ENVIRONMENTAL SERVICES

EXAMINATION OF ROUTING ALTERNATIVES FOR THE ALASKA HIGHWAY GAS PIPELINE IN THE KLUANE LAKE REGION

SUBMISSION 3-5

NOVEMBER, 1981

Foothills Pipe Lines (South Yukon) Ltd.

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ADDENDUM TO THE ENVIRONMENTAL IMPACT STATEMENT FOR THE YUKON SECTION OF THE ALASKA HIGHWAY GAS PIPELINE

THE ALASKA HIGHWAY GAS PIPELINE PROJECT

Foothills Pipe Lines (South Yukon) Ltd.

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This document is one of a series of addenda prepared to meet information requirements placed on Foothills Pipe Lines (South Yukon) Ltd. by the Federal Environmental Assessment and Review Office. Addenda within the series are divided into seven sets of submissions dealing with separate subject areas:

1. Introduction to Addenda Submissions.

2. Project Description and Update for Addenda Submissions.

3. Alternative Routes.

4. Geotechnical, Hydrological, Design Mode and Revegetation Issues.

5. Fisheries, Wildlife and Scheduling Issues.

6. Issues Related to Pipeline Facilities.

7. Other Issues.

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EXECUTIVE SUMMARY

The purpose of this document is to demonstrate the process of pipeline route selection adopted by Foothills Pipe Lines (Yukon) Ltd. for the Alaska Highway Gas Pipeline in the Kluane Lake region of Yukon Territory. An environmental assessment of the route selected by this process is also included.

In selecting the route, a multi-disciplinary approach was used, involving construction, engineering, environmental, socio-economic and operations evaluation. As a result, certain segments of the pipeline route were located in areas considered to be sensitive for environmental reasons, such as the area in the vicinity of Kluane Lake, and criticisms of the route have been voiced by individuals and groups with environmental interest. This report gives details of the process involved in selecting a route from four alternatives passing through the area, and describes potential impacts, mitigative measures and residual impacts along the preferred route.

In order to choose an acceptable route, an evaluation reflecting engineering and construction difficulties as well as environmental concerns, land-use issues and the matter of public safety related to potential third party damage to the pipeline was completed. Specific factors considered in the evaluation included:

<u>engineering</u> aspects of watercrossings, slope stability, wetlands, permafrost and third party right-of-way interactions;

<u>construction</u> difficulties associated with watercrossings, permafrost, slope stability, wetlands, near-surface rock, access, materials and third party rights-of-way;

<u>socio-economic</u> impacts involving mineral leases, residential properties, agricultural land, commercial and recreational property, lands held or claimed by native persons and heritage sites;

<u>environmental</u> impacts involving existing fish, raptor, waterfowl and big game populations and their habitats; and

operational aspects of possible third party damage related to public safety.

Engineering and construction factors were evaluated by completing cost estimates for each alternative while other factors were evaluated using an ordinal rating scale.

Four alternatives were examined (see Map 3-5.1): one departs from the western shore of Kluane Lake south of the mouth of Congdon Creek, traverses the lake and reaches the eastern shore in the Cultus Bay region, follows the Cultus Creek Valley and then proceeds southeasterly to the Alaska Highway near Sulphur Lake (Alternative #1); a second route departs from the western lake shore at the same point as Alternative #1, but follows a southeasterly alignment across Kluane Lake and leaves the lake on the eastern shore approximately 3 km south of Cultus Bay, then proceeds southeasterly to the Alaska Highway near Sulphur Lake (Alternative #2); a third route enters the lake approximately 2 km south of the mouth of Congdon Creek, traverses the lake and exits at the same location as Alternative #2, and then follows an alignment identical to that of Alternative #2 to the Alaska Highway near Sulphur Lake (Alternative #3); and, a fourth alternative which follows the Alaska Highway along the eastern lake shore and across the Slims River. This latter route is situated south of the Alaska Highway from the Slims River crossing to a point near Sulphur Lake (Alternative #4). Alternative #3 was selected by the Project as the preferred route.

Specific descriptions of potential environmental impacts and mitigation measures for the preferred route are presented in this report. Potential impacts include those on fish spawning areas in Kluane Lake, the possible disturbance of nesting raptors and the potential for interactions with grizzly bears. Land-use conflicts are also a possibility. Proposed mitigative approaches to meet potential environmental impacts include pursuing the possibility of depositing the spoils from trenching in Kluane Lake in a deepwater area of the lake, timing restrictions on pre-mainline construction activities to limit disturbance of nesting raptors to a minimum number of seasons, and strict control of waste management practices together with orientation of Project personnel to avoid potential nuisance bear problems. The only residual environmental impacts predicted involve the disturbance of normal breeding behaviour by raptors at two nests, possibly resulting in reduced productivity at one of the nests.

PART 1

INTRODUCTION

In making application to the National Energy Board in 1976 for a certificate of public convenience and necessity to construct the Alaska Highway Gas Pipeline in Yukon Territory, Foothills Pipe Lines (Yukon) Ltd. (the Project) identified a route which paralleled the Alaska Highway along the southwest shore of Kluane Lake, crossed the Slims River at the south end of the lake, and continued along the Shakwak Valley on the south side of the Alaska Highway. During public hearings concerning the Project's application, the routing around the south side of Kluane Lake was criticized by a number of individuals and organizations, in particular by Parks Canada and the Yukon Territorial Wildlife Branch. Specific concern was expressed for Dall's sheep habitat and mineral lick(s) on Sheep Mountain, the presence of a cabin of historic value, and the aesthetic effect of the pipeline right-of-way traversing Sheep Mountain. In addition, it was established that several unique plant species occur on Sheep Mountain and on the adjoining Slims River Delta. These various factors resulted in the Project being directed by the Environmental Assessment and Review (EAR) Panel to reassess the routing in the Kluane Lake region. The EAR Panel concluded in its 1977 report that detailed environmental assessments of the proposed and alternative routings for the Kluane Lake region were required. Re-assessment was undertaken and a revised routing was chosen in 1979 which crossed Kluane Lake from the region of Congdon Creek on the eastern lake shore to the region of Cultus Bay on the western shore and proceeded in an easterly direction to intersect the previously-proposed route near Sulphur Lake.

In 1979, after reviewing the material submitted in the Project's Environmental Impact Statement and information brought forward at further public hearings, the Panel acknowledged that the then-preferred routing across Kluane Lake avoided serious environmental, engineering and aesthetic problems in the vicinity of Sheep Mountain and the Slims River Delta. In relation to this realignment, however, the EAR Panel requested a typical crossing evaluation, and the identification of sensitive areas, potential environmental impacts and mitigation measures along this alignment. With regard to the probable extent of burial of the underwater section on the lake crossing, the Panel requested design concepts and a discussion of the potential environmental impacts as a consequence of such factors as turbidity, siltation of spawning areas and physical interference with fish movement. Mitigation measures proposed in order to overcome the potential impacts outlined were also requested. Finally, the Panel requested a scenario describing a major pipeline break in Kluane Lake complete with potential environmental impacts and mitigation measures.

As the Panel seeks further information on pipeline routes on the Kluane Lake region, this report has been prepared with the objective of demonstrating the process adopted by the Project for route selection, and to review the advantages and disadvantages of reasonable routing alternatives. At the time of preparation of this analysis, three potential routes across Kluane Lake are under consideration. As a consequence, four alternative routes in the Kluane Lake region are considered in this report; three which involve lake crossings, and one which follows the lake shore around the south end of Kluane Lake.

The route evaluation procedure presented in this submission is complimented by an environmental assessment of the preferred routing. This assessment consists of a discussion of potential environmental impacts along the preferred route, followed by the planned Project responses which are designed to ameliorate possible adverse impacts. A final section of the report delineates residual impacts which will result from construction of the selected route in the Kluane Lake region. The environmental assessment component of this routing submission has been incorporated to assist the EAR Panel in reviewing the document which in its original form dealt solely with route selection. To further facilitate this review, the reasons for arriving at specific evaluation scores for the various components under review for each alternative are appended to this submission (Appendix IV).

In addition to the route evaluation process, this submission addresses questions raised by the EAR Panel in regard to the design, operation and maintenance standards to be applied to temporary and permanent access roads. In order to demonstrate these standards, road requirements for the section of the selected route along the east shore of Kluane Lake are used as an example. This approach was discussed with the Panel in 1980, and was agreed to as noted in the Panel's letter of clarification issued December 18, 1980.

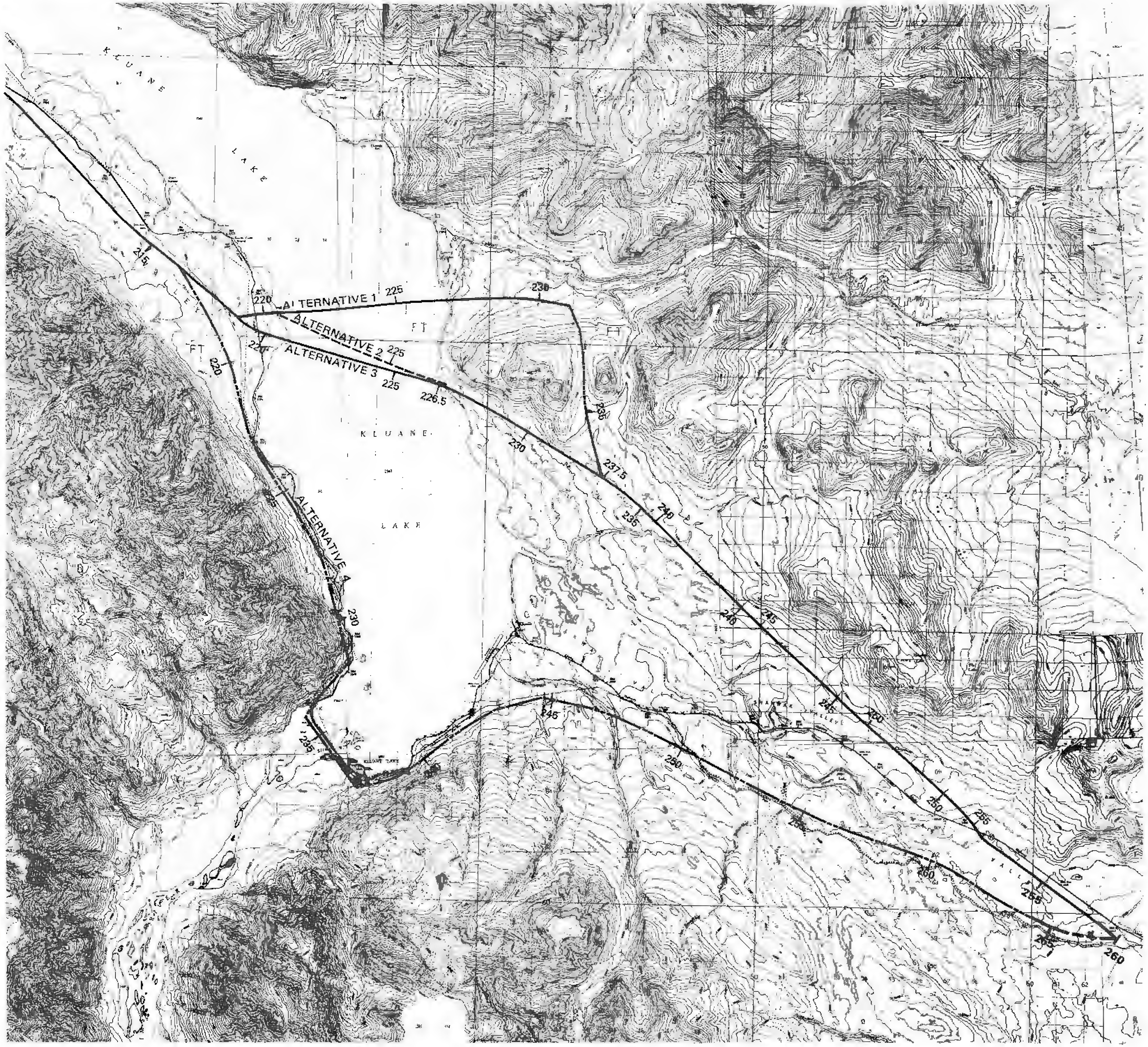
PART 2

ALTERNATIVE ROUTES IN THE KLUANE LAKE REGION

Four possible routings have been considered for the Alaska Highway Gas Pipeline in the Kluane Lake region. One route, referred to here as Alternative #1, departs from the western lake shore approximately 1 km south of the mouth of Congdon Creek, approaches the eastern lake shore immediately south of Cultus Bay, proceeds easterly along the Cultus Creek Valley, southerly between two small peaks in the Kluane Hills, and southeasterly along the Shakwak Valley to converge with the original proposed route near Sulphur Lake (Map 3-5.1). Alternative #2 departs the western shore of Kluane Lake from the same point as Alternative #1, but follows a southeasterly alignment across the lake (Map 3-5.1). Alternative #2 approaches the eastern lake shore approximately 3 km south of Cultus Bay, and proceeds southeasterly along the Shakwak Valley to converge with the original route near Sulphur Lake. A third potential lake crossing alignment, referred to here as Alternative #3, departs from the western lake shore approximately 2 km south of the mouth of Congdon Creek, proceeds southeasterly across Kluane Lake to the same landing site as Alternative #2, and follows the same alignment along the Shakwak Valley to the original route as Alternative #2 (Map 3-5.1). The originally-proposed route, referred to here as Alternative #4, closely parallels the Alaska Highway along the eastern lake shore and across the Slims River, then travels south of the Alaska Highway along the Shakwak Valley to the point where the four alternative alignments converge near Sulphur Lake (Map 3-5.1).

The comparative line lengths of Alternatives #1, #2 and #3, all of which involve lake crossings, are 48.5, 44.5 and 44.0 km respectively. Alternative #4 has a length of 53.0 km, between KP 216 and KP 269 on the originally-filed route (Map 3-5.1). The construction schedule for this region of mainline pipeline specifies winter construction from the point of origin of the alternatives to the western shore of Kluane Lake (KP 220), and summer construction east of the lake. The lake crossing itself is scheduled for summer construction.

Foothills Pipe Lines (Yukon) Ltd.



MAP 3-5.1
ALTERNATIVE ROUTES IN THE KLUANE LAKE REGION

5 0 5 10

Kilometres

PART 3

ROUTE LOCATION FACTORS

Pipeline routes have traditionally been determined by evaluating plausible, constructable alternatives, and selecting the one that is the shortest and most economically feasible.

In order to choose the most advantageous alternative route in the Kluane Lake region, evaluation of specific location factors has continued for several years. In completing the route evaluations factors which fall into five broad categories were considered:

- engineering
- construction
- socio-economic matters
- environmental matters
- operational matters

Specific factors within each category and the manner in which they affect route selection are briefly outlined in Appendix I.

PART 4

EXISTING CONDITIONS ALONG ALTERNATIVE ROUTES

All of the alternative routes in the Kluane Lake region lie within the Shakwak Valley. This valley forms a trench separating two major geological zones, represented by the Ruby Range to the north and the Kluane Range to the south. The Kluane Hills are included in the Ruby Range batholith, which consists mainly of granitic rocks. Metamorphic rock also occurs adjacent to the north side of Kluane Lake and extends eastward. The Kluane Range, which is located on the south side of the lake, has a complex geology consisting of major sequences of sedimentary and volcanic rocks with granitic intrusions.

Pleistocene glaciers deposited deep mantles of morainal and glaciofluvial materials in the Shakwak Valley. Subsequent fluvial action has eroded or masked portions of these deposits. Recent fluvial deposits vary in texture from gravel and boulder alluvial fans on steep slopes to the sand, silt and clay floodplain of the Slims River. The inactive alluvial fans and terraces of the major river valleys often have a veneer of loess.

4.1 MAJOR ROUTING ISSUES

Conditions along routes in the Kluane Lake region have been the subject of study by the Project and others from a time prior to the initial application for a pipeline route in 1976. Information gathered in studies completed to date has been made available to interested parties and has been the subject of previous review. A listing of reports dealing in whole or in part with conditions in the Kluane Lake region is included in Appendix II of this report.

A number of "major" issues have arisen from studies conducted and from public hearings related to alternative alignments in the Kluane Lake region. Major issues involved with an alignment across Kluane Lake include: concerns regarding pipe installation across the lake and the potential effects on fish; disturbance of raptor nests; and construction of the pipeline on the southeast side of Kluane Lake in a region known for native heritage significance and utilization by natives for hunting and trapping. Major issues regarding an alignment following the periphery of Kluane Lake relate to slope and soil stability problems in the Sheep Mountain and Slims River Delta area; Dall's sheep and nesting raptors on Sheep Mountain; and, the presence of a cabin with historic value and the presence of the pipeline right-of-way on Sheep Mountain within Kluane National Park. These issues, together with other terrain features that limit pipeline construction, have played a major role in route selection. The various "major" factors and issues along each potential alternative are summarized in the following descriptions.

Alternative #1

Alternative #1 involves a route which departs from the region of the Alaska Highway near mainline KP 216, crosses Kluane Lake and approaches the eastern lake shore near Cultus Bay, passes through the extremity of the Kluane Hills and follows the Shakwak Valley to rejoin the mainline near Sulphur Lake at KP 269. Environmental issues along this alternative involve the Kluane Lake crossing and possible effects on fish populations and raptor nests; land-use issues relate to the presence of a native heritage site, a native hunting camp and a traditional hunting area on the northeast side of Kluane Lake; and design and construction factors involve the lake crossing. Issues relating to public safety and third party damage are minimal.

Alternative #2

Alternative #2 involves a crossing of Kluane Lake which has the same point of origin as Alternative #1, with an approach to the eastern shore south of Cultus Bay. From that point Alternative #2 follows a route identical to that of Alternative #1. Environmental issues along Alternative #2 involve the Kluane Lake crossing and possible effects on fish populations and raptor nests; land-use issues involve the existence of a native hunting camp and traditional hunting area along the pipeline route; and design and construction factors involve the lake crossing itself. Issues relating to public safety and third party damage are minimal.

Alternative #3

Alternative #3 involves a lake crossing which originates south of the mouth of Congdon Creek, with the approach to the eastern lake shore and the routing along the northeasterly region of the Shakwak Valley being identical to Alternative #2. Environmental issues involve the Kluane Lake crossing and possible effects on fish populations and raptor nests; land-use issues involve the existence of a native hunting camp and traditional hunting area along the pipeline route; and design and construction factors involve the lake crossing itself. Issues relating to public safety and third party damage are minimal.

Alternative #4

Alternative #4 follows the Alaska Highway along the western shore of Kluane Lake across the Slims River, and then follows a northeasterly direction to converge with the alternative routes near Sulphur Lake. Environmental issues involve Dall's sheep and raptor nests; land-use issues primarily relate to the presence of the pipeline in Kluane National Park, while design and construction factors involve unstable slopes at the base of Sheep Mountain and soil instability across the Slims River Delta. Issues relating to public safety and third party damage relate to the presence of the pipeline adjacent to the Alaska Highway along the periphery of Kluane Lake and across the Slims River Delta.

A major routing issue in relation to Alternatives #1, #2 and #3 is the crossing of Kluane Lake. The EAR Panel has requested a scenario outlining a major pipeline break in the lake, a description of potential environmental impacts and potential mitigation measures which may be employed to protect the aquatic biota in the event of such an occurrence. Such a scenario has been prepared, and is included in its entirety in Appendix V of this submission.

4.2 DISCUSSION OF EXISTING CONDITIONS ALONG ALTERNATIVE ROUTES

It is apparent from the preceding descriptions that no single route alternative is free of concerns related to major routing issues. This section of the report discusses nature of concerns along the route alternatives in relation to engineering, construction, socio-economic, environmental and safety factors, and, where possible, quantifies information available. In addition, the kind and extent of possible Project responses to concerns is outlined.

4.2.1 Engineering and Construction

Engineering and construction factors pertinent to route selection relate to line length, design difficulties, source and movement of materials, impediments to construction, and access. Variation in these factors can affect cost, and the route with the combination of factors resulting in the least cost is the most desirable. Estimates of direct costs for the four route alternatives were completed based on the amount of timber, grade, rock and swamp for each alternative and the costs for special designs to overcome permafrost conditions and the crossing of Kluane Lake, where applicable. Direct costs were estimated in constant 1979 dollars. Indirect costs were added to direct cost estimates through the use of a multiplier, which in turn was based on the most recent detailed estimate of costs for the construction spread involved. This applicable multiplier in the Kluane Lake region is 2.1. Total costs, both direct and indirect, are presented in Table 3-5.1 for each alternative. The estimated cost of

TABLE 3-5.1

KLUANE LAKE REGION ALTERNATIVE
ROUTES COMPARISON OF LENGTHS/COSTS

	Line Length (km)	Cost Estimates ($000,000) Direct	Indirect	Total
Alternative #1	48.5	77.7	85.5	163.2
Alternative #2	44.5	74.6	82.1	156.7
Alternative #3	44.0	73.3	80.6	153.9
Alternative #4	53.0	89.3	98.2	187.5

crossing Kluane Lake is included in the totals presented for Alternative #1, #2 and #3. The total costs also represent the Project response to engineering and construction concerns and difficulties.

Design difficulties involved in those alternatives requiring a crossing of Kluane Lake include the necessity to overcome difficult lake bottom conditions and the possibility of seismic activity which may cause instability in lake bottom sediments. Construction difficulties posed by the lake crossing include preparation of a suitable site for pipe fabrication, weighting and testing, as well as a site for placement of large pulling winches. In addition, the depth of lake water combined with a requirement to trench substantial portions of the pipe alignment will necessitate the movement of large and sophisticated marine equipment to the site as well as the equipment required to launch and pull the pipe across the lake. These difficulties must be compared with those faced along Alternative #4, where potentially unstable slopes along the base of Sheep Mountain and unstable soils across the Slims River Delta (both related to possible seismic events) require special designs and difficult construction techniques. An additional construction factor in the Sheep Mountain area is the constricted working area available between the base of the mountain, the existing highway and Kluane Lake. Terrain types encountered along the four alternatives are presented in Map 3-5.2.

Readers should note that a discussion of design limits and construction techniques related to a Kluane Lake crossing is included in the impact section of this document (Part 6).

4.2.2 Environmental Conditions

As previously outlined, environmental factors which are major routing issues in the Kluane Lake region involve fish populations in Kluane Lake, the Dall's sheep population on Sheep Mountain, and nesting raptors.

Fish

Studies of fish inhabiting waterbodies crossed by the alternative routes have been conducted and the results reported (see Appendix II). A brief summary of results for the alternative routes in the Kluane Lake area is presented in Table 3-5.2; a comprehensive summary of the results of fisheries investigations is presented in Appendix III. Alternatives #1, #2 and #3 cross 7, 6 and 8 waterbodies respectively, while Alternative #4 crosses 29 waterbodies. Of these crossings, Alternatives #1, #2 and #3 each cross 2 waterbodies which support important fish species, or which exhibit some potential for supporting important fish. Alternative #4 crosses 4 such waterbodies.

Alternatives #1, #2 and #3 all involve a crossing of Kluane Lake. The major fisheries concern regarding a lake crossing is the potential for sedimentation of spawning areas in proximity to the alignment. Definitive information is not available regarding either the particle size of the spoil to be excavated during a lake crossing or lake current velocity, although preliminary sampling and measurement has been completed. These efforts indicate sediments ranging from fine silts through sands and gravels, with fine silts predominating. While these preliminary data indicate the kind of environment involved, they do not allow a rigorous estimate of how large a sediment plume might result from dredging, or the spatial extent of such a plume. For the purpose of delineating a zone around the pipeline route where sedimentation may be a concern, the natural sedimentation process at the mouth of Slims River is used here as a guideline. This approach is likely conservative as the volume of suspended sediment carried by the Slims River is much greater than that which would be created during trenching, and the sediment load would likely be carried at a higher velocity by the Slims River discharge than the spoil which is expelled from the pipeline trench.

TABLE 3-5.2

KLUANE LAKE REGION ALTERNATIVE ROUTES
COMPARISON OF FISHERY RESOURCES

Alternative	Total Number of Waterbody Crossings	Total Number of Crossings with No Fisheries Potential[1]	Total Number of Crossings Supporting Important Fish Species[2]	Number of Other Waterbody Crossings[3]
1	7	5	1	1
2	6	4	1	1
3	8	6	1	1
4	29	25	3	1

[1]Waterbodies which do not exhibit habitat suitable for use by fish, usually because of one of the following characteristics: steep gradient; obstructions present such as log jams, waterfalls, impassable culverts; inadequate discharge; low water levels; or intermittent flow.

[2]Important fish species are: chinook salmon, chum salmon, Arctic grayling, lake trout, lake whitefish, Dolly Varden char, northern pike and burbot.

[3]Those waterbodies which have low or fair potential for supporting fish and/or support unimportant fish species.

The turbid plume boundary at the mouth of Slims River is variable, depending on wind velocity and direction. In general, however, the plume boundary extends 4 to 5 km from the river mouth[1]. Therefore, the zone of concern proposed for the purposes of this analysis is from the region of the pipeline trench to a point 5 km northwest of the alignment. It is anticipated that regions to the southeast of the alignment will not be affected by sedimentation, as the spoil cloud will be carried toward the Kluane River by the prevailing lake current.

The location of spawning areas was determined by fisheries investigations in the lake which involved the netting of adult fish. A documented lake trout spawning area was identified where at least 20 lake trout were captured in a standard (24-h, 137.2-m) net set, which included both ripe (about to spawn) and spent (recently spawned) individuals. "Suspected" lake trout spawning areas were defined as those where between 10 and 20 lake trout were captured in a standard net set in which the number of ripe fish exceeded the number of spent fish. Relatively few lake whitefish were captured during the spawning period for this species; no documented spawning areas were identified. Areas in which at least 10 lake whitefish were collected in a standard net set, among which both ripe and spent fish were represented, were termed "suspected" lake whitefish spawning areas. A total of three documented or suspected lake trout spawning areas and three suspected lake whitefish spawning areas have been identified from 5 km northwest of Alternative #1 lake crossing to the location of Alternative #3 lake crossing (see Map 3-5.3). Alternative #1 lies within 5 km of two documented lake trout spawning areas, and all three suspected lake whitefish spawning areas. Alternative #2 lies within 5 km of only one suspected lake trout spawning area, and all three suspected lake whitefish spawning areas. Alternative #3 lies within 5 km of only one suspected lake trout and one suspected lake whitefish spawning area within the defined 5-km zone of concern. For the purposes of this discussion, all suspected

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1. Bryan, M.L. 1974. Water masses in southern Kluane Lake. Icefield Ranges Research Project, Scientific Results (4): 163-169.

spawning areas are considered to be used for spawning areas, and are therefore treated with the same degree of concern as documented spawning areas.

Project response to fisheries concerns can take a number of forms, including:

1. Relocation of the route to avoid sensitive areas.

2. Scheduling constraints to ensure activities within waterbodies occur during a period when fish are absent or least sensitive to disturbance.

3. Use of special construction techniques when working in waterbodies to reduce or eliminate adverse effects upon fish during sensitive periods.

4. Utilizing post-construction techniques to rehabilitate habitat or enhance production.

5. No action and acceptance of the impacts.

In planning for Project activities, fisheries studies have been completed or are presently underway at all watercrossing sites. Sensitive areas and periods have been identified for each stream crossing with respect to important fish species. The approach taken in developing preliminary fisheries protection plans has been to schedule construction activities in these watercourses wherever possible to avoid sensitive periods. Where scheduling is not possible due to constraints of season (for example, when overwintering fish occur in a winter construction zone in an area where construction cannot be undertaken in summer due to streamside terrain conditions), special instream construction measures are being developed. Such special measures for streams may include flume installations, abovewater crossings, stream diversions, or damming and pumping around a dry ditch. Other more usual practices that will be instituted during construction, depending upon site-specific conditions and concerns, have been outlined in the Project's Environmental Statement[2] on pages 9-6 and 9-7.

In the case of Kluane Lake, the extent of probable effects from dredging and the distribution of sensitive spawning sites makes relocation of the alignment an unproductive exercise. Combined with these factors are the physical impediments to re-routing which in the Kluane Lake region are severely limiting. Similarly, constraints on construction timing are severe. Crossing operations must take place during the open-water period and these will require virtually the entire period available.

Efforts to minimize the effects of construction in Kluane Lake on fish are limited by the kinds of construction equipment available. To date, a number of options appear to be available and these are discussed in Part 6 of this submission.

Birds

Field studies have revealed two active Bald Eagle nests within 2 km of Alternative #1 (Table 3-5.3), in Cultus Bay and at Sulphur Lake. The latter nest is also involved with Alternatives #2 and #3 as this section of the route is common to all three alternatives. A few waterfowl congregate in the Cultus Bay area during fall staging periods. Field studies have failed to reveal any other concerns for birds along Alternative #1; however, one additional active Golden Eagle nest lies within 2 km of Alternative #2 and #3 along the eastern shore of Kluane Lake.

The number of raptor nest sites along Alternative #4 is similar to the numbers along Alternatives #1, #2 and #3. Currently, one Bald

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2. Foothills Pipe Lines (South Yukon) Ltd. 1979. Environmental Impact Statement for the Alaska Highway Gas Pipeline Project.

TABLE 3-5.3

SUMMARY OF RAPTOR NEST LOCATIONS ALONG
ALTERNATIVE ROUTES IN THE KLUANE LAKE REGION*

(Number of nests active in at least one of last three years shown in brackets)

Alternative	Nests Within 4 km		Nests Within 2 km	
	Golden Eagle	Bald Eagle	Golden Eagle	Bald Eagle
#1	33 (9)	3 (2)	3 (0)	3 (2)
#2	27 (7)	3 (2)	7 (1)	2 (1)
#3	27 (7)	3 (2)	7 (1)	2 (1)
#4	25 (5)	2 (1)	20 (4)	2 (1)

*Only nests in good repair included.

Eagle and four Golden Eagle active nests are known to occur within 2 km of this Alternative. Also, staging waterfowl use the Slims River Valley and Kluane Lake at the Slims River outlet primarily during fall. Use of the area is primarily by ducks and involves hundreds of birds.

Project response to concerns related to staging waterfowl or raptor nests can take the following forms:

1. Location of the pipeline route to avoid close proximity to staging areas or active raptor nest sites.

2. Scheduling of pipeline activity to periods when waterfowl are not staging, or to non-nesting periods or periods when sensitivity at raptor nest sites is low.

3. Use of special construction techniques to reduce or eliminate adverse effects upon staging waterfowl or raptors during sensitive periods.

4. Utilizing post-construction techniques to rehabilitate habitat or enhance production.

5. No action and acceptance of impacts.

Raptor nest sites occur throughout the portion of Yukon Territory traversed by the pipeline and avoidance of all raptor nests through location of the route is not possible. In addition, the nesting period for the raptors present in Yukon Territory can extend from March through August with the result that both winter (January to April) and summer (June to November) mainline construction periods will overlap nesting periods. This situation limits the extent to which the project can react to raptor nesting concerns. Preliminary Project planning to date has utilized route location to avoid raptor nests by 2 km wherever a reasonable routing alternative is available. In addition, pre-construction activity within 2 km of nests has been restricted to less sensitive periods, and a similar approach will be used wherever possible for pre- and post-mainline activities. Rescheduling of mainline construction activity will not be undertaken to avoid the nesting period. However, normal restrictions on such activity associated with ground conditions will likely reduce the severity of disturbance at the nests. Raptor sensitivity to disturbance is thought to peak during egg laying, incubation and the hatching period (April 1 to May 31). Since mainline construction will be halted by spring break-up (April 1 to 15) in most areas, such activity will be minimal throughout most of the sensitive nesting period. Rescheduling of mainline activities would be pursued if conflicts existed with the use of major spring staging areas by migrating waterfowl; however, no major staging areas exist in the vicinity of the pipeline alternative routes. Other practices that will be instituted during construction have been outlined in the Project's Environmental Statement[2] on pages 9-7 through 9-10.

