pipeline barging and related water traffic activities.

The Firth River ecological reserve would be crossed for its entire length (MP 195-240). In addition compressor station CA-05, a wharf and stockpile site and related access roads and 5 borrow pits in rivers are proposed within the area. This region is also being considered as a Yukon Territorial Park (Hutton 1975).

The Rat River ecological reserve would be crossed by coastal route MP 405-418. Compressor station CA-09 and a borrow pit proposed from the Rat River itself also fall within the area.

The Brackett Lake and River site would be crossed by the Arctic Gas project from MP 417-422. A wharf and work pad at the Great Bear River crossing point fall just within the area.

The Ebbutt Hills site would be crossed by Arctic Gas MP 635-638.

The proposed Canadian portion of the Arctic International Wildlife Range (McRea 1971) would be crossed by 215 km of pipeline (coastal MP 195-330). In addition compressor stations CA-05, -06, -07 are located within it as are two wharf and stockpile complexes and related access roads and nine borrow pits, all in or beside rivers.

Comparison Summary

For ecological reserves and wildlife sanctuaries, the Alaska Highway route is preferred over the Arctic Gas route. Both proposed routes, however, would affect important special areas. Along the Alaska Highway pipeline the greatest concern would be for the Duke Meadows and the Sheep Mountain area. Along the Arctic Gas route, important special areas affected include the Firth River ecological reserve and the Yukon North Slope which contain the calving grounds of the Porcupine caribou herd. Pipeline activities are not considered compatible with the purposes for which the Firth River ecological site was proposed (Peterson 1975). Crossing of the other three ecological reserves may be compatible with proper controls. The boundaries of Brackett Lake and River and the Rat River sites, in particular, have been designed to include part of the proposed pipeline route so that the areas can be used for long-term ecological monitoring (Peterson 1975). Other areas in these sites, however, should be protected from development activities.

Overall, the Alaska Highway route is preferred. With proper timing and route selection, the crossing of the bottom of Sheep Mountain could be carried out when the sheep are absent. No permanent facilities would remain on the sheep range. For the Arctic Gas pipeline, however, although construction would be timed to avoid the caribou and geese, numerous summer activities will take place and permanent installations will remain. Repairs in an emergency should be easier to accomplish along the Alaska Highway route where access would be by existing roads instead of by air and overland travel, as would be required along the Arctic Gas route.

The Transmission of Prudhoe Bay Gas to American Markets: A Preliminary Environmental Comparison of the Canadian Arctic Gas Pipeline and the Foothills (Yukon) Pipeline in the Yukon and Northwest Territories

BACKGROUND DOCUMENTATION

INFRASTRUCTURE

CONTENTS

England, R.E. 1977. Infrastructure: Planning and Administrative Services. Pages 407 to 409 in Background documentation. Appendix to The transmission of Prudhoe Bay gas to American markets: A preliminary environmental comparison of the Canadian Arctic Gas pipeline and the Foothills (Yukon) pipeline in the Yukon and Northwest Territories. Alaska Highway Pipeline Panel, Winnipeg. 420 pp.

Johnston, K.M. 1977. Infrastructure: Transportation. Pages 410 to 414 in Background documentation. Appendix to The transmission of Prudhoe Bay gas to American markets: A preliminary environmental comparison of the Canadian Arctic Gas pipeline and the Foothills (Yukon) pipeline in the Yukon and Northwest Territories. Alaska Highway Pipeline Panel, Winnipeg. 420 pp.

SUMMARY[1]

For the Infrastructure component two parameters were examined: the administrative and planning infrastructure, and transportation. With respect to the former we concluded that an effective response by government to either of the proposed projects would require a considerable expansion of existing government programs and consequently staff. The existing administrative and planning infrastructure in both regions, we concluded, is inadequate and consequently incapable of effectively responding to projects of the scale proposed.

The lack of data and any clear indication of how responsibility for increased transportation infrastructure and operating costs will be allocated, meant that a definitive conclusion was difficult to make. Without doubt, both projects possess the potential to disrupt community resupply functions and contribute to the degradation of the existing transportation infrastructures. However we feel that the relatively well-developed transportation system in the Yukon, with year-round service, lends that region a greater flexibility in adapting to project activity. Therefore the Alaska Highway route is slightly preferred.

[1]See also "Human Environment--Overview", pages 331-333.

PLANNING AND ADMINISTRATIVE SERVICES

Problem Definition

Of concern here is the adequacy of existing government planning and administrative infrastructures to respond effectively to the increased demand for a wide range of public services anticipated as a result of large-scale project activity. There is growing recognition that planning and administrative infrastructures require buoying up in response to major development undertakings and that considerable public costs are incurred as a result of the increased demand for public services (US Department of Commerce 1976).

The Alaskan experience, briefly reviewed in our initial evaluation of the Alaska highway pipeline route (England 1977), clearly indicates that greatly increased demand for a wide range of public services occurred as a result of Alyeska project activity (Alaska Department of Community and Regional Affairs 1976).

Potential Impact

In our brief appraisal of the adequacy of the planning and administration infrastructures of the Yukon Government we focussed attention upon one department, the Department of Local Government. We concluded that this

Department, which is responsible for responding to the municipal type requirements of all corridor settlements, had insufficient staff to respond effectively to the demands anticipated as a result of pipeline construction activity. On the basis of personal discussions with personnel of the Water, Land and Forest division of the Department of Indian and Northern Affairs we also concluded that this federal agency was in no better position to respond to the increase in land-use permit appraisals and monitoring requirements anticipated as a result of project activity (England 1977).

The adequacy of government agencies in Northwest Territories to respond to a major development undertaking like the Arctic Gas pipeline was touched on in the wide ranging studies undertaken by Forth et al. (1974). For example, one Task Force study concluded "At present available resources in this field (social services) are insufficient to provide anything but corrective measures. Little is being accomplished in the area of preventative services or is indeed possible with present levels of staff." Elsewhere, with particular reference to the Department of Social Development, the investigators concluded, "It is expected that the kinds of demands that may be placed upon the Department will primarily require an acceleration in development of normal services offered or supported by the Department.....it is recognized that the Department will be required to strengthen and expand existing services and introduce new programs to deal with the probable increase in social problems."

A perusal of Commission Counsel (1976a) submissions to the Mackenzie Valley Pipeline Inquiry clearly indicates that existing planning and administrative infrastructures in the Northwest Territories are not capable of responding to the type and magnitude of demand anticipated as a result of project activity. These submissions are replete with recommendations for new and expanded programs required for an effective response to pipeline construction.

Comparison Summary

The limited information available to us would seem to indicate that the planning and administrative infrastructures in both project areas are insufficient to respond effectively to a major development undertaking. It is therefore impossible to ascribe any preference from this perspective.

We would suggest, however, that the task in the Northwest Territories may be more difficult and costly to achieve than in southern Yukon given the problems associated with access to many Mackenzie Valley communities and the fact that the Arctic Gas pipeline project within territorial jurisdiction is larger in scale.

The above notwithstanding, we are unable to assign greater preference to one route over the other with respect to this parameter.

TRANSPORTATION

Problem Definition

Large-scale project activity will give rise to an increase in the demand for transportation services, and will affect the quality of existing infrastructure.

The first concern deals with the maintenance of the flow of goods to Yukon communities (community resupply). Competition for transportation services could result in a displacement of commodities for community resupply in favour of meeting the needs of pipeline construction; this could result in shortages of materials for local communities. In addition, a rapid increase in the demand for transportation could lead to increased costs for these services to local communities. The rationale behind this is based on: (1) expansion of the transportation sector will likely be achieved with increasing costs, which would be generalized over all users of the service; (2) a shortage in the supply of one mode of transport could lead to a substitution to a more expensive mode; and (3) some element of monopoly pricing during a boom period could lead to a higher costs for local users of the service. These impacts would be reflected in a higher cost of living in each of the regions.

The second concern, the quality of existing infrastructure, will likely be most evident in highway degradation, and perhaps to a lesser extent, with increased costs for airport and runway maintenance.

The lack of available information with respect to all aspects of the transportation sector precluded the possibility for a true comparison. For example, present capacity utilization rates, associated costs of expansion, and the future level of final demands are not known for either region. Neither can we forecast the costs associated with road degradation. Therefore, the following will attempt to put the problems into some perspective, rather than to arrive at a definitive conclusion.

Potential Impact

Using prorated data, the Arctic Gas project will require somewhere in the neighbourhood of 1,485,000 tons of material north of 60° (CAGPL 1974). This figure excludes pipe requirements, which will be in the order of 876,000 tons (based on 13.9 tons per 80-foot length of 48-inch-diameter pipe, and 956 miles of pipeline north of 60°). Total requirements then, will be somewhere around 2,361,000 tons of material.

Arctic Gas recognizes that the main transportation mode will be via rail to the Hay River/Enterprise staging area, and then by barge down the Mackenzie River. Further, they recognize that the existing infrastructure in the Mackenzie barge system will be insufficient for their needs. Given that expansion of the system is necessary, the question remains as to how the increased costs of expansion will be recovered during the construction period. In other words, are costs of expansion to be reflected in the local inflation rate? We cannot, however, estimate the actual impact that this will have on the availability and costs of transportation services for community resupply. The seasonal nature of the barge system, though, restricts the potential of the system to respond to winter requirements.

Road transport and associated degradation of roads is expected to be minimal in the District of Mackenzie, in view of the heavy reliance on the barge system. Arctic Gas will utilize air services to some extent although they have stated their willingness to avoid "overtaxing" the local air transport sector.

The Alaska Highway pipeline will require about 470,000 tons of pipe (based on 13.9 tons per 80-foot length of 48-inch-diameter pipe, and 512 miles of pipeline). Assuming that the ratio of other material requirements to pipe requirements will be similar for both projects (1.68 for Arctic Gas), then total material requirements for the Alaska Highway project could be in the order of 1,260,000 tons. It has been suggested that the White Pass and Yukon Railway could handle traffic in the order of 2.4 million tons annually with additional rolling stock and engines (Gillis 1975). Considering that present inbound freight is about 111,000 tons annually (Hagglund 1976), it would seem that railway capacity could supply both pipeline and community resupply needs. However the question of allocation of increased costs for expansion still remains.

Further, if we consider that the northern terminus of the railway is at Whitehorse, and that further transportation will be via highway, it is likely that trucking costs will increase. Again, the actual magnitude of these costs and their effects on the local cost of living cannot be determined. However, the year-round access to local communities should mean that the flow of commodities to Yukon communities can be sustained.

Road maintenance costs will be much higher with the Alaska Highway project, due of course, to the lack of highways in the District of Mackenzie. While we do not wish to infer that the Alyeska project is a wholly adequate basis for comparison here, it is interesting to note that estimates of increased highway maintenance costs in Alaska, due directly to pipeline activity, were about $118 million (Alaska Department of Community and Regional Affairs, 1976).

Comparison Summary

An adequate comparison of the effects of both projects on community resupply is difficult to make at this time. Even though the material requirements for the Arctic Gas proposal are almost double the estimate for the Alaska Highway pipeline, the fact remains that we are dealing with different modes of transport and with inadequate information regarding these different modes. If we accept that expansion of the transportation sectors will be necessary with either project, the costs associated with this expansion and the allocation of these costs among the users of the services will determine the ultimate effects on community resupply.

An obvious conclusion that we can draw, is that highway maintenance costs will be higher with the Alaska Highway pipeline, by virtue of the fact that highway transport is much more important to that project. Again, it is not clear just how these costs will be allocated among users, the Federal government, the Territorial government, and the pipeline company.

Strictly on the basis of the seasonal nature of transportation in the Mackenzie Valley as compared to the year-round system in the Yukon, we feel that community resupply will be easier to sustain with the Alaska Highway proposal. Therefore, it is slightly preferred in this instance.

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