SUPPLEMENT TO APPLICATION

FOR

RIGHT-OF-WAY GRANT

VOLUME V

ALASKA SEGMENT

ALASKA NATURAL GAS TRANSPORTATION SYSTEM

Alaskan Northwest Natural Gas Transportation Company

SUPPLEMENT TO APPLICATION

FOR

RIGHT-OF-WAY GRANT

VOLUME V

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COMMENTS ON BASIC 1/
ASSUMPTIONS AND CONCLUSIONS

ASSUMPTIONS

STATEMENT OF ASSUMPTION NO. 1

"The Pipeline will be a cold buried line (chilled below 32°F)."

Response

Concur. This is a valid assumption. The pipeline is designed to operate at temperatures below 32°F in order to mitigate the degradation of permafrost and to avoid thawing of ice rich soils. The alternative of operating at temperatures above 32°F will cause thawing of ice and degradation of the environment (permafrost). In ice rich soils, this would lead to loss of structural strength in the soil around the pipe and threaten the stability of the pipeline.

STATEMENT OF ASSUMPTION NO. 2

"Outstanding environmental and technical concerns will be resolved prior to construction in accordance with the Department of Interior and State of Alaska Right-of-Way Grant Requirements and Procedures."

Response

Concur. Substantial progress has been made in resolving environmental and technical concerns to the point that there is a reasonable basis for confidence that there are no environmental or technical concerns that cannot be resolved fully before construction commences. This progress is reflected by NWA's presentation in the documents submitted with the June 1980 FERC Filing. Additional field data acquisition, office studies, and extensive detailed design work by scientists and engineers will be aggressively pursued over the time remaining prior to commencement of construction.

1/ The Assumptions and conclusions quoted herein were presented to Northwest Alaskan Pipeline Company (NWA) in Enclosure B to a June 13, 1979, letter from Assistant Secretary of the Interior, Guy R. Martin, to NWA's Edwin A. Kuhn.

STATEMENT OF ASSUMPTION NO. 3

"Stipulations will be complied with, which prevents adverse effects in fish passage and wildlife movement."

Response

Concur. NWA has essentially completed the compilation of baseline fish and wildlife data for the project. These data have been used to develop criteria for engineering design, site selection, and construction planning to meet draft stipulations (Enclosure A) which require free passage and movement of fish and wildlife. NWA fully intends to comply with these stipulations. As additional data become available, they will be used to refine and update these criteria.

STATEMENT OF ASSUMPTION NO. 4

"Environmental and technical standards for the Northwest project will be compatible with the standards for TAPS."

Response

Concur. The standards set for TAPS are of a high order, and NWA is in agreement with this concept.

CONCLUSIONS

STATEMENT OF CONCLUSION NO. 1

"A nominal 80-foot Centerline (CL) of oil line to CL of gas line spacing is acceptable. A nominal 70-foot CL Highway to CL of gas line is acceptable; however, there shall be no aboveground structure or appurtenance within 30 feet of the highway shoulder. Workpad requirements and construction modes within Enclosure No. 2 to Northwest Alaskan Pipeline Company letter dated April 30, 1979, to Guy R. Martin are acceptable, with the exception that the spacing on the M9 and M10 drawings should be increased to 80 feet and M1 and M2 drawing spacing should be decreased to 44 feet."

Response

Concur, except with respect to decreasing the spacing in the M1 and M2 drawings to 44 feet. This spacing would require that the haul road be used as a part of the work area, and the State of Alaska position on that subject is: "The highway itself is not to be used as a work pad...." (Letter from Amos C. Mathews, State Pipeline Coordinator, to NWA's Edwin (Al) Kuhn, dated June 22, 1979.) NWA in general concurs in this position for the reasons cited in the response to Conclusion No. 8, below.

(The M1 and M2 construction mode concepts, along with others orginally cited in NWA's letter of April 30, 1979, to Assistant Secretary of the Interior Guy Martin, have been incorporated with modification into the design represented in the June 30 FERC filing and are subsequently referred to as "typical construction zone cross sections.")

STATEMENT OF CONCLUSION NO. 2

"Joint use of R/W is compatible with a 15 foot safety zone adjacent to all related facilities. No activities will occur within the safety zone."

Response

Concur. NWA has designed the gas pipeline to include joint use of the existing workpad (where TAPS and the gas pipeline are adjacent) with a 15 foot safety zone during the construction phase. The 15 foot safety zone will be delineated throughout. Barriers will be placed as required to bar construction activities within the zone.

STATEMENT OF CONCLUSION NO. 3

"Use of the existing workpad in preference to the haul road may not result in:

- o Lower cost of construction
- o Increased potential for environmental protection unless construction mode alternative from Northwest's proposal is used
- o Reduction in commitment of natural resources (land, gravel, energy).

However, a judicious route selection using both the haul road and workpad has advantages and complies with Section 28(p). of Mineral Leasing Act."

Response

Concur. NWA agrees that a judicious route selection using both the haul road and workpad has advantages and complies with Section 28(p) of the Mineral Leasing Act. NWA has made such a selection in the route shown in Enclosure B. Use of the existing workpad throughout would not necessarily result in lower costs, increased environmental protection or reduction in commitment of natural resources. These items are difficult to generalize. NWA studies indicate that they are sometimes true and sometimes false on a site-specific basis.

STATEMENT OF CONCLUSION NO. 4

"TAPS workpad will require extensive upgrading and widening to support the construction effort."

Response

Concur in the sense that the existing workpad will need repair in some locations to bring it up to a standard necessary to support construction of the gas pipeline. NWA has observed that deterioration of the workpad has occurred in some places during recent years, and additional upgrading beyond what was originally anticipated by NWA will be required due to degradation during the several years of project delay experienced to date. Nevertheless, use of the existing workpad is the overall best approach for the areas shown in NWA's current alignment sheets. Furthermore, NWA has observed areas which have not deteriorated. Generally, widening of the existing workpad is required.

STATEMENT OF CONCLUSION NO. 5

"Surface drainage can be accommodated by proper design and location."

Response

Concur. Approved standard drainage structures will be installed during construction to accommodate surface drainage. Drainage structure types that will be used where appropriate are:

- o Acrow truss bridges
- o Laminated wood beam bridges
- o Timber material bridges
- o Multiplate culverts
- o Circular metal pipe culverts
- o Low water crossings
- o Ditches.

The impacts of drainage systems, e.g., extending TAPS culverts, have been reviewed for design purposes. (More details of design and application of solutions can be found in the subsequent enclosure, concerning specific technical issues. Specifically, see the response to Concern No. 12 and also the material in the FERC Filing Exhibit Z-9.1.) Maintaining existing flow patterns and stream locations are prime criteria.

STATEMENT OF CONCLUSION NO. 6

"Winter construction from snow pads is a viable alternative and is expected to be used where desirable from environmental and construction scheduling standpoint."

Response

Winter construction from snowpads has been advocated as a means to minimize environmental impacts. However, the inherent risk associated with the inability to predict, with any degree of accuracy, the availability of natural snow for pad construction, along with the difficulties associated with use of manufactured snow and the extremely high cost of that process, with limited water supplies, virtually preclude reasonable acquisition of fixed-price contracts, establishment of reliable schedule completion dates, and credible project cost estimates. Coupled with the uncertainties of winter weather, cross slope construction, schedule unpredictability, short daylight hours, low winter productivity, and maintenance and annual reconstruction costs, this leads to the conclusion that snow pads cannot be cost effective on this project and that environmental impacts can best be mitigated in other fashions, during normal summer and shoulder month construction.

The use of snow workpads during construction, moreover, would leave no all-weather access for maintenance and operation of this pipeline over its lifetime. Activites such as erosion control (necessary for at least the initial 2-3 years), and maintenance simply cannot be accomplished on a winter schedule without a year-round access. NWA's costs to meet stipulations and regulatory requirements would thus become intolerable. In summary, NWA does not agree that snow pads -- as a primary workpad surface -- are a viable alternative to gravel workpads.

Attached, following this enclosure is a document prepared by Northwest Alaskan entitled: Position Paper: Use of Of Snow/ Ice Roads, Snow/Ice Workpads, and Winter Construction Program, dated June 20, 1980, that further defines NWA's concerns and evaluates the only acceptable construction approach, i.e., conventional summer/shoulder month construction from all-weather gravel workpads.

It is the considered judgment of NWA and experienced Arctic consultants that a mandate for use of snow/ice pad or snow/ice road winter construction cannot be accepted. Consequently, NWA's capital cost estimates are based on utilization of all-weather gravel workpads with a summer and shoulder month construction schedule. Any deviation from this plan, as may be mandated by any government official, must be a change in design or scope that will not affect our performance under the incentive rate of return mechanism. In addition, we will not accept responsibility for the effect that such a mandate would have on our ability to finance the project, obtain fixed price contracts, or prevent schedule slippage.

STATEMENT OF CONCLUSION NO. 7

"Other than the Yukon River Bridge, the pipeline will not be installed on highway bridges."

Response

Concur. NWA does not plan to use any highway bridge to support the gas pipeline except the Yukon River Bridge which was designed so that it is capable of supporting additional pipelines.

STATEMENT OF CONCLUSION NO. 8

"Traffic can be controlled to use part of the Haul Road traffic surface for construction (e.g., TAPS Fuel Gas Line)."

Response

Concur in the sense that the Haul Road can be used for rubber-tired vehicles to support construction. However, the State of Alaska's letter of June 22, 1979, to NWA, referred to above, states, "The highway itself is not to be used as a workpad, although you may apply for an exception where absolutely necessary." NWA, in general, concurs in this position because of the following considerations: safety, avoiding major damage to the highway, minimizing disruption of traffic, and the highly adverse cost and schedule control implications associated with extensive use of the highway surface for construction purposes.

Conclusion No. 8 is valid in the sense that it is possible to control traffic sufficiently on a localized basis to use part of the Haul Road to support construction. NWA plans to apply for exceptions, as suggested by the State, where necessary on a site-specific basis.

STATEMENT OF CONCLUSION NO. 9

"Alignment as proposed and those recommended considerations for realignment are within the constraints of the Presidential Decision, Alaska Natural Gas Transportation System, Federal Land Policy Management Act and the Mineral Leasing Act of 1920, as amended."

Response

Concur. NWA's intent is that the alignment will be within the constraints of the Presidential Decision and all applicable Federal Statutes.

STATEMENT OF CONCLUSION NO. 10

"Controlled blasting will not adversely affect TAPS, but there are special cases where additional analysis is required. (For example, proximity to adfreeze VSM's, thawed and different geologic conditions were not considered in the specific study case.)"

Response

Concur. This is supported by NWA's previously conducted 1977 field blasting tests which will be supplemented and further verified during the 1980 field testing program. The 1980 program will involve a full-scale pipeline mock-up testing facility and ditch stability test sites.

There is no realistic, reasonable alternative to controlled blasting along a majority of the route. Ditching machines have been designed to cut frozen soils, but they have not proved successful in cutting a ditch for 48 inch pipe in frozen granular soil. Rerouting would provide greater separation between TAPS and the gas pipeline, but blasting would still be required. (For further detailed explanation and discussion of controlled blasting and effects on TAPS, see the technical response concerning Blasting in Section 4.0 of the enclosure following.)

STATEMENT OF CONCLUSION NO. 11

"Requirements of 49 CFR 192 have been incorporated into these conclusions and/or assumptions."

Response

Concur.

STATEMENT OF CONCLUSION NO. 12

"The Northwest proposal will not adversely affect the fuel gas line."

Response

Concur. The following concerns have been expressed regarding the fuel gas line at locations where the workpad is placed over the pipeline:

- o Additional fuel gas line stresses will be caused by external loading of NWA earthmoving and pipelaying equipment passing over the fuel gas line. Stress analysis, referenced below, leads to a conclusion that the increase in pipe stresses is within allowable limits on the fuel gas pipeline.

- o Further thermal degradation over the fuel gas line could be caused by the NWA structural workpad which would allow thawing of the subgrade; however, this can be controlled within acceptable limits by appropriate workpad design, as summarized below.

Detailed stress calculations were performed assuming the following:

- o Earthmoving equipment: CAT 769 off-highway truck, CAT 773 off-highway truck, and CAT 657B tractor-scraper

- o Pipelayer equipment: CAT 594 H

- o Depth of unfrozen cover: 18 inches, 24 inches, 30 inches and 36 inches

- o Internal pipe pressure: 0 psig

  NOTE: Alyeska's construction plans indicate 36 inches of cover over the pipeline.

The continuing degradation around the fuel gas line will be limited by the insulating properties of the new NWA structural workpad laid over the existing surface vegetation. Further thermal studies are planned for detail design to reduce pad material requirements and increase insulation efficiency by the use of manufactured insulation material in the workpad.

An alternative worthy of additional consideration is as follows: the fuel supply for TAPS pump stations could be provided from the NWA pipeline. This would eliminate concern for the long-term integrity of the existing fuel gas line, and the fuel gas line could be eliminated entirely following commissioning of the NWA gas line. Informal discussion with TAPS representatives indicates a willingness to consider this possibility.

STATEMENT OF CONCLUSION NO. 13

"There are several generic site-specific conditions where there are insufficient data to determine compatibility between the gas line and other manmade structures. Minimum separation distances cannot be determined until compatibility is resolved. In these cases, the applicant must demonstrate their proposal is compatible. For example, the closer the gas pipeline is to highway (minimum 44' separation centerline highway to centerline gas pipeline) the better environmentally and technically."

Response

NWA does not agree that any "generic" conditions exist that create incompatibility. Separation distances between the gas pipeline and other man-made structures should depend upon a reasonable evaluation of all relevant engineering, construction, and cost considerations. This is a basic concept in all pipeline design, and existing pipelines are separated from other structures by as little as a few inches. Because of its size and its environment, the gas pipeline should be afforded a relatively wide separation. Therefore, a nominal 70 foot separation from a highway and a nominal 80 foot separation from another pipeline have been proposed. The impacts of blasting have been assessed; the possibilities of thermal interference have been studied; and the probabilities of damage during construction have been addressed by the use of barriers between pipelines. Additional data is being collected to support this position.

POSITION PAPER:
USE OF SNOW/ICE ROADS, SNOW/ICE WORK PADS, AND WINTER CONSTRUCTION PROGRAMS

prepared by
Northwest Alaskan Pipeline Company

June 20, 1980

Exhibits

Note: Exhibits are placed at the end of each chapter in order of their exhibit number

Introduction

In accordance with the President's Decision[1] of September 1977 and subsequent Congressional action, Northwest Alaskan Pipeline Company (Northwest Alaskan) has assumed responsibility for financing, designing, constructing, and operating a transportation system to deliver natural gas from Prudhoe bay to lower-48 markets in a cost-effective and judicious manner. To help ensure that this objective is achieved, the President's Decision mandates the use of fixed-price contracts in the execution of the project, with any exceptions requiring special approval from the Office of the Federal Inspector (OFI). In addition, the Federal Energy Regulatory Commission (FERC) has established an Incentive Rate of Return (IROR) mechanism to ensure that the natural gas is provided to consumers in the most cost-effective manner possible.

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1. Executive Office of the President, Energy Policy and Planning, Decision and Report to Congress on the Alaskan Natural Gas Transportation System (September 1977), hereinafter cited as the President's Decision.

The Department of Interior (DOI) has indicated that it may mandate that Northwest Alaskan made extensive use of winter construction techniques, particularly in the pipeline segment north of Atigun Pass in the Brooks Range (Section I)[2]. DOI's announced intentions differ in a fundamental respect with a basic premise upon which the entire Northwest Alaskan project was conceived, justified, and defended before the Federal Power Commission (FPC), selected by the President, and approved by Congress.

Since the Alaskan Natural Gas Transportation System (ANGTS) was originally proposed in 1976, Northwest Alaskan has planned to use only proven construction techniques. The fundamental construction philosophy for the project is of general summer and shoulder-month construction of a buried gas pipeline, using conventional construction techniques, from a full-width, all-purpose, all-weather gravel work pad in all locations where such a pad is required to provide year-round, all-weather access to the pipeline by tracked vehicles for construction, operation, maintenance, or repair.

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2. Letter of June 13, 1979, from Honorable Guy R. Martin, Assistant Secretary for Land and Water Resources, Department of Interior to Edwin A. Kuhn, Director, Government and Environmental Affairs, Northwest Alaskan Pipeline Company.

Specifically, in its original submission to FPC, Northwest Alaskan stated that "a gravel work pad concept, proven in the construction of the Alyeska system, is included in Alcan's plan to allow pipeline construction from March through November. Such a construction season facilitates operating within the 'time windows' established to protect sensitive species and locations; it also includes periods when streams and rivers are frozen. Productivity is enhanced by avoiding construction during the winter period of low efficiency caused by the harsh climate and darkness."[3]

It has always been Northwest Alaskan's position that the use of snow/ice roads, snow/ice work pads, and winter construction programs are unproven construction practices for a large-diameter pipeline of the magnitude of the proposed project. Consequently, these techniques were not planned for any segment of the pipeline as a primary method of construction.

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3. Alcan Pipeline Project, 48-Inch Alternative Proposal, Submittal of Alcan Pipeline Company at Docket No. RM77-6 before the Federal Pipeline Commission, March 1977, page 5.

Northwest Alaskan questions the government's rationale for reopening this fundamental issue, which was explored exhaustively in the events preceding the President's Decision and resolved with the participation of all relevant federal agenies, including DOI. Nonetheless, in response to DOI's letter, and to facilitate timely preconstruction planning and subsequent execution, we have reexamined our position on this important issue. Based on this reexamination, Northwest Alaskan's position is unchanged: we cannot accept a mandate to make use of snow/ice roads and construction work pads.

The adoption of the winter construction concepts proposed by DOI would constitute an imprudent and unsound management decision. The required use of winter construction techniques, particularly snow/ice work pads for pipeline construction will increase the risk of delay or noncompletion to the point where the project cannot be financed or constructed because of the inability to forecast the final cost. Timely completion and project cost control are the major areas of concern to potential debt lenders. Therefore, a decision by DOI to mandate the use of snow/ice roads, snow/ice work pads, and winter construction programs will shift the responsibility for project schedule and cost control from Northwest Alaskan to the government.

The Northwest Alaskan position is based on review and analysis of three areas:

- Construction costs
- Environmental impacts
- Construction contracting, efficiency, and safety.

Based on our analysis in each of these areas, Northwest Alaskan concludes that the use of snow/ice work pads, snow/ice roads, and winter construction programs is not cost-effective, will not minimize environmental impacts, and is impractical from a construction contracting, efficiency, and safety points of view.

The analysis supporting this conclusion is presented in the following three chapters.

1 CONSTRUCTION COSTS

The use of snow/ice work pads for pipeline construction will cost more than three times as much as the use of conventional gravel work pads. Specifically, using a snow/ice work pad, each mile of the pipeline will cost $5,818,015, compared to $1,639,263 when using a gravel pad. For example, if snow/ice pads are used for all 132 miles of Section I of the pipeline, project costs will increase by at least $551,595,264, or $4,178,752 per mile (see Exhibit 1.a and 1.c). The incremental cost to the consumer during the first year of pipeline operations will be at least $108,112,620 for the 132 miles of snow/ice work pads (see Exhibit 1.b).

The increase in project costs results from the following four factors:

- Incremental costs of snow/ice work pad construction
- Incremental costs of snow/ice work pad maintenance
- Incremental costs of pipeline construction from snow/ice work pads
- Impacts on overall system cost of construction schedule slippage.

Incremental Costs of Snow/Ice Work Pad Construction

Construction of snow/ice work pads will cost approximately $840,451 more per mile than construction of conventional gravel pads (see Exhibit 1.c). Although construction of a gravel pad requires more volume of material than a snow/ice work pad, the cost of each volume unit for a snow/ice pad is approximately 5.3 times greater than for a gravel pad.

Based on an analysis of two projects that used snow/ice work pads on roads (NPR-4 and TAPS), we estimate that the cost of constructing a snow/ice work pad capable of withstanding heavy tracked-vehicle traffic averages $2.77 per cubic foot, or $1,128,914 per mile. (We converted the costs of these two snow/ice pads to dollars per cubic foot to eliminate the effects of different pad dimensions.) In 1979, contractors building ice roads in NPR-4 incurred an costs of $0.95 per cubic foot (direct labor and equipment cost). Assuming that total cost for work pad construction in Section I is 2.36 times direct costs,* the equivalent cost would have been $2.24. Adjusted for inflation at 8 percent per year, the 1980 cost would be $2.42 per cubic foot. In November 1975, Alyeska built a snow/ice work pad near Globe

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* The 2.36 multiplier consists of: indirect costs (construction support activities, e.g., camp operations, catering, supervision, etc.) equaled 100 percent of direct costs. In addition contractor' profit and overhead of 18 percent applied to both direct and indirect costs.

Creek on the TAPS right-of-way. Job accounting reports indicate that the snow pad (which was 2,500 feet long, 65 feet wide, and an average of 3 feet deep) would cost a total of $437,353 (direct labor and equipment costs). Again, assuming that total cost is 2.36 times direct costs, the result is a 1975 cost of $2.12 per cubic foot, and a 1980 cost of $3.12 per cubic foot (at an annual inflation rate of 8 percent).

The average of these costs is $2.77 per cubic foot for snow pad construction in 1980.* We used this value to develop a cost per mile for using snow/ice work pads. Because such pads are most likely to be considered in Section I, we used this section for our analyses.

The average dimensions of snow/ice work pad in Section I would be 61.75 feet wide and 1.25 feet thick. The average width was determined assuming a combination of two construction techniques. Specifically, when ditch excavation is not used for backfill, and instead hauled away to a spoil disposal area (i.e., 85 percent of the length of

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* The Arctic Gas Project estimated the costs of using snow pads and roads for construction activities. However, because those estimates include the cost of 955 miles of snow pads and 536 miles of snow roads of unspecified dimensions, we did not believe that they were comparable with this project.

Section I), the work pad surface is assumed to be 55 feet wide. For approximately 15 percent of Section I, the soil can be used for backfill and can be piled adjacent to the ditch on a wider work pad until the backfill activity takes place. This technique results in a snow/ice pad 100 feet wide. The weighted average width for Section I is thus 61.75 feet.

Assuming average work pad dimensions of 61.75 feet by 1.25 feet at $2.77 per cubic foot, a snow/ice work pad will cost approximately $1,128,914 per mile in 1980.

Current estimates of the cost of constructing a gravel work pad of average dimension (37.125 feet by 2.83 feet)* in Section I are $0.52 per cubic foot. These figures were derived from a detailed analysis of the direct labor costs and equipment expenses, indirect costs, and contractors' overhead and profit. The cost of a gravel work pad is therefore estimated to be $288,463 per mile. This is approximately one-fourth the cost of constructing a snow/ice work pad.

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* 37.125 feet average width is the weighted-average of 36.5 miles of Section I 25 feet wide, 78.7 miles 40 feet wide and 16.8 miles 50 feet wide. 2.83 feet is the thickness required to support construction operations during anticipated shoulder-month construction periods.

Incremental Costs of Snow/Ice Work Pad Maintenance

The use of heavy tracked vehicles in pipeline construction will require substantial snow/ice pad maintenance. It is estimated that the top 2 inches of the snow pad will be bladed and rebuilt four times during pipeline construction.*

Using the previously developed costs, we estimate the costs of snow pad maintenance to be $605,098 per mile (61.75 feet x 0.67 feet x 5,280 feet x $2.77). These costs are 23.7 times greater than current estimates for combined gravel pad and road maintenance for Section I ($2,556,000 for 132 miles of pipeline).

Incremental Costs of Pipeline Construction from Snow/Ice Work Pads

Pipeline construction progress can be severely limited by winter temperatures. In fact, Northwest Alaskan estimates that no more than 24 miles of continuous pipe could be laid per section during any winter construction season (see

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* Repairs will be made after passage of major track equipment following pipebending, welding, bedding, and lowering-in activities.

Appendix A). It is estimated that construction costs will be 3.07 times higher ($4,084,003 per mile) if construction takes place in the winter instead of the summer and shoulder months, as currently planned (see Exhibit 1.c)*. This construction estimate incorporates the following assumptions:

- A progress rate of 3,200 feet per day (384,000 feet for four months) will be achieved in the summer and shoulder months**

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* These figures do not include the impact of wind chill on construction productivity. If wind chill is included, the costs per mile could increase to over $8,069,00 per mile constructed from a snow/ice work pad.

** Assuming an average pipe lay rate of 3,200 feet per day per section.

- The average cost per mile for pipeline construction will be $1,331,436 during the summer and shoulder months*

- Additional construction spreads including support must be used to maintain a lay rate of 3,200 feet per spread per day during winter construction from snow/ice work pads.

Using these assumptions and considering ambient air temperature data without wind chill effects, we calculated that pipeline construction costs from a snow/ice pad will be $4,084,003 per mile. This is $2,757,567 per mile more than the estimated cost of construction from a conventional gravel work pad during the shoulder and summer months (see Exhibit 1.c).

Impacts on Overall System Cost of Construction Schedule Slippage

Even if additional spreads were added during the winter to maintain scheduled construction completion, the effects of abnormal temperature and wind chill could delay the project

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* Including both direct costs (survey, ditching, haul and stringing, bend, line up and weld, weld repair, field joints, lower-in, tie-in crews, ditch insulation, bedding, padding, backfill, clean-up, testing, road crossing, and test support) and indirect costs (field supervision, camp maintenance, equipment service, general haul maintenance of vehicles for others, indirect consumables, catering, and 18 percent for contractors' overhead and profit).

for an entire construction season. If the schedule slipped an entire season, the following types of costs would be incurred:

- Execution contractor mobilization for the next season
- Camp utilization costs for an additional season
- Additional season of project management costs
- Costs of delaying overall system completion.

The last cost, delay of overall system completion, is critical. Under the Incentive Rate of Return (IROR) procedure established in the President's Decision, costs incurred by the project will earn a 12 percent return for each year they are invested prior to project completion.

This return (total project costs x 0.12) is added to the rate base. Assuming that the project were completed at estimated costs,* the consumer would be charged the following amount as a result of the schedule slippage (in addition to the incremental costs incurred as a result of construction from snow/ice work pads):

$$\text{INCREASED TARIFF DUE TO DELAY} = \begin{bmatrix}\text{Total}\\\text{Project}\\\text{Costs}\end{bmatrix} \times (0.12) \times (0.175).$$

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* An overrun due to schedule slippage as a result of snow/ice work pad construction will be allowed as a design change by the Office of the Federal Inspector (OFI). Therefore, the overrun would be added to the original Certification Cost Estimate filed with the Federal Energy Regulatory Commission (FERC).

Exhibit 1.d demonstrates the impact on the consumer of project delays due to snow/ice work pad construction for different levels of project cost.

Using the same approach, the incremental cost to the consumer resulting from the increased construction costs can be calculated as follows:

$$\text{INCREASED TARIFF DUE TO SNOW /ICE PAD CONSTRUCTION} = \begin{bmatrix}\text{Incremental Cost} \\ \text{Snow/Ice Work Pad}\end{bmatrix} \times (1.12) \times (0.175)$$

In the first year of pipeline operations, these costs will total $819,035 for each mile of snow/ice pads. Exhibit 1.b demonstrates the increased cost to the consumer for each mile of snow/ice pad constuction. These costs should be considered low because they include direct construction costs only and do not include all costs resulting from schedule delays (e.g., no allocation for project management or taxes and insurance).

Exhibit 1.a

INCREMENTAL COST OF
SNOW/ICE WORK PAD

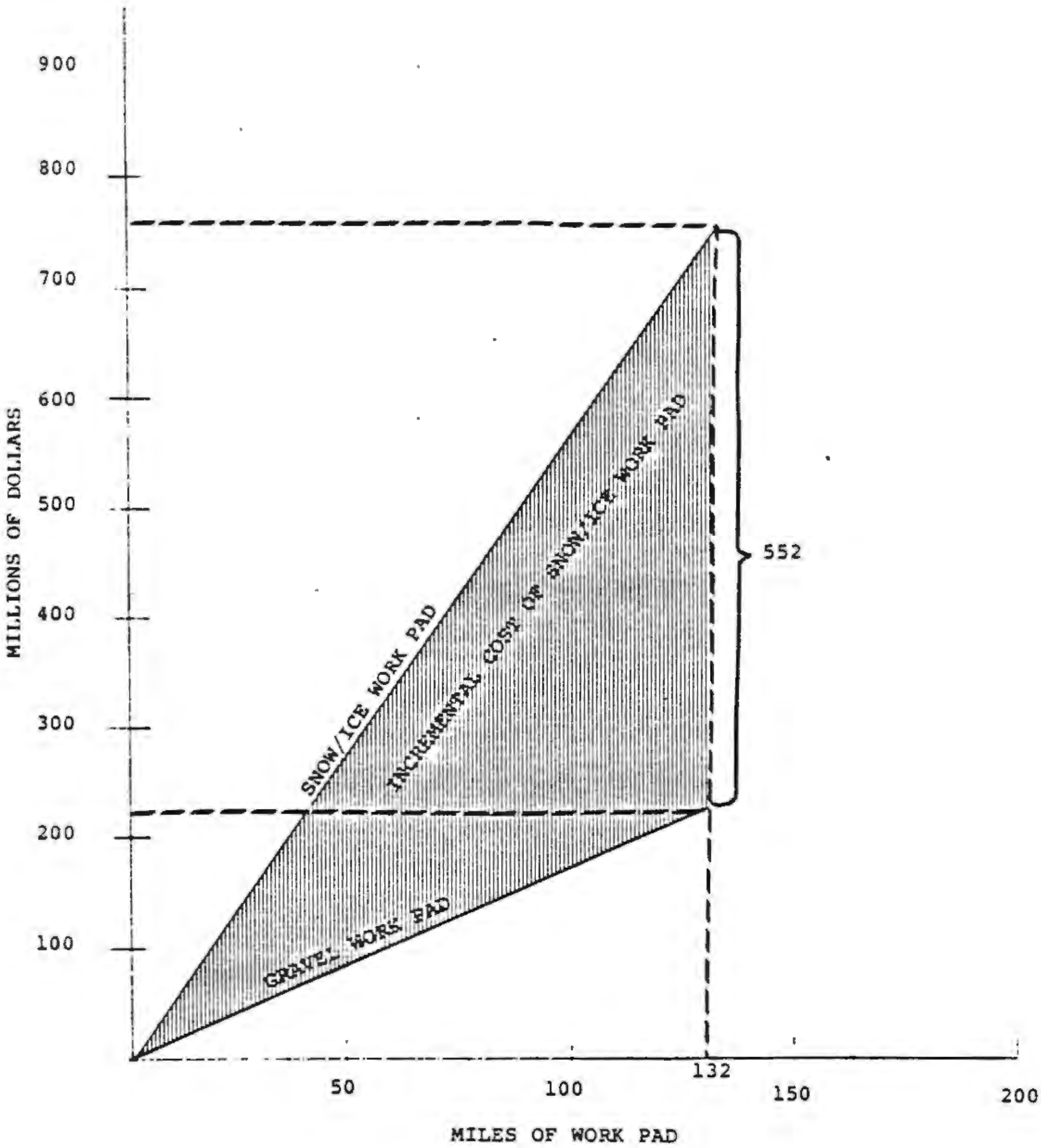
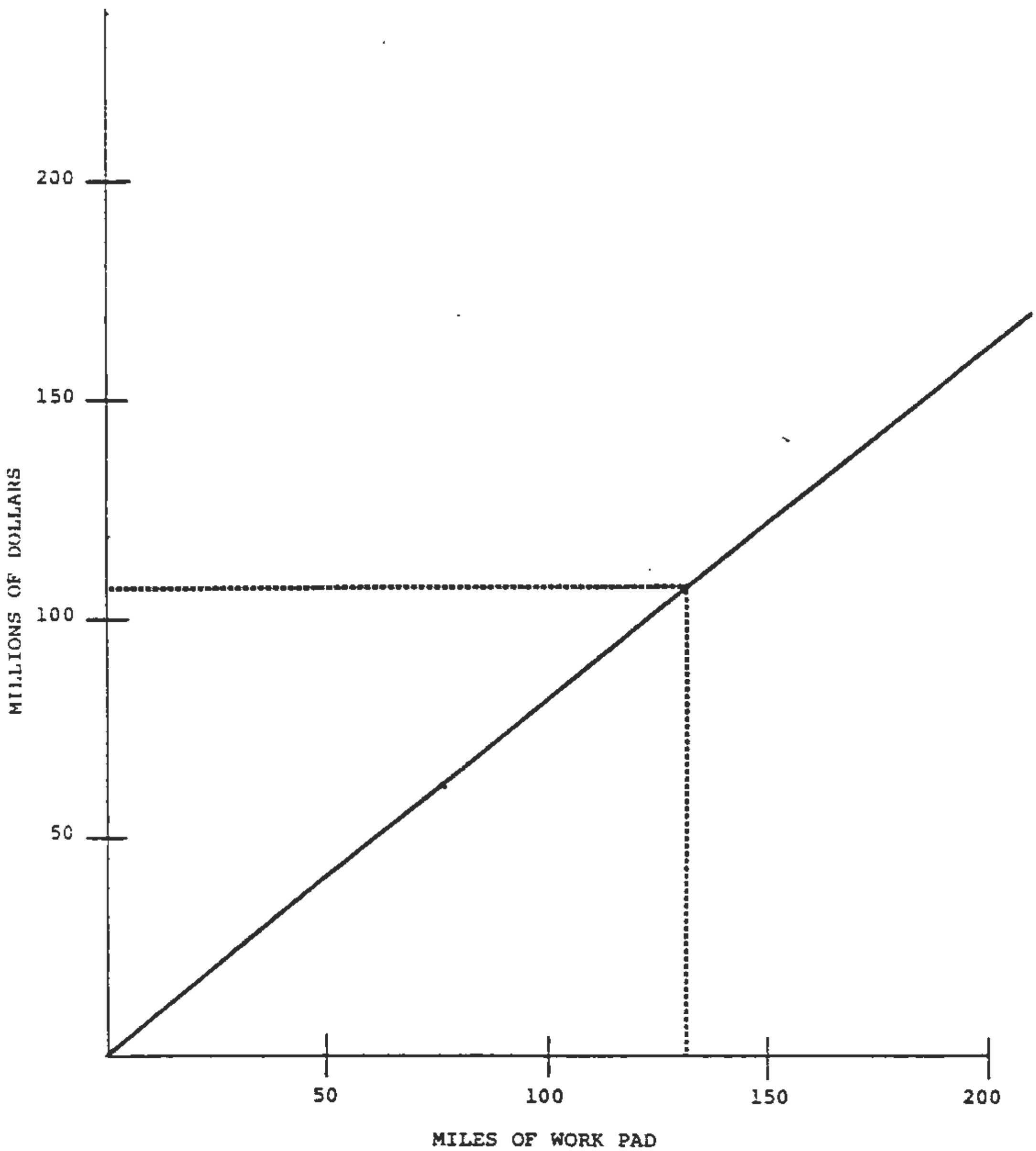


Exhibit 1.b

INCREMENTAL COST TO CONSUMER
OF SNOW/ICE WORK PAD CONSTRUCTION



* First year of pipeline operations

Exhibit 1.c

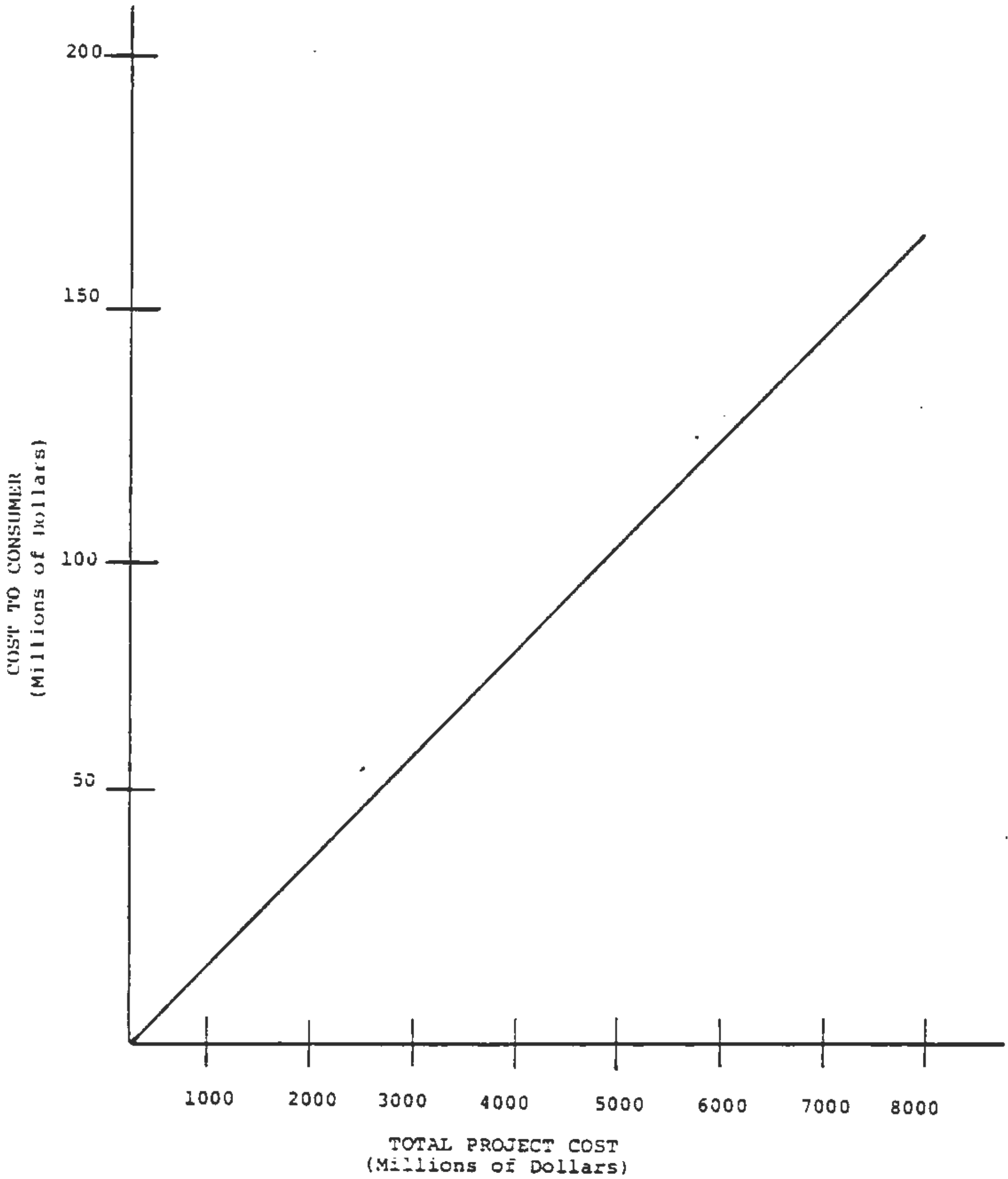
INCREMENTAL COST OF SNOW/ICE
WORK PAD CONSTRUCTION

	Construction Cost Per Mile	Maintenance Cost Per Mile	Pipeline Construction Cost Per Mile	Total Cost Per Mile
Snow/Ice Work Pad	1,128,914	605,098	4,084,003	5,818,015
Gravel Work Pad	288,463	19,364	1,331,436	1,639,263
Incremental Cost of Snow/Ice Work Pad	840,451	585,734	2,752,567	4,178,752

6/1/80

Exhibit 1.d

INCREMENTAL COST TO CONSUMER DUE
TO SLIPPAGE FROM SNOW PAD CONSTRUCTION*



* First year of operations only.

2 ENVIRONMENTAL IMPACTS

The concept of construction from snow/ice work pads and roads has been advocated from an environmental viewpoint. However, our analysis indicates that winter construction of a large-diameter buried pipeline from a snow/ice work pad will not mitigate critical environmental concerns. In addition, the provisions of the grant of right-of-way stipulations cannot be met when constructing a pipeline from a snow/ice work pad.[1]. Environmental advantages are offset by corresponding environmental disadvantages.

The use of snow/ice work pads or roads does not minimize overall environmental impacts. This conclusion is based on a review of three important environmental aspects of employing such a construction concept:

- Tundra and terrain degradation
- Natural snow and water requirements
- Impacts of wildlife and fish

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1. Draft Department of Interior Right-of-Way Stipulations.

Tundra and Terrain Degradation

Although it is theoretically possible to keep tundra and terrain degradation within acceptable limits while constructing a large-diameter, buried pipeline from a snow/ice work pad, practical considerations prevent such accomplishment under full-scale field operations (see Appendix B). Restoration of the pipeline right-of-way where the pipeline trench has been excavated and backfilled in a frozen condition has not been tested under field conditons, much less executed successfully after the installation of a pipeline. Furthermore, servicing of a large-diameter buried pipeline and maintenance of the right-of-way without a gravel pad is not practical and would lead to additional tundra and terrain disturbances (see Appendix B).

In theory, winter construction from a snow/ice work pad appears to offer two important advantages over construction from a gravel work pad:

- After melt-off, the ground underneath a snow/ice pad would require little or no restoration because little or no disturbance has taken place.*

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* This advantage is only true where little nonretreivable contamination of the snow/ice pad occurs.

- The absence of a remnant gravel work pad avoids the interception of natural sheet flow which is important to flat terrain ecology, and avoids the need for longitudinal-drainage structures to concentrate the sheet flow into cross-drainage structures.

However, each of these apparent advantages has a corresponding disadvantage.

Regarding the lack of impact on the tundra under a snow/ice pad, the preliminary surf cial results of the TAPS experiments are impressive. However, with a large-diameter, buried pipeline, the need for stabilization and restoration of the pipe ditch is more important a concern than the need for restoration of the pad area. In the event that immediate post-construction restoration and grading efforts (e.g. backfill with frozen material) were not successful, summer vehicular access would be mandatory. Without a permanent traffic surface adjacent to the buried pipeline, restoration activities would be limited to workers on foot (supported by helicopter) using hand tools to establish proper grading and to control thaw settlement or possibly major longitudinal hydraulic/thermal erosion problems. Any subsequent major restoration of the ditch area would require the construction of a new snow/ice work pad for access during the winter months.

With respect to avoiding interception of natural sheet flow, it is doubtful that winter restoration practices will successfully eliminate ponding along the ditch and work pad areas. Without summer access to the ditch area to ensure proper final grading of the ditch it is likely that the sheet flow will pond. Any longitudinal-drainage control required after construction would negate the advantage of using snow/ice work pad.

Overall, winter construction of a large-scale, buried pipeline is impractical when restoration and erosion control schemes are considered. Current plans require access to all sections of the pipeline in each of at least the four summers seasons following the pipeline construction season for certain maintenance activities, including terrain rehabilitation and restoration. In addition (see Appendix C), some activities performed in the summer will require direct access to the pipeline ditch from a gravel pad (e.g., hydrotest, erosion control and revegetation).

The successful use of snow pads would reduce the quantity of granular materials required and incrementally reduce the adverse impacts of mining on aquatic and terrestrial habitats as well as associated fish and wildlife. Substituting water removal for granular material under winter conditions has potential adverse environmental consequences as described in the following section.

Natural Snow and Water Requirements

Major pipeline construction during the winter from snow/ice work pads capable of withstanding the weight and abuse of heavy equipment will require vast quantities of natural snow and water. Although the exact volumes of snow, water, and crushed-ice aggregate needed will depend on the densities required and site-specific pad specifications for load-bearing capabilities, it has been clearly established from historical weather records that sufficient supplies of natural snow will not be available anywhere along the pipeline route (see Appendix C) to meet even minimal demands. In some areas, particularly the North Slope, water for snowmaking or direct water layering will be in extremely short supply, if available at all. Moreover, in some areas, water use will adversely affect fish overwintering.

Based on discussions with Arctic construction experts, it appears unlikely that sufficient snow, will be available to begin construction of a snow/ice work pad in November (see Appendixes B and C). In fact, in some years, accumulations may not be adequate to start pad construction until January. Exhibit 2.a represents the amount of snow that can be expected to be on the ground from October through May in the North Slope basin.

To compensate for the lack of sufficient supplies of natural snow in the early winter season months, it will be necessary to manufacture snow. This need, combined with the usual water requirements of forming a layered snow/ice pad, will place tremendous demands on winter water supplies. These supplies will decrease rapidly in the early winter as the ice on lakes thicken and streams stop flowing. In addition, water supplies will be restricted where water removal from lakes and rivers will jeopardize fish overwintering. As a result water probably will have to be hauled long distances via large fleets of insulated trucks.

Assuming an average snow/ice work pad volume for Section I of 407,550 cubic feet (61.75 feet wide by 1.25 feet thick by 5,280 feet long), the water requirements are greater than 3 million gallons per mile. Water requirements of this magnitude will be difficult to meet, particularly on the North Slope. For example, the current total winter reservoir volume for the Prudhoe Bay Development Area on the North Slope is 274 million gallons. The current winter demand is 208 million gallons.[2]

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2. "Prudhoe Bay Water Problems," Alaska Construction and Oil, Parts I and II, April and May 1980.

Water is in critically short supply on the North Slope, especially in the winter. Several plans are being developed to bolster supplies; for example, the Prudhoe Bay Development Area is planning to add about 3 billion gallons of winter storage capacity over the next several years.[3] However, it is unclear whether the plans to ensure supply can be carried out, given limits on total water availability and the increasing difficulty of obtaining permits for water use on the North Slope.

Impacts on Wildlife and Fish

The use of snow/ice work pads, snow/ice roads, and winter programs for pipeline construction is theoretically less disturbing to animals and birds than construction during the shoulder months from conventional gravel work pads. The direct impacts of pipeline construction during the fragile winter months on fish and local ecosystems will, however, be more severe (see Appendix B) and such a construction approach will be incompatible with the grant of right-of-way stipulations.

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3. "Prudhoe Bay Water Problems," Alaska Construction and Oil, Parts I and II, April and May 1980.

The absence of remnant gravel work pads or roads may possibly limit the disruption of mammal and avian movement and migration. However, the dynamics of animal and bird avoidance of or attraction to foreign structures of this nature cannot be impirically proven. In fact, there is no apparent mammal avoidance of the gravel work pad adjacent to the buried oil line or the haul road per se. With either a snow/ice or gravel work pad the pipe ditch area will continue to act as a possible modifier of lateral or longitudinal animal and bird movements regardless of construction method.

