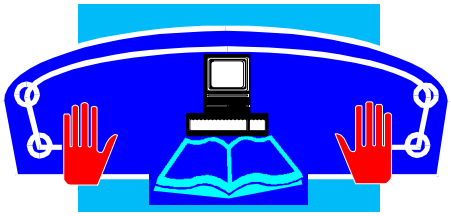


Mackenzie Valley Gas Pipeline - Potential Cost Overruns

Type of Study: Analysis/review

Mining/oil/energy, Nwt Gas Industry

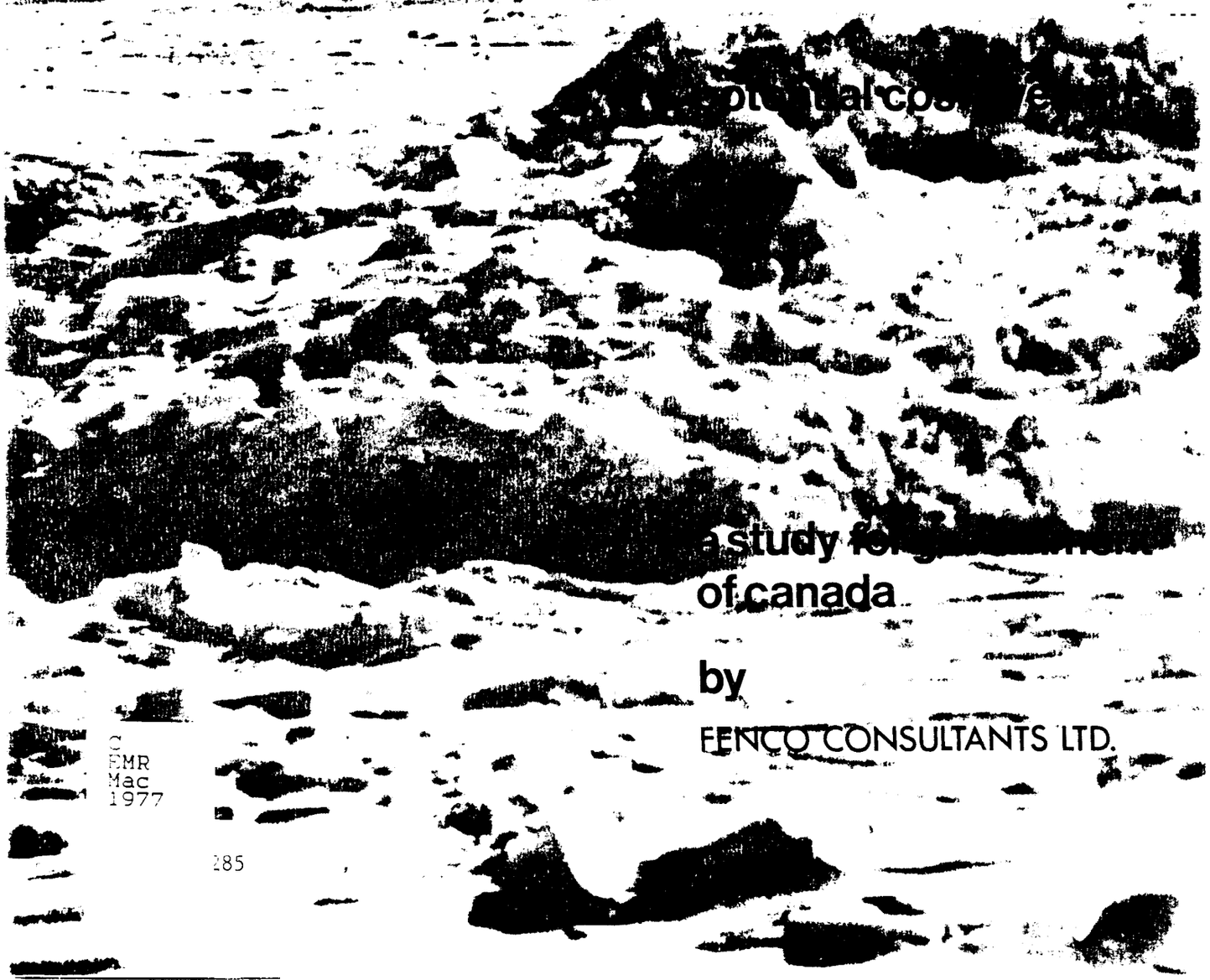
Date of Report: 1977

Author: Fenco Consultants Ltd.

Catalogue Number: 6-2-10

executive summary

mackenzie valley gas pipeline



a study for the government of canada

by

FENCO CONSULTANTS LTD.

executive summary

mackenzie valley gas pipeline potential cost overruns

a study for the
government of canada

Planning
Engineering
Project Management

FENCO

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March 30, 1977

Energy, Mines and Resources
580 Booth Street
18th. Floor, Room 1935
OTTAWA, Ontario

Attention: C. R. Winter - Chairman
Senior Advisor
Petroleum Resources Division

Dear Sir,

MACKENZIE VALLEY GAS PIPELINE
POTENTIAL COST OVERRUN
FINAL REPORT
DSS FILE NO. 11KT. T9200-6-6524

The Cost Overrun study contained herein was commissioned on October 1, 1976 and we trust that the product of the ensuing examination will be of assistance to the Government in their deliberations on a gas pipeline undertaking.

A number of suggested on-going study matters have been itemized in the report in Section 4.3. Should you wish to discuss any part of these or other parts of the final report, FENCO would be pleased to be of assistance.

We have found the assignment to be a difficult and challenging one, and we appreciate having had the opportunity of working with you and your Steering Committee.

Yours very truly,
FENCO CONSULTANTS LTD.

GBM/jcs
6735-100

G. B. Morris, P.Eng.
VICE PRESIDENT

* *This summary document is a portion of the full report (referred to above) which was available for Public viewing by appointment at the library of:*
FENCO CONSULTANTS LTD.
1 Yonge Street
Toronto, Ont.
M5E 1E7

THIS REPORT IS THE RESULT OF A STUDY CONDUCTED BY FENCO CONSULTANTS LTD , IT PRESENTS THE PROFESSIONAL OPINION OF THE CONSULTANT AND DOES NOT NECESSARILY REPRESENT THE VIEWPOINT OF THE GOVERNMENT OF CANADA OR OF THE DEPARTMENTS INVOLVED IN THE STUDY,

APRIL 1977

INTRODUCTION

1.1.1 Project Description

Canadian Arctic Gas Pipeline Ltd. and Foothills Pipeline Ltd. have applied for authority to build natural gas pipelines from Arctic fields to southern markets. Each total project includes a major section north of 60°N. and new pipelines and/or expansion of existing systems south of 60° N. This study is primarily concerned with the sections north of 60° N. in Canada. These two pipelines are respectively 1,000 miles and 800 miles long. Peak carrying capacity of the two pipelines is projected to be 4.5 Bcfd for CAGPL and 2.38 Bcfd for Foothills.

1.1.2 Purpose of Study

The projects will have a major impact upon the Canadian economy and social structure and, if approved, may require financial support of the Canadian government. Those portions of the projects located north of 60°N. will be built through terrain where, for the most part, conventional design and construction is unsuitable. There is a real risk of substantial overrun of projected costs in these Arctic Sections. This study attempts to identify the source of such risks and their potential magnitude.

1.1.3 Terms of Reference

The study of cost overruns began on October 1, 1976 with a very limited budget of $200,000 for the purpose of assessing the work done by CAGPL and Foothills at costs of some $125 and $8 million respectively. Throughout the study, comparisons of relative overall suitability of the Applicants' projects were avoided. Moreover, no attempt was made to quantify risk for factors of environment, native peoples, land claims or gas field reserves.

Firm decisions were difficult to arrive at on the basis of hearings data, inhibited by many factors. New testimony pro and con was continually being introduced by the Applicants, including new engineering approaches and schedule and cost updating. Berger hearings staff conclusions were published along with F.P.C. statements and could affect the project approach.

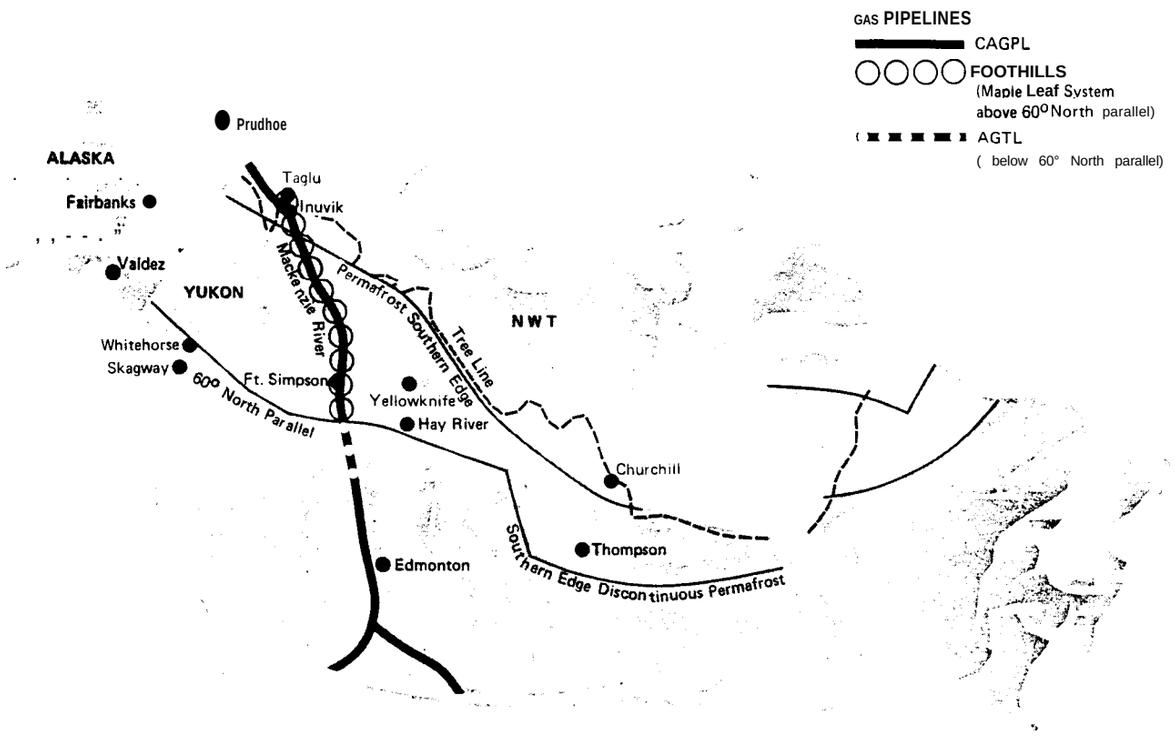
Finally and most crucial has been the mid-February 1977 partial submission by CAGPL of changed design to deal with the frost heave problems, with a one year schedule deferment. This latter submission is not complete and its impact upon the report cannot be fully assessed at this time other than to say that it will be substantial.

The study addresses those portions of the proposed gas pipelines in Canada north of 60° N, the characteristics of which are as follows.

PIPELINE	CAGPL	CAGPL SUBMISSION FEB.1977	FOOTHILLS
pipe uninsulated miles	1,006	845	817
insulated miles		161	
diameter (inches)	48-		42
thickness (inches)	0.72		0.54
Compressors (number)	20	21	17
Refrigeration plants (no.)	16	14	13
Mechanical Coolers (no.)		5	
Max. inlet gas flow Bcfd.	4. 5		2.38

1.1.4 Study Assistance

It should be stated that both CAGPL and Foothills have afforded the Study the utmost in helpful co-operation, in furnishing information of every kind, often at considerable inconvenience to themselves. These data included such matters as breakdowns of hearings submissions and support of those positions, beyond what was readily available in their documentation. Seminars provided by both parties added immeasurably to the Study's understanding of the total concepts involved.


GAS PIPELINES
CAGPL
FOOTHILLS
(Maple Leaf System
above 60° North parallel)
AGTL
(below 60° North parallel)
Prudhoe
ALASKA
Taglu
Inuvik
Fairbanks
Valdez
YUKON
Mackenzie River
Permafrost Southern Edge
Tree Line
NWT
Whitehorse
Skagway
Ft. Simpson
600 North Parallel
Yellowknife
Hay River
Churchill
Thompson
Edmonton
Southern Edge Discontinuous Permafrost

1.2.1 Major Risks

Overrun risks of up to several billions of dollars are possible in the event of three years' failure to meet projected schedules. This is termed slippage. The causes of slippage are most likely to be:

i Selection of technology, particularly in the area of new construction techniques, which do not allow schedules to be maintained, The most contentious single item in this category is the selection of temporary winter roads and snow roads as means of access and working platforms. Since the overall construction schedule depends on a continuous cycle of summer barge transport followed by winter construction, difficulties in either area would tend to be of a compounding nature, thus increasing the risk of schedule slippage.

ii Failure to properly manage such enormous projects.

iii Application and enforcement of regulations and stipulations in a manner which either prevents proper planning of compliance, or impedes progress, or both.

Initially, it was not anticipated that consideration of these items would form a part of the study, but, as each specific cost item was examined, it became increasingly evident that although many items (discussed in 1.2.2 below) had a potential for cost overrun, the risk here would be relatively small in comparison to the major risks referred to above.

There are still other potential causes of slippage which could add substantially to the cost. These include unsettled native land claims and direct and indirect labour strife which are outside the scope of this study.

One other aspect of the pipeline comparison should be mentioned, Only Arctic Gas requires the pipeline leg across the Arctic North Slope to the Prudhoe gas field in Alaska. This region holds more risk than that of the area along the Mackenzie River valley.

1.2.2 Other Risks

Both permit Applicants have prepared comprehensive construction schedules and cost estimates which, broadly speaking, are comparable. Within these estimates are specific possibilities for cost overruns as well as counterbalancing savings.

Some examples of potential cost overrun are:

i cost of borrow materials such as gravel;

ii late freeze-up, early break-up or lack of snow for snow roads, adding to transport and construction costs;

iii strikes, wobbles or slow downs by the labour force;

iv Injunctions or other delays due to local residents' rejection of the pipeline or because of unsettled land claims;

v tight construction schedules,

Some examples of potential savings are:

i tax and duty refunds presently carried as costs in the estimates;

ii innovative design and construction equipment to serve as alternatives to currently planned more conservative approaches;

iii savings on quoted prices for materials and equipment;

iv better than anticipated construction productivity.

When compared to the major risks discussed in paragraph 1.2.1 above these factors are relatively smaller but still these variables have potential cost variations of tens and even hundreds of millions of dollars. If design and planning are allowed to proceed in an orderly fashion, on a sound basis, cost estimates can be fixed to within more certain limits prior to construction by reducing the unknowns to a more manageable degree.

1.2.3 Schedule Risks

It is felt that the schedules as currently presented, especially those for CAGPL, may be optimistic for Arctic work, particularly as they rely upon technology for means of access as yet unproven on such a massive scale. Examination of other similar Arctic projects indicates that the actual work of construction is the least restrictive part of completing an Arctic project. The most difficult part is to schedule and transport men, materials and equipment to the work sites and to have the necessary support facilities there to maintain a suitable working environment. It is mandatory that fully prepared recovery plans and alternatives be available for use in the event that project plans do not work out as originally conceived.

Inability to react successfully and quickly to adverse situations affecting all construction spreads could conceivably frustrate a complete season's work. Both Applicants are, of course, aware of this possibility and are considering programmed to minimize the risk. Slippage of one year could increase the cost to CAGPL by S0.5 to S2.0 billions in slippage costs alone and to Foothills by proportionally smaller amounts. This is in addition to the base cost technical overrun which, it is estimated, could be as high as $1.2 billion for CAGPL and S0.8 billion for Foothills,

POTENTIAL COST OVERRUNS

1.3.1 Construction Cost Estimates Chart

The following chart of "oil-producing installations insevere operating regions'' was published in the Oil and Gas Journal, December 20, 1976.

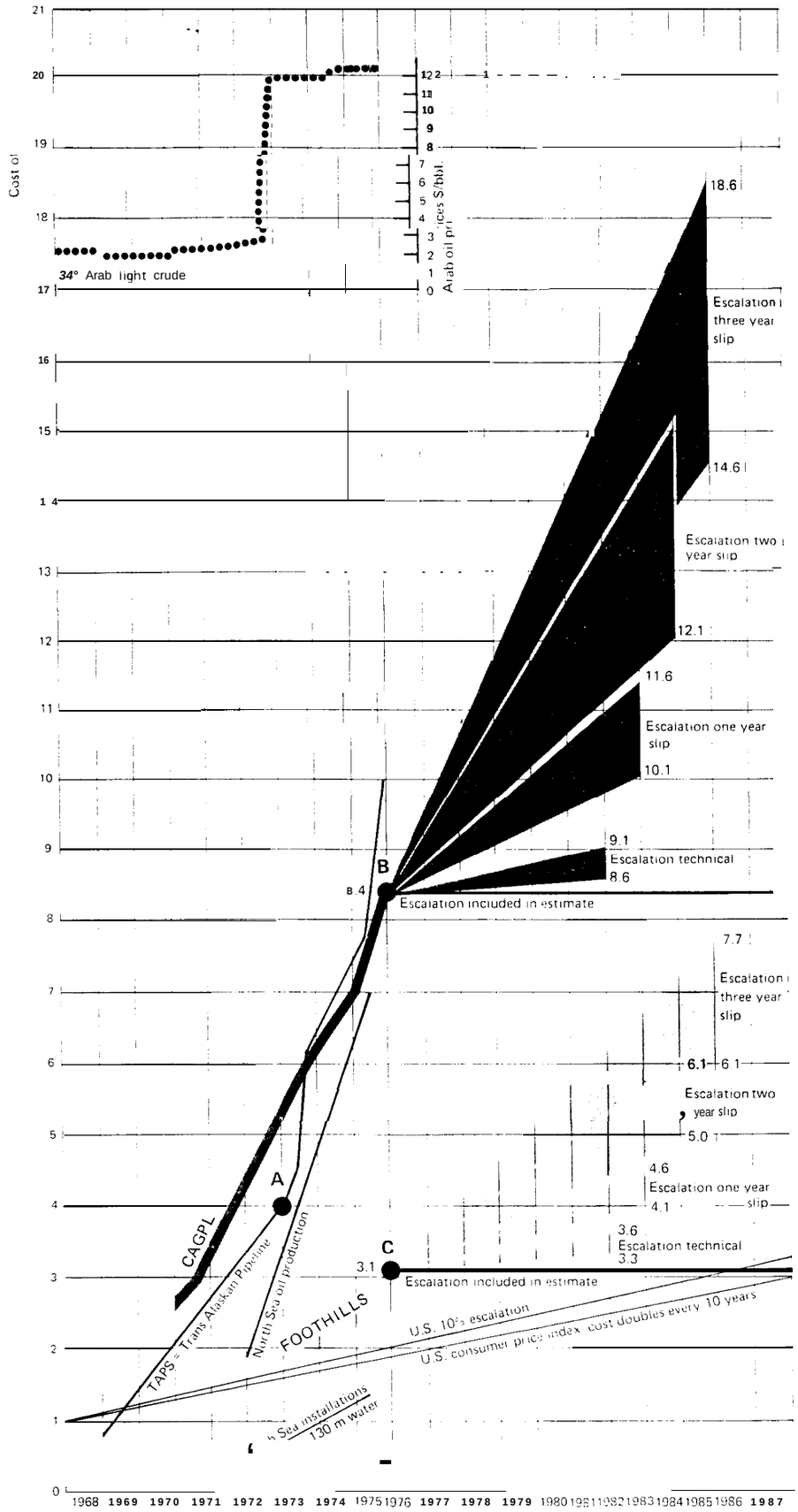
This chart indicates the escalation of cost estimates over the period of time from 1968 to 1976 for such projects as the Alyeska pipeline, North Sea installations and the Trans-Peru pipeline, plus other indices such as the U.S. Consumer Price Index and the Arab light crude price. To this chart has been added cost estimate information for CAGPL and Foothills as periodically published.

It should be noted that points B and C respectively on the CAGPL and Foothills curves might correspond to the equivalent project timing represented by point A on the Alaskan pipeline curve (the point at which that project received permission to proceed).

The chart has then had added to it the projections for cost overrun estimates based on schedule slippages and technical problems to indicate the exposure of the projects.

It should be noted that in February 1977, CAGPL submitted to N.E.B. new proposals for dealing with frost heave as well as a one year deferment of scheduled gas production. This submission has been only partially made. It totals a half billion dollars added capital cost. This has not been reflected in the chart. It is believed that these CAGPL changes will affect many aspects of this report.

Cost **Estimate Projections**



% Over-Run
74 to 121
44 to 80
20 to 38
2 to 8
0
97 to 148
61 to 97
32 to 48
6 to 16
0

Note:
CAGPL Figures Increased $0.5 Billion By Feb. 1977 Submission Over Those Charted Here

Extract from "The Oil and Gas Journal" Dec 20, 1976, with CAGPL & Foothills record added

COST BREAKDOWN

1.4 Each Applicant has submitted capital cost **estimates** for their respective systems. The estimates in summary form are as follows (All costs are shown in millions of dollars):

	CAGPL				Foothills	
ITEM	TOTAL SYSTEM IN CANADA		CANADA NORTH OF 60°N.		MAPLE LEAF System	
	Escalated	Unesc.	**Escalated**	Unesc.	**Escalated**	Unesc.
1. Total System	8,434	5,525	5,154	3,374	3,085	N/A
2. Breakdown of Total System:						
- Labour	N/A	996	N/A	668	532	N 1A
- Equipment	N/A	443	N/A	299	306	N 1A
- Material	N 1A	3,274	N 1A	1,953	904	N/A
- Sub-Contr.	N/A	80	N/A	44	578	N/A
Indirect cost	N/A	732	N/A	410	765	N/A

Foothills' costs include only those of the "Maple Leaf" system which excludes 6 miles of AGTL (Canada) system required to connect the "Maple Leaf" system to the AGTL Alberta system.

It should be noted that the CAGPL costs have been increased by $543 million as a result of their February 1977 submission to the N. E.B. which contained amendments of the frost heave design and also deferral of construction schedule by one year. The costs of this amendment have not been included in the above table nor are the cost breakdowns presently available.

Cost Breakdowns were submitted by the Applicants in two forms: "Escalated" and ''unescalated'', based on 1976 dollars,

The "Escalated Costs" refer to the fact that Facility Costs, used in preparing their cost summaries, nave been escalated for future assumed cost increases above current levels.

The ''Unescalated Costs" were prepared on the same basis but were not escalated beyond the 1976 cost base.

It should be noted that escalation factors used by the Applicants in preparing their estimates were not analysed by FENCO.

- *N/A (no t a vailable) – Breakdown figures were derived from Applicants' estimates and not all breakdo wns were made available.*

1.5.1 General Considerations Related to Cost Overruns

Four broad categories of uncertainty were identified as having significant potentials for cost overrun impact. These items do not lend themselves readily to cost quantification, but were important factors contributing to overall judgments of risk in specific cost areas.

1.5.1.1 Design

The Applicants' design effort is still at a preliminary stage in many areas and, in fact, fundamental design concepts are still undergoing change, as evidenced by CAGPL's current (Feburary 1977) frost heave design amendment.

FENCO does not doubt that adequate designs can be achieved, but rather questions whether or not there will be a sufficient budgeting of time and money to execute this design function properly prior to commencement of construction. A study commissioned by the British Government on North Sea cost overruns provides well-documented case histories of substantial cost overruns because of design revisions occurring at a late stage. It is FE NCO'S judgement that the northern pipeline projects could be vulnerable to the same kind of problem,

1.5.1.2 Project Management

FENCO has judged this to be the single most important risk factor for the following reasons:

i use of Arctic construction techniques on a scale previously untried;

ii unprecedented design;

iii massive scale of work which will strain the supply of human resources;

iv tight schedule restrictions related to winter work limit the practicality of contingency alternatives;

v vulnerability to labour problems and disputes with local residents.

If construction scheduling allows an adequate opportunity for "learning" time by the management team, these problems can be reduced.

Since neither Applicant has yet made specific plans for his management systems, this area remains one of uncertainty.

1.5.1.3 Regulatory Jurisdiction

The nature of the regulatory authority is unknown at this time. If the Berger commission staff report is illustrative of the form that such regulations will take, then such regulations may be overly complex and can cause difficulties in compliance. Similarly, the single Agency concept discussed in the Berger staff report appears to be unduly fettered by outside monitoring and would have difficulty functioning in a responsive and timely fashion. Difficulty in the regulatory process would greatly impede project management.

1.5.1.4 Construction Plan

There is a significant degree of difference between the two Applicants in terms of their opinions as to the amount of work that can be achieved in the winter months. Foothills adopts a more conservative approach by scheduling winter work to commence in January, whereas CAGPL commences in November.

Furthermore, Foothills believes that it is not possible to work productively on the North Slope in the winter, whereas CAGPL has scheduled all their work in this area for the winter months. FENCO does not believe that it is impossible to work

in the winter in these areas, but does judge CA GPL'S construction plan to have greater risk of slippage than Foothills'.

1.5.2 Construction Operations

1.5.2.1 **Logistics**

The approach taken by FENCO was to compare the logistics cost estimates submitted by each Applicant. Based upon such comparisons and FE NCO's independent judgement, cost overrun estimates were made in each logistics category, In a few instances, a judgement was made that an overly conservative estimate had been made and an underrun potential was identified.

In general terms, the Applicants' logistics plans are similar, being dependent on the Mackenzie River barging system for the majority of their material movement. Foothills does plan a somewhat greater reliance on trucking than does CAGPL.

The greatest difference in the cost estimates occurs in the area of materials handling costs both at the staging and stockpiling sites. While both Applicants have similar equipment fleets and labour forces, Foothills forsees considerably higher operating costs, particularly for equipment. CAGPL has considerably less in their estimate for provision of items such as warehouses and other building facilities at stockpile sites. overrun potentials were identified accordingly.

Foothills does not allow for construction of new airstrips and depends on existing airstrips to meet its needs. CAGPL allows for construction of several new airstrips. Since no all-weather access exists, it was FE NCO's judgement that CAGPL'S position in constructing additional airstrips will be necessary and a cost overrun potential was Identified for Foothills.

Finally, the dependence of the logistics plan on the Mackenzie River barging system with its seasonal restraints creates a considerable risk of failing to meet annual targets.

Accordingly, an overrun potential for additional contingency transport by winter road and air freight was assessed.

In summary, the overrun potential for each Applicant is shown below (unescalated).

LOGISTICS FUNCTION	CAGPL 1s000,000)	FOOTHILLS (s000,000)
Staging	9	–8
Transport	26	23
Stockpiling	59	15
Mobilization/De-mobilization	6	–
Contingency Transport	55	**30**
Air strips	–	**46**
	155	60*

Estimated Range	CAGPL High	CAGPL Probable	CAGPL Low	FOOTHILLS High	FOOTHILLS Probable	FOOTHILLS Low
	200	**155**	**100**	90	60	**30**

' *Excludes airstrips inasmuch as the cost for airstrips is shown as an overrun in In fras true ture.*

1.5.2.2 Camp Utilization

The principal difference between the Applicants' plans is that CAGPL envisages the movement of their camps during the construction season whereas Foothills does not. In FENCO'S judgement, a plan without movement during the winter season is preferable, in order to reduce risks. CAGPL had filed such a plan as rebuttal evidence at F.P.C. hearings. Based on costs as filed by CAGPL, the cost overrun potential for CAGPL was estimated. On the basis of a comparison with CAGPL'S costs, an estimate was made of cost overrun potential for Foothills. Cost overrun potential is summarised below (unescalated).

CAGPL **($000,000)**	Foothills **($000,000)**
60	31

1.5.2.3 Roads

The subject of roads for access and working pads for pipeline laying is a matter of disagreement between the Applicants, The matter is extremely critical to the project's success, Not only do the CAGPL and Foothills approaches differ but there is a wide variance in their estimated costs. Moreover, there is no certainty that the government will consider all the construction methods proposed as being environmentally acceptable.

By and large, CAGPL has used processed snow to surface the road and working pad. Foothills has used a winter road surface based on frost driven into the ground and surfaced with ice and snow.

Both parties have made their estimates and itemized their costs under various categories in a manner that makes the cost analysis and comparison difficult, and it was only with considerable assistance from the Applicants that meaningful comparisons could be made.

in addition to these two estimates for snow and winter roads, Environs made a submission in the form of the Green Report. This dealt with snow roads and was subsequently rebutted by CAGPL. Green's snow road cost estimates were higher than CA GPL'S as given in the subsequent rebuttal but about the same as shown in the FENCO analysis.

Because of these uncertainties and disagreements, FENCO has attempted to make separate snow road and working pad estimates. It's figures arrived at exceeded the other estimates, owing to the use of greater thicknesses of processed snow, longer haul distances and greater surface maintenance. The following are the concluding comparison costs (unescalated):

	Pipeline Miles requiring Snow road	FENCO estimated per mile S(000)	FENCO Estimate Total S(000)	Applicants' Estimate Total S(000)	Potential Overrun S(000)
Construction					
CAGPL	850	180	153,000	**99,000**	**54,000**
Foothills	600	180	108,000	14,000	94,000
Maintenance During Construction					
CAGPL	850	59	50,000	**10,000**	**40,000**
Foothills	600	59	35,000	3,000	32,000

The large scatter in estimated costs underlines the need for agreement between the designer, constructor and regulatory authorities as to the type of road required.

1.5.2.4 Borrow Materials

The requirements for borrow materials are very large being given as 30 million cubic yards by CAGPL and 14 million cubic yards by Foothills. There is a major risk related to these materials for such quantities located or to be located throughout the north, not only as to quantity but as to quality and condition. It is FENCO'S judgement that there are overrun risks in the order of $150 million for CAGPL and $80 million for Foothills. In addition, a $47 million overrun is shown here for provision of airstrips on the Foothills system. There are risks of schedule slippage and the snowballing of such effects on other construction operations arising from borrow operations.

1.5.2.5 Mackenzie Highway

The completion of the missing 440 mile portion of the Mackenzie Highway has not been a part of either Applicant's submissions. However, seeing the pipelines' need for year round access is so great, its completion would result in reduced pipeline costs and a highly desirable increase in flexibility, as well as a substantial reduction in the risk of cost overruns. Rough cost estimates were made which indicated that the savings to the pipeline might well equal the cost of completion of the highway, and on a macro cost benefit basis, the highway could be considered as being built at no cost Increase in the regional development sense.

1.5.3 **Construction Operations (Gas Carrier)**

1.5.3.1 Pipeline Construction

Each of the specific activities involved in pipeline construction was examined and discussed in terms of its cost overrun or underrun potential.

Any operations depending on unproven or untried procedures were judged to have a considerable degree of cost variation potential, either as to overrun or underrun. An example of this would be ditching, where successful operation of a "Superditcher" prototype could reduce costs. Conversely, in soil conditions more difficult than expected, ditching costs could increase. Similarly, welding represents an area of risk, Procedures required to obtain quality welds could be more time-consuming and costly than presently envisaged. On the other hand, successful development of automatic welding procedures could reduce costs.

Operations such as backfilling and cleanup will be highly dependent on the environmental stipulations laid down in the permit, and it is judged that they will have significant overrun potential but little underrun possibility.

Finally, some operations are uncertain with respect to conditions anticipated in design conditions (such as river crossings), *or* are inherently risky by their very nature (such as hydrostatic testing].

In order to assess overrun potential, each Applicant's estimate was compared in equivalent sections of their systems. It was found that in terms of labour and total costs, both Applicants' estimates were generally comparable when allowance was made for the fact that Foothills has a smaller diameter, thinner wall pipeline. On the basis of these comparisons and FE NCO's judgement, each operation was assessed for overrun and, if applicable, underrun potential on percentage terms. Wherevera significant difference occurs between the Applicants' base cost estimates, an adjustment was made to the higher level before application of the percentage overruns or underruns. This is refereed to as an "Adjusted Total" in the following table which summarizes the net results of the pipeline construction overrun potential (unescalated dollars).

	CAGPL		FOOTHILLS	
Item	($000,000)	%	($000,000)	%
1. Applicant's Base Estimate Total	635	—	336	—
2. Adjusted Total	710		396	—
3. Range of Overrun Potential				
High	438	62	204	52
Low	-137	-19	-53	-13
Probable	150	21	76	19

1.5.3.2 Pipeline Material

The costs of pipeline materials are predominantly those of pipe. A comparison was made of the Applicants' estimates for pipe and it was found that they corresponded to within $20/ton (Foothills $780/ton, CAGPL $760/ton). Since the Applicants (particularly CAGPL) have already had extensive discussions and preliminary negotiations with pipe suppliers, it is not believed that this item offers a significant cost overrun or underrun potential, A plus or minus ten percent cost potential was assigned to pipeline materials as follows (unescalated):

	CAGPL ($000,000)	Foothills ($000,000)
Total	904	423
Overrun	**90**	**42**
Underrun	-90	-42

1.5.3.3 Compressor and Refrigeration Stations

The Applicants propose to use similar types of compressor stations, with those in the northern part of the Mackenzie Valley and across the North Slope being refrigerated. At this time, both Applicants are basing their costs on typical designs which do not reflect specific site considerations.

The principal difference in design assumptions is the use by Foothills of aero-derivative type gas turbines, whereas CAGPL assumes industrial type turbines,

On a cost per horsepower basis, CAGPL costs are approximately 50% higher than Foothills It was FE NCO'S judgement that CAGPL's unit costs should be imposed on the Foothills estimate, thus adjusting it upwards.

An assessment was then made of the cost overrun and underrun potential as summarized below (unescalated).

	CAGPL ($000,000)	Foothills ($000,000)
Base Cost Est. Total	666	305
Adjusted Est. Total	666	463
Range of Overrun Potential		
High	152	**110**
Low	-67	-46
Probable	42	32

1.5.3.4" Operation and Maintenance Facilities

The Applicants have estimated similar expenditures for these facilities, both in terms of maintenance buildings and equipment. Since there will be a substantial inventory of construction equipment to draw from at the completion of the construction operation, any currently unforeseen maintenance equipment requirements can probably be met from this source.

The cost overrun potential assessed for operation and maintenance facilities is as follows (unescalated):

	CAGPL ($000,000)	**Foothills ($000,000)**
Base Cost Estimate	63	41
Range of Overrun Potential		
High	16	10
Low	o	0
Probable	8	5

1.5.4 Design Uncertainties

The analysis of design uncertainties does not purport to be an exhaustive list of all possible design problems but rather highlights those areas which FENCO judges to be particularly susceptible to major cost overruns.

The major design uncertainty is in the treatment of frost heave problems. CAGPL has recently filed (February, 1977) a major amendment to their pipe design with resultant cost changes. This study has not made detailed assessment of this recent filing, but a very cursory overview of the filing indicates that changes were extensive. With CAGPL'S new position on frost heave, there now exists a wide divergence of opinion between CAGPL and Foothills as to design. If CAGPL is correct, then Foothills would face major cost additions. If Foothills is correct in their approach, then CAGPL could have underruns.

Other areas of design uncertainty Include crack arrestors (applicable to CAGPL only), river crossings, pipe coating (field versus mill applied), and erosion control. Erosion control measures required will be largely dependent on the stipulations attached to the permit. Earlier indications from the Berger staff report are that these conditions could be very demanding. In summary, an overall assessment was made of cost overrun potential arising from design uncertainties. It needs to be stressed that these estimates are strictly judgmental in nature and could change drastically as further information becomes available in these design areas (unescalated).

	CAGPL **($000,000)**	Foothills **($000,000)**
Base Cost Estimate	costs included under other items	$26 + costs included under other items
Range of Overrun		
High	360	120
Low	160	60
Probable	260	90

1.5:5 Construction Productivity

The productivity of the pipeline crews as estimated by the Applicants includes some measure of contingency allowance by, for example, paying the men for a whole winter season, whereas they anticipate losing a certain number of working days per season owing to adverse weather conditions. The efficiency of the crews is most critical to the progress of the work and Canadian pipeliners are respected for their good performance.

Wages of the workmen have been based on present labour agreements and have been escalated over the years as the project schedule progresses. In this respect, there are risks that these escalations might be inadequate, or that the higher Alaska rates and lesser productivity could filter through to the Canadian situation.

A number of mathematical and graphical analyses are made in the body of the full report to illustrate how sensitive the projects are to the productivity of the crews and the effect it has on the overall costs and scheduling. Two of these charts are shown here to illustrate these principles.

1.5.6 **Indirect Costs**

The estimates of the Applicants are derived primarily from the direct costs of construction operations. The remaining costs for overhead and engineering as well as contingency are derived as percentages of direct costs to obtain indirect costs. It is to be noted that the "contingency" item makes no attempt to address the big job contingencies which are dealt with in direct costs, but covers miscellaneous unknowns as a composite coverage.

No attempt has been made to assess the overrun potential of indirect costs except the interest on the invested money in the event of slippage of the schedules.

1.5.7 Schedule Slippage

The study thus far has concluded that the risk of cost overrun from purely technical reasons is not excessive and the estimates made by the two Applicants were defendable.

However, when the possibility of schedule slippage in terms of the date when gas could be delivered to the customer was assessed, it indicated that the risk of cost overrun with slippage could become very large. The projects, subject as they are to many restraints of access, would not likely slip by small lengths of time if they were to do so at all, but would slip by a whole year or more whole years, as the case might be. Moreover, when such slippage does occur, there would be a snowballing effect and the technical aspects of the project would likewise suffer.

The cause of slippage could be any one of many causes or combinations thereof. Some are within the control of management or government, but some are possibly beyond the control of either party. Each of these causes is dealt with in the body of the full report, but is merely listed here:

i Logistics and infrastructure services
ii Design and Construction activities
iii Weather
iv Pipeline route residents and unsettled land claims
v Environmental factors
vi Disaster

Labour Sensitivity to Productivity & Wage Rates (Escalated Cost)

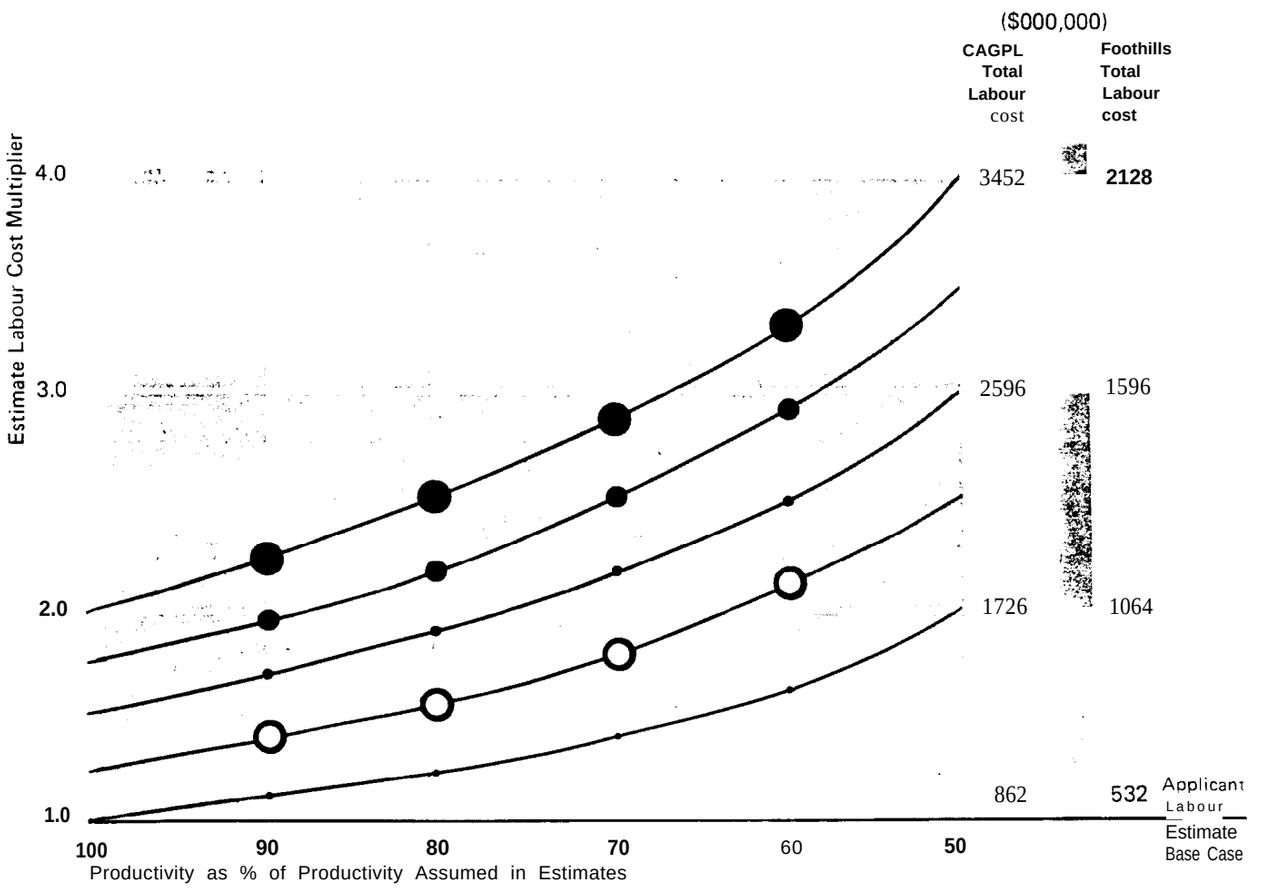
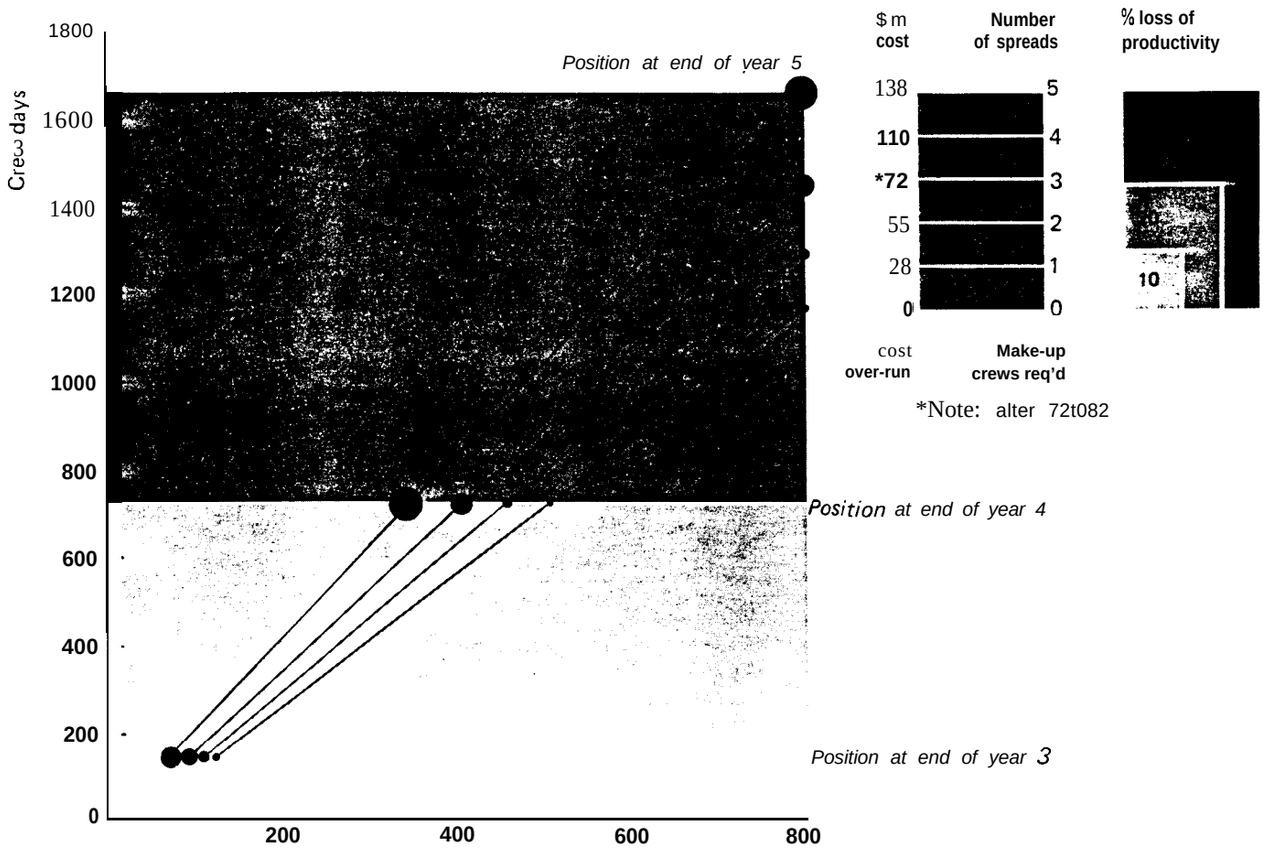


FIGURE C-2: Cost of Make-Up in Year 5 of Construction Shortfalls in Years 3 & 4 (Foothills) **(Unescalated** Cos-



Notes

Average crew days per spread	**87**
Average spread costs	$ m
labour	**16.5**
equipment operating	2.5
equipment write off (assumes 50% over 1 yr.)	8.5
	S 27.5

A similar chart is shown for CAGPL in the main report.

and finally of most importance,

vii Management

viii Government

The cost of schedule slippage and the assessment of other technical risks are summarized in the form of a credibility table which follows. In addition, a chart is provided for CAGPL and Foothills which indicates the cost components contributing to the technical risk totals.

Project Cost and Schedule Credibility – Summary
(1976 Escalated Dollars) *

	CAGPL $ Billions	FOOTHILLS $ Billions
Project	**B.4**	**3.1**
Overruns Technical	**0.2 Unlikely**	**0.2 Unlikely**
	1.2 Likely	**0.8 Likely**
	2.2 Possible	**1,6 Possible**
Slippage Cost		
One Year	**0.5 to 2.0 Likely**	**0.2 to 0.7 Possible**
Two Years	**2.0 to 5.0 Possible**	**0.7 to 1.8 Remote**
Three Years	**4,0 to 8.0 Remote**	**1,4 to 3.0 More Remote**
Project Cost Range		
No Slippage	**8.4 + 0.2 to 0.7 = B.6 to 9.1**	**3.1 + 0.2 to 0.5 = 3.3 to 3.6**
One Year	**8.4+ l.2+0.5t02.0 =10.1 to 11.6**	**3.1 +0.8 +0.2 toO.7 = 4.1to4.6**
Two Years	**8.4 + 1.7+ 2.0 to 5.0 =12.1 to 15.1**	**3.1 + 1.2 + 0.7 to 1.8 = 5.0 to 6.1**
Three Years	**8.4 + 2.2+ 4.0t08.0= 14.6 to 18.6**	**3.1 + 1.6 +1.4 to 3.0 = 6.1 to 7.7**

The above judgement analyses are based on the engineering and other conditions as they existed as of January, 1977.

Note: all figures for CA GPL chart are to be increased by $0.5 billion as per their submission of February 1977 on frost heave and schedule change.

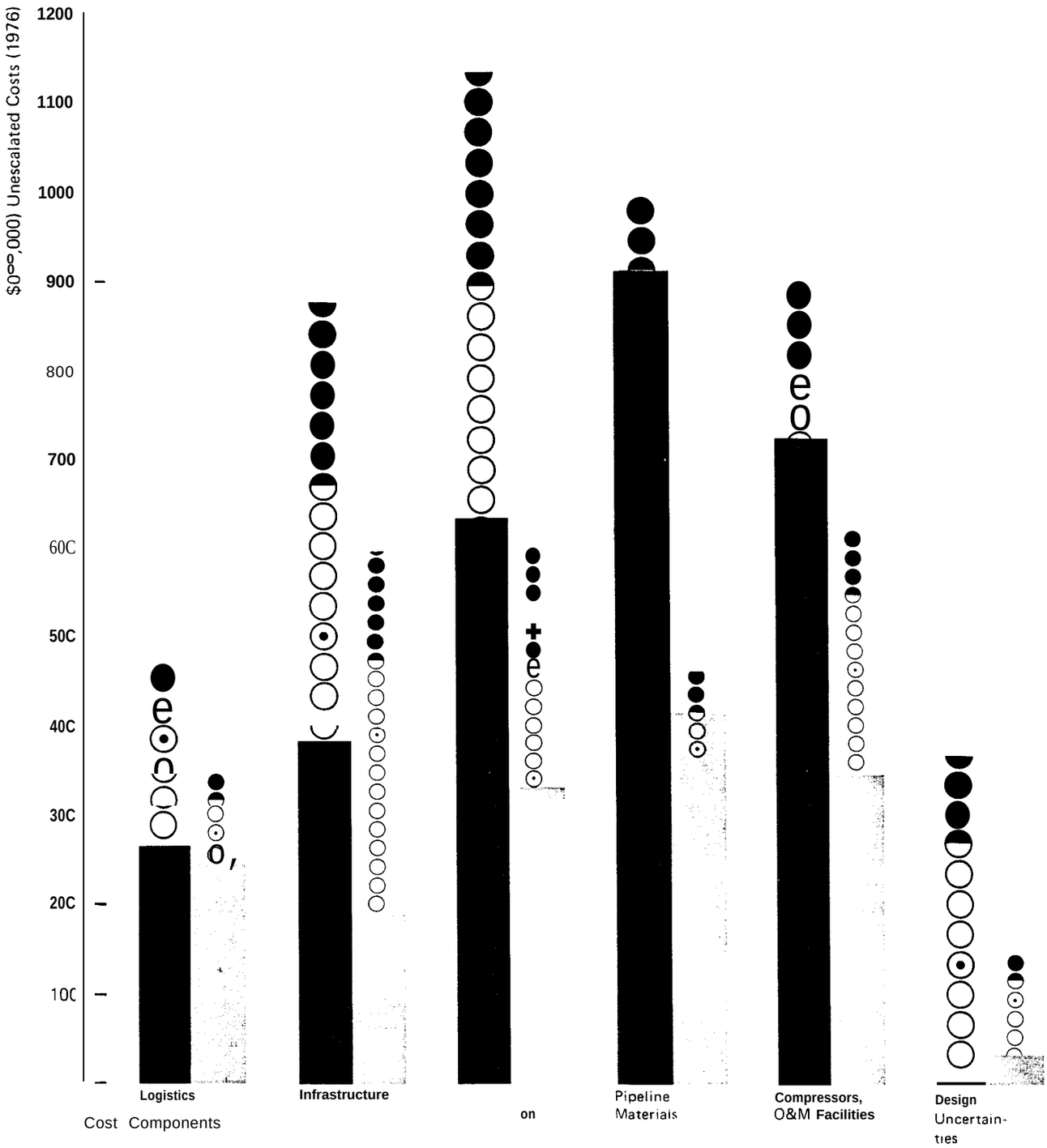
* 1976 *Escalated Costs – are the applicants' projected capital cost estimates based on 1976 market prices, increased to cover inflation over the scheduled project construction period.*

Range of Technical Cost Overrun Potential

Applicant's Base Cost Estimate
Total CAGPL System
Direct Costs
N of 60°N **in Canada = S2,964**

Applicant's Base Cost Estimate
Total Foothills System Cost
Direct Costs = $1,673

CAGPL System
Foothills System
high range of overrun
probable level of overrun
low range of overrun
overrun
Applicant's base cost estimate



1.6 HISTORY OF OTHER MAJOR CONSTRUCTION PROJECTS

There are lessons to be learned from other billion dollars construction projects which have been undertaken recently. Their experience especially in instances where they have been grappling with new technologies and severe environmental situations has been that of severe cost overrun. It would almost appear that some of these projects are becoming too big to be encompassed by human organizational capabilities. Most certainly, a learning curve is involved that must be given adequate consideration.

One of the best lessons is that of the development of the North Sea oil and gas fields. The British Government published a cost escalation study dated December 31, 1975 and their observations are most apt for comparison with the Mackenzie Valley situation. The North Sea pipeline design had to cope with unusually deep and rough waters. Resource shortages affected the project. The learning process proved to be costly. Tight schedules were pushed on the designers and construction contractors with little regard to cost, and escalation rates were phenomenally high.

Alyeska's oil pipeline experience should be an even better object lesson than the North Sea except for the fact that official assessment of their many troubles and increasing costs has not been made public. If The Mackenzie Valley pipeline cannot avail itself of the lessons of Alyeska, the omissions could be costly.

The Canadian Olympics experience, although less pertinent, still contains lessons in the overrun costs due to over-tight schedules and the expense of the unknown technical problems stemming from design innovation.

1.7 ACTIONS TO REDUCE COST OVERRUNS

The success of any multi-billion dollar gas pipeline project out of the Arctic will depend in large measure on the capability and good organization of the Owner and the Government. Risks in this respect overshadow all others. A total capability of one party without the other can invalidate the potential of that capability.

The Owner's organization or systems are not presently in existence. it takes time to put a team together and retaining that team throughout a lengthy project is also a demanding task. In addition to this, the design, despite large expenditures of money, is far from being ready for construction. All these matters as well as many others entail risk of overruns.

Cost **overruns are** likely to **occur despite the best efforts of the project owners.** However, this can be minimized by:

i continuing the critical examination of design schedules and construction modes, and adjusting and altering these when required;

ii managing the work in units that are small enough to be autonomous, and effectively monitoring and controlling costs and schedules;

iii developing recovery plans and alternatives with back-up ready for implementation;

iv allowing sufficient lead time to establish suitable construction facility and design bases which will allow development of optimum project mobilization and construction efficiency;

v providing incentives for all parties to perform as forecast. Implicit in this is allowing each party to perform its function free from unwarranted, untimely and misinformed interference.

Government has its own unique problems best exemplified by those encountered on the Alyeska pipeline. Like the Owner, a governmental system or body has yet to created to deal with the pipeline construction.

Government has the capability of reducing risks to the venture by other means as well. Decisions can be made on duties and taxes at an early date so that the pipeline Owners do not have to wait to know what their exposure or incentives are to be. Completion of the Mackenzie Highway would increase the pipeline construction flexibility and reduce risks of overrun. Decisions can be made by Government to the effect that the pipeline builder knows what transport assists he can expect, what environmental norms he must conform to, whether the land will be available for use, what various assistance will be available in labour relations, and whether a multiplicity of policy decisions will receive specific and timely answers.