Mammals

Dall's sheep ranges lie adjacent to all four alternative routes under consideration in the Kluane Lake region. Portions of these ranges support certain sheep activities sensitive to disturbance. The occurrence of small numbers of other large mammals in the region of all four alternative routes has been documented. Map 3-5.3 shows ranges of Dall's sheep along the four alternatives.

Along Alternative #1, Dall's sheep occupy range year-round to the north and east within direct line of sight of the proposed route, although all utilized range is more than 2 km from the pipeline route. Alternative #4 passes within 2 km of range used year-round by a population of approximately 200 Dall's sheep on Sheep Mountain. Sheep also frequent the western part of Outpost Mountain, overlooking the Slims River within 2 km of the route.

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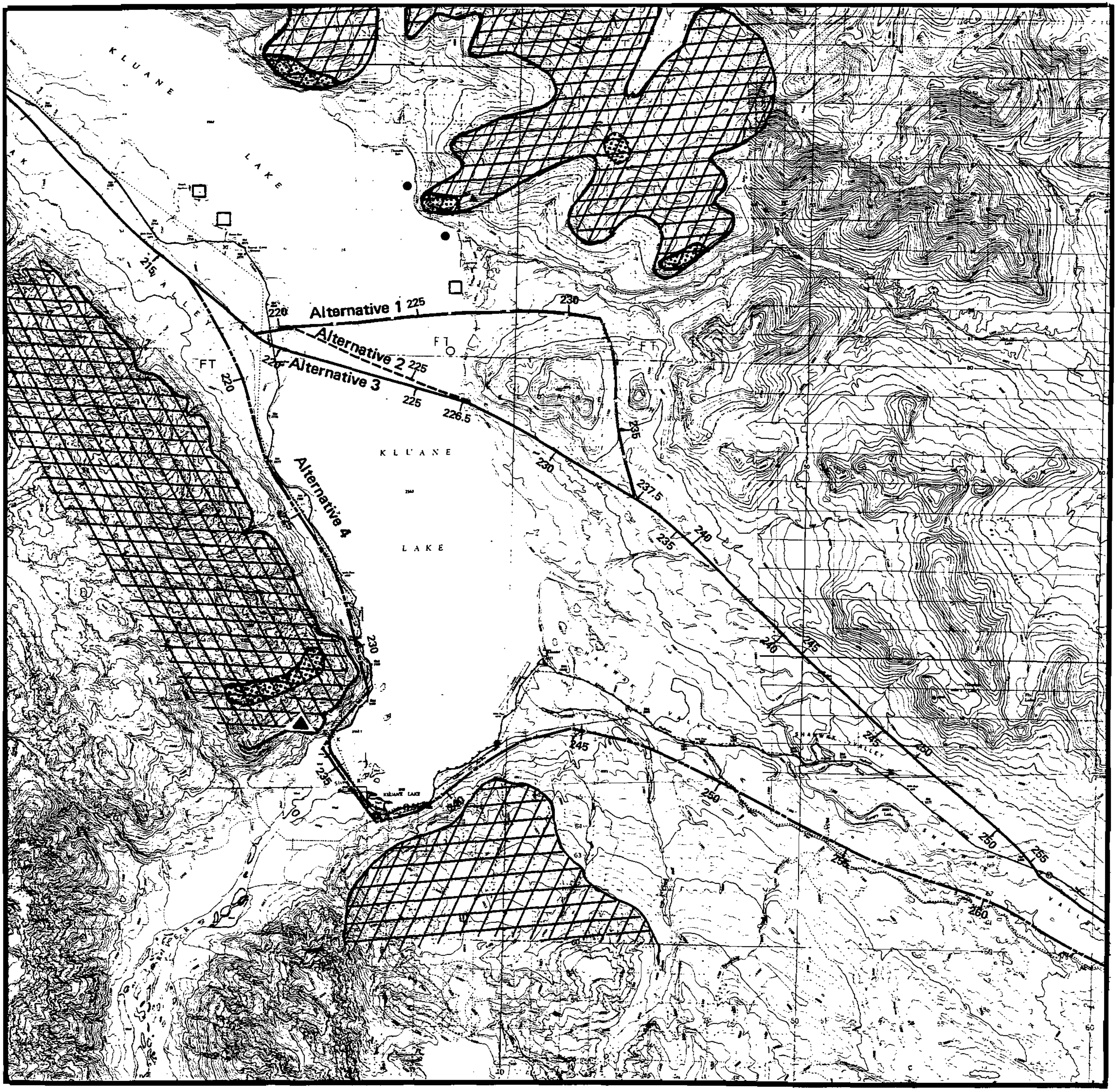
2. Foothills Pipe Lines (South Yukon) Ltd. 1979. Environmental Impact Statement for the Alaska Highway Gas Pipeline Project.



MAP 3 - 5.3

DALL'S SHEEP RANGES AND LAKE TROUT AND LAKE WHITEFISH SPAWNING LOCATIONS ALONG THE FOUR ALTERNATIVE PIPELINE ROUTES IN THE KLUANE LAKE AREA

1 0 1 2 3 4 5 Kilometres

LEGEND

YEAR ROUND DALL'S SHEEP RANGE

DALL'S SHEEP LAMBING AREAS

▲ DALL'S SHEEP MINERAL LICK

● DOCUMENTED LAKE TROUT SPAWNING AREA

○ SUSPECTED LAKE TROUT SPAWNING AREA

□ SUSPECTED LAKE WHITEFISH SPAWNING AREA

Winter range on Sheep Mountain is found at low elevations on the southeast face and in the vicinity of Williscroft Creek and is used between September and June. Lambing takes place at high elevations in May, and use of a mineral lick near the Alaska Highway takes place in May and June.

Some evidence has been collected regarding moose winter use of sub-alpine areas in the Cultus Creek drainage, Kluane Hills east of Alternative #1, and the Hayden Lake ridge area. These areas are also more than 2 km from all of the alternative routes. Similarly, sightings of a few woodland caribou have been collected in the Cultus Creek drainage to the east of Alternative #1, while evidence of their presence have been located in the Hayden Lake ridge area. All evidence and sightings came from areas more than 2 km from the routes, and no evidence of caribou movements across the routes or use of habitat in the vicinity has been obtained. Grizzly bears have been sighted occasionally in the vicinity of Alternative #1 in the Cultus Bay area and also in more easterly sections of this alternative and Alternatives #2 and #3. A grizzly bear has been observed more than 2 km north of Sulphur Lake in mid-summer where the route is common to Alternative #2 and #3. Alternative #4 also passes within 2 km of range used by grizzly bears on Sheep Mountain and the western part of Outpost Mountain. As grizzly bears are found along all four alternatives, they are not an issue favouring one alternative route over the others.

Project response to concerns related to mammals can take the following forms:

1. Location of the pipeline route to avoid close proximity to migration routes, winter ranges, lambing or calving areas, or mineral licks.

2. Scheduling of pipeline activity to periods of time when the species of concern are least-sensitive to disturbance.

3. Use of special construction techniques to reduce or eliminate adverse effects upon mammals during sensitive periods.

4. Utilizing post-construction techniques to rehabilitate habitat or enhance production.

5. No action and acceptance of impacts.

Project studies have been undertaken which have identified Dall's sheep ranges and sensitive areas within these ranges such as lambing areas, mineral licks and winter ranges. Project planning has incorporated the results of these studies to the extent that relocation is considered, or rescheduling of construction activities is pursued to avoid sensitive periods. In instances where the species of concern is wide ranging, such as the case with grizzly bears, there are few Project actions that can be anticipated to directly affect the animals in a positive or negative way. The consequences of encountering grizzly bears during foraging movements may result in an adverse affect indirectly, but control over the outcome of such encounters would rest with the appropriate response of personnel. Factors which are under Project control include personnel education, and waste management strategies which would not attract animals to Project facilities. Such actions are within Project jurisdiction, and are components of specific protection plans. Other more usual practices that will be instituted during construction have been outlined in the Project's Environmental Statement[2] on pages 9-7 through 9-10.

4.2.3 Socio-economic (Land-use) Conditions

Land use may be divided into the following categories: residential, commercial, recreational, agricultural, mineral extraction, lands

2. Foothills Pipe Lines (South Yukon) Ltd. 1979. Environmental Impact Statement for the Alaska Highway Gas Pipeline Project.

held in reserve by federal government departments and agencies, lands used or claimed by native people, and lands with historic value.

Concerns related to pipeline routing and socio-economic or land-use issues can involve all of the categories noted, but in the Kluane Lake area, land uses are few. For the most part, present land uses tend to be compatible with pipeline activity (see Map 3-5.4). A summary of existing land use and approaches to addressing pipeline and land-use conflicts follows.

Residential and Commercial Land Use

Concerns for conflicts between residential and commercial land use and pipeline activity stem from: inconvenience to land users; the requirement for special design, construction and operational procedures; and, the possibility that future development may be limited. Project response for any inconvenience to existing residents most often takes the form of special efforts and procedures to reduce inconvenience of construction to an acceptable level. Such response includes working during limited hours, replacing fences and other disturbed structures, and rehabilitating disturbed sites. None of the four alternatives under consideration in the Kluane Lake area cross any residential or commercial property.

Lands Involving Native Interest

Each of the three alternatives involving a lake crossing lie in close proximity to an area used for traditional resource-harvesting activities, and each also passes in close proximity to a native hunting camp. No such areas exist in the region of Alternative #4.

A major concern in relation to Alternative #1 is the presence of an area of native cultural significance and potential archaeological sites on the east shore of Kluane Lake.

Other Land Uses

Alternatives #1 and #2 pass within 800 m of the developed portion of a Yukon Territorial Government Campground Reserve. Both alternatives will cross a presently unused Yukon Territorial Government Gravel Pit Reserve for approximately 1100 m. Selection of either of these alternatives necessitates the location of a major staging area for the crossing within this gravel pit reserve.

Alternative #3 will cross 1158 m of an undeveloped Yukon Territorial Government Campground Reserve between the Alaska Highway and Kluane Lake. Selection of this alternative will require that a major staging area for the crossing be located within the same campground reserve. The Project has consulted with Yukon Territorial Government representatives and they have confirmed that no expansion of campground facilities in the affected portion of the campground reserve is anticipated. Alternative #3 lies in close proximity (200 m) to an inactive commercial campground and boat docking facility.

Alternative #4 passes within 100 m of a closed Yukon Territorial Government campground, and lies within Kluane National Park from the region of Congdon Creek to the Slims River. This alternative also lies in close proximity to a cabin of historic significance at the base of Sheep Mountain. The pipeline, in Alternatives #1, #2 and #3, traverses Kluane National Park for approximately 1600 m in the vicinity of Congdon Creek.

Alternatives #1, #2 and #4 each cross one gravel reserve while direct contact with such areas is avoided with Alternative #3.

4.2.4 Factors of Operational Safety

The largest single cause of pipeline failure over the years of pipeline operation has been third party construction activities in the vicinity of the pipeline. Recognition of this cause of failure has led in part to the special design factors and codes in areas of residential or commercial land-use. While such design factors are effective in reducing the risk to the pipeline and to persons and property, they do not eliminate the possibility of damage.

The public safety aspects of each of the four alternatives are different owing to the relative remoteness of Alternatives #1, #2 and #3. Public contact with these routes is very limited, with the exception of the common eastern section of these routes where the alternatives rejoin the Alaska Highway corridor. Alternative #4 follows the Alaska Highway from the region of Congdon Creek through to Topham Creek, at the south end of Kluane Lake. However, no permanent residential land exists along this section of the Alaska Highway, with little or no build-up projected. It should be noted that issues of public safety posed by Alternative #4 are no different in kind from those in all other areas where the proposed pipeline route follows the Alaska Highway. Similarly, concerns related to third party damage (see below) are lesser in remote areas and greater in areas of human activity. Assessment of the four alternatives is therefore the same for third party damage as it is for public safety.

Third Party Damage

Although pipeline design codes make provision for high pressure gas pipelines in suburban areas, the trend in the industry is to avoid these areas. The largest single cause of pipeline failure is by third-party damage, that is, construction activities by others on or across the right-of-way of the operating pipeline which occasionally results in accidentally severing the high pressure gas pipeline, which in turn could result in an explosion and fire. As suburban areas encroach and cross the right-of-way of an operating pipeline, the extension of underground and above-ground services required by the municipality increases the risk of third party damage. It is this activity which presents the greatest safety hazard to the general public who reside or work near an operating high pressure gas pipeline. The only way to avoid this type of conflict, and the hazards that may result, is to locate the pipeline in a corridor that is remote from areas of actual or potential population concentration. No such areas of population concentration exist along any of the Kluane Lake alternatives.

4.3 OTHER ISSUES

4.3.1 Compression Requirements

The issue of compression requirements is considered during the route evaluation process because alternatives with large differences in line length may necessitate the identification of several alternative compressor station locations. Due to the similarities in the length of the four alternatives under consideration here, no changes in the location of compressor station locations is necessary. The locations of compressor stations are identified in the "Project Description" (Submission 2-1) of the addenda submissions. No compressor stations are located on any of the Kluane Lake alternative routes.

4.3.2 Access

The issue of whether pipeline construction will create access to areas outside the Alaska Highway corridor has been raised for all potential alternative alignments. Relatively good access to the east shore of Kluane Lake in the region of Alternatives #1, #2 and #3 presently exists in the form of a road which follows the lake shore. Therefore, this area is already accessible, and construction of any one of the three alternatives requiring a lake crossing should be viewed from this perspective. The use of existing access along the eastern lake shore has, however, been precluded for Project construction purposes due to a socio-economic concern; therefore, the topic of facilitated access is reduced to potential right-of-way use north or south of the highway, neither of which may be considered a remote area.

The EAR Panel has requested examples of the application of design, operation and maintenance standards to temporary and permanent access roads. To provide this information, access roads required for pipeline construction and operation on the east side of Kluane Lake are discussed in Part 6 of this submission.

PART 5

EVALUATION OF ALTERNATIVES AND SELECTION OF A ROUTE

Having determined the presence and magnitude of routing constraints and concerns in the Kluane Lake region, a comparison of alternative routes is possible. Since every route involves some unavoidable concern, selection of a route cannot be made solely on the basis of avoidance through location but rather on the likelihood and/or difficulty of overcoming concerns through some action.

Ideally, in undertaking the approach suggested above, each mitigative response required for each alternative would be costed and a final comparison of costs made. While such costing is relatively easy for engineering and construction factors for which accepted estimation techniques exist, applying a similar approach to responses required to meet environmental, socio-economic and safety concerns is made difficult by a lack of established costing procedures. Consequently, in the following evaluations, engineering and construction responses have been based on total cost figures, while environmental, land-use and safety responses are rated on an ordinal scale.

5.1 EVALUATION OF ALTERNATIVES

Cost evaluations for construction and design are based on estimates presented in Table 3-5.1.

Comparison of alternative routes for environmental, socio-economic and safety factors was facilitated through the use of a system of scoring using an ordinal scale. Scores were established for each factor along each alternative for both the degree of concern for the routing factors involved and the extent of Project response that would likely be required. Scores were listed under headings titled Importance of Concern

(I.C.) and Project Response (P.R.). For example, a road crossing may have a very limited degree of concern attached to it by persons outside the Project but involve a specific response with a measurable additional cost. In comparison, crossing of agricultural land involves a high degree of concern by the land holder but requires little in the way of Project response beyond standard rehabilitation techniques.

5.1.1 Rating Scales

Where a location factor has been identified as being present on any alternative under consideration, an assessment of the importance of the concern (I.C.), and the requirement for Project response (P.R.) was made. The assessments were rated using an ordinal scale.

For Importance of Concern (I.C.), the rating scale and ordinal values used were as follows:

Rating Scale	Rating Value
Factor absent	0
Factor present but with no concern	1
Factor present with low concern	2
Factor present with moderate concern	3
Factor present with high concern	4
Factor present with extreme concern	5

For Project Response (P.R.), the rating scale and values assigned were as follows:

Rating Scale	Rating Value
No response required	0
Response required is known to be effective and is part of standard plans or practice and involves no discernible extra cost	1
Response required is known to be effective and while not part of standard practice involves little if any additional cost	2
Response required is known to be effective, is not part of standard practice and involves a measurable additional cost	3
Response required is known to be effective, is not part of standard practice and involves substantial additional cost	4
Response required may not be effective based on previous experience and involves exceptional additional cost or the possibility of delay if necessary innovation is not effective	5

5.1.2 Evaluation

The four viable alternatives were evaluated using the rating scales described in Section 5.1.1. The results of the assessments are presented in Table 3-5.4. This table lists the factors considered in the assessment down the left hand column and the alternatives considered across the top.

The Evaluation Table presents on a single page, the degree of concern and the difficulty of resolving concern for the full range of routing factors considered. As a result, comparison of concerns and difficulty of resolution can be more easily made for individual alternatives. Totals for columns and rows have been included as they offer an indication of the degree of concern. Readers are cautioned against use of column and row totals for anything other than an indication of possible relationships. In order to assist reviewers in interpreting the information presented in Table 3-5.4, the rationalization used in arriving at values for the degree of concern and Project response required for each concern is presented in Appendix IV of this submission.

The Evaluation Table clearly indicates that any route selected will not be ideal and that trade-offs will be required. Since every route involves some unavoidable concern, selection of a route must be made not on the basis of avoidance through location but rather on the likelihood and/or difficulty of overcoming concerns through some Project response (mitigation measure). Selection of a route in this situation must be made on the basis of the fewest, or alternatively the least difficult, series of Project responses.

5.2 COMPARISON AND ROUTE SELECTION

In order to compare the various alternatives in terms of the subjective environmental, socio-economic and safety evaluations and dollar

LOCATION FACTORS	ALTERNATIVES	ALTERNATIVE NO. 1 I.C	ALTERNATIVE NO. 1 P.R	EVALUATION SCORE (a)	ALTERNATIVE NO. 2 I.C.	ALTERNATIVE NO. 2 P.R.	EVALUATION SCORE (a)	ALTERNATIVE NO. 3 I.C.	ALTERNATIVE NO. 3 P.R.	EVALUATION SCORE (a)	ALTERNATIVE NO. 4 I.C.	ALTERNATIVE NO. 4 P.R.	EVALUATION SCORE (a)
SOCIO-ECONOMIC													
LAND USE	MINERAL LEASES	0	0	0	0	0	0	0	0	0	0	0	0
	RESIDENTIAL	0	0	0	0	0	0	0	0	0	0	0	0
	AGRICULTURAL	0	0	0	0	0	0	0	0	0	0	0	0
	COMMERCIAL	0	0	0	0	0	0	0	0	0	0	0	0
	RECREATIONAL	3	2	5	3	2	5	3	2	5	4	3	7
	WATER SUPPLY	0	0	0	0	0	0	0	0	0	0	0	0
	HERITAGE	4	5	9	0	0	0	0	0	0	3	3	6
	NATIVE	3	2	5	3	2	5	3	2	5	0	0	0
	GRAVEL RESERVE	1	1	2	1	1	2	0	0	0	1	1	2
TOTAL		11	10	21	7	5	12	6	4	10	8	7	15
ENVIRONMENTAL													
FISH	HABITAT	4	3	7	3	3	6	3	3	6	1	0	1
BIRDS	RAPTORS	3	2	5	2	2	4	2	2	4	2	2	4
	WATERFOWL	1	0	1	0	0	0	0	0	0	2	1	3
MAMMALS	DALL'S SHEEP	2	1	3	0	0	0	0	0	0	4	3	7
	OTHERS	2	1	3	2	1	3	2	1	3	2	1	3
TOTAL		12	7	19	7	6	13	7	6	13	11	7	18
OPERATIONS													
PUBLIC SAFETY		2	1	3	2	1	3	2	1	3	3	1	4
THIRD PARTY DAMAGE		2	1	3	2	1	3	2	1	3	3	1	4
TOTAL		4	2	6	4	2	6	4	2	6	6	2	8

a. THE TERM "EVALUATION SCORE" IS SYNONYMOUS WITH THE TERM "RATING OF CONCERN" USED IN A COMPARABLE TABLE REGARDING POTENTIAL WHITEHORSE — IBEX ROUTE ALTERNATIVES.

I.C. = IMPORTANCE OF CONCERN.

P.R. = PROJECT RESPONSE (FOR EXPLANATION, SEE TEXT)

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TABLE 3 - 5.4

EVALUATION OF ALTERNATIVE ROUTES IN THE KLUANE LAKE REGION

	DRAWN	CHECKED	APPROVED	APPROVED
BY	H. R			
DATE	7.12.81			

SCALE N.A

PREPARED BY

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costs, the evaluation scores for each alternative from Table 3-5.4 were categorized as low or high, depending upon which side of the midpoint within the total range of scores they fell. Table 3-5.4 details the categorization process for environmental, land-use and safety factors. Factors related to engineering and construction are expressed in dollar amounts based on detailed estimates (Table 3-5.1), as relationships between these factors and cost estimates are obvious. Table 3-5.5 combines the categories for the main routing disciplines together with estimated costs for construction.

A comparison of the advantages and disadvantages of the four alternatives is summarized below:

Alternative #1
- low cost
- high potential for environmental impacts
- high potential for land-use conflicts
- low potential for risk to public safety and possibility of third party damage

Alternative #2
- low cost
- low potential for environmental impacts
- low potential for land-use conflicts
- low potential for risk to public safety and possibility of third party damage

Alternative #3
- low cost
- low potential for environmental impacts
- low potential for land-use conflicts
- low potential for risk to public safety and possibility of third party damage

Alternative #4
- high cost
- high potential for environmental impacts
- low potential for land-use conflicts

TABLE 3-5.5

COMPARISON OF COSTS AND EVALUATION SCORES FOR ENVIRONMENTAL AND SOCIO-ECONOMIC (LAND-USE) FACTORS, AND PUBLIC SAFETY FACTORS RELATED TO THIRD PARTY DAMAGE

Alternative	Total Capital Cost ($ 000,000)	Evaluation Score[1]		
		Environmental	Socio-economic (Land-use)	Public Safety
#1	163.2	19	21	6
#2	156.7	13	12	6
#3	153.9	13	10	6
#4	187.5	18	15	8

- high potential for risk to public safety and possibility of third party damage

The Project has chosen Alternative # 3 as the preferred route, as it offers the lowest cost, a low potential for environmental impact, a low potential for land-use conflicts, and a low potential for risk to public safety and possibility of third party damage. While Alternative #2 offers comparable advantages in several categories, this alignment scored higher (and is therefore less desirable) in the socio-economic category, and is estimated to cost $2,800,000 more to construct than Alternative #3.

PART 6

ENVIRONMENTAL IMPACT ASSESSMENT OF ALTERNATIVE #3

The environmental implications of constructing the pipeline along Alternative #3 are discussed in this section of the submission. The existing environment along this routing was presented in Section 4.2.2; following is a discussion of unmitigated environmental impacts, proposed mitigation measures and predicted residual impacts.

In order to facilitate the review of this assessment, as well as provide information requested by the EAR Panel, this section of the submission is prefaced by a description of the design concepts which would be involved in a pipeline crossing Kluane Lake. The Panel has also requested design, operation and maintenance standards to be applied to temporary and permanent access roads. This information is also provided in the following discussion.

6.1 KLUANE LAKE CROSSING

Major considerations which were applied to the lake crossing concept in identifying potential alignments were: space for fabrication of the long sections of pipe required in a large watercrossing; space for the placement of a large winch to pull pipe across the lake; extent of slope stabilization required; lake bottom profile; and, depth and extent of liquefiable soils. With these constraints in mind, three potential alternative alignments have been identified, all of which are technically feasible to construct. The concepts employed for the design and construction of the lake crossing are common to the three alternative alignments; these concepts will be outlined in the following discussion. It must be emphasized, however, that the actual method to be employed at the lake crossing has not been finalized, and the information presented here must be considered as conceptual.

One of the major considerations in designing a pipeline crossing of Kluane Lake is the presence of the Shakwak Fault lying along the western lake shore and crossing the lake's southern end. The design concepts presented here are based on the seismic design criterion that the line will not suffer any damage during a Design Contingency Earthquake (DCE), which has a 200- to 500-year return interval. The design criterion for the onshore portion of the line is that no damage will result from a Design Operating Earthquake (DOE), which has a 50- to 100-year return interval, and that there should be only a brief shut-down for inspection and limited repair following a DCE. The DCE for the crossing of Kluane Lake has a magnitude of 7 on the Richter scale. It is estimated that the probability of exceeding the DCE in a 30-year operation period is approximately 5 percent.

The nature of the concern in relation to the consequences of seismic activity at the lake crossing involves, but is not limited to the existence of potentially-liquefiable soils, and potential consequences of a liquefaction event. A series of test holes have been drilled, and sediment samples secured in the region of the lake crossing to determine the stability of lake sediments. This program is on-going and the data presented here are preliminary in nature; thus, the approaches discussed are conservative. The analyses of sediment samples indicate that soils present in the eastern and western slopes have a medium to high liquefaction potential, while sediments across the relatively flat lake bottom have a high liquefaction potential under the DCE. Soil liquefaction may result in slope movements on the eastern and western lake shores. Liquefaction on the lake bottom is not likely to cause mass movement of soils, due to the topographically flat nature of this component of the lake crossing. It has also been surmised that slopes steeper than 5° which are composed of cohesionless, coarser-grained, non-plastic soils will likely result in slope movements during a DCE.

Three basic methods are available for controlling slope instability problems: (i) supporting the pipeline on piles; (2) trenching to competent material; and, (3) removal of overburden to achieve slope stability. The third approach was considered to be the most desirable, as removal of overburden, which also results in reduction of the slope angle, increases the stability of the slope while reducing pipe stresses due to bottom irregularity. Thus, the following design concept is based on the conservative approach that the slopes on the lake shore are unstable, and the problem of potential slope instability will be overcome by removal of overburden.

The pipe diameter to be used for the lake crossing is the same as that employed on either side of the lake crossing (1219 mm O.D.), but the wall thickness will be increased to 25.4 mm from 13.71 mm. The pipe will be coated with concrete to a thickness which will allow the pipe to rest at the soil-water interface but not sink into the lake bottom. To this end, a concrete coating 121 mm thick will be used in water depths up to 30 m, and 108 mm in depths in excess of 30 m.

Through an analysis of profile stresses (caused by bending due to an irregular lake bottom) and operating stresses (due to internal gas pressure and the temperature differential between the gas and the pipeline at the time of installation), it has been determined that trenching near the shore approaches is required in order to reduce normal operating stresses to acceptable levels. Trenching may also be necessary to prevent potential slope movements from overstressing the line, as discussed above. A summary of conservative estimates for required trenching of shore approaches along the three alternatives is as follows:

Route Alternative Number	Maximum Trench Depth (m)	Maximum Water Depth For Trenching (m)	Estimated Trench Length (m)[3]	Spoil Removal, Estimated Volume (m^3)[3]
1	9	34	760	63,000
2	18	55	1,040	367,000
3	18	55	850	305,000

3. Both shore approaches included.

The shore approaches would be backfilled to a depth of approximately 10 m subsequent to pipe installation. This procedure provides for mechanical protection from storm damage or vandalism, and also protects the pipe from ice pressure at the shoreline, when the lake freezes in winter.

When it rests horizontally on a smooth lake bottom, the pipeline is in an unstressed condition. However, the lake bottom profile is not uniformly flat and is characterized by high and low areas along the pipeline route. These undulations will induce bending and shear stresses in the pipe as the pipe bends to conform to the bottom profile, or as it spans between high points. These potential stresses must be eliminated to ensure that the pipeline is not overstressed in its final resting position, by trenching through undulations. In addition, offshore trenching of slopes may be required to resolve potential slope stability problems, if the results of geotechnical programs indicate such instability is likely on the undulating lake bottom. The depth of trench in offshore areas is presently anticipated to range from 1.0 to 14.6 m. In all cases, the width at the bottom of the trench would be 6 m, with a slope to the natural lake bed on the sides of the trench of approximately 12°. The width at the top of the trench on the lake bottom would therefore range from approximately 15 m (ditch depth - 1 m) to 143 m (ditch depth - 14.6 m). There is no necessity for burial of the pipe between the shore approaches (offshore areas).

Construction Techniques

The requirements for trenching vary for the nearshore and offshore zones. The concept presently under consideration for nearshore trenching involves the installation of sheet piling out to a water depth of 10 m. This piling will keep the trench open, decrease the amount of excavation required, and decrease the amount of backfill required to close the trench. To install the pilings, the tops of the pilings will be braced and decked, and a crawler crane will advance on this decking, driving new pilings ahead of it. When the 10 m depth is reached, a crawler-mounted dredge or other suitable trenching equipment can be used to excavate the soil between the piles. This trenching will continue onshore by clam shell or drag line to the required depth for the land line. Backfill will be light and non-liquefiable, such as crushed gravel, to avoid the possibility of the backfill sinking in the event of liquefaction of the underlaying sediments, or liquefaction of the backfill itself during the DCE. After the trench is backfilled, the pilings will either be cut at the bottom or pulled out of the lake.

Several techniques for offshore trenching are presently under consideration, although the availability of equipment is problematic in southern Yukon Territory. One technique involves the use of two anchored barges from which a drag line or clam shell is operated. Another technique involves use of a remotely-operated, or mechanically-towed dredging machine (Figure 3-5.1 and 3-5.2). In either instance, ditch spoils would not be brought to the surface, but would be deposited or discharged to the side of the ditch. Another technique which is being considered consists of an airlift system, in which air is pumped into the bottom of a pipe which opens at the substrate to be trenched. The air rises in the pipe, and draws water and lake sediment up to the surface in this vessel. A grinding head is attached to the mouth of the pipe, which dislodges or loosens the substrate to assist in drawing this material to the surface. Once at the surface, the material may be released, pumped back to the lake bottom in a comparable piece of pipe, piped to shore, or may be stored in a barge and hauled away to a disposal site.

Pulling

The procedure currently under consideration for installing the pipeline in the lake bed calls for pulling the line from the western shore to the eastern shore. This would involve establishing a fabrication site on the western lake shore. At this locale, the pipe would be welded into lengths of approximately 600 m, coated with concrete and pressure tested. A pull site would be located on the eastern shore, which would consist of a

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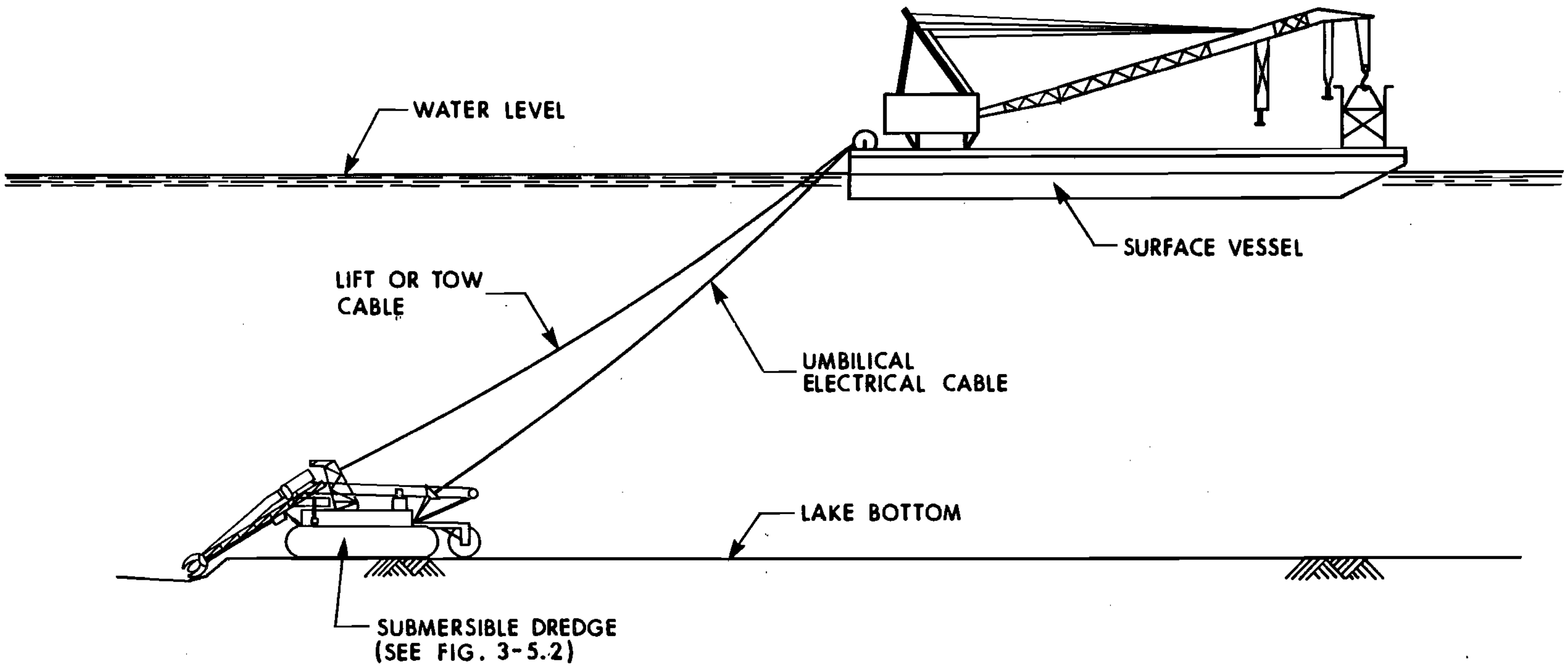


Foothills Pipe Lines (Yukon) Ltd.

	DRAWN	CHECKED	APPROVED	APPROVED
BY	D.K.M.			
DATE	81/12/04			

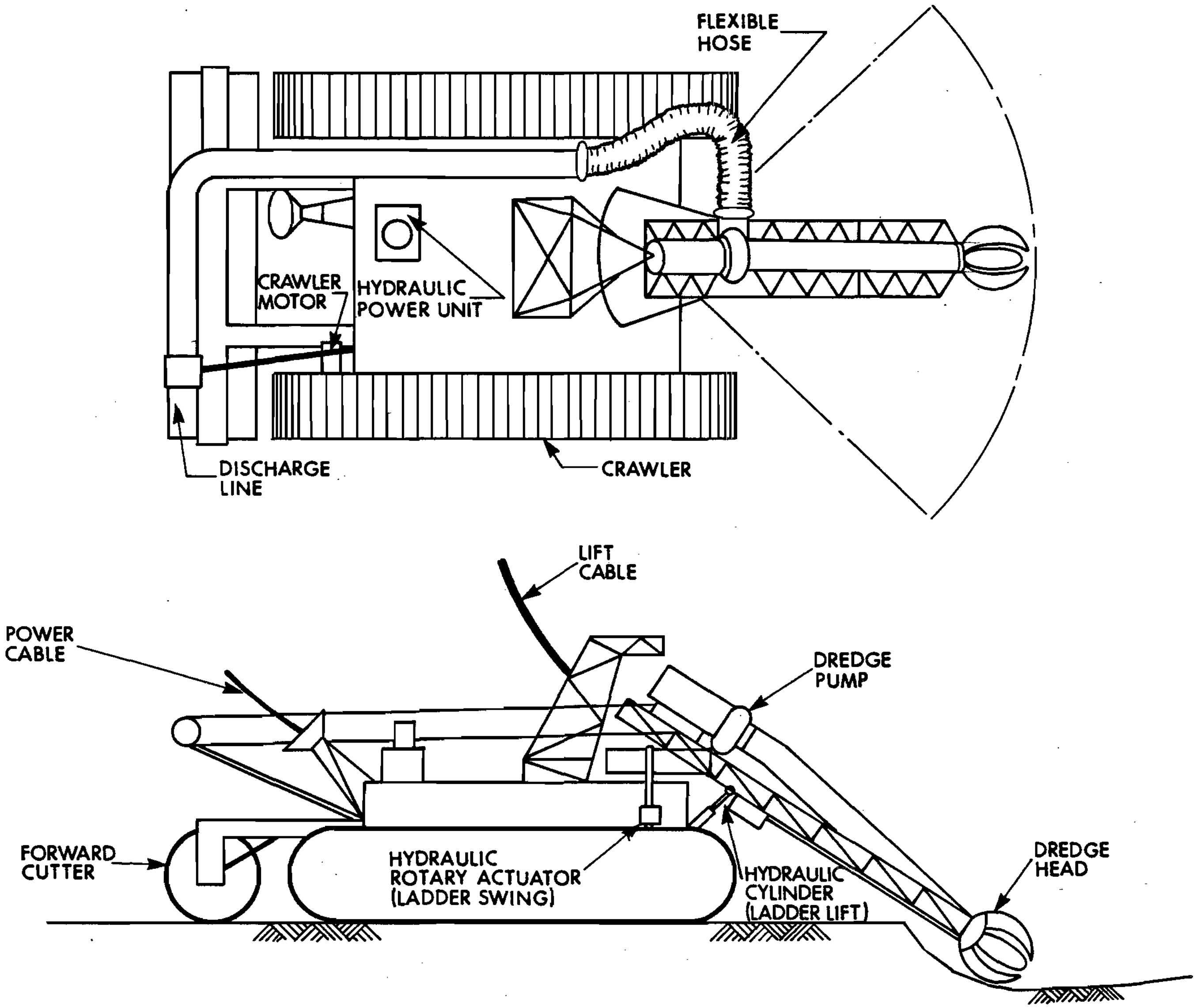
TITLE
THE ALASKA HIGHWAY GAS PIPELINE PROJECT

DREDGING ARRANGEMENT

SCALE N.T.S

PREPARED BY BROWN & ROOT, INC.

FIGURE 3-5.1



CONCEPTUAL SKETCH

Foothills Pipe Lines (Yukon) Ltd.

TITLE
THE ALASKA HIGHWAY GAS PIPELINE PROJECT

SUBMERSIBLE DREDGE
(SELF PROPELLED)

	DRAWN	CHECKED	APPROVED	APPROVED
BY	D.K.M.			
DATE	81/12/04			

SCALE N.T.S. PREPARED BY BROWN & ROOT, INC.

FIGURE 3-5.2

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pulling winch anchored to the ground in the pipe trench. The winch would have a pull capacity of approximately 100 tonnes.

The likely sequence of events in completing a pipe pull such as that proposed for Kluane Lake is as follows. Following testing of the pipe, the pipe string is moved onto pipe rollers to decrease the pulling load. The pull cable is attached to the pulling head, and a cable from a holdback winch is attached to the rear of the pipe section. Buoys are then attached to the pipe string at the design spacings, which reduces the submerged weight of the pipe and decreases pulling friction. Tension is then applied to the pull cable until the pipe string begins to move. Once the specified amount of cable has been played in, the pull cable is stopped, holdback tension is applied, and the pipe is halted. The next string is then welded into place, and the pull procedure repeated. This process continues until the pipe has been pulled across the lake. With the pipe in position, the cables and buoys are removed. A "cleaning pig" will then be run through the line to remove debris. Once the pipe has been cleaned, a gauging pipe will be inserted to check the pipe for any excessive ovalization or buckles. The line will then be pressure tested to verify the pipe integrity. Finally, backfilling to a depth of approximately 10 m on the shore approaches is conducted, and the sheet pilings are removed.

The stresses encountered during installation are expected to be low. With trenching conducted prior to the pull, the bending stress will be well within the allowable levels, largely because of buoying the pipe during the pull. The anticipated stresses from the pull tension and bending fall well below the recommended allowables.

6.2 DESIGN INFORMATION FOR ACCESS ROADS

Given the selection of Alternative #3 as the preferred route in the Kluane Lake region, the following section presents access road requirements and design standards for these roads on the east side of the lake.

6.2.1 Temporary Access Roads

Temporary access roads will be constructed for Project pre-construction and construction activities. The principles used in planning, locating and implementing such roads are those of shortest distance and minimal work requirement for installation and maintenance. Temporary roads will be constructed to a standard which is based on the anticipated traffic loads and season of construction for which access is required.

On permafrost soils, measures to minimize surface disturbance will be employed, which include developing work surfaces of granular material on a "preliminary pad" of vegetation cleared for the road, or the use of an insulating material placed in the road bed to limit permafrost regression. Snow compaction may also be used on level areas to induce frost penetration.

On non-permafrost soils, standard grading and leveling procedures would be employed. Preparatory activities involve maximum possible utilization of existing soil materials through grading of high spots and filling and leveling low areas along the proposed access road.

The temporary access road on the east side of Kluane Lake will be constructed on the pipeline right-of-way from the lake shore to the Alaska Highway crossing at KP 252.9. Access to this alignment will be at the intersection of the highway and pipeline route. Due to a socio-economic constraint, the existing access road along the east shore of Kluane Lake will not be available for use by the Project during construction. The schedule for Section 5 specifies mainline construction during the summer of 1983. Preparation of the access road is presently planned to commence in July, 1982; the road would be completed by November of that year. The period of road use will therefore span from July, 1982, through to the end of September, 1983. The location of the temporary access road is therefore shown on maps as Alternative #3. The location of the existing road along the east shore of Kluane Lake is shown as a dotted line on the 1:50,000 scale maps accompanying Submission 2-1, "Project Description".

This access road will be constructed using standard cut and fill procedures. Wet areas will be filled using end-dump operations, with fill requirements ranging from standard pit run to heavy rip-rap materials. No fisheries concerns exist in the crossing regions of any streams along this section of the pipeline route, thus removing any requirements for facilitating fish passage at watercrossings. Culverts will be placed along the alignment to allow water passage for the period of construction, in a manner comparable to that depicted for permanent access roads in Figure 3-5.5. Further information on the criteria used for selecting culvert diameters is given in Submission 5-3, "Design and Use of Culverts".

Following the construction phase, access to this region of the pipeline will no longer be required on a regular basis by the Project, and non-project vehicular traffic will be discouraged. However, the requirement for access will exist in order to facilitate right-of-way maintenance on an "as-required" basis, and also for the mobilization of men and equipment in the unlikely event of a pipeline rupture. To this end, the following Project action will be employed.

The approach to the right-of-way at KP 252.9 may be removed, as resolved in consultation with the Yukon Territorial Government Department of Highways and Public Works. The approach will be located on the Alaska Highway right-of-way, which is under control of this department. For Project purposes, retention of this approach is favored in conjunction with the use of suitable obstacles to deter use of the right-of-way by unauthorized vehicles. The type of obstacles under consideration are locked gates, large boulders, or an excavated pit in the right-of-way.

All culverts will be removed from the right-of-way following the construction phase. As a consequence of this procedure, access for wheeled traffic from the south will be blocked near the crossing of Christmas Creek. The right-of-way crosses muskeg-type terrain in this locale, which will act as a barrier to traffic. Project access to the section of line between the east shore of Kluane Lake and Christmas Creek will be facilitated through the use of the existing road along the lake shore, and the right-of-way. It is anticipated that vehicular access required for Operations and Maintenance purposes across Inlet Creek (KP 237) will be possible by fording the creek at the right-of-way, as the creek bottom consists of stable, granular material at the pipeline crossing location. In this manner, this entire section of the pipeline is accessible to the Project, but is unattractive to others in that an uninterrupted route from Sulphur Lake to Kluane Lake is not available.

6.2.2 Permanent Access Roads

Permanent access roads will be constructed to all compressor station sites and intermediate block valves from the Alaska Highway. Roads and road structures will be designed and constructed generally in accordance with the standards set forth in the Highways Regulations affixed to the Highways Ordinance of the Yukon Territory. The proposed road design classification is RLU 70 as defined in the "Geometric Design Standards for Canadian Roads and Streets". Should revisions be necessary, the revised standards will be submitted to the Director of Highways and Public Works for approval in accordance with clause 3(a)V of the Highway Regulations.

Roads which are constructed solely for Operations and Maintenance purposes will have a trafficable surface of 6 m. Permanent access roads which are also used during the construction phase will have a trafficable surface of 8 m.

Materials Requirements

The road sub-base will be composed of high quality granular borrow. No preparation of this material will normally be required. The base will be constructed using select granular material, mechanically prepared if required, which will not contain any aggregate in excess of 20 mm. The quantities of material required are anticipated to be an average of 11 m^3/m

of roadway for roads with a 6 m travelled surface, and 13.5 m^3/m of roadway with a 8 m surface. Of these material requirements, 1 m^3 will be select granular base.

Standard Design

The standard design is that of a roadway with a 6 m travelled surface and a passing lane located at 500 m intervals. To enable tractor trailer access, a minimum curve radius of 15 m will be standard. Access approaches to the highway will conform with the criteria of Public Works Canada for typical commercial access flares to the Alaska Highway.

Design Criteria and Construction Details

Terrain and soil conditions vary along the length of the pipeline route in Yukon Territory and road construction modes vary accordingly. Designs have been developed for frozen and unfrozen terrain.

Design Standard for Unfrozen Terrain

The design for road construction in unfrozen terrain will be employed in areas where the road bed will be subject to seasonal freeze-thaw and where the entire road and subgrade remain above freezing for an extended period of time. This mode may be employed in thaw-stable permafrost terrain.

The construction technique employed with the unfrozen terrain design is grubbing, stripping and organic soil removal, followed by placement of fill. Typical cross sections of this type of construction are illustrated in Figures 3-5.3 and 3-5.4. Excavated materials are disposed of at approved disposal sites. Culverts are installed as required, using a 100-year flood peak as the design criteria. A typical culvert installation

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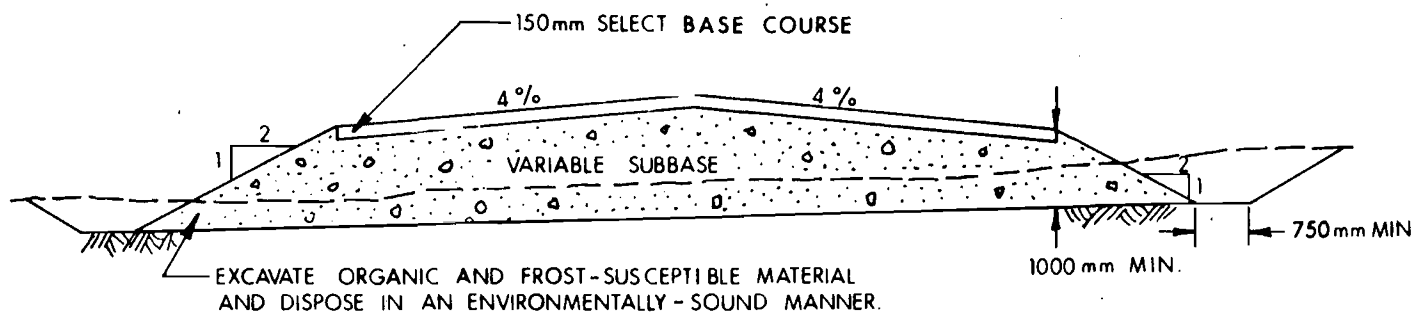


Foothills Pipe Lines (South Yukon) Ltd.

	DRAWN	CHECKED	APPROVED	APPROVED
BY	A. M.	[illegible]		
DATE	81 05 08	81-5 11		

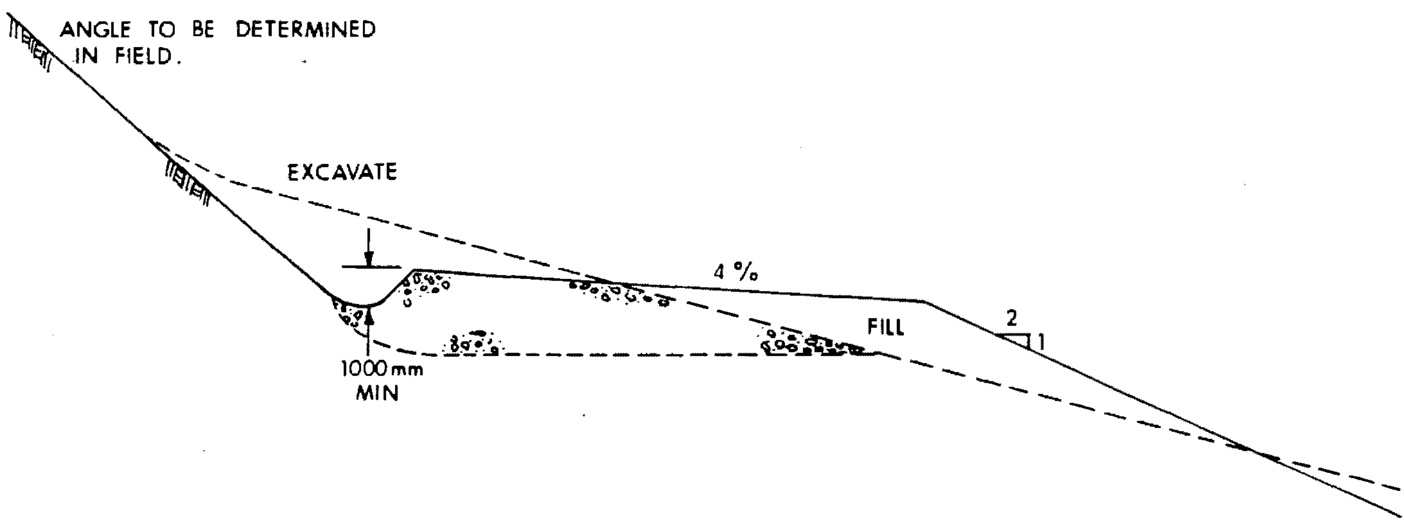
TITLE

THE ALASKA HIGHWAY GAS PIPELINE PROJECT
ACCESS ROAD:
TYPICAL CROSS SECTION
UNFROZEN TERRAIN

SCALE N T S

PREPARED BY

FIGURE 3-5.3



NOTES :

1. EXCAVATION OF SIDE HILL SHOULD BE MINIMIZED, FILL MAXIMIZED.

2. INTERCEPTOR DITCH DEPTH OF 1000mm MIN. WITH FREQUENT SMALL - DIAMETER CULVERTS RATHER THAN LARGE - DIAMETER CULVERTS.

3. SAFE ANGLE OF REPOSE ON SIDE HILL CUT TO BE DETERMINED BY ENGINEER. (1:4 MAXIMUM)

4. DOWN HILL FILL SLOPE TO BE AT 2:1 OR NATURAL GRADE (IF WITHIN SAFE ANGLE OF REPOSE.)

REV 81 07 02

Foothills Pipe Lines (South Yukon) Ltd.

TITLE

THE ALASKA HIGHWAY GAS PIPELINE PROJECT
ACCESS ROAD:
TYPICAL SIDE HILL CUT
UNFROZEN TERRAIN

	DRAWN	CHECKED	APPROVED	APPROVED
BY	T A O	RPT		
DATE	81 05 11	81 05 11		

SCALE N T S

PREPARED BY

FIGURE 3 - 5.4

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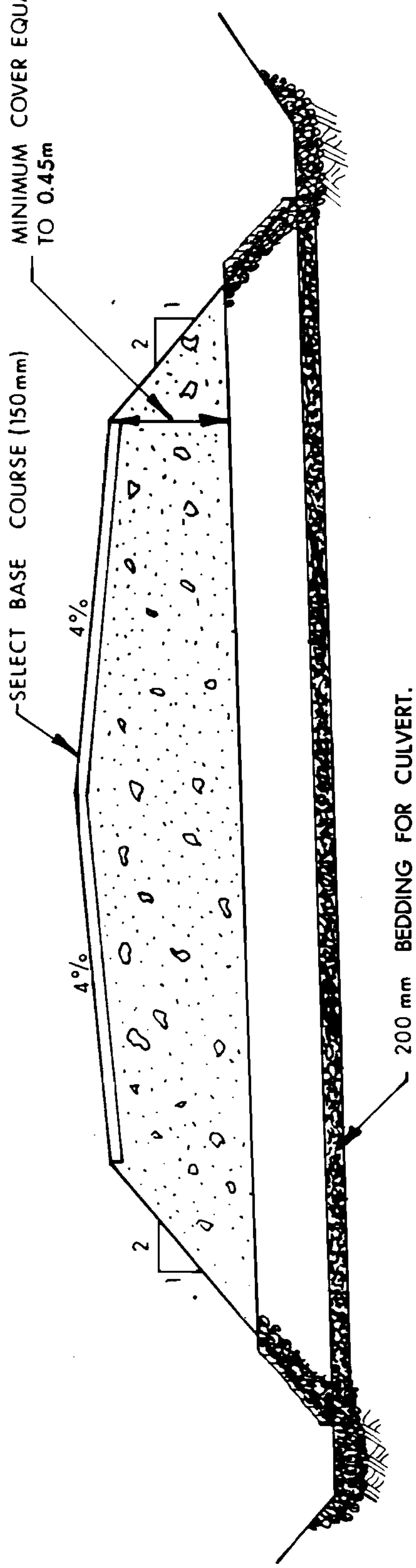
is illustrated in Figure 3-5.5 for the unfrozen terrain design. Culverts will be sized to discharge the peak design flow at a maximum headwater depth on the invert of 1.5 pipe diameters or as limited by the height of road grade. Freeboard at design flow will be in the order of 0.5 m. Rip-rap will be sized to the required dimensions and placed at the pipe outlet and inlet to prevent erosion. If any fish-bearing watercourses are crossed by permanent access roads, culverts will be designed and installed in accordance with "Guidelines for the Protection of the Fish Resources of the Northwest Territories During Highway Construction and Operation".

Design Standard for Frozen Terrain

Areas of permafrost are generally stabilized by the insulating layer of organic mat and vegetation. To protect against thermokarst subsidence, this layer must be protected from damage. This is accomplished by utilizing an end-dump technique, filling directly over the surface layer. Fill material is applied to a minimum depth of 1 m, to allow the permafrost to move into the road sub-base and thus stabilize the road-bed, and prevent permafrost regression and differential settlement. The road-bed depth may be increased to ensure the permafrost layer does not regress to the organic material, or an insulating material may be placed in the road bed to limit permafrost regression and reduce borrow requirements. A typical cross section of permanent access road construction in the frozen terrain design is illustrated in Figure 3-5.6.

No fill material will be dumped into free-standing water. Ponded water will be drained, the road bed placed, and the pond permitted to refill naturally. Culverts will be installed as required to allow cross drainage. Figure 3-5.7 illustrates the installation of a culvert in the frozen terrain design. Such culverts will be installed at the same level as the lower elevation of the active layer, to ensure the maintenance of natural drainage patterns. A layer of insulation is placed beneath the culvert to prevent permafrost regression. Materials placed above the insulation in a culvert installation will be frost-stable. A minimum height



NOTE. THE USE OF CULVERT END SECTIONS IS RECOMMENDED

REV. 81-07-02

Foothills Pipe Lines (South Yukon) Ltd.

TITLE

THE ALASKA HIGHWAY GAS PIPELINE PROJECT
ACCESS ROAD:
TYPICAL CULVERT INSTALLATION
UNFROZEN TERRAIN

	DRAWN	CHECKED	APPROVED	APPROVED
BY	D. KELLAM	[illegible]		
DATE	81 05 08	[illegible]		

SCALE N.T.S.

PREPARED BY

FIGURE 3-5.5

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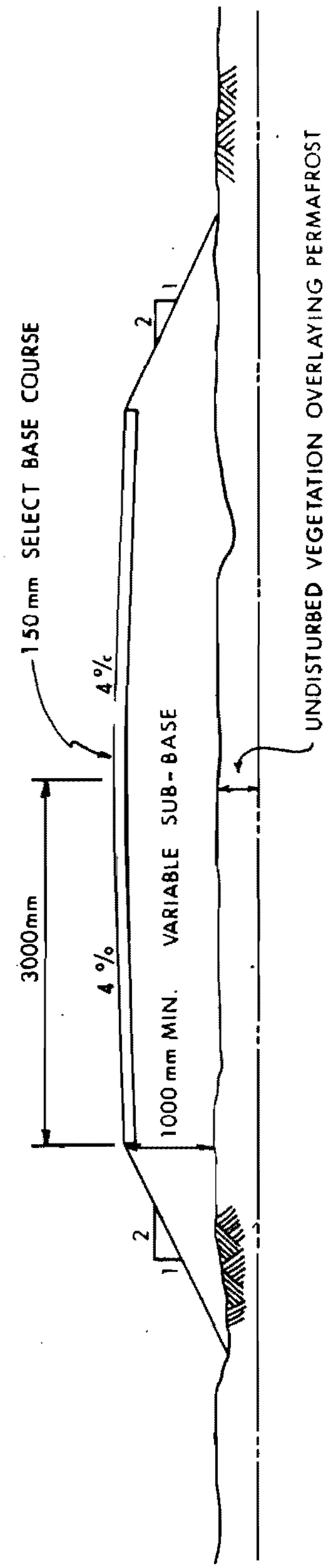

REV : 81·06·30

Foothills Pipe Lines (South Yukon) Ltd.

TITLE
THE ALASKA HIGHWAY GAS PIPELINE PROJECT
ACCESS ROAD:
TYPICAL CROSS SECTION
PERMAFROST MODE

	DRAWN	CHECKED	APPROVED	APPROVED
BY	S. J. G.	[illegible]		
DATE	81 05 08	[illegible]		

SCALE N.T.S.

PREPARED BY

FIGURE 3-5.6

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A4 FORM 258

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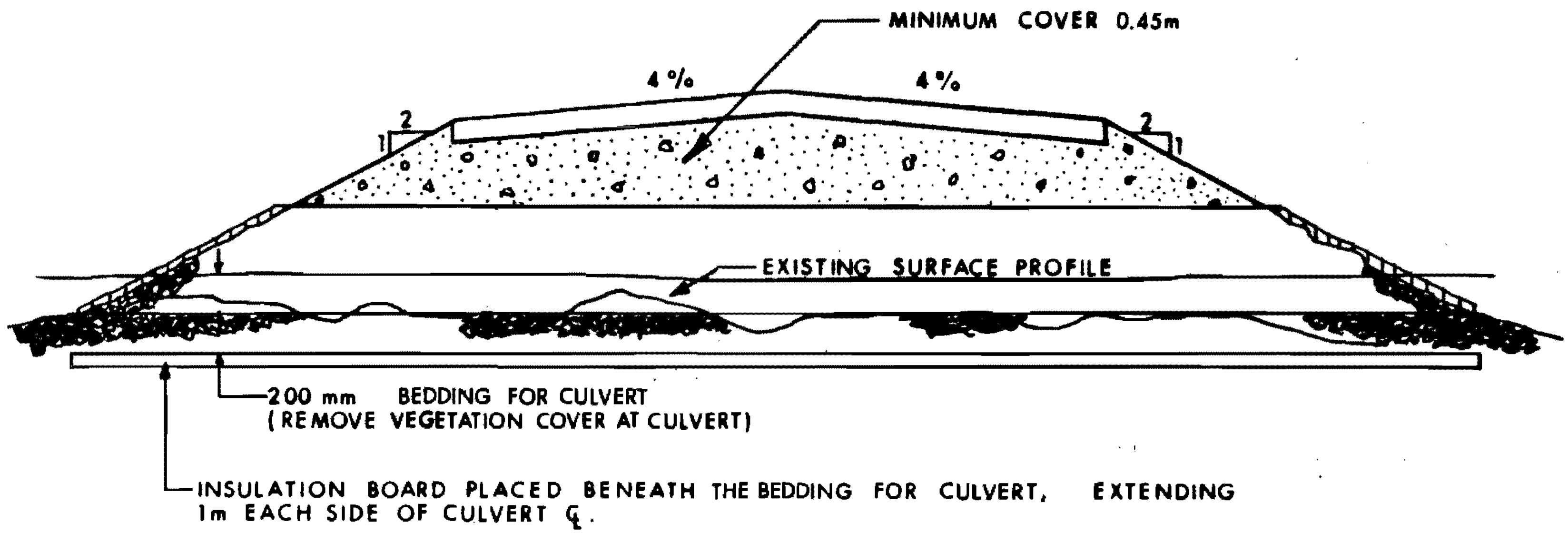

NOTE: THE USE OF CULVERT END SECTIONS IS RECOMMENDED.

Foothills Pipe Lines (South Yukon) Ltd.

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BY	G. Y	[signature]		
DATE	81 05 08	810511		

TITLE
THE ALASKA HIGHWAY GAS PIPELINE PROJECT
ACCESS ROAD:
TYPICAL CULVERT INSTALLATION
PERMAFROST MODE

SCALE N.T.S.

PREPARED BY YUKON PIPELINE DESIGN

FIGURE 3-5.7

of cover of 0.45 m will be maintained above the culvert. No ditches are installed in the frozen terrain design, which increases the quantity of culverts required. If any fish-bearing watercourses are crossed by permanent access roads, culverts will be designed and installed in accordance with "Guidelines for the Protection of the Fish Resources of the Northwest Territories During Highway Construction and Operation".

Post-Construction Road Maintenance

Snow Removal

The raised road bed will assist in keeping permanent roadways clear in areas without tree and shrub growth. During snow removal, side banks will be kept as low as possible to discourage blowing snow build-up. In some instances, tracked snow vehicles may be used for access to intermediate block valves to reduce snow removal requirements.

Spring Thaw Drainage

During periods of heavy run-off, culverts will be maintained free of debris and ice. Culverts will be marked by maintenance crews in the fall to facilitate spring cleaning where problems may arise, and to enable the location of culverts when they are submerged in snow or ice.

Road Surface

The traffic surface will be maintained to permit efficient traffic movement. This maintenance will consist of blading the surface to remove corrugations (wash board) and maintain an even surface, as well as replenishing the surface gravel where required.

Permanent Access Road - KP 253.9

A permanent access road will be constructed to the intermediate block valve at KP 253.9. This is the only permanent access road which would be constructed along Kluane Lake Alternative #3. The existing road would be used for access to the block valve at KP 226.8, on the east shore of Kluane Lake. This road would not be upgraded.

The location of the permanent access road to the block valve at KP 253.9 is shown on the 1:50,000 scale maps accompanying Submission 2-1, "Project Description". This access road will be 310 m in length, of which 195 m will be inside the pipeline right-of-way, and 50 m will be within the Alaska Highway right-of-way. An existing road has been identified in this vicinity, but no decision has been made to date on the suitability of this alignment for access to the block valve.

The terrain condition at this location consists of surface organics, fine silts and clays underlain by till, silty sand, silty gravel and sand and gravel. All these materials have a low to medium frost-heave potential. A few ice lenses may be present in the upper 6 m, with the likelihood of such lenses being rare below this depth. These conditions are suited to the standard mode of road construction. The previously-outlined unfrozen terrain design will therefore apply. No drainages are crossed by this alignment, which precludes any requirement for culverts.

6.3 UNMITIGATED ENVIRONMENTAL IMPACTS

The construction of Alternative #3 with no mitigative action to protect fish and wildlife resources could result in a variety of impacts on these resources. The first 4 km of this alignment (KP 216 to KP 220) is scheduled for winter construction. The remainder of this alignment (KP 220 to KP 260) will be constructed during the summer season.

Fish

The only waterbody crossed by Alternative #3 which supports fish in the vicinity of the proposed pipeline crossings is Kluane Lake (see Appendix III). The construction schedule for Kluane Lake extends from May 1 through to August 31. The sensitive life history stages of the important fish species identified within the defined 5 km zone of concern during this time period are incubating lake trout and lake whitefish eggs. Studies have not been conducted to determine hatching times for lake trout or lake whitefish in Kluane Lake. On the basis of literature reviews, fry emergence should be complete in the first week of April, and the third week of April, respectively. Fry are considered to be susceptible to disturbance for a period of time following emergence, until the fry are motile and capable of avoiding disturbances in their environment. Therefore, the sensitive time period defined by the Project for lake trout eggs and fry extends until May 15, while that period for lake whitefish terminates on May 31.

Lake Trout

One suspected lake trout spawning area exists within 5 km of Alternative #3, on the east margin of the lake approximately 2 km north of the pipeline route. Dredging activity in the eastern side of Kluane lake could result in sediment deposition on incubating eggs or newly-hatched fry during the first two weeks of May. This could result in complete loss of recruitment from this spawning bed during the year of construction. On the basis of surveys conducted by the Project in the central region of Kluane Lake, this is one of nine spawning areas in this locale. The total numbers of lake trout spawning areas in the entire lake is unknown, but spawning is anticipated to take place in many other regions of the lake. While the loss of recruitment from this spawning area would result in a complete loss of an age class from that spawning location, recruitment from other spawning areas would ensure that this age class is not absent from the Kluane

Lake population. It is unlikely that the reduction in numbers of that particular age class could be detected in subsequent years in Kluane Lake.

Lake Whitefish

One suspected lake whitefish spawning area has been identified within 5 km of Alternative #3. This spawning area is also located on the east side of Kluane Lake, approximately 3.5 km north of the pipeline route. Dredging activity in the eastern shore of Kluane Lake could result in sediment deposition on incubating eggs during the month of May. This could result in complete loss of recruitment from this spawning area during the year of construction. On the basis of surveys conducted by the Project in the central region of Kluane Lake, this is one of six suspected spawning areas in this locale. The total number of lake whitefish spawning areas in Kluane Lake is unknown, but the results of Project studies indicate the central region of Kluane Lake is not heavily used for this purpose, and that major spawning areas exist in other areas of the lake. The loss of recruitment from this spawning location would result in a reduction in the numbers of lake whitefish of that age class in Kluane Lake; however, as a result of recruitment from other spawning beds, it is unlikely that this reduction in numbers would be detectable in the lake whitefish population.

Physical Habitat

No spawning habitat has been detected at the actual location of the pipeline crossing and therefore no loss of spawning habitat will result at the crossing itself. The spawning areas which are in proximity to the lake crossing are located approximately 2 km and 3.5 km to the north. If these locations are subject to sedimentation, they may be rendered unsuitable for use in the years subsequent to pipeline construction activities. However, the potential loss of this habitat (and the incubating eggs referred to in the discussion above) is not considered likely for the following reasons. Lake trout prefer to spawn over rubble or boulders at depths of less than 12 m, while lake whitefish spawn over substrates ranging from stone to sand at depths typically less than 7.6 m. All such areas are nearshore in Kluane Lake, due to the pronounced u-shape of the lake basin. During trenching activities, the heavier particles introduced into suspension (e.g., sand-sized particles) will settle out of the water column relatively quickly, given the slow current in a waterbody such as Kluane Lake. The remaining materials in suspension would settle out at varying distances from the trench, depending on the density of each particle. At a distance of 2 km, only the very fine materials (e.g., glacial flour) would still be in suspension. These very small particles would not settle to the bottom until they are transported to the calm waters found in the deeper areas of the lake. In the shallower areas of the lake, water movement from wave action would prevent the settling of these particles, or, if the lake was very calm during trenching, wave action from the next storm event would reintroduce these particles into suspension, and eventually these finer particles would be transported to the deeper areas of the lake. However, given a scenario that a lake trout or lake whitefish spawning area is subject to the sedimentation process during the month of August, these spawning areas would not be suitable for use during the year of construction. The results of Project studies indicate lake trout spawning occurs from mid-September through to mid-October, while lake whitefish spawning commences during mid-October and continues into November. Therefore, the fish using these areas would be required to locate alternate spawning locations for the year of construction, which may reduce recruitment if the characteristics of the alternate spawning habitat are less than optimal. Such a reduction in recruitment would have less impact than inundation of incubating eggs, and therefore would not be detectable in the age-class structure of these fish populations. If these spawning areas were not scoured by natural lake processes, any such reduction in recruitment may be a long-term impact. It should be noted that in at least one instance, lake trout have been observed to clean sediment from a spawning area. It is not known if the lake trout population in Kluane Lake exhibits this behaviour pattern.

Other concerns raised regarding consequences of a pipeline crossing of Kluane Lake involve factors such as turbidity and physical interference with fish movements. The probable consequence of an increase in turbidity during trenching activities is limited to a slight decrease in primary productivity in the nearshore areas of the lake. Offshore trenching activities, conducted by drag line, clam shell, dredging machine (see Figure 3-5.2) or airlift system with deepwater disposal would discharge ditch spoil several metres off the lake bottom. It is anticipated that the spoil cloud would be carried to the northwest by the prevailing current along the lake bed. No upward movement of the spoil cloud is likely, as the cool waters would not normally rise in the water column, and the density of the spoil cloud would be greater than that of the surrounding waters due to the sediment particles it would contain. The suspended sediment would settle out at a rate dependent on the particle size of the spoil and the actual lake current. The turbidity resulting from offshore trenching would not likely have any effect on the primary productivity of Kluane Lake, as this productivity generally occurs in surface waters, to a depth of 10 to 15 m. Approximately 80 percent of trenching activity will be conducted at water depths in excess of 30 m. Trenching of shore approaches would increase the turbidity of nearshore areas, which would affect the primary productivity of surface waters in this zone. Such effects are not anticipated to differ greatly from those caused by increases in turbidity observed during storm events as a consequence of wave action on the shoreline, as well as the increased turbidity which results from discharge of the numerous high-energy ephemeral streams along the west shore of the lake during such storms or periods of high runoff.

An analysis of the potential for the interruption of fish migrations as a consequence of pipeline construction activities leads to the conclusion that any blockage of fish movement is unlikely. The linear distance of such a lake crossing is in the range of 6 km. The linear distance along which activities take place in the lake, which may approximate a blockage (e.g., pilings along shore approaches, lay barge) would not likely exceed 1 km, or 16 percent of the surface area. Therefore, fish passage would always be possible across the pipeline corridor, although migrating fish may, in some instances, have to circumvent the loci of activity.

In responding to the Panel's request regarding a major pipeline rupture in Kluane Lake and a discussion of the consequences on aquatic biota, a scenario has been prepared on this subject and is presented in Appendix V of this submission.

Summary

Anticipated impacts upon fish populations in the absence of mitigative efforts are, at worst case, minor reductions in the numbers of lake trout and lake whitefish in Kluane Lake. Such impacts are not considered to be realistic. The loss of spawning habitat is considered unlikely, but, if such a situation arose, the impact would be a minor, permanent reduction in the numbers of lake trout and lake whitefish in Kluane Lake.

Birds

Two active raptor nests have been identified within 2 km of Alternative #3, one of which is a Golden Eagle nest, while the other is a Bald Eagle nest. The consequences of unmitigated project activities are variable and highly speculative. The most severe impact, however unlikely, would be permanent abandonment of these nest sites, and failure of the raptors either to establish new nest locations during the year of impact or to nest during subsequent years, or both. An alternative scenario would be loss of production from the nest sites for the year of mainline construction only. Alternatively, the raptors may use the nest sites, but, due to a decreased ability of the adult birds to tend their eggs or young, the productivity may be reduced during the year of impact; or, the productivity of the nests may be maintained in spite of construction activities. A complete loss of production from the Bald Eagle nest would constitute a greater impact on the regional population than would loss of production from the Golden Eagle nest. Complete loss of production from the Golden Eagle nest is of greater likelihood due to its proximity to the right-of-way (0.7 km vs 2.0 km). Also meriting consideration are the facts that the Golden Eagle nest is likely to be out of sight of most if not all ground-based pipeline activity, as is the Bald Eagle nest, and the Alaska Highway lies between the Bald Eagle nest and the pipeline route.

No waterfowl concerns exist along Alternative #3, hence no unmitigated impacts are anticipated on waterfowl populations along this route.

Mammals

No Dall's sheep, moose or caribou ranges lie within 2 km of Alternative #3, hence no unmitigated impact is anticipated on these animals. Mammal concerns relate to the occasional presence of grizzly bears. Mortality of bears resulting directly from pipeline construction is highly unlikely, and the concern must focus on the possibility of bears becoming a nuisance and threat to construction personnel, and subsequently being destroyed. A review of Kluane National Park records of encounters with grizzly bears adjacent to the Alaska Highway and in back-country situations reveals eight encounters have been recorded since 1973. On average, this represents less than one encounter per year. However, this information should not be construed as census data. If the Project did not institute mitigatory measures in terms of waste management and personnel orientation, a situation may arise where several bears may have to be destroyed because of a nuisance problem or threat to personnel safety. Given their low density in Yukon, such a consequence could have short- to medium-term ramifications to the regional grizzly bear population in the Kluane Lake region.

6.4 PROJECT RESPONSE TO ENVIRONMENTAL ISSUES

Given the selection of Alternative #3, and a winter construction schedule for the section of the alignment from KP 216 to KP 220, and a summer construction schedule for the remainder of the alternative, the following Project responses are planned.

Fish

An analysis of fisheries concerns and conflicts is presented in Table 3-5.6. From this table, it is apparent that no concerns exist for any stream crossings along Alternative #3. There is an apparent conflict with incubating lake trout and lake whitefish eggs in regards to the crossings of Kluane Lake. However, due to the size of the crossing involved, rescheduling of construction activities is not a mitigative option available to the Project. If construction were to commence June 1 instead of May 1, the construction activities would then impinge on lake trout spawning activities during September. Due to the nature of construction activities in Kluane Lake, there are no conventional mitigative measures known to the Project which would reduce the anticipated silt loads created in Kluane Lake. However, several mitigative options are being pursued, including the release of sediments to the deepest part of the lake, where concern for the effects of turbidity and sedimentation are virtually nonexistent, if an airlift system is developed for offshore trenching. A further mitigative option which is being considered in conjunction with the airlift system is the removal of sediments by pipeline or barge for disposal at an alternative location. Removal of sediments from the lake would, however, pose serious disposal problems.

Birds

Two active raptor nests are located within 2 km of Alternative #3. Given that mainline and lake crossing activities will commence after the most sensitive portion of the nesting period, the concern for production from these nests is not sufficient to warrant relocation of the route, or rescheduling of mainline construction activities to avoid the remainder of the nesting period (June - July). However, any construction activities

TABLE 3-5.6

WATERCROSSINGS, FISHERIES DATA, SCHEDULED INSTREAM CONSTRUCTION PERIOD AND RESOLUTION OF FISHERIES/CONSTRUCTION CONFLICTS FOR ALTERNATIVE #3

Crossing Number	Approximate KP	Water-Crossing Name	Important Fish Present*	Use of Habitat By Fish**	Sensitive Habitat Use	Sensitive Period	Cumulative Sensitive Period	Construction Season For Section	Scheduled Mainline Construction Period	Conflict	Action (Schedule Change)	Remaining Conflict
98	218.5	Congdon Creek	None	None	None	N/A	N/A	Winter	Feb 1-Apr 15	No	None	No
99	219.9	Unnamed	None	None	None	N/A	N/A	Winter	Feb 1-Apr 15	No	None	No
100	220.2	Unnamed	None	None	None	N/A	N/A	Winter	Feb 1-Apr 15	No	None	No
101	220.9 - 226.5	Kluane Lake	Cu.S.	a	a	Sept 15-Oct 31	Sept 15-May 31	Summer	May 1-Aug 30	Yes	None	Yes
			A.G.	c,d,e,f	f	Freeze-up to Break-up						
			L.T.	b,c,d,e,f	b,f	Sept 21-May15						
			L.W.F.	b,d,e,f	b,f	Oct 15-May 31						
			Burbot	e								
102	237.1	Inlet Creek	None	None	None	N/A	N/A	Summer	June 1-Sept 30	No	None	No
103	244.2	Unnamed	None	None	None	N/A	N/A	Summer	June 1-Sept 30	No	None	No
104	247.8	Christmas Creek	None	None	None	N/A	N/A	Summer	June 1-Sept 30	No	None	No
105	251.3	Sulphur Creek	None	None	None	N/A	N/A	Summer	June 1-Sept 30	No	None	No

*Fish species abbreviations: Cu.S. = Chum Salmon; A.G. = Arctic grayling; L.T. = Lake Trout; L.W.F. = Lake Whitefish
**a) spawning migration; b) spawning (includes incubation through to emergence); c) nursery; d) rearing; e) summer; f) overwintering of important fish species

not included in the category of mainline construction, such as clearing, rock work and blasting, will be confined where possible to the mainline summer construction schedule for the overland component of Alternative #3 east of Kluane Lake, and for the Kluane Lake crossing. If such activities cannot fall within the mainline construction section, they will be scheduled to avoid the nesting period. These restrictions will apply in the vicinity of the Golden Eagle nest and the Bald Eagle nest near KP 259. This will limit disturbance to the birds to a minimum number of nesting seasons.

As no concern exists for staging waterfowl along Alternative #3, no Project response in this regard is required.

Mammals

The single concern regarding mammals during the construction of Alternative #3 relates to the presence of grizzly bears in this region of the pipeline. The concern centres on the attraction of bears to facilities such as construction camps, rather than the potential for mainline crews encountering these animals during construction activities. In order to reduce the attractiveness of facilities to bears, strict waste management programs will be carried out, which will specifically involve incineration of all garbage which may be attractive to bears. The Project will also maintain close liaison with Yukon Territorial Wildlife Branch and Parks Canada personnel with regard to effective nuisance bear handling procedures. Strict control will also be maintained over Project personnel from the standpoint of feeding bears, or habituating bears to Project facilities.

6.5 RESIDUAL ENVIRONMENTAL IMPACTS

This section of the submission presents impacts which may persist in light of the Project's proposed mitigation measures.

Fish

If the results of Project studies indicate that sedimentation of spawning areas during trenching and dredging in Kluane Lake is unavoidable, the lake crossing at Alternative #3 may result in loss of recruitment from one lake trout and one lake whitefish spawning area. The degree of concern and potential impacts have been discussed in Section 6.3 of this report. Briefly, a loss of recruitment from these two spawning areas for the year of construction would result in a loss of an age class from those spawning areas. It is anticipated that recruitment from other spawning areas in Kluane Lake would partially compensate for any such loss, and there would be no detectable difference in the standing crops of lake trout or lake whitefish in Kluane Lake as a consequence of the lake crossing. If inundation of spawning habitat results from trenching or dredging activities, and this habitat was lost permanently, the impact could be a minor, long-term reduction in the numbers of lake trout and lake whitefish in Kluane Lake. Neither of these potential impacts are considered to be realistic, particularly if deep-water disposal of trenching spoils is feasible.

Birds

Bearing in mind the Project response to the concern and the location of the two nests in relation to the route and pipeline activities, it is considered that the impact of pipeline construction will probably involve minor disturbance to the Golden Eagle nest, possibly resulting at worst in reduced productivity during the year of construction, and no impact on the Bald Eagle nest. If these predictions are proved correct, the effect on the regional population of Golden Eagle in southern Yukon Territory will be imperceptible.

Mammals

The first grizzly bear encounters with construction activities are not anticipated to result in any mortality, as bears will probably respond initially by avoiding the vicinity of construction. Given the waste management practices to be instituted at pipeline facilities, the orientation of Project personnel, and the implementation of effective bear handling procedures should a nuisance bear problem arise, the residual impacts on grizzly bear populations are anticipated to be minor as a consequence of constructing Alternative #3 in the Kluane Lake region. It is important to note that pipeline construction activities on the east side of Kluane Lake will encompass approximately a three-year period for Alternative #3. Therefore, the potential for problems arising from nuisance bears is limited in time compared to permanent non-pipeline facilities in other areas, such as landfill sites and campgrounds.

APPENDIX I

ROUTE LOCATION FACTORS

FACTORS RELATED TO ENGINEERING

Engineering factors which affect route selection involve the requirement for the development and utilization of either "typical" or "unique" design solutions. As a general rule, an engineering preference is given either to the route which has a requirement for the fewest "unique" or specialized designs, or makes greatest use of "typical" designs.

Watercrossings

Major

The presence of a "major watercrossing" on a route requires an intense design effort to produce a unique crossing design. A preference is given to major watercrossing locations that have the fewest design difficulties. The major watercrossing along Alternatives #1, #2 and #3 is the crossing of Kluane Lake; no major river crossings occur along those three alternatives. The only major watercrossing along Alternative #4 is that of the Slims River.

Other

For other watercrossings, the total number of crossings, requirement for non-typical design and general design difficulty are considered.

Geotechnical

Permafrost

The presence of permafrost is considered in view of the requirement for special designs to accommodate potential terrain instability problems, and/or pipeline integrity.

Slope Stability

Potentially unstable slopes are noted and considered for the probable requirement of slope stabilization designs.

Wetlands

The presence of wetland terrain along a route may require the utilization of weighting, and/or heavy wall pipe.

Right-of-Way Crossings

Roads

The crossing of a public road or highway requires the utilization of a road crossing design and the requirement for heavy wall pipe and possibly casing pipe.

Other

Other right-of-way crossings could include power lines, telephone lines, control weirs and canals, and other pipelines. Any such crossings may require the utilization of a special design.

FACTORS RELATED TO CONSTRUCTION

In general, construction factors which affect route assessment involve the ease or difficulty of construction required. As a rule, preference is given to the route which exhibits the fewest instances where difficult or specialized construction procedures are required.

Watercrossings

Major

Difficulty of construction is an important consideration in route assessment when major watercrossings are involved. The major watercrossing involved in Alternative #1, #2 and #3 is the Kluane Lake crossing. The only major watercrossing in Alternative #4 in the Slims River.

Other

For other watercrossings on the alternatives, the total number of crossings and degree of construction difficulty are considered.

Geotechnical

Permafrost

The presence of permafrost and/or thermokarst is considered for the possibility of construction difficulty as well as the probable requirement for special or unique design calling for special or unique construction procedures.

Slope Stability

The presence of naturally-unstable slopes requires the utilization of special slope stabilization techniques.

Wetlands

The presence of wetlands, particularly along the pipeline right-of-way, is considered in view of the effect on machinery and material movement, as well as the requirement for pipe weighting and/or rip-rapping. In addition, where the presence of wetland is extensive, consideration may have to be given to winter construction.

Rock

The presence of rock along the right-of-way indicates a requirement for blasting, with attendant increases in cost, time and bedding material requirements. This requirement includes an assessment for both rock grade and rock ditch work. In addition, where rock grade and rock ditch work is required close to public roads or areas, additional scheduling requirements are likely.

Right-of-Way Crossings

Roads

The crossing of a public road may involve the use of special construction techniques as well as the installation of heavy wall pipe and possibly casing pipe.

Other

Other right-of-way crossings may involve the use of special construction techniques.

Constructability

Access

The route alternatives are assessed for ease of access for construction purposes including an examination of the status of existing access and the possible requirement for expanded access.

Materials

The availability of construction materials, such as gravel, is assessed.

Grading

The requirement for right-of-way grading for construction purposes is assessed.

SOCIO-ECONOMIC FACTORS

Socio-economic factors which affect route selection all involve land-use issues. Consideration is given to existing, proposed and historic land-uses, with a general preference given to the routing with fewest land-use conflicts.

Land Use

Mineral Leases

Mineral leases indicate a mining interest in an area and must be noted as such for routing assessment.

Residential

Where a route is proximal to or crosses residential development land, consideration must be given to the requirement for control of project activities and special design.

Agricultural

Where land is used for agricultural purposes, topsoil conservation and compensation for right-of-way are likely requirements.

Commercial

Where a route is proximal to or crosses land used for commercial activity, compensation for right-of-way, and the use of heavy wall pipe may be required. In addition, consideration for control of construction activities may be required.

Recreational

Where a route is proximal to or crosses land designated for recreational use, consideration must be given to the recreational values to be encountered, and the effect of project activities on recreational land-use.

Water Supply

Where a route crosses land designated as a watershed area supplying drinking water or is proximal to control dams or weirs, consideration must be given to the effect of project activities on such locations.

Heritage

Where a route crosses or lies proximal to an area designated by legislation, or known to have heritage values, consideration must be given to the maintenance or salvage of the heritage resources encountered.

Native Lands

Where a route crosses or lies proximal to an area designated by appropriate government authority for use by native persons, consideration must be given to the importance and planned uses of that area.

Gravel Reserve

Where a route crosses a gravel reserve, consideration must be given to the status of that reserve, to any restrictions that the pipeline may place on future use of the reserve, and to any pipeline design requirements that will result from proposed future use of the reserve.

ENVIRONMENTAL FACTORS

Environmental factors which affect route selection involve consideration of both the physical and biological environment.

Fish, Birds and Mammals

The presence of habitat used by important species of fish, birds and mammals is considered in route assessment. Of prime concern for fish are spawning, overwintering and migrating activities; for birds, nesting, moulting and staging (migration) areas are of concern; for mammals, winter range, migration corridors, birthing areas, den sites, rutting areas and mineral licks are of concern.

OPERATIONAL FACTORS

Costs of system operation are generally not considered separately during the route refinement process as design and construction considerations outlined in the foregoing produce a system which can be operated efficiently. However, two operations factors which are considered during route selection are public safety and the possibility of third party damage. The two factors are interrelated. Routes are selected to maximize public safety and to reduce the possibility of third party damage.

APPENDIX II

REPORTS CONTAINING INFORMATION ON THE KLUANE LAKE REGION

Beak Consultants Limited. 1976.
Fall (1976) waterfowl migration: implications for the proposed Alaska Highway pipeline, southern Yukon Territory. Prepared for Foothills Pipe Lines (Yukon) Ltd. 21 pp. + app.

Beak Consultants Limited. 1977.
Spring waterfowl migration: Alaska Highway gas pipeline route, southern Yukon Territory. Prepared for Foothills Pipe Lines (Yukon) Ltd. 30 pp. + app.

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Fall (1977) waterfowl concentrations: proposed Alaska Highway gas pipeline route, southern Yukon Territory. Prepared for Foothills Pipe Lines (Yukon) Ltd. 25 pp. + app.

Beak Consultants Limited. 1977.
A spring inventory of fishery resources along the proposed Alaska Highway gas pipeline in Yukon Territory, 1977. Prepared for Foothills Pipe Lines (Yukon) Ltd. 54 pp. + app.

Beak Consultants Limited. 1977.
A summer inventory of the fishery resource along the proposed Alaska Highway pipeline in Yukon Territory, 1977. Prepared for Foothills Pipe Lines (Yukon) Ltd. 45 pp. + app.

Beak Consultants Limited. 1977.
A survey of fall spawning fish species in waterbodies within the influence of the proposed Alaska Highway pipeline in Yukon Territory, 1977. Prepared for Foothills Pipe Lines (Yukon) Ltd. 40 pp. + data sheets.

Beak Consultants Limited. 1977.
Winter ungulate surveys along the proposed Foothills Pipeline route (Yukon Territory). Prepared for Foothills Pipe Lines (Yukon) Ltd. 23 pp.

Beak Consultants Limited. 1978
Inventory studies of birds along the proposed Alaska Highway gas pipeline route, southern Yukon Territory, summer, 1977. Prepared for Foothills Pipe Lines (Yukon) Ltd.

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Raptor nest sites - summer 1977 - Alaska Highway gas pipeline route. Prepared for Foothills Pipe Lines (South Yukon) Ltd.

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Spring (1978) waterfowl migration: proposed Alaska Highway gas pipeline route, southern Yukon Territory. Prepared for Foothills Pipe Lines (South Yukon) Ltd. 40 pp.

Beak Consultants Limited. 1978.
A summary of fishery investigations in waterbodies within the influence of the proposed Alaska Highway pipeline in Yukon Territory, 1976-1977. Prepared for Foothills Pipe Lines (South Yukon) Ltd. 2 vols.

Beak Consultants Limited. 1978.
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Beak Consultants Limited. 1978.
Winter ungulate surveys (1978): Alaska Highway pipeline route. Prepared for Foothills Pipe Lines (Yukon) Ltd. 30 pp.

Beak Consultants Limited. 1979.
A catalogue of nest sites of golden eagles, bald eagles, ospreys and gyrfalcon along the Alaska Highway gas pipeline route, southern Yukon Territory. Prepared for Foothills Pipe Lines (South Yukon) Ltd.

Beak Consultants Limited. 1979.
Fishery resource investigations of waterbodies within the influence of the Alaska Highway gas pipeline alternative alignment, 1978. Volume I (report) Volume II (data sheets). Prepared for Foothills Pipe Lines (South Yukon) Ltd.

Beak Consultants Limited. 1979.
A summary of fisheries resource investigations in waterbodies within the influence of the Alaska Highway gas pipeline in Yukon Territory, 1978. Prepared for Foothills Pipe Lines (South Yukon) Ltd.

Beak Consultants Limited. 1979.
Winter ungulate surveys (1979): Alaska Highway pipeline route. Prepared for Foothills Pipe Lines (South Yukon) Ltd. 17 pp. + maps.

Beak Consultants Limited. 1980.
Summary of fisheries investigations of new crossing locations, Alaska Highway gas pipeline, Yukon Territory, 1979. Report prepared for Foothills Pipe Lines (Yukon) Ltd.

Blood, Donald A. & Associates. 1979.
1979 inventory of raptor nests within 3.5 km of Foothills gas pipeline preferred alignment in southern Yukon Territory by G.G. Anweiler, M.J. Chutter and D.A. Blood. Prepared for Foothills Pipe Lines (South Yukon) Ltd.

Environmental Management Associates. 1980.
Enumeration of spawning salmon in aquatic systems along the Alaska Highway gas pipeline in southern Yukon Territory, 1980. Prepared for Foothills Pipe Lines (South Yukon) Ltd., Calgary. 47 pp. + app.

Environmental Management Associates. 1980.
Fall fisheries investigations of Kluane Lake and north-shore creeks. Prepared for Foothills Pipe Lines (South Yukon) Ltd., Calgary. 29 pp + app.

Foothills Pipe Lines (South Yukon) Ltd. 1978.
Golden eagles, bald eagles, osprey and gyrfalcon active nest sites, identified within 3.2 km of the Alaska Highway pipeline Project in Yukon Territory. 8 maps.

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Environmental impact assessment for the Alaska Highway gas pipeline project. Report includes: Overview Summary and 29 annexes.

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Overview summary of the environmental impact statement for the Alaska Highway gas pipeline project.

Foothills Pipe Lines (South Yukon) Ltd. 1980.
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The Alaska Highway Gas Pipeline Project, Geotechnical Atlas.

Interdisciplinary Systems Ltd. 1977.
Initial environmental evaluation of the proposed Alaska Highway gas pipeline, Yukon Territory. Prepared for the Alaska Highway Pipeline Panel as sponsored by Foothills Pipe Lines (Yukon) Ltd. 667 pp.

Lifeways of Canada Ltd. 1978
Historical site reconnaissance (1977), Alaska Highway gas pipeline route, Yukon Territory. Prepared for Foothills Pipe Lines (Yukon) Ltd.

Lifeways of Canada Ltd. 1978
Historical site inventory forms, Alaska Highway pipeline route, Yukon Territory. Prepared for Foothills Pipe Lines (Yukon) Ltd.

Lifeways of Canada Ltd. 1978.
Historical site reconnaissance (1978), Alaska Highway gas pipeline route, Yukon Territory, Canada. Prepared for Foothills Pipe Lines (South Yukon) Ltd.

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Historical site inventory forms - 1978, Alaska Highway gas pipeline route, Yukon Territory. Prepared for Foothills Pipe Lines (South Yukon) Ltd.

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Newmark, N.M. 1978.
Seismic design criteria for Foothills Alaska Highway gas pipeline. Prepared for Foothills Pipe Lines (South Yukon) Ltd.

Northwest Hydraulic Consultants Ltd. 1978.
Hydrological assessment of the proposed crossing of Kluane Lake. Prepared for Foothills Pipe Lines (South Yukon) Ltd.

Vaartnou & Sons Enterprises Ltd. 1978.
Grasses, legumes and shrubs adjacent to the Alaska Highway of Yukon Territory. Prepared for Foothills Pipe Lines (South Yukon) Ltd. 47 pp.

Vaartnou & Sons Enterprises Ltd. 1978.
Pipeline revegetation research. Haines Junction test site. Prepared for Foothills Pipe Lines (South Yukon) Ltd.

Vaartnou & Sons Enterprises Ltd. 1979.
Pipeline revegetation research: Haines Junction test site progress report 1978. Prepared for Foothills Pipe Lines (South Yukon) Ltd.

Vaartnou & Sons Enterprises Ltd. 1979.
Pipeline revegetation research: Alaska Highway test sites, progress report, 1978. Prepared for Foothills Pipe Lines (South Yukon) Ltd.

Vaartnou & Sons Enterprises Ltd. 1980.
Pipeline revegetation research: Haines Junction test site progress report - 1979. Prepared for Foothills Pipe Lines (Yukon) Ltd., Calgary.

Windsor, J. 1978.
Survey of raptor nests in the south Yukon Territory (data sheets). Prepared for Yukon Territorial Government, Wildlife Branch. Funded by Foothills Pipe Lines (South Yukon) Ltd.

Windsor, J. 1979.
Survey of raptor nests in the southern Yukon Territory. Data sheets and maps 1:250,000. Prepared for Foothills Pipe Lines (South Yukon) Ltd.

Windsor, J. 1979.
Birds of prey in the southern Yukon Territory in relation to the Alaska Highway and proposed gas pipeline. Prepared for Foothills Pipe Lines (South Yukon) Ltd. February 1979. + maps.

APPENDIX III

HABITAT UTILIZATION BY IMPORTANT FISH SPECIES IN WATERBODIES CROSSED BY ALTERNATIVE #1

Approximate KP	Waterbody	Habitat Utilization[1] Chinook Salmon	Chum Salmon	Arctic Grayling	Lake Trout	Lake Whitefish	Dolly Varden	Northern Pike	Burbot	Reference[2]
218.6	Congdon Creek	Intermittent.								5
220.1-225.2	Kluane Lake[3]		M	N,R,S,OW	Sp,N,R S,OW	Sp,N,R, S,OW			S	2,7
227.3	unnamed creek	Intermittent.								8
239.2	Inlet Creek	Low potential - sampled, no important species collected.								4
246.3	unnamed creek	Bog-like.								4,5
249.9	Christmas Creek	Steep gradient, discontinuous.								4,5
253.4	Sulphur Creek	Intermittent.								6

[1]M = Migration Route; N = Nursery Area; R = Rearing Area; Sp = Spawning Area; S = Summer Habitat; OW = Overwintering Area.

[2]See end of Appendix III.

[3]Spawning areas in Kluane Lake are those identified within a corridor extending 5 km to the northeast of the alternative route.

HABITAT UTILIZATION BY IMPORTANT FISH SPECIES IN WATERBODIES CROSSED BY ALTERNATIVE #2

Approximate KP	Waterbody	Habitat Utilization[1] Chinook Salmon	Chum Salmon	Arctic Grayling	Lake Trout	Lake Whitefish	Dolly Varden	Northern Pike	Burbot	Reference[2]
218.6	Congdon Creek	Intermittent.								5
220.1-226.3	Kluane Lake[3]		M	N,R,S,OW	Sp,N,R S,OW	Sp,N,R, S,OW			S	2,7
236.9	Inlet Creek	Low potential - sampled, no important species collected.								4
244.0	unnamed creek	Bog-like.								4,5
247.6	Christmas Creek	Steep gradient, discontinuous.								4,5
251.1	Sulphur Creek	Intermittent.								6

[1]M = Migration Route; N = Nursery Area; R = Rearing Area; Sp = Spawning Area; S = Summer Habitat; OW = Overwintering Area.

[2]See end of Appendix III.

[3]Spawning areas in Kluane Lake are those identified within a corridor extending 5 km to the northeast of the alternative route.

HABITAT UTILIZATION BY IMPORTANT FISH SPECIES IN WATERBODIES CROSSED BY ALTERNATIVE #3

Approximate KP	Waterbody	Habitat Utilization[1] Chinook Salmon	Chum Salmon	Arctic Grayling	Lake Trout	Lake Whitefish	Dolly Varden	Northern Pike	Burbot	Reference[2]
218.5	Congdon Creek	Intermittent.								5
218.9	unnamed creek	Intermittent.								5,8
220.2	unnamed creek	Intermittent.								5,8
220.9-226.5	Kluane Lake[3]		M	N,R,S,OW	Sp,N,R S,OW	Sp,N,R, S,OW			S	2,7
237.1	Inlet Creek	Low potential - sampled, no important species collected.								4
244.2	unnamed creek	Bog-like.								4,5
247.8	Christmas Creek	Steep gradient, discontinuous.								4,5
251.3	Sulphur Creek	Intermittent.								6

[1]M = Migration Route; N = Nursery Area; R = Rearing Area; Sp = Spawning Area; S = Summer Habitat; OW = Overwintering Area.

[2]See end of Appendix III.

[3]Spawning areas in Kluane Lake are those identified within a corridor extending 5 km to the northeast of the alternative route.

HABITAT UTILIZATION BY IMPORTANT FISH SPECIES
IN WATERBODIES CROSSED BY ALTERNATIVE #4

Approximate KP	Waterbody	Habitat Utilization[1]: Chinook Salmon	Chum Salmon	Arctic Grayling	Lake Trout	Lake Whitefish	Dolly Varden	Northern Pike	Burbot	Reference[2]
218.8	Congdon Creek	Intermittent.								5
219.0	unnamed creek	Intermittent.								5,6
221.4	unnamed creek	Intermittent.								8
222.8	unnamed creek	Intermittent.								8
225.4	Williscroft Creek	Intermittent.								1,3
227.4	unnamed creek	Intermittent.								8
229.1	unnamed creek	Intermittent.								8
230.2	unnamed creek	Intermittent.								8
232.5	unnamed creek	Intermittent.								8
233.8	unnamed creek	Intermittent.								8
236.0	Slims River				R,S	S				2
238.8	unnamed creek	Intermittent.								8

Alternative #4 Continued

Approximate KP	Waterbody	Habitat Utilization[1]								Reference[2]
		Chinook Salmon	Chum Salmon	Arctic Grayling	Lake Trout	Lake Whitefish	Dolly Varden	Northern Pike	Burbot	
239.8	unnamed creek	Intermittent.								8
240.5	unnamed creek	Intermittent.								8
240.9	unnamed creek	Intermittent.								8
241.4	unnamed creek	Intermittent.								8
241.8	unnamed creek	Intermittent.								8
242.2	unnamed creek	Intermittent.								8
243.5	Topham Creek			S						3
245.1	unnamed creek	Intermittent.								8
245.8	unnamed creek	Intermittent.								8
245.9	unnamed creek	Intermittent.								8
246.3	unnamed creek	Intermittent.								8
246.5	unnamed creek	Intermittent.								8

Alternative #4 Continued

		Habitat Utilization[1]								
Approximate KP	Waterbody	Chinook Salmon	Chum Salmon	Arctic Grayling	Lake Trout	Lake Whitefish	Dolly Varden	Northern Pike	Burbot	Reference[2]
247.6	Silver Creek	Intermittent.								2,3
248.0	unnamed creek	Intermittent.								8
254.4	Boutellier Creek	Fair potential - sampled, no important species collected.								2
254.6	unnamed creek	Intermittent.								8
261.6	Sulphur Creek			N						2

[1]M = Migration Route; N = Nursery Area; R = Rearing Area; Sp = Spawning Area; S = Summer Habitat; OW = Overwintering Area.

[2]See end of Appendix III.

REFERENCES FOR APPENDIX III

1. Northern Natural Resource Services Ltd. 1977. Collection of fisheries information from waterbodies along the proposed Alaska Highway Gas Pipeline Route to July 15, 1977. Prepared for the Department of Fisheries and the Environment, Vancouver.

2. Beak Consultants Limited. 1978 A summary of fishery investigations in waterbodies within the influence of the proposed Alaska Highway pipeline in Yukon Territory, 1976-1977. Prepared for Foothills Pipe Lines (South Yukon) Ltd. 2 vols.

3. Thurber Consultants Ltd. 1978. Winter and summer fisheries surveys for the Shakwak Highway Improvement Project. Prepared for the Department of Public Works, Whitehorse.

4. Beak Consultants Limited. 1979. Fishery resource investigations of waterbodies within the influence of the Alaska Highway Gas Pipeline alternative alignments, 1978. Prepared for Foothills Pipe Lines (South Yukon) Ltd.

5. Beak Consultants Limited. 1979. Catalogue of fisheries resource information for waterbodies crossed by the preferred route of the proposed Alaska Highway Gas Pipeline in southern Yukon Territory. Prepared for Foothills Pipe Lines (Yukon) Ltd.

6. Beak Consultants Limited. 1980. Summary of fisheries investigations along the Alaska Highway Gas Pipeline, Yukon Territory. Prepared for Foothills Pipe Lines (Yukon) Ltd.

7. Environmental Management Associates. 1980.
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8. D.A. Fernet, Partner, Environmental Managment Associates, personal communication.

APPENDIX IV

BASIS FOR SCORES ASSIGNED TO IMPORTANCE OF CONCERN AND PROJECT RESPONSE

ALTERNATIVE #1

LOCATION FACTORS

Socio-economic (Land-use)

Mineral Leases   No Project Concerns or Responses Identified
Residential   No Project Concerns or Responses Identified
Agricultural   No Project Concerns or Responses Identified
Commercial   No Project Concerns or Responses Identified
Recreational
Importance of Concern - 3: Proximity to 1 developed campground.
Project Response - 2: Normal construction practices; possibly restrict hours of work.
Water Supply   No Project Concerns or Responses Identified
Heritage
Importance of Concern - 4: Region of native spiritual significance and archaeological sites on east side of Kluane Lake.
Project Response - 5: Routing should be avoided.
Native
Importance of Concern - 3: Proximity to native hunting area and hunting camp.
Project Response - 2: Normal construction practices; traverse area as quickly as possible.
Gravel Reserve
Importance of Concern - 1: Line encroaches on one gravel reserve, passes in close proximity to one reserve.
Project Response - 1: Provide for access to reserves; appropriate identification of pipeline and restrictions because of right-of-way.

Environmental

Fish
Habitat
Importance of Concern - 4: Two lake trout, three lake whitefish spawning areas within 5 km of lake crossing.
Project Response - 3: Possible measures to reduce the potential for sedimentation of spawning areas in Kluane Lake.
Birds
Raptors
Importance of Concern - 3: Two active Bald Eagle nests, one active Golden Eagle nest within 2 km of route.
Project Response - 2: Scheduling of pre- and post-mainline activities to avoid nesting period. Restrictions on Project-controlled aircraft overflights during nesting perod.

Waterfowl

Importance of Concern - 1: Minor staging area in Cultus Bay.

Project Response - 0: No Project response required.

Mammals

Dall's Sheep

Importance of Concern - 2: Dall's sheep range, but in excess of 2 km from pipeline route - potential problem for aircraft approaching from west side of lake.

Project Response - 1: Restrictions on aircraft overflights during sensitive periods in life history.

Other

Importance of Concern - 2: Presence of grizzly bears.

Project Response - 1: Strict waste management practices; control over Project personnel activities.

Operations

Public Safety

Importance of Concern - 2: Public contact with route on west side of Kluane Lake.

Project Response - 1: Meet standard codes and regulations.

Third Party Damage

Importance of Concern - 2: Public contact with route on west side of Kluane Lake.

Project Response - 1: Meet standard codes and regulations.

ALTERNATIVE #2

LOCATION FACTORS

Socio-economic (Land-use)

Mineral Leases — No Project Concerns or Responses Identified
Residential — No Project Concerns or Responses Identified
Agricultural — No Project Concerns or Responses Identified
Commercial — No Project Concerns or Responses Identified
Recreational
Importance of Concern - 3: Proximity to 1 developed campground.
Project Response - 2: Normal construction practices; possibly restrict hours of work.
Water Supply — No Project Concerns or Responses Identified
Heritage — No Project Concerns or Responses Identified
Native
Importance of Concern - 3: Proximity to hunting area and hunting camp.
Project Response - 2: Normal construction practices; traverse area as quickly as possible.
Gravel Reserve
Importance of Concern - 1: Line encroaches on one gravel reserve, passes in close proximity to one reserve.
Project Response - 1: Provide for access to reserves; appropriate identification of pipeline and restrictions because of right-of-way.

Environmental

Fish
Habitat
Importance of Concern - 3: One lake trout, three lake whitefish spawning areas within 5 km of lake crossing.
Project Response - 3: Possible measures to reduce the potential for sedimentation of spawning areas in Kluane Lake.
Birds
Raptors
Importance of Concern - 2: One active Bald Eagle nest; one active Golden Eagle nest within 2 km of route.
Project Response - 2: Scheduling of pre- and post-mainline activities to avoid nesting period. Restrictions on Project-controlled aircraft overflights during nesting period.
Waterfowl — No Project Concerns or Responses Identified
Mammals
Dall's sheep — No Project Concerns or Responses Identified
Other
Importance of Concern - 2: Presence of grizzly bears.
Project Response - 1: Strict waste management practices; control over Project personnel activities.

Operations

Public Safety

Importance of Concern - 2: Public contact with route on west side of Kluane Lake.

Project Response - 1: Meet standard codes and regulations.

Third Party Damage

Importance of Concern - 2: Public contact with route on west side of Kluane Lake.

Project Response - 1: Meet standard codes and regulations.

ALTERNATIVE #3

LOCATION FACTORS

Socio-economic (Land-use)

Mineral Leases — No Project Concerns or Responses Identified
Residential — No Project Concerns or Responses Identified
Agricultural — No Project Concerns or Responses Identified
Commercial — No Project Concerns or Responses Identified
Recreational
Importance of Concern - 3: Proximity to 1 developed campground.
Project Response - 2: Normal construction practices; possibly restrict hours of work.
Water Supply — No Project Concerns or Responses Identified
Heritage — No Project Concerns or Responses Identified
Native
Importance of Concern - 3: Proximity to hunting area and hunting camp.
Project Response - 2: Normal construction practices; traverse area as quickly as possible.
Gravel Reserve — No Project Concerns or Responses Identified

Environmental

Fish
Habitat
Importance of Concern - 3: One lake trout, one lake whitefish spawning area within 5 km of lake crossing.
Project Response - 3: Possible measures to reduce the potential for sedimentation of spawning areas in Kluane Lake.
Birds
Raptors
Importance of Concern - 2: One active Bald Eagle nest; one active Golden Eagle nest within 2 km of route.
Project Response - 2: Scheduling of pre- and post-mainline activities to avoid nesting period. Restrictions on Project-controlled aircraft overflights during nesting period.
Mammals
Dall's sheep — No Project Concerns or Responses Identified
Other
Importance of Concern - 2: Presence of grizzly bears.
Project Response - 1: Strict waste management practices; control over project personnel activities.

OPERATIONS

Public Safety
Importance of Concern - 2: Public contact with route on west side of Kluane Lake.
Project Response - 1: Meet standard codes and regulations.

Third Party Damage

<u>Importance of Concern</u> - 2: Public contact with route on west side of Kluane Lake.

<u>Project Response</u> - 1: Meet standard codes and regulations.

ALTERNATIVE #4

LOCATION FACTORS

Socio-economic (Land-use)

Mineral Leases — No Project Concerns or Responses Identified
Residential — No Project Concerns or Responses Identified
Agricultural — No Project Concerns or Responses Identified
Commercial — No Project Concerns or Responses Identified
Recreational

Importance of Concern - 4: Proximity to 1 campground reserve; line traverses more distance in Kluane National park and Kluane Game Reserve; construction activities along a greater portion of the western lake shore.

Project Response - 3: Normal construction practices; possibly restrict hours of work.

Water Supply — No Project Concerns or Responses Identified
Heritage

Importance of Concern - 3: Presence of cabin with historic significance in close proximity to line.

Project Response - 3: Implement suitable protection measures or relocate if damage to cabin is unavoidable.

Native — No Project Concerns or Responses Identified
Gravel Reserve

Importance of Concern - 1: Line encroaches on one gravel reserve, passes in close proximity to one reserve.

Project Response - 1: Provide for access to reserves; appropriate identification of pipeline and restrictions because of right-of-way.

Environmental

Fish

Habitat

Importance of Concern - 1: Three creeks crossed which support important fishes, no sensitive habitat present.

Project Response - 0: No Project response required.

Birds

Raptors

Importance of Concern - 2: Four active Golden Eagle nests and one active Bald Eagle nest within 2 km of route.

Project Response - 2: Scheduling of pre-mainline activities to avoid sensitive periods in the breeding cycle. Restrictions on Project-controlled aircraft overflights during nesting period.

Waterfowl

Importance of Concern - 2: Staging area in Slims River Valley and Slims River outlet at Kluane Lake.

Project Response - 1: Restriction of blasting and aircraft overflights during periods of staging use.

Mammals

Dall's sheep

Importance of Concern - 4: Presence of ranges on Sheep and Outpost mountains within 2 km of route; presence of lambing areas and mineral lick within 2 km of route.

Project Response - 3: Restrictions on timing of all activities associated with the project.

Other

Importance of Concern - 2: Presence of grizzly bears.

Project Response - 1: Strict waste management practices; control over project personnel activities.

Operations

Public Safety

Importance of Concern - 3: Public contact with route along length of southwest lake shore.

Project Response - 1: Meet standard codes and regulations.

Third Party Damage

Importance of Concern - 3: Public contact with route along length of southwest lake shore.

Project Response - 1: Meet standard codes and regulations.

APPENDIX V

ENVIRONMENTAL CONSEQUENCES OF A PIPELINE RUPTURE IN KLUANE LAKE

REVISED FINAL REPORT

MAJOR GAS RELEASE SCENARIO FOR A HYPOTHETICAL PIPELINE RUPTURE ON THE BOTTOM OF KLUANE LAKE UNDER WINTER ICE COVER

Prepared for

FOOTHILLS PIPE LINES (YUKON) LIMITED

Prepared by

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ESL ENVIRONMENTAL SCIENCES LIMITED

Vancouver, B.C.

February 1982

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MAJOR GAS RELEASE SCENARIO FOR A PIPELINE RUPTURE ON THE BOTTOM OF KLUANE LAKE UNDER WINTER ICE COVER

1.0 INTRODUCTION

The Alaska Highway gas pipeline proposed by Foothills Pipe Lines (Yukon) Limited will cross Kluane Lake near its southeast end, thus avoiding unstable terrain around the Slims River Delta (Figure 1). The design criteria proposed for the underwater crossing are conservative and state of the art. It is the belief of both Foothills and their consulting engineers (Brown and Root Limited and Monenco Pipeline Consultants Limited, 1981) that the lake crossing designed to their proposed guidelines will not experience a line failure during the life of the system. However, a remote possibility does exist that the pipeline could rupture and the Environmental Assessment Panel, as part of its clarification requirement outlined in a letter to Foothills Pipe Lines Ltd. dated December 18, 1980, has requested: "a scenario of a major break in the pipeline in Kluane Lake with a description of potential environmental impacts and mitigation measures".

The following report presents a hypothetical scenario for a major gas pipeline rupture at the bottom of Kluane Lake during winter ice cover. It was prepared for Foothills Pipe Lines (Yukon) Limited by ESL Environmental Sciences Limited. The report is divided into three parts. The first is entitled "Introduction" which describes the contents and methods used to prepare the scenario. The second is "Background Information" which acquaints the reader with relevant pipeline design criteria and layout for the underwater crossing; standard pipeline operating procedures; pertinent physical and biological features of Kluane Lake at the time of the hypothetical break; general properties of underwater shock waves that could be caused during a pipeline rupture; and, observations and findings concerning gas well blowouts in Arctic hydrocarbon development areas. The third is the hypothetical "Gas Pipeline Rupture Scenario" which describes the series of biophysical events which could occur when the gas pipeline ruptures in 30 m of water near the western shore of Kluane Lake; introduces a transient shock wave into the water column; releases large volumes of natural gas; uplifts large volumes of bottom sediment during venting; and, fractures the overlying ice cover on Kluane Lake.

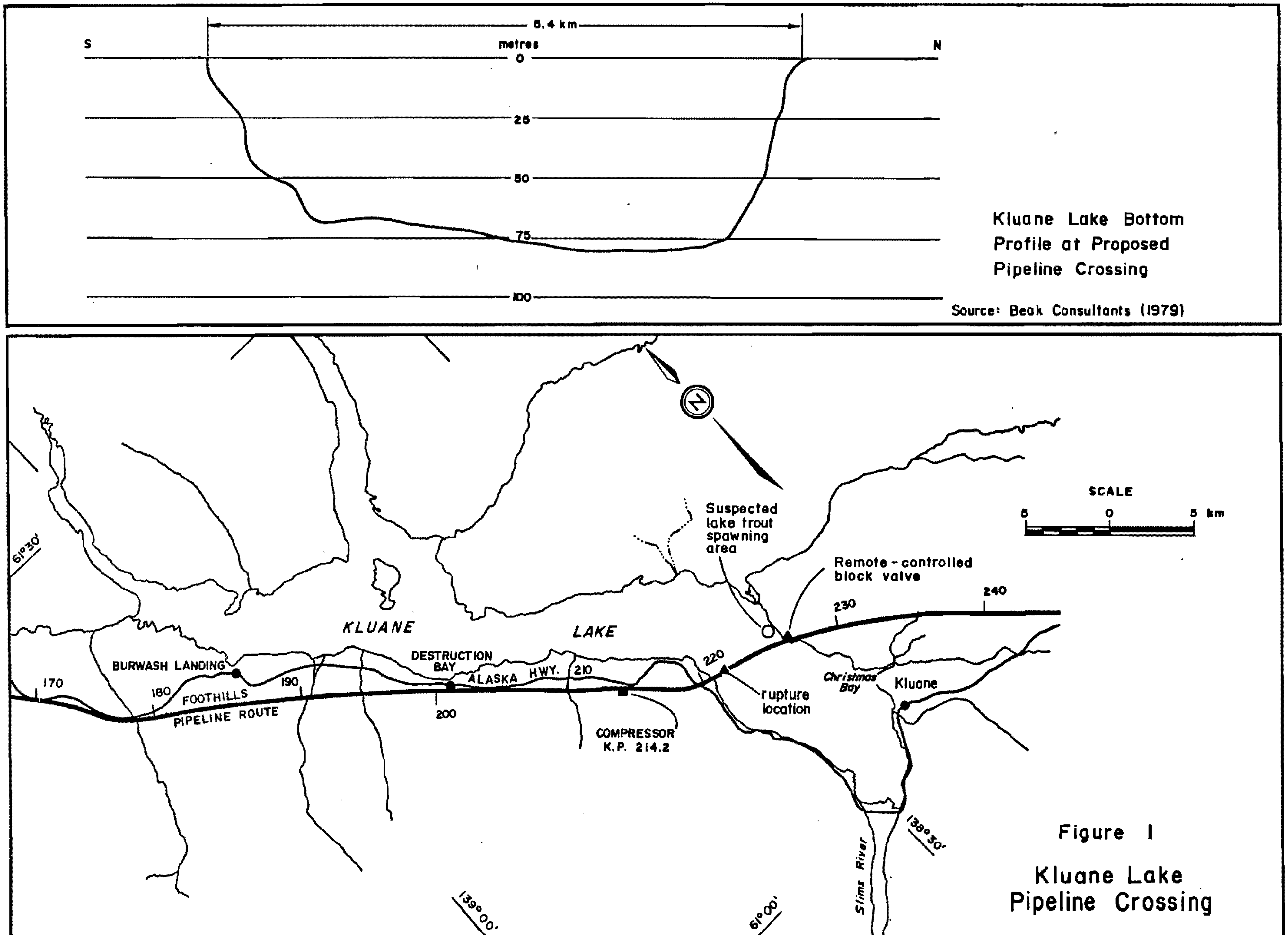


Figure 1

Kluane Lake Pipeline Crossing

Release of natural gas due to accidental pipeline rupture in Kluane Lake could have adverse effects on bioresources at all times of the year and under a wide range of conditions in Kluane Lake. However, for the purpose of this hypothetical scenario, mid-March was selected as the time of rupture to coincide with the period of expected maximum ice thickness. A substantial ice cover could contain some of the escaped natural gas under the ice for longer periods and would also amplify the propagation characteristics of any shock waves produced during the pipeline rupture (although, as the scenario will show, the large volume of escaping gas during a hypothetical pipeline rupture in Kluane Lake is expected to fracture the ice cover and vent most of the gas.).

Relevant information for this scenario was identified through both manual and key-word computer searches, as well as through discussions with Mssrs. R. Owens, E. Baddaloo, G. Thornton, C. Fooks and T. Ersoy [Foothills Pipe Lines (Yukon) Limited]; and Mr. D. Fernet [Environmental Management Associates (EMA)]. Dr. G.V. Parkinson of the Department of Mechanical Engineering, University of British Columbia provided background information and calculations concerning the propagation characteristics of the expected underwater shock wave from the rupture point. His report and calculations are presented in the Appendix. Dr. W. Duval of ESL Environmental Sciences Limited reviewed the report.

The data bases accessed during the computer search included:

Pollution Abstracts	1970 - Mar 1981
Enviroline	1971 - Jun 1981
ERIC	1966 - Jul 1981
BIOSIS	1969 - Jul 1981
GEOREF	1961 - Jul 1981
ELIAS	1976 - May 1981
AQUALINE	1974 - Apr 1981
SSIE Current Research	1978 - May 1981
NRIS	1976 - May 1980

Each base was searched for titles or abstracts containing the following pertinent key words: "gas", "methane", "ice", "water", "lake", "limnology", "Kluane Lake", "underwater shock", and "blast". Manual searches were also conducted for relevant publications and unpublished manuscripts dealing with the dynamics and biophysical consequences of potential gas well blowouts under ice cover. Several recent investigations by Topham (1981, 1975 and 1978), Hill (1978) and Milne (1980) were found to contain useful information concerning the theoretical dynamics of gas blowouts under land-fast Beaufort Sea ice, which is generally similar in thickness and probably in structure to that observed on Kluane Lake. These studies provided the most pertinent physical modelling information for the hypothetical gas pipeline rupture scenario in Kluane Lake.

2.0 BACKGROUND INFORMATION

2.1 Pipeline Design and Layout

From the lake shoreline out to depths of about 55 m the 1219 mm (48 in) diameter pipe will be placed in an excavated trench (maximum depth 18 m) to prevent potential slope movements from overstressing the line. After installation, this trench will be backfilled in nearshore areas to protect the pipe against wave effects and ice scour. The depth of pipeline trench near the hypothetical rupture point is expected to be approximately 5 m.

During the initial flow conditions of the pipeline the closest compressor station upstream of the Kluane Lake crossing will be Station 313, located approximately 7 km from the western lake entry point at KP 214.2, while the nearest downstream compressor station will be Station 315, approximately 151 km from the eastern lake exit point at KP 378.3. A remote controlled block valve will be located at KP 226.8 at the eastern lake exit point. A manually operated pipeline block valve will be located approximately 27 km downstream (southeast) from the eastern lake exit point at kilometre post (KP) 254.0.

Temperature and pressure sensors will be located at each compressor station along the pipeline to sense any significant variations in temperature or line pressure caused by leaks or pipe failures. The ambient pressure experienced by each of these remote sensors will be continuously transmitted to the Whitehorse Regional Center and to the Canadian Division Control Centre in Alberta via satellite. There will also be remotely monitored ground movement sensors located at the same compressor stations to detect the occurrence and location of seismic events.

2.2 Standard Pipeline Operating Conditions

The initial average gas throughput of the 1219 mm outside diameter pipeline in Kluane Lake will be about 57 x 10^6 m^3/day. The resultant line pressure of the pipe near Kluane Lake will be approximately 8000 kilopascals (kPa) or 79 atmospheres. To maintain this gas throughput, compressor stations are required every 150 to 200 km. At each compressor station there is a remotely operated block valve which when activated can reduce or prevent entirely gas flow through the station. If compressor maintenance should be required, the gas can be diverted to a separate by-pass loop either manually by on-site personnel or automatically through command signals transmitted via satellite from the control centres. The line gas could then by-pass the compressor facility completely.

2.3 The Physical Environment of Kluane Lake

The following sections present a summary of available information concerning the physical environment within the Kluane Lake region during March when the hypothetical pipeline rupture described in Section 3 is assumed to occur.

2.3.1 Geographic Setting

Kluane Lake is approximately 60 km long and 5 km wide. It is drained by the Kluane River which is a part of the Yukon River System. The principal inflowing watercourse is the Slims River. The northwest end of Kluane Lake is shallow (<15 m), but the southeast end near the proposed pipeline crossing is relatively deep with some areas being >100 m deep. The southwest lakeshore is closely paralleled by the Alaska Highway and the proposed route for the gas pipeline. Figure 1 shows a transect of the lake at the proposed 5.4 km pipeline crossing, where the average depth is about 55 m (Beak 1979).

2.3.2 Climate

The mean daily air temperature in March at Burwash Airstrip on Kluane Lake is about -13.0^{o}C. Daily maximums and minimums are typically -4.0^{o}C to -21^{o}C. Light snow flurries usually occur on about five occasions throughout the month, and account for an average March snowfall of about 10.2 cm. Annual snowfall at Burwash Airstrip has ranged from about 95 to 230 cm. By March, accumulated snowfall usually averages about 30 cm, but this is variable from year to year. In addition, drifting snow can cause accumulations near the lakeshore 10 to 50 cm deeper than this average.

Prevailing winds during March are almost equally from two octants, east to southeast (28 percent) and west to northwest (32 percent), and have an average speed of 9.3 km/h. The strongest winds (>20 km/h) are usually from the east to southeast and frequently cause visibility restrictions in the form of blowing snow. Calm conditions prevail about 36 percent of the month, with the longest calms usually being associated with cold spells.

2.3.3 Shoreline Morphology and Lake Sediments

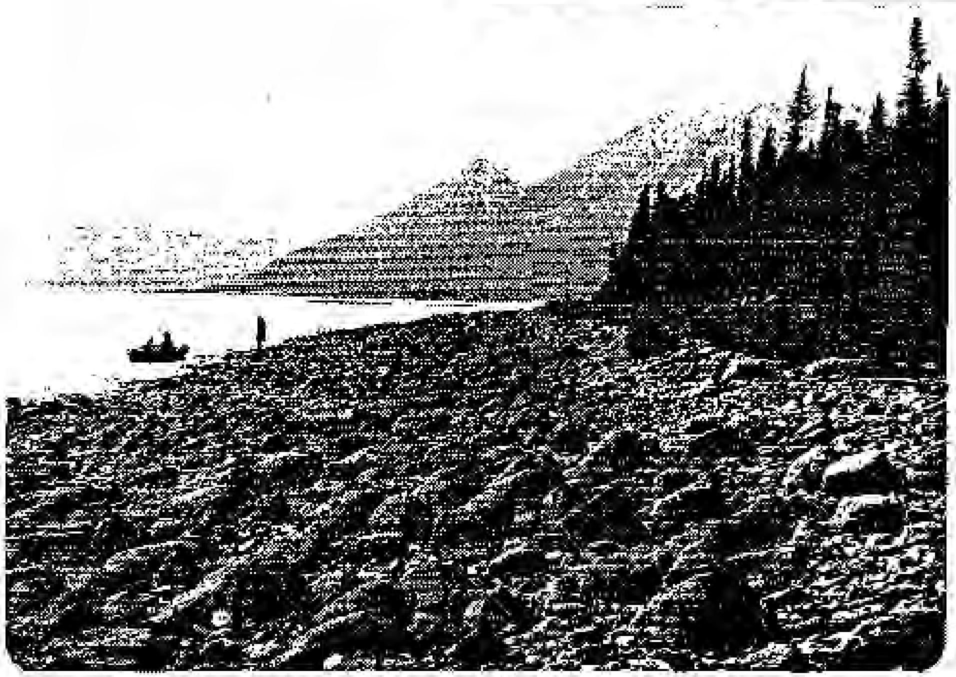
The shoreline along the west bank of Kluane Lake near the proposed gas pipeline crossing is relatively stable with no signs of long-term erosion. A boulder lag is present to a depth of about 3 m (Figure 2). Farther offshore, the bottom sediments range from clayey silts to sandy silts with traces of organics occurring out to about the 50 m isopleth (Klohn Leonoff Consultants Ltd. 1980). Maximum sand content is found at 32 m, where the substrate is comprised of 30 percent fine to medium sands. Silts and clays usually dominate the substrate composition in deeper portions of the lake (>50 m depth).

2.3.4 Limnology - Winter regime

In late March, Kluane Lake is completely ice-covered; ice thickness is variable, but averages about 1 m near the proposed gas pipeline crossing. According to a local resident and fishing guide at Destruction Bay, the ice thickness near the south end of Kluane Lake is usually less than in the northern end because of the influence of the Slims River. Complete freeze-up of the northern end of Kluane Lake is monitored near Burwash Landing and usually occurs in early to mid November. In the southern end of the lake near the Slims River inflow, freeze-up is usually delayed until early December. As a result, ice thickness near the pipeline crossing is probably less than that reported at Burwash. In early March 1980, Klohn Leonoff Consultants Ltd. measured an average ice thickness of about 1.0 m near the western end of the proposed pipeline crossing. In contrast, maximum ice thicknesses near Burwash have been reported up to almost 2 m (Environment Canada 1977). Strong winds during the freeze-up period on Kluane Lake can create a rough ice cover with thickened pressure ridges (D. Wooldridge, B.C. Hydro and Power Authority, pers. comm.).

Figure 2

Shoreline Characteristics of West Pipeline Approach to Kluane Lake



The water under the ice in winter is usually colourless and contains no sediment loading. By March, water temperatures are approximately $0^{o}C$ at the surface and then gradually increase to values near $3-4^{o}C$ at depths >50 m. The water level in Kluane Lake shows considerable annual variation, with maxima usually occurring in August and minima in late April - early May. The average annual variation is about 1.4 m, while the largest recorded annual variation at Burwash Landing is 2.4 m. In March, the lake level is usually about 1.3 m lower than the previous summer maximum and still decreasing (Environment Canada 1978).

Under-ice water movements are expected to be extremely low in March, and should average <1 cm/sec probably towards the Kluane River. The discharge of the Slims River under the ice in March will probably be nil (i.e. completely frozen) or certainly near its annual minimum. If there is under-ice movement of river water inflow to the lake it will probably be restricted to the near surface layer in Kluane Lake because the inflow water temperature would be near $0^{o}C$.

The potential trapping of natural gas in lake water under ice could cause localized reductions in dissolved oxygen levels due to methane-oxidizing bacteria or bubbles of gas stripping the oxygen from the water. Welch et al. (1978) concluded that a pipeline rupture under winter ice cover would probably not result in severe oxygen depletion in the lake if it was not naturally or artificially eutrophic. Elevated nutrient levels can enhance bacterial action.

There are no available winter nutrient data for Kluane Lake itself, although one water sample was analysed from the Kluane River near the outlet from Kluane Lake by Environment Canada (1975). Dissolved nitrate/nitrite was 0.040 mg/L, dissolved inorganic phosphate was 0.003 mg/L, dissolved orthophosphate was <0.002 mg/L and reactive silica was 4.3 mg/L on February 3, 1973. ESL Environmental Sciences Limited collected temperature and nutrient data in single vertical profiles near both shorelines of the pipeline crossing corridor on June 18, 1981 (Appendix 1). The Slims River is probably a contributing source of some nutrients since glacial runoff can contain elevated levels of nitrates and silica (Apollonio 1973).

2.4 Underwater Shock Waves

The general properties of shock waves in water with and without an ice cover have most recently been summarized by Hill (1978) for point source explosions. No published information could be found concerning the nature of shock waves produced during the rupture of a submerged high pressure gas line. Underwater shock waves are created naturally by earthquakes or may be artificially induced by explosives. They are compressional waves having an almost instantaneous rise time to a very high peak pressure (Pm) and, in the case of those arising from detonation of explosives, followed by a rapid decay to ambient or below ambient hydrostatic pressure. Peak pressures can be sufficiently high to cause significant changes in water density during the passage of the wave. In contrast the density changes caused by low intensity sound waves are infinitessimally small (Hill 1978).

The shock wave created by a point source detonation under water, propagates rapidly outward from its source. The initial speed of the shock wave through the water is greater than that of low intensity waves because of the pressure (density) changes it causes. Much of the shock wave's energy is quickly lost through the production of heat because of its high intensity. These losses combined with spherical divergence cause the peak pressure to drop rapidly as it propagates outward (Hill 1978). The result is that its speed also quickly diminishes with distance to that of low intensity sound (approx. 1500 m/s).

The rate of energy and pressure decrease with distance for a shock wave generated in a flat-bottomed lake covered with a thick rigid layer of ice has been discussed in Hill (1978). In the water region closest to the bottom source point (i.e. where range R is less than the water depth) the energy of the propagating wave per unit area of a hypothetical sphere of radius R should diminish as $1/R^2$ and the pressure will diminish as $1/R$. This is the spherical spreading law. In the region where the range R from the source point is several times the water depth, the energy per unit area will diminish as $1/R$, and the pressure will diminish as $1/\sqrt{R}$ (cylindrical spreading law).

The arrival of the shock wave at a water surface results in some loss of energy due to scattering. There is also a reflected negative pressure wave (Figure 3) since the pressure on the air side of the boundary is very small (Hill 1978).

The arrival of the incident shock wave at a lake bottom usually causes a reflected wave of positive pressure. Figure 4 shows the additive pressure characteristics when the reflected and the incident pressure waves are received at a point further downstream. Significant energy can be lost due to scattering of the incident wave if the lake bottom is very rough. Complex combinations of reflected and refracted wave patterns can also develop if the lake bottom is either layered with materials of different acoustic properties (eg. mud, sand and rock) or has different levels of compaction. Muddy bottoms which contain significant concentrations of gas bubbles can also theoretically produce a reflected wave of negative pressure (Hill 1978).

The reflection of pressure waves from an ice/water boundary are positive, governed by many of the same considerations as bottom reflections. The bottom of a growing ice cover usually consists of a thin layer (1 - 2 cm) of ice crystals projecting vertically into the lake water which has acoustic properties intermediate between lake water and ice. This layer makes an excellent couple between the two media and can allow a significant fraction of incident energy to pass through the boundary into the ice. The energy is usually dissipated by deforming and cracking the ice cover or in the production of ice flexural waves (Hill 1978).

2.5 Under-ice Gas Blowouts

The physical dynamics of gas blowouts with and without gas hydrate formation have been investigated by Topham (1981, 1978, 1975) and summarized by Milne (1980). Depths and pressures much greater than those found in Kluane Lake are required to produce hydrates (Topham 1978). Figure 5 shows a

Figure 3

Reflected Shock Wave from a Water Surface
(from Hill 1978)

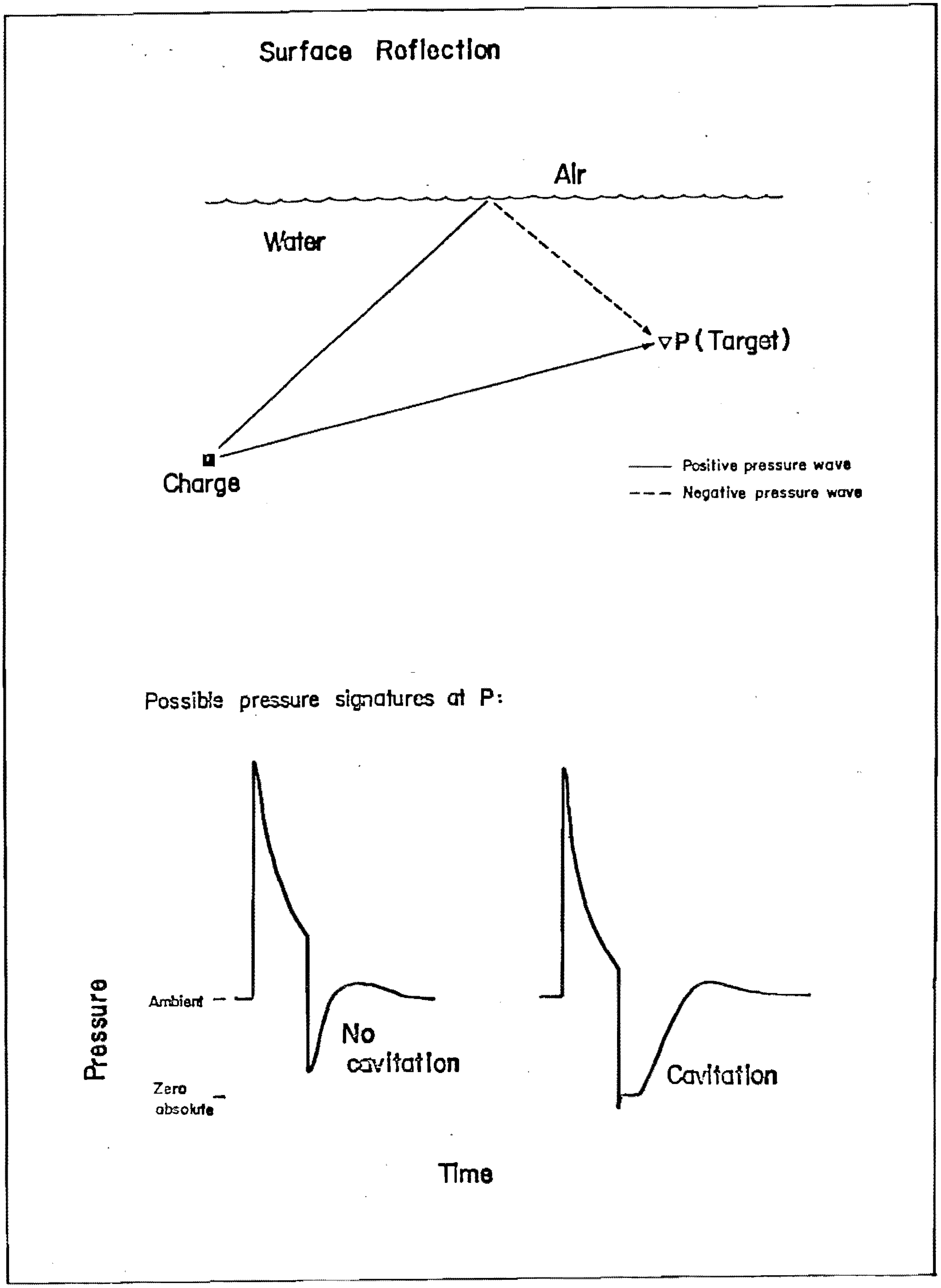


Figure 4

Reflected Shock Wave From a Lake Bottom
(from Hill 1978)

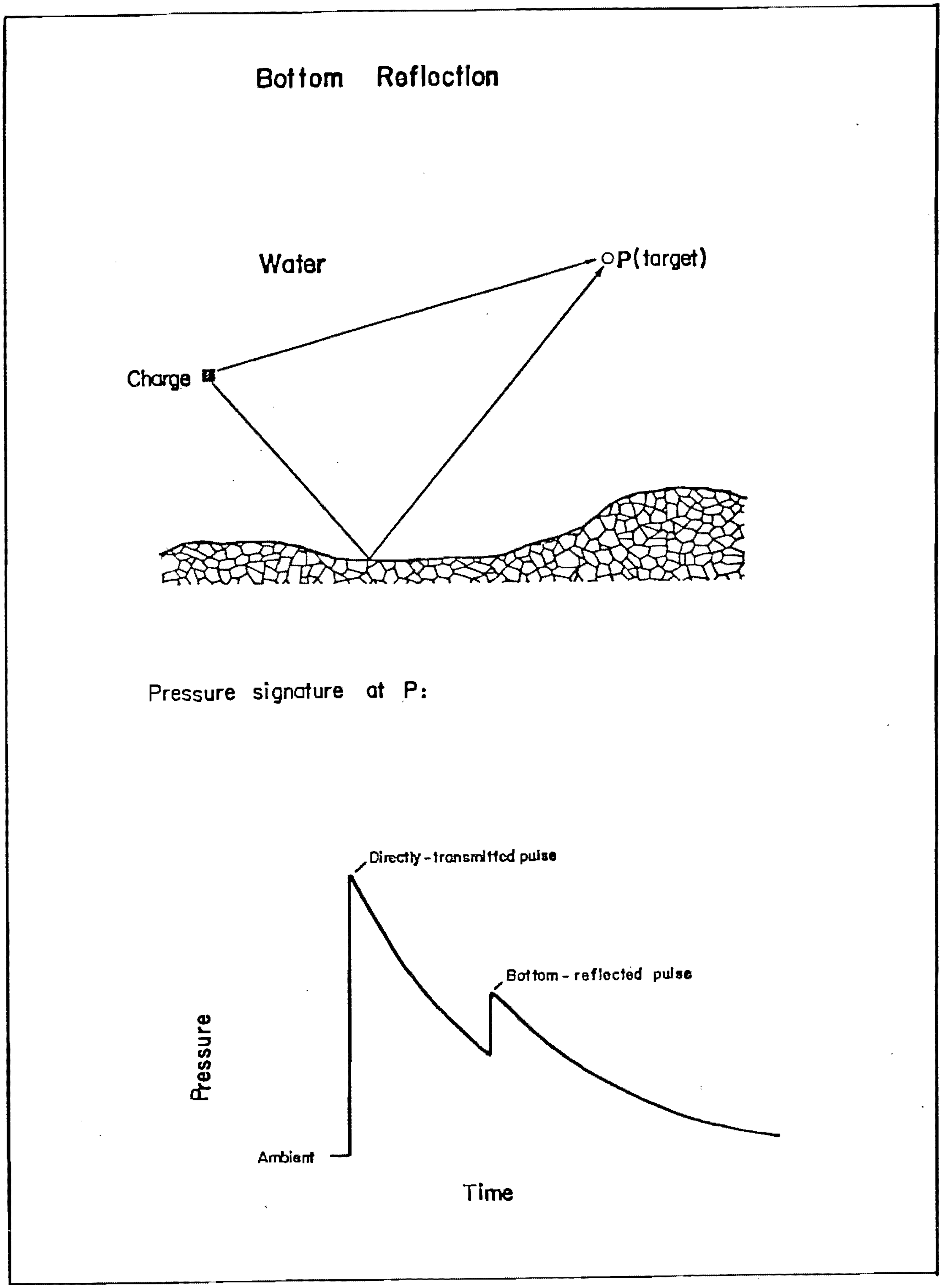
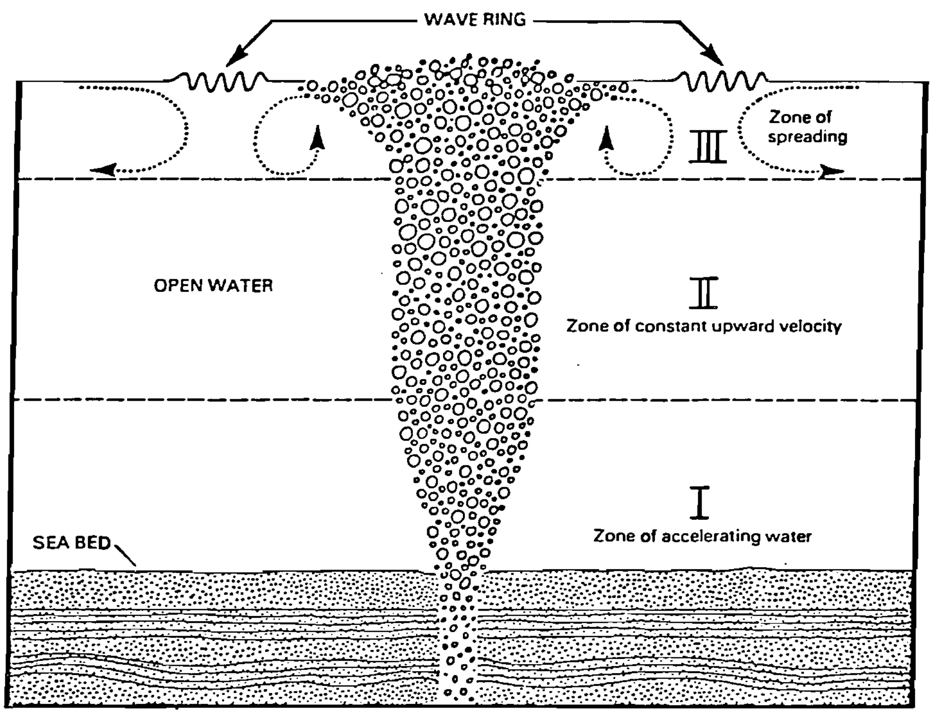


Figure 5

Circulation in seabottom blowout in open water
(from Milne 1980)



typical model of a gas blowout in open water discussed by Milne (1980). In Zone I near the sea floor, the released gas spreads out and breaks into ever-proliferating bubbles whose buoyancy accelerates the upward flow of water. In Zone II, water and gas bubbles move up at a nearly constant speed of about 0.6 metres per second. The volume of upward moving water usually far exceeds the volume of gas so that cooling effects of the gas are localized.

In Zone III near the surface, currents flow radially out from the rising bubble plume, and most of the gas escapes to the atmosphere. Strong currents exist out to a certain radius where the water flow then curls downward carrying small gas bubbles with it. These bubbles will descend to a depth of a few metres in a large, wobbling, doughnut-shaped flow pattern. Seen from above, the surface movement is one of expanding vortex rings that can be likened to smoke rings successively hitting a ceiling and then expanding outwards. These rings stop expanding at a radius where the flow of water at the surface suddenly plunges downward. Here a "wave ring" is observed and serves as a sink for the collection of floating debris. If the gas is released 60 m below the surface, the wave ring will have a radius of between 35 and 50 m and the expanding vortex rings will extend down to a depth of about 10 m. Topham (1978) suggests the wave ring is potentially a function of gas flow rate and water depth and would be the same under ice (Appendix 2).

The effects of a buoyant gas layer trapped under the first year ice have been the subject of considerable investigation as a result of recent oil and gas exploration programs in Canada's Arctic (Topham 1977; Malcolm and Cammaert 1981). Milne (1980) described the buoyant effects of a gas layer wedged under newly formed nearshore land-fast ice, which is probably comparable to the ice cover of Kluane Lake. As trapped gas accumulates in the irregularities on the lower surface of land-fast ice, it can eventually provide enough buoyant force to completely split the ice layer rather than to cause extensive small-scale cracking. The diameter of the gas area required to fracture the ice depends on the amount of gas trapped under the ice, and hence on the size of the under-ice irregularities as well as the delivery rate and horizontal rate of spreading of the gas. For 1 m thick land-fast ice, Milne (1980) suggests that the vertical variation in the under-ice surface is typically about 20 cm. This could retain a trapped gas layer about 10 cm deep which, if spread to a diameter of 70 m, would have enough buoyant force (385 m^3 of gas) to rupture the 1 m thick ice by upward bending. Malcolm and Cammaert (1981) suggest that an ice sheet 2 m thick would fracture at the bubble centre when the trapped gas bubble is 15 cm thick and 100 m in radius.

2.6 Biological Environment of Kluane Lake

The following sub-sections summarize the available information on the aquatic and terrestrial biota which inhabit Kluane Lake and its shoreline.

2.6.1 Fish

Five species of fish in Kluane Lake are commercially or recreationally important: Arctic grayling, lake trout, lake whitefish, round whitefish and chum salmon. Grayling are prized as gamefish, while lake trout are sought in both recreational and native/commercial fisheries. The two whitefish species also comprise a portion of the commercial catch. Chum salmon apparently do not enter Kluane Lake in large numbers, and only represent a minor fraction of the total catch. There are five other fish species reported in Kluane Lake: longnose sucker, northern pike, burbot, lake chub, and slimy sculpin. None of these latter species is economically important, but probably provide occasional forage for lake trout.

2.6.1.1 Life History Summaries

Lake Trout (Salvelinus namaycush) - Spawning in Kluane Lake occurs between mid-September and mid-October, with this species preferring gravel shoals approximately 5-10 m deep (Fernet and MacHutchon 1980). There is one suspected lake trout spawning area (Figure 1), approximately 2 km north of the pipeline route on the eastern shore [D. Fernet, Environmental Management Associates (EMA), pers. comm.]. Adult trout tend to enter shallower water in fall for spawning, and they remain in these areas until warming conditions in early summer cause adults to eventually seek deeper water. Deposited eggs remain on the lake bed for many weeks and, based on available water temperature and spawning time information, the eggs are thought to hatch during March (D. Fernet, EMA, pers. comm.). Young fish probably spend their first year in shallow waters around the lake margin.

Lake Whitefish (*Coregonus clupeaformis*) - Kluane Lake populations begin spawning around mid-October and probably end in mid-November (Fernet and MacHutchon 1980). Eggs are deposited randomly over a variety of substrates, but usually in less than 8 m of water (Scott and Crossman 1973). The nearest suspected whitefish spawning area to the pipeline is approximately 6 km north of the western pipeline entry point, while another suspected site is located about 3.5 km north of the eastern pipeline exit point [Foothills Pipe Lines (Yukon) Ltd. unpubl. map of Kluane Lake, Sept. 1980]. Hatching takes place in late winter or early spring, and young fish generally congregate in shallow waters during the summer.

Round Whitefish (*Prosopium cylindraceum*) - This species apparently spawns in Kluane Lake from late October through November, but spawning habitats have not been delineated in the pipeline vicinity. Eggs are generally broadcast over gravel in lake shallows, and hatch between April and May. Both fry and adults tend to remain in shallow waters.

Chum Salmon (*Oncorhynchus keta*) - Small numbers of chum salmon may spawn near the mouths of Christmas Creek and the Slims River, although this has not been substantiated (D. Fernet, EMA, pers. comm.). Chum salmon generally prefer to spawn in rivers.

Arctic Grayling (Thymallus arcticus) - Grayling typically spawn in small tributary creeks shortly after breakup in the spring. They return to the lake shallows from summer through winter if these spawning creeks are ephemeral.

Other Species - Four of the five remaining species present in Kluane Lake - longnose sucker (Catostomus catostomus), northern pike (Esox lucius), lake chub (Couesius plumbeus) and slimy sculpin (Cottus cognatus) - are spring spawners which, like the grayling, prefer to spawn in small tributary streams. They spend most of their lake residence time in shallow waters. However, burbot (Lota lota) prefer deep water habitats of lakes except in late winter when they spawn beneath the ice in lake shallows less than 2 m deep (Scott and Crossman 1973).

2.6.1.2 Winter Distribution of Fish

Hydroacoustic studies conducted in Kluane Lake during November surveys (Beak Consultants Ltd. 1979) indicate that fish densities were roughly 4 times higher at depths between 0-15 m along the western shore (x = 3.30 targets/10^4 m^3) than along the eastern shore (x = 0.82/10^4 m^3). Also the numbers of fish were much higher in shallow areas (depths less than 15 m) than in deeper water. For example, the single hydroacoustic transect across the lake in November revealed no acoustic targets in areas near the 30 m depth. Gillnet catches in November indicate that the most abundant species were lake whitefish and lake trout. It is likely that these two species were congregated at preferred spawning areas during this period. As the winter progresses, either the majority of fish could disperse after spawning (Scott and Crossman 1973), or they may congregate at certain preferred overwintering areas, such as near the mouths of tributaries and the lake outlet (D. Fernet, EMA, pers. comm.).

2.6.2 Other Aquatic Organisms

There is apparently no published information on other aquatic organisms in Kluane Lake, although some incidental observations were made during recent fisheries investigations by EMA in Kluane Lake (D. Fernet, EMA, pers. comm.). The lake appears devoid of aquatic vegetation around most of the shoreline, and this may be due to the frequent wind sessions and wave action during the open water season, as well as the generally low nutrient levels in this oligotrophic lake. The high water clarity in June suggests a relatively low phytoplanktonic standing crop which may continue throughout the growing season. Knowledge of the benthic community in Kluane Lake is fragmentary, and restricted to observations of freshwater gastropods and mysids in fish stomachs (EMA 1980 Data Files).

2.6.3 Terrestrial Animals

The distribution and abundance of birds and mammals on the surface of Kluane Lake in winter is not documented. However, most waterfowl will not have arrived in the area in March when the hypothetical pipeline rupture is assumed to occur. Even if raptors or upland birds were present, there would be negligible impact on these species from an underice pipeline rupture. Mammals do not typically overwinter along the shoreline habitats of Kluane Lake, although there are probably occasions when ungulates, furbearers or canids travel across the ice.

2.7 Biological Effects of Methane, Underwater Shock Waves and Sedimentation

2.7.1 Effects of Methane

Methane is the dominant component (85.34 percent) of the natural gas which will be transported by the Alaska Highway Gas Pipeline (Foothills Pipe Lines 1979b). The remainder of the natural gas is comprised of 8.09 percent ethane, 4.35 percent propane and 2.22 percent miscellaneous gases. Methane, also called marsh gas, is a common anaerobic decomposition by-product found in many lakes having extensive accumulations of submerged vegetation. There are records of bottom water samples from some lakes containing almost 40 ml of methane per litre of water (Welch 1952). However, bottom sediments in oligotrophic waters such as Kluane Lake do not usually receive much plant detritus. As a result, natural methane generation is expected to be low.

In nature, when methane and other decomposition gases are continuously released from bottom deposits, they tend to reduce the dissolved oxygen content of the water column. A gas such as oxygen may be entirely removed ("stripped") from solution by bubbling another gas through the water in which it is dissolved. This is due to the fact that a gas will leave solution and pass into a physical space (e.g. a bubble) until the concentration inside the space reaches the concentration in solution. Bubbles of methane passing through the water produce a relatively large surface area for transport of dissolved oxygen out of solution. Beak Consultants Ltd. (1977) examined the acute toxic effects of natural gas on rainbow trout (Salmo gairdneri) and found no mortality when air was bubbled into the test water with the natural gas. However, without the air input, dissolved oxygen levels dropped from 11.8 mg/L to 1.4 mg/L in the test containers within 60 min, and this was lethal to the rainbow trout.

The oxidation of methane by bacteria is limited to very few species, whereas the ability to oxidize ethane, propane, butane and other hydrocarbons is widespread among eubacteria. Methanomonas is a strict aerobe which uses methane as its sole source of carbon and energy. Welch et al. (1979) predicted that gas pipeline leaks would not result in severe oxygen depletion beneath the ice cover of oligotrophic lakes although methane-oxidizing bacteria were active in the sediments all winter. However, methane oxidation was the most important contribution to total lake anoxia under ice cover of an artificially eutrophic lake (Rudd and Hamilton 1978). It seems unlikely, however, that the quantity of natural gas which would escape from a major pipeline rupture could be substantially reduced by the metabolic capabilities of a winter population of Methanomonas, even if this bacterium was present in Kluane Lake.

2.7.2 Effects of Underwater Shock Waves

A number of factors influence the intensity of an initial underwater shock wave and the subsequent pressure waves on fish. These include (1) the size and type of shock wave source, (2) the character of the bottom, (3) the presence and thickness of any ice cover, (4) water depth, (5) the depth of source point, (6) the distance of fish from the shock wave source, and (7) orientation of the fish body relative to the direction of shock wave travel. Shock wave reflections and absorption at an interface between two different media within an animal (e.g. bone and muscle, muscle and air-filled cavities) may cause tissue damage and death. If the peak pressure and impulse (rate of change of pressure) of the shock wave are high and the density difference between the tissues is large enough, the difference in imparted particle velocities on either side of the interface may become so great, that the tissue surrounding the interface is violently torn apart. Haemorrhaging will also occur if capillaries or blood vessels are present (Hill 1978).

Hill (1978) identifies the four primary characteristics of shock waves which are documented to have caused damage to living orgnisms: (1) the peak pressure; (2) the impulse; (3) the duration of the overpressure; and (4) the energy flux density of the shock wave. The relative importance of these variables depends on the properties of the tissues involved (Clemedson and Criborn 1955, cited in Hill 1978). For example, if the natural period of oscillation of a tissue is short compared to the duration of the overpressure, then peak pressure will be the primary cause of damage; if, on the other hand, the tissue's natural period is long relative to shock wave duration, then damage will be related to the impulse (Hill 1978). While species and weight of fish also affect the level of damage due to shock waves, most authors indicate that the gas bladder is the primary damage site in fish (Hill 1978). Shock pressures between 40-70 psi (276-483 kPa) have been reported as lethal to fish with swimbladders (Hubbs and Rechnitzer 1952; Falk and Lawrence 1973). Teleki and Chamberlain (1978) reported a very low lethal range of overpressures from 30 to 150 kPa (5 to 22 psi).

The susceptibility of fish eggs to underwater shocks depends on their developmental stage. Post et al. (1973) reported that the sensitive stage of most salmonid eggs is generally during the first half of the incubation time. However, they found no significant difference between survival rates of controls vs. eggs exposed to peak accelerations of 1, 2, 5 and 10 g's during this period. Physical shock is commonly used in salmonid hatcheries after 18 days to agitate newly-fertilized eggs; this procedure ruptures the yolk membrane of the infertile eggs, turning them white for identification and subsequent removal. Viable salmonid eggs are particularly tender to shock between about 9 and 16 days at $10^{o}C$ (Leitritz and Lewis 1980). Kostyuchenko (1973, cited in Hill 1978) reported reduced survival rates of eggs and larvae of four marine fish species following detonation of small (50 g) charges of TNT, although the experimental distances were not specified. Damage to the eggs included deformation of the membrane, curling and displacement of the embryo, and impaired integrity of the vitelline membrane.

2.7.3 Effects of Sedimentation

The large predominance of silts and sands in the substrate of Kluane Lake represent a potential source of environmental concern with respect to uplifted sediments and adjacent lake trout spawning areas. The effects of sedimentation on fish eggs are reasonably well documented. The degree of impact of sediments is influenced by several factors including fish species, developmental stage of the eggs, depth of egg burial, sediment particle sizes, depth of sediment deposition, and the amount of interstitial water flow. Since lake trout, lake whitefish and round whitefish do not dig redds, but deposit their eggs directly on the bottom substrate or in crevices, the spawn of these species are highly susceptible to the effects of sedimentation.

Increased suspended sediment levels generally have fewer and less pronounced adverse effects on fry, juveniles or adult fish than on eggs. Although both lethal and sublethal effects of sediments on young and adult fish have been observed. Noggle (1978) reported lethal suspended sediment ranges for coho and chinook salmon (*Oncorhynchus kisutch* and *O. tshawytscha*) between 1200 and 35,000 mg/l in 96 hr lethal bioassay tests. However, under natural conditions, most individuals will exhibit avoidance reactions when sediment concentrations reach an irritation threshold. In certain situations, high particulate levels in the water column may cause physical damage to the gills and could induce bacterial or fungal gill diseases which ultimately kill the affected fish.

The effects of sedimentation on freshwater benthos are better documented in streams than lakes. The benthic fauna of Kluane Lake is probably well-adapted to the fine-grained sediment habitats naturally found there, although eggs or sensitive stages which are unable to cope with sediment loads at unusual seasons may be smothered by localized depositions.

3.0 HYPOTHETICAL GAS PIPELINE RUPTURE SCENARIO

On the evening of March 20 the pipeline ruptures near the western pipeline entry point to Kluane Lake and one 12.2 m section of pipe is displaced from the trench due to forces generated by the escaping gas. The location of the rupture is at approximately KP 222 in 30 m of water at a point about 500 m from the western pipeline entry point to Kluane Lake (Figure 1). The pipeline had been laid in a 5 m deep trench and back-covered at this point.

The rupture of the pipe generates rarefaction waves inside the pipe which move upstream and downstream from the rupture point at approximately the speed of sound in methane at 0°C (430 m/sec). As a result the first depressurization wave arrives at Compressor Station 313 (KP 214.2) approximately 18 seconds after the rupture and at Compressor Station 315 (KP 378.3) approximately 6 minutes after the rupture. The dropping pressure at Compressor Station 313 is initially compensated for by automatic increases in the compressor speed to maintain line pressure. However, with the continued drop in pressure it soon becomes apparent that a major rupture has occurred somewhere downstream. The time required to block gas flow to the rupture point will be short, likely in the order of 3 to 7 minutes. However, for the purposes of this scenario, a conservative period of 15 minutes is assumed. At 15 minutes from the time of rupture, gas flow at Compressor Station 313 (KP 214.2) and at the remote-controlled block valve at the eastern pipeline exit point from Kluane Lake (KP 226.8) is blocked.

During the first 15 minutes following the rupture, approximately 10×10^6 m^3 of gas escapes into the lake. This total includes gas from upstream sections of pipe between the rupture and Station 313 as well as from downstream sections between the rupture point and Station 315. Assumptions made in reaching the above total loss are that upstream sections lose volumes equalling throughput from Station 313 plus 10 percent as well as gas in the line at the time of the rupture (linepack) and that downstream sections of pipe lose one half of linepack.

The initial force generated by the gas venting from the two broken pipe ends causes considerable lateral migration of both pipe ends. The sediments (primarily silts, sands, and clays) are uplifted at the rupture point out to a distance of 5 m on either side of the pipe ends. Approximately 600 m^3 of sediments are uplifted from both pipe ends as a result of these forces. Soon the pipe ends lift entirely out of the trench releasing gas in an arc over a radius of about 50 m from both ends.

An underwater shock wave is generated by the initial high pressure venting of natural gas (initial peak pressure (Pm) ≅ 8162 kp) to the water at a depth of 30 m where the ambient pressure is about 400 kp (Appendix 4). The most likely form of this underwater shock wave is depicted in Figure 6. The shock wave is extremely thin, and the wavefront is effectively a discontinuity surface across which the pressure rises abruptly by Pm. In the first 30 m before any reflections from the ice surface, the shock wave propagates through the water from the rupture point according to the laws of spherical spreading and thereafter it is assumed the spreading is more cylindrical in nature (Appendix 4). The calculated attenuation in peak pressure (Pm) with range (R) is shown in Table 1.

The time decay of the pressure rise at a fixed point following the passage of the wavefront is approximately exponential for the first few microseconds. The initial rate of pressure drop is given by:

$$\frac{dp}{dt}\,t_1 = -120\ Pm(R)\ (kPa/ms).$$

Figure 6 Probable shape of shock wave as it passes a fixed point near the pipeline rupture point

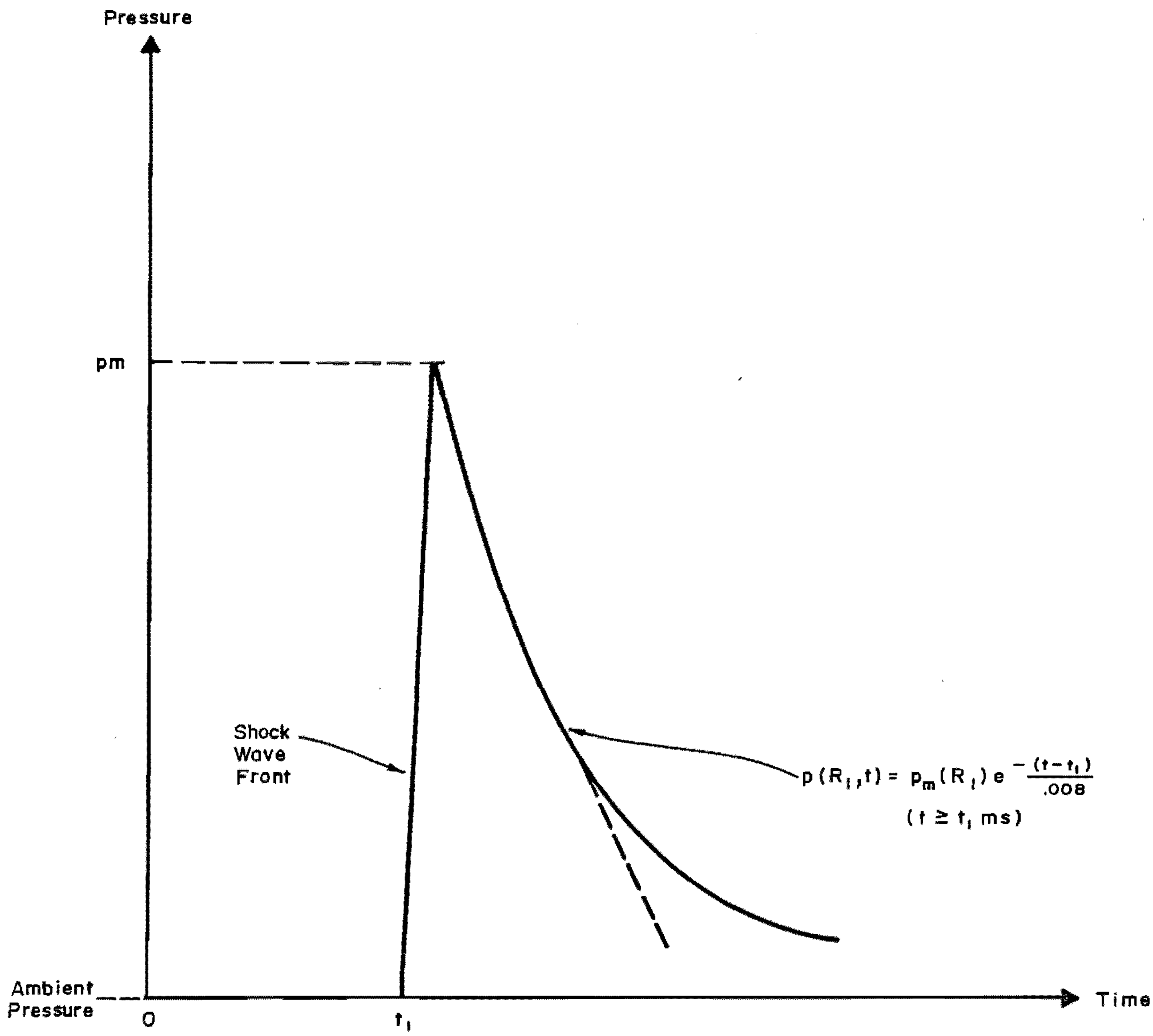


TABLE 1

ATTENUATION OF PEAK PRESSURE (P_m) OF THE SHOCK WAVE WITH RADIAL DISTANCE (R)

Spherical Attenuation		Cylindrical Attenuation	
R (m)	$P_m = \frac{4560}{R}$ (kPa)	R (m)	$P_m = 152\sqrt{\frac{30}{R}}$ (kPa)
0.6	7600	30.	152
1.0	4560	40.	132
2.0	2280	50.	118
5.0	912	69.	100
10.0	456	100.	83
20.0	228	200.	59
30.0	152	500.	37
		1000.	26

The arrival of the shock wave at the ice surface immediately above the pipeline occurs almost simultaneously with the rupture (i.e. within 1/50 of a second) because of the relatively shallow water depth (30 m). The sharp reflection and absorption of energy causes slight fracturing and some vertical motion of the 1 m thick ice cover.

The initial shock wave is also followed by the production of high intensity sound waves during the period of venting of the compressed gas. However, the frequency range, intensity and propagation characteristics of this produced sound are not known.

The impacts of this shock wave and its attendant high underwater noise levels on the biological resources of Kluane Lake are not easily predicted. Fish outside the zone of immediate lethality would likely experience various sublethal effects including stress and these fish may succumb at a later time. As a worst case, all fish within a hemisphere receiving at least 100 kPa (15 psi) are assumed to be killed outright. This figure represents a moderately low lethal pressure as reported by Teleki and Chamberlain (1978). Assuming a conservative high population density of 3.30 fish per $10^4 m^3$ as recorded in November for the western shoreline (Beak Consultants Ltd. 1978), about 150 fish will be killed outright or seriously injured in the cylinder of water with an estimated radius of 69 m from the rupture point which receives an expected shock wave with peak pressure greater than 100 kPa (Table 1). No lake trout or whitefish spawning areas were identified within 1.5 km of the pipeline crossing and hence no eggs or juvenile fish were affected in the lethal pressure zone (69 m radius).

The temperature of the gas arriving at the under-ice surface is well below $0^{o}C$ due to its adiabatic expansion even though the gas bubbling to the surface will have entrained large amounts of warmer bottom waters (temperatures 3-4°C). The flailing action of the pipe ends during venting (estimated out to a 50 m radius) should also enhance the mixing and reduce the cooling effects to some degree. However, some additional ice formation is expected in areas where any of the gas accumulates. The character of the 1 meter thick ice cover on Kluane Lake in March is assumed to be relatively similar to that of first year land-fast ice in the Beaufort Sea. According to Milne (1980) only 385 m^3 of gas trapped under ice are required to crack 1 m of land-fast ice. During this hypothetical pipeline rupture under Kluane Lake, approximately 10 x 10^6 m^3 of gas are released from the broken pipe ends in the first 15 minutes. This large volume of gas rises with considerable turbulence to the under-ice surface where it soon accumulates in a thick enough layer to crack extensive areas of ice cover within about a 100 m radius of the rupture. Most the gas vents freely and quickly to the atmosphere, although approximately 1000 m^3 of natural gas are trapped outside the fracture zone under an outer perimeter of unbroken ice between radii of 100 and 200 m.

This residual 1000 m^3 of unvented gas persists beneath the ice because the cold air temperatures (-13°C) refreeze the fractured ice cover within a day after the rupture. Methane oxidation by bacteria in the water column is assumed to be very low, averaging about 0.2 μM/L/day at an initial concentration of 120 μM/L (Welch et al. 1978). This degree of bacterial response under winter oligotrophic conditions does not reduce dissolved oxygen levels in the water column.

The solubility of oxygen in fresh water varies with temperature and under normal conditions is 12.8 mg/L at $5^{o}C$ and 14.5 mg/L at $0^{o}C$. By March natural oxygen reduction to perhaps 11 mg/L had occurred beneath the ice in Kluane Lake as a result of respiration, decomposition, and inflow of ground water over the winter. During the pipeline rupture, some additional dissolved oxygen is stripped from the water column by the rising bubbles of natural gas. However, large quantities of water having 11 mg/L dissolved oxygen are continually entrained into the zones of upwelling such that as a worst case the levels of dissolved oxygen are reduced from 11 mg/L to perhaps 6 mg/L within a vertical cylinder of about 100 m radius from the rupture site. The bubbles of gas which accumulate beneath the ring of uncracked ice also remove oxygen from the water until the natural gas becomes saturated with oxygen. Weak under-ice currents restrict the movement of oxygen-deficient surface water to within 500 m from the vent point. Within the first week dissolved oxygen concentrations in this surface layer are further reduced to about 5 mg/L but then increase slowly to ambient levels after four weeks as the weak lake circulation gradually mixes and disperses the oxygen-deficient water mass. These reduced oxygen levels could cause some stress to fish but cause no direct mortality. The fish would probably avoid this very localized near-surface area until subsequent mixing returns the dissolved oxygen levels to natural again.

The entrained water and sediments uplifted with the rising gas bubbles spread quickly under the broken ice and adjacent ice cover. Initial horizontal velocities are several metres per second but decrease with subsequent radial spreading. The radius of the area of total suspended sediments movement (radius of initially disturbed area + radius of wave ring) is estimated at about 100 m from each pipe end during the first 15 minutes after the rupture. The average concentration of suspended solids in the water column within 100 m of each pipe end is approximately 320 mg/L, assuming 600 m^3 of silts and sands were initially uplifted from both pipe ends.

After venting ceases, the spread of the suspended sediments is much slower and approaches that of the unaffected water column (i.e. <1 cm/s). Most of these suspended sediments settle out within about 10 days. The heaviest particles (i.e. sand and gravel) settle out within approximately 50 m of the rupture site. The silts and clays settle over a larger area, estimated maximum radius of 1 km.

The average suspended sediment concentration of 320 mg/L caused during the first 15 minutes of the event does little harm to resident fish since those fish not immediately killed in the vicinity of the rupture evacuate the area due to noise and shock waves that continue with the event. Lake trout and lake whitefish eggs have a relatively low tolerance to sedimentation due to their autumn spawning and winter incubation cycles when natural suspended sediment levels are lowest. However no spawning areas are known or suspected within 1.5 km of the hypothetical rupture and no impacts on fish eggs are expected from this rupture-related sedimentation. Small numbers of freshwater snails in the immediate area are also subjected to variable sediment deposition and some mortality occurs from instant burial. Nevertheless, impacts on total benthic populations in the lake are negligible and short term, due to the relatively small area affected in relation to the total lake bed, and therefore cause no serious food shortages to members of dependent trophic levels.

In summary, the combined environmental impacts associated with this hypothetical pipeline rupture could result in a total mortality of an estimated 150 overwintering fish within about 69 m of the pipeline rupture point. The underwater shock would account for all of the fish mortality. The associated sedimentation would affect a much larger area (approximately 1 km radius) but with no attributable mortality to fish and very little mortality to freshwater benthic fauna. Possible impacts due to the increased methane and decreased oxygen and temperature levels are also considered negligible since most of the gas is vented to the atmosphere. The overall fish population in Kluane Lake would not be substantially reduced due to the pipeline rupture.

The most probable cause of a pipeline failure in Kluane Lake will be an earthquake in excess of design contingency (magnitude 7.0 on the Richter Scale). Such an earthquake would have a much greater effect on the biophysical resources of Kluane Lake than any major pipeline rupture. The significant ground movement during this earthquake would cause considerable upheaval of lake bottom sediments and suspension of heavy loads of silts and clays in the water column. Nearshore areas would be most affected where the lake substrates and ice cover impact directly on one another. Numerous bottom slumping and submarine slides would probably occur where shoreline gradients are steepest. The ice cover would certainly be fractured along the Lake perimeter. Large losses of smaller fish and benthic fauna would probably occur along the shorelines where the moving rubble and underwater slides were occurring. Major lake trout and whitefish spawning areas could be lost due to the slides or the high suspended loads settling out and smothering the eggs. The overall result would be a much greater impact on the biological resources of Kluane Lake due to the earthquake than the described pipeline rupture in this scenario.

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APPENDICES

APPENDIX 1

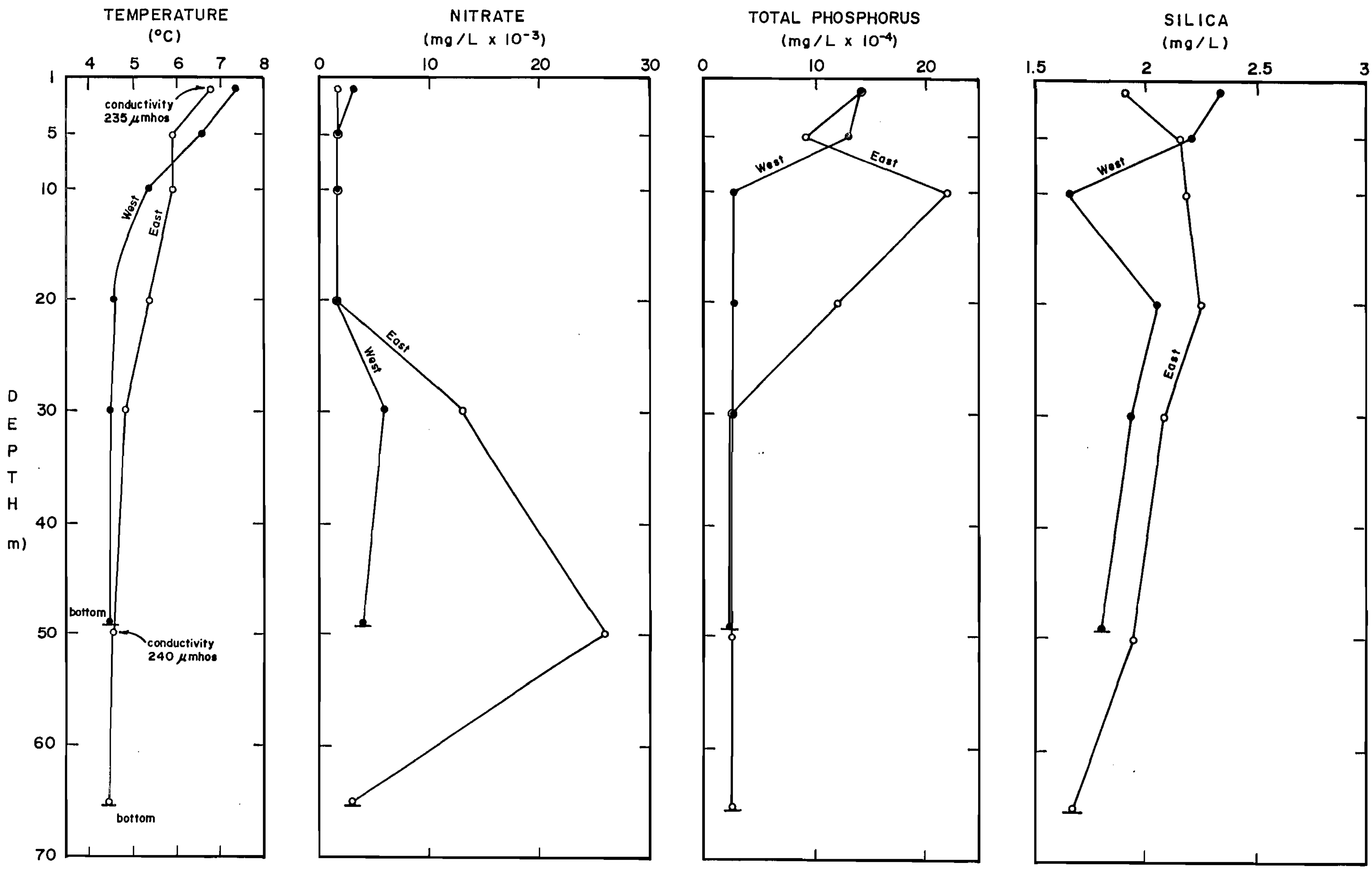
NUTRIENT ANALYSIS OF WATER SAMPLES COLLECTED IN THE PROPOSED CROSSING CORRIDOR OF KLUANE LAKE ON JUNE 18, 1981

VERTICAL PROFILE APPROXIMATELY 800 m FROM WESTERN SHORE

Depth (m)	Nitrates (mg/L)	Nitrites (mg/L)	Total Phosphates (mg/L)	Ortho Phosphates (mg/L)	Silica (mg/L)	Conductivity (μmhos)
1	0.003	<0.001	0.14	<0.030	2.33	-
5	<0.002	<0.001	0.13	<0.030	2.20	-
10	<0.002	0.002	<0.030	<0.030	1.65	-
20	<0.002	<0.001	<0.030	<0.030	2.05	-
30	0.006	<0.001	<0.030	<0.030	1.93	-
49	0.004	0.001	<0.030	<0.030	1.80	-

VERTICAL PROFILE APPROXIMATELY 800 m FROM EASTERN SHORE

Depth (m)	Nitrates (mg/L)	Nitrites (mg/L)	Total Phosphates (mg/L)	Ortho Phosphates (mg/L)	Silica (mg/L)	Conductivity (μmhos)
1	<0.002	<0.001	0.14	<0.030	1.90	235
5	<0.002	0.001	0.091	<0.030	2.14	-
10	<0.002	<0.001	0.22	<0.030	2.18	-
20	<0.002	0.002	0.12	<0.030	2.25	-
30	0.013	<0.001	<0.030	<0.030	2.08	-
50	0.026	0.002	<0.030	<0.030	1.95	-
65	0.003	0.002	<0.030	0.046	1.67	-



Nutrient Profiles for Kluane Lake Crossing, June 18, 1981

APPENDIX 2

AREA OF HORIZONTAL WATER MOVEMENT AT THE SURFACE DURING A GAS BLOWOUT

Topham (1978) suggested that at a certain radius the horizontal flow of water away from the gas venting point at the surface would cease and the water would plunge downward forming a "wave ring". The radius of the wave ring (R) is potentially a function of gas flow rate and water depth:

$$R = 0.39 \times Z \times \left[\frac{(V_f \times 10.36)^{1/3}}{(z + 10.36)}\right]$$

where:

z = depth (m)

V_f = volume flow of free gas m^3/min

APPENDIX 3

VOLUME INCREASE OF GAS RELEASED INTO KLUANE LAKE

Assuming adiabatic expansion of the released gas (i.e. no heat loss), the volume increase of the gas as it expands from a pressure of 8000 kp to a pressure of 100 kp at the surface is calculated as follows:

$$P_O V_O^{\gamma} = P_F V_F^{\gamma}$$

where:

γ = ratio of specific heats = 1.3 for methane

P_O, V_O = initial pressure and volumes

P_F, V_F = final pressure and volumes

therefore:

$$8000\ V_O^{\gamma} = 100\ V_F^{\gamma}$$

and $$\frac{V_F}{V_O} = \sqrt[\gamma]{80}$$

$$= 29 \text{ times}$$

APPENDIX 4

AN ESTIMATE OF FLOW CONDITIONS FOLLOWING UNDERWATER GAS PIPELINE RUPTURE

G.V. Parkinson, P.Eng.

1. ASSUMED CONDITIONS BEFORE AND AFTER RUPTURE

Methane (gas constant R = 520 $m^2/s^{2\circ}K$, specific heat ratio k = 1.30) flows steadily at 0°C through pipeline (diameter D = 1.192 m, effective roughness ε = 0.0076 mm) at the mass rate of 587.7 kg/s. At the compressor discharge at K.P. 213.9* pressure p = 8240 kPa (absolute), and velocity V = 9.07 m/s. Speed of sound in methane at 0°C, c = 429.6 m/s, so Mach number M = 0.0211. Corresponding values of p, V, and M at the point where rupture will occur, K.P. 219*, are 8162 kPa, 9.16 m/s, and 0.0213 respectively. These values have been calculated for isothermal flow (adiabatic flow gives nearly identical results), and are slightly lower than Foothills' values, presumably because of some differences in assumptions.

The lake has a thick ice cover and an irregular bottom. To simplify calculations for the initial period following rupture, during which the shock wave is propagating outward, an idealized model of ruptured pipeline and lake is assumed, as shown in Figure 1. The lake is a semi-infinite water layer 60 m deep bounded by flat solid surfaces on top (the ice) and bottom, and by a plane vertical wall (the shore near the rupture point). Pipeline rupture is assumed to occur at the wall at a depth of 30 m. The gas expands and the shock wave propagates initially with spherical symmetry from this point, the gas flow equivalent to that from the two pipe sections on either side of the rupture. The net effect of these simplifying assumptions is conservative, since wave reflections from the assumed surfaces will produce a stronger pressure field than would reflections from the actual surfaces.

*A slight change in Kilometer Post indications occurred after Dr. Parkinson completed his calculations. The compressor station location became K.P. 214.2 instead of K.P. 213.9 and the hypothetical rupture point became K.P. 222 instead of 219.

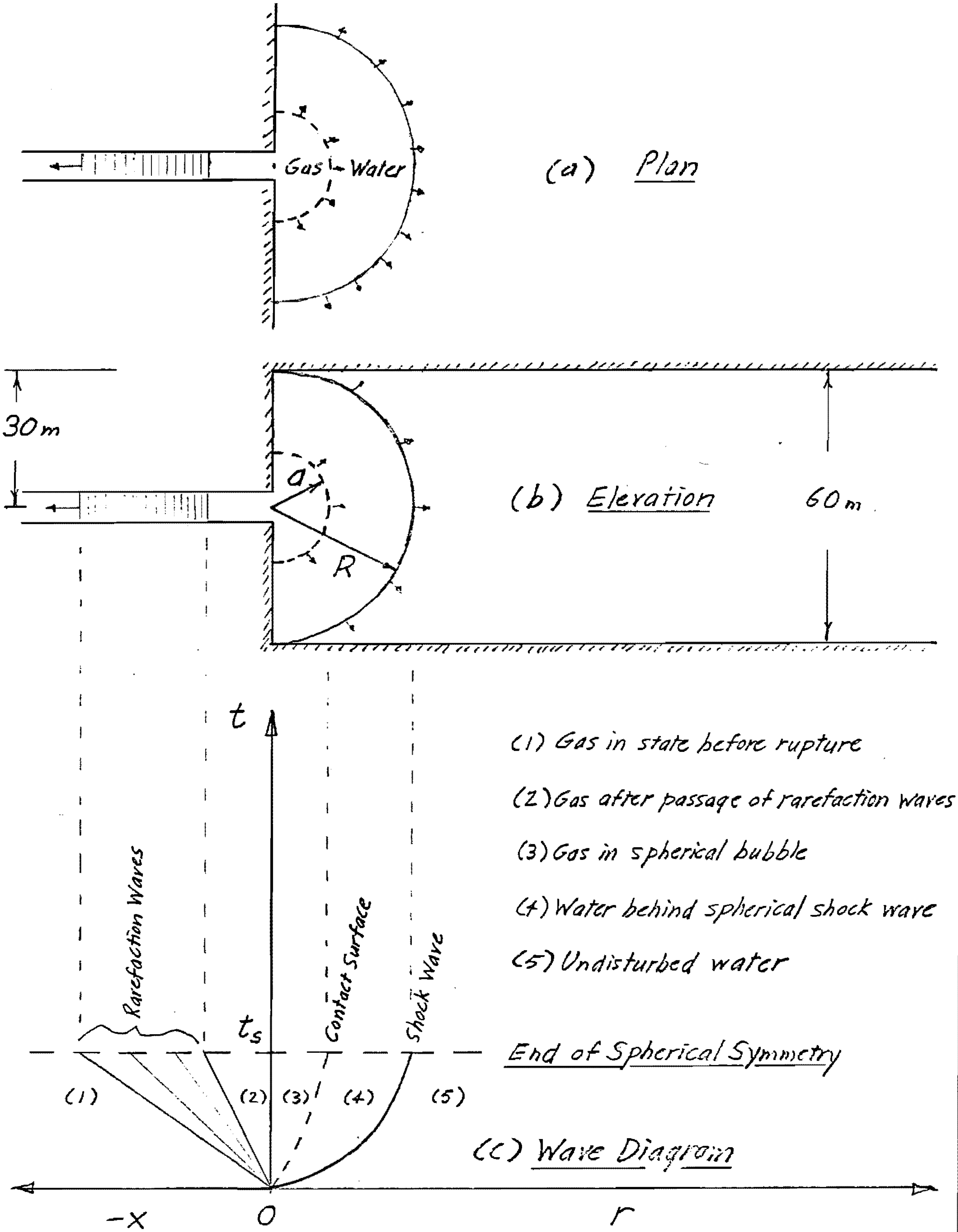


Figure 1

Flow Geometry and Wave Diagram for Period of Spherical Symmetry

2. THE IDEALIZED FLOW FIELD JUST AFTER RUPTURE

Since the steady flow Mach number is very low, the gas just prior to rupture can be considered at rest at p = 8162 kPa, and in the idealized model rupture consists of bursting a diaphragm closing the end of the pipe in the wall at t = 0. This puts the high pressure gas in contact with lake water assumed at 400 kPa absolute pressure, and immediately a hemispherical shock wave forms and propagates outward into the water, while a centered fan of rarefaction waves propagates back into the pipeline. In between, the contact surface between gas and water moves outward into the water, forming a hemispherical gas bubble. These events are sketched qualitatively in Figure 1.

The pressure in the fluid between the shock wave and the rarefaction waves is less than the ambient gas pressure and greater than the ambient water pressure, and it can be solved for using the equations of unsteady gas and hydrodynamics and the compatability condition that pressures and velocities are equal on the two sides of the gas-water contact surface. These calculations lead to initial values for the shock wave as it forms with a spherical radius R_0 = 0.6 m at t = 0+. Its propagation velocity U is only slightly higher than the acoustic velocity in water, c = 1500 m/s, so c can be used in further calculations. Its peak pressure rise p_m = 7600 kPa, and the particle velocity of the water following it, u_r = 5.3 m/s.

3. THE NATURE OF THE SHOCK WAVE PROPAGATION

A shock wave is extremely thin, and the wavefront is effectively a discontinuity surface across which the pressure rises abruptly by p_m. In a plane wave p_m is constant and equal to the pressure rise of the fluid following the wave. In a spherical shock wave, however, energy considerations require p_m to be an inverse function of radius R, and pressure rise behind the wave to decrease rapidly from p_m as the wave recedes.

In the absence of a detailed flow field solution to the present problem the best alternative is to use results from the theory of underwater explosions (see R.H. Cole, 'Underwater Explosions', Dover, 1965). The flow field from an explosion differs from the present flow field in that the gas bubble is formed at $t = 0^+$ from the explosion products and there is no further flow of high pressure gas into it. This difference should not have a strong effect on the shock wave characteristics, and here we adapt the shock wave formulas for underwater explosions to our requirements.

In underwater explosions, the attenuation of p_m as the shock wave propagates outward is observed to follow the relation $p_m \propto 1/R^\alpha$, where $\alpha = 1.13 \rightarrow 1.15$. On the other hand very weak spherical waves would obey the acoustic propagation law, for which $\alpha = 1$. Here we make the conservative choice of the acoustic law, since its more gradual attenuation allows for the effects of wave reflections from the solid top (ice) and bottom surfaces bounding the lake water, effects not possible to calculate precisely. The time decay of the pressure rise at a fixed point following the passage of the wavefront in an underwater explosion is observed to be approximately exponential for the first few microseconds. Incorporating this in the present model for the expanding hemispherical shock wave leads to the following formula for pressure rise p' as a function of radius r and time t for points near the wavefront:

$$p'(r,t) = \frac{p_m\ (Ro)Ro}{r}\ e^{-\left(\frac{t - \frac{r-Ro}{c}}{\theta}\right)} \quad , \ t \geq \frac{R-Ro}{c} \ , \ r \leq R \qquad (1)$$

$$= 0\ , \quad t < \frac{R-Ro}{c}\ , \ r > R$$

Here $R_o = 0.6$ m, $p_m\ (R_o) = 7600$ kPa, $c = 1500$ m/s, $\theta = 8\ \mu s$. Eq. (1) applies to the lake water for $r < 30$ m up to time $t_s = 20$ ms, when the shock wave reaches the solid bounding surfaces and spherical symmetry is lost. From Eq. (1), for $t = t_w = \frac{R-Ro}{c}$, the time of arrival of the wave front at radius R, we have

$$p'(R\ , t_w) = p_m(R) = \frac{p_m(Ro)Ro}{R} = \frac{4560}{R}\ \text{kPa} \qquad (2)$$

and

$$\frac{dp'}{dt}(R,\ t_w) = -\frac{p_m(R)}{\theta} = -\frac{570}{R}\quad \text{kPa}/\mu s \qquad (3)$$

At sufficiently high values of R the radius becomes effectively cylindrical, with the cylinder axis vertical through the rupture centre in the vertical wall. At such radii, the formula for the attenuation of $p_m(R)$ can be taken as

$$p_m(R) = p_m(R_s)\ \sqrt{\frac{Rs}{R}}\ , \text{ for } R \geq R_s \qquad (4)$$

We chose R_s = 30 m and p_m (R_s) = 152 kPa, the value given by Eq. (2) for R = 30 m, so that the spherical and cylindrical attenuation laws are matched at R = 30 m. This again is conservative, since the cylindrical attenuation is much more gradual. The following variation of p_m with R results:

R (m)	$p_m = \frac{4560}{R}$ (kPa)	R (m)	$p_m = 152\sqrt{\frac{30}{R}}$ (kPa)
0.6	7600	30.	152
1.0	4560	40.	132
2.0	2280	50.	118
5.0	912	69.	100
10.0	456	100.	83
20.0	228	200.	59
30.0	152	500.	37
		1000.	26

Table 1: Attenuation of Shock Wave Peak Pressure

It can be seen from Table 1 that for R > 69 m, p_m < 100 kPa, the minimum shock wave pressure assumed in the scenario to be potentially harmful to fish.

4. FLOW CONDITIONS AT THE CONTACT SURFACE

As the gas bubble expands into the lake water the compatibility conditions at the contact surface r = a are that radial velocity $u_{r_{gas}} = u_{r_{water}} = \frac{da}{dt}$, and that pressure $p_{gas} = p_{water} = p_a$. The flow field equations needed to satisfy field conditions and these compatibility conditions lead to a difficult nonlinear problem, which I have not had time to solve. However, some progress can be made for the water side of the contact surface by assuming incompressible potential flow there. Integration of the field equations leads to the relation

$$\frac{\rho_w}{2} a^3 \left(\frac{da}{dt}\right)^2 + 1/3\, p_\infty a^3 - \int_0^t p_a a^2 da = C \qquad (5)$$

Where C is a constant, ρ_w is water density, and p_∞ is undisturbed water pressure. One can then proceed by relating Eq. (5) to conditions in the gas.

It should be noted that at t = 0+, a = 0.6 m and $u_r = \frac{da}{dt} = 5.3$ m/s, so the bubble will not have expanded very much in 2/3 sec., by which time the shock wave has travelled 1 km and the shock pressure rise has dropped to 26 kPa.

SUPPORTING CALCULATIONS

by

Dr. G.V. Parkinson

Calculation of Steady Flow in Line beyond K.P. 213.9:

O.D = 1219 mm , t = 13.72 mm ∴ I.D. = D = 1.192 m

$W = \rho g A V = 4.664(10)^6$ lbm/hr = 587.7 kg/s   Assume 0°C

Point 1: Compressor Disch. $p_1 = 8136.8$ kPag = 8240.1 kPa ($p_{at} = 101.3$ kPa)

$A = \frac{\pi}{4} D^2 = 1.116 \ m^2$, $R_{methane} = 520 \ m^2/s^2 °K$, $k = 1.30$

$\rho_1 = \frac{p_1}{RT_1} = \frac{8240(10)^3}{520(273)} = 58.04 \ kg/m^3$

$\therefore V_1 = 587.7/58.04(1.116) = 9.073 \ m/s$

$c_1 = c = \sqrt{kRT} = \sqrt{1.30(520)273} = 429.6 \ m/s$ $\therefore M_1 = 0.0211$

Isothermal Flow

$$f\frac{L}{D} = \frac{1}{kM_1^2}\left\{1 - (p_2/p_1)^2\right\} - 2 \ln p_1/p_2$$

Use Incompressible Flow $f(R_e, \epsilon/D)$ from Moody Diag.

$R_e = \text{constant} = \frac{\rho V D}{\mu} = \frac{58.04(9.073)1.192}{1.05(10)^{-5}} = 5.98(10)^7$

$\epsilon = 300 \mu in = 0.0076$ mm $\therefore \epsilon/D = \frac{.0076}{1192} = 0.0000064$ $f = .0075$

Case 1: $L = 255.7 - 213.9 = 41.8$ km $\therefore f\frac{L}{D} = .0075 \frac{41.8(10)^3}{1.192} = 263$

Neglect ln term: $1 - (p_2/p_1)^2 = 263(1.30)(.0211)^2 = .152$

$\therefore p_2 = \sqrt{.848}(8240) = 7587$ kPa $= 7486$ kPag

ln term: $2 \ln \frac{8240}{7587} = .165$ ✓

Case 2: $L = 227.0 - 213.9 = 13.1$ km $\therefore f\frac{L}{D} = .0075 \frac{13.1(10)^3}{1.192} = 82.4$

$\therefore 1 - (p_2/p_1)^2 = 82.4(1.30)(.0211)^2 = .0477$

$\therefore p_2 = \sqrt{.9523}(8240) = 8041$ kPa $= 7940$ kPag

Given Values:

	K.P.	213.9	218.5	223.9	227.0	255.7
	km	0	4.6	10.0	13.1	41.8
J.Mc.	p kPag	8138.8	—	—	8025.0	(7069.4) ← Probably Should Be 7609.4
R.O.		8136.1	8108.5	80??.5	—	—

$$p/p_1 = \left(1 + \frac{k-1}{2}M_1^2\right)\rho/\rho_1 - \frac{k-1}{2}M_1^2\frac{\rho_1}{\rho} = \left(1 + 66.78(10)^{-6}\right)\frac{\rho}{\rho_1} - 66.78(10)^{-6}\frac{\rho_1}{\rho}$$

$$\overset{.0075}{f}\underset{1.192}{\frac{L}{D}} = \frac{1}{kM_1^2}\left(1+\frac{k-1}{2}M_1^2\right)\left[1-\left(\rho/\rho_1\right)^2\right] + \frac{k+1}{k}\ln\frac{\rho}{\rho_1} = \frac{1+66.78(10)^{-6}}{578.8(10)^{-6}}\left[1-\left(\rho/\rho_1\right)^2\right] - 1.77\ln\frac{\rho_1}{\rho}$$

ρ/ρ_1	p/p_1	p_G kPa	L km
.90		7315	52.15
.91			
.92		7480	42.16
.93			
.94		7645	31.95
.95			
.96		7809	21.52
.97			
.98		7974	10.87
.99			
1.00		8139	0

Indistinguishable from Isothermal

See Fig. (i)

At Rupture Point: $L = 5.1$ km, $p \doteq \underline{8061}$ kPag $= \underline{8162}$ kPa, $\rho = \frac{8162}{8240}(58.0) = \underline{57.5}$ kg/m³

$\therefore V = \frac{8240}{8162}\,9.07 = \underline{9.16}$ m/s, $M = \frac{8240}{8162}(.0211) = \underline{0.0213}$

Above calculated p-values about 1% low, on average, either because line is actually descending, or because Foothill is using a lower value of f_1 or using incompressible flow calculations.

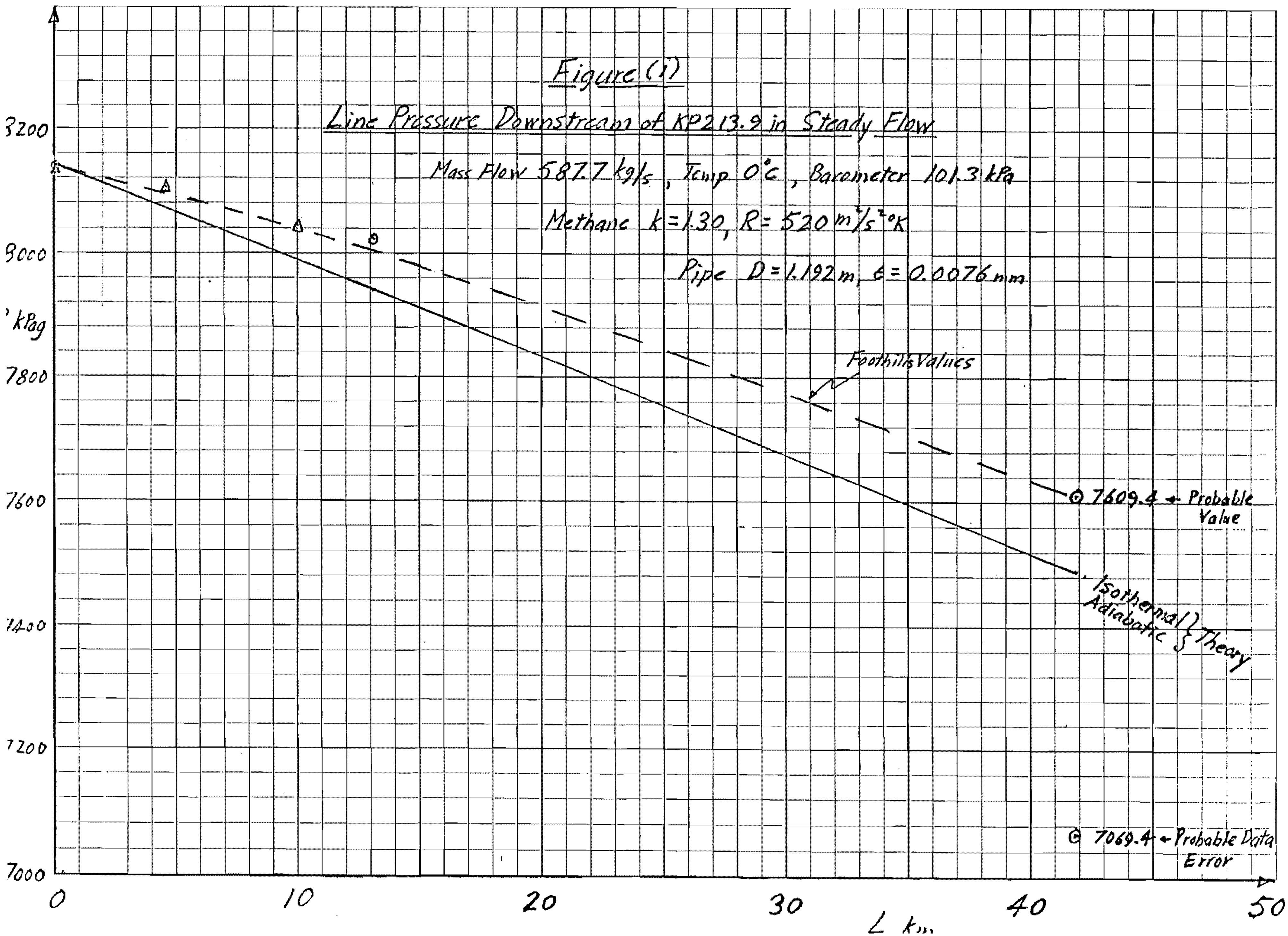
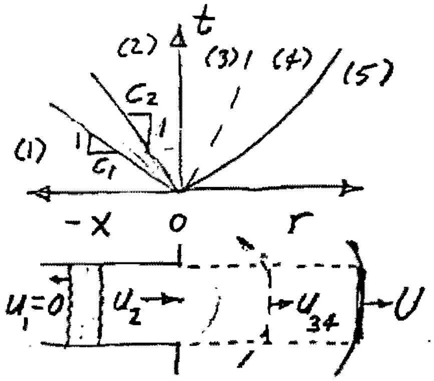


Figure (1)
Line Pressure Downstream of KP213.9 in Steady Flow
Mass Flow 587.7 kg/s, Temp 0°C, Barometer 101.3 kPa
Methane k=1.30, R=520 m²/s²°K
Pipe D=1.192 m, ε=0.0076 mm
Foothills Values
7609.4 ← Probable Value
Isothermal } Theory
Adiabatic }
7069.4 ← Probable Data Error
kPag
8200
8000
7800
7600
7400
7200
7000
0
10
20
30
40
50
L km



Across rarefaction fan:

Neglect u_1, which is in opposite directions w.r.t. rupture for the 2 pipe sections.

$$\therefore u_2 = \frac{2c_1}{k-1}\left\{1-\left(\frac{p_2}{p_1}\right)^{\frac{k-1}{2k}}\right\} + \cancel{u_1} \quad \cdots (1)$$

$c_1 = 430$ m/s, $p_1 = 8162$ kPa, $k = 1.30$

Conditions across Shock Initially:

To get initial conditions at contact surface & shock wave, we assume 1D flow just after $t=0$, both to L & R at origin. Subsequently flow is 1D to L, but spherical to R. Therefore, at $t = 0+$:

From Cole, p. 44: $\Delta p_{45} = \dfrac{\rho_5 c_5^2}{n}\left\{\left(\dfrac{\rho_4}{\rho_5}\right)^n - 1\right\} = p_4 \cdots (2)$ $\qquad \rho_5 = 1000$ kg/m³

$$u_4 = \frac{2c_5}{n-1}\left\{\left(\frac{\rho_4}{\rho_5}\right)^{\frac{n-1}{2}} - 1\right\} \cdots (3) \qquad c_5 = 1500 \text{ m/s}$$

$$\& \; U = c_5\left\{1 + \frac{n+1}{4c_5}u_4\right\} \cdots (4) \qquad n = 7$$

Eliminating ρ_4/ρ_5 from Eqs. (2) & (3):

$$\left(\frac{\rho_4}{\rho_5}\right)^n = \left\{1 + \frac{n-1}{2}\frac{u_4}{c_5}\right\}^{\frac{2n}{n-1}} \quad \therefore p_4 = \frac{\rho_5 c_5^2}{n}\left[\left\{1+\frac{n-1}{2}\frac{u_4}{c_5}\right\}^{\frac{2n}{n-1}} - 1\right] \cdots (5)$$

In the initial 1D Flow, $p_4 = p_3 = p_2$ & $u_4 = u_3 = u_2$

$$\therefore u_4 = \frac{2c_5}{n-1}\left[\left\{1 + n\frac{p_2}{\rho_5 c_5^2}\right\}^{\frac{n-1}{2n}} - 1\right] = \frac{2c_1}{k-1}\left\{1 - \left(\frac{p_2}{p_1}\right)^{\frac{k-1}{2k}}\right\} = u_2$$

$$\text{or} \quad 1 - \left(\frac{p_2}{8162}\right)^{\frac{0.3}{2.6}} = \frac{0.3}{6}\,\frac{1500}{430}\left[\left\{1 + 7\frac{p_2}{1(1500)^2}\right\}^{3/7} - 1\right]$$

$$\text{or:} \quad p_2 = 8162\left(1 - \frac{15}{86}\left[\left\{1 + \frac{7}{2.25}(10)^{-6}p_2\right\}^{3/7} - 1\right]\right)^{\frac{2.6}{0.3}}$$

By Trial: $p_2 = \underline{8032}$ kPa $= p_4$

$\therefore u_2 = u_4 = \underline{5.31}$ m/s

& $U = 1500\left\{1 + \dfrac{2(5.31)}{1500}\right\} = \underline{1511}$ m/s

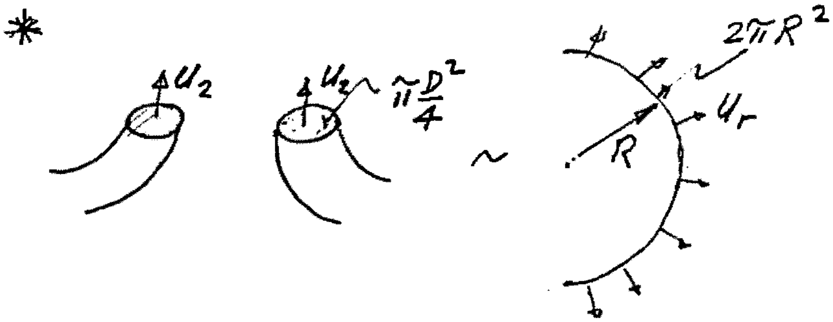
(above three results) @ $t = 0+$

We can round these figures off so that, as the shock wave starts out @ $R_0 = 0.\underline{6}$* m, $p_4 = \underline{8000}$ kPa, $p_5 = \underline{400}$ kPa (hydrostatic p @ 30m)

$U = \underline{1500}$ m/s = constant (i.e., negligibly different from $c_5 = 1500$ m/s)

$u_r = \underline{5.3}$ m/s* (Continuity argument on p. 4)*

*



Continuity:

$$2 u_2 \frac{\pi D^2}{4} = u_r \, 2\pi R_0^2$$

$\therefore$ If $R_0 = \frac{D}{2} = 0.6$ m

$u_r = u_2 = \underline{5.3}$ m/s

<u>Shock Wave Propagation & Form</u> - during period of spherical symmetry.

Max. Pressure (Cole, p. 241): $p_m(R) \doteq k_1 \left(W^{1/3}/R \right)^{\alpha} = p_m(R_0) \left(R_0/R \right)^{\alpha}$

& @ a given radius, $p \doteq p_m e^{-t/\theta}$

where $\theta \doteq k_2 W^{1/3}$ (Acoustic Approx.)

$\therefore k_1 (W^{1/3})^{\alpha} = p_m(R_0) R_0^{\alpha}$, or $W^{1/3} = \left\{ \frac{p_m R_0^{\alpha}}{k_1} \right\}^{1/\alpha} = R_0 \left\{ \frac{p_m}{k_1} \right\}^{1/\alpha}$

$\therefore \theta = k_2 R_0 \left(\frac{p_m}{k_1} \right)^{1/\alpha}$, take $\alpha = 1$ because of other approximations in this calculation

$= \frac{k_2}{k_1} p_m R_0 \quad \frac{\mu sec/lb^{1/3}}{psi - ft/lb^{1/3}} (psi)\, ft$

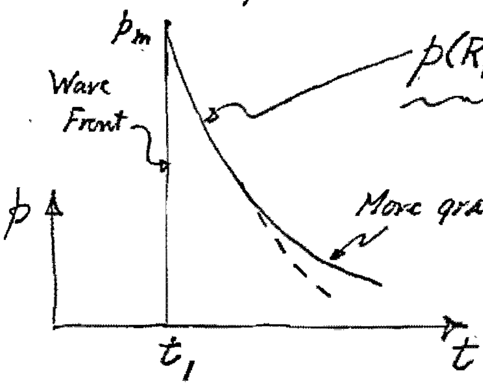
$= \frac{70}{2.2(10)^4} (1160)(1.97) = 7.3\ \mu sec = \underline{.0073}$ ms

Again, from Hill, p. 11: $\theta = \frac{92.5}{526} (80)(0.6) = 8.4\ \mu s = \underline{.0084}$ ms   (80 bars, 0.6 m)

$\therefore$ Take $\theta = 8\ \mu s = .\underline{008}$ ms

$\therefore$ Take p-t curve near the wavefront @ radius R_1 as:

$$p(R_1, t) = p_m(R_1) e^{\frac{-(t-t_1)}{.008}}, \quad t \geq t_1 \ \text{ms} \quad \cdots (6)$$



$\therefore$ Initial rate of pressure drop behind wavefront:

$$\left. \frac{dp}{dt} \right|_{t_1} = \frac{-p_m(R_1)}{.008} = -\underline{120}\, p_m(R_1) \ \text{kPa/ms} \quad \cdots (7)$$

Spatial Attenuation of Spherical Shock Waves

– until $t = t_s$ (Fig. 1) $= \frac{30}{1500}(10)^3 = \underline{20}$ ms

From p.3, ; Cole, p.241: $p_m(R) = p_m(R_0)\left(\frac{R_0}{R_m}\right)^{\alpha}$, $\alpha \doteq 1.13 - 1.15$ ···(8)

for explosive charges ; p_m as low as 650 kPa.

This relation would apply to the present shock wave. The limiting weak form of spherical wave is given by acoustic theory :

Velocity potential $\phi(r,t) = \frac{1}{r} f(r-ct)$, $c = c_s$ of p.3 ···(9)

Pressure disturbance $p'(r,t) = p(r,t) - p_0 = \frac{\rho_0 c}{r} f'(r-ct)$ ···(10)

where p_0, ρ_0 are ambient pressure ; density

On the wavefront, $r - ct = R - ct = R_0$ = constant as wave propagates outward at speed c, ; $R = R_0$ (= 0.6 m here) @ $t = 0$

$$\therefore p'(R) = p_m(R) = \frac{\rho_0 c f'(R_0)}{R} = p_m(R_0)\frac{R_0}{R} \quad \text{·····}(11)$$

Taking p_m to mean pressure rise above ambient in both Eqs (8) ; (11) then p_m = 7600 kPa @ R_0 = 0.6 m . Take $\alpha = 1.13$ in Eq.(8)

R m	$p_m = 7600\left(\frac{0.6}{R}\right)^{1.13}$ kPa	$p_m = 7600\left(\frac{0.6}{R}\right)$ kPa
0.6	7600	7600
1.0	4267	4560
2.0	1950	2280
5.0	692	912
10.0	316	456
20.0	145	228
30.0	91	152

For $R > 30$ m, wave reflections from top ; bottom increase the pressure calculated for the basic spherical wave. At sufficiently higher values of R, the radius is effectively cylindrical, with the cylindrical axis in the vertical wall.

Cylindrical Wave Far-Field Attenuation. (Acoustic)

$$p_m(R) = p_m(R_1)\sqrt{\frac{R_1}{R}} \quad \text{- - - - (12)}$$

Overall Spatial Attenuation: The spherical attenuation with $\alpha = 1.13$ is more accurate, but the acoustic version is conservative & will compensate for effects of reflection for $t > t_s = 20\,ms$. For $R > 30m$ we match the cylindrical law @ $R_1 = 30m$, $p_m(R_1) = 152\,kPa$

R m	$p_m = 152\sqrt{\frac{30}{R}}$ kPa
30	152
40	132
50	118
100	83
500	37
1000	26

This again will be conservative. From pp. 5 & 6:

Pressure Variation in Water for $t < t_s = 20ms.$, $R < 30m$:

$$p'(r,t) = \frac{p_m(R_0)R_0}{r} e^{-\frac{(t - \frac{r-R_0}{c})}{\theta}}, \quad t \geq \frac{R-R_0}{c}, \; r \leq R$$

$$= 0, \quad t < \frac{R-R_0}{c}, \; r > R$$

$r = R$ @ Wavefront - - - - (13)

$R_0 = 0.6m$, $p_m(R_0) = 7600\,kPa$, $c = 1500\,m/s$, $\theta = 0.008\,ms$.

Flow Conditions at the Contact Surface for $t < t_s$

Consider incompressible inviscid radial flow on the water side:

Continuity: $\cancel{\frac{\partial \rho}{\partial t}} + \cancel{u\frac{\partial \rho}{\partial r}} + \rho\frac{\partial u_r}{\partial r} + \frac{2\rho u_r}{r} = 0$

$\rho = \text{const.} = \rho_w \quad \therefore \quad \frac{\partial u_r}{\partial r} + \frac{2u_r}{r} = 0 \quad \text{- - - - (14)}$

Motion: $\rho_w\frac{\partial u_r}{\partial t} + \rho_w u_r\frac{\partial u_r}{\partial r} + \frac{\partial p}{\partial r} = 0 \quad \cdots\cdots (15)$

ignoring hydrostatic p-variation.

Integrating Eq.(14): $u_r(r,t) = \frac{u_1(t)}{r^2}$ & substituting in Eq.(15):

$$\frac{\rho_w}{r^2}\frac{du_1}{dt} + \frac{\rho_w}{2}\frac{\partial u_r^2}{\partial r} + \frac{\partial p}{\partial r} = 0 \quad \cdots (16)$$

Integrating Eq.(16) w.r.t. r from $r = a \to \infty$, & using

$u_r(a,t) = \frac{u_1(t)}{a^2} = \frac{da}{dt}$, & $p = p_\infty$ @ ∞

$$* \quad \frac{\rho_w}{a}\frac{d}{dt}\left(a^2\frac{da}{dt}\right) - \frac{\rho_w}{2}\left(\frac{da}{dt}\right)^2 - (p_a - p_\infty) = 0 \quad \text{---(17)}$$

Multiplying Eq.(17) by $a^2\frac{da}{dt}dt$ & integrating w.r.t. t gives

$$\frac{\rho_w}{2}a^3\left(\frac{da}{dt}\right)^2 + \frac{1}{3}p_\infty a^3 - \int_0^t p_a a^2 da = C \quad \text{--- (18)}$$

This is easily shown to be an energy equation.

$$* \quad \frac{1}{a}\frac{d}{dt}\left(a^2\frac{da}{dt}\right) - \frac{1}{2}\left(\frac{da}{dt}\right)^2 = a\frac{d^2a}{dt^2} + \frac{3}{2}\left(\frac{da}{dt}\right)^2$$

$\times a^2\frac{da}{dt}dt$, & $\int_0^t$ gives $\int_0^t a^3\frac{da}{dt}\frac{d^2a}{dt^2}dt + \frac{3}{2}\int_0^t a^2\left(\frac{da}{dt}\right)^3 dt$

$$= \left[\frac{a^3}{2}\left(\frac{da}{dt}\right)^2\right]_0^t - \cancel{\frac{3}{2}\int_0^t a^2\left(\frac{da}{dt}\right)^3 dt} + \cancel{\frac{3}{2}\int_0^t a^2\left(\frac{da}{dt}\right)^3 dt}$$

$$= \frac{a^3}{2}\left(\frac{da}{dt}\right)^2 - \underbrace{\frac{a_0^3}{2}\left(\frac{da}{dt}\right)_0^2}_{\text{constant}}$$

– No time for further analysis –

KLUANE LAKE REGION ALTERNATIVES: TERRAIN TYPES

MAP 3-5.2 SHEET 1

TERRAIN TYPING LEGEND

GENETIC COMPOSITIONAL CATEGORY → tLP(k) ← PROCESS OR FORM MODIFIER(S)

TEXTURAL MODIFIER(S) → tLP(k) ← MORPHOLOGIC MODIFIER(S)

m gA - INDICATES CATEGORY CHARACTERIZED BY TWO TEXTURES, THE FIRST MODIFIER DOMINANT

MH M - INDICATES CATEGORY CHARACTERIZED BY TWO MORPHOLOGIES THE FIRST MODIFIER DOMINANT

tAP / aGM - STRATIGRAPHIC RELATIONSHIP WHERE UPPER UNIT IS OFTEN LESS THAN 3 METRES THICK

← - INDICATES TERRAIN TYPE OR FEATURE BEING DESCRIBED

GENETIC COMPOSITION CATEGORIES

- A ALLUVIAL DEPOSITS SILT SAND OR GRAVEL
- C COLLUVIUM UNSORTED MIXTURES OF FINE GRAINED MATERIALS & RUBBLE
- D DRIFT UNDIFFERENTIATED GLACIOFLUVIAL LACUSTRINE & MORAINAL DEPOSITS
- E - EOLIAN DEPOSITS. SILT. SAND & VOLCANIC ASH
- G - GLACIOFLUVIAL DEPOSITS. SAND OR GRAVEL. RARELY SILT
- L - LACUSTRINE & POND DEPOSITS: SILT & SAND. RARELY ORGANIC OR GRAVEL
- M MORAINAL DEPOSITS. TILL. OCCASIONALLY GRAVEL. SAND & SILT
- O - ORGANIC DEPOSITS. PEAT. ORGANIC SILT. RARELY MARL
- R BEDROCK

TEXTURAL MODIFIERS

- a SAND OR GRAVEL COARSE-GRAINED
- b BOULDERS. BLOCKS BOULDERY. BLOCKY
- c - CLAY CLAYEY
- d - DIAMICTON. UNSORTED MATERIAL
- f - FINE GRAINED SILT SAND. CLAY FREQUENTLY ORGANIC
- g - GRAVEL. GRAVELLY
- m SILT SILTY
- o ORGANIC
- p - PEAT PEATY
- r RUBBLE. RUBBLY
- s - SAND. SANDY
- t TILL
- v - VOLCANIC ASH TEPHRA
- x COMPLEX

PROCESS or FORM MODIFIERS

- (A) ACTIVE ALLUVIATION
- (E) STREAM ERODED STREAM ERODING
- (G) CHANNELLED BY MELTWATER STREAMS
- (L) MODIFIED DUE TO SLOPE FAILURE OR RAPID MASS MOVEMENT
- (P) - PITTED (KETTLE HOLE)
- (S) - SOLIFLUCTION LOBES & TERRACE
- (k) - THERMOKARST MODIFIED BY THERMOKARST
- (V) - GULLIED
- (W) - WAVE WASHED
- (Z) - PATTERNED GROUND

MORPHOLOGIC MODIFIERS

- A - APRON
- B - BLANKET
- C - CHANNEL NO VEGETATION COVER
- D - DELTA
- F - FAN
- G - GENTLY SLOPED (<5°)
- H - HUMMOCKY
- M - ROLLING UNDULATING
- N - MODERATELY SLOPED (5-15°)
- P - PLAIN POND
- R - RIDGE
- S - STEEPLY SLOPED (>15°)
- T - TERRACE
- V - VENEER
- X - COMPLEX

BLANKET - CONTINUOUS COVER GENERALLY 0.5-3 METRES THICK

VENEER - BROKEN THIN COVER AVERAGING 0.5 METRES IN THICKNESS

KLUANE LAKE REGION ALTERNATIVES:
TERRAIN TYPES
MAP 3-5.2
SHEET 2

TERRAIN TYPING LEGEND

GENETIC-COMPOSITIONAL CATEGORY → fLP(k) ← PROCESS OR FORM MODIFIER(S)

TEXTURAL MODIFIER(S) → fLP(k) ← MORPHOLOGIC MODIFIER(S)

m-gA - INDICATES CATEGORY CHARACTERIZED BY TWO TEXTURES THE FIRST MODIFIER DOMINANT

MH-M - INDICATES CATEGORY CHARACTERIZED BY TWO MORPHOLOGIES THE FIRST MODIFIER DOMINANT

'AP / aGM - STRATIGRAPHIC RELATIONSHIP WHERE UPPER UNIT IS OFTEN LESS THAN 3 METRES THICK

← - INDICATES TERRAIN TYPE OR FEATURE BEING DESCRIBED

GENETIC COMPOSITION CATEGORIES

- A - ALLUVIAL DEPOSITS SILT, SAND OR GRAVEL
- C - COLLUVIUM UNSORTED MIXTURES OF FINE-GRAINED MATERIALS & RUBBLE
- D - DRIFT UNDIFFERENTIATED GLACIOFLUVIAL, LACUSTRINE & MORAINAL DEPOSITS
- E - EOLIAN DEPOSITS: SILT, SAND & VOLCANIC ASH
- G GLACIOFLUVIAL DEPOSITS. SAND OR GRAVEL, RARELY SILT
- L - LACUSTRINE & POND DEPOSITS. SILT & SAND, RARELY ORGANIC OR GRAVEL
- M - MORAINAL DEPOSITS TILL, OCCASIONALLY GRAVEL, SAND & SILT
- O - ORGANIC DEPOSITS. PEAT ORGANIC SILT, RARELY MARL
- R - BEDROCK

TEXTURAL MODIFIERS

- a - SAND OR GRAVEL COARSE GRAINED
- b - BOULDERS, BLOCKS, BOULDERY BLOCKY
- c - CLAY, CLAYEY
- d - DIAMICTON, UNSORTED MATERIAL
- f - FINE-GRAINED, SILT, SAND, CLAY, FREQUENTLY ORGANIC
- g - GRAVEL, GRAVELLY
- m SILT, SILTY
- o ORGANIC
- p - PEAT, PEATY
- r - RUBBLE, RUBBLY
- s - SAND, SANDY
- t TILL
- v - VOLCANIC ASH, TEPHRA
- x - COMPLEX

PROCESS or FORM MODIFIERS

- (A) - ACTIVE ALLUVIATION
- (E) - STREAM ERODED STREAM ERODING
- (G) - CHANNELLED BY MELTWATER STREAMS
- (L) - MODIFIED DUE TO SLOPE FAILURE OR RAPID MASS MOVEMENT
- (P) - PITTED (KETTLE HOLE)
- (S) - SOLIFLUCTION LOBES & TERRACES
- (k) - THERMOKARST, MODIFIED BY THERMO KARST
- (V) - GULLIED
- (W) - WAVE WASHED
- (Z) - PATTERNED GROUND

MORPHOLOGIC MODIFIERS

- A - APRON
- B - BLANKET
- C CHANNEL (NO VEGETATION COVER)
- D DELTA
- F FAN
- G - GENTLY SLOPED (<5°)
- H - HUMMOCKY
- M - ROLLING, UNDULATING
- N - MODERATELY SLOPED (5°-15°)
- P - PLAIN, POND
- R - RIDGE
- S - STEEPLY SLOPED (>15°)
- T - TERRACE
- V - VENEER
- X - COMPLEX

BLANKET - CONTINUOUS COVER GENERALLY 0.5-3 METRES THICK

VENEER - BROKEN THIN COVER AVERAGING 0.5 METRES IN THICKNESS

MAP 3-5.4
KLUANE LAKE REGION ALTERNATIVES:
LAND STATUS
SHEET 1 OF 2

LEGEND

YUKON TERRITORY

TERRITORIAL LANDS
(GOVERNMENT OF CANADA ADMINISTERED)
ENVIRONMENT CANADA
- KLUANE NATIONAL PARK
WATER SURVEY RESERVE
DEPT. INDIAN AFFAIRS AND NORTHERN DEVELOPMENT (NORTHERN PROGRAM) — DIAND
- INDIAN AND INUIT AFFAIRS — I & IA RES
- MINING CLAIMS
AGRICULTURAL/GRAZING LEASE/TITLE
MINISTRY OF TRANSPORTATION — MOT RES
PUBLIC WORKS CANADA
- BRIDGEHEAD RESERVE — PWC BH RES
- GRAVEL PIT RESERVE — PWC GP RES
- ROAD RELOCATION RESERVE — PWC RR RES
REVENUE CANADA CUSTOMS RESERVE

COMMISSIONER'S LANDS
(TERRITORIAL LANDS COMMISSIONER ADMINISTERED)
DEPT. OF HIGHWAYS AND PUBLIC WORKS: — YTG GP RES
DEPT. OF MUNICIPAL AFFAIRS
BLOCK LAND TRANSFER
DEPT. OF RENEWABLE RESOURCES
- CAMPGROUND RESERVE
RECREATIONAL RESERVE
REST AREA
BOAT LAUNCH RAMP
KLUANE GAME SANCTUARY

PRIVATE LANDS
- RESIDENTIAL, RECREATIONAL OR COMMERCIAL LEASE/TITLE

BRITISH COLUMBIA
MINISTRY OF LANDS, PARKS AND HOUSING
B.C. RECREATION RESERVE

MISCELLANEOUS
COMMUNITY WATER WELL OR INTAKE
FLOAT PLAN DOCK

MAP 3-5.4
KLUANE LAKE REGION ALTERNATIVES:
LAND STATUS
SHEET 2 OF 2

LEGEND

MOT RES

PWC BH RES
PWC GP RES