Winter construction using a snow/ice work pad could have serious negative impacts on fish and other fresh-water life along the pipeline corridor. The critical areas are fish stream crossings and fish overwintering areas from which water might be withdrawn.

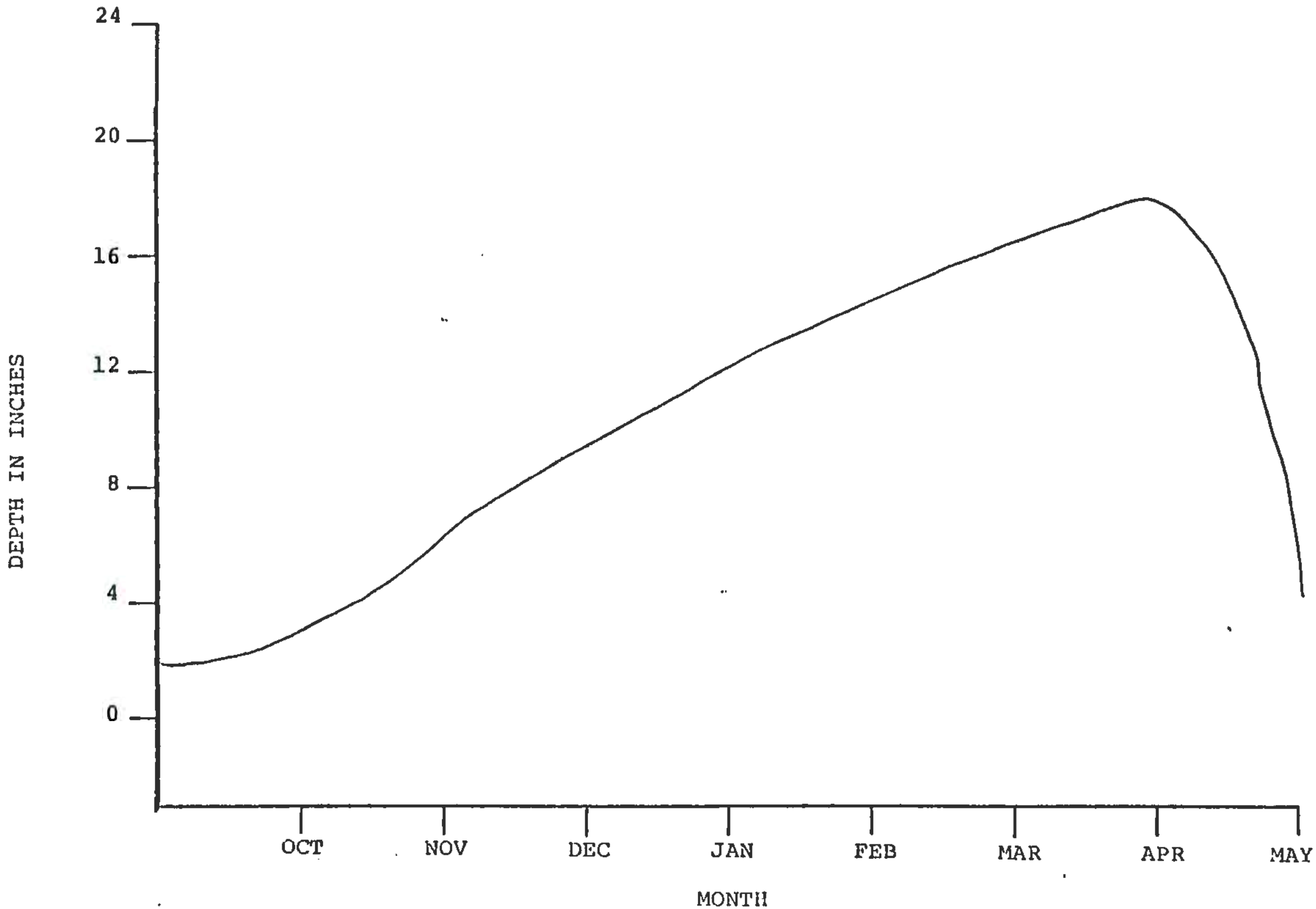
For many fish streams, winter construction would avoid most of the significant biologically sensitive periods. While this is generally true for most mammal and avian species it is not always the case for fish. In fact, winter construction crossings of many streams will not be permitted because of sensitive winter fish habitat conditions. In other cases, where winter crossings may be preferable, the early winter shoulder months may be unavailable due to inadequate snow or depth of freeze down for the establishment of snow/ice pads.

Whether a gravel or snow/ice work pad is used approaching stream crossings, the pipeline ditch will definitely disturb the stream bed and banks. Furthermore, summer access to streambed crossings for tracked equipment for bank stabilization and erosion control would be virtually impossible without a gravel approach. Also access limited to the winter months would require that initial construction of fish passage or habitat protection structures be accomplished in the winter; the results of constructing such structures in the winter has often proved unsatisfactory.

In summary, the general use of snow pads for below ground construction will result in greater adverse impacts to the ecosystems involved. Snow pad utilization will present compliance with right of way stipulations designed to assure environmental protection.

Exhibit 2.a

AVERAGE CUMMULATIVE MONTHLY SNOW DEPTH IN THE NORTH SLOPE BASIN



6/1/80

3 CONSTRUCTION CONTRACTING, EFFICIENCY, AND SAFETY

The concept of a snow/ice work pad, snow/ice roads, and winter construction programs for a buried, large-diameter pipeline is totally impractical from construction contracting, efficiency, and safety points of view. It is not planned that any part of the pipeline will be built using unproven construction techniques.

Construction Contracting

Northwest Alaskan intends to match the specific type of contract with the degree of risk in contract performance. However, under the terms of the President's Decision, Northwest Alaskan will be required to use fixed-price contracts unless the Federal Inspector determines that special conditions justify cost-plus contracts.

Because uncontrollable risks associated with snow/ice work pads, snow/ice roads and winter construction programs are so great, Northwest Alaskan is certain that no execution contractor with Arctic experience will submit a bid for this work under the terms of a fixed-price contract (see Appendix C).

In the event that snow/ice work pads or roads become mandatory, Northwest Alaskan would prepare a cost estimate for the change in design and schedule. This estimate will be submitted to the OFI for approval by the Federal Inspector. Once approved, it will be added to the base estimate as required by the Incentive Rate of Return (IROR) mechanism. Using the philosophy consistent with the President's Decision, it is unlikely that the Federal Inspector will accept a cost estimate with contingencies. However, any experienced contractor who must submit a fixed-price bid for pipeline construction from a snow/ice work pad will include a significant contingency, possibly 100 percent or more. This contingency will compensate for the risks inherent in this type of construction. As a result of this contingency, the competitive bids received will greatly exceed Northwest Alaskan's estimate. In effect the adoption of a winter construction concept is contrary to the President's Decision from a contracting point of view, inconsistent with the objective of the IROR procedure, and the project equity participants would be unfairly penalized.

CONSTRUCTION CONTRACTING, EFFICIENCY, AND SAFETY 3.3

Construction Efficiency

Pipeline construction is a highly mobile, labor-intensive, assembly-line production effort. Rather than the product moving through the assembly point, the assembly progresses over the product. Enclosing a mobile construction operation to provide a temperature-controlled environment will be virtually impossible to accomplish in a manner that will permit both efficient construction operations and the adherence to high standards of quality control (see Appendix C).

Severe cold temperatures places constraints on activities such as welding, coating, and backfilling and causes a significant reduction in the efficiency of all operations exposed to the cold temperatures. Also, equipment breakdown is more frequent, lubrication imparied, and maintenance and repairs will be difficult and costly (see Appendix C).

In addition, worker efficiency in cold weather drops significantly, with an estimated productivity ranging from 25 to 75 percent of that experienced during a normal moderate month. Operations such as welding and coating must normally be shut down when ambient temperatures drop to -20^{0}F to -30^{0}F, and all operations will generally cease below -35^{0}F.

Another important construction and logistics consideration would be the limited amount of natural light during winter months. Although artificial lighting has been provided successfully for fixed construction sites in the Arctic (e.g., Prudhoe Bay facilities), the actual concept of providing such construction support for a large-diameter pipelaying operations is untested. The maintenance and logistics requirements of a major, mobile artificial lighting operation are expected to be prohibitive (see Appendix B).

Another untested aspect of snow/ice work pad and road construction is the building of an extensive layered snow/ice work areas of nonuniform thickness on side slopes. It is unknown whether it is possible to contain the fluid snow/ice mixture on a side slope to maintain a uniform density for strength. For any large-scale operations, it would be necessary to develop and test new water application methods and equipment prior to any significant amount of winter construction scheduling. Even then, there is some risk that the thick sides of snow/ice work pads and roads will collapse under concentrated traffic loads of heavy sideboom tractors (see Appendixes B and C).

The majority of snow/ice pads and roads constructed in the Arctic to date have been to accommodate rubber-tired vehicles for the purpose of transporting bulk materials to isolated gravel drilling pads. There is very little experience with the use of snow/ice structures to support large-scale, heavy construction using tracked equipment. However, all experience available indicates that abrasion and surface deterioration will be severe. In fact, tracked equipment are ordinarily prohibited on snow/ice roads. Pad maintenance is expected to be costly* (more than gravel work pad maintenance), eliminates the possibility of a two-shift operation, and is distruptive to the normal cadence of pipeline construction operation (see Appendix C).

Construction Safety

The use of heavy construction equipment to lay large-diameter pipe from a snow/ice work pad is a dangerous construction practice. It creates an unreasonable safety hazard for workers.

Heavy equipment, even with snow grousers, has little traction and limited control. The snow/ice compacts between the grousers resulting in loss of traction. This is particularly true when under load on an incline or on uneven surfaces (see Appendix C).

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* See Chapter 1 for a comparison of maintenance costs.

CONSTRUCTION CONTRACTING, EFFICIENCY, AND SAFETY 3.6

Any construction or monitoring personnel required to work on the snow/ice pad surface around the heavy equipment would be subjected to an unreasonable level of danger on the construction site (see Appendix C).

Appendix A

ESTIMATE OF PIPELAYING PRODUCTIVITY DURING A WINTER CONSTRUCTION SEASON

Northwest Alaskan estimates that there is a high probability that no more than 24 miles of continuous pipe could be laid per section during any winter construction season using snow/ice work pads. This estimate is based on an analysis of winter construction uncertainties associated with a decision to construct from a snow/ice work pad and is, fundamentally, an analysis of weather patterns and the effect of ambient air temperature on construction productivity. Unlike construction from a conventional, all-season gravel work pad, construction from a snow/ice work pad is dependent on temperatures conducive to snow/ice work pad construction and maintenance. Efficient project scheduling is, therefore, subject to the vagaries of weather and the pipelaying production limits due to weather-related delays, worker efficiency under adverse climate conditions, and traditional holiday periods. These factors must be examined in detail.

ESTIMATE OF PIPELAYING PRODUCTIVITY A.2

We followed a three-step analytical approach in developing the 24-mile estimate:

Step 1: Estimate the number of expected construction days available based on weather records and seasonal constraints

Step 2: Refine the estimate of available pipeline construction days to a higher level of statistical probability

Step 3: Estimate pipelaying productivity during available construction days taking account of operations sequence and efficiency.

Each of these steps is discussed below.

Step 1: Estimate the Number of Expected Construction Days Available

The average number of construction days expected to be available between October 1 and April 30, working from a snow/ice work pad, is estimated to be 106 days (1.8 days in October, 13.3 in November, 20.4 in December, 17.8 in January, 20.1 in February, 23.9 in March, and 8.7 in April). The primary factors considered in estimating the number of days available are:

- Temperature constraints
- Time period required for mobilization and pre-construction of snow/ice work pad
- Time period required for final backfill and demobilization
- Time period allotted for traditional holiday season.

Temperature Constraints

The number of construction days available working from snow/ice work pads or roads is limited by several temperature constraints:

1) Initial construction of snow pads requires ambient air temperatures <0°F. Construction of the initial work pad foundation depends on rapid freezing of large volumes of water to a thickness and a snow/water density that can support heavy construction loads. The experience of Bearfoot, Inc. gained from extensive Arctic work (for the Arctic Gas project, NPR-4, etc) along with that of Alyeska and others, indicates that temperatures less than 0°F are necessary for this freezing when laying a snow/ice work pad.

2) Snow/ice work pad maintenance operations require temperatures <20°F. Once a snow/ice work pad is laid, maintenance operations (e.g., repairing pot holes, reblading, adding make-up snow or water) can be accomplished at higher temperatures than those required for initial construction. The volumes of water that must be frozen rapidly and the ability to control snow/water densities on an existing snow pad foundation do not require the

subzero temperatures needed for initial construction. Nonetheless, the maintenance of snow/ice work pads that will be exposed to the high wheel loads of heavy construction equipment and degrading action of tracked equipment requires substantially colder temperatures regimes than are required for manufacturing snow (at near thawing temperatures) for recreational sking purposes.

3) Pipeline construction operations cease at temperatures below -35°F. At extremely low temperatures, labor and equipment efficiency rates decline to a level where construction efforts are no longer cost-effective, regardless of whether pipeline operations are being conducted from a snow/ice work pad or a conventional gravel pad, a "no-work" condition is assumed to exist at temperatures below -35°F.

4) Pipeline construction operations from a snow pad must cease at temperatures above 20°F. When snow/ice work pad maintenance ceases to be effective at temperatures above 20°F, then pipeline construction operations must also terminate to prevent destruction of the pad. Therefore, a "no-work" condition also exists for temperatures of 20°F and higher

Since the development of the Prudhoe Bay area and the construction of the Trans-Alaskan Pipeline System (TAPS), a substantial amount of North Slope weather data has been collected.* To identify the months in which winter construction from a snow/ice work pad is possible, Northwest Alaskan used detailed records of hourly weather readings, covering the 10 year period from 1969 through 1979, to compute the average daily high and average daily low for each month (see Exhibit A.1).

Using the raw weather data from AEIDC, we categorized hourly temperature readings into six temperature ranges compatible with our construction assumptions:

Temperature Range	Work Conditions
>32°F	No work; snow/ice work pad thawing
20°F to 31°F	No work; snow/ice work pad remains frozen but can not withstand construction activity loads
0°F to 19°F	Snow/ice work pad maintenance and pipeline construction are possible
-20°F to -1°F	Snow/ice work pad and pipeline construction are possible
-34°F to -21°F	Snow/ice work pad and pipeline construction are possible at reduced productivity
<-35°F	No work; too cold.

* The primary source for the data is the Arctic Environmental Information and Data Center (AEIDC), located in Anchorage, Alaska.

The number of days in each month were then sorted into the six temperature ranges in each of the 10 years for which data were available, and computed the average number of days in each month falling within each range (see Exhibit A.2).

Using the construction assumptions and temperature data, the average or expected work days available per month were estimated for the months of October through April (see Exhibit A.3). Because of mobilization, work pad pre-building, and the traditional holiday season, no pipeline construction can be scheduled during the months of October, November, December and the first week of January. Similarly, because of the pre-breakup demobilization, no pipeline construction can be scheduled during May.

Mobilization and Work Pad Pre-Building

If winter construction follows a summer and fall construction season, the time required for mobilizing construction equipment and crews can be reduced by enabling prepositioning of major equipment prior to freeze-up. Work can then begin almost immediately upon governmental issuance of an on-tundra permit. The remaining mobilization task, then, is the necessity of starting each season by pre-building snow/ice work pads of sufficient length to support the transient nature of pipeline operations.

Because the temperatures required for initial snow/ice work pad construction are lower than the temperatures required for pipeline construction, days that would otherwise be acceptable for pipeline construction from a weather standpoint are unusable until a sufficient length of work pad is pre-built. For construction scheduling, all of the available work days in October (1.8 days), November (13.3 days) and December (20.4 days) will be used for mobilization of major equipment and pre-building the snow/ice working surface. Therefore, no pipeline construction would occur during this period.

Time Required for Demobilization

In a manner similar to mobilization, the end of each winter construction season requires that time be scheduled for demobilization prior to break-up. Furthermore, pipeline welding operations must often be terminated before demobilization begins to ensure that all welded pipe can be lowered in and backfilled before the equipment is demobilized. For schedule purposes, demobilization will require all available working days in May, and all pipe welding and pipelaying activities will have to terminate at the end of April.

Time Allocated for Holiday Season

It is customary in the pipeline industry to cease major construction activity during the Christmas and New Year's holiday season. Therefore, the last week of December and the first week of January are treated as a "no-work" period.

Step 2: Refine the Estimate of Available Pipeline Construction Days

In this step of the analysis, the estimate of the available number of work days for pipeline construction is refined to establish higher levels of statistical confidence for predicted weather patterns.

The use of mathematical averages, or more precisely the arithmetic mean, in calculating the number of winter days likely to be available during a typical winter season in Step 1, assumes a probability of occurrence of 50 percent (P = 0.5). The extremely large capital investment necessary for the Northwest Alaskan project cannot logically be attracted on such a 50-50 chance basis.

Accordingly, we used historical data to more accurately predict the number of work days available per month (see Exhibit A.4). For example, the historical data may show that the average number of days within a certain temperature range is 5, with a standard deviation of 1. While the use of a mathematical average implies only that there is a 50 percent chance of at least 5 available work days, the distribution implies that there is an 84 percent chance of at least 4, or more available working days. This approach, based on one standard deviation of the normal distribution, can be used to predict the minimum number of available work days in each month with greater certaintly.

Using this methodology, the estimate of the probable work days available per month was refined as follows (see Exhibit A.5):

Work Days Available (P = 0.84)

Temperature Range	Month Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
$-35^{o}F$ to $20^{o}F$	6.8	21.5	22.0	21.0	21.6	27.2	22.2
$-35^{o}F$ to $0^{o}F$	0	4.9	15.4	13.0	17.7	15.6	2.4

However, for the purposes of construction scheduling, it is important to note that the number of work days available in any month may not be consecutive or even in reasonably close sequence. For example, a day or two of cold weather at the beginning of the month may be followed by a series of warm days. Consequently, the month of November, with only 4.9 probable work days available is unusable for mobilization and pre-building. Similarly, the month of December with only 15.4 work days (i.e., 50 percent of the total days in the month) is only marginally dependable for mobilization and initial snow/ice work pad construction. The months of January, February and March contain 46.3 expected work days for snow pad construction (52 percent of the total season) and 69.8 expected work days for pipeline construction (78 percent of the total season). The month of April offers no opportunity for further construction of snow/ice work pads and must be dedicated to final wrap-up of the winter pipeline construction season (i.e., backfilling, cleanup, and the beginning of equipment and labor demobilization).

Step 3:
Estimate Pipelaying Productivity

Northwest Alaskan has estimated and scheduled the construction rate for installing buried gas pipeline in Alaska, operating from a gravel work pad during the summer months, to be 3,200 feet in pipe per day per section. This planning figure can be modified for use in estimating winter construction by considering the special constraints encountered when laying pipe from a snow/ice pad. The results provide a model of a typical season for a single construction spread that, allowing for weather and variations in available working days and worker efficiency, estimates the total length of pipe that can be laid.

The factor controlling the length of pipe that can be laid in any period of time is pipeline welding operations. In the case of construction from a snow/ice work pad, sufficient time must be scheduled at the start of the season to pre-build the pad, shoot and excavate a ditch, and string and bend pipe far enough in advance of the welders to ensure continuity of operations. Based on the expected number of work days available in a typical season on Alaska's North Slope, it is not feasible to mobilize an entire construction crew until some of these preliminary activities are well under way.

The period with the highest risk of schedule delays due to temperature constraints are the months of November and December. No snow/ice work pad construction can be scheduled during November because of limited cold temperatures, and only skeleton crews can be expected to be available during December due to the holiday season interruption. Consequently, the following assumptions must be incorporated into our construction model:

1) Construction camps and support facilities can be activated and (upon receipt of on-tundra permits) snow/ice work pad construciton can commence in December.

2) Skeleton crews can continue to work through the holiday season building snow/ice work pads whenever the temperatures are low enough, i.e., less than 0°F. These crews could pre-build the work pad at the average rate of one-third mile per day. During the 15 days likely to be available in December, the resulting 5 miles of snow/ice work pad will require approximately 1,013,800 gallons of water per day. During the 40 working days available in January, February, and March, snow/ice work pad construction rates must increase to one-half mile per day with corresponding water requirements of 1,520,700 gallons per day.

3) Blasting and ditching crews can mobilize on the first of January, followed closely by the stringing and bending crews. Production must initially average one-third mile per day, increasing in later months.

4) Welding can commence the second week of January and continue to mid-April, when it must terminate to ensure the lowering-in and backfilling of all welded pipe before spring break-up. Work days scheduled for welding are, therefore, reduced to 75 percent of the time available in January and 67 percent of the time available in April, for a seasonal total of 78 days in which temperature ranges are expected to be satisfactory (with an 84 percent probability).

5) Northwest Alaskan has adopted the following worker efficiency rate for pipeline welding operations under adverse temperature conditions:*

Temperature Range	Work Efficiency**
0° to 20°F	75 percent
-20° to -1°F	50 percent
-35° to -21°F	20 percent
below -35°F	Nil

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* This estimate is based on advise from consultants with extensive Arctic construction experience.

** Precentage of estimated summer or moderate month rates.

ESTIMATE OF PIPELAYING PRODUCTIVITY A.14

Using welding operations as the basis for reductions in worker efficiency (down from an optimum of 3,200 feet per day), Northwest Alaskan estimates that no more than 24 miles of continuous pipeline construction could be scheduled during a winter construction season. This estimate is based primarily on an analysis of ambient temperatures. This optimistic estimate of 24 miles per construction season is the sum of estimated pipeline construction during three different temperature ranges for each of the four months when pipe construction could take place (see Exhibit A.6).

Other factors such as the effects of wind and blowing snow will further reduce the estimated pipelaying productivity. For example, considering wind chill effects and assuming that no pipeline construction operations will take place when wind chill falls below -35°F, the available work day would be reduced by 44 percent. This, in turn, will reduce the pipelaying productivity to approximately 12 miles per section for an entire season.

Exhibit A.1

AVERAGE MONTHLY AMBIENT TEMPERATURES
(^{o}F) OCTOBER THROUGH APRIL

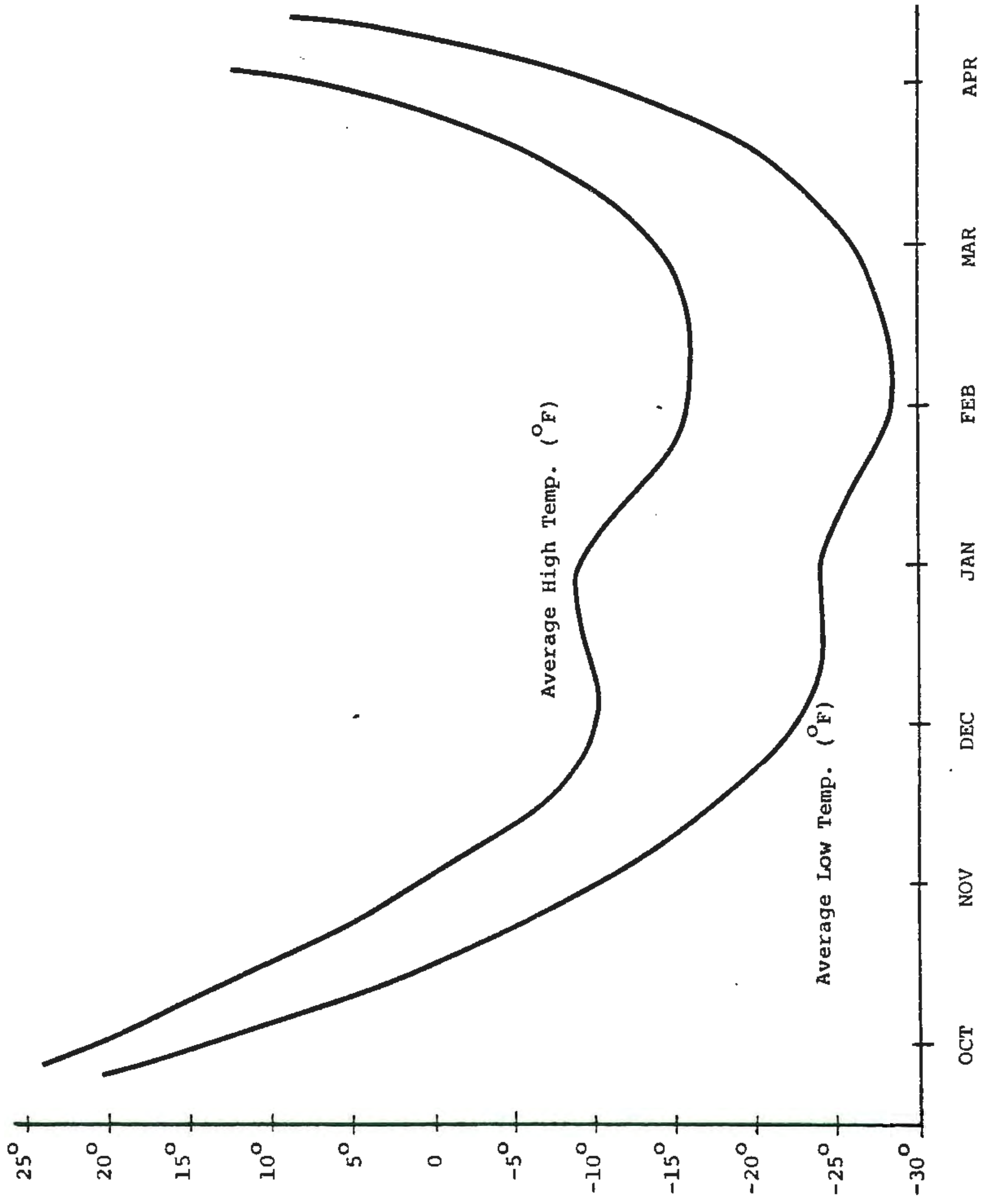


Exhibit A.2

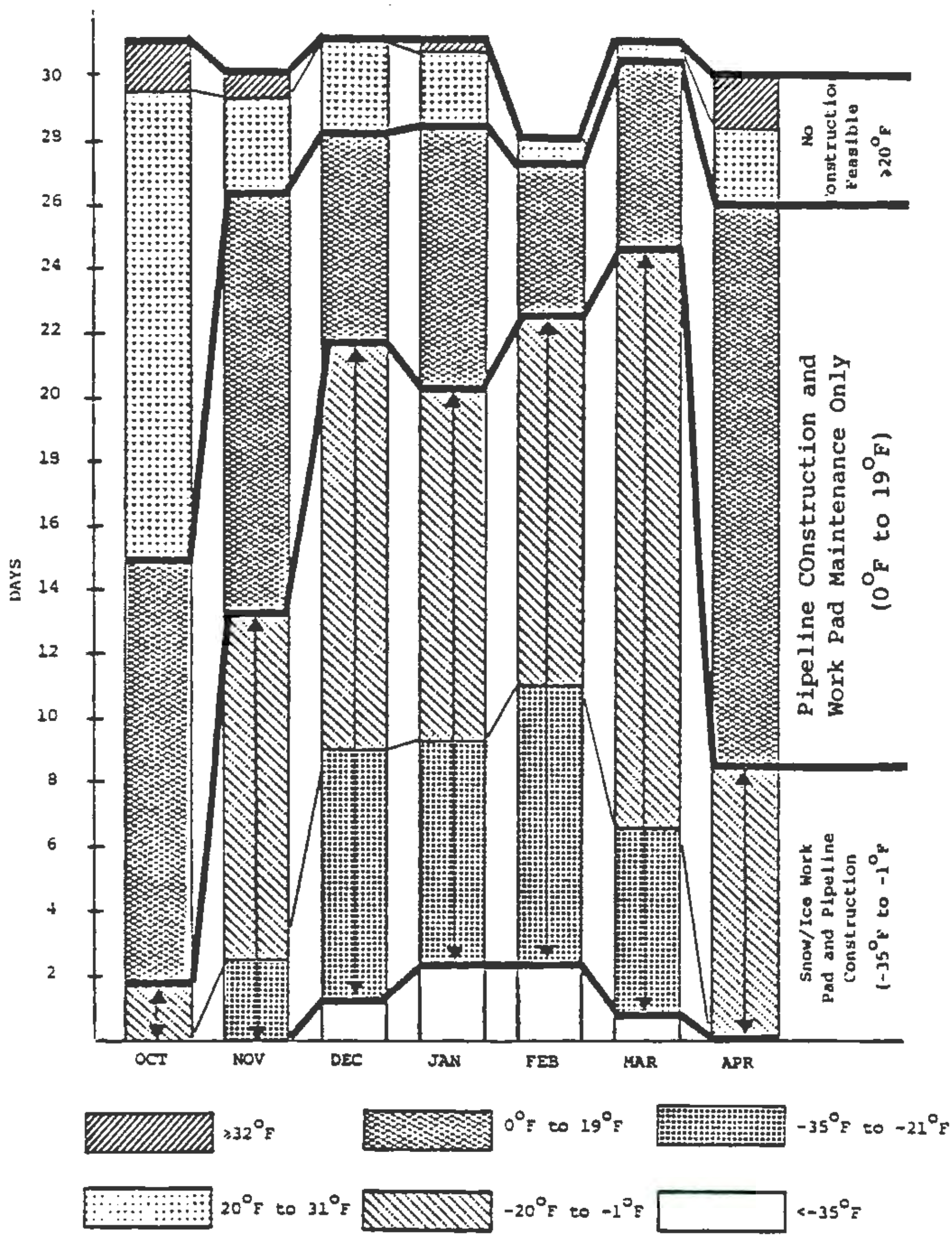
DISTRIBUTION OF NORTH SLOPE TEMPERATURE DATA*
(Average days per month within selected temperature ranges)

TEMP. RANGE (°F)	OCT		NOV		DEC		JAN		FEB		MAR		APR	
	HI	LOW	HI	LOW	HI	LOW	HI	LOW	HI	LOW	HI	LOW	HI	LOW
≥32°	1.5	0.2	0.7	–	–	–	0.2	–	–	–	–	–	1.6	–
20° to 31°	14.4	7.0	2.9	0.7	2.8	–	2.3	0.1	0.7	–	0.6	–	2.3	0.8
0° to 19°	13.3	14.5	13.1	7.3	6.4	3.3	8.2	3.5	4.6	0.9	5.6	1.3	17.4	7.2
-20° to -1°	1.8	8.7	10.7	15.9	12.8	10.4	11.0	9.3	11.6	6.6	18.1	7.9	8.7	15.4
-35° to -21°	–	0.6	2.6	5.8	7.6	10.2	6.8	8.3	8.5	10.9	5.8	14.6	–	6.4
<-35°	–	–	–	0.3	1.4	7.1	2.5	9.8	2.6	9.6	0.9	7.2	–	0.2
	31 DAYS		30 DAYS		31 DAYS		31 DAYS		28 DAYS		31 DAYS		30 DAYS	
AVERAGE MONTHLY TEMPERATURE (°F)	20.8	14.7	2.5	-10.8	-10.3	-22.6	-8.9	-23.6	-16.3	-18.9	-13.8	-26.3	9.6	-10.8

* DATA SOURCE: Arctic Environmental Information and Data Center, University of Alaska, Anchorage (for 10 year period, 1969-1979)

Exhibit A.3

AVERAGE MONTHLY WORK DAYS AVAILABLE
FOR SNOW/ICE WORK PAD CONSTRUCTION*



* Assumes that an ambient air temperature of 0°F or less is required for snow/ice work pad construction.

Exhibit A.4

SAMPLE DISTRIBUTION OF
AVAILABLE WORK DAYS

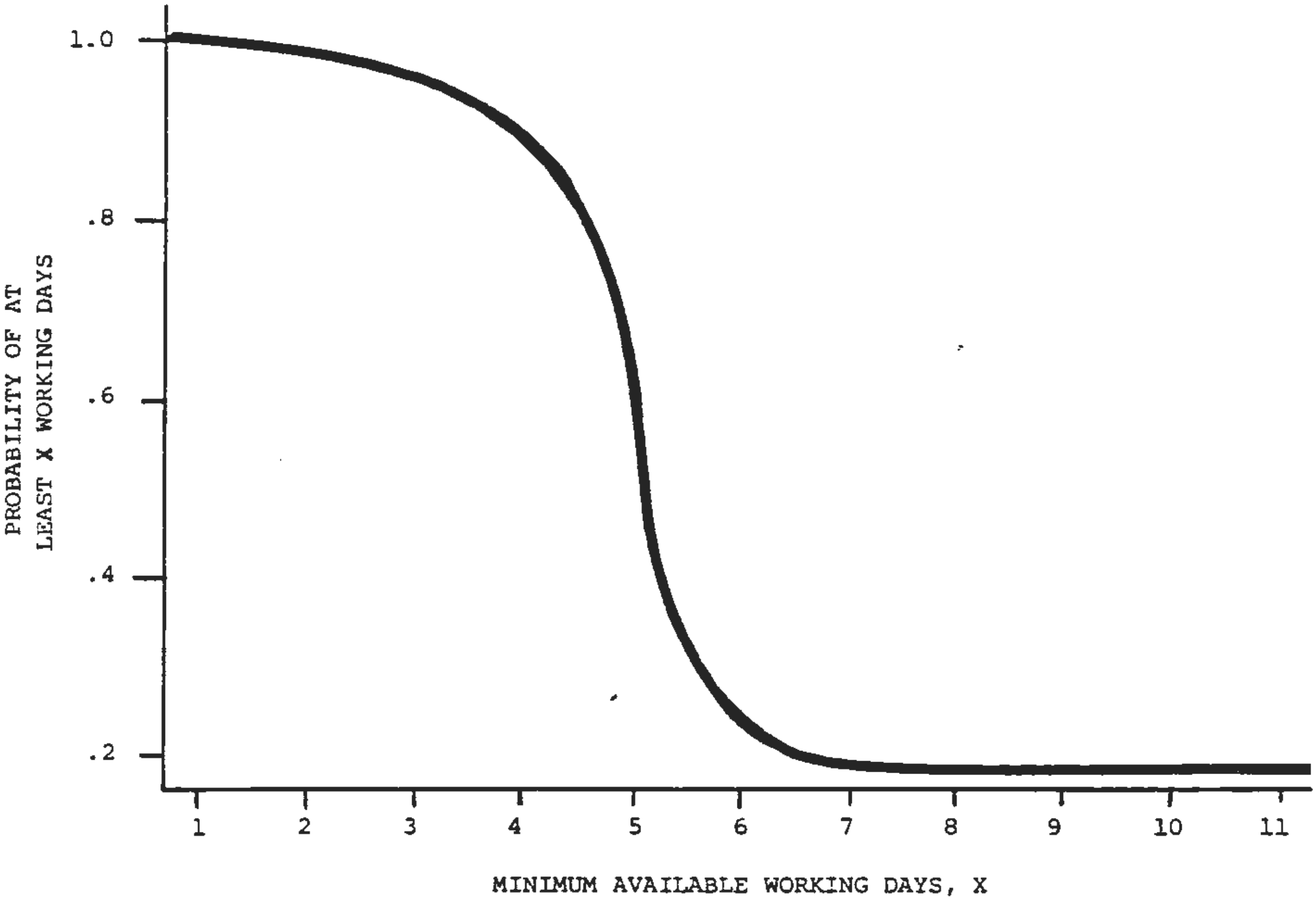
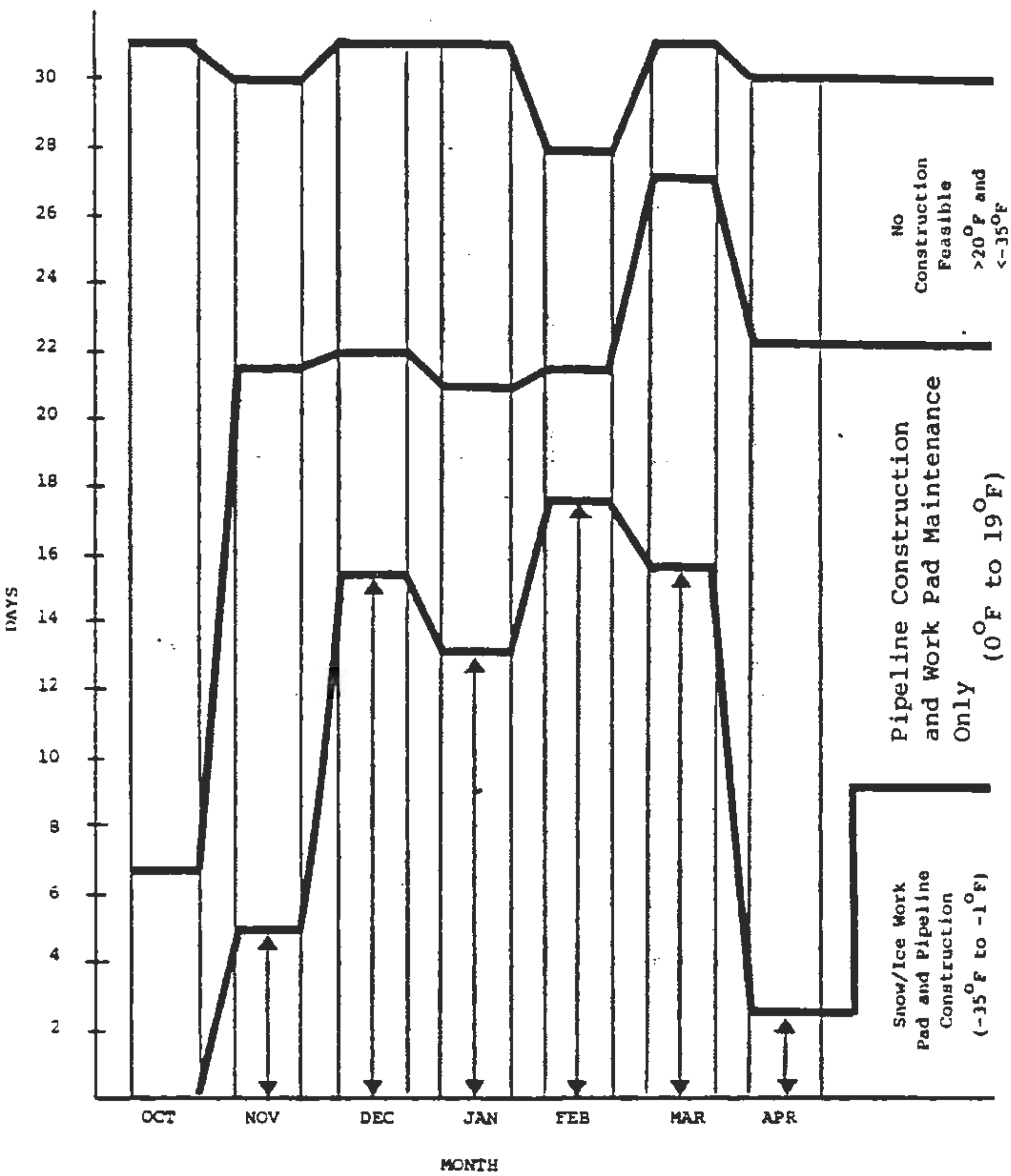


Exhibit A.5

MONTHLY WORK DAYS AVAILABLE
WITH PROBABILITY OF 0.84*



* Assumes that an ambient air temperature of 0°F or less is required for snow/ice work pad construction.

Exhibit A.6

ESTIMATE OF PIPELAYING PRODUCTIVITY
(Work Days Per Montn and Production of Welded Pipeline)

TEMPERATURE AND LAY RATE	MONTH: JANUARY	FEBRUARY	MARCH	APRIL	WINTER CONSTRUCTION SEASON
0°F to 20°F 2400 Feet Per Day[1]	5 Days 2.27 Miles	4 Days 1.82 Miles	4 Days 1.82 Miles	9 Days 4.09 Miles	22 Days 10.00 Miles
-20°F to -1°F 1600 Feet Per Day[2]	6 Days 1.82 Miles	10 Days 3.03 Miles	17 Days 5.15 Miles	5 Days 1.52 Miles	38 Days 11.52 Miles
-35°F to -21°F 640 Feet Per Day[3]	5 Days 0.61 Miles	7 Days 0.85 Miles	6 Days 0.73 Miles	0 Days 0.00 Miles	18 Days 2.19 Miles
-35°F to 20°F	16 Days	21 Days	27 Days	14 Days	78 Days
TOTALS	4.70 Miles	5.70 Miles	7.70 Miles	5.61 Miles	23.71 Miles

1 Assumes 0.75 labor efficiency factor.

2 Assumes 0.50 labor efficiency factor.

3 Assumes 0.20 labor efficiency factor.

6/1/80

Appendix B

EXTRACT FROM TERMINUS LIMITED REPORT

SECTION 10

WINTER CONSTRUCTION

ALASKA PIPELINE OFFICE
OF
U.S. DEPARTMENT OF INTERIOR

TRANS-ALASKA PIPELINE - SPECIAL STUDY

AN OVERVIEW STUDY WITH RESPECT TO EFFECTIVENESS OF THE STIPULATIONS DURING THE CONSTRUCTION PHASE AND AN ANALYSIS OF EXPERIENCE GAINED WHICH MAY BE OF USE FOR GRANT OF ROW FOR FUTURE PIPELINE PROJECTS

INTERIM REPORT

JUNE 1977

UPDATED AUGUST, 1977

PREPARED FOR MECHANICS RESEARCH, INC.

BY TERMINUS LIMITED
TORONTO, CANADA

ITEM 10 - WINTER CONSTRUCTION AND SNOW ROADS

10.1 PREAMBLE

The construction plan for the Trans-Alaska pipeline called for extensive logistics operations during the winter, including the transportation of materials and equipment, in order to meet the construction schedule. The plan did not call for the construction of any sections of the main pipeline during the winter months. During the winter season of 1975-76, however, an attempt was made to construct a section of the main pipeline in the elevated mode, using a snow pad. During the same winter season, approximately 147 miles of fuel gas line, running from Prudhoe Bay to the pump stations on the North Slope, were scheduled to be constructed using a snow pad.

One of the proposals for transporting Alaskan natural gas from Prudhoe Bay to the lower 48 states contemplates a winter construction scheme (i.e., construction activities on the ROW limited to the winter season) on the North Slope of Alaska and on the northern sections of the pipeline route through Canada (herein collectively referred to as "The North Slope"). It would therefore appear that an analysis of the Trans-Alaska winter pipeline construction experience would be useful in evaluating the relative viability and the potential environmental impact of any future pipelines on the North Slope. Moreover, such an analysis would facilitate the setting of terms and conditions for grant of ROW across federal public land for such pipelines.

"PHILOSOPHY" OF WINTER CONSTRUCTION

The proposed scheme to limit pipeline construction on the North Slope to the winter season apparently developed from the premise that winter construction virtually eliminates adverse environmental impacts. Winter construction is thought to protect the tundra from construction impact through the use of snow roads and snow construction pads, in lieu of gravel roads and construction pads. It is thought to limit the field activities on the ROW to a season when there is minimal presence of wildlife and no fish migrations in the streams and rivers. And, with its reduced requirements for gravel for roads and construction support facilities, it is thought to reduce disturbance of streams and rivers and to minimize the adverse visual impacts of construction.

THE WINTER CONSTRUCTION SCHEME

The season for the winter construction scheme theoretically commences with sufficient freeze-up in the fall to permit travel on the tundra and lasts until the break-up of snow roads and snow construction pads in the spring.

The viability of a winter construction scheme for a big-inch pipeline in the north is based on the following assumptions:

that snow roads can be built to handle all transport of materials, equipment, and supplies required for the construction of a big-inch pipeline;

- that such snow roads, if constructed and used in accordance with certain specifications, will not cause degradation of the tundra;
- that the installation and use of the snow construction pad will not cause degradation of the tundra;
- that all the pipeline spread construction activities can be carried out from a snow pad designed to handle the construction traffic;
- that the complete pipeline ROW can be restored from the snow pad, including erosion control measures;
- that all activities for a big-inch pipeline spread on the North Slope can be carried out at a reliable production rate throughout the winter construction season, allowing for certain reductions in the productivity of men and equipment;
- that all pipeline maintenance can be carried out using LGP vehicles or helicopters, without permanent roads along the ROW.

10.4 CONCLUSIONS

Environmental Aspects:

The winter construction concept is not a panacea for the environmental problems connected with the construction of a big-inch pipeline in the north. In the terms of its direct impact on animals and birds during construction, the winter scheme is theoretically the least disturbing. Regarding direct impact on fish and local ecosystems, however, the winter scheme may not be the best solution. Experience on the Trans-Alaska pipeline shows that direct impact on wildlife, fish, and local ecosystems can be kept within acceptable limits using the moderate weather season for the principal construction activities in the north, provided the work is properly planned and scheduled with a view to minimizing such direct impact. An extension of the moderate weather season scheme to an all-year schedule will further reduce direct impact on the environment, an alternative which also has substantial economic and social advantages.

In terms of terrain degradation, the winter construction scheme theoretically appears to be an ideal solution. In practice, however, the near-perfect performance required to minimize terrain degradation from construction and use of snow roads and snow construction pads will be difficult to achieve. Practical experience in Alaska and northern Canada indicates a very high probability of deficiencies in the execution of an all-winter scheme. The winter construction concept is based on the assumption that the pipeline trench can be backfilled and the ROW restored with frozen material in the winter, thus preventing thermal degradation and controlling erosion. From even a theoretical point of view, this assumption is highly questionable; from a constructability point of view, such a restoration and erosion control scheme must be classed as impractical.

The winter construction concept also makes the assumption -- as yet untested -- that the operation and maintenance of a pipeline system can be carried out without permanent road access to either the compressor or pump stations.

Construction Aspects:

The success of cold weather construction, as developed in Alaska and Canada, has been based on creating an artificial climate for the work. By constructing enclosures, such artificial climates can be created economically for both large industrial installations and commercial building. In northern Canada, entire hydro-electric powerhouse sites have been enclosed, thus facilitating the placing of mass concrete during the winter months. The experience in Alaska and Canada clearly shows that enclosure of the work site is the most practical and economic way to assure productivity and quality construction in sub-zero weather. Individual shelters for specific activities are not practical on a production basis, because the necessary concurrent logistics activities involved in keeping such enclosures operative and heated are subject to full exposure to the climatic elements, rendering unpredictable the performance of both workers and equipment. If the enclosure for a single pipeline activity becomes non-operational, the whole spread may be brought to a halt.

There is no record of the successful artificial lighting of a complete buried mode big-inch pipeline spread, which stretches between 4 to 10 miles and is required to move at rates of up to 1 mile per day. The additional technical and logistics requirements to keep such an artificial lighting installation in operation under the climatic conditions in the north during December and January would further reduce the overall efficiency of a big-inch pipeline spread. In terms of constructability, such a scheme appears impractical.

Assuming the foregoing is correct, the practical daylight season for winter construction in the north is limited to 85 to 95 calendar days. In order to meet the objectives of environmental protection, this season is unyielding in terms of scheduling work, because it is controlled by the climate. The latest potential freeze-up for practical purposes eliminates pipeline construction prior to the Christmas - New Year holidays, due to the lack of daylight hours; the earliest break-up in the spring fixes the end of the winter season.

This study has revealed no facts indicating that the plan to limit the construction of a buried mode big-inch pipeline to the winter season serves any objectives other than environmental protection. No technical or cost advantages have been claimed for the winter construction concept, although experience in Canada (mainly south of 60° latitude) has shown that a buried pipeline in muskeg and similar wet terrain may be easier to construct when the ground is frozen and no special ground protection is required.

A construction scheme based on an annual 85-95 calendar day schedule in the winter, at a time of year when the productivity of men and equipment will be at best 50% of that for an extended moderate season schedule, is totally uneconomical. Direct construction cost for workers, equipment, logistics, and supplies is likely to run 4 to 6 times the cost of an all-year construction scheme, exclusive of the cost of schedule slippage. Moreover, the winter construction concept does not meet any test for "balancing environmental amenities and values with economic and technical capabilities, so as to be consistent with applicable national policies."

10.5 ANALYSIS AND EVALUATION OF RELATED EXPERIENCES

Preamble

The following analysis and evaluation deals with the various issues raised in the general discussions of winter construction of a big-inch pipeline in the north, and supports the foregoing conclusions. The related experience is based on records from the construction of the Trans-Alaska pipeline, submissions before the Federal Power Commission in the United States and the National Energy Board and the Mackenzie Valley Pipeline Inquiry (Berger Commission) in Canada, regarding gas transportation systems from Prudhoe Bay to the lower 48 states. In addition, background information was collected through interviews with persons having expertise or experience pertinent to these issues.

The basic intent of the agreement and grant of right-of-way for the Trans-Alaska pipeline was that "the parties shall balance environmental amenities and values with economic practicalities and technical capabilities, so as to be consistent with applicable national policies." It seems proper to test the "philosophy" of winter construction in terms of its effectiveness in satisfying this basic objective, as it may apply to any future pipelines using federal public land. For the purposes of these discussions, the terms "environment" and "environmental" have a limited connotation; for clarity, "socio-economic aspects" which are proper environmental concerns have been labelled separately. Further, the term "The North Slope" refers to the geographical area of the North Slope of Alaska and the Yukon (and the lower Mackenzie Valley north of the Arctic Circle.)

Environmental Aspects

The potential environmental impact during the construction of a big-inch pipeline in the north takes two main forms. The first is terrain disturbance, which results in visual impact, thermal degradation, and erosion (erosion may have a secondary impact on fish populations). The second is damage to wildlife, fish, and local ecosystems through the direct disturbance of construction activities, such as noise, harassment, water pollution, and air pollution.

In terms of terrain disturbance, both all-year construction (using gravel roads and gravel construction pads) and winter construction (using snow roads and snow construction pads) can theoretically keep damage to the terrain within acceptable limits. Experience in Alaska and the Canadian North demonstrates conclusively that gravel roads and construction pads, when properly constructed, keep terrain disturbance to a minimum. Further, the existence of roads and gravel construction pads facilitates terrain rehabilitation and maintenance within the pipeline right-of-way without further terrain disturbance.

On the other hand, experience in both Alaska and northern Canada shows that under operational conditions in the field it is extremely difficult to comply with the specifications for the construction and use of snow roads as required in order to prevent terrain degradation. Although there is no actual experience in Alaska or Canada of snow construction pads on a big-inch buried pipeline, there is limited experience available from the Alyeska installation of 4.5 miles of above-ground mode of the main line Trans-Alaska pipeline. There is also related experience from the Alyeska 8- and 10-inch gas fuel line on the North Slope. The Alyeska fuel gas line experience indicates that where blasting for the trench is required, it will be very difficult to prevent terrain degradation if the construction is carried out from a snow pad (Ref.10.7). The Alyeska fuel line experience does indicate that, where trenching machines can be used and where excavated material can be removed from the ROW and replaced with processed backfill material which is not susceptible to frost, terrain degradation may be within acceptable limits (Ref.10.7). However, while it is theoretically possible to keep terrain degradation within acceptable limits while constructing a big-inch pipeline from a snow pad, analysis of related experience in Alaska indicates that it is very doubtful if it can be done under full-scale field operation. The restoration of the pipeline right-of-way where the pipeline trench is excavated and backfilled in frozen condition has not been tested under field conditions, much less executed successfully after the installation of a pipeline. Furthermore, on a production basis.the servicing of a big-inch buried pipeline and the maintenance of the right-of-way without a gravel service road appear totally impractical, in fact virtually impossible, without causing additional terrain disturbance.

The Alyeska experience does show that a big-inch pipeline in the elevated mode can be constructed from a snow pad without causing unacceptable terrain disturbance (Ref. 10.8).

Regarding the second form of potential environmental impact from the construction of a big-inch pipeline, namely the direct disturbance of wildlife, fish, and other ecosystems, a schedule limited to the winter months should have the least impact. This does not mean, however, that there will be no impact during winter construction nor that the potential impact for any other construction schedule, whether an extended summer season or an all-year schedule, will be unacceptable. The experience with the Trans-Alaska pipeline shows clearly that, by proper planning and scheduling of the construction operations, direct disturbance to wildlife and aquatic animals can be kept within acceptable limits for an extended summer season schedule. Further, if such a schedule is extended to an all-year schedule with selected winter activities, additional "windows" with minimal direct impact of the construction operations on wildlife, fish, and local ecosystems will become available.

With regard to potential conflicts with mammals, a winter construction scheme involves about the same conflicts as an all-year scheme. As for fish populations, experience in Alaska shows that smaller streams may be as important as large rivers, and uncontrolled winter crossing by the pipeline installation may have quite severe secondary impact.

If a rigid winter construction schedule is compared with a flexible or all-year construction schedule, in terms of the desired balancing of "environmental amenities and values with economic practicalities and technical capabilities," this study shows that there are serious doubts as to whether this balance can be achieved if a restricted to winter operation construction scheme is implemented.

Regarding the socio-economic impacts of a major pipeline construction schedule limited to less than 100 days a year, it is unquestionably the least desirable scheme for the local people and communities affected by the construction operations. This question is of less concern on the Alaskan North Slope, where there are few individuals or communities, but it is of major concern for the people in the lower Mackenzie Valley of Canada. Taking into account both regional and national socio-economic effects, it is much more desirable to spread employment within physical and cost limits over the longest practical construction season. A year-round schedule designed to level employment peaks would be the most preferable scheme, in terms of both the local socio-economic impact and the regional economic benefits.

Constructability and Cost Aspects

The success of a winter construction scheme in the North, as has been proposed for a Prudhoe Bay-Lower 48 gas pipeline, is totally dependent upon the following untested assumptions:

- that a big-inch buried pipeline can be constructed during the winter months, using a snow construction pad only, at a production rate in excess of 50% of the rate which has been recorded in Alaska for summer construction;
- that snow roads can handle all transportation of equipment, materials, supplies, and logistics along the pipeline ROW;
- that a big-inch pipeline spread can be lighted artificially, to permit work during December and January;
- that sufficient workers and supervisors will be available for a full-scale pipeline operation during December and January.

Experience in Alaska and Canada shows clearly that reliable production during winter construction in the North (or in any sub-zero or inclement weather condition) can only be achieved by creating an artificial climate at the work site. The enclosure of individual work activities has not proved successful on a production basis; nor is it economical. Experience and independent studies both show a tremendous impact of sub-zero and inclement weather on construction activities which are not fully protected. The required time to carry out work varies from a slightly reduced performance rate for straight manual work which is not hindered by protective clothing, to a rate ten times as long for complex mechanical tasks requiring exposure of the hands. It is therefore very doubtful that an average production rate in excess of 50% of the actual summer production in Alaska could be accomplished during the winter in the North. Related Alyeska experience shows poor production rates, with virtually no buried pipeline completed during the months of December and January (Ref. 10.7, 10.8 and 10.9).

There is no actual experience in Alaska or Canada of snow roads being used for "production transport" for the sorts of tonnages during a limited season that are involved in a big-inch buried pipeline (Ref. Green Report). Nor is there any experience in either Alaska or Canada of the artificial lighting of a big-inch buried pipeline spread. The experts before the F.P.C. and the N.E.B. "totally" disagree as to the feasibility of such a scheme. Extrapolation from other construction experience indicates that, even if it is feasible to light satisfactorily each of the pipeline spread activities, this will constitute one more concurrent and dependent operation which will reduce the average production rate.

Both past experience and the current trend in Alaska and Canada is towards a shut-down of all but essential functions in the North for an extended Christmas-New Year holiday, lasting as long as 3 to 4 weeks. Alyeska's experience on the fuel gas line and on the elevated mode mainline section confirms this fact. It is very doubtful if sufficient workers and supervisors can be induced to forego their traditional holiday reunion with family and friends, when they have been working in remote areas and particularly the North.

Moreover, the first two potential winter construction months in the North, namely December and January, have more adverse conditions for outside construction activities than the last 3 to 4 months from February to May. The weather during this period is generally more stormy, there are fewer hours of daylight, and inadequate freeze-up can limit traffic and make the crossing of rivers and streams more time-consuming and dangerous. These problems, coupled with low morale among both workers and supervisors due to the curtailment of traditional holidays, support the conclusion derived from practical experience in the North that outdoor activities on a large construction job during the months of December and January are almost counter-productive.

One further point requires mention. The safety of workers who are scattered over a long distance, as is the case in a big-inch pipeline spread, when they are exposed to sub-zero weather, high wind-chill factors, and "white-outs," has not been properly considered in the winter construction scheme.

Weighing the foregoing factors, it must be concluded that full-scale pipeline installation in the buried mode, or in any other mode, during December and January borders on the impractical. The additional cost due to potential premature mobilizations and additional holiday premiums for workers and supervisors, together with the cost and the production impact of artificial lighting, make it impossible to predict with any degree of accuracy either the cost or the rate of progress of the construction. If one assumes that construction in the North during December and January is not practical, the winter construction "window" becomes 85-95 calendar days. By comparison, an extended summer season schedule should yield 180-200 calendar days, and an all-year schedule 250-280 calendar days. If one takes the average production rate for winter work at 50% of an extended summer season production rate, which has roughly twice the number of days per schedule season, the direct field cost for the winter construction scheme (comprising labour costs, equipment capital cost, logistics facilities, etc.) will be four times as great. This figure does not include the significant impact of learning curves for twice the number of workers and supervisors for a limited season, and their inevitably lower average skill. Moreover, the Alyeska experience fully supports the DOE risk analysis evaluation of schedule slippage during the winter construction of a gas pipeline. Both the short section of the mainline in the elevated mode and the fuel gas pipeline "slipped a season."

Considering the massive negative factors of the projected cost increase and the high probability of schedule slippage, with little or no potential reduction in direct environmental impact, there appears to be valid reason to reassess the merits of a winter construction scheme. Furthermore, from a socio-economic point of view, a winter construction scheme is most undesirable. The inevitable vastly increased demand for equipment is certainly not in the national interest;

nor is the potential delay of a year in a planned schedule. The high seasonal business and employment is not desirable from any regional economic point of view.

10.6 THE ALYESKA FUEL GAS LINE

The Alyeska fuel gas line is designed to supply gas to pump stations 1 through 4. It runs from Prudhoe Bay to pump station no. 4 south of Galbraith Lake, for a total length of 146.6 miles. The size is norminally 8 inches in diameter. The pipeline is located partially adjacent to the state highway, and partially adjacent to the gravel construction pad for the main pipeline.

Alyeska proposed the use of a snow pad adjacent to the highway or the gravel pad for winter construction during the 1975-76 season for this pipeline. The scheme was approved by APO, and construction commenced in December 1975. By mid-February 1976, approximately 8 miles had been completed, and by April 30, 1976 a total of 35 miles. From April 30 to the end of the season (about mid-June), another 35 miles was completed, giving a season total of approximately 70 miles. The work was rescheduled for the 1976-77 season. By February 13, 1977, some 27 miles of snowpad had been constructed and approximately 26 miles of ditch excavated, but no pipe lowered into the ditch. Completion was scheduled for May 1, 1977.

The figures indicate that during the 1975-76 winter season very little work was accomplished before mid-February. Production after April 30 to breakup equalled the total for the season prior to that date. During the 1976-77 season, no pipe lowering-in or backfill had been started by February 1977. Moreover, pictures taken during summer

1976 show that considerable disturbance of the tundra had taken place (Appendix 10-A2).

Conclusions

Snow pads can be constructed to the various classifications outlined in the Alyeska snow-ice road manual.

When a ditcher can be used and excavated material is removed from the ROW and backfill is done with processed non-frost material, minimal terrain disturbance takes place. However, when blasting for the ditch is required, the ground adjacent to the ditch gets disturbed, the snow pad gets contaminated, and the terrain disturbance along the ROW is considerable.

It is impractical to schedule production work in December and January because workers in the north, who have been away from their families for extended periods of time, want to go home for the holiday period. Furthermore, darkness and severe weather severely limit outdoor activities and affect the morale of the workers during this period.

Experience on the fuel gas line clearly shows that winter construction is no panacea for environmental protection, as far as terrain disturbance is concerned. In fact, if the highway and the gravel pad had not been adjacent to the snow construction pad to handle the transport traffic during construction and to facilitate the remedial work during the summer, the terrain would have been even more damaged than it was.

10.7 ALYESKA WINTER CONSTRUCTION OF MAIN PIPELINE - ELEVATED MODE

Field Data

On March 27, 1975, APO issued a NTP for the construction of an elevated mode section of the main pipeline on A.S. 117-118, a distance of approximately 5 miles. Snow for the construction pad was collected, with snow fences installed during December 1975. The pad was graded and compacted during January 1976. The installation of VSM's cross-members and pipe was carried out from February through April, 1976.

The snow pad served the intended purposes during the construction activities. Although the work on the section did not get completed before spring break-up, the schedule slippage was not related to the utility of the snow pad. Reports by APO/TSC and CRREL concur that the terrain disturbance by the construction activities was minimal, and aerial photos taken in late summer 1976 show little impact on the tundra along this section of pipeline.

The pipeline on this section parallels the main Yukon-Prudhoe Bay road, which was used for all supply and logistics traffic. Thus the snow pad was used for construction purposes only.

It should also be noted that grades both transverse and longitudinal were slight to moderate for this section of the pipeline.

Conclusions

A snow pad is practical for the installation of a large-diameter pipeline in the elevated mode.

A snow pad adequately protects the tundra if it is constructed according to Alyeska design standards after there is sufficient freeze-up and if use is discontinued before break-up in the spring (see pictures, Appendix 10-A3).

Except for activities connected with the snow pad construction, no activities of the VSM-Pipe installation took place during December and January.

10.8 NOTES FROM MEETING WITH DR. TERRY MCFADDEN AND PHILIP JOHNSON OF CRREL, FORT WAINWRIGHT, ALASKA, MARCH 16, 1977

The Cold Regions Research and Engineering Laboratory (CRREL) of the U.S. Corps of Engineers is conducting an ongoing operation of "spot" observations for various types of work, covering the performance of both equipment and workers. CRREL's final reports will be prepared in Hanover, N.H. Their observations have led them to the following preliminary conclusions:

Productivity

- factors ranging from 1 to 10 have been recorded for the time required for workers to perform tasks in cold weather, as compared to the summer season, depending on the type of work and the chill factor;
- the worst impact is on any activities requiring exposure of hands, such as equipment repair; the least impact is on simple manual work;
- equipment is affected as much as workers. It almost seems to acquire human idiosyncrasies when it gets cold, and a lot of small things go wrong;
- in general on Alyeska work, a factor of 3 may be a good average for winter vs. summer;
- the months of December and January have for practical purposes been non-productive, due to bad weather, darkness, and the fact that workers want to go home;
- most types of work can be accomplished in the winter, but at "a cost";
- the answer is to create your own climate.

Artificial Lighting

- no full-scale operations were observed, but considerable work in fixed locations was carried out under artificial light;

- the operation and maintenance of lighting equipment falls in the most affected class, in terms of productivity.

Fuel Gas Line

- all observations were taken during the 1975-76 season;

- construction of the snow pad is no particular problem. The standards set in the Alyeska Manual are sound and can be accomplished in the field;

- works well for most construction equipment, but there were traction problems and consequent breakdown of the surface for trucks and truck trailers, particularly on the slopes - used dozer for assistance (Note: Exactly the same as Green report);

- ditching in silts, etc., was fine, but the ditchers did not perform in frozen gravel;

- there was considerable disturbance to the ground where the ditch needed to be blasted, as well as contamination of the snow pad.

- in the spring, rock dust was put on top of the snow pad to complete the work. The cleanup and restoration work afterwards did disturb the tundra; and would have been impossible without the adjacent highway or gravel pad.

- no follow-up observation on terrain degradation was conducted by CRREL during Summer 1976.

Regarding Winter Construction

- environmental impact evaluations were not part of CRREL's Alyeska programs;

- in general, they cannot see that environmental protection is "automatic" with winter construction;

- this season (i.e., 1976-77) the drilling at Naval Petroleum Reserve No. 4 was much delayed due to lack of snow. The plan had been to work from central camp with snow roads to each drill site, but little was accomplished before January;

- from the point of productivity, don't do anything in the early winter which can be done in the moderate seasons;

- there are lots of problems with stream crossings during early winter.

WINTER CONSTRUCTION-FUEL GAS LINE

Total Length 774,036 ft.
146.6 Miles

1975-76 SEASON AS PER ALYESKA AND APO REPORTS

PROGRESS ANALYSIS:	April 30, 1976	June, 1976 End Season
Snow Pad	435,397	
Ditch	287,012	365,407 (AL)
String	398,138	578,326 (MRI)
Weld	371,512	508,407 (AL)
Lower-In	230,519	375,397 (MRI)
Back-Fill	186,386	365,407 (AL)

1976-77 SEASON AS PER ALYESKA PROGRESS REPORT

	February 13, 1977	Plan May 1, 1977
Snow Pad	145,000	405,000
Ditching	138,699	405,000
String	45,061	206,000
Weld	14,470	272,000
Lower-In	Nil	405,000
Back-Fill	Nil	405,000

WINTER CONSTRUCTION

ALYESKA BELOW-GROUND PRODUCTION RATES

NORTH SLOPE - SPRING, FALL AND "BORDER LINE" WINTER

Week Ending	Production Rate (miles per day)	Week Ending	Production Rate (miles per day)
Oct. 5, 1975	0.36	April 25, 1976	0.11
Oct. 12, 1975	0.10	May 2, 1976	0.16
Oct. 19, 1975	0.40	Oct. 3, 1976	0.043
Oct. 24, 1975	0.41	Oct. 10, 1976	0.014
Nov. 2, 1975	0.07	Oct. 17, 1976	0.043
Nov. 9, 1975	0.13	Oct. 24, 1976	0.57
Nov. 16, 1975	0.14	Oct. 31, 1976	0.014
Nov. 24, 1975*	0.014	Nov. 7, 1976	0.028
Nov. 30, 1975	0.03	Nov. 14, 1976	0.10
April 11, 1976	0.44	Nov. 21, 1976	0.13
April 18, 1976	0.20	Nov. 28, 1976	0.10

* Begin winter shutdown.

Source: Alaska State Pipeline Coordinator Office.

Appendix C

LETTERS FROM ARCTIC CONSTRUCTION EXPERTS

Bearfoot, Inc.

H. C. Price of Canada Ltd.

Majestic Wiley Contractors Limited

Travis E. Smith

Frank Moolin and Associates, Inc.

Curran Houston, Inc.

'ARFOOT INC.

130 West International Airport Road • Suite M • Anchorage, Alaska 99502 • (907) 279-6223

July 9, 1979

Mr. R. N. Hauser
Northwest Alaskan Pipeline Corporation
P. O. Box 1526
Salt Lake City, Utah 84110

Dear Mr. Hauser: Re: Contract A79-152

Transmitted under cover of this letter is our analysis of the current state of the art of snow road and snow pad construction as practiced on the North Slope of Alaska and its relation to a winter big-inch pipeline construction.

We are prepared to do further work on this or related subjects as you may require.

BEARFOOT, INC.

Robert E. Hiukka

Robert E. Hiukka, President

James K. Trimble

James K. Trimble, P.E.

REH/km

Enc.

INTRODUCTION

Snow roads as used on the North Slope of Alaska, particularily in the Prudhoe Bay area and vicinity have been constructed with water saturated snow, built up thin layer by thin layer to a thickness of 6 to 12 inches. These roads have served primarily for rubber-tired traffic in the winter haul of gravel for the construction of permanent gravel roads, drilling pads and production facilities. These roads for these specific uses have been employed to minimize damage to the tundra and effects on wildlife. They were used for construction of the high voltage overhead electric distribution system at Prudhoe Bay and in conjunction with the gravel road network for the relatively short oil and gas gathering lines. Other uses have included access roads to winter test sites and infrequent or low density rubber-tired heavy load transport accesses.

The owner of Bearfoot, Inc., Robert Hiukka has built many snow roads on the Arctic Slope. First as Superintendent for Rivers Construction Company from 1969-1974, he was in charge of all civil works for Rivers Const. in the Prudhoe Bay oil field. He built snow roads to haul large amounts of gravel at Prudhoe Bay for B.P.-Sohio and Atlantic Richfield Company. These were successful operations with minimum damage to the tundra. Later with Arctic Constructors for the Alyeska Pipeline Construction as a construction superintendent, he built snow roads for access and gravel hauling for the pipeline pad in the Franklin Bluff's section of the pipeline just south of Prudhoe Bay. While with River's Construction, he built a snow airstrip for Hercules Aircraft specification 150' wide by 5,000' long, at Happy Valley Camp about 100 miles south of Prudhoe Bay.

Another principal, James K. Trimble was involved in the snow road construction as chief site engineer and assistant construction manager for Brown and Root. He was in charge of construction for the B.P.-Sohio portion of Prudhoe Bay. As Director of Engineering, he was in charge of Arctic Gas experimentation for snow roads and construction pads in Alaska.

The principals of Bearfoot, Inc. have been actively engaged in Arctic planning and testing of snow road construction.

The unsuccessful Arctic Gas proposal involved several hundred miles of snow road and snow construction pad area across Northern Alaska and Canada and down the Mackenzie River Valley. Bearfoot also made several trips to northern Canada and the Mackenzie River Valley in regard to snow road construction for both the Alaskan and Canadian portion. In addition Bearfoot directed ice aggregate experiments for both Alaskan Arctic Gas and Atlantic Richfield Company.

For the last two winter construction seasons, Bearfoot, Inc. has furnished construction management assistance to Husky Oil Co. in the National Petroleum Reserve on the Alaskan North Slope, on civil works which included snow roads, snow landing fields and winter cat trails.

IMPACT FACTORS

There is no significant accumulation of snow on the North Slope until November and some of the years much later. In at least two years since 1969 there has not been enough snow to construct snow roads until January or February unless supplemented by other materials or hauling from natural snow traps.

The North Slope is characterized by frequent winds which are often high enough to blow snow and increase the chill factor making work at times not only difficult but often impossible. The wind is also an important factor in the accumulation of snow either by natural or man made traps, thus affecting availability for snow road construction.

Construction of snow roads is temperature dependent. Either too high or too low temperatures increases the difficulty of construction. Although the overall average temperature is fairly constant from year to year, there is often significant variation on a weekly or monthly basis.

Permits are required from State and Federal Government to get on the tundra in the fall and they are subject normally to cancellation on 72 hour notice during the approach of breakup time in the spring. The time of issuance of permits is heavily dependent on the freezing of the unfrozen layer of tundra, the active layer between the top of the ground and the top of the underlying permafrost layer, and also the presence of sufficient snow cover to protect the surface vegetation.

In our experience, the tundra has been completely frozen sometime in November, often by the middle of November. It can be said with reasonable certainty that the tundra is frozen, in most years by mid November. Snow cover is another question and it is doubtful that in most years there will be sufficient snow naturally available to start in November. It has been our experience that there may in some years be a deficiency into January.

CONSTRUCTION PROCEDURES

The construction procedures used in the 70's at Prudhoe Bay evolved from experience and basic methods used earlier in the 60's and results are similar. The roads are essentially snow saturated with water and built up in thin layers of 2 or 3 inches at a time with densities in the order of 0.8 in comparison with ice at 0.9.

Although these snow roads are approaching the density of ice, their behavior is different than a road constructed by freezing water poured out on the ground, being tougher and more resistant to cracking and chipping. Not only does the snow serve as a sponge to contain the water until it freezes, it also promotes a mat of ice crystals which interlock and are stronger than the ice structure of standing water which is frozen and has the ice crystal all oriented in one direction.

Snow road construction starts with stripping the existing snow layer down to the tundra, leaving just enough snow that the dozer operator doesn't scar the existing vegetation or cut off the natural ridges of the tundra.

It is necessary to remove the snow from depressions, as all of the road has to be built up in thin layers to avoid bridging over snow pockets. These pockets would be weak and the surface would soon break through under any traffic necessitating continuing repair.

After the snow is removed from the tundra, the tundra is flooded with water and allowed to freeze.

Then a layer of snow about 2 to 4 inches deep is applied and dragged or bladed over the route, leveled and then sprayed with water to saturate the snow. This surface is compacted and smoothed with the special drag and then allowed to freeze. This is repeated in several layers until 6" to 12" of dense, hard, durable road surface is built up.

Repairs are accomplished in the same way as construction, with pot holes and other areas being filled in with snow, saturated and allowed to freeze before being subjected to traffic. Most snow roads are made wide enough to allow traffic to bypass areas being repaired.

Our own experience has been with snow roads used primarily by heavy hauling equipment mounted on rubber tires such as scrapers, dump trucks and front end loaders. There was occassional traffic with tracked dozers and other equipment but it was avoided when possible, as the tracked vehicles would require the necessity for repair on a frequent basis.

There was considerable tracked equipment used on the construction of the 10 inch gas line south from Prudhoe Bay to the Brooks Range. Most if not all of this snow pad was directly off the shoulder of the gravel haul road and was not used for logistic traffic, which used the main gravel road. Thus there was much less traffic on the snow pad than would have been the case if it had been the only surface utilized. Furthermore this pad was, to the best of our knowledge, not constructed by the layered snow and water method previously described.

We do not believe that there have been any examples of snow road construction which would demonstrate those wearing and maintenance qualities required for a full big-inch pipeline spread working solely from snow roads.

REQUIREMENTS FOR EARLY START OF CONSTRUCTION

The worst period for construction during the winter is January and February with the extreme cold and long hours of darkness.

Due to inadequacy of snow in the early winter in November and December, prime winter construction months, it may be necessary to supplement the natural snow with other materials and methods.

We participated in some research in the winter of 1976-1977 on the use of snow fences to entrap snow during the early part of the winter. These experiments were encouraging, however, only a preliminary beginning was made with much work remaining to be done before it could be even considered for a major construction project.

Snow making has been tried but to date without a great deal of success. It is a slow, costly method involving handling very large volumes of water at a time of the year when water supplies are low or non-existant requiring long hauls and vast numbers of water trucks to cover long distances. Research had been projected for large scale experiments on very large scale equipment but was not accomplished.

We have been involved in experiments in using crushed ice in lieu of snow for making ice aggregate roads in Fairbanks in February 1977 which was successful on a very small scale. However, the surface of this type of road was severely abraded with the introduction of track vehicle traffic.

More recently we were involved in an ice aggregat. experiment under entirely different conditions in the field on the North Slope but they were inconclusive and the data so far obtained is the proprietary information of the client.

It would appear that this method has some promise for an early start in construction but a great deal of work and experimentation remains to be done before the method could be perfected or shown to be applicable as a pipeline work pad.

We do not believe that there has been any Alaskan North Slope experience with construction and use of snow pads built on side slopes requiring a snow pad of non-uniform thickness. These roads and pads present additional problems in construction and maintenance. Such construction at a minimum would require considerably more snow which may be short supply. It is unknown if it is possible to contain the necessary water on the side slope to maintain a uniform density for strength. The development of highly sophisticated and specialized water application methods and equipment would of necessity need to occur for this type of large scale application. Even then it cannot be guaranteed that the thick side of the snow road will stand up under the concentrated traffic loads of sideboom tractors.

INHERENT RISKS

Present techniques of snow road construction as practiced on the North Slope are highly dependent on weather conditions of temperature, wind, snow fall and snow accumulation on the ground. Variations in weather has shown by experience the inability to predict when it can be reliably stated that a full scale snow road could be constructed. This ability to predict is a basic requirement for any contractor to bid fixed price on a definite starting date and on a known construction schedule.

It may be possible that sufficient snow has accumulated in November sometime to permit construction of a snow road or working pad. However, in our experience, there have been years when even as late as January and February there has been a severe shortage of accumulated snow. Under these conditions, using presently developed techniques, a work pad could not be completed in time for large scale pipeline construction. As another weather dependent variable, temperatures should ideally be about -20°F. When the temperature is substantially above or below, snow pad construction would be greatly slowed down.

It is very difficult to make any progress at temperatures much above 0^{o}F as freeze back times are greatly increased. At temperatures much below -20^{o}F water penetration into the snow is poor and water handling problems are great. At this temperature construction becomes difficult and slow.

Construction may require hauling snow in from catchment areas which is slow, costly and inefficient due in part to the light weight of snow and other gathering and handling problems.

The winter construction period means construction during the period of the year when temperatures are usually very low, when high winds are common, greatly increasing the effect of cold by wind chill and producing white-out (a reduction or complete loss of visibility due to blowing snow.) In addition, the periods of daylight varies from a few hours to virtually none. For nearly two months the sun does not rise at all and there is only a mid-day twilight, resulting in the great inefficiency of having to do everything in the dark under the difficulty of trying to keep adequate portable lighting systems running under arctic conditions. Operating under the conditions of poor lighting and intense cold results in very poor working conditions and a low level of workmen efficiencies. In many operations where the worker is exposed to the weather the efficiency may be 25% or less. Equipment breakdown is more frequent, lubrication impaired and maintenance and repairs are difficult and costly.

The construction of the saturated snow road requires large quantities of water. In the winter time supplies of water are very limited. The quantity decreases rapidly in the early winter as ice thickness increases. The constraint is added to severe restrictions on water removal from fish bearing lakes and rivers. As a consequence, water probably would have to be hauled long distances requiring a large fleet of water trucks.

Access to an area during a second winter season will require the construction of an entirely new set of roads and work pads which is a duplication of previous work, as of course, the structure is lost at the melting at breakup. This creates the potential for delay in the construction schedule and the associated cost over-runs.

As influenced by the conditions of weather, construction rates would be unpredictable for any designated period making scheduling difficult.

In our experience there has been little use of snow roads for tracked vehicle use. Those used have been for gravel hauling with rubber-tired equipment for road and drilling pad construction and drilling rig moves. Tracked vehicles abrade the surface and for such reasons are ordinarily kept off the snow roads. There has been no large scale experience to our knowledge in handling large pipe over the ditch on a snow pad. It is expected that abrasion and pad deterioration will be severe. Due to the congestion of the working area, maintenance will be difficult and disruptive as it requires wetting and refreezing of the surface. Traffic must be halted in this area and cannot resume until refreezing occures.

We have directed our remarks to the proven methods of snow road construction. There are possibilities of being able to develop means for collecting early snow, for manufacturing snow on a grand scale and in using new techniques and materials such as ice aggregate. These developments are either in the conceptual stage or are in the early experimental stage and not yet are ready for a project of this type. A large scale testing and Research and Development program would be required and positive results obtained to justify utilization on a large scale "fixed price" project.

As a conclusion, we do not believe that the present use of snow road construction is predictable enough to permit a contractor to present a reasonable fixed price bid for pipeline construction from a snow pad on the Arctic Slope. It would be extremely difficult to get fixed price bids due to the following reasons:

- Not complete control over natural events
- Confined working schedule
- Simultaneous construction tasks
- Limited schedule flexibility
- Snow pad not known to be resistant to severe deterioration by pipeline equipment and concentrated work areas.
- Requires additional equipment
- Severe weather problems encountered
- Low workmen productivity
- Increased maintenance problems
- Reduced daylight work time

In summary, the unpredictable nature of the entire snow road concept contributes to the inability of any contractor or company to assess potential final cost with any degree of accuracy.

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214 - Chinook Centre, P.O Box 5038, Postal Station "A",
Calgary, Alberta T2H 1X1

.lephone (403) 253-2815 Telex 038-24696

August 22, 1979

Northwest Alaskan Pipeline Company
P.O. Box 1526
Salt Lake City, Utah 84110

Attention: R. N. Hauser
Director of Construction

Gentlemen:

Subject: Contract No. 179-158, Report on Winter Construction and use of Snow Roads

Pursuant to your request we are pleased to enclose herewith our summation of our views concerning winter construction of a large diameter pipeline under arctic conditions.

We are pleased to assist you in your efforts and should you need any further assistance or have any questions please feel free to contact me.

Yours very truly,

J. G. Beddome
President

DRB/dh

encl.

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214 - Chinook Centre, P.O Box 5038, Postal Station "A",
Calgary, Alberta T2H 1X1

Telephone (403) 253 2815 Telex 038-24696

A COMPARISON OF WINTER PIPELINE CONSTRUCTION TECHNICS

Pipeline Construction Technics in Northern Regions vary depending upon the many variables affected by the design and construction of major pipeline projects in different locations. Some of the parameters affecting pipeline construction methods are as follows:

A. Terrain
B. Soil Conditions - Muskeg, permafrost
C. Weather - Temperature and Precipitation i.e., rainfall and snowfall
D. Daylight working hours per day
E. Construction time frame and related progress
F. Vegetation - heavy timber, sparce growth

Primarily, pipelining in northern regions must be broken down into summer or winter construction based on the preceding parameters. By assessing the impact of each variable, a viable construction sequence must be evaluated to determine the best practical way to approach a particular project obtaining a construction procedure which will be both environmentally sound and effective to the extent of project completion within the construction time frame alloted in an efficient, safe and cost affective effort of the owner companies, state and federal agencies and the contractor.

From a construction point of view, the most important aspect is the related progress that must be achieved to complete the project both on schedule and under budget. However, overcoming the terrain and weather conditions in northern regions can become the foremost obstacle in achieving these goals.

In Northern Canada and Alaska how to approach building a large diameter pipeline with the existing ground conditions such as permafrost and muskeg along with the extremely harsh weather conditions and their effects that plague construction efforts becomes a major concern. Looking at pipeline practices in Northern Canada and Alaska there are two methods of construction which are used to proceed with the work in an effective manner. They are as follows:

1. Build the pipeline in the winter utilizing winter construction practices to overcome the inherent soil problems. Canadian construction practices dictate that

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where stable soil conditions exist these areas are con-constructed in the summer while areas which have muskeg and ice rich soil are constructed during winter months.

2. For Alaskan pipeline projects, working from a work pad placed on the right-of-way to protect the ice rich layers of soil provides a workable surface to support heavy equipment.

In the past, a method of construction in Northern Canada has been devised and is working extremely well in areas where there is a combination of both heavily timbered areas with intermixed areas of low lying muskeg and small bush.

In this instance, to move the pipeline spread across these areas of muskeg it is more economical to use the winter construction technics rather than summer construction practices.

One of the advantages in Canadian winter pipeline construction seasons compared to Alaska is the approximate eight working hours of daylight. Also, the time frame for winter construction in Canada is generally from November 10 thru December 15 at which time pipeline operations would normally be shut down with work resuming on approximately January 5 thru March 25 of the following year. During this time one could expect to have at least one to two weeks of extremely cold weather in January along with extremely harsh conditions in which to achieve any suitable production.

Assuming the type of terrain in Canada as previously mentioned, the typical construction sequence would be as follows:

> The initial construction crews beginning on the pipeline right-of-way would be the clearing and grading crews. As the timber and brush are being cleared the grading crew is immediately following this operation. Snow and loose debris from clear-ing and grade operations would be pushed into a berm over the ditch line to heights of up to ten feet with an approximate width of fifteen feet to create an insulation barrier over the ditch line thereby protecting the soil over the ditch from the extremely low temperatures.

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'ephone (403) 253-2815 Telex 038 24696

The winter construction method previously mentioned may appear to be desirable to construct pipelines in areas such as Alaska, however the concept differs due to some of the same parameters previously listed.

For instance, the severe weather conditions along with reduced daylight working hours are good examples. The long summer construction season available in Alaska negates the use of conventional Northern Canadian pipeline practices as previously discussed or the use of snow pad construction for winter pipelaying.

An alternate previously used to construct pipelines in potential ice rich areas is one of building a gravel work pad along the right-of-way in order to prevent vegetative growth of permafrost areas from being damaged to a point that degradation of ice lenses occurs prompting settlement and permanent soil instability. In doing so, this alternate has many other advantages over building of a snow pad in winter months as a working surface.

By using the gravel work pad for pipeline construction in Alaska, the contractor is able to take advantage of the eight months of workable temperatures along with sufficient daylight hours.

Also, during the actual pipelaying activities, working from a level gravel work pad on steep terrain can be a vital advantage for standard pipelaying. In section III (North and South of Fairbanks) of the Alyeska Project H.C. Price Co. experienced one section of constructing the 48" pipeline where snow pad construction was mandated due to sensitive soil conditions. When laying pipe in choppy terrain with sidehill slopes it is very difficult for the equipment to maintain the traction needed. Once the pipe is skidded up, it has a tendency to slide downhill creating a very dangerous situation to workers. On this particular location H.C. Price Co. had a near fatal accident resulting from just this kind of a problem.

In addition the extensive heavy equipment traffic requires a constant repair and maintenance program for the snow pad. The turning of tracked equipment and the heavy weights particularly with sidebooms shifting weight on only one of the tracks causes immeasurable damage to the snow pad and makes the snow pad maintenance non existant in a short time.

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Calgary, Alberta T2H 1X1

Telephone (403) 253 2815 Telex 038-24696

In relying on a snow pad for means of construction, all operations are more dependent on the weather, for example having delayed winter temperatures or an early spring break-up can disrupt all planning and coordination of intricate construction schedules to meet environmental deadlines. In conclusion, H.C. Price Co. having worked both Alaskan and Canadian pipeline projects during both summer and winter schedules have concluded that even though winter pipeline technics such as those used effectively in Canada, may not be desirable for other areas.

Contractors recognize certain environmentally critical areas must be constructed during winter months and in our opinion the gravel work pad enables the contractor to perform his duties in these areas in the winter and complete the non sensitive areas during the summer construction period.

James G. Baldwin

MAJESTIC WILEY CONTRACTORS LIMITED

George M. Oswald
Vice-President, Construction

September 18, 1979

Northwest Alaska Pipeline Company
P.O. Box 1526
Salt Lake City, Utah
84110

Attention: R. N. Houser
Director of Construction

Subject: Contract No. A79-159 Report on Winter Construction and use of Snow Roads

Gentlemen;

We herewith submit our opinions to the best of our knowledge on the construction of large diameter pipelines under Artic Conditions.

We appreciate the opportunity to assist you on this subject and any further assistance you may require please feel free to contact us.

Yours truly,

MAJESTIC WILEY CONTPACTORS LTD.

G. M. Oswald
Vice-President, Construction

GMO/ce

Encls.

10123 - 118 STREET, EDMONTON, ALBERTA T5K 1Y4 — TEL: (403) 482-5921, TELEX: 037-2713

MAJESTIC WILEY CONTRACTORS LIMITED

A Comparison of Winter Pipeline Construction Methods

Winter pipeline construction in Northern Canada has been determined by the following:

A) Access

B) Ground conditions   Muskeg - Permafrost

C) Weather conditions

D) Time frame

E) Environmental restraints

F) Fish - Wild life

A construction plan must be prepared taking into consideratin all of the above mentioned items to ensure that the project meets all environmental requirements, completion dates, and to ensure a safe but cost effective pipeline is constructed which will satisfy the requirements of the Owner, Governmental Agencies and the Contractors.

Looking at winter pipeline construction in Northern Canada and Alaska, where there is a considerable amount of Permafrost and muskeg to conte:d with, there are only two methods to follow which we believe will satisfy all concerned.

The current approved winter construction method used in Northern Canada, could be used on the southern portion of the proposed Alaskan Gas Pipe Line.

The time frame for winter construction in Northern Canada is generally from November 10th through the end of March.

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Time between November 10th and the month of January is the time usually set aside for Clearing, Grading and obtaining the proper frost penetration. The months of February and March are basicly for completing all the pipe related activities.

The initial construction crews on the pipeline right-of-way would be the clearing and grading crews. As the timber and brush are being cleared the grading crew is immediately following this operation. Snow and loose debris from clearing and grade operations would be pushed into a berm over the ditch line to heights of up to ten feet with an approximate width of fifteen feet to create an insulation barrier over the ditch line thereby protecting the soil over the ditch from the extremely low temperatures.

By utilizing this technique, the soil is prevented from freezing enabling the ditching equipment to excavate under almost normal summer conditions. In addition the equipment should stay off the ditch line as much as possible to prevent driving the frost down. In the low lying areas (muskeg and wet areas), wide pads would be used to remove the snow to obtain the opposite effect of the insulation barrier. By using low ground pressure equipment, the snow can be removed without the equipment breaking through these soft areas. Also, the same pieces of equipment would "walk down" the frost to a desirable depth from two feet or more under normal winter temperatures. In effect, an ice bridge is created across an area which before would have prevented passage of heavy equipment.

As ditching commences, the removal of berm to spoil side of ditch would be immediately in front of the ditching crew and removed only to anticipated length to be ditched in a single day.

.../3

To facilitate this method of winter construction, the sequence of operations would be changed somewhat from normal cross-country pipelining practices. Instead of bending and laying pipe (welding) behind the ditch, the pipe is bent, welded and placed on skids in front of the ditch operation. This procedure prevents the backfill from freezing in place on the right-of-way and provides the contractor with near summer backfilling conditions.

The previous mentioned methods of pipeline construction can not be used on the northern portion of this anticipated project. We would propose an alternate previously used to construct pipelines in potential ice rich areas of building a gravel work pad along the right-of-way in order to prevent vegetative growth of Permafrost areas from being damaged to a point that degradation of ice lenses occurs propting settlement and permanent soil instability. In doing so, this alternate has many other advantages over building of a snow pad in winter months as a working surface.

By using the gravel work pad for pipeline construction in Alaska, the contractor is able to take advantage of the eight months of workable temperatures along with sufficient daylight hours and to be able to ensure the anticipated progress to meet the completion dates and to come within budget.

Furthermore, once this gravel pad is in place it will be an asset to the Owning Company for their maintenance program to enable them to comply with all Governmental requirements.

The question arises: Can the use of a Snow Pad accomplish the same end results as a Gravel Work Pad?

We are not aware of any pipeline being constructed from a Snow Work Pad in Northern Canada, although being Assistant Project Manager on Section II of the Alyeska Pipeline Project we know of the problems that H. C. Price had on the short section that was installed off of a Snow Pad just out of Fairbanks, Alaska.

We wish to bring your attention to some of the problems that occured:

A) All operations are more dependent on the weather.

B) Additional Right-way Maintenance people are required for constant repairs due to the extensive heavy equipment traffic.

C) In order to hold the snow on the work pad, it has to be watered down thereby forming a "skating rink" for equipment and hands to work on, contributing to a higher accident rate.

D) Inability to maintain the same progress as working from a Gravel Work Pad.

E) No access for maintenance purposes.

F) Due to the rigid time schedule, the project would not be economically feasible to be constructed off of a Snow Pad.

Majestic Wiley Contractors LImited, having played a major role in the construction of the Alyeska Pipeline Project and being one of the major pipeline contractors who have pioneered winter construction pipeline proedures, highly recommend the use of a Gravel Work Pad.

TRAVIS E. SMITH
850 CHERRY LANE
BARTLESVILLE, OKLA. 74003

September 28, 1979

Mr. R. N. Hauser
Northwest Alaskan Pipeline Co.
P. O. Box 1526
Salt Lake City, Utah 84110

Dear Bob:

In accordance with your request, the following are my comments on the use of snow pads and snow roads for construction of the Alaska portion of the Alaska Natural Gas Transportation System:

1. Snow roads are only suitable for light vehicular traffic if extensive use is required. They can handle infrequent heavy wheel loads, but the thickness must be increased. Maintenance becomes a serious and costly problem when tracked construction equipment is used on snow roads or pads as the road/pad deteriorates rapidly under use. The pad must be maintained daily and the surface watered down each night so that it will harden prior to the next day's activities.

2. Generally there is insufficient snowfall during the winter from Fairbanks to Prudhoe to provide the quantity of snow needed for significant pad construction (e.g., there was only enough for infrequent 3-to-4 mile maximum segments on TAPS), and much of the snow has to be manufactured to meet the total requirements.

3. Snow fences North of the Brooks-Range generally have been ineffective in collecting snow for snow pad requirements, because of the limited snowfall and the frequent shifting winds.

4. Manufactured snow is the only reliable means of providing your snow requirements. It is mandatory if snow pad construction is to commence in October and November. If snow is to be manufactured, the following must be borne in mind:

   (a) Making snow requires that a large volume water source be available during the full duration of the winter months. Such large sources are very limited in number and generally they are remote from the work site.

   (b) Snow or water normally must be transported significant distances from the water source to the work site.

   (c) Manufacturing of snow cannot begin until ambient temperatures are consistently below freezing.

(d) Snow normally must be manufactured 24 hours/day to meet placing requirements.

(e) The production rate from one snow machine is generally insufficient, so that numerous units will be required for extensive pad construction requirements. As an example, two machines operated 24 hours/day for three weeks to construct 2500 feet of snow pad in Section 3 of the TAPS line.

5. Use of ice aggregate for pad construction cannot commence until the thickness of ice on the lakes is sufficient to support mining equipment. Furthermore, large bodies of water will be needed to provide adequate quantities of material for significant pad construction. This will usually necessitate long haul distances from the source of supply to the work site.

6. The progress rate for snow pad construction is significantly less than for gravel pad construction unless large quantities of hauling equipment (either snow or water) are used.

7. You must allow a minimum of one month advance start for snow pad construction before subsequent activities can commence. Otherwise, critical construction activities will be delayed by the pad construction effort. Thus, a minimum of one month will be lost during the critical <u>Fall-Winter</u> shoulder months for pipeline construction.

8. A snow pad deteriorates rapidly during the <u>Winter-Spring</u> shoulder months. Use of snow pads will result in loss of a minimum of one month during this period for pipeline construction when compared with the use of a gravel work pad.

9. Use of snow pad is extremely sensitive to winter temperatures. An abnormally warm winter will make the use of snow pads impractical. When this becomes apparent, it will be too late to build a gravel pad. Should this occur, the critical Winter construction scheduled for that season will have to be delayed until the following year. There will be no assurance that the same situation will not occur again the following season.

10. Construction from a snow pad in hilly terrain is extremely hazardous since even tracked equipment with snow grousers tend to slide under load when on an incline.

11. Based upon my TAPS experience, the cost of work pad construction using snow will be at least ten times, if not greater, the cost of a gravel work pad.

Frank Moolin &
Associates, Inc.

July 27, 1979

AIC/FAI-0651

Mr. Edwin (Al) Kuhn
Director of Government &
Environmental Affairs
Northwest Alaskan Pipeline Co.
1001 "K" Street
Washington, D.C. 20006

Subject: Location of Gas Line

Dear Al:

Your letter of June 28, 1979 transmitted additional information and requested comments regarding the concept of the gas line "hugging" the haul road for substantial lengths of line, instead of being placed alongside an extended Alyeska work pad. Also, when I was in Washington, D. C., you related to me some of the discussions going on about locating the gas line along the Haines line right-of-way from the Salcha River area south of Fairbanks to Delta Junction, instead of paralleling the crude line. This letter will address these two issues.

Firstly, regarding proximity to the haul road I strongly disagree with and am bothered by the paragraph contained on page 2 of the June 13, 1979 letter from the DOI that says, "where the gas line is routed along the Yukon River to Prudhoe Bay State Highway, the minimum separation distance between the gas pipeline center line and the highway center line shall be nominally 44 feet...". The 44' distance from the center line of haul road to the gas line is much too close and is obviously predicated on statements included in Jack Turner's June 7, 1979 memo to the Assistant Secretary where he says, "...preferably such construction should be done in winter when snow pads can be used both for equipment support and storage". (emphasis added)

I can summarize my opinion regarding "hugging" the haul road by saying that it is practical to locate a buried gas line 55-60' from the center line of the haul road. This is somewhat less then the 70' proposed by Northwest in previous submissions to the DOI. However, the fact that it is practical does not necessarily mean that such a location would be the least costly.

The 55-60' spacing (haul road to gas line) is based on the following:

1). A gravel work pad would be built between the shoulder of the haul road and the edge of the ditch for stringing, line-up, welding, side boom cradling of the pipe, lowering into the ditch and backfill.

2). One lane of the haul road would be used as a part of the work pad for the movement of equipment and personnel along the line.

3). The other lane of the haul road will be kept open for one-way controlled, non-pipeline construction traffic.

4). No snow pads will be used. As I have indicated in earlier correspondence (my letter dated July 10, 1979 containing a draft copy of prepared testimony to the Dingell Committee), Northwest must not agree to build significant lengths of snow pad or snow road. This statement applies regardless of whether the gas line "hugs" the haul road, is built adjacent to the Alyeska work pad or is built at any other location. An all-weather, full width gravel work pad is absolutely essential to your project, and locating the gas line alongside the haul road does not change this situation.

I do not share many of Northwest's concerns about using one lane of the haul road as a part of the work pad. The haul road lane used as a part of the work pad would primarily be for passing of equipment. All work relating to stringing, line-up and clamping, welding, cradling, lowering-in and backfilling would be done off the gravel work pad, which would be built alongside of the shoulder of the haul road. I have included a rough sketch of this concept as an attachment to this letter.

Dust would be controlled by watering the haul road. One-way, non-gas line traffic could be safely controlled on the other lane of the haul road. I don't believe that the volume of traffic will be so significant that safety problems or bunching up of haul road traffic would develop. After completion of gas line construction, the haul road would have to be dressed and recontoured to repair the damage done moving heavy equipment over the haul road shoulder. Again, I don't believe this is extraordinarily difficult or costly to accomplish.

I believe the basic criteria for the location of the gas line, whether it is to hug the Alyeska gravel work pad, hug the haul road or be built from a totally separate and distinct work pad, should be cost and schedule effectiveness. In other words, Northwest should locate the gas line at that location where the total cost of the project would be the least.

At these locations where the Alyeska line is buried soil conditions are favorable to buried pipeline construction...in other words the ground is thaw stable. When possible, the gas line should also be buried at such locations, "hugging" the Alyeska work pad as close as possible, so that the advantages of the favorable soil conditions can be realized. Exceptions to this basic rule should be made only to reduce the number of river crossings or where another alignment is clearly more cost and schedule effective. Northwest people have rightfully pointed out that, to the extent that the gas line deviates from the crude line, changes due to unexpected subsurface conditions increases dramatically. One only has to look at the negative geotechnical surprises that Alyeska endured to support this statement.

To summarize the "hugging the haul road" situation, I do not have a basic concern about locating the gas line 55-60' away from the haul road, as long as there is a gravel work pad between the shoulder of the haul road and the edge of the ditch. I believe that one lane of the haul road can be used as a part of the work pad and therefore the width of gravel work pad that has to be constructed for the gas line can be correspondingly reduced. Of course, the cost effectiveness of this solution is directly related to whether or not a heavy wall pipe is going to be required by regulatory agencies. Intuitively, I believe that heavy wall pipe should not be required, but the number of dollars at stake is so significant that formal approval must be obtained from the regulatory agencies.

I will leave this issue by again expressing my concern about the number of times I see comments being made about building extensive lengths of the gas line from a snow pad, with the gas line as close as 44' to the center line of the haul road. Any attempt to do this would result in tremendous additional costs and schedule slippages.

By the way, several miles (perhaps as many as four) of the crude line were built immediately adjacent to the haul road in the Finger Mountain area south of Old Man Camp. I refreshed my recollection about building this length of the crude line by talking with some of the field people involved with its construction. There were no significant problems with building the crude line adjacent to the haul road, although the crude line was 75' from the center of the haul road. Of course, a full width gravel work pad was built between the haul road and the edge of ditch.

Now I will get into the subject of the re-route proposed by the regulatory agencies in the Salcha River area south of Fairbanks and north of Delta Junction. I indicated to you that Alyeska also studied this re-route and did not resolve the final location of the pipeline until mid 1974. The so-called Salcha River re-route, similar to what is being proposed by the agencies in much of the correspondence that I reviewed, was rejected by Alyeska for the following reasons:

1). The re-route alignment traversed very rugged and choppy terrain.

2). There was no definitive data available about soil conditions on the re-route location.

3). Because of the side slope construction, a slope stability problem could exist.

4). Access roads, although short, would have to be numerous and contain exaggerated looping to maintain reasonable grades.

5). Considerable use of terraced, shoofly roads could be anticipated due to the rugged nature of the terrain.

6). There were numerous parcels of private patented land and a number of old and new mining claims on the re-route.

7). Although material for the work pad would be available, it would have to be hauled up very steep access roads.

8). The proposed re-route was about 8 miles longer than the Alyeska alignment.

9). Following the ridge lines and close to the Haines right-of-way and the Richardson Highway would mean the crude line would pass through high use recreational areas, and the visual impact would be significant.

10). There would be any where from 6 to 15 miles of steep side slope construction required.

11). Substantial through cuts would be required at as many as three locations.

The conclusion of the Alyeska study was that the cost of the re-route would be considerably greater than the cost of the present crude line alignment. Also, the uncertainties associated with the unknown soil conditions were such that the risks were just too great to change the alignment to a location closer to the Richardson Highway. I don't believe that the situations that exist today are any different than they were for the crude line so my recommendation to you is to stick with your proposed alignment.

As requested by John McMillian and John Mason, I am in the process of reviewing the construction communication requirements and should have something to you in 2 weeks. Also, I have again reviewed all of the documents given me, primarily the exchange of letters between DOI/Northwest and DOI/Alyeska, and my comments and recommendations regarding these will be in your hands shortly.

If there are any questions, please do not hesitate to get in touch with me. I am also available to meet with you at any time.

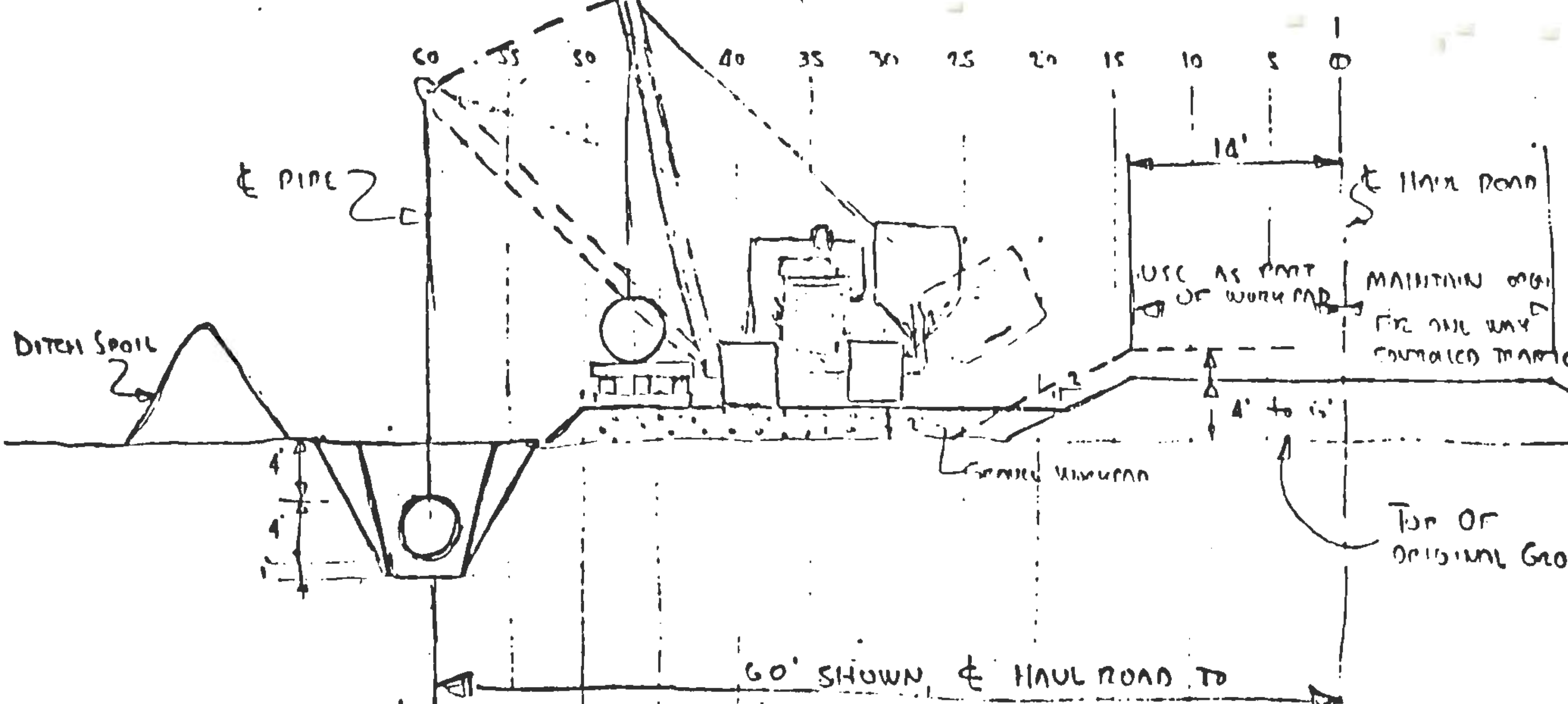
Sincerely,

Frank P Moolin /Bjm

Frank P. Moolin, Jr.

FPM:bjm

cc: John Mason/NWP/SLC
Darrell Mackay/NWP



60' SHOWN ℄ HAUL ROAD TO ℄ OF PIPELINE; USED ON BASIS THAT ONE LANE OF HAUL ROAD CAN BE USED FOR CONSTRUCTION AS TEMPORARY PART OF "WORK PAD".

TRAFFIC TO BE CONTROLLED ON OTHER LANE OF HAUL ROAD.

POSSIBLE TO REDUCE TO 55' [illegible] HAUL ROAD THICKNESS IS 4'.

[illegible] July 15. 1979

cc: NCPV
TES
DHG

CURRAN HOUSTON, INC.
PIPE LINE CONTRACTORS
1770 YORKTOWN, HOUSTON, TEXAS 77056

713-961-4200
TELEX-77-5262

April 7, 1980

Mr. Robert N. Hauser,
Vice President
Northwest Alaskan Pipeline Co.
3333 Michelson Drive
Irvine, California 92730

Dear Mr. Hauser:

Subsequent to our conversation relative to our firms experiences in winter pipeline construction north of the Alaska Brooks Range and more specifically the utilization of snow work pads, I submit to you our comments which are based on our construction activities spanning a period of six years. During this period we have constructed over 300 miles of various size pipelines (6" thru 38") using the following construction modes.

1) Pipeline Construction Activities Performed in Winter and Summer

   A) Ditch excavation

   B) Hauling, stringing, fabrication, pipe laying, lowering-in, and tie-ins

   C) Drilling and vertical pipe support (VSM) installation

   D) Thermal insulation

   E) Hydrotesting (using water and water/antifreeze test medium)

2) Pipelines Constructed in Both the Above and Below Ground Modes

3) Pipelines Constructed Utilizing Both Snow and Gravel Work Pads

Approximately 76 miles of the work accomplished by our firm was installed utilizing a snow work pad. This 76 miles was the portion of the Alyeska Fuel Gas Line that was constructed during the 1976-77 winter season.

The construction plan for the Trans-Alaska Pipeline called for the system to go on stream in early summer of 1977. To that end, completion of the fuel gas line before break-up was of the utmost importance. To accomplish this task, our crews were mobilized in mid-November, 1976 to start snow pad construction. This proved to be a slow, costly operation since there was no significant accumulation of snow until mid-January and in some areas mid-February. To augment the amount of natural snow accumulated in November, December, and January, we resorted to several methods of entrapment. More specifically these methods were:

1) Erecting snow fences

2) Constructing a snow berm along the R.O.W. on the off-side to the prevailing winds

3) Utilizing natural traps and transporting snow to needed areas

The area from Franklin Bluffs to Prudhoe Bay is characterized by frequent winds high enough to move large quantities of snow. In this area, we were able to trap snow with an acceptable degree of success. However, our production in this area was very erratic and was controlled by the frequent shifting winds. Trapping of snow in all other areas proved to be very ineffective.

The costly and slow method of layering snow and water was not used. This method was considered, but was ruled out based on the following:

1) Schedule - Construction of a pad using materials other than natural snow could not be accomplished at a rate that would allow completion of the fuel gas line before break-up.

2) Cost - Due to the logistics involved in getting water to the work site and the large quantity of equipment that would be required, it was agreed that the cost of this type construction would be unacceptable. It was estimated that the cost associated with this method would be in excess of $100.00 per linear foot.

3) Pad Utilization - Since the snow pad was to be located immediately adjacent to the haul road or Alyeska work pad, traffic could be reduced to a minimum on the snow pad. Only the tracked equipment essential to pipe handling was allowed on the snow pad. All support equipment would traverse the haul road or gravel work pad. As a result of our ability to keep snow pad traffic to a minimum, combined with the fact that all the equipment needed for small diameter pipe laying is relatively light, the need for a high density pad such as the snow/water layered pad was not necessary.

4) Safety - It is our opinion that the use of conventional tracked crawler equipment on a snow/water layered pad would be very dangerous. The build up of ice on the track pads would build to a point where the track grousers would not contact, the pad surface reducing traction to near zero.

Additionally, all employees that are required to work on the pad surface would be subjected to unreasonable dangers due to working on ice and also would be in danger due to the possible movement of skids supporting sections of welded pipe.

After ruling out the use of the snow/water layered method, we elected to build a pad of natural snow using the following procedures.

1) The first passes over the pad surface were made using a low ground pressure Rologon. This process was continued until the pad thickness and density was great enough to protect the tundra from damage by light tracted vehicles.

2) After the base layer was completed, additional pad depth was obtained by rolling in additional snow from natural snow fall, snow entrapment and snow transported from natural traps. Motor graders and dozers pulling compacting and leveling equipment was used for leveling and compaction. This process was continued until the optimum depth was obtained.

By mid-January we had completed only 10 miles of snow pad, and on February 6, 1977, with 22 miles of snow pad, we started our pipe laying operations. In mid April, we were experiencing temperatures forty degrees above zero and pad degradation was considerable. The impact of this unseasonable phenomenon was minimized due to our ability to divert all equipment not essential to pipe handling or ditching to gravel pad. The snow pad was constructed adjacent to either the haul road or the oil line pad throughout the project.

The risk of schedule disruption due to the unpredictable nature of snow pad construction was great and both owner and contractor were faced with the ever present possibility that the schedule would slip into the next construction season delaying project completion for one year. Due to this unpredictable nature (i.e., warmer than normal temperatures in early winter, the lack of natural snow fall in November, December, and January, periodic high temperatures throughout the winter resulting in pad degradation) a delay of the project would have been inevitable had completion of the project been dependent on snow pad utilization. The last 16 miles of the gas line was constructed from the oil line gravel pad and not a snow pad.

Reference has been made to Alyeska's Fuel Gas Line as evidence that the use of snow pads is a viable and proven mode of construction and should be used on portions of the Alaskan Natural Gas Transportation System. Based on our experience in Arctic construction and the use of snow pads, we strongly recommend that Northwest vigorously oppose the snow pad concept. Further, it is our opinion that two monumental facts were learned from the fuel gas line construction.

1) The snow pad, as constructed, would be totally and completely unacceptable for your project.

2) Development and execution of a coherent schedule would be next to impossible due to the unpredictable nature of the entire snow pad concept.

Additionally, due consideration should be given to the following:

1) Construction of large diameter pipelines utilizing a snow work pad is an "unproven" construction technique.

2) Construction would be restricted primarily to the winter months and would have a very significant impact on the cost effectiveness of the project. This would be primarily due to:

   A) Worker effectiveness and losses in productivity due to extremely cold temperatures, wind and artificial lighting. To compensate for some of this loss of productivity per worker, additional manpower would be needed. This would impact camp facilities and transportation. From our experience, we calculate productivity losses for winter construction to be:

      From +10°F to -5°F a 5% loss in productivity
      From -5°F to -20°F a 10% loss in productivity
      From -20°F to -30°F a 17% loss in productivity
      From -30°F to -40°F a 30% loss in productivity

3) Equipment down-time and maintenance becomes more of a problem and cost factor during the extreme winter months than the human element. Operating costs could increase by as much as 40% during this period due to the following:

   A) Equipment maintenance and service personnel would double during this period

   B) Fuel requirements would increase by approximately 50% due to the fact that all equipment would be running 24 hours a day

   C) Spare equipment and parts inventory would be increased by 10%

   D) Overall equipment life would be much shorter

4) There are certain construction activities that must be performed during the summer months, e.g., hydrotest, backfill armor and erosion control, sand-blasting and painting above ground facilities, revegetation, etc., all of which would be very difficult to carry out without the benefit of free access. In the area where construction utilizing a snow pad is advocated, there could be as many as 20 test sections and 20 test manifolds where access with heavy equipment would be essential.

   Additionally, since water will be the test medium for hydrotesting, access to the water sources and transporting by truck or pipeline will be next to impossible without gravel access roads.

5) Maintenance after construction would become a very expensive and difficult operation without the benefit of year-long access. As maintenance contractor for Alyeska Pipeline Service Company, we encountered many maintenance problems in our 250 mile area of responsibility which I would consider as almost impossible to correct without free access. Our area of responsibility was from

Pump Station 1 to south of Atigun Pass and would cover the entire area where snow pad construction is advocated.

Much of the area in question is subjected to flooding during breakup and erosion and settlement of backfill is significant. In some flooded areas of the fuel gas line, large amounts of backfill was washed away allowing the ditch insulation board to float out. Replacement of this material was very difficult due to the fact that all equipment was restricted to either the haul road or oil line work pads.

In conclusion, we wish to reiterate our concern as to the inherent risks and problems that would be associated with constructing large diameter pipelines using the snow pad concept.

Very truly yours,

CURRAN HOUSTON, INC.

V. E. Seale
Vice President

VES:mc

Enclosure N

DOI's Technical Questions/Concerns 1/

Index

1/ As raised by Assistant Secretary of the Interior, Guy R. Martin, in his letter of June 13, 1979.

1.0 FROST HEAVE DESIGN

1.1 STATEMENT OF CONCERN

"Frost heave design must be studied to permit timely resolution of this design feature. Although steps have been taken in the area of frost heave, there was little in the way of definitive information available for review by the Department as it considered the alignment questions."

1.2 DEFINITION OF ISSUES

1.2.1 Principal Issue

The issue is the demonstration of satisfactory progress toward an acceptable, timely frost heave project design that will ensure pipeline integrity along frost-heave susceptible portions of the route.

1.2.2 Definition of Terms

Frost heave is the uplifting of the soil mass caused by the freezing of water in frost-susceptible soils. The total heave and the rate of heave are dependent on the thermal regime, the overburden pressure, the original moisture content of the soil mass, and on the amount of water migrating to the freezing front.

Differential heave is the difference in total heave between any two points along the route at any given time. Different points may exhibit different total heaves as a result of different gradations, densities, overburden pressures, moisture contents, and/or groundwater availabilities.

1.3 FACTORS AFFECTING HEAVE

1.3.1 Frost Heave Susceptible Soils

Almost all soils will heave to some degree when freezing, depending on the overburden pressure, water availability, and other variables. However, past studies have shown that one of the more important indicators of frost heave potential is silt content. Unfrozen soils at the depth of the pipeline, nominally 7 feet, and within the potential frost bulb, are being considered frost-susceptible only if they contain some silt or clay-sized particles.

- If the percentage of particles that will pass the No. 200 sieve is less than 6 percent (i.e., the silt content is less than 6 percent), the soil is considered to have low frost susceptibility, i.e., heave generated by freezing such a saturated soil is expected to be minor.

- If the amount passing the No. 200 sieve is between 6 percent and 12 percent, the soil is classified as being of moderate frost susceptibility.

- If the percentage of silt is greater than 12 percent, the classification is high frost susceptibility.

1.3.2 Availability of Water

Where there is no water to freeze, there can be no heave. However, the freezing isotherm will travel quickly through a dry soil and can reach a water table at depth in much less time than it would take a frost bulb to reach the same depth in a saturated soil. The factors involved, i.e., rate of propagation of the freezing isotherm and the heave that may develop with the water table at different depths below the pipe, are being studied in computer simulations and laboratory tests.

In classifying the soils in the terrain units with respect to their potential for heaving, the depth to the level of the water table has been taken into account (see Section 1.7).

1.3.3 Depth to Permafrost

The shallower the depth to the permafrost table, the lower will be the maximum heave generated by the pipeline, and as the frost bulb merges into the permafrost, further heaving of the pipe will cease.

Where the chilled pipe crosses a thawed zone with sloping permafrost sides, it is expected that as the frost bulb grows, the permafrost will creep inwards towards the center of the thawed zone and decrease the thickness of soil available for freezing by the pipeline. Moreover, the heave generated by the frost bulb generally will increase from the side towards the center of the thawed area (as the depth of the thawed zone increases) so that the most rigid portion of the pipe will be subjected to the least heave, and the least rigid, the most heave.

1.3.4 Ground Temperatures

Soil temperatures vary with increasing depth from the ground surface due to changing climatic conditions at the surface. Ground temperature profiles establish the heat transfer rate between the pipeline at gas temperature, buried approximately 7 feet deep, and the surrounding freezing soil. This relationship between varying pipe temperature and varying ground temperature provides the positive or negative heat flux that establishes the geometry of the frost bulb. Where ground temperatures are continually below 32°F (permafrost), it is assumed that no significant frost heaving occurs.

1.3.5 Pipe Temperatures

Gas temperatures in the pipe will be kept below 32°F. To ensure this, the discharge temperature of the gas from the upstream compressor station will be adjusted by heating or cooling the gas depending on the ground temperature.

Gas pressure in the pipeline will normally be between 1050 and 1260 psi. As the gas leaves the upstream compressor stations, it will expand and cool as described by the Joule-Thomson effect.

Northwest is investigating the effect of different pipe temperatures on the development of the frost bulb and potential heave of the pipeline.

1.4 DATA ACQUISITION

In order to design the pipeline on a mile-by-mile basis, Northwest must know what soils exist along the pipeline route, their distribution, their thermal states, and their climates, as well as the availability of groundwater. The field programs described below are designed to obtain this information.

1.4.1 Route Soils Data

Boreholes provide information to investigate soil properties in a particular terrain type and to substantiate the inferred thermal state of the soil from the geophysical surveys.

In selecting a route, Northwest used the following data purchased from Alyeska:

- o Alyeska's mode confirmation borehole logs
- o Logs of centerline borings
- o VSM borehole logs
- o Ditch logs
- o Haul road and material site logs
- o Soil Index Properties (10 volumes) listing grain size, gradation, Atterberg limits, moisture content and thermal state

The above data cover the pipeline route from Delta Junction north to Prudhoe Bay.

Additional data used include the highway borings along the Alaska and Elliott Highways as well as CRREL's borehole data along the haul road.

Since 1976, approximately 1,240 holes averaging about 45 feet in depth have been drilled along the pipeline route. Approximately 200 holes will be drilled after the 1980 breakup.

Information being collected includes the thermal state of the soils, the soil types, and the depth to the water table, if present.

Since 1978, Northwest has performed resistivity surveys along the pipeline route. Data from those surveys are being used in conjunction with data from the borings to produce a longitudinal profile of frozen and unfrozen soils along the route.

1.4.2 Groundwater Table Data

Approximately 37,000 locations along the route provide information on the presence of groundwater. In addition to these observations approximately 125 standpipes have been installed to facilitate continuing monitoring of groundwater levels.

1.4.3 Ground Temperature Data

As part of Northwest's program to obtain information on existing ground temperatures to refine calculations of heat transfer between the soil and the chilled pipe, thermistor cables are being installed in conjunction with the center-line drilling program. To date, 75 strings of thermistors are being read on a monthly basis.

1.4.4 Climatological Data

Climatological data from some Alyeska camps, Fort Wainwright, Eielson Air Force Base, Fort Greely, Tanacross and Northway Airports, and other weather stations are available for use in the computer modeling of the effect of climate on the development of the frost bulb. Weather stations will be installed at proposed test sites.

1.4.5 Testing Program Data

Several test programs are operational and others are planned for Alaska and Canada Segment data sharing and operational monitoring.

The objectives of the test facilities are basically fourfold:

- To obtain an understanding of frost heave effects on a 48-inch chilled pipe.
- To test the effectiveness of mitigative designs.
- To provide input to substantiate and improve the empirical frost heave predictive model.
- To provide input to substantiate pipeline structural analysis models.

Mitigative Design Testing - Several mitigative designs have been applied to various test sections at each site in order to monitor their effectiveness.

Five test sections are currently operated at the Calgary Frost Heave Test Facility. This includes two test sections that are subjected to increased soil stress, one test section underlain by granular material, one insulated test section and one insulated section with granular soil replacement.

The Fairbanks Frost Heave Test Facility has one test section utilizing heat pipes and a number of test sections with varying amounts of insulation and soil replacement. There is also one uninsulated control section with which to compare the results.

Substantiate Predictive Model - A frost heave predictive model is being developed to estimate upward deflection of a pipeline by the action of frost heave. The model performs a thermal analysis of a buried pipe. An ice segregation ratio (heave divided by depth to frost line) together with the calculated frost penetration results in a prediction of frost heave.

The full-scale testing facilities provide a substantiation of the thermal calculations and provide data on heave to refine the heave prediction capability of the model.

Verification of Structural Models - Northwest has been using various structural analysis computer programs (e.g., PIPLIN), to study the structural effects of differential frost heave on a buried steel pipeline. One test section of the Fairbanks Test Site will serve to provide data on the pipe-soil interaction to substantiate these analytical studies.

This particular test section is 400 feet long and crosses a natural permafrost interface. Strain gauges are installed to monitor pipe wall strain due to the anticipated differential frost heave. This test has been designed to accelerate differential heave to examine the stresses and deformations which may eventually develop at soil interfaces.

Soil restraint to pipeline lateral movements is an important input parameter to the stress analysis model. Soil pressure instrumentation has therefore been applied around this interface test section to determine the pressures imposed by the soil on the pipe.

Detailed descriptions of the Calgary Test Facility, the Fairbanks Test Facility and additional proposed full-scale tests are included in Appendix I of this report.

1.4.6 Laboratory Heave Tests

The purpose of this program is to obtain laboratory data from representative soils along the route which will be used in conjunction with field data as a basis for input into the project frost heave design process.

Two types of laboratory tests are:

- o Frost heave tests
- o Soil classification tests

The frost heave tests yield data on heave and on the movement of the freezing front with time. Tests are being done to classify the soils so that a correlation can be developed between ice segregation ratio and index properties.

The heave data from the laboratory tests are used with the semi-empirical model to predict heave of the full-scale pipe. When the correlation between laboratory ice segregation ratio and the appropriate index test for the soil is derived, Northwest will be able to predict heave for the pipeline in a wide variety of soils based on that correlation.

Heave Tests - A laboratory testing technique is required in order to determine the ice segregation ratio (I_s^i). In setting up the testing procedure, the following considerations are essential:

- o Soil sample size
- o Water accessibility
- o Temperature and heat flux
- o Soil pressure
- o Testing duration (time)

Soil Sample Size - The soil sample should be large enough so that the particle size of the soil grains will not affect the overall result. Where gravels are involved, a larger sample size may be required than for tests on fine-grained soils. Since gravel and coarse sand are both frost stable, a 4-inch sample can be used by replacing the gravel content in the soil with sand.

Water Accessibility - Access of water to the freezing front is the most important factor to the occurrence of frost heave. It may come from the natural groundwater regime, or from surface drainage or ponding. For the field conditions along a pipeline route, a combination of the sources mentioned above may be the general case. The configuration of a laboratory sample (Figure 1-1) is set up to simulate the condition of the soil element X_n of Figure 1-2. In the laboratory test, free water access is provided with the water table maintained at the same elevation as the top of the sample. For other cases where the static water pressure may be significant, such as in the area of a river crossing, the testing program can readily simulate this water condition by raising the water level.

In many areas along the route, the natural water table will be well below the pipe elevation. Such low water tables will cause a significant reduction in the frost heave. However, due to the difficulty in the laboratory set-up for simulating a low water table condition with small samples, the standard test will be conducted with a free water table at the same elevation as the top of the test sample. In order to simulate more closely variable water table effects in the laboratory, one meter long column tests will be conducted at the U.S. Army Cold Regions Research and Engineering Laboratories. These tests will provide additional test data for the analysis of the water accessibility parameter not available from the smaller sample freeze tests.

Temperature and Heat Flux - The temperature of a soil element below a chilled pipeline is a function of its position relative to the chilled pipe, the natural ground temperature regime, and time duration of the pipeline operation. Frost heaving occurs mainly within the fringe just behind the 32°F isotherm. The prescribed laboratory test cold side temperature (T_S in Figure 1-2) should be maintained as close to 32°F as the controlling accuracy of testing equipment allows, and the warm side temperature (T_B in Figure 1-2) maintained to simulate the field condition. The cold side temperature for most frost heave tests is maintained at about 30°F.

In addition to the temperature, the heat flux condition simulated in the laboratory testing should reflect the field heat flux condition.

Figures 1-3 and 1-4 show the heat flux variation with frost depth for bare and insulated pipelines respectively.

- For a 48-inch pipeline operating at 15°F with an average ground temperature of 40°F, the net heat flux reduces exponentially with frost penetration, varying from about 15 Btu/hr/ft^2 at 1 foot of frost depth to about 0.4 Btu/hr/ft^2 at 10 feet of frost depth. The effect of ice content in the soil is small.

- For the case where the pipe is insulated with six inches of styrofoam equivalent material, the computed net heat flux at the freezing front is further reduced by about ten times that of the noninsulated condition at equal frost depths. It should be noted that the ground temperature considered is 33°F, which represents cold unfrozen ground.

Heat Flux Range of Laboratory Testing - The configuration of a one-dimensional frost heave test with free access to water and prescribed cold and warm plate temperatures is shown on Figure 1-2.

In general, the heat flux over the laboratory freezing process, with the cold temperature of 30°F (Figure 1-5), varies from about 30 to about 0.01 Btu/hr/ft^2, which is about the range of heat flux for a pipeline condition (Figures 1-3 and 1-4).

Effects of Cold and Warm Side Temperatures on Heat Flux - For a constant warm side temperature, the heat flux, as expected, increases with decreasing cold side temperatures (Figures 1-6 and 1-7). For a constant cold side temperature of about 30°F, and warm side temperatures of 33°F and 35°F, the heat flux range for the laboratory testing is approximately that of the pipeline field condition.

Effects of Sample Length on Heat Flux - Figure 1-8 shows that the longer the testing sample, the smaller the heat flux at the frost front. Since the range of the heat flux varies from about 30 Btu/hr/ft^2 to about 0.01 Btu/hr/ft^2 over the freezing process, the use of a 4-inch long sample adequately simulates the heat flux range of a pipeline in the field.

Soil Pressure - The frost bulb penetration beneath a bare pipe line during its design lifetime may be about 30 feet. The overburden pressure that the soil is subjected to for such a frost bulb, has an effect on the frost heave for fine-grained soils. For dirty, coarse-grained material the magnitude of stress exerted by the overburden material may have a significant effect. Since the laboratory testing will be conducted under selected pressures, the effect of pressure on the frost heave behavior of the soil will be inherently considered.

Duration of Frost Heave Testing - Ground freezing by a chilled pipeline is a slow transient thermal process. Over the lifetime of a pipeline, the thermal state of the ground will likely not reach its ultimate state, i.e., the steady-state condition. A soil element below the pipe, depending on its relative location with respect to the chilled pipe and the time duration of the pipeline operation, very likely will not reach its thermal steady-state equilibrium. The maximum ice segregation is achieved at the steady-state condition, and hence the use of laboratory measured heave ratio will over-estimate the heave the pipe will experience. Serious consideration is therefore being given to modifying the tests to as to obtain more accurate values of ice segregation ratio. These procedures will also likely lead to shorter durations of testing time.

1.4.7 Laboratory Frozen Soil Uplift Resistance Tests

The restraining effect of the soil cover on pipeline movement needs to be investigated as the stresses and strains developed in the pipe are significantly affected by the load-deformation characteristics of the soil assumed in the analysis.

The initial phase will identify the mode of soil deformation and failure during uplift, and establish the relative importance of the many parameters that must be considered in pipeline design. The second phase will concentrate on those conditions that are identified, in the initial phase, as most critical to pipeline design. The purpose of the testing program is to obtain uplift resistance values of frozen soil against an upward moving (heaving) chilled buried pipeline. The program will be designed to:

- Develop suitable apparatus and detailed procedure for the model uplift tests.

- Observe, record and document the mode or modes of soil deformation and failure during the model uplift tests.

- Determine the uplift resistance/pipe displacement curves for conditions that are most relevant to pipeline design.

- Determine the stress-strain relationship for the frozen soils using strain-rate controlled compression and possibly tension tests.

The program will investigate the uplift resistance forces using plane strain model tests and will correlate the results of the model tests with those of simpler tests (uniaxial compression/tension tests and engineering indices). Such model tests are inherently complex and, because there is no precedence for guidance, the program must have an exploratory aspect. The testing program will concentrate on conditions that are most critical to this project. The program will require flexibility to achieve its objectives. As knowledge is gained during testing, the remaining tests can be redirected and/or redesigned if necessary to provide in a timely manner the maximum cost-effective information to the project design.

1.5 SEMI-EMPIRICAL MODEL

A purely theoretical approach is currently considered to be unsatisfactory for the practical requirement of a pipeline design. Therefore, a semi-empirical design approach is being developed for the frost heave design.

The rationale of the semi-empirical approach is as follows:

- The theoretical heat transfer aspect of the frost heave model involves a finite element analysis of heat transfer mechanisms in both the frozen and unfrozen zones of the soil domain, and the growth of the frost bulb.

- The mass transfer aspect of the frost heave model, which evaluates the heave ratio will be determined by laboratory frost heave testing, rather than theoretically evaluated using the soil parameters of thermodynamic suction pressure, hydraulic permeability and the coefficient of consolidation or expansion of the soil. Since the ice segregation ratio is a cumulative function of these coupled parameters, a laboratory determined heave ratio method should eliminate the quantitative uncertainty inherent in the theoretical approach.

In summary, the semi-empirical approach transforms the complicated heat and mass transfer aspects of the frost heave mechanism into a conventional thermal problem, with the heave ratio defined (the ratio of heave to frost penetration) as another input parameter determined by laboratory testing techniques. Figure 1-1 presents the approach schematically.

As the frost heave of a chilled pipeline is mainly a result of ice segregation of the soil column below the pipe, the one-dimensional (vertical direction) behavior of the soil column below the pipe centerline is being considered for the semi-empirical approach. This is a result of symmetry with respect to the thermal and hydraulic (water access) boundary conditions. The frost heave of a pipeline h is:

$$h = \int_{o}^{x} \frac{dh}{dX} \, dX$$

where:

$\frac{dh}{dX}$ = ice segregation ratio (heave per unit frost depth), and

X = frost depth

The frost depth is a function of:

- o Thermal properties of soils (thermal conductivity, specific heat and volumetric latent heat);
- o Thermal boundary conditions such as geometry, pipe and ground temperatures, and
- o Time

The evaluation of X (frost depth at any time) is a conventional thermal problem whose method of analysis, analytical or numerical, has been well established. This is the heat transfer portion of the semi-empirical frost heave model.

The infinitesimal ice segregation ratio by definition, is:

$$\frac{dh}{dX} = \lim_{\Delta X \to o} \frac{\Delta h}{\Delta X}$$

This can be approximated by a soil element with finite length of ε, (say a few inches) so that:

$$\frac{dh}{dX} = \lim_{\Delta X \to \varepsilon} \frac{\Delta h}{\Delta X} = I_s^i = \text{elemental ice segregation ratio}$$

where:

I_s^i = Ice segregation ratio of soil element i, which can be of the same or different soil type from its adjacent soil element i + 1.

Let $\varepsilon = X_i$ (finite frost depth increment), then the total frost depth X becomes

$$X = \sum_{i=1}^{n} X_i$$

Figure 1-1 describes schematically the above definition.

When pure ice formation is considered, $I_s^i = 1.0$, and the frost heave equals the frost depth such that

$$h = \sum_{i=1}^{n} X_i = X$$

This semi-empirical model has been used with data on laboratory heave ratios, ground temperatures and climate to predict the rate of heave at both the Calgary and Fairbanks test sites. At this time, estimates of heave exceed actual heave recorded by a substantial margin. While some over-prediction is expected because the model currently does not take into account the restraint on heave exerted by the pipe and a large frost bulb, attempts are being made to refine the model so that the predicted heave is a closer estimate of the actual heave.

1.6 STRESS ANALYSES

1.6.1 Sensitivity Studies

Parametric studies have been performed to investigate the sensitivity of imposed pipeline displacements and generated loadings to variations in assumed geotechnical boundary conditions. These studies are used in the preliminary development of a preliminary design. (See FERC Filing Exhibit Z-9.1)

The criteria for structural tolerance limits are tentatively established to limit the maximum allowable strain in the pipe. The maximum longitudinal compressive strain is limited to prevent localized bellows wrinkling in the pipewall. The maximum longitudinal tensile strain is limited to ensure ductile behavior of the steel and mitigate the possibility of fracture propagation.

The restraining effect of the soil on pipeline movement is idealized by the bilinear load-deformation curve shown in Figure 1-9. From this curve, it is seen that the soil resistance is assumed to increase linearly with increasing deformation until a yield deformation is reached. For deformation greater than this yield deformation, the resistance of the soil is constant and is equal to the ultimate uplift resistance "K" (in Kips per linear foot of pipe).

The depth of cover above the pipe is assumed to be 30 inches. The soil above the pipe is assumed fully frozen at an average temperature of 20°F for an eight month period each year, followed by thawing to a point one foot above the pipe for four months each summer at an average temperature of 31°F.

Uplift resistance values for the soil based upon the above conditions are assumed at this time to be 150 kips per foot for the winter condition and 30 kips per foot for the summer condition for a medium dense backfill. The effective continuous uplift resistance is then assumed to be 50 kips per foot due to the effect of seasonal relaxation.

1.6.2 Modeling of Pipeline Heave Forces

The computer program "PIPLIN II," used for the analyses was developed by Dr. G. H. Powell at the University of California to analyze the bending response, including inelastic behavior of a buried pipeline.

The effects of differential frost heave are modeled as a midspan displacement of the pipeline as it crosses a segment of frost susceptible soil subject to the strength of the surrounding soil. Based upon the ultimate soil strength, curves representing allowable displacement of the pipe versus span of heave have been produced. Studies were performed using the computer program PIPLIN II for two basic modeling configurations for maximum allowed pipe displacement versus span. These configurations are as follows:

- A uniform heave force modeled as shown in Figure 1-10. That is, the effect of heave is considered to exert a net uniform distributed loading of equal magnitude over the full span of frost susceptible soil.

- A uniform heave displacement model as shown in Figure 1-11. That is, the frost bulb is considered to displace upward an equal distance over the full span. Uplift resistance "K" is mobilized in the frost span only when the pipe tends to deflect upward from the displaced soil profile.

A series of analyses were run for each configuration under operating pressure and maximum temperature differentials. Analyses were made for spans ranging from 20 feet to 100 feet, for uplift resistance values (K) ranging from 2 to 100 kips per linear foot.

Results of the analyses were plotted to show the relationship of pipe stress, pipe strain, pipe displacement, span of heave, uplift resistance and heave loading. Based upon these results, the following general observations are made:

- The stress and strain induced in the pipe as the result of a given displacement decreases as the length of span of the heave increases. Thus, the allowable differential frost heave increases with span length.

- The stress and strain induced in the pipe as the result of a given displacement, increases as the uplift resistance of the soil increases.

- The reactive force exerted by the pipe on the supporting soil and transmitted to the freezing front increases as the length of span decreases, and increases as the uplift resistance increases.

- Analysis based on the assumption of an abrupt displacement at the interface between the nonheaving soil and the heaving segment (Figure 1-11) indicated that very high forces are generated on the freezing front and restraining soil. This assumption would in effect limit the maximum allowed pipe displacement to a value not exceeding that allowed for a span of approximately 50 feet, regardless of the actual length of heaving segment.

1.6.3 Preliminary Design Basis

Figure 1-12 shows the maximum allowed midpoint displacement due to frost heave plotted against heave span for a range of uplift resistance values, "K." Figure 1-13 shows the heave load generated at maximum displacement versus heave span. Note that for preliminary design the value of "K" is taken as 50 kips per foot.

As the frost front progresses away from the pipe, the generated upward force on the pipe tends to be spread over a longer span. To illustrate this effect, a simplified assumption may be made which considers the force to be transmitted from the frost front to the pipe uniformly over an effective span equal to the actual heave span plus twice the distance to the frost front as shown in Figure 1-14. Based on this assumption, Figure 1-15 shows the allowable heave plotted against the depth to the frost front for several spans of segregated ice. If the allowable heave found from Figure 1-15 was greater than the actual predicted heave for the uninsulated mode of construction, the uninsulated mode could be chosen as the working mode. If the allowable heave was less than the actual predicted heave, alternate construction modes could be considered.

Based on the preliminary studies, it can be concluded that allowable heave:

- Increases with the increase in span length.
- Decreases with an increase in soil resistance.
- Increases as the geometry of the transition zone is smoothed.

Further Study - The preliminary analysis was based on conservative assumptions and methodology in an attempt to define particular problem areas. Further work is planned to refine the analysis procedure and analysis tools.

1.7 DESIGN CRITERIA

The following principles guided the development of the design criteria:

- The gas pipeline shall be buried
- The gas in the pipeline shall be chilled below 32°F

- The design shall be such that the allowable limits on stress and strain will not be exceeded i.e. heave generated in any section on the pipeline must be acceptable with respect to the structural loading it puts on the pipeline

- Effects of allowed heave shall not adversely affect the environment or adjacent structures.

To satisfy these criteria, the soils were classified with respect to their potential for heave. Preliminary ice segregation ratio values were chosen and a number of possible construction modes designed to mitigate the heave expected if the standard burial configuration gave unacceptable values of heave. This approach is discussed in more detail below.

1.7.1 Frost Heave Potentials

Frost heave potentials have been assessed along the route based on preliminary frost heave criteria. Three heave potentials, low (LHP), moderate (MHP), and high (HHP) were defined in terms of three field conditions: soil thermal state (frozen or unfrozen), silt content, and ground water conditions. These frost heave criteria will be refined as additional field and laboratory data become available.

Application of the frost heave criteria requires the geotechnical assessment of the states and confidence levels of thermal, silt content, and groundwater conditions encountered along the pipeline alignment. Geotechnical criteria for that assessment are shown specifically for use on a mile-by-mile basis with the stated frost heave criteria (see FERC Filing Exhibit Z-9.1) The resultant assessment is termed the frost heave route geotechnical characterization and classification. The assessment criteria are subject to modification and refinement as improvements are identified.

The geotechnical assessment process uses input data from: terrain unit maps, landform profiles, airphotos, borehole logs, laboratory data, and statistical tabulations of laboratory soil information. All geotechnical interpretations used in assessing frost heave potentials are documented, mile-by-mile.

1.7.2 Preliminary Ice Segregation Ratios

Frost heave potentials are quantified by assigning ice segregation ratios to the different classifications for the purpose of preliminary frost heave design.

Low Heave Potential (LHP) = 0% Ice Segregation Ratio (ISR)
Moderate Heave Potential (MHP) = maximum 20% ISR
High Heave Potential (HHP) = maximum 50% ISR

Differential heave over limited pipe span lengths was assumed to limit the above ice segregation ratios. Preliminary pipe stress analyses predicted allowable heaves for various soil strengths and heave lengths. To illustrate how these studies would impact design heave ratio values, a heaving length of 100 feet was assumed. Stress analyses predicted an allowable heave of 18 inches to correspond to this heave length. For reasons listed below, it was assumed that over a span of 100 feet, the differential heave would be about 1/2 of the maximum total heave. That is, the difference in ice segregation ratios between any two points separated by 100 feet would not exceed 1/2 of the total heave ratio at any point. This is equivalent to using 1/2 the assumed ice segregation ratio for examining heave induced stress effects on the pipe. The resulting values are shown below:

LHP = 0% Differential ISR in 100 feet
MHP = 10% Differential ISR in 100 feet
HHP = 25% Differential ISR in 100 feet

The basis for these assumptions ultimately rests on engineering judgment; rigorous justification for any reasonable number is not possible with the current state of frost heave understanding. The values for differential ice segregation ratio have been strongly conditioned by several observations:

1. There is wide scatter in the (CRREL) data between frost heave magnitudes and soil types; potentially excessive heave behavior has been observed in the lab for nearly all natural soils.

2. The Calgary test site, located in silt and clay, shows a) only about 20 percent heave ratio, and b) differential heave is a small fraction of total heave.

3. In situ freeze plate tests in White River and Beaver Creek floodplains showed no heave in clean sands and gravels.

4. Pipe flexural rigidity and soil uplift resistance will dampen total heave by imposing significant stress on heaving soils and reduce differential heave by stress redistributions over short span lengths. In addition, it will provide potential total and differential heave mititgation by soil creep in the frost bulb over the 25-year design life.

5. Natural limits on in situ water availability will restrict actual heave below potential heave as measured in lab tests.

6. Geotechnical variability is generally less over short distances relative to longer distances.

7. Pipe padding and bedding will tend to lessen differential heave over short distances.

8. Where used for frost heave mitigation, overexcavation and backfill with nonfrost-susceptible soil will lessen differential heave over short distances.

Observation 3 was used to set LHP to zero ice segregation ratio. The unacceptability of excessive potential heave strains suggested by Observation 1 was judged unrealistic because of Observations 2a, 3, 4 and 5. Observations 2b, 4, 6, 7, and 8 suggested a reduction in total heave to account for reasonable differential heave over short span lengths.

Northwest expects to be able to make the criterion for ice segregation ratio and the span over which it acts more definitive as improvements are made to laboratory testing techniques and to the semi-empirical model. Moreover, one of the test sites Northwest hopes to use for a full-scale test will incorporate a pipe section frozen into permafrost on both ends but spanning a deep-thawed frost susceptible zone. Such a section will be heavily instrumented so that a better understanding may be obtained of pipe-soil behavior under these severe conditions.

1.8 DESIGN MODES

1.8.1 EPR Thermal Model

The Exxon Production Research (EPR) computer program simulates two-dimensional heat conduction with a change of state for a variety of boundary conditions. A variational technique is used to obtain temperature distributions and thaw or freeze-front locations at discrete times. The heat of fusion, and changes in heat capacity and thermal conductivity due to thawing or freezing are taken into account.

The work was divided into two phases:

1.8.2 Mode Geothermal Analysis With Varying Insulation

The first phase examined six hypothetical insulation geometries. This phase employed a single set of soil properties (see table below) and an initially thawed soil profile in determining the effect of these proposed design modes on the growth of the frost bulb. Each analysis represented 25 years of chilled pipe operation. The insulating efficiency of each mode was related to frost growth around a bare pipe. Thermal properties of insulation were also considered.

SOIL PROPERTIES USED FOR PHASE ONE GEOTHERMAL ANALYSIS

Material	Heat capacity BTU/cu ft-°F		Thermal Conductivity BTU/ft-hour-°F		Latent* Heat BTU/cu ft
	Frozen	Unfrozen	Frozen	Unfrozen	Heave State
Silt	29.5	39.0	1.21	1.13	3217

*Note that latent heat varies as a function of temperature below 32°F. The listed value is the total extractable latent heat.

Ditch Mode Analysis - The most efficient design mode to minimize the effect of frost heave, based on geothermal analysis of several buried chilled pipeline configurations, was circular insulation placed around the pipe. The results were developed using the EPR computer program. Six inches of insulation was considered a practical (construction) upper limit for conceptual work. As additional site-specific data become available, insulation thickness refinements will be made as part of the mile-by-mile design.

Results and Applications - Based on the results of gas temperature and the ditch mode thermal analysis, a mitigative ditch mode was developed using:

- An insulated pipe

- An insulated pipe and overexcavation (replacement of frost susceptible soil with nonfrost susceptible soil)

The amount of overexcavation (OX) required is found using the following equation:

$$OX = R - \frac{\text{Allowable Heave (AH)}}{\text{Ice Segregation Ratio (ISR)}}$$

R = Frost depth below the pipe (from thermal analyses)

AH = Allowable heave

Crossings - Pipeline stream and river crossings will be buried below the scour depth. The effect of the chilled pipeline operating below major rivers will be minimal.

Other pipeline crossings were simulated using the EPR program. The chilled line was located in an aboveground embankment and allowed to cross (approximately perpendicular) the buried TAPS pipeline. The preliminary results indicated that the frost bulb will not penetrate sufficiently to cause danger to the TAPS pipeline.

Mitigative Modes - The mitigative modes developed to minimize the effects of frost heave over a 25 year project life in problem soils include:

- Reroute to avoid soil problem areas
- Insulate the pipeline
- Insulate the pipeline and overexcavate

Insulation Analysis and Results - Computer simulations performed for two different insulation k-factors show that a 25 percent reduction in the k-factor, from 0.02 to 0.015 Btu/ft-hr-°F, results in a 15 percent reduction in the frost depth. A search of available literature, summarized below, indicated that it was reasonable to use a k-factor of 0.015 Btu/ft-hr-°F.

The foam insulations generally have thermal conductivity (k-factor) ranging from 0.010 to 0.014 Btu/ft-hr-°F. However, during the operational life of a foam insulated pipeline, temperature, water, air, exposure to ultra-violet rays and vapor migration can affect the thermal properties of the insulation. At the present time, several long-term aging tests have been performed. Results of these tests show that the k-factor of this type of insulation can decrease (17 percent to 30 percent) with regard to insulative value during its design life. depending on exposure.

However, a buried section of insulation with aluminum-faced panels shows no change in k-factor.

1.8.3 Mode Geothermal Analysis With Varying Ditch Configuration

Using six inches of circular pipe insulation with a k-factor equal to 0.015 Btu/ft-hr-°F, a study of the effect of variable ditch configuration on frost penetration was performed. This study incorporated the effects of backfill soil with properties different from the natural in situ soils.

Soil Properties - Two natural soils and one backfill soil were used in the simulations. The soil types, whose properties are shown on Table 1-1, consisted of:

- A moderately dense moisture-saturated frost susceptible silt.
- A dense moisture-saturated frost susceptible predominantly sandy soil.

The backfill was a sandy nonfrost susceptible 90 percent saturated soil. The soil properties listed in Table 1-1 require assumed values for the heave ratio and the dry density of the thawed (unheaved)soil. Those parameters actually input to the EPR model are indicated by an asterisk.

The values for the frozen and thawed heat capacities and the frozen and thawed thermal conductivities are representative values (not necessarily conservative with respect to the contribution to frost bulb growth).

ALP and GAM are parameters used in the EPR model to define the amount of soil moisture remaining unfrozen as a function of temperature below 32°F. The values chosen for silt are typical of a frost susceptible silt. The values chosen for the sand and sandy backfill closely approximate isothermal freezing of all soil moisture at 32°F.

Ground Temperatures - Preliminary results suggest that ground surface temperatures varying seasonally about a given mean temperature have almost exactly the same effect on soil temperatures below the pipe as does a constant surface temperature equal to that mean value.

TABLE 1-1

SOIL PROPERTIES USED FOR PHASE II SIMULATIONS

	Heave Ratio (Assumed) (%)	(Assumed) γ_d Thawed State (lbs/cu ft)	γ_d Heaved State (lbs/cu ft)	w Thawed (% dry weight)	w Heaved State (% dry weight)	C* Thawed (Btu/cu ft-°F)	C* Frozen (Btu/cu ft-°F)	K* Thawed (Btu/ft-hr-°F)	K* Frozen (Btu/ft-hr-°F)	L* Heaved State (Btu/cu ft)	ALP*	GAM*
SILT	50	112	75	18.5	42.1	40	28	1.0	1.3	4260	7.0	0.24
SAND	20	130	108	11.0	18.7	40	28	1.25	2.0	2918	0.01	1.0
BACKFILL	0	130	130	10.7	10.7	40	25	1.5	2.5	2000	0.01	1.0

NOTE: It is assumed for this study that 2.6 percent (percent dry weight) of the water in the frozen silt remains in the liquid phase.

* EPR input parameter.

γ_d = dry density
w = water content
C = heat capacity
K = thermal conductivity
L = latent heat

These results apply to level ground surfaces only. For nonlevel ground surfaces (e.g., embankments) or where seasonal frost behavior is important (e.g., frost jacking or pipe uplift resistance), it may be found that seasonally varying surface temperatures is a necessary refinement.

For phase two analyses, as in phase one, the temperature at the ground surface was constant with time at 32.1°F. Other warmer, less conservative, temperatures will be assessed in the future as their justification becomes warranted.

1.9 DESIGN SOLUTION PROCESS

Summary

The overall frost heave design process is summarized in Figure 1-16, which identifies the essential elements of the process under implementation.

There are seven distinctive but interactive design tasks identified in Figure 1-16. These are:

Task 1 Route Geotechnical Characterization and Classification

Task 2 Frost Heave Prediction

Task 3 Develop Analytical Tools

Task 4 Separate Route into Segments

Task 5 Parametric Engineering Analysis

Task 6 Frost Heave Design Mode Development

Task 7 Segment by Segment Mode Selection

Simplistically, the frost heave design process, as outlined in Figure 1-16 proceeds as follows. Having identified the route and set operational criteria, Tasks 1 and 4, as conditioned by Task 2, establish route segments. Tasks 2, 3, 5 and 6 establish candidate design modes to mitigate frost heave effects. If a given segment has a frost heave potential, then the design enters Task 7, a segment-by-segment mode selection process to determine the appropriate mode for frost heave mitigation. Having selected a design mode for a given segment, one proceeds to mile-by-mile design.

1.9.1 Design Tasks

The tasks outlined in Figure 1-16 are:

Task 1 Route Geotechnical Characterization and Classification

This task coordinates the collection of field data and its subsequent geological and geotechnical synthesis into appropriate field design soil types (FDST). This task includes a procedure for characterizing the soil conditions between borings and accounting for geotechnical variability. This task is directed towards both the overland and river crossing portions of the route.

Task 2 Frost Heave Prediction

Based on field and laboratory frost heave testing program results, soil, groundwater and thermal conditions along the alignment will be characterized in terms of frost heave susceptibility. Similar soil, groundwater and thermal conditions along the route will be described in summary form by deriving Field Design Soil Types. Empirical predictive correlations based on laboratory and field data will be utilized to relate frost heave and frost heave rate to Field Design Soil Types. In those soil types where a satisfactory predictive correlation cannot be obtained, appropriate conservative upper bound heave values will be adopted. The correlation between frost heave and Field Design Soil Types will be mode-dependent wherever the design mode configuration affects potential frost heave.

Task 3 Develop Analytical Tools

This task acquires and/or develops for project use the necessary analytical tools required for the frost heave design process. Examples are geothermal conduction or convection models, and the model or models necessary for pipeline stress analysis.

Task 4 Separate Route Into Segments

The output of Tasks 1 and 2, when combined and conditioned by Tasks 5 and 6, result in the route being separated into segments.

Task 5 Parametric Analysis

Analysis of pipe stresses and strains due to prescribed frost heave induced pipe boundary conditions is being conducted on a parametric basis for each design mode configuration. Prescribed boundary conditions, soil load/deformation behavior, and time-dependent effects due to frost bulb/growth are being considered, including creep effects and flexural rigidity of the composite pipe/frost bulb beam.

Input into this task are other parametric studies including geothermal and frost heave effects.

Task 6 Frost Heave Design Mode Development

Pipeline construction mode designs have been developed to mitigate potential frost heave to acceptable limits. Construction modes are integrated with pipeline frost heave monitoring systems and remedial action plans to provide for a variety of overall designs. These overall designs, called design modes, have been developed to provide reliable designs for potential pipeline frost heave conditions. Beginning with conventional burial, design modes will be ranked in order of increasing cost per typical mile.

Task 7 Segment-by-Segment Design Mode Selection Process

The seven tasks identified in Figure 1-16 are precursors to the final selection of a frost heave design mode for the segments making up the frost heave susceptible portions of the route. The route will be moded segment-by-segment. Where a segment's Field Design Soil Type is nonfrost-susceptible, a conventional burial design is adopted directly.

If the segment's Field Design Soil Type is frost-susceptible, the first trial design mode, conventional burial, is selected (based on least-cost) for evaluation of suitability. Using the segment's Field Design Soil Type, the conventional burial mode is checked against the results of Task 5 (parametric analysis) to determine if stresses and strains are maintained in the acceptable range. If so, conventional burial is adopted. If not, the next trial mode, in order of increasing cost, is selected and analyzed to determine its suitability. This process continues until a trial mode is found to be adequate. This final trial mode would constitute the least-cost acceptable mode for the segment.

Before each trial mode is selected, a check will be made to determine if a reroute could be cost-effectively used to eliminate or mitigate the potential frost heave problem. The whole process is repeated segment-by-segment until all segments are properly moded.

Design refinements or any special alignment considerations requiring attention are addressed during the mode selection process. Further analysis or design changes are performed at that time on a segment-specific basis.

1.9.2 Mile-by-Mile Design

Detail design, in the preparation of mile-by-mile designs, will select the specific frost heave mitigation mode, if required, using the design solution process described above.

1.10 CONTINUING STUDIES

To confirm the construction mode selected, Northwest has the following studies either on-going or planned for implementation in the near future.

1.10.1 Laboratory Testing Program

This, as described, consists of two types of tests: frost heave tests and classification tests. Large diameter samples will be obtained from the new test sites and from special borings along the route in soils typical of the terrain units. Frost heave tests will be performed on these samples as well as index property tests. The ice segregation ratios obtained in the laboratory will be used in the semi-empirical model to predict heave of the pipeline and a correlation will be developed between ice segregation ratio and index properties.

1.10.2 Full-Scale Test Facilities

Additional full scale test facilities will be installed in soils with different silt contents. Test sections at these sites as well as those at the existing Fairbanks and Calgary sites will be monitored for heave and frost bulb growth with time. Data obtained will be compared with predictions made for each site using the empirical model to confirm not only the predictive capabilities of the model but also the construction modes proposed for those soils.

1.10.3 Soil Uplift Resistance

A laboratory study is currently under way to model the resistance of the frozen soil overburden to pipe uplift. From these tests Northwest expects data on values of uplift resistance and a better understanding of the creep behavior of the frozen soil.

1.10.4 Semi-empirical Model

Additional work is being done on the semi-empirical model to improve its predictive function so that predictions of heave of the pipeline will more closely approach the actual heave being obtained.

1.10.5 Work by Government Agencies

Northwest has and will be keeping itself abreast of theoretical and experimental work proposed by governmental agencies, in particular by the Office of the Federal Inspector, who will be trying to show that a theoretical model of frost heave can be developed.

1.11 POTENTIAL FOR CHANGES

A preliminary analysis indicates that the chilled pipe may be buried in a conventional mode with little or no risk of heave for approximately 75% of the route. The remaining 25% is of moderate to high frost heave potential. Of this 25%, approximately 17% is of high frost heave potential, and it is to this portion that a back-up design is being primarily addressed.

By the end of 1980, Northwest will have completed a preliminary back-up design employing heave prevention construction modes. Designs being investigated include:

- a heavily-insulated mitigation design
- a variety of berm and embankment designs involving insulation where necessary
- a standard mitigative design supplemented by heat tracing.

By the end of the second quarter in 1981, Northwest expects to have:

- o Developed a correlation between laboratory ice segregation ratio and index properties
- o Developed a simulation of pipe-soil interaction taking into account the soil uplift resistance.
- o Improved the empirical model so that it more closely predicts the actual heave of the pipeline, and confirmed its predictive capabilities for the soils being tested at the full-scale testing facilities.
- c Confirmed the construction modes chosen for the soils being tested at the full scale testing facilities.
- o Increased the confidence level in predicting heave in soils not subjected to full-scale testing.

APPENDIX I

The existing and proposed full-scale test facilities are described in detail below.

Calgary Test Facility

Foothills Pipe Lines (Yukon) Ltd. has acquired and is continuing to operate the Canadian Arctic Gas Pipe Line Frost Effects Test Site in northwest Calgary. This test facility was constructed in the winter of 1973-74 to study the behavior of noninsulated 48 inch diameter pipe in unfrozen frost susceptible soil at below freezing (chilled air) temperatures. Two additional insulated 48 inch diameter test sections were installed in February 1979. The site will continue to be operated at least through 1980 and probably longer.

This test facility has provided useful information about frost penetration and heave strain around chilled pipe. Continued operation of the facility will be of great value in the design for frost heave mitigation.

Site Geotechnical Conditions - The subsurface conditions at the Calgary test site contain most of the conditions that could lead to troublesome frost heave problems. These conditions are as follows:

- The upper strata at the site are frost susceptible. The soils possess both the ability to draw water to the freezing front and have a high enough permeability to permit the passage of water to the freezing front.

- The presence of a high water table ensures a ready supply of water to the freezing front.

- A sufficient depth of frost susceptible soil is available to ensure that the frost line remains within this material over the lifetime of the test.

Original Calgary Test Facilities - The test facility was designed to monitor the movement of the chilled test sections, to determine the effect of increased surcharge loading in reducing frost heave, and to examine the effects of replacing a portion of the frost susceptible material beneath the pipeline with a granular material.

For a layout of the facilities see Figure 1-17.

Four test sections were installed at the test site in the winter of 1973-74. The "Control Section," buried 30 inch and without bedding, provided the reference to which the other test sections could be compared. This section was removed in September 1977. Absence of the control does not jeopardize the value of future results obtained from the remaining sections; the data accumulated during its 3-1/2 years of existence should suffice.

The "Deep Burial Section" was buried 65 inches below ground surface. The effect of the added overburden weight on frost bulb growth and frost heave was studied with this test section.

The "Restrained Section" was 30 inches below ground. The restraint can be applied with any desired constant load by hydraulic jacks. Piles and beams near the ends of the section provide reactive resistance.

The "Gravel Section" was buried 30 inches below ground with 36 inches of granular material placed beneath the pipe. The effect of replacing the frost-susceptible soil directly under the pipe with non frost-susceptible soil was studied at this section.

Chilled air is supplied to the test sections from a chiller consisting of a standard reciprocating industrial type ammonia compressor, liquid ammonia receiver, and a multi-row cooling coil mounted in the blower unit. The blower circulates 6,000 cfm of approximately 15°F air at atmospheric pressure through each test section at a velocity of about 12 ft/sec.

Instrumentation - Thermistor strings installed adjacent to the test sections monitor the movement of the frost front through the soil. Two additional thermistor strings were installed away from the test sections to monitor the ground thermal regime outside the zone affected by the chilled test sections.

Steel heave rods are welded to the top of each section. Rods are also attached to 3-inch diameter plates adjacent to each pipe. Pipe and soil heave is monitored by surveying and noting rod top elevations at regular intervals.

Several piezometers are installed at each test section to measure pore pressure in the vicinity of the frost front.

Instrumentation to measure ovalling of the pipe under lateral loading was installed in the Control and Restrained Sections.

Observations - To date a number of significant observations have been made at the test site. The determination of the relationship between effective soil stress on the rate and amount of frost penetration and the rate and amount of frost heave was one of the major objectives of the test. Arctic Gas had recognized early in their study of the frost heave phenomenon that increased effective soil stress at the front would slow the rate of frost heave. This was observed at the test site.

In all of the test sections, the heave rate, apart from minor fluctuations, generally decreases with time. This is at least partially due to the increasing soil pressure with depth. In mid-1975 a surcharge berm was applied to both the Control and Deep Burial test sections. A sudden reduction in heave rate was achieved with the extra weight.

Core samples obtained in 1977 and 1978 from frost bulbs around the test sections have been examined and tested to ascertain the variation of heave ratio with depth beneath the pipe. This data combined with that derived from 6 years of site operation will assist in the refinement of frost heave predictive techniques.

Additional Test Sections - Two full-scale insulated test sections have been added to the Calgary Frost Heave Test Facility. Frost penetration and heave data as well as future core sampling will provide an excellent test of the predictions made.

Both new test sections are 48-inch outside diameter pipe with 0.40-inch wall thickness and are about 40 feet long. Both sections were initally coated with 0.013-inch polyethylene tape, then urethane foam was sprayed to an approximate thickness of 0.65-inch. The foam has a density of 4 pcf and thermal conductivity of 0.014 Btu/ft-hr-°F. The insulation is coated with a 0.05-inch coat of urethane elastomer for moisture and mechanical protection.

The new test sections are supplied with chilled air from the existing refrigeration system. New aboveground duct work was installed for supply and return air.

Insulated Test Section No. 1 has been buried 30 inches below the ground with native soil used to backfill the ditch, without select bedding or padding. The ditch bottom was carefully shaped to fit the outside surface of the pipe which, together with careful backfill procedures, eliminated voids around the pipe. Any frost bulb growth around this test section would be into frost susceptible soil. This section will provide data on the effect of the reduced heat flux and penetration rate of the frost on the ice segregation ratio.

Insulated Test Section No. 2 has also been buried 30 inches deep. The ditch was excavated an additional 36 inches to provide space for selected granular bedding and padding. Padding was placed to 12 inches above the top of the pipe. Thermal calculations indicate that the frost bulb (32°F isotherm) will remain within this granular material over the life of the experiment. This test section will therefore monitor the stability of the chilled pipe while the frost bulb remains in a nonfrost susceptible soil. Some advance and retreat of the 32°F isotherm is apparent over a year with less than complete thaw back of the frost bulb, as predicted by the empirical model.

Instrumentation - The insulated test sections are being monitored for frost penetration depth and frost heave. The frost penetration is being measured with temperature strings installed to a depth of 10 feet below the bottom of the pipe. One string was installed directly below the pipe with four other strings on 30 inch centers to either side of the test sections. Rods attached to the pipe are being surveyed periodically to determine the amount of pipe heave.

Fairbanks Test Facility

The site selected is located on Chena Hot Springs Road, approximately 4 miles north and 7 miles east of Fairbanks.

This facility operates with chilled air circulating through a 48 inch outside diameter, 0.46 inch and 0.56 inch wall thickness coated steel pipe. The layout is shown in Figure 1-18. Most of the construction and installation of equipment at the test facility was completed by early 1979. Chilling startup was on October 13, 1979 after the ground around the pipe sections was thawed as indicated by the temperature strings and probes. Discussed below are first, the shorter test pipes (Heave Test Pipes) and then the longer pipe (Interface Test Pipe), and finally the support test facilities.

Heave Test Sections (Pipes) - Each pipe is approximately 120 feet long except Section 10. Typical ditch sections are shown by Figure 1-19. Backfill is primarily material excavated from the ditches.

The pipe designations shown below are used for reference in Figures 1-18 and 1-19.

1. Uninsulated, control, without gravel bedding.

2. Insulated 2-inch urethane, without gravel bedding.

3. Insulated 6-inch styrofoam, with 6 inch gravel bedding between styrofoam boards and pipe.

4. Uninsulated, with 36 inch thick gravel bedding.

5. Insulated 2-inch urethane, shallow burial with a 36 inch thick gravel berm and without gravel bedding.

6. Uninsulated, with adjacent heat tubes, without gravel bedding. See Figure 1-4 for layout.

7. Insulated 2-inch urethane, with 12 inch thick gravel bedding.

8. Insulated 4-inch urethane, with 36 inch thick gravel bedding.

9. Interface test pipe discussed below.

10. Uninsulated, 40 foot long, with 6-inch thick gravel bedding in permafrost.

The test pipes are intended to show the relative heave under a variety of insulation and gravel bedding thickness conditions and, in the case of section 6, the effect of prefreezing the ground beneath the pipe. The length of these sections, 120 feet, has been selected to minimize the effect of end conditions.

The principal test results are expected to be derived from the following evaluations and comparisons:

- Insulation and bedding thicknesses for Sections 2, 4, 5 and 7 were chosen with the expectation that an appreciable amount of heave will occur during the test period. Section 8, on the other hand, is expected to heave very little and is considered to be a possible prototype of the mitigative measures that will be found adequate for soil and meteorological conditions at the test site.

- Relative heave of pipes without bedding is designed to show the mitigative effects of insulation, shallow burial and heat tubes.

- Comparison between uninsulated Sections 1 and 4 will demonstrate the heave mitigative effect of gravel. The same effect will be revealed by comparing insulated Sections 2 and 7.

- It is anticipated that the frost bulb will pass through the granular bedding beneath Sections 4 and 7 sometime during the test period. The alteration of heave rate after this happens will be observed and evaluated.

- Section 3 is insulated with styrofoam board. This type of insulation is less expensive to install than circular insulation but preliminary analysis has indicated that it is less effective for heave mitigation. This method may prove adequate in areas in which the average (design) gas temperature is predicted to be 25°F or higher. The lower temperatures at the test site will accelerate frost formation and thus allow more timely evaluation of this mitigative approach. After the test, an examination of the glued joint between bottom and ditch-side boards will be made to provide guidance in designing a connection for permanent installation.

- Heat tubes installed adjacent to test Section 6 (see Figure 1-20) in October 1978 were spaced to freeze completely the area beneath the pipe in one winter. This was accomplished and the ground beneath the pipe remained frozen throughout the summer.

- Section 10 is installed to confirm that minimum heave will occur to a chilled pipe in permafrost.

Interface Test Pipe - The interface test pipe is 400 feet long with a configuration shown by Figure 1-21. It is placed in permafrost at one end while the other end is in thawed indigenous soil (silt). A manhole is installed in this pipe to make access possible during operation.

The length of pipe within permafrost and thawed ground is installed to provide a good simulation of a continuous pipeline. This test is designed to accelerate differential heave in order to examine the stresses and deformations which may eventually develop at soil type interfaces. It is emphasized that this is a test situation; during construction, some type of mitigative measure may be taken to reduce heave at such interfaces if it should prove necessary.

Instrumentation - A review of past test experience led to the selection of the instrumentation described below. Certain instruments have not been included either because the data they would produce are not considered necessary or because their information can be obtained by other means. Pyranometers and infrared radiometers are omitted because sufficient information about albedo and greenhouse effects in the Fairbanks area is already known. Thermal conductivity probes and moisture cells are not included because periodic coring is expected to give more reliable results.

Readings from the instruments described below are being automatically scanned by a microprocessor and recorded on tape. To reduce the possibility of losing data, two tape recorders are being used simultaneously. Provision has been made for entering manually obtained data on the tapes.

- Ground temperatures are obtained by resistance temperature detectors (sensistors) beneath and at the sides of test pipes. These detectors are accurate to the nearest 0.1°F. They are the primary source of frost bulb dimensional change data.

- Heat flux transducers encircle one insulated pipe to measure differential and total heat flux. In addition, a string of these transducers is placed on one heat tube to aid in evaluation of the prefreezing technique.

- Test pipe temperature is obtained adjacent to the two rings of heat transducers mentioned above, and at the supply and return ends of the circulating compressed air system. These temperatures are recorded with test data and are also displayed within the equipment building for monitoring refrigeration equipment.

- Air temperature is obtained at two representative locations by reading standard sheltered meteorological thermometers twice a day. Temperatures are manually entered on the data tapes.

- Heave rods are attached to the top of each test pipe, at locations adjacent to them and at several control locations on site. All rods are made of steel or aluminum and are placed in plastic standpipes. The rods have survey targets attached to their projecting ends. The displacements are measured by a surveying instrument once a week. The instrument selected accurately records the position of the targets. This manually obtained information is entered on the data tapes.

- Radial extensometers have been placed inside two of the pipes to measure changes in ovality. At each location measured, the extensometers cross, one vertical and one horizontal. Three locations within the interface test pipe are also instrumented. One set of extensometers has been installed at the longitudinal center of the heat tube test pipe to determine whether or not the pressure of frost formation around the adjacent heat tubes causes deformation.

- Strain gauges are installed within the interface test pipe only. They are of three types. Single axis gauges, with axis parallel to pipe centerline, are placed at the top and bottom of the pipe to ascertain stress profiles. Biaxial gauges are placed at top, bottom and sides near the extensometers and at points midway between them. Triaxial rosettes are installed to determine the principal strain directions. All will help evaluate the stress changes coincident with pipe deformation.

- Test system air pressure is measured within the equipment building at the supply and return ends of the air circulation system. This information is displayed within the building and periodically entered on the data tapes.

- External soil and ice pressures are measured on the interface and heat tube test sections. At five locations along the central portion of the interface test pipe and near the longitudinal center of the heat tube pipe, pressure is measured at the top, bottom and sides of the pipe. At locations toward the ends of the interface test-pipe, soil pressure is measured at top and bottom only. The reason is that beyond the central heave area, because of end effects, the only data of interest are uplift resistance on top and an indication of whether or not a void forms, and thus zero soil pressure exists, as the pipe bottom rises from the non-heaving gravel beneath. Two types of instruments are used to obtain external pressure information. One, which has been developed for this project, has a large sensing area, 12 inches square or larger. These units are attached to a flexible belt around the pipe. The other type is a standard 4 inch diameter pressure disc. Both types employ hydraulic sensors and electric transducers. The idea of using a large sensing area is to reduce the possible distorting effect of ice bridging. The discs are to provide iteration so that data may be obtained even if the new larger sensors fail.

- o Pore water pressure is measured beneath several test pipes by electric transducers. In previous tests by others, results of pore pressure determination have been disappointing. A number of open stand-pipes have been installed to measure groundwater levels.

- o Snow depth gauging is done by direct measurement. The readings are entered on the data tapes whenever significant changes in snow depth occur.

Additional Full-Scale Test Sites

Site selection for additional test sites along the pipeline route is being based on the following criteria:

- o Unfrozen soils - The soils to be tested shall be unfrozen and, if frozen soils are present they should be below a depth of 30 feet.

- o Shallow Groundwater - The water table should be at or near the bottom of the pipe.

- o Soil Grain Size Distribution - As the amount of frost heave experienced by the soil appears to be associated more strongly with the amount of silt and clay-sized particles (percent passing the #200 sieve) than with any other textural characteristic, the sites will be located in representative soils along the route spanning the range of observed silt contents.

- o Access - As the sites will be operated over extended periods, it is essential that each site have year-round access for fuel trucks, maintenance equipment, and site personnel.

Facility Description - The primary elements of each test site will include two 80-foot sections of buried 48-inch diameter pipe, associated instrumentation and piping, and a prefabricated building that houses a chiller unit and, at remote sites, power generation equipment. This test will be located within a 100-foot by 200-foot fenced area. A larger area will be required during the site construction period for temporary storage of pipe ditch spoil, storage of construction materials, and parking of construction equipment and vehicles. A general site layout is shown in Figure 1-22.

An all weather access road/driveway will be required at many sites in order to permit access during construction and operation periods. Construction requirements assuring such access are dependent upon site specific soil conditions at each location.

One of the 80-foot sections of pipe will be installed in a conventional buried configuration, that is, bare pipe with approximately 2.5 feet of cover.

The second 80-foot pipe section will include insulation up to 6-inch in thickness applied to the outer surface of the pipe. Soils beneath this pipe may be over-excavated and backfilled with non-frost susceptible material. The depth of over-excavation if any will vary between 2.5 feet and about 6 feet, depending upon pipe operating temperatures and soil characteristics. This will limit frost heaving by controlling the depth of the frost penetration into frost susceptible soils.

The pipe will be closed at each end. A circulating chilled brine system has been chosen. Normal operation temperature will be between 10° and 25°F, depending on site location.

The chiller unit will have about 5 tons of refrigeration capacity. The unit will be installed within a heated prefabricated structure. Commercial power will be utilized where available; however, at remote sites it will be necessary to power the chiller unit with onsite generation equipment using onsite fuel storage.

Instrumentation will include survey rods extending from the pipe to the surface for monitoring heave movements. Thermistors installed in the soil at various depths and distances from the pipe will provide soil temperature measurements. Groundwater conditions will be monitored.

Three frost proof benchmarks will also be installed in order to provide assurance of a stable elevation datum.

Pneumatic load cells will be installed immediately above and below the pipe and at depth intervals below the pipe to provide data for determining the effective soil pressure at the frost front.

In addition, internal extensometers will be installed to monitor pipe ovalling in both the horizontal and vertical directions.

Operations - The site will be monitored on a weekly basis, except during the initial start-up period, when data will be collected on a twice-a-week basis. Data recording, validation and filing will be done with a data acquisition system.

Heave measurements will be made by conventional elevation survey techniques to an accuracy of about ± one millimeter.

In addition to data collection, the operation activities will include servicing and repair of equipment (particularly at sites having onsite power generation equipment) and the validation and management of the collected data. Preparation of a weekly summary plot of critical data items will facilitate review of overall test status and progress.

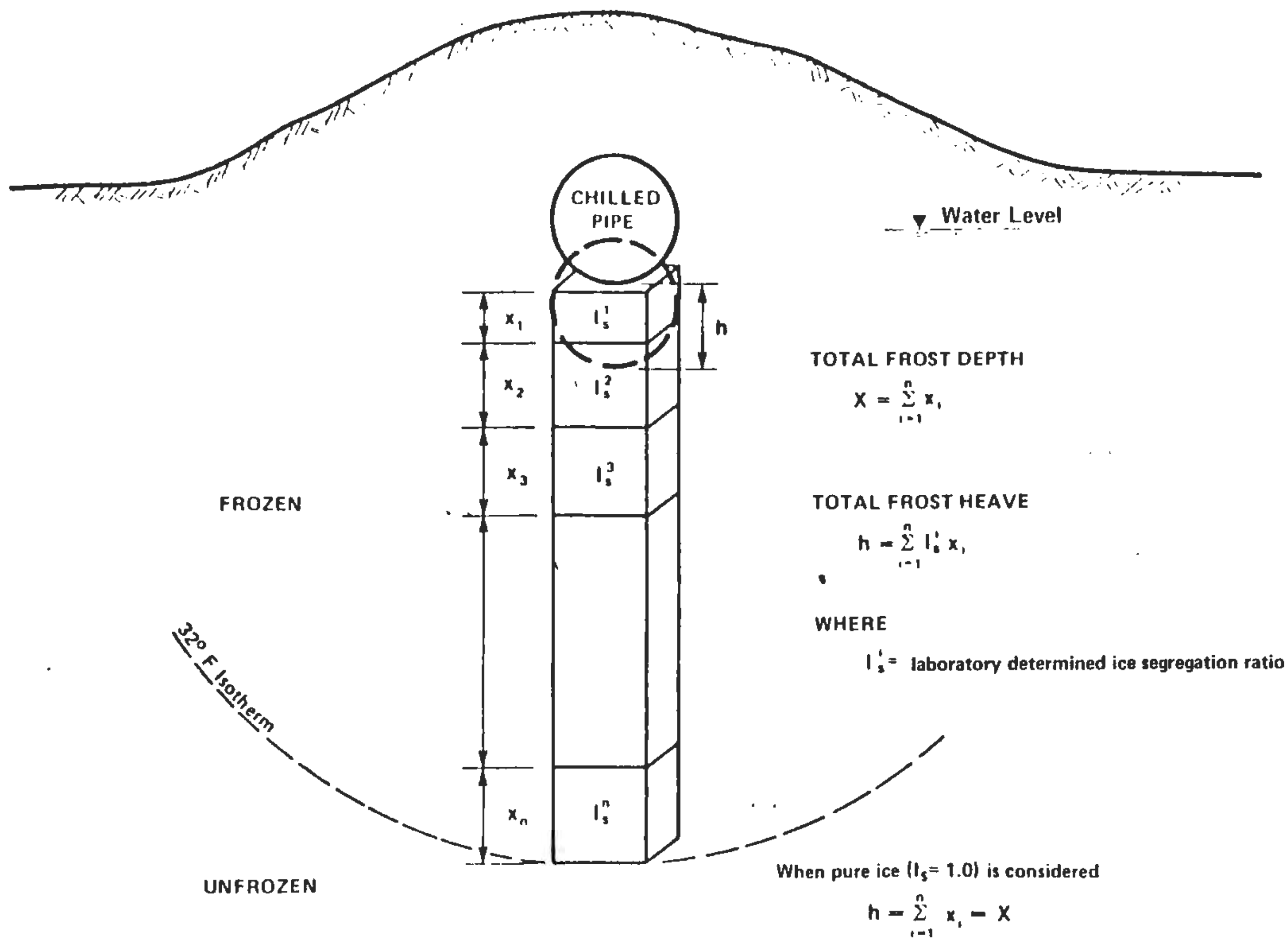


FIGURE 1–1 SUMMATION OF ELEMENTAL HEAVE TO BECOME TOTAL HEAVE

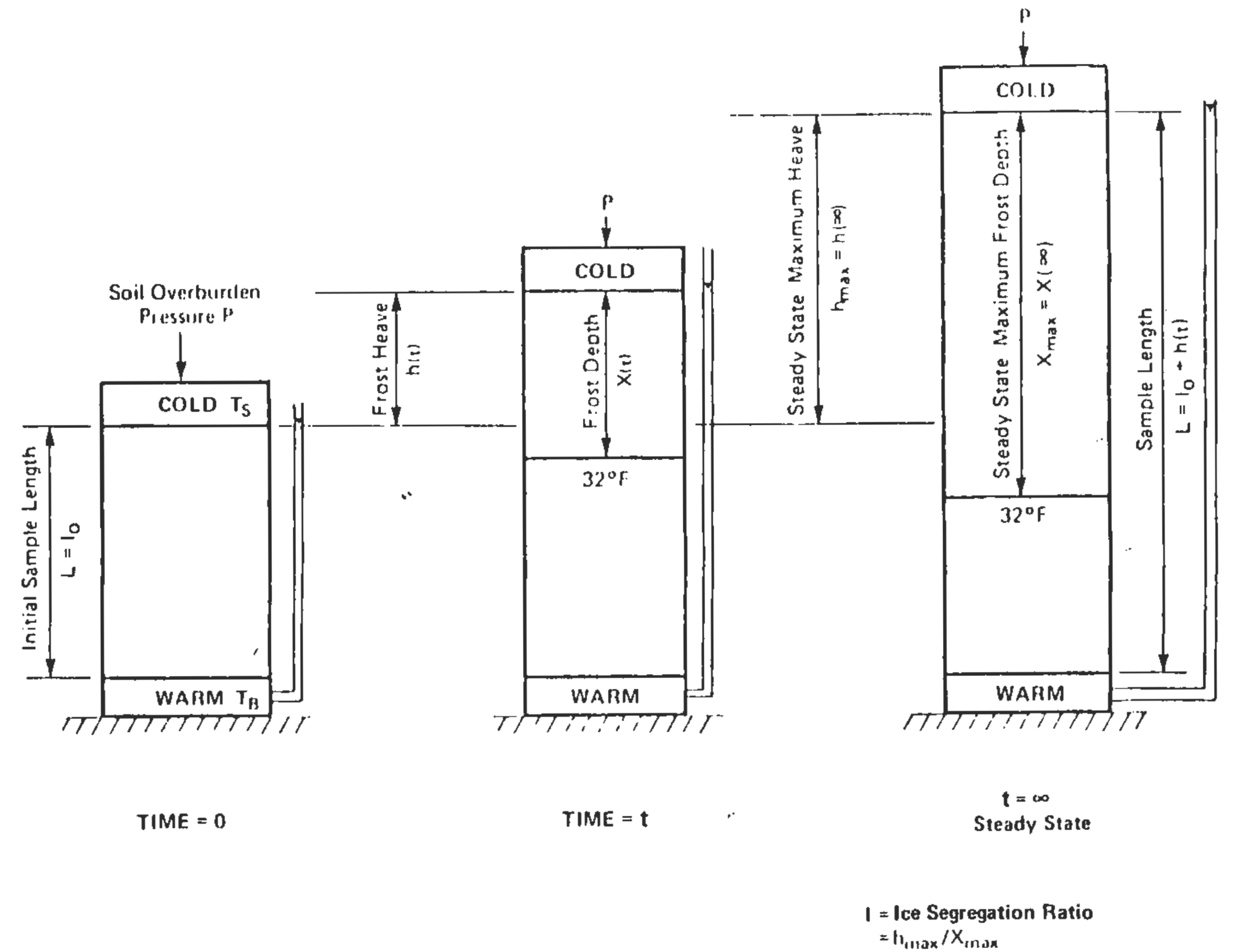


FIGURE 1–2 THERMAL CONFIGURATIONS OF A LABORATORY SAMPLE AT THREE STAGES OF THE FROST HEAVE TEST

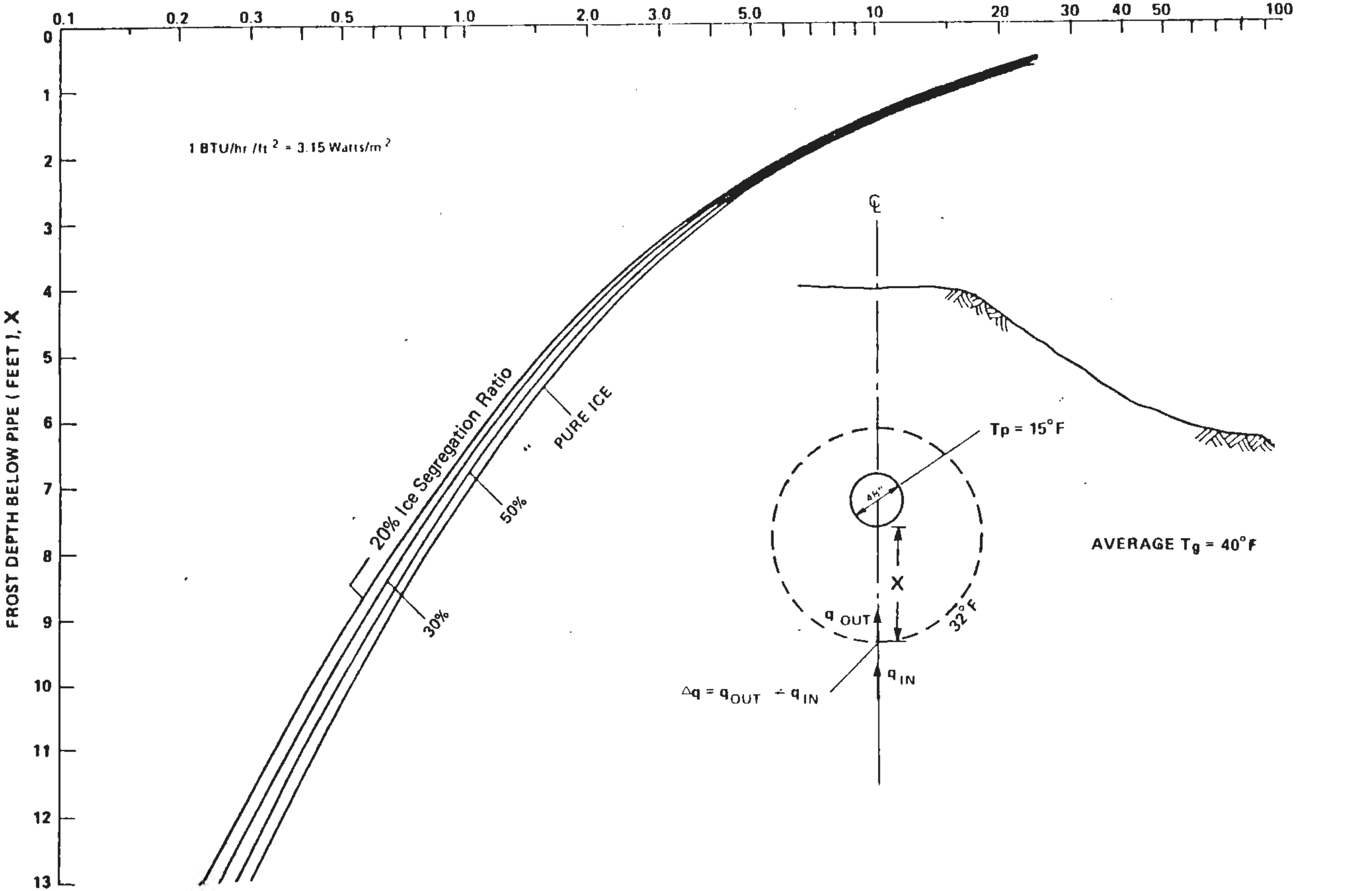


FIGURE 1–3 CALCULATED NET HEAT FLUX AT FREEZING FRONT
DEEP BURIAL SECTION
CALGARY FROST HEAVE TEST SITE

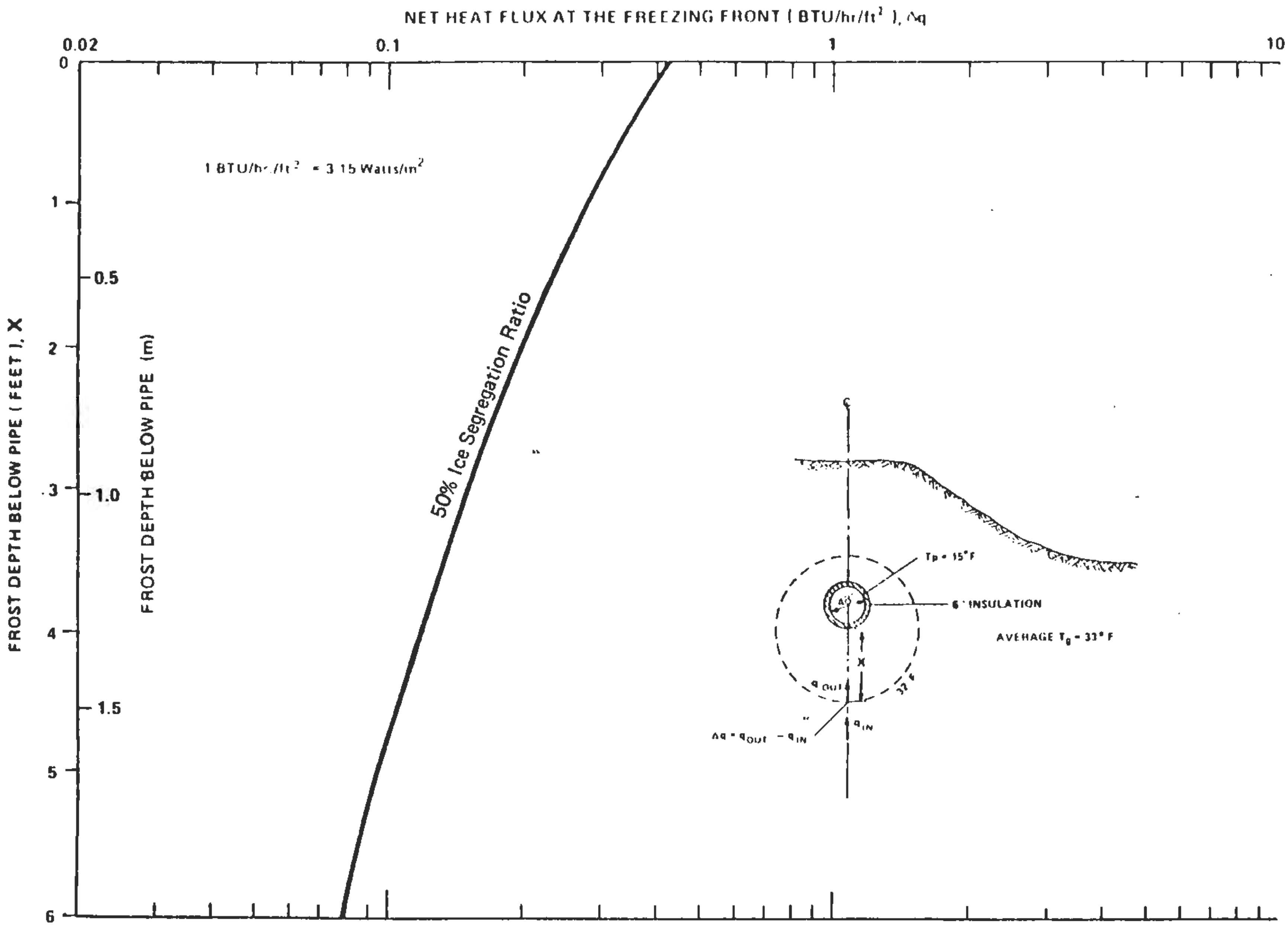


FIGURE 1–4 CALCULATED NET HEAT FLUX AT THE FREEZING FRONT FOR AN INSULATED COLD PIPE IN UNFROZEN GROUND

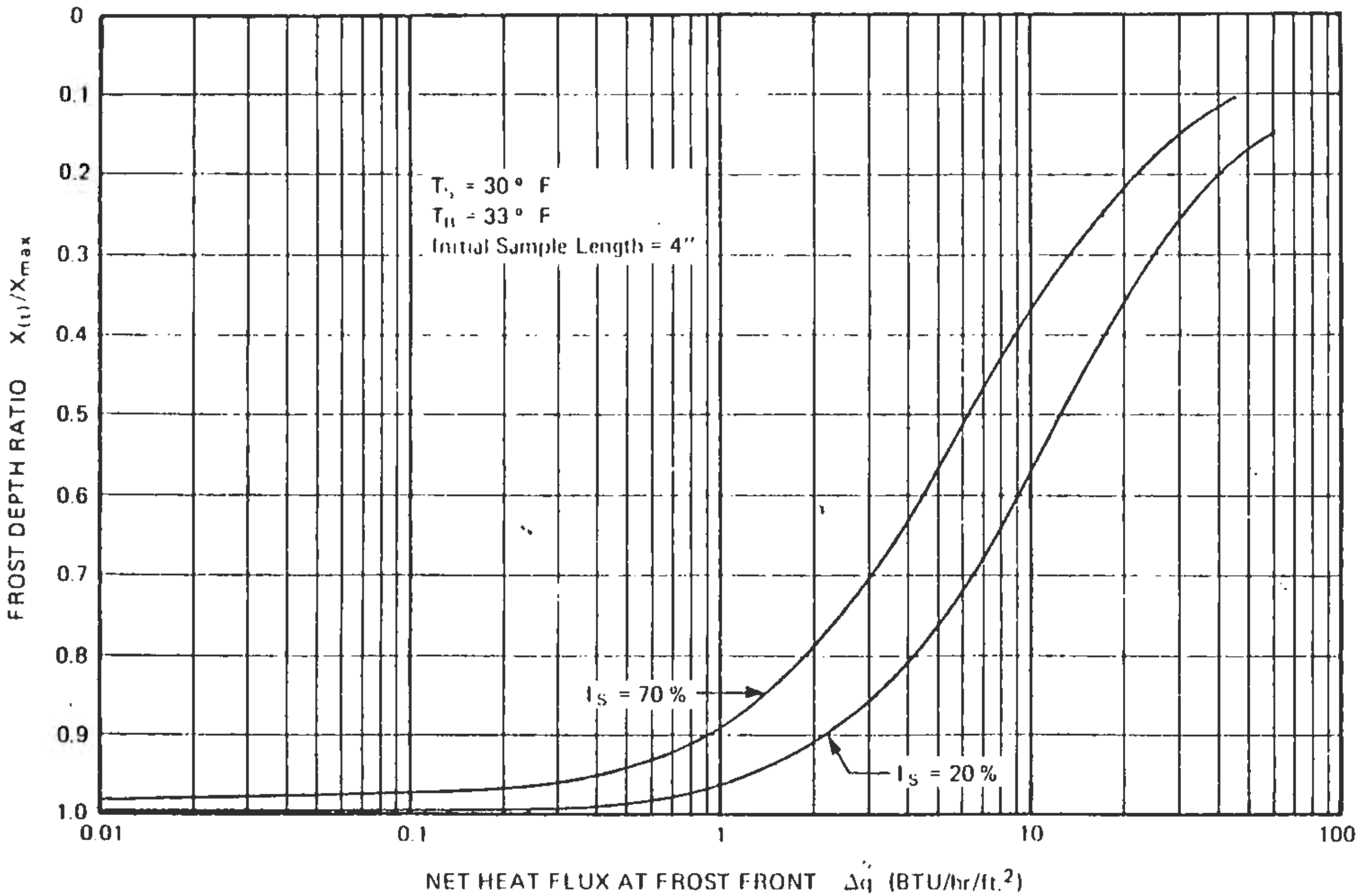


FIGURE 1–5 COMPARISON OF NET HEAT FLUX FOR VARIOUS ICE DISTRIBUTIONS

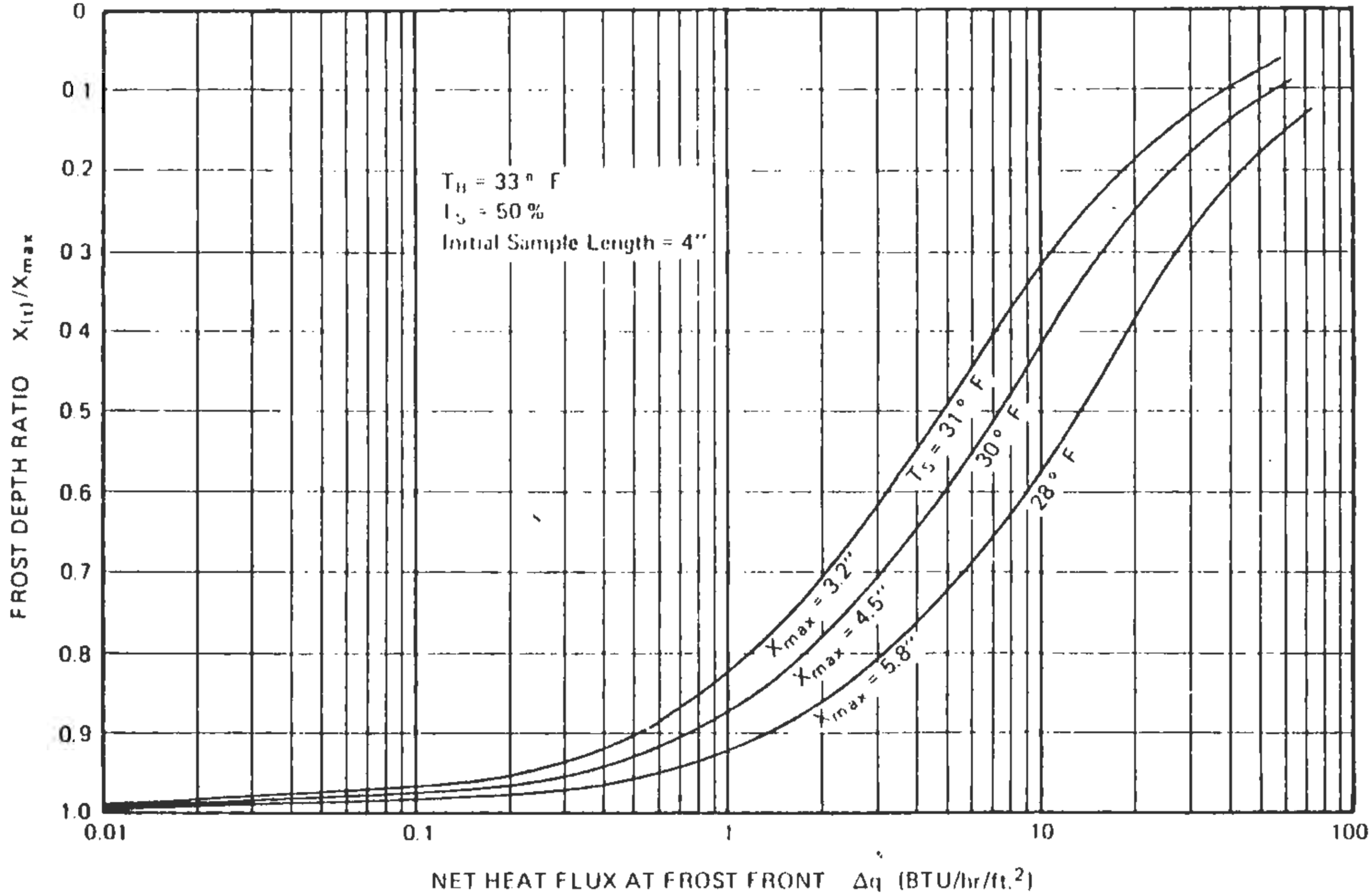


FIGURE 1–6 COMPARISON OF NET HEAT FLUX FOR VARIOUS COLD SIDE TEMPERATURES
(Warm Side Temperature = 33°F)

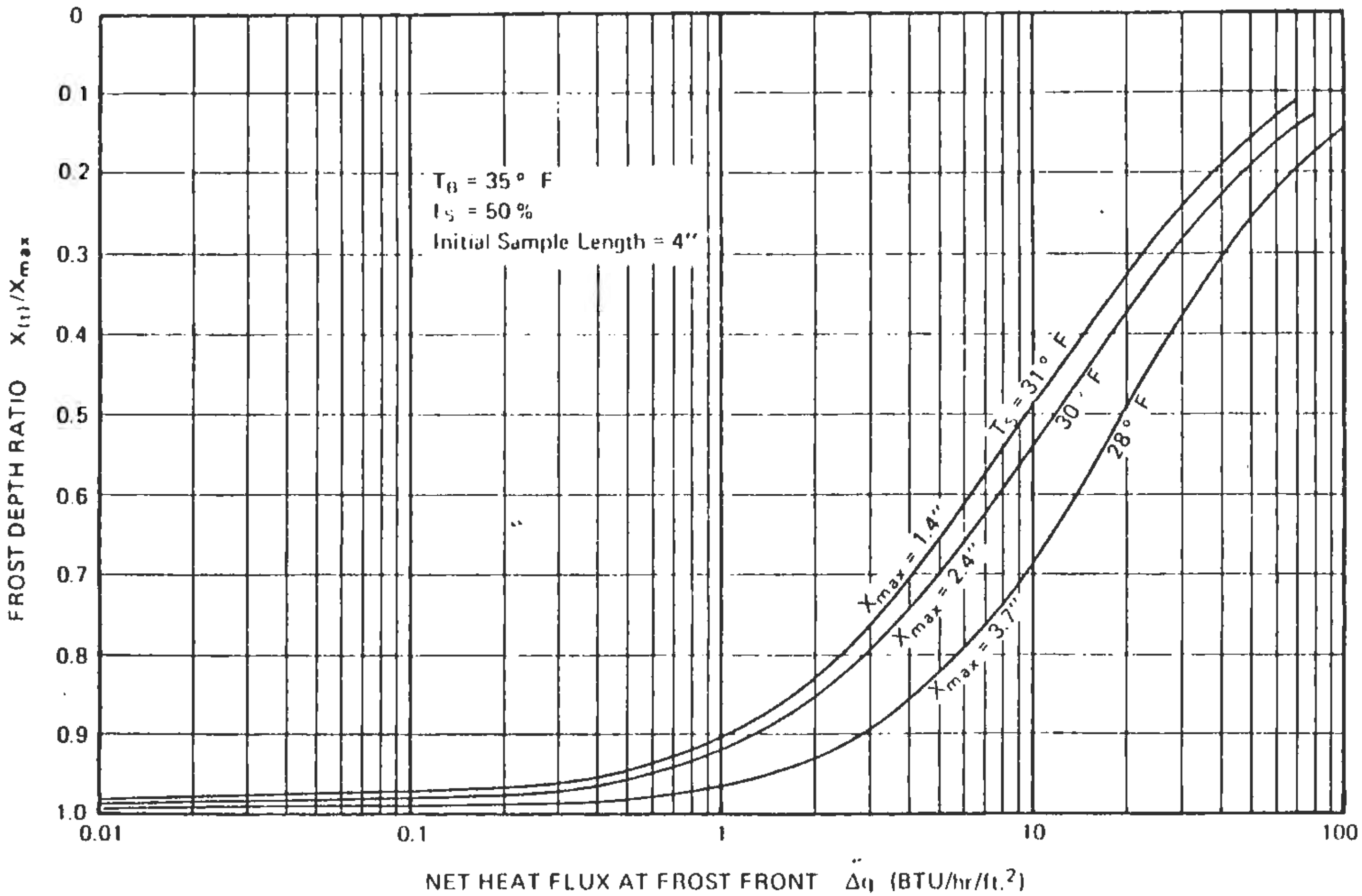


FIGURE 1–7 COMPARISON OF NET HEAT FLUX FOR VARIOUS COLD SIDE TEMPERATURES (Warm Side Temperature = 35°F)

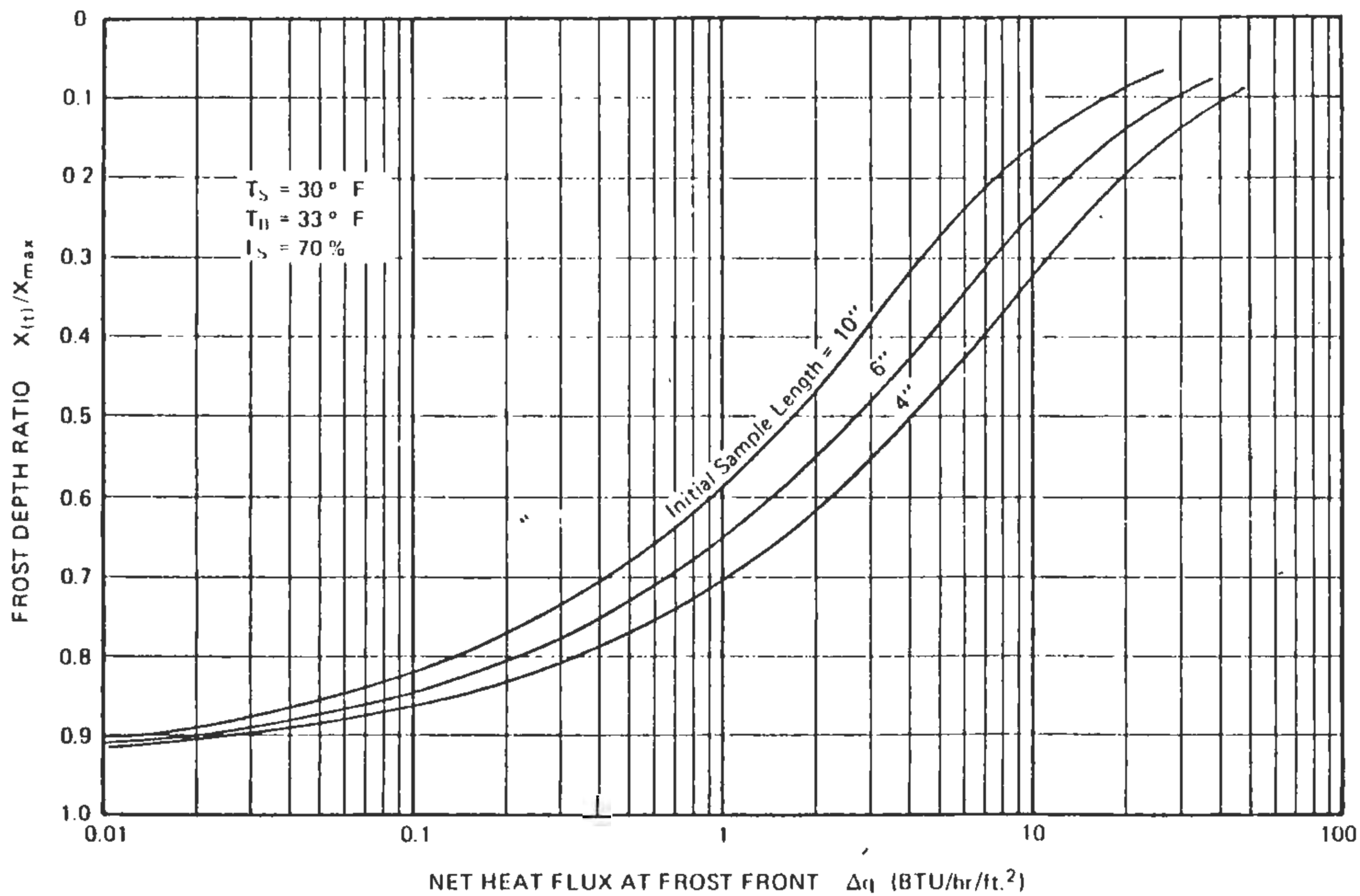


FIGURE 1–8 COMPARISON OF HEAT FLUX FOR VARIOUS SAMPLE LENGTHS

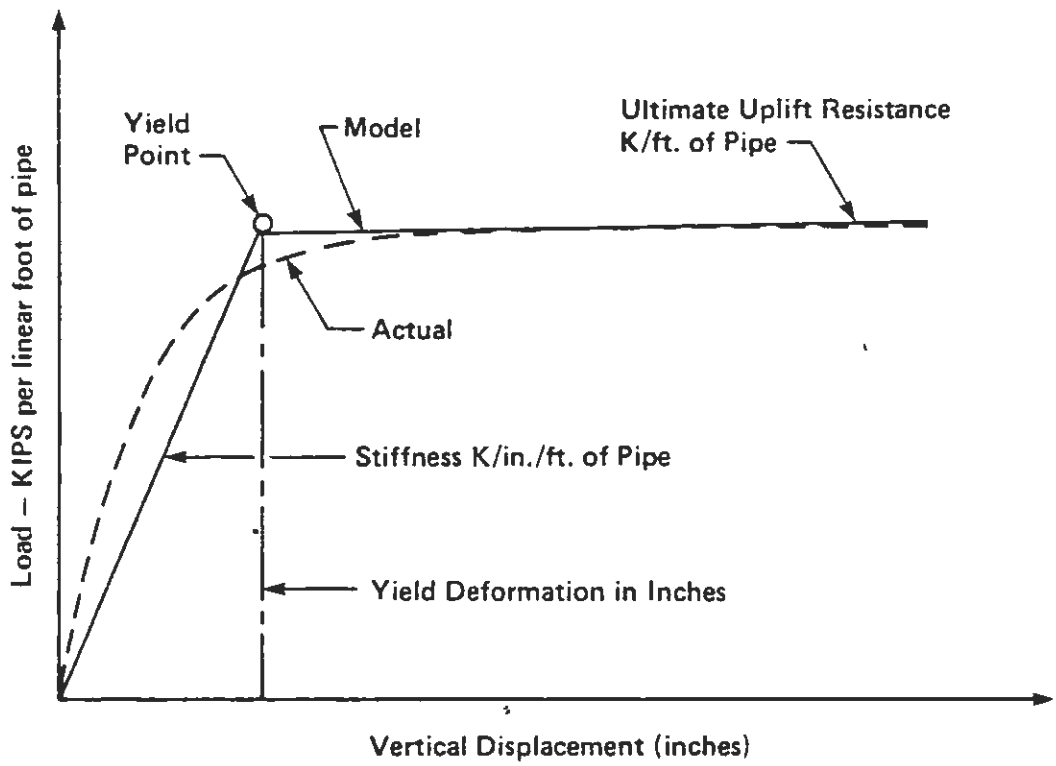


FIGURE 1–9 LOAD DISPLACEMENT CURVE – GENERAL FORM

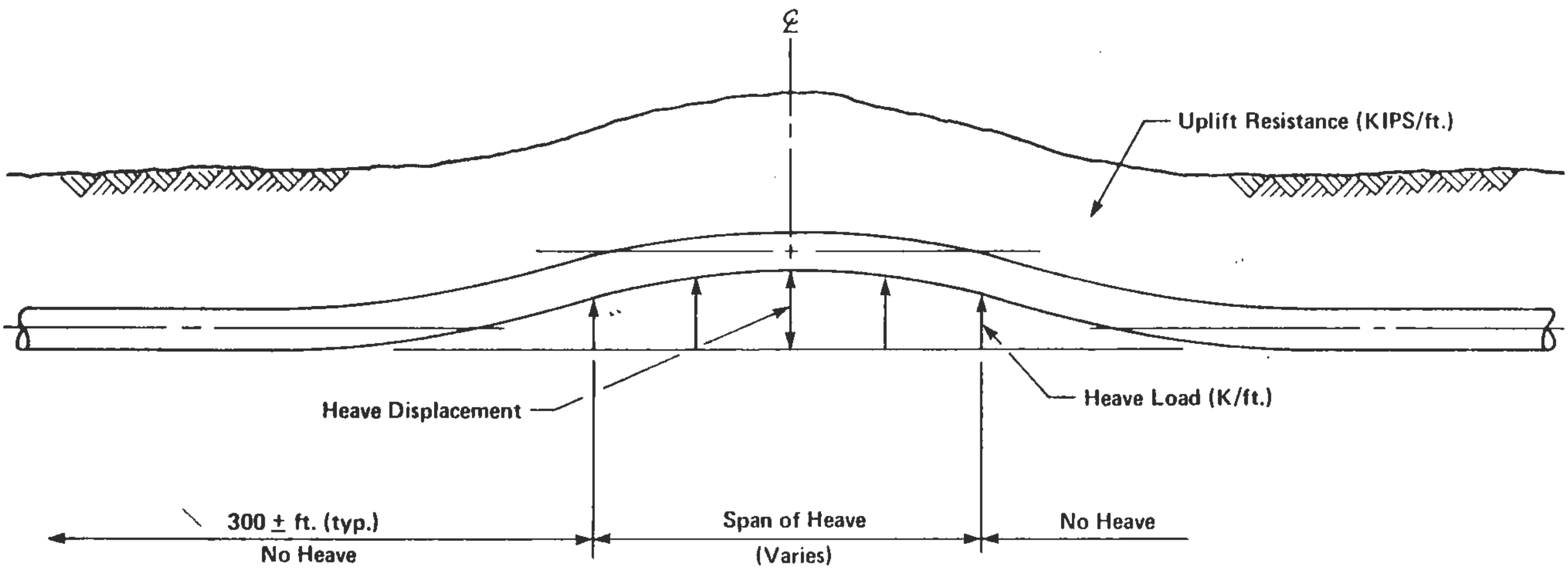


FIGURE 1–10 UNIFORM DISTRIBUTED LOAD CONFIGURATION FOR COMPUTER ANALYSIS

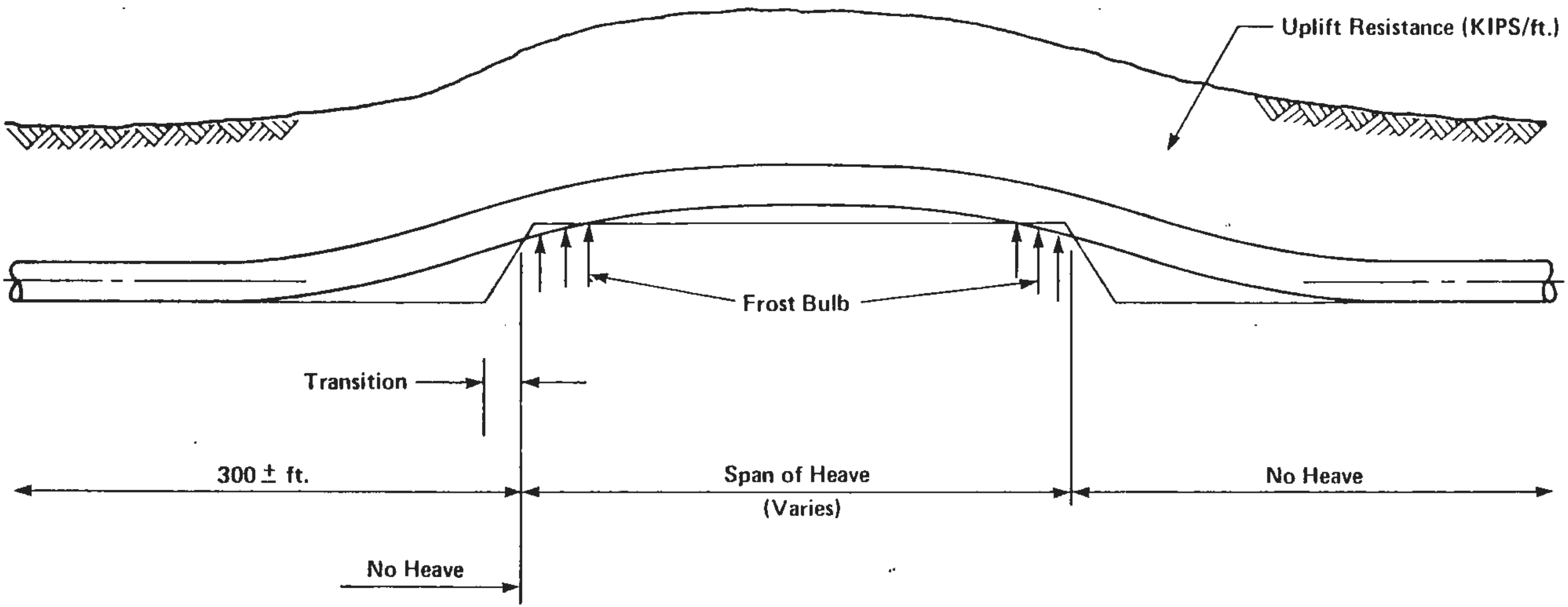


FIGURE 1–11 UNIFORM HEAVE DISPLACEMENT CONFIGURATION FOR COMPUTER ANALYSIS

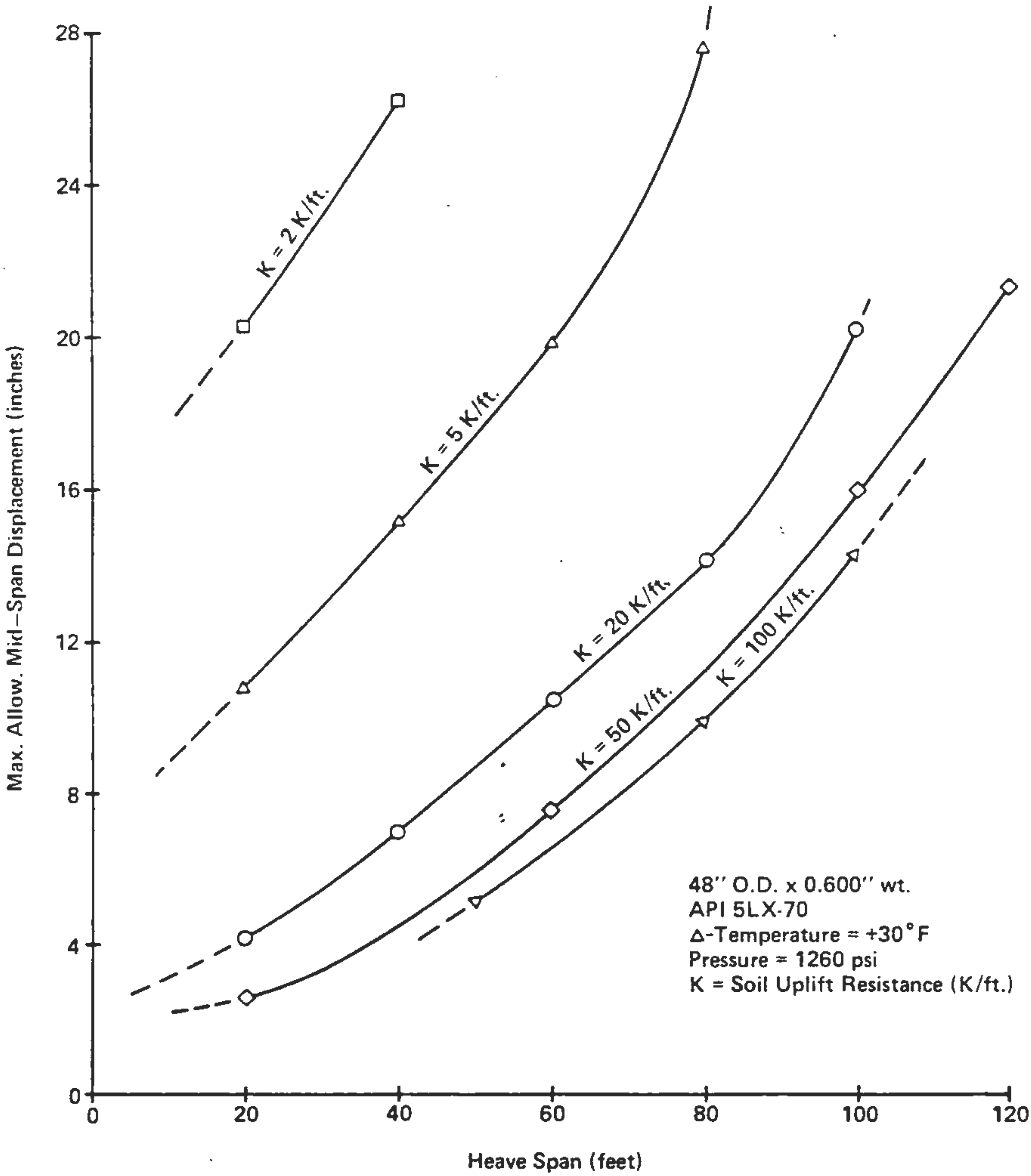


FIGURE 1–12 MAXIMUM MID – SPAN DISPLACEMENT Vs. SPAN
UNIFORM DISTRIBUTED HEAVE LOAD

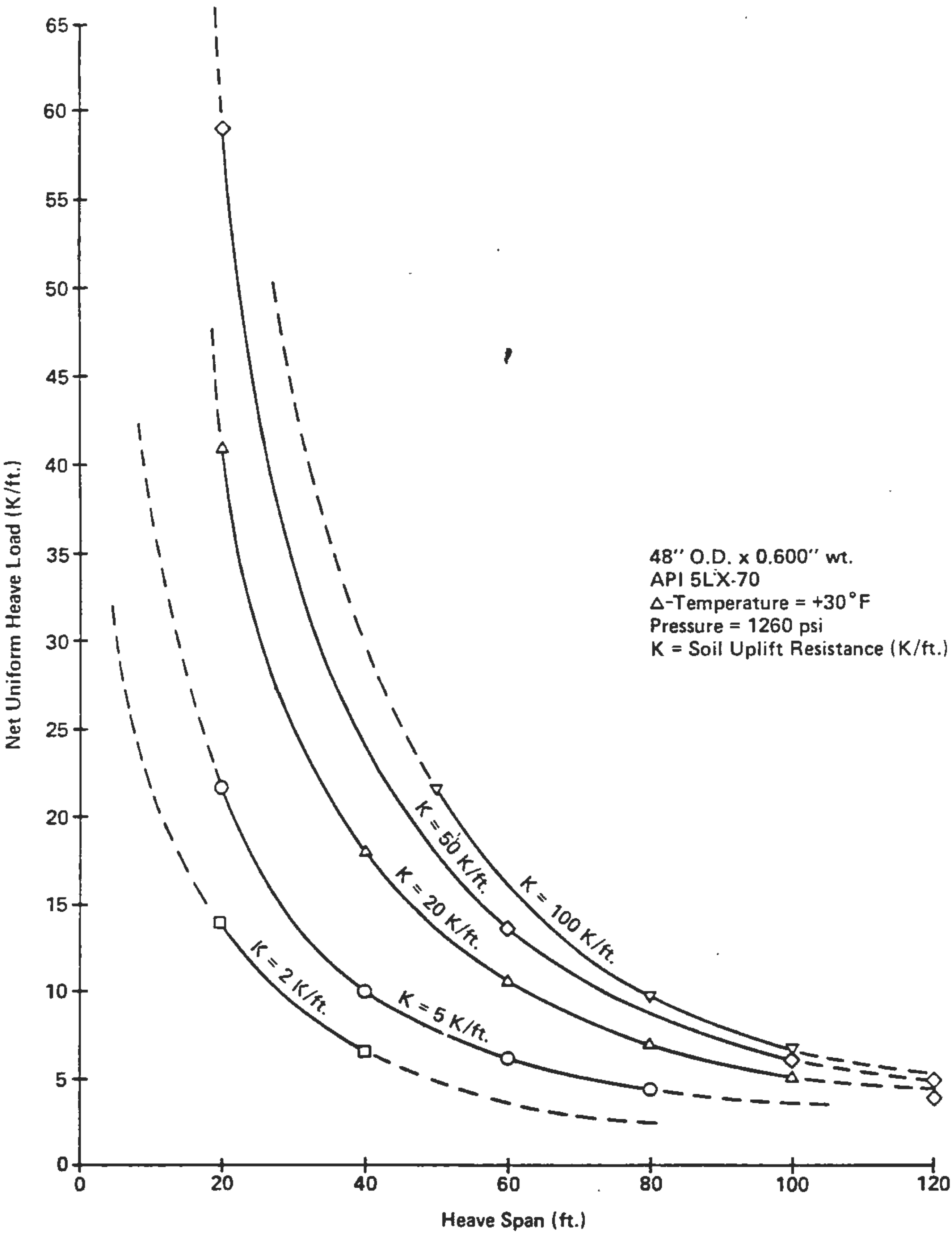


FIGURE 1–13 UNIFORM DISTRIBUTED HEAVE LOAD Vs. SPAN AT MAX. MID-SPAN DISPLACEMENT

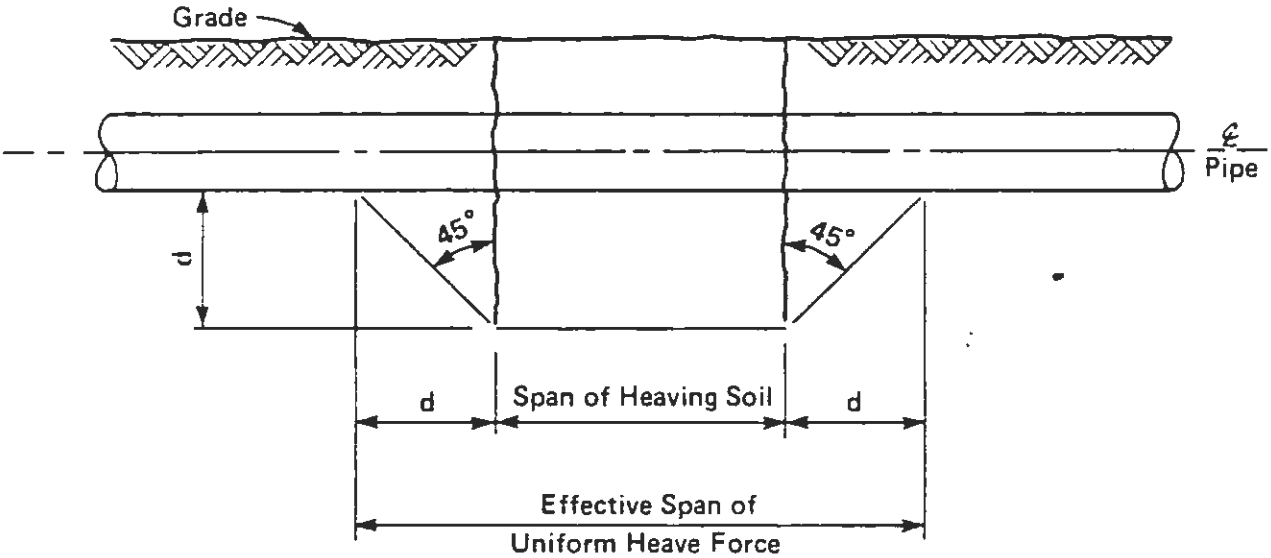


FIGURE 1–14 LOAD DISTRIBUTION ILLUSTRATION

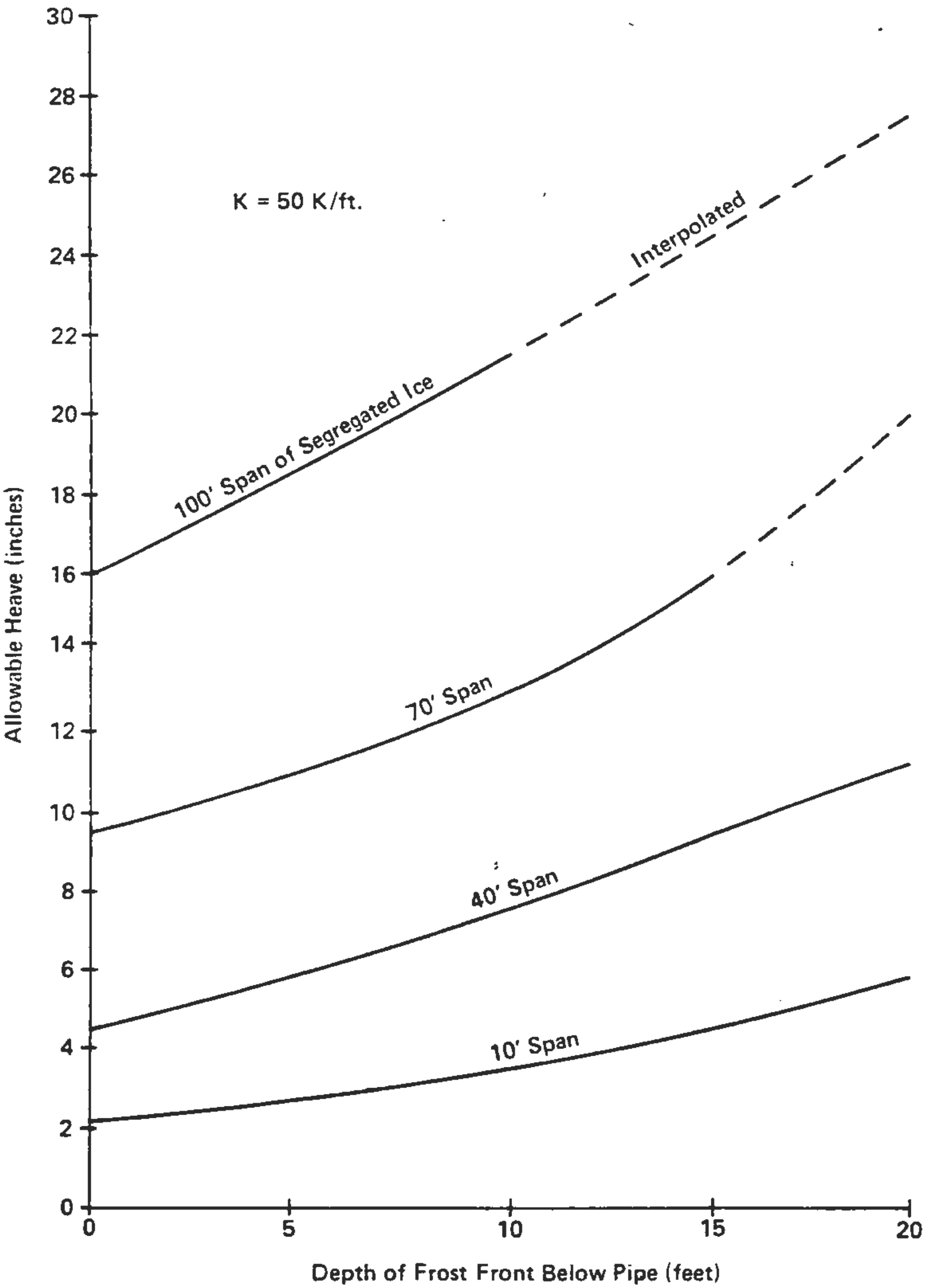
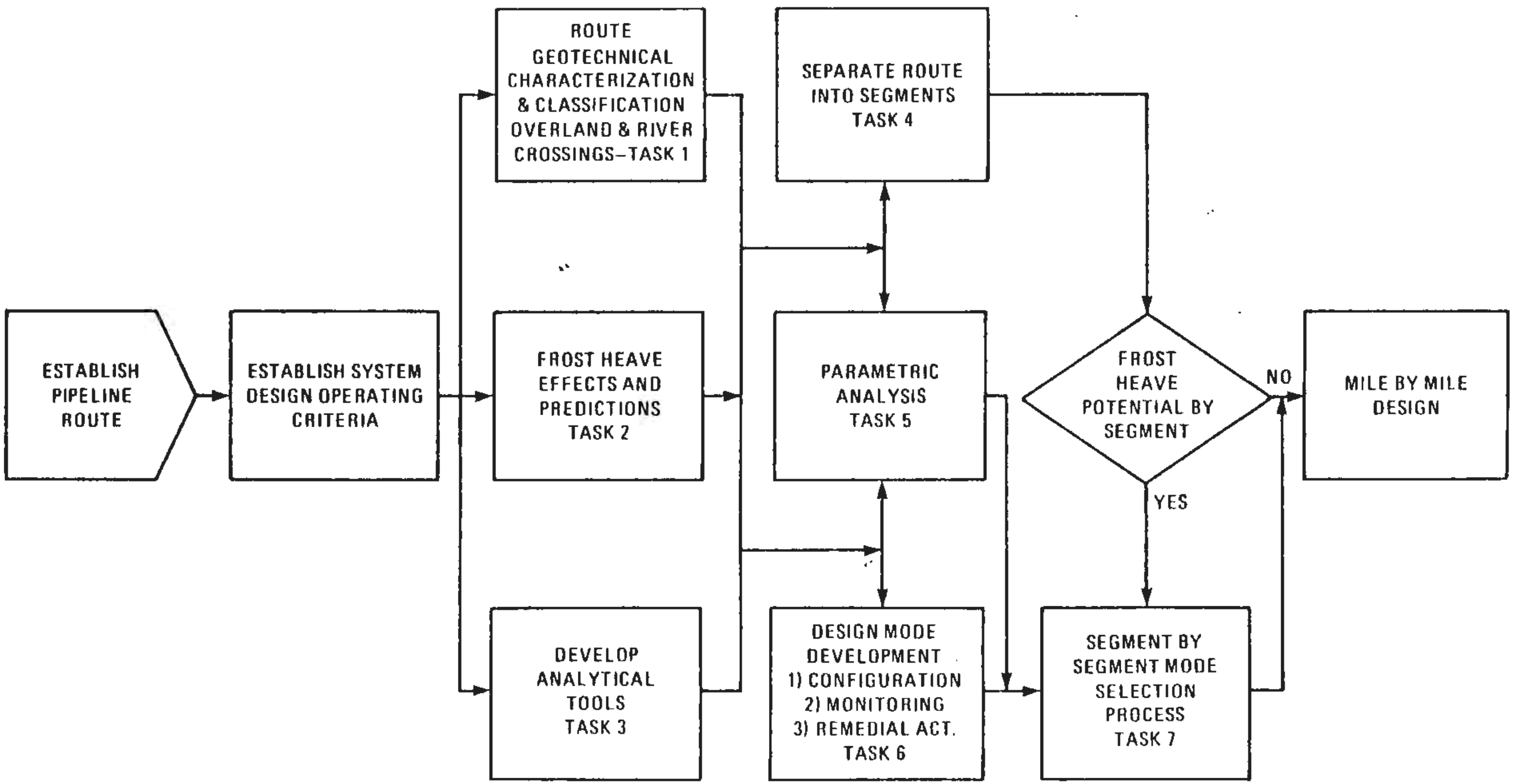


FIGURE 1–15 ALLOWABLE HEAVE Vs. DEPTH OF FROST FRONT BELOW PIPE

FIGURE 1–16 PIPELINE FROST HEAVE DESIGN ABBREVIATED FLOW DIAGRAM



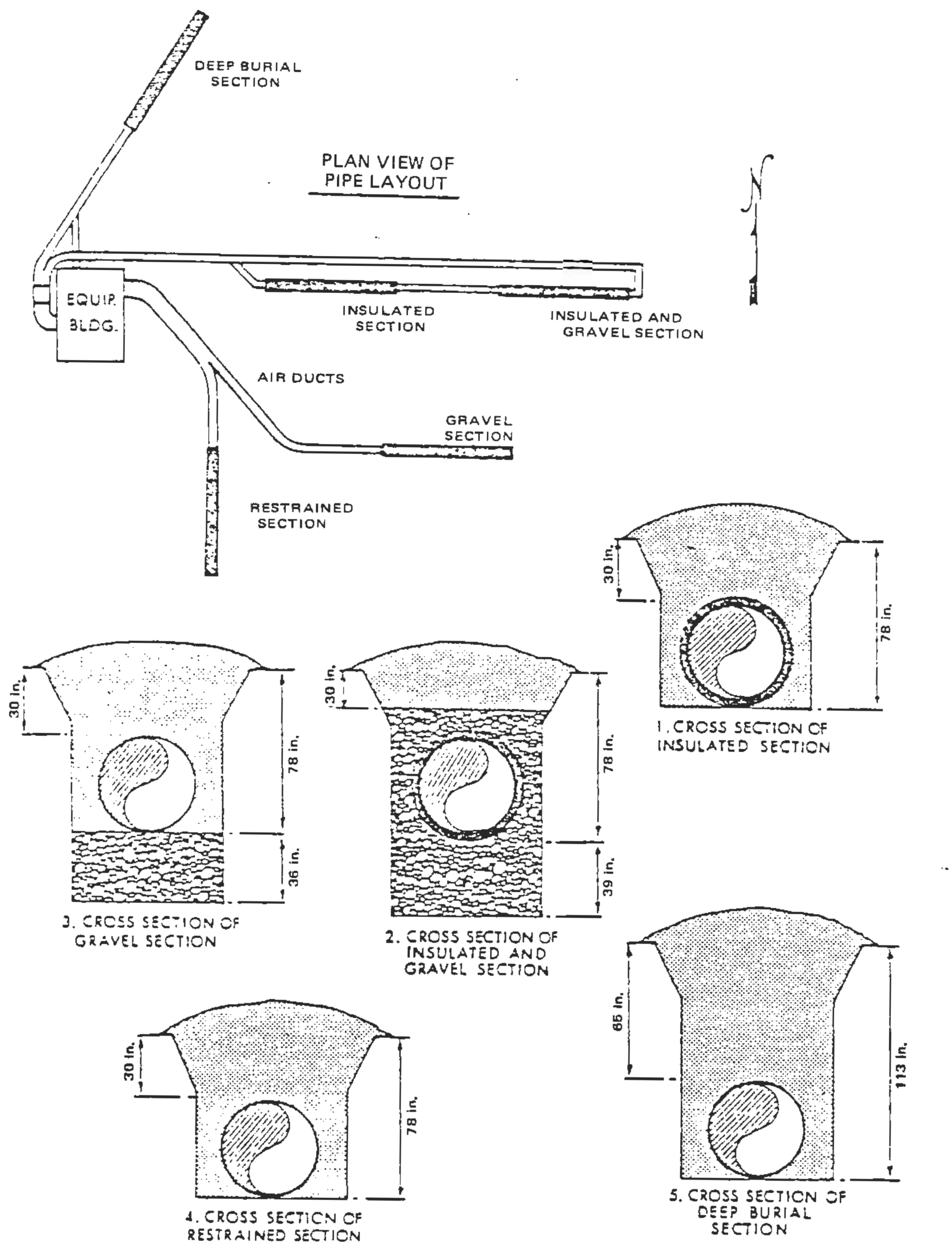


FIGURE 1—17 CALGARY FROST HEAVE TEST FACILITY

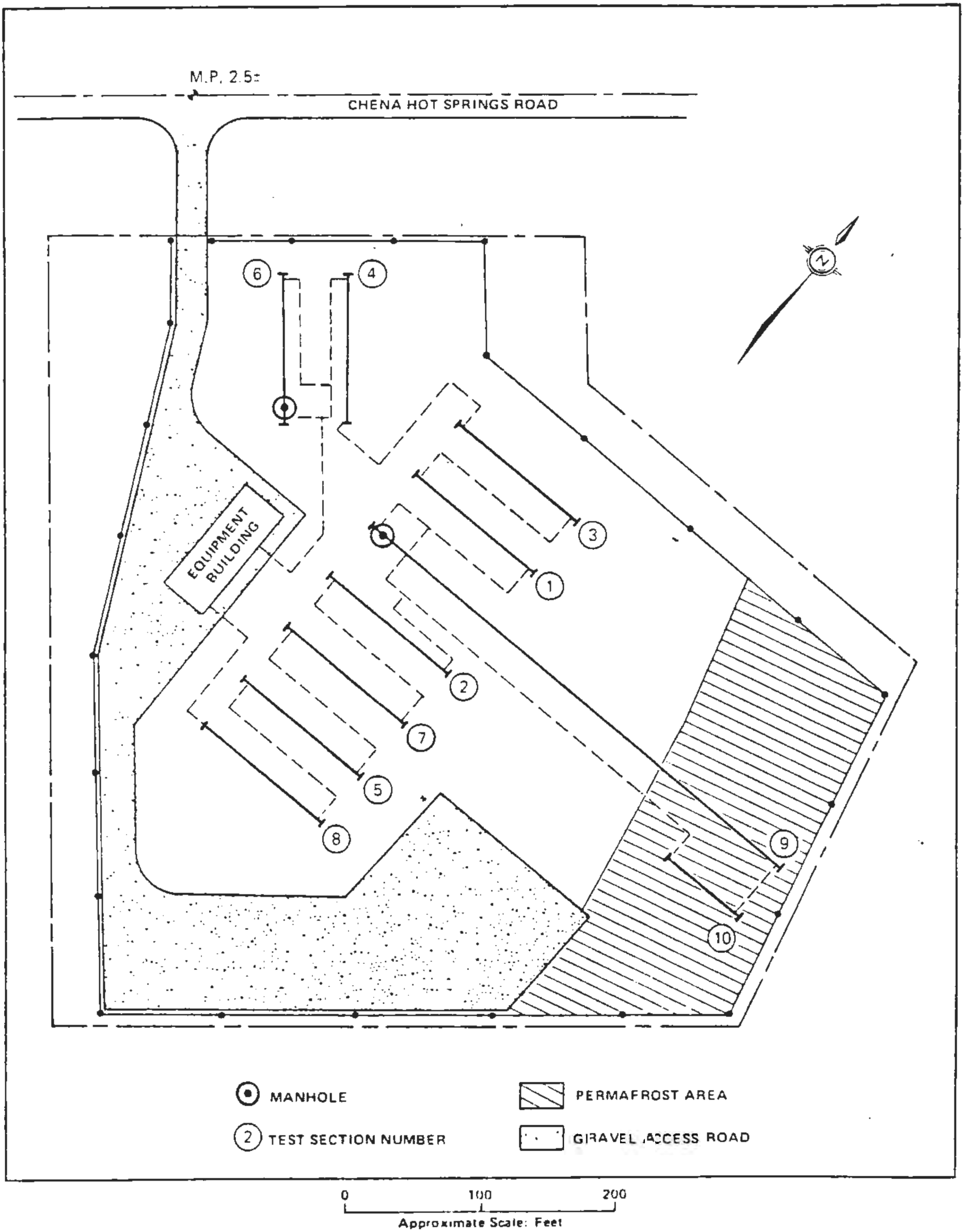


FIGURE 1–18 LAYOUT OF THE FAIRBANKS FROST HEAVE TEST FACILITY

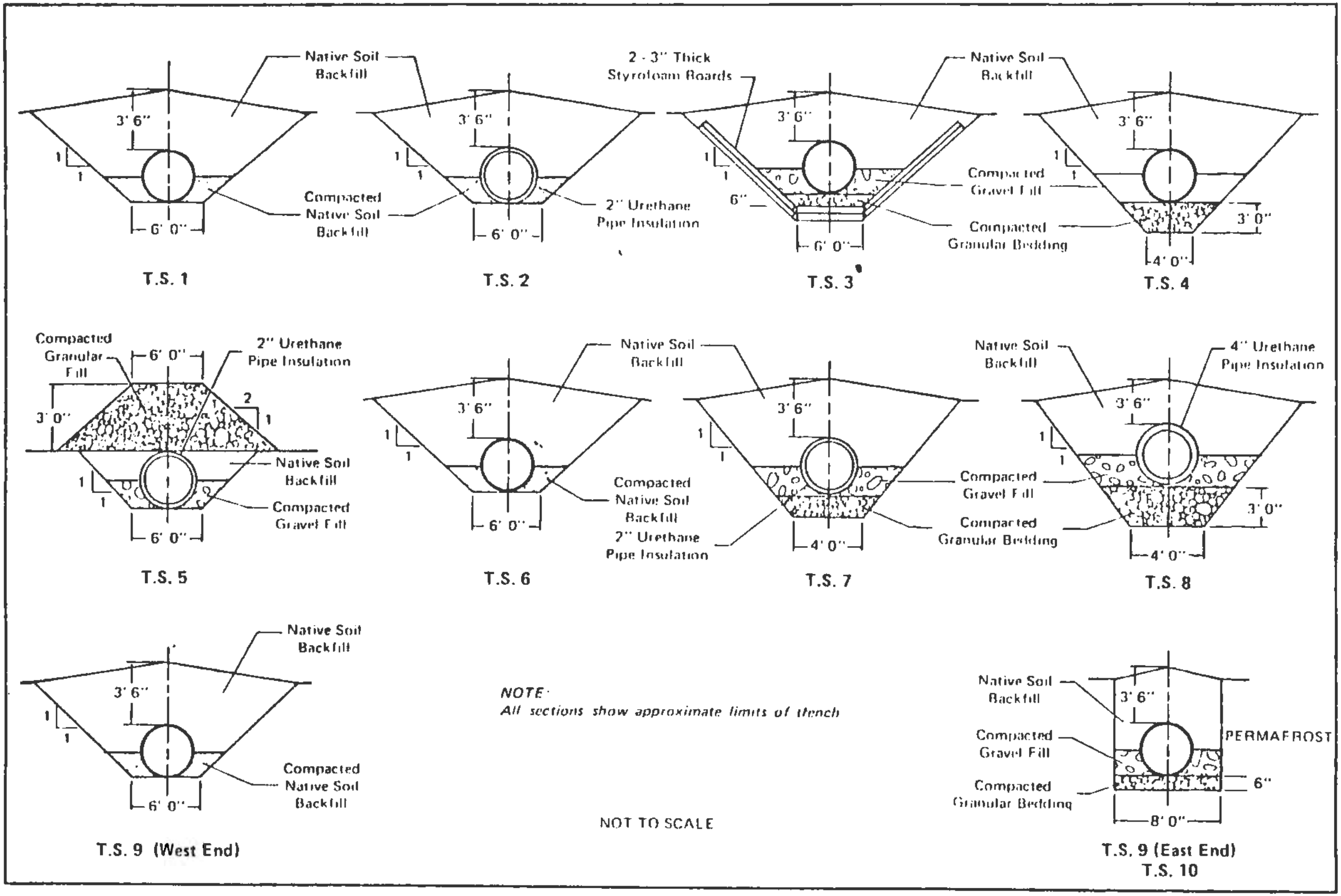


FIGURE 1–19 CONFIGURATIONS OF TEST SECTIONS FAIRBANKS FROST HEAVE TEST FACILITY

FIGURE 1–20 HEAT PIPE TEST SECTION (PIPE 6)

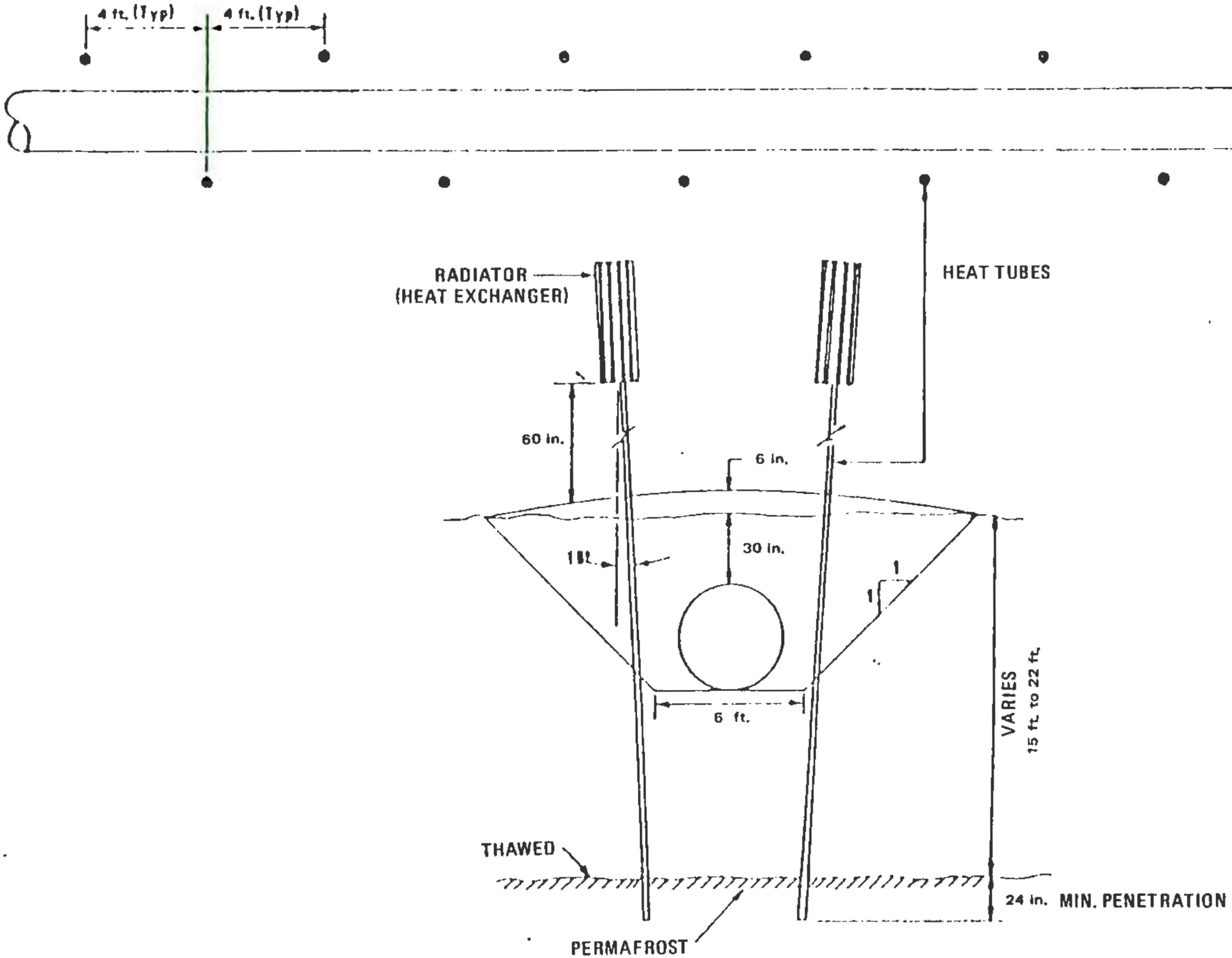
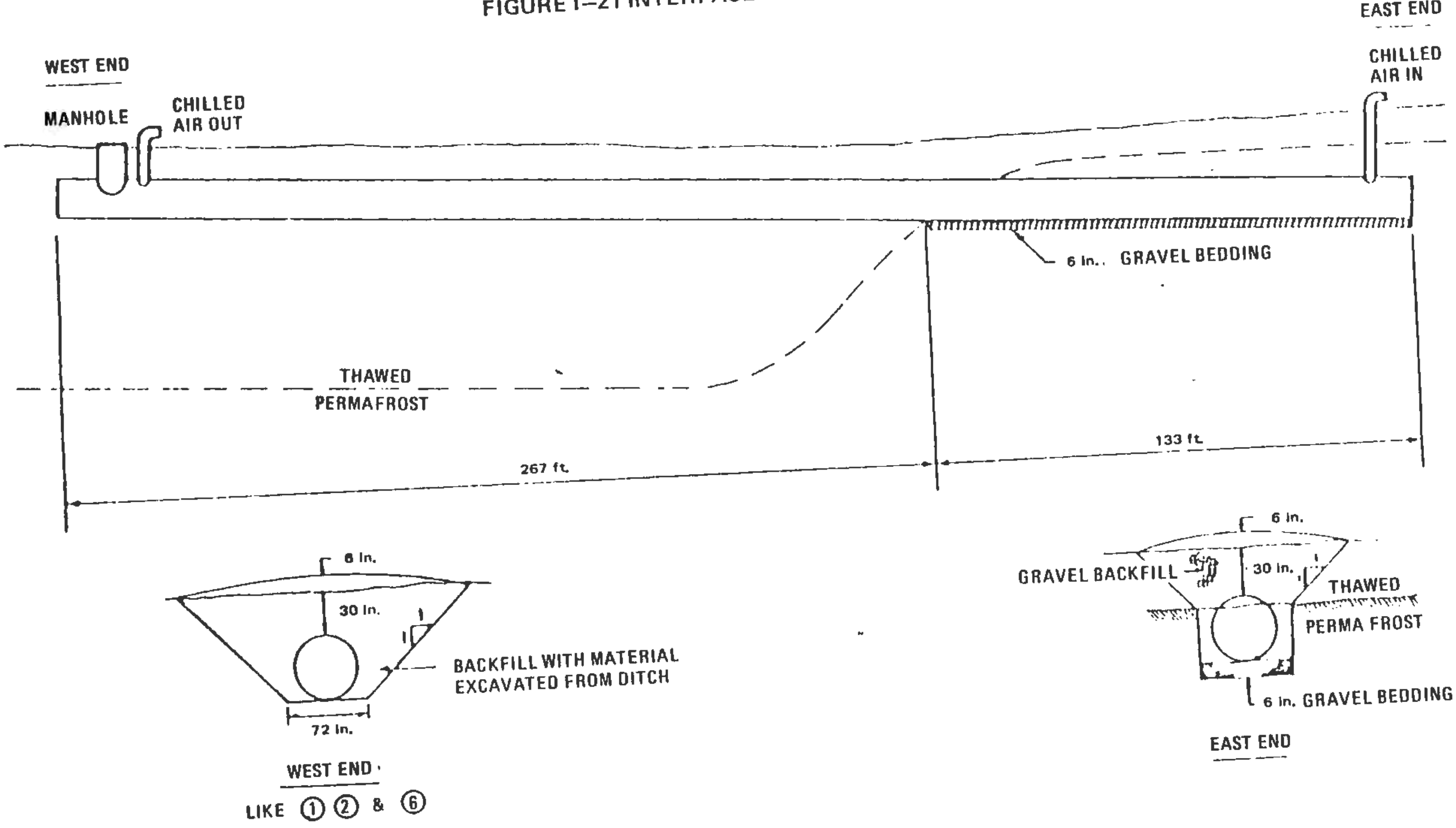


FIGURE 1–21 INTERFACE TEST PIPE



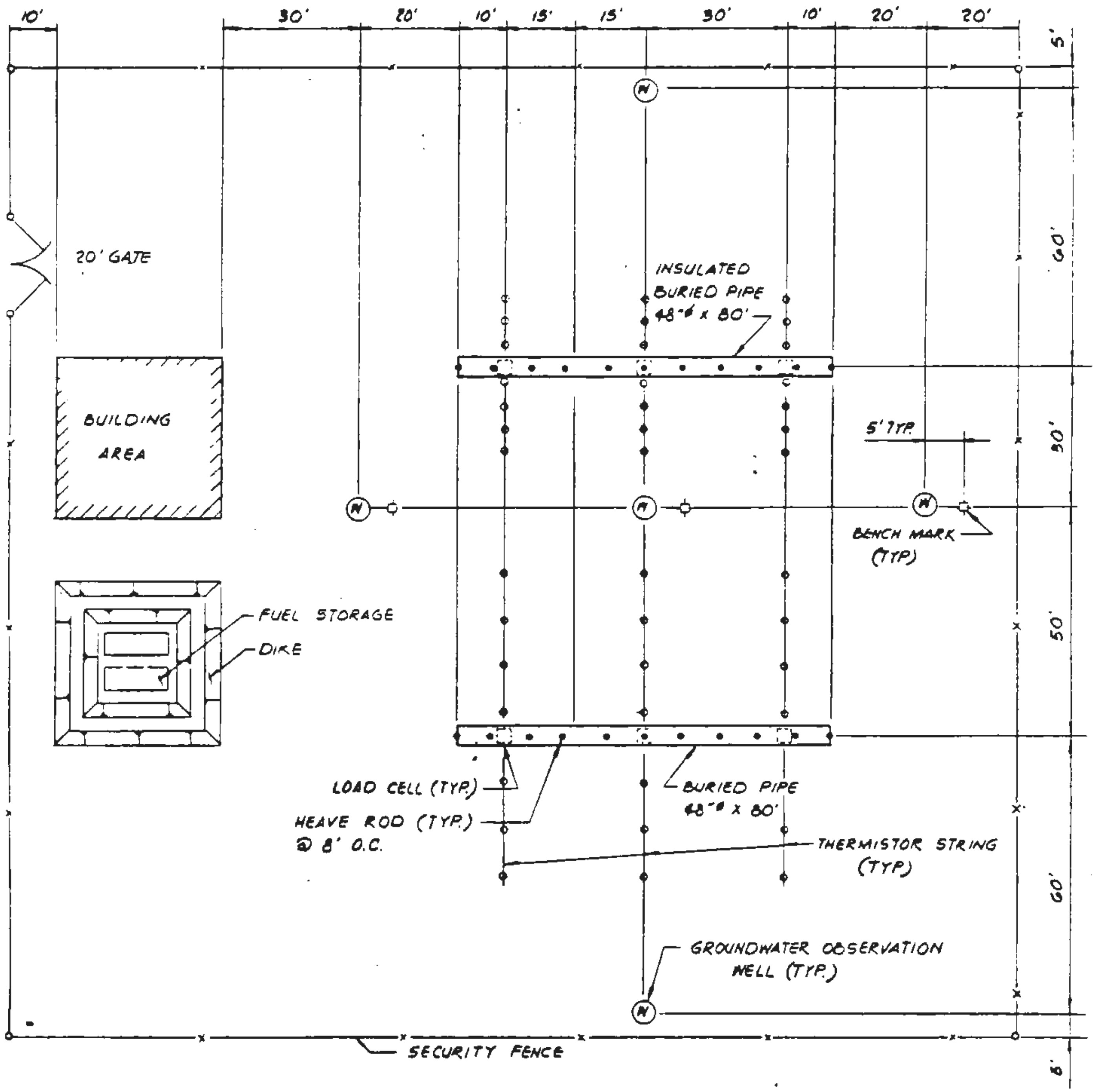


FIGURE 1–22 FROST HEAVE TEST SITE – SITE PLAN

2.0 GROUNDWATER

2.1 STATEMENT OF CONCERN

"Solutions for groundwater problems such as thaw plug stability, liquefaction, freezebulb as it affects aquifers and other erosion problems must be provided".

2.2 DEFINITION OF ISSUES

The groundwater concerns expressed above are separated into four categories, as follows:

- o Thaw plug stability
- o Liquefaction
- o Freezebulb effects on groundwater flow
- o Erosion

2.2.1 Thaw Plug Stability

The thaw plug which may be created during construction may be aggravated by the redirection of groundwater flow. This can occur in areas of active groundwater movement if the backfill material has a hydraulic conductivity different from the surrounding soil mantle. Further discussion of this issue can be found in Section 3.0 (Geotechnical) and in Section 7.0 (Ditch Stability).

2.2.2 Liquefaction

Redirected groundwater could increase the soil liquefaction potential along certain sections of the route by increasing soil water pore pressure. Further discussion of this issue can be found in Section 3.0 (Geotechnical).

2.2.3 Freezebulb Effects on Groundwater Flow

The potential redirection of groundwater flow by the pipeline and its associated freezebulb may force some of the groundwater to migrate to the surface, causing potential aufeis formation (the term aufeis is used interchangeably with "river icing", "icing", and "glaciering"). Alternatively, the redirection of groundwater flow might be parallel to the pipe.

There are three types of groundwater occurrences along the proposed route which may lead to the possible formation of aufeis. They are:

- o Occurrences related to groundwater discharge areas (Figure 2.2.3-1)
- o Occurrences dependent upon active layer flow regimes (Figure 2.2.3-2A & B)
- o A combination of active layer and groundwater discharge occurrences at the same location.

Since the combination type is dominated by the discharge area portion, it is treated the same as the first occurrence listed.

2.2.3.1 Aufeis in Groundwater Discharge Areas

Marshlands and floodplains are characteristic of groundwater discharge areas. During certain winter conditions, floodplains are subject to heavy aufeis accumulations as a result of surfacing baseflow. Typical examples are selected reaches in the Dietrich, and Middle Fork of the Koyukuk Rivers, as well as the Robertson and Johnson River floodplains. Occasionally, aufeis in these rivers is very extensive.

In some cases the presence of the gas pipeline may induce the formation of aufeis where none existed naturally or may increase existing aufeis. The presence of aufeis in a river channel over the chilled gas pipeline, or other facility, could cause increased scour.

2.2.3.2 Aufeis in Active Layer Groundwater Flow Areas

Active layer groundwater areas are characterized by a thawed zone overlaying the permafrost. Under natural conditions, aufeis occurs where active layer groundwater flows are forced to the ground surface by freezing, creating surface icing.

Presence of the buried gas pipeline may induce formation of aufeis by blocking groundwater flow in the active layer and thereby causing seepage upslope of the line.

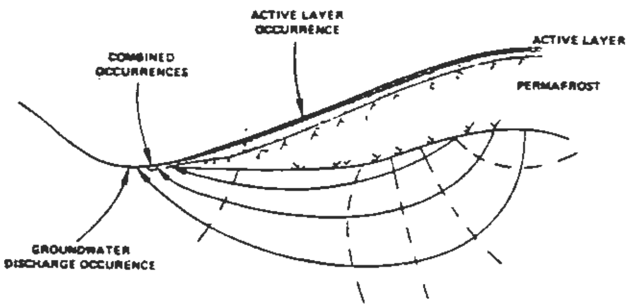


FIGURE 2.2.3-1 AUFEIS AT STREAM CROSSINGS
GROUND WATER DISCHARGE AREAS

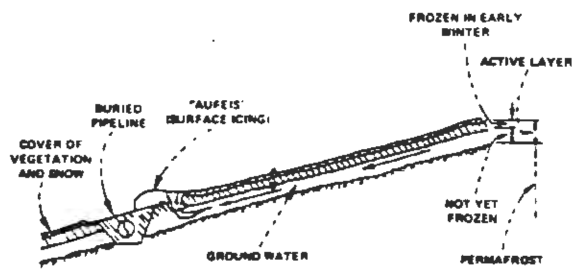


FIGURE 2.2.3-2A FROSTBULB INDUCED AUFEIS (AFTER TCHEKOTILLO,1946
ACTIVE LAYER OCCURENCE

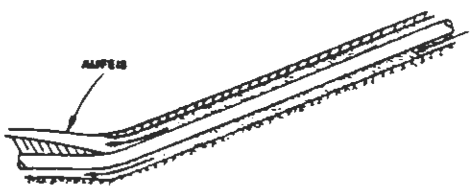


FIGURE 2.2.3-2B AUFEIS AT BREAKS IN SLOPE
ACTIVE LAYER OCCURRENCE

The occurrence of aufeis could pose environmental and structural consequences. An environmental consequence of aufeis is change in surface drainage patterns. Structural consequences, for example, could be aufeis surrounding a TAPS VSM which might lock the oil pipeline in place on the bent, thereby subjecting it to overstress during periods of shutdown. The buildup of aufeis on the haul road or other traffic surface poses a safety hazard.

2.2.4 Erosion

Erosion can be classified into two categories; surface and subsurface erosion. The formation of aufeis may lead to minor changes in surface drainage patterns such as concentrating hillside sheet flow increasing the erosive potential of the runoff, discussed in Section 12.0.

Subsurface erosion is a phenomenon concerned with removal of the soil in a ditch and subsequent removal of fines from the backfill material and ditch sides by groundwater flow which has become redirected along the ditch axis. The resulting loss of soil support, which may be brought about by the removal of soil, can lead to pipeline differential settlement.

Segments of the pipeline parallel to slopes are most susceptible to erosion of soil and the consequent loss of soil support. In this configuration, the pipeline ditch might experience groundwater flow because the backfill material would provide a conduit with less flow resistance than the surrounding undisturbed material. When the velocities of the flow within the backfilled ditch exceed a critical value, as might occur on particularly steep slopes, the potential for erosion will be significant.

2.3 CATEGORIES

The following have been identified as encompassing all the basic variables which are required in defining and characterizing groundwater flow phenomena:

- Principal types of terrain
- Aspect
- Terrain units

- Size and area of groundwater flow system
- Type of occurrence
- Pipeline orientation with respect to groundwater flow direction.

All six variables have been used to evaluate the type of groundwater occurrence anticipated with each issue. In addition, when addressing erosion the hydraulic conductivity of the ditch backfill needs to be determined in order to compare it to the hydraulic conductivity of the surrounding soil.

2.3.1 <u>Principal Types of Terrain</u>

Groundwater flow systems operate in four basic types of terrain along the route: range front, foothills, lowlands, and transitional. Range front terrain is characterized by youthful, mountainous topography and adjoining alluvial fans. Groundwater flow conditions, within the range front, vary with route location and require certain active layer and groundwater flow system analyses. Range front is principally a recharge area. Foothills terrain is characterized by mature topography and generally rolling hills. Groundwater conditions are generally predominated by active layer consideration. Lowland terrain is typified by wide floodplains and is characterized by regional groundwater discharge conditions. Transitional types of terrain occur where there is no distinct break between any two of the other three types. Groundwater conditions are variable and are analyzed accordingly.

2.3.2 <u>Aspect</u>

Aspect refers to slope orientation relative to the sun angle. When combined with type of terrain, terrain aspect is a description of the slopes along the route, including slope grade, orientation, and length. The terrain aspect is necessary for determining watershed characteristics such as groundwater recharge, discharge, and lateral flow areas, which are critical for aufeis analysis. Terrain aspect is used for evaluation of the active layer thickness and fluctuation.

2.3.3 Terrain Units

Terrain units are used to describe the principal soil types along the pipeline route. The terrain units are used along with such hydraulic properties as hydraulic conductivity and effective porosity in conducting groundwater analyses.

2.3.4 Size and Area of Groundwater Flow System

The size and area of groundwater flow systems relate to the division of systems on the basis of size and position of recharge areas with respect to neighboring lowlands. Local, intermediate, and regional are the three flow systems that have been recognized (Toth, 1963). Within a flow system, three flow conditions are operative: recharge, discharge, and lateral flow.

2.3.5 Type of Occurrence

Along the pipeline route, there are three basic types of groundwater occurrences: a flow system occurrence, an active layer occurrence, and a combination of flow system and active layer occurrences. For each segment, the type of groundwater flow occurrence is assessed.

2.3.6 Pipeline Orientation

The pipeline orientation with respect to the groundwater flow direction is necessary for determining possible effects of the pipeline on groundwater flow.

2.4 DATA ACQUISITION

2.4.1 Data Necessary

Data requirements for the proper evaluation of the groundwater issues, described under Section 2.2, consist of three basic types:

- Terrain aspect data
- Surficial hydrogeological data
- Climatological data.

2.4.1.1 Terrain Aspect Data

Data necessary for developing terrain aspect are topographic maps and aerial photos.

2.4.1.2 Surficial Hydrogeological Data

Surficial hydrogeological data are obtained and provide information about hydraulic properties of the surficial materials and groundwater occurrence along the route. These data include:

- Soil types and composition
- Vegetation
- Active layer occurrence
- Groundwater levels
- Permafrost depths
- Soil temperatures

In addition, other hydraulic parameters may be obtained indirectly by using empirical relationships established from laboratory analysis. For instance, soil effective porosity and hydraulic conductivity may be determined in this manner.

The surficial hydrogeological data provide the bulk of the input for aufeis and erosion evaluation.

2.4.1.3 Climatological Data

Climatological data are required to analyze the active layer. This analysis is necessary for evaluating aufeis potential in active layer occurrences. Data requirements consist of:

- Surface temperature
- Wind speed
- Solar radiation
- Precipitation

2.4.2 Data Acquired to Present

2.4.2.1 Terrain Aspect

Topographic maps of the entire route have been obtained from the USGS. Alignment sheets, with 10-foot contour intervals prepared from aerial photos, are available for the route. The terrain aspect data acquisition is complete.

2.4.2.2 Surficial Hydrogeological Data

Vegetation data are available from aerial photos. Geotechnical data are available from Alyeska and the continuing NWA acquisition of borehole data summarized in Section 3.0 (Geotechnical). Data is available along the entire length of the route. Open standpipes are installed in selected boreholes along the route for additional shallow groundwater data.

2.4.2.3 Climatological

Climatological data has been obtained from existing stations along the route. The data available presently covers representative areas of the route.

2.5 GROUNDWATER CRITERIA

Groundwater-related criteria are of two types, (1) criteria used in route selection and (2) criteria used for design.

2.5.1 Route Selection Criteria

The primary solution to groundwater problems is in the selection of a route which minimizes or avoids hazard to the integrity of the natural gas pipeline, other structures or the environment. This general statement can best be described by Sections 2.8.1, 3.3.1, and 3.4.1.1 of the draft stipulations.

> "2.8.1. All activities of the COMPANY in connection with the PIPELINE SYSTEM that may create new lakes, drain existing lakes, significantly divert natural drainages and surface runoff, permanently alter stream or ground water hydrology, or disturb significant areas of streambeds are prohibited unless such activities

along with necessary mitigation measures are approved in writing by the FEDERAL INSPECTOR."

"3.3.1. Areas subject to mudflows, landslides, avalanches, rock falls and other types of mass movements shall be avoided where practicable in locating the PIPELINE SYSTEM. Where such avoidance is not practicable, the PIPELINE SYSTEM design, based upon detailed field investigations and analyses, shall provide measures to prevent the occurrence of, or protect the PIPELINE SYSTEM from, the effects of mass movement. The PIPELINE SYSTEM shall be designed to protect existing facilities, including the TRANS-ALASKA PIPELINE SYSTEM, from the effects of mass movement caused by the COMPANY's activities or the activities of its agents, employees, contractors (including subcontractors) and the employees of each of them and not (sic) shall not adversely affect slope stability protection measures of existing structures."

"3.4.1.1. The PIPELINE SYSTEM shall be designed so as to both minimize the number of stream and WETLAND crossings and to include, but not be limited to, consideration of aufeis development, erosion and sedimentation, restriction of natural meander, or alteration of the physical or chemical nature of the water body, and the effect of any alteration in these factors caused by the COMPANY's activities or the activities of its agents, employees, contractors (including subcontractors) and the employees of each of them upon existing facilities including the TRANS-ALASKA PIPELINE SYSTEM."

2.5.2 Design Criteria

Avoid adverse effects on the TAPS pipeline and other adjacent facilities by minimizing:

- o Aufeis development
- o Alteration of groundwater hydrology
- o Erosion of soil in the ditch

2.6 DESIGN PROCEDURE

2.6.1 Groundwater Classification Procedure

The groundwater classification procedure provides the basis for analysis and development of a logical approach to the solution of specific concerns.

The procedure starts with the division of the route into four major regions:

- The North Slope, which extends from the Brooks Range drainage divide to Prudhoe Bay
- The North Yukon, from the Yukon River to the Brooks Range drainage divide
- The South Yukon, from Delta Junction to the Yukon River
- Tanana, from Delta Junction to the Alaska/Canada border.

Each region is further divided into segments which represent a continuous portion of the route with similar characteristics. The segments are grouped into categories.

Categories are defined by a combination of selected parameters from the classification scheme. Grouping the segments into categories with similar hydraulic properties and groundwater flow conditions provides a practical means for determining effective solutions.

To date, the entire pipeline alignment has been classified. Because data is acquired on a continuing basis, computer storage and retrieval systems are being developed to incorporate any additions or corrections to the classification parameters in order that a segment's category status can be reevaluated in a timely manner. The principal categories are listed below as a percentage of the route.

Categories as a Percentage of Route

Category	Percent of Route	Category	Percent of Route
TAFH 1	8.68	TALL 11	0.37
TAFH 2	5.34	SYFH 1	5.14

Category	Percent of Route	Category	Percent of Route
TAFH 3	3.11	SYFH 2	0.53
TAFH 4	0.81	SYFH 3	0.22
TAFH 5	0.10	SYFH 4	0.10
TARF 1	3.67	SYFH 5	1.26
TARF 2	4.49	SYFH 6	2.04
TARF 3	2.12	SYFH 7	7.01
TARF 4	2.32	SYFH 8	0.14
TARF 5	14.89	SYLL 1	6.12
TARF 6	4.32	SYLL 2	10.30
TARF 7	0.05	SYTR 1	0.13
TARF 8	1.23	SYTR 2	1.29
TALL 1	5.22	SYTR 3	0.33
TALL 2	0.07	NYLL 1	4.85
TALL 3	0.83	NSFH 1	0.26
TALL 5	0.49	NSFH 2	0.06
TALL 6	0.37	NSRF 1	0.04
TALL 7	0.10	UNDEFINED	1.60

TAFH Tanana Foothills
TARF Tanana Range Front
TALL Tanana Lowlands
NSFH Northslope Foothills
NSRF Northslope Range Front
SYFH South Yukon Foothills
SYLL South Yukon Lowlands
SYTR South Yukon Transitional
NYLL North Yukon Lowlands

2.6.2 Design Procedure for Aufeis in Discharge Areas

Where aufeis conditions exist naturally, the presence of the chilled gas pipeline is not considered to appreciably aggravate the situation. A potential for concern occurs only if the pipeline route is aligned with the axis of the discharge region.

2.6.2.1 Site Evaluation and Analysis

At specific sites where the gas pipeline is parallel to TAPS, the possibility of increased scour due to the reduction in channel conveyance from the differential break-up of aufeis will be determined. In situations where the gas line is on the edge of a channel, the conveyance of the channel is considered reduced by an amount equivalent to the maximum encroachment of aufeis into the channel. Where the gas pipeline is in the channel and the potential for splitting the flow exists, the conveyance is considered reduced by an amount equivalent to the width of the aufeis over the top of the ditch. The analysis for scour is to follow the methodology in Section 9.0 (River Crossings).

2.6.2.2 Design Alternates

If conventional burial poses a significant site-specific hazard, then the following design alternatives are considered;

- o Insulated Pipe
- o Deep Burial
- o Embankment Mode
- o Heat Tracing
- o Alignment Adjustments.

2.6.3 <u>Design Procedure for Aufeis on Slopes</u>

Analytical studies define groundwater flow patterns along slopes and include the time dependent behavior of groundwater flow. Hydraulic conductivity, hydraulic gradient, and effective porosity form the physical bases to conduct the analytical work. It is expected this analytical work will be verified with the result of the ice-damming field investigation.

The analytical studies are summarized as follows:

- o Analyze unconfined flow along a slope
- o Determine the time required to drain the slope.
- o Determine the critical time (the period of time between the last significant rainfall and the onset of freeze-up).
- o Determine if aufeis will form by comparing the time required to drain the slope to the critical time.
- o Estimate aufeis volume and area available for accumulation. Reduction of channel conveyance or increase in channel discharge is evaluated by methodology described under River Crossings (Section 9.0).

2.6.3.1 Site Evaluation and Analysis

The present route has been selected to minimize aufeis problems. Each location along the route identified as a potential aufeis problem area is assessed and classified as having a low, moderate, or high aufeis risk. Specific sites require special design considerations in order to reduce the potential risk posed by the presence of aufeis to the pipeline, environment, and adjacent facilities.

2.6.3.2 Design Alternates

Alternatives to the preferred conventional burial mode will be considered on an individual basis to identify an acceptable solution. Alternative design solutions to be considered are:

- o Overexcavate and fill with free draining materials
- o Provide cross drainage
- o Deep burial into permafrost
- o Embankment mode
- o Alignment adjustment.

These solutions provide alternative designs that can be applied to site-specific conditions and will be selected on the basis of the most cost effective solution for each condition.

2.6.4 Design Procedure for Subsurface Erosion

Where there is a potential for flow along the axis of the pipeline, the backfill material in the pipe ditch is considered saturated with groundwater flow in the direction of the grade.

2.6.4.1 Site Evaluation and Analysis

In those areas where flow is occurring along the axis of the pipeline, an analysis is made to determine spacing for drainage. Proper drainage spacing controls the potential for erosion of soils from the backfill and surrounding ditch.

2.7 SOLUTION

Due to the nature of groundwater concerns and the large number of variables inherent, it is not expected that all areas where problems might appear will be defined at this time. During final design, these areas will be evaluated for the degree of complexity, and final solutions selected. The design will be consistent with maintaining a balance between cost effectiveness, environmental concerns and impact on adjacent facilities.

2.7.1 Route Selection

The proposed pipeline route is presently located to minimize adverse effects on the TAPS pipeline, adjacent facilities, and the environment. The route is superior to alternative routes identified to date based on NWA evaluations performed to ensure the selection of the optimum route. However, where there is a potential for problems to develop, the design will incorporate appropriate mitigative solutions.

2.7.2 Solution for Problems Associated with Aufeis on Slopes

Several design solutions are available in Section 2.6.3 to mitigate aufeis on slopes.

2.7.3 Solution for Subsurface Erosion

Subsurface erosion control along the pipeline axis is provided as needed with ditch plugs spaced for adequate drainage.

2.8 CONTINUING STUDIES FOR DESIGN SUPPORT

2.8.1 Ice-Damming Study

A full-scale chilled pipe test will be constructed to investigate ice-damming of cross drainage. The objective of the investigation is to support design evaluation by developing field data concerning ice-damming, the development of aufeis, and to substantiate mitigative techniques. Test results will be available in sufficient time to analyze the data and prepare additional mitigative design measures, if necessary.

The proposed field test is designed to obtain an assessment of the conditions under which ice-damming occurs. The groundwater instrumentation program will monitor the parameters that relate to potential ice-damming. The specific objectives are to monitor these parameters in areas affected by the proximity of the chilled pipe. In addition, measurements will be made in undisturbed areas. The parameters are: temperature of the air, soil, and water; location of the freeze front; soil tension; soil permeability; and groundwater pressures.

2.8.2 Selected Groundwater and Climatological Data From Frost Heave Field Test Sites

Frost heave field test sites will be constructed and will contain instrumentation which will provide groundwater and climatological data. Groundwater data include head distribution and hydraulic conductivity of the soils. Air temperature, precipitation, solar radiation, and relative humidity will be measured and provided to the groundwater program for analysis.

2.8.3 Standpipe Data

Over 125 boreholes drilled for acquisition of geotechnical data are completed with standpipes. Water levels are taken during and after borings. After the boreholes have been completed, they will supply primary water levels from the open end of the standpipe. This information augments other data, such as borehole data, resistivity data, VSM borehole data, and test site data for assessing groundwater conditions along the pipeline alignment.

2.9 POTENTIAL CHANGES

The results of the ice-damming field test are expected to corroborate the effectiveness of a mitigative technique. Significant changes to the design process and solution as described herein are not anticipated.

3.0 GEOTECHNICAL

3.1 STATEMENT OF CONCERN

"The geotechnical issues include the potential alteration of the thermal conditions of the TAPS work pad, the haul road and the fuel gas line during the construction and operation of the proposed chilled gas pipeline. Of particular concern was the thawing during the dormant period after burying a large diameter pipe in the ice-rich permafrost which TAPS avoided by using an elevated mode. The sensitivity of the TAPS workpad and haul road, when aggravated by additional adjacent construction, will require a detailed mile by mile analysis to avoid damage from liquefaction, thaw plug instability and erosion."

3.2 DEFINITION OF ISSUES

This concern relates to the potential impacts of adjacent construction and operation of the chilled gas pipeline on the geotechnical thermal and mechanical stability of the TAPS workpad, haul road and fuel gas pipeline. Specifically, the impacts stated are as follows:

- Alteration of the thermal conditions of the TAPS workpad.
- Alteration of the thermal conditions of the haul road.
- Alteration of the thermal conditions of the fuel gas pipeline.
- Sensitivity of the TAPS workpad to damage from liquefaction.
- Sensitivity of the TAPS workpad to damage from thaw plug instability.
- Sensitivity of the haul road to damage from liquefaction.
- Sensitivity of the haul road to damage from thaw plug instability.

Hydraulic erosion effects are covered under Sections 2 and 12; therefore, erosion will not be covered in specific detail here.

The primary concern is the potential increase in thaw plug instability and liquefaction potential of the TAPS workpad and haul road, and fuel gas pipeline caused by adjacent construction and operation of the chilled gas pipeline. Ground subsidence caused by induced thermal degradation increases the potential for ponding, diversion of surface drainage and reduction in workpad support capacity. These are accepted concerns. Alteration of the thermal conditions of the TAPS workpad, fuel gas pipeline, and haul road is only of significant concern to the extent such alterations could increase the potential for thaw plug instability or liquefaction.

Thaw subsidence from thermal degradation is considered a stability assessment concern because of its tendency to increase the potential for ponding, diversion of surface drainage and the resulting decrease in workpad support capacity. However, design solutions are typically included in the civil and erosion control design process. Thus, by itself, alteration of thermal conditions is not considered a significant stability issue.

These concerns are covered as part of the project geotechnical terrain stability assessment program of the construction zone right-of-way. Geotechnical terrain stability is concerned with thermal and mechanical stability of the natural soils in the construction zone along the alignment.

3.3 CATEGORIES

3.3.1 Geotechnical Terrain Stability

Geotechnical terrain stability includes thaw plug stability and thaw degradation effects, liquefaction, and slope stability.

The importance of geotechnical stability is reflected in:

- The provision of structural integrity for both the NWA system and TAPS oil and fuel gas pipelines and appurtenant facilities.
- The limitation of any functional loss of workpad or haul road usability during or after construction.
- The limitation of potential negative environmental impacts.

Structural integrity is of concern because excessive soil and/or rock movements due to geotechnical terrain instability effects are capable of damaging, by overstressing, the NWA pipeline, the TAPS pipeline, or appurtenant facilities. It is of concern that workpad or haul road traffic usability can be hindered or disrupted by geotechnical terrain instability. Environmental concerns of geotechnical terrain instability include potential aesthetic impacts of slope failures and siltation of water bodies.

3.3.1.1 Thaw Plug Stability

As used here, "thaw plug stability" is concerned with thaw degradation of frozen soils and the consequent geotechnical terrain instability effects. Thaw degradation can occur in or adjacent to the construction zone (due to disturbance from construction activities), existing TAPS facilities or the haul road. Influences from TAPS facilities include thaw bulb effects of the buried hot oil pipeline, and/or workpad.

It is expected that any developing thaw bulbs will not be capable of adversely affecting pipeline structural integrity once a sufficiently large frost bulb builds up around the chilled line. Until that time, the risk of thaw plug instability must be below an acceptable level to ensure pipeline structural integrity. Risks of potential instability must also be sufficiently low to assure workpad usability both during construction, and thereafter for use in system maintenance and monitoring operations.

Where TAPS is buried, the stability of existing TAPS thaw plugs could be affected by adjacent construction. However, TAPS criteria specify burial in thaw stable material; it is therefore unlikely that the buried oil pipeline could be significantly damaged by a thaw plug failure. Failure of TAPS thaw plug overburden material ("slop on top") will not jeopardize pipeline integrity, but would disrupt workpad usage. Therefore, maintenance of thaw plug stability is considered necessary.

3.3.1.2 Liquefaction

Soil liquefaction from earthquake ground motions can occur in certain saturated, unfrozen soil deposits because of the tendency of soil to develop excess soil pore water pressures due to earthquake shaking. This can result in short-term loss of soil shear strength. Large soil strains and permanent ground movement, including settlements, can occur because of liquefaction. Liquefaction is a project concern to the extent it can affect NWA and/or TAPS structural integrity and disrupt workpad usage.

3.3.1.3 Slope Stability

Slope stability is concerned with disturbance of the existing equilibrium of slopes along the route due to natural events, including earthquakes, and construction impacts. Slope instability can result in large, permanent total and differential ground displacements. Slope stability is a project concern to the extent it can affect NWA and/or TAPS structural integrity, disrupt workpad usage, or cause unacceptable environmental impacts.

3.3.2 Route Conditions

Geotechnical terrain stability is dependent on subsurface conditions, climatic thermal conditions, construction zone geometry, earthquake ground motion effects, and groundwater effects. To the extent that significant changes in any of these categories occur, geotechnical terrain stability will be significantly influenced.

3.3.2.1 Route Geotechnical Characterization and Classification

Subsurface and climatic thermal conditions influencing geotechnical terrain stability are assessed mile-by-mile along the route on a segment-by-segment basis. This is done with a systematic process termed route geotechnical characterization and classification. Subsurface conditions include soil index properties, soil strength and compressibility parameters, and soil thermal properties. Climatic thermal conditions include ground surface and climatic parameters that influence the overall ground heat balance.

3.3.2.2 Right-of-Way Configuration

- o Hot Oil Pipeline/Workpad

  Where the NWA pipeline is located in proximity (approximately 80 foot separation) to the TAPS pipeline, both present and future surface geometry and subsurface soil/thermal changes are important considerations. Actual and interpreted potential time dependent ground modifications associated with anticipated thermal degradation are included in the assessment process.

- Haul Road/Fuel Gas Pipeline

  Where the NWA pipeline is located adjacent to the haul road and/or fuel gas pipeline, consideration is given to both present and future surface geometry and subsurface soil/ thermal changes.

- Other Appurtenances (GVEA, Haines Products Line)

  Where the NWA pipeline is located adjacent to the Golden Valley Electric Association (GVEA) and Haines Products Line alignments, consideration is given to both present and future surface geometry and subsurface soil/thermal changes.

3.3.2.3 Earthquake Ground Motion Design Zones

Design considerations for earthquake ground motions and faulting are addressed in Section 6 of this Enclosure. Design earthquake parameters characterized for each segment of the route include: acceleration, velocity, displacement and magnitude.

3.3.2.4 Groundwater Characterization

The presence of groundwater and the associated changes produced by pipeline construction activities and thermal effects are important considerations. Characterization of groundwater parameters is addressed in Section 2 of this Enclosure.

3.4 DATA ACQUISITION

3.4.1 Data Necessary

The geotechnical data needed for the design of the chilled gas pipeline follows.

3.4.1.1 Soil Boreholes

Soil borehole logs present the information gained during the hole drilling operation. The data obtained include, but are not necessarily limited to:

- o Standard identification information.
- o Type of rig and method of drilling.
- o Weather.
- o Groundwater.
- o Vegetation.
- o Instrumentation, if applicable.
- o Sampling method.
- o Sampling location.
- o Sample Recovery.
- o Blow counts for drive samples.
- o Soil thermal state.
- o Percentage of visible ice.
- o Soil graph with depth in feet.
- o Moisture content of unfrozen soils.
- o Consistency of unfrozen soils.
- o Verbal description of soil characteristics.

3.4.1.2 Laboratory Soil Tests

While soil logs alone provide a general evaluation of the soils and soil conditions encountered during drilling, it is necessary to provide more specific information on the properties of the individual soil units. This information is obtained by means of the following.

3.4.1.2.1 Index Property Tests

- o Moisture content.
- o Dry density.

- Organic content.
- Liquid limit.
- Plastic index.
- Grain size distribution.
- Specific gravity.

3.4.1.2.2 Engineering Property Tests

- Shear strength, frozen and unfrozen.
- Compressibility.
- Permeability.
- Uniaxial thaw consolidation.
- Long term frozen soil strain rate controlled tests.

3.4.1.3 Ground Temperature

The behavior of a chilled gas pipeline and the throughput of that pipeline are affected by the temperature of the soil in which it is buried. The diverse effects of ground temperature on pipeline performance and long term integrity are exemplified by the case of cold, continuous permafrost versus warm, wet, unfrozen fine grained soils. The former presents concerns of thaw degradation during the dormant period and in the workpad area during operation, whereas the latter presents concerns of frost heave during operation.

3.4.1.4 Groundwater Observations

Many of the geotechnical problems associated with construction of a chilled gas pipeline are intimately involved with the presence or absence of groundwater. As an example, liquefaction potential and slope stability are sensitive to soil water pore pressure. The acquisition of groundwater data is detailed in Section 2.

3.4.1.5 Climatological

Weather data is required because of its influence on the ground temperature, the presence or absence of permafrost and the scheduling of actual construction of the line.

3.4.1.6 Resistivity

Ground resistivity is needed in the preconstruction phase where it is used to help extrapolate borehole data and provide a higher degree of confidence between boreholes.

3.4.1.7 Earthquake Ground Motions

Ground motion velocities and acceleration along the route by earthquake design zone are needed for pipeline design. These studies are currently being conducted, and preliminary values have been provided, by Dr. Newmark.

3.4.1.8 Aerial Photography

Aerial photos are used for photo interpretation in preparing terrain unit maps, route reconnaissance and investigations of special design areas.

3.4.1.9 CRREL Haul Road Performance Study Reports

These reports will provide data on the overall performance of TAPS and will in particular provide information on thaw degradation which may have taken place. The data will be very useful in design of the NWA facilities.

3.4.1.10 Existing ROW Performance Data

The performance of TAPS will provide information on the behavior of the soils under actual operating conditions. These data will be very helpful in prediction of soil behavior in the case of the NWA project.

3.4.1.11 Workpad Assessment Data Report

This work will be an extension of the information on TAPS ROW Performance (3.4.1.10). In addition, it will provide information on the performance of access roads which are not adjacent to or affected by the hot oil line. This information will be very valuable in designing the NWA facilities.

3.4.1.12 Slope Assessment Data

This study utilizes the available Alyeska slope stability reports as a basis for continuing studies. The report will contain an assessment of all slopes previously indicated to be potentially unstable, an assessment of the effect of TAPS on terrain stability and an analysis of all slopes found to be potentially unstable.

3.4.2 Data Acquired to Present

NWA has been acquiring field data since 1976 when the first field borehole drilling program was initiated. Acquisition is still in progress with the programs now being designed to fill gaps in earlier programs or to aid site specific investigations for final design.

3.4.2.1 Soil Boreholes

The NWA borehole program has produced approximately 1,240 boreholes along the present centerline, campsites, field test locations, compressor stations, and material sites. In addition, approximately 5000 Alyeska centerline, haul road, materials site and pump station boreholes, over 31,000 Alyeska VSM logs and over 100 miles of Alyeska ditch logs were purchased and are in use. Also used are borehole data from other sources such as government agencies, the Alaska Department of Transportation and the Golden Valley Electric Association. Many of these boreholes, which amount to several hundred, are near the route in areas that assist in terrain unit selection and characterization. Many boreholes were sampled extensively but some, particularly those drilled during TAPS construction, were drilled for specific information such as depth to bedrock or permafrost. Frequently these types of borings required no sampling.

3.4.2.2 Laboratory Soil Tests

To date NWA has tested samples from over 1,000 boreholes and has obtained laboratory test results from approximately 1,700 Alyeska boreholes. Several samples were tested from most holes, with the average number of tests per hole estimated to number over 15. The total number of index property test results available to the project is approximately 43,000. In addition to the standard index property tests, engineering property tests have been conducted on selected samples. These tests include both frozen and unfrozen samples for such properties as shear strength, compressibility, permeability, thaw strain, frost heave and creep in frozen soils. Several hundred of these tests have been performed with more planned in the future. Additionally, a number of test results from borehole samples provided by the various groups mentioned have been used.

3.4.2.3 Ground Temperatures

Data on ground temperature have been obtained from available literature, CRREL studies, Alyeska, and NWA installed thermistors. Subsurface temperature data from 92 sites, representing approximately 1,600 individual temperature transducers, have been utilized in developing the ground temperature profiles presently in use. Thirty-four additional sites have been recently instrumented and are being read; the profiles will be updated to reflect these data.

3.4.2.4 Groundwater

In excess of 37,000 locations along the route have information on the presence or absence of groundwater. In addition to these observations, approximately 125 standpipes have been installed to facilitate continuing monitoring of groundwater levels. More sophisticated testing is also being done. These programs are described in Section 2.

3.4.2.5 Climatological

These data have been obtained from 20 weather stations of varying quality along the route. They range in quality from the government station in Fairbanks to the somewhat discontinuous observations at remote stations such as Wiseman.

3.4.2.6 Resistivity

Ground resistivity measurements have been used to assist in the extrapolation of borehole data and in selecting borehole locations. Approximately 390 miles of information taken by non-ground contact devices has been obtained by NWA.

3.4.2.7 Earthquake Ground Motion

The preliminary assessment of earthquake ground motion parameters for the NWA pipeline has been developed by Dr. Newmark.

3.4.2.8 Aerial Photography

Complete stereographic coverage of the NWA route is available at scales varying from 1:24000 to 1:36000 in color and black and white. Complete coverage was flown by NWA in 1976 and in 1978. In addition, earlier photos are available from the government for some areas, and use has been made of these photos for assessing pre-TAPS conditions. Also, low level oblique photos of the entire route have been taken. These photos also include transverse flights at such points as stream crossings.

3.4.2.9 CRREL Prudhoe Bay Road Performance Study Reports

These studies provide information on thermal degradation and thaw subsidence of the haul road and some TAPS workpad locations for the past five year period.

3.4.2.10 Licensed Alyeska Geotechnical Reports

3.5 DESIGN CRITERIA

The fundamental design objectives are:

- Provide NWA pipeline system integrity.
- Maintain integrity of existing facilities.

Specific criteria developed for each of the terrain stability aspects are:

3.5.1 Thaw Plug Stability

Criteria used to assess thaw plug stability address both static factors of safety and potential slope displacements during earthquakes.

- o Thaw plugs affecting pipeline integrity will require mitigation or detailed site-specific field and/or analytical qualification where: (1) the computed static factor of safety is less than 1.5, or (2) computed permanent displacement exceeds 5 inches under design contingency earthquake loading.

- o Thaw plugs not affecting pipeline integrity will require mitigation only if the computed static factor of safety is less than 1.1.

3.5.2 Liquefaction

Criteria used to assess liquefaction potential address both shear strength losses and differential settlements.

Segments will require mitigative designs or detailed site-specific field and/or analytical qualification where:

- o Liquefaction induced differential settlement predictions exceed 12 inches in 100 feet.

- o An excessive risk of potential, massive confined talik liquefaction is assessed.

3.5.3 Slope Stability

Criteria used to assess slope stability address both static factors of safety and earthquake-induced permanent displacements.

Slopes will require mitigative designs or detailed site-specific field and/or analytical qualification where:

- o The computed static factor of safety is less than 1.5.

- o The computed permanent displacement exceeds 5 inches under design contingency earthquake loading.

3.6 DESIGN PROCEDURES

3.6.1 Geotechnical Terrain Stability Assessment Process

The design procedure used for geotechnical terrain stability assessment is summarized in Figure 3-1.

The entire alignment is examined mile-by-mile on a segment-by-segment basis. The assessment is done in two stages: (1) initial identification of potentially unstable segments along the route using generalized assessment techniques, followed by (2) site-specific detailed engineering analysis of potentially unstable areas, as identified in (1).

Liquefaction, slope stability, and thaw plug stability analyses are closely coordinated to achieve efficient, accurate assessment and provision of geotechnical terrain stability. Each of these analysis tasks are interrelated, not separate; and to some extent overlap with each other. They are integrated in the assessment process to ensure that all factors contributing to construction zone geotechnical stability have been properly considered in the geotechnical terrain stability assessment. Each segment is examined in overview to check that:

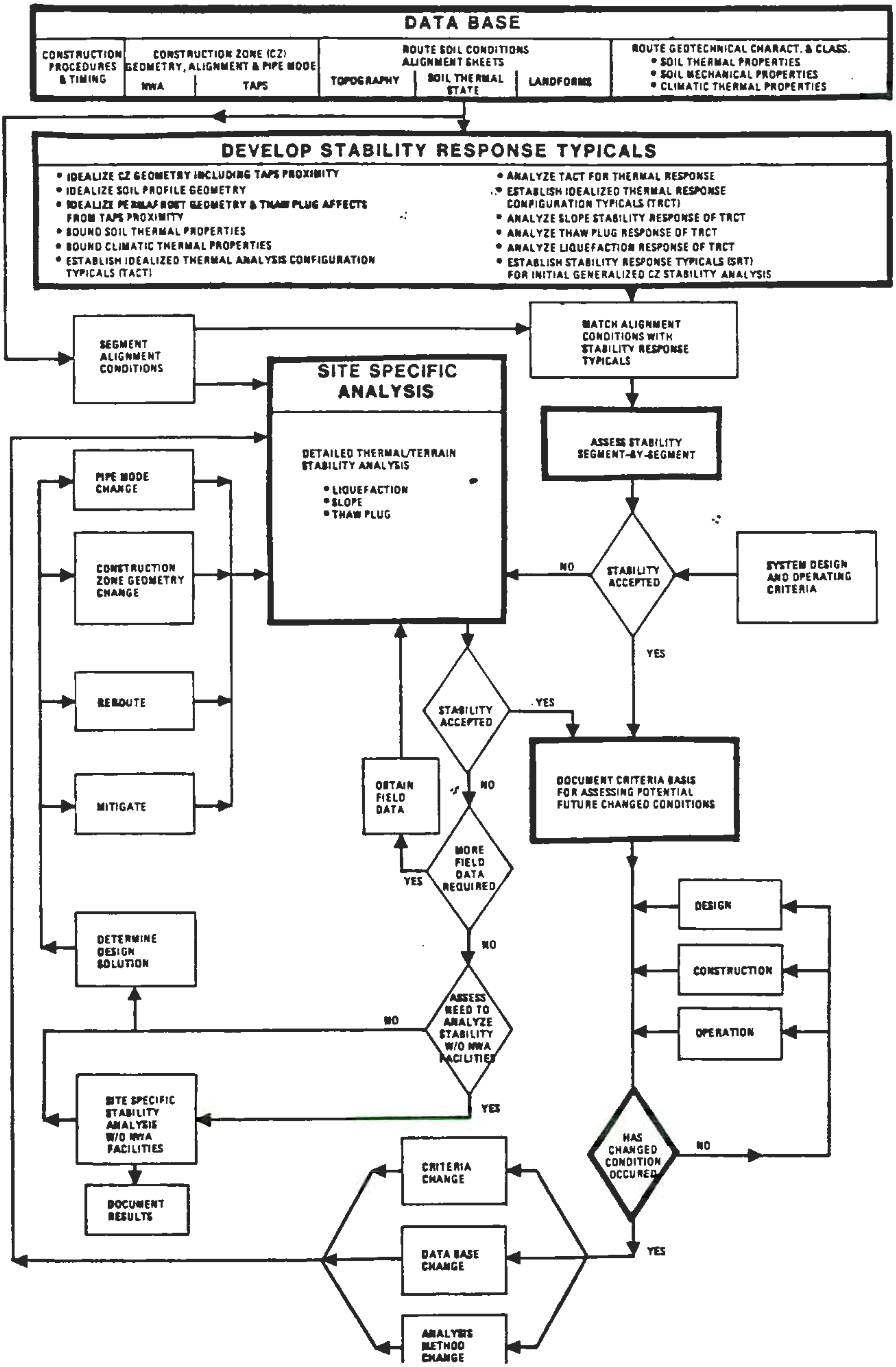
- o All contributing factors to geotechnical terrain stability have been identified and adequately considered in analysis.
- o Subsurface conditions, characterizations, assumptions, and construction parameters are reasonable and compatible for each analysis.
- o Results of each analysis are consistent and reasonable.
- o Analysis results are properly integrated, reasonable, and compatible with other segment assessments.

Geotechnical terrain stability assessment is iterated as needed to accomplish these requirements.

3.6.1.1 Geotechnical Data Base

The first step of the geotechnical terrain stability assessment process is to develop the geotechnical data base as design input to identify segment alignment conditions and to

GEOTECHNICAL TERRAIN STABILITY — CONSTRUCTION ZONE STABILITY ASSESSMENT PROCESS



develop stability response typicals. This data base is derived from four primary sources:

- Route Geotechnical Characterization and Classification - (RG2C) is a system designed to provide mile-by-mile geotechnical mechanical and thermal input data for each of the geotechnical engineering considerations, including: thaw plug stability, liquefaction, slope stability, and thaw strains.

  Criteria used to select data values include consideration of: geotechnical variability, constraints/limits imposed by the available data base, details of the analysis methodology, and sensitivity of final designs to error in the data set.

  Each characterization consists of the data set required for the specific geotechnical terrain stability analysis. Parameter values are established by analysis and synthesis of data, including: Route Soil Conditions Alignment Sheets, borehole logs, soil laboratory data, and other pertinent data.

- Route Soil Conditions Alignment Sheets - This series of 131 sheets provides a mile-by-mile graphic compilation of much of the geotechnical data. The route soil sheets show the following data: terrain unit map with contours and borehole locations, landform type profile with ground surface profile and selected borehole data, permafrost, ground ice, soil type, frost heave classification, soil erosion code, temperature range, and potential hazards.

- Construction Zone Geometry - Preliminary identification of construction zone geometry has been accomplished.

- Construction Procedures and Scheduling - Preliminary identification of construction procedures and scheduling has been accomplished. This information is presently being utilized to define and bound design parameters associated with development of typical configurations.

3.6.1.2 Initial Generalized Assessment

Initial, generalized analysis is accompanied by the development of stability response typicals (SRT). These are compared to alignment conditions along the route on a segment-by-segment basis. Where stability is found to be unsatisfactory using the SRT, site specific detail geotechnical terrain stability analysis is conducted.

Stability response typicals, used in the initial phase of analysis, represent a limited set of conservatively developed geotechnical terrain stability analyses based on generalized characterizations of pertinent conditions influencing geotechnical terrain stability. In this way, a limited number of SRTs are used to conservatively assess the alignment.

Segments which are found to be unsatisfactory by this conservative procedure are then reanalyzed site-specifically in detail.

Stability response typicals are developed as summarized below; and include complete documentation for each SRT, stating the assumptions and describing the development methodology.

1) Examine the state of all conditions along the alignment which are pertinent to geotechnical terrain stability (GTS), including:

- o Construction zone geometry
- o Right-of-Way Configuration (Hot Oil Pipeline/Workpad, Haul Road/Fuel Gas Pipeline, GVEA, Haines Products Line)
- o Topography
- o Terrain Unit and Landform Profile
- o Soil Types
- o Permafrost state and ground ice conditions
- o Earthquake ground motion design zone.

2) Group similar conditions into a limited number of representative configurations or "typicals".

3) Idealize subsurface thermal configuration including potential thaw plug geometry due to existing facilities.

4) Characterize typicals in terms of:

- o Subsurface thermal and mechanical properties
- o Thermal climatic conditions
- o Groundwater conditions
- o Thermal boundary conditions including construction disturbance effects.

5) Develop idealized thermal analysis configuration typicals (TACT) from the results of (2), (3), and (4) above. TACTs include thermal loadings from climatic conditions, chilled pipe, and TAPS. Surface thermal boundary conditions due to constructed facilities are included.

6) Analyze TACTs for short and long-term thermal responses of importance to GTS. Response includes pre-startup dormant phase and operations phase.

7) Establish idealized thermal response configuration typicals (TRCTs) for use in slope stability, thaw plug stability, and liquefaction analyses. TRCTs are based on a conservative interpretation of (6).

8) Analyze TRCTs for slope stability, thaw plug stability, and liquefaction.

9) Establish stability response typicals, based on a conservative interpretation of the results of (8). Each SRT includes an application basis summary stating the conditions and limitations for which it can be used in segment-by-segment GTS analysis.

These stability response typicals are compared and matched to alignment conditions on a segment-by-segment basis. GTS is assessed from the typicals to identify potentially unstable segments along the alignment which require site specific, detailed GTS analysis. Importantly, the same group of analysts who develop the SRTs make the GTS assessment and also perform the site-specific analyses. Thus, continuity and the basis for quality engineering judgments during GTS analysis is maintained.

3.6.1.3 Site-Specific Detailed Analysis

Segments identified as unsatisfactory in the initial generalized GTS assessment must be analyzed site-specifically in detail. GTS conditions are analyzed in detail using the same general analytical techniques as used to develop the stability response typicals, but with site-specific input data and more detailed interpretation.

During the analysis, examination is made to determine if increased field data would be effective in qualifying the segment as acceptably safe. If the segment cannot be analytically and/or field qualified as stable, a design solution is selected to provide an acceptable design. This can consist of pipe mode change, construction zone change, mitigative design or reroute. The segment is reanalyzed for GTS with the adopted design solution. This is done in an iterative manner until the most effective, least costly design solution is obtained and the segment is assessed as satisfactory against potential instability.

GTS concerns due to TAPS proximity are addressed segment-by-segment as part of the construction zone stability assessment process. Any segment not found to have an acceptable level of stability (with the NWA facilities as configured) is analyzed for stability without the NWA facilities to document expected stability conditions without NWA effects.

Each segment analysis is documented, and the basis for changed conditions which could alter the potential future stability of the segment is formulated from this documentation. As conditons occur during subsequent design, construction, and operation, these criteria-bases can be checked to see if a changed condition has in part occurred which could alter the stability of the segment. The segment's GTS can be reanalyzed accounting for the changed conditions as required.

Once a segment is characterized, analyzed and if necessary provided with a design solution, there is a potential for future changed conditions. Such changed conditions are anticipated to be associated with: (1) the data base, (2) methods of analysis, or (3) project criteria. Any combination of these potential changed conditions may occur during subsequent design, the construction process, or during the operations phase. These changes may or may not be significant in terms of influencing the assessed GTS of any given segment. Significant changes would require reassessment of stability.

To formally account for potential changed conditions which could influence GTS, the basis for assessing whether changed conditions have occurred is documented at the time the segment is assessed as safe. The basis is the set of operative assumptions and design conditions subject to potential changes which could influence the GTS. At any future time, that documentation can be compared to the conditions existing at that time to see if a changed condition has occurred. If it has, GTS can be reassessed with the changed conditions.

A potential changed condition occurs if there is a change in alignment, construction zone geometry, pipe mode, or a change in the understanding of subsurface conditions (soil properties, permafrost conditions, groundwater conditions, thaw bulb conditions), criteria changes (earthquake parameters, required safety factors, acceptable risk, design life, stability aspects of concern), construction procedures (construction season, excavation techniques, restoration plans), or analysis methodology (physical characterization, computational procedure). All of these potential changed conditions can be accounted for as they influence GTS by (subsequent) reanalysis and redesign if necessary.

The analytic procedures used for GTS (liquefaction, slope stability, and thaw plug stability) are discussed in detail in FERC Exhibit Z-9.1, Section 4.8.2. Analytic procedures for thermal analysis are based on analysis using a two-dimensional finite element thermal modeling computer program and various simplified closed form and graphical thermal analysis techniques.

3.7 SOLUTIONS

The initial route selection criteria and process provided considerable emphasis on the avoidance of areas of potential terrain instability. Subsequent route modifications have also incorporated the same selection criteria. Large portions of the route extend through stable unfrozen granular or weathered bedrock and thaw stable frozen materials. In these areas, conventional construction zone grading and erosion control procedures established for this project minimize the potential for subsequent development of terrain instability.

A rough estimate of the magnitude of potential geotechnical terrain stability concerns along the route has been made. These have been based on expected final results from the segment-by-segment route geotechnical terrain stability assessment program now in progress.

- One-half the route could potentially experience limited thaw degradation in the construction zone right-of-way due to construction effects. A portion of these areas will require design solution applications.

- 25 to 65 miles of the route could potentially be assessed as having thaw plug instability concerns requiring design solution applications.

- 20 to 30 miles of the route could potentially be assessed as having liquefaction potential concerns requiring design solution applications.

- 15 to 30 locations along the route could potentially be assessed as having slope stability concerns requiring design solution applications from the current set of about 100 study areas.

3.7.1 Significant Potential Geotechnical Impacts

Segments where satisfactory stability cannot be assured by analytical and/or field qualification will require a design solution to provide the necessary stability. Design solutions can be classified as:

- Ditch mode or construction zone geometry change.

- Minor alignment adjustments.

- Direct mitigation.

The most appropriate design solution to remedy unsatisfactory stability conditions will vary from segment to segment. This will depend not only on the geotechnical factors involved, but on civil/pipeline design and construction considerations, including environmental and drainage concerns.

The selection of the most appropriate design solution and the details of the solution is an iterative process. That is, a trial solution is chosen, one which is also satisfactory to the nongeotechnical considerations, and analyzed for stability. The cost effective solution producing a satisfactory stability condition is the one adopted.

Design solutions based on direct mitigation may be used to achieve satisfactory stability wherever changes in ditch mode, construction zone geometry, or alignment cannot be implemented or are excessively costly. Mitigation techniques include:

- o Pipe burial below hazardous soils.
- o Replacement of hazardous soil.
- o Grading to flatten slopes .
- o Provision of subsurface drainage paths.
- o Soil densification.
- o Grouting or chemical stabilization.
- o Ground freezing.
- o Slope buttressing.
- o Insulating.
- o Construction scheduling.
- o Overfill in thaw subsidence areas.

The cost-effective treatment which provides a satisfactory stability condition for the particular segment of concern is the basis of selection.

3.7.1.1 Ditch Mode or Construction Zone Geometry Change

As a part of the design process, modification of ditch mode and construction zone geometry may be implemented as required. Variations of ditch mode and construction zone geometry are continuously reviewed on a segment-by-segment basis and related to grading and terrain stability criteria.

3.7.1.2 Mitigating Potential Impact Areas

3.7.1.2.1 Pipe Burial Below Hazardous Soil

This solution is considered appropriate where pipe integrity is assured and instability of overburden materials will not result in adverse consequences. It has proven successful even in ice rich frozen soil where major thaw degradation was anticipated. Design solutions will be applied on a mile-by-mile basis using appropriate frozen soil grading, thaw plug overburden and seepage induced erosion control criteria. The success of this particular design solution, where the hot oil pipeline was introducing greater potential for thaw degradation and instability, is considered to be a direct demonstration that dormant period thaw degradation concerns can be accommodated in an appropriate manner.

3.7.1.2.2 Replacement of Hazardous Soil

Excavation and replacement of potentially unstable materials representing hazardous zones is considered to be appropriate where sufficient replacement materials are available and associated costs are acceptable. Because of the typically larger quantities of materials involved, this solution is only applied to site specific or shorter route segments.

3.7.1.2.3 Grading to Flatten Slopes

Grading and excavation techniques to flatten slopes are utilized to provide an acceptable solution where potentially unstable slopes are encountered. These grading and excavation techniques have been successfully applied on common civil work projects and more particularly on TAPS.

3.7.1.2.4 Provision of Subsurface Drainage Paths

In certain locations, control or modification of subsurface drainage will be necessary and application of subsurface drainage solutions is appropriate. Such solutions used in combination with insulation materials are employed primarily at site specific locations (streams, confined drainage, paths, etc.), where subsurface groundwater flow conditions and soil characteristics are adequately defined.

3.7.1.2.5 Soil Densification

At certain route locations, densification can be utilized to improve soil strength characteristics and consequent stability conditions. Application of this solution is also on a site specific basis where suitable compaction is attainable. This solution is also utilized in conjunction with ditch overexcavation procedures to assure pipe bearing on stable materials.

Variations to this approach have been utilized throughout the pipeline industry.

3.7.1.2.6 Grouting or Chemical Stabilization

Use of grouting or chemical stabilization procedures to improve soil strength characteristics and terrain stability is considered to represent a viable solution. This solution is only applicable on a limited site-specific basis.

3.7.1.2.7 Ground Freezing

This solution involves the use of mechanical or natural freezeback techniques that assist in freezing unfrozen soil, maintaining the frozen soil state or retarding potential thermal degradation. This solution is only applied on a limited site-specific basis.

Utilization of soil freezing procedures has been successfully applied in a number of instances in the construction industry. TAPS has successfully used heat pipes and mechanical refrigeration to freeze or maintain the frozen soil state along extensive segments of the hot oil pipeline route. NWA is presently evaluating this technique at the Fairbanks Frost Heave Test Site.

3.7.1.2.8 Slope Buttressing

Use of buttress material to stabilize slopes is a commonly accepted practice. This solution is only applied on a limited site-specific basis.

Buttresses have been successfully applied as a design solution for TAPS to stabilize slopes within the transportation corridor.

3.7.1.2.9 Insulating

Application of various insulation materials as a means of reducing and controlling thermal degradation has been applied at locations where protection of terrain stability was required. This solution is only applied on a limited site-specific basis.

Insulation materials have been used in embankments and on slopes to limit thermal degradation and thawing at a number of locations along TAPS and at other facilities within the immediate area of the transportation corridor.

3.7.1.2.10 Construction Scheduling

Project construction scheduling has been and will be sensitive to the specific concerns associated with construction disturbances and consequent potential for thermal degradation. Preliminary identification of soils exhibiting potential for significant thaw degradation has been accomplished. Both preliminary design moding and construction timing have been developed with the intent of minimizing undesirable terrain disturbances. Ditch stability during construction and the dormant period is addressed in Section 7.

3.7.1.2.11 Overfill in Thaw Subsidence Areas

Overfill material, in areas where significant ground thaw subsidence is anticipated, has been successfully applied as a solution for accommodating time dependent thaw degradation and drainage changes. Use of granular overfill as light surcharge provides material sufficient for filling thaw depressions and reshaping affected areas after subsidence occurs. This solution was utilized on TAPS to mitigate anticipated thaw subsidence effects.

3.7.1.3 Minor Alignment Adjustments

Minor alignment adjustments are treated on a very specific segment basis. Any proposed minor alignment adjustment is assessed with regard to geotechnical terrain stability in the construction zone stability assessment process.

As a solution technique, successful application of this procedure has been well demonstrated on a number of various transportation corridor projects.

3.7.1.4 Design Solution Summary

The design solutions have been utilized successfully on other projects. Specific techniques for each proposal solution have varied on different projects and consequently the success of these techniques has varied. In addition, application of certain solutions on some projects has occurred well after thaw degradation and unstable conditions have developed. In these cases, mitigation has been accomplished after the fact. Again, success of these applications has varied with the technique utilized.

3.8 CONTINUING STUDIES

Geotechnical terrain stability assessment of the alignment is currently in progress; it is a continuing design effort. NWA studies are continuing and take two general forms.

3.8.1 Field Measurements and Monitoring

Follow-on work required to monitor or maintain previously installed field tests or devices. This involves periodic reading of:

- o Thermistor strings.
- o Standpipes.
- o Test site instrumentation.

3.8.2 Field Studies

New information to expand on previous data will be acquired from future field studies as necessary.

Previous work on terrain stability included a reconnaissance level review of most of the route. These studies will be completed this season and any sites designated for further study will be evaluated by drilling or other appropriate means. Limited bedrock studies were carried out along the route in 1979. This work is to be extended along the rest of the route. The preliminary bedrock study, which is basically a compilation from published sources is still to be field checked. The borehole drilling programs will include additional centerline holes as well as those holes needed to assess site specific requirements for the terrain stability study. Resistivity surveys are planned to fill in previous work and thereby assist in the interpolation of soils and permafrost data between the boreholes.

Radar imagery is still in the conceptual stage and is at this time considered a promising tool for operation and monitoring. It has apparent potential for assisting in both soil and groundwater studies and since it uses different physical principles than resistivity, the two methods will complement each other.

3.9 POTENTIAL FOR CHANGE

Subsurface conditions contain the greatest, most obvious source of significant uncertainty in terms of geotechnical terrain stability (GTS). This is accounted for in the method of subsurface characterization and the GTS analysis by balancing the conservatism of pertinent assumptions about conditions with the level of uncertainty and consequences of error in the true state of those assumptions. For example, greater uncertainty requires more conservatism in direct proportion to the consequences of error in GTS assessment.

The results of continuing studies will provide additional data, and the geotechnical terrain analysis will be updated to include these data. Refinements of the preliminary design will have an effect on the geotechnical terrain analysis, and the analysis will be updated when these changes occur.

Acceptable geotechnical terrain stability for the project can be provided in a reliable, effective manner. The potential for change that would materially alter the alignment selected is comparatively slight.

4.0 BLASTING

4.1 STATEMENT OF CONCERN

"Northwest must determine what effect, if any, blasting will have on the oil pipeline with respect to short-term and long-term stability of the TAPS fully restrained pipeline, the adfreeze strength of the VSM supports, and blast effects in conglomerate materials."

4.2 DEFINITION OF ISSUE

The main issue addressed in the concern is the effect that blasting may have on TAPS. The fact that it is technically feasible to conduct blasting operations in close proximity to an existing oil pipeline cannot be effectively refuted. In fact, it is a common procedure in certain cities, where rock is exposed or very near the ground surface, to conduct blasting operations for every manner of excavation in very close proximity to many different types of pipelines, conduits, buildings and other facilities. The issue in this case is not technical feasibility but the need to establish a number of separate criteria and methods for implementing compliance with the criteria.

Northwest, government and TAPS officials do not appear to have any fundamental disagreements on the basic question of blasting in proximity to TAPS. Alyeska makes this conclusion implicit in the document of May 8, 1979, "Blasting Restriction near the Trans-Alaska Oil Pipeline System." In this document, Alyeska suggests recommendations for criteria to be used for those situations where the proposed gas line is located:

- o 60 feet or more from the existing oil pipeline.
- o 30 feet or more from the pipeline.
- o Less than 30 feet from the pipeline.

On the other hand, Northwest considers it desirable to provide definitive limitations on certain physical effects of blasting, and to provide a suitable quality control plan that will provide conformance to the established limits, yet will permit efficient construction procedures.

There are minor differences in the recommendations of the blasting consultants for Northwest and for Alyeska. For prediction purposes, Alyeska recommends a somewhat more restrictive particle velocity limitation, but a more liberal use of explosives. NWA recommends a more restrictive use of explosives, but a slightly higher particle velocity limitation.

4.3 CATEGORIES

The following elements or categories comprise the major parameters which Northwest considered in establishing its route and developing safe and effective blasting limitations. These parameters deal with soil classifications, adjacent facility configurations, environmental considerations, and construction requirements.

4.3.1 Soil Classifications

The soil types in which blasting operations are expected to occur, and in particular, whether a soil type is stable or potentially unstable, directly affects the specified blasting techniques for that soil area.

4.3.2 Adjacent Facility Configuration

Whether the existing oil pipeline is aboveground or buried in those parts of the route where the two pipelines are adjacent also affects the blasting techniques designated for those areas. An obvious example is that for those portions of the alignment where the aboveground TAPS configuration is used, blasting mats will probably be required, whereas they will not necessarily be required adjacent to buried portions of the TAPS line.

4.3.3 Environmental Considerations

Blasting may be constrained by environmental considerations, particularly in certain unusual wildlife habitats or near streams containing fish.

Certain other criteria have been developed as industry standards, for example, those for residential structures and their human occupants. Similar data exist for non-residential buildings, machinery and other facilities.

4.3.4 Construction Requirements

The following construction factors must be considered when planning the blasting procedures:

- o Depth and width of ditch required
- o Degree of fragmentation required
- o Equipment availability
- o Trench wall roughness and alignment
- o Select backfill material availability
- o Ambient temperature
- o Desired production rate

4.4 DATA ACQUISITION

4.4.1 Data Required

The data required are the soil conditions, structural characteristics, blasting vibration characteristics and location of blasting relative to structures.

4.4.2 Data Acquired to Present

4.4.2.1 Published Data

Published data relating to blasting effects date back to at least the early 1940's. In 1942, the U.S. Bureau of Mines published its first bulletin on the subject. From the mid 1950's until the present date, the Bureau has published a series of Reports of Investigations on blasting effects, and Bulletin 656, dated 1971, summarizing the Bureau's view of the state of the art of blast effects on residential structures to that time. A number of individual contracts on various aspects of blasting research have been awarded by the Bureau in recent years, and the ensuing publications are available for examination at Bureau offices.

In addition, various universities, consultants and individual researchers have published data, case histories and research conclusions. Northwest's blasting consultant, L. L. Oriard, has published widely on various aspects of the subject, and is a recognized authority in this field. His research and field experience cover all the topics related to explosives engineering and blast effects that are of interest to this project.

Additional publications on blasting are found scattered throughout the engineering, construction, mining, rock mechanics and research literature. Recently, the Society of Explosives Engineers has begun to publish its annual proceedings.

A review of existing literature and previous construction experience provides support of Northwest's criteria for the general case and demonstrates clearly the feasibility of proximity blasting.

4.4.2.2 1977 Test Data

In 1977, Northwest conducted an initial test blasting program to demonstrate to interested parties that controlled blasting operations could indeed be conducted safely in close proximity to the existing oil line.

The demonstration blasting tests were designed and implemented at three sites near Fairbanks. The test sites were selected to represent geological conditions that were considered to be typical of those found along major portions of the route. During these tests, there was (1) monitoring of ground vibrations at the surface and below ground at distances of 20 feet to 80 feet from the ditch being blasted, (2) monitoring of airblast overpressures at different distances, and (3) flyrock control. Following the blasts, evaluations were made of the fragmentation that was achieved, the ease of subsequent ditch excavation, and the extent of fracturing relative to the required dimensions of the ditch. A report on the test results was prepared for Northwest by Lewis L. Oriard, Inc. and Woodward-Clyde Consultants.

The results of these blast tests demonstrated that the upper bounds of ground vibrations can be predicted reliably and that control of ground vibrations and flyrock can be exercised to whatever degree may be deemed necessary. No effort was made during these tests to include all expected geological conditions, all possible blasting techniques, or any pipeline structures. Following are some of the significant conclusions drawn from the tests:

1. The carefully controlled ditch blasting techniques utilized produced satisfactory ground breakage and trench geometry. The ground vibrations produced by these blasts were of such a low level as to be expected to have no significant effects on an adjacent buried or elevated pipeline.

2. Ground vibrations were in close agreement with values that were predicted with the use of Oriard prediction formulae. Blasting in a broader range of materials would not have added significantly to the large data base already existing.

3. In agreement with well-known theory, the tests demonstrated that ground surface vibrations have characteristically higher particle velocities than those at depth. Thus, it is conservative to monitor blasting vibrations at the ground surface. There is no need to place instruments below ground if the vibrations below ground are assumed to be equal to those at the surface.

4. Airblast overpressures were low and would not represent a significant potential for damage to an adjacent elevated pipeline.

5. Flyrock could be controlled by blasting design in combination with containment devices such as blasting mats.

4.4.2.3 SWRI Test Report

A full-scale test program was conducted in 1978 by Southwest Research Institute for the Pipeline Research Committee of the American Gas Association. In this study, both model and full-scale pipelines were used to evaluate the effects of nearby blasting on pipelines. The structures were instrumented with strain gages and velocity transducers to evaluate ground motion effects generated by nearby blasting. The final report provides a detailed description of the blasting tests and the measured effects. The report also includes statistical analyses of the data and certain empirical relationships which were developed to predict stresses induced by blasting.

Although the study was conducted in geological settings different from those found along the TAPS alignment, and other limitations restrict the application of some portions of the information, the relationships provide a valid summary of the parameters which are pertinent to the prediction of blast-induced stresses.

During the tests conducted by SWRI, it was not possible to induce yielding of buried pipelines unless explosives charges were placed within a few feet of the pipes. In one example, this constituted a charge of 15 lbs. at a distance of 6 feet from a 24-inch pipeline under an operating field environment, an order of magnitude closer than that which is anticipated for a similar charge for Northwest's proposed construction work. In reality, it is highly likely that the SWRI test pipeline was thus placed within the rupture zone of the test blast, and that the pipe was not merely subjected to an elastic stress wave but may have suffered damage due to ground displacements.

As was pointed out in this study, a complete analysis of the question requires consideration of other stresses besides those induced by blasting. These include such items as internal pipe pressure, thermal expansion or contraction, surcharge or overburden, and residual stresses from welding and other assembly processes.

Nevertheless, the SWRI study confirms the general observation made by experienced construction personnel that welded steel pipelines are more resistant to vibration damage than is generally expected.

4.4.2.4 Northwest Geotechnical Data

Northwest has implemented field studies to gather geotechnical data by means of drilling programs, resistivity studies, aerial photo interpretation, and shallow seismic refraction tests.

Northwest has generated geotechnical data from approximately 1,240 boreholes that have been drilled at various times along the gasline route. Aerial photo interpretation has been completed for the entire route, describing the site-specific terrain units along the route. Electro-magnetic resistivity methods were used to assist in delineation of the frozen and unfrozen soil. The shallow seismic refraction tests were performed to identify locations of bedrock within the depths of interest.

4.4.2.5 Oriard Data and Prediction Formulae

The Oriard prediction formulae are based on a very large volume of data gathered over several decades. One of the chief benefits of such a large data base is that it permits a quick appraisal of new data relative to norms or extremes for the type of geological setting and the type of blasting involved, and permits a more reliable prediction of effects for an untested site. For example, the results of the 1977 blasting tests were accurately predicted. Appropriate limitations can be established for future blasting with more confidence than would be the case if such data and prediction formulae did not exist.

In the absence of any test data for a new site or details of future blasting plans, it is still quite feasible to assume conservative conditions for both aspects of the questions and place reasonable upper bounds on the effects that might be anticipated. Rather than being beyond control or prediction, blasting effects can, indeed, be controlled and predicted within the bounds described above.

4.4.2.6 Alyeska and Other Geotechnical Data

Northwest has acquired the major portion of the geotechnical data applicable to blasting that was generated throughout the TAPS project. This data has an abundance of information related to the alignment of the oil line and was analyzed by NWA and used to help define the soil conditions and geotechnical features in proximity to the oil line.

Data has also been acquired from the Alaska Highway Department for those areas of concern along the highway system including the Prudhoe Bay "haul road". Certain data was also obtained from Cold Regions Research Engineering Laboratories (CRREL) from their testing along the pipeline route.

4.5 DESIGN CRITERIA

The following design criteria have been established and used as the guidelines to develop the general blasting limitations:

1. There must be no blast damage to TAPS or the haul road.

2. Developed blasting specifications must not only provide protection to existing facilities, but be prepared in such a way that the construction progress is facilitated rather than impeded.

3. The blasting plan must be economically feasible.

4. The blasting plan must be environmentally sound.

5. The quality control program for blasting must be conducive to conventional monitoring techniques.

4.6 DESIGN PROCEDURES/ALTERNATIVE ANALYSIS

4.6.1 Evaluation of Alternatives

Northwest has evaluated the feasibility of using alternative excavating methods in lieu of blasting. Alternatives include ditching machines, rock saws and impact breakers. Other alternatives include jet piercing and various forms of hard-material excavators found in underground workings. Although one or more of these alternatives may have occasional application where only a small volume of material is involved, or in extremely close proximity to a zone or structure of concern, the overall conclusion is that blasting is the most practical method for fragmenting the majority of hard materials found along the pipeline route.

4.7 SOLUTION

4.7.1 General Solution

Northwest has selected its route knowing that in some areas it will be necessary to blast in proximity to the TAPS line. However, a well-established base of experience has demonstrated that it is feasible to blast in proximity to existing pipelines, as well as more delicate facilities. Some of this experience has been verified in such demonstrations as the 1977 tests near Fairbanks, conducted by Northwest, and the research conducted by Southwest Research Institute in their 1978 study for the American Gas Association.

The general solution to minimize potentially adverse blasting effects is that of limiting surface ground vibrations to an acceptable level. The general case for the relative position of the two lines is for a nominal separation distance of 80 feet and a stable soil condition. For this condition, Northwest has proposed a blasting vibration limit of 8 inches per second for the peak particle velocity of the ground surface motion at the point of concern. A memorandum from the Executive Policy Board of Washington, D. C., dated August 29, 1978, discloses that its Geology Subcommittee on Pipeline Trench Blasting Parameters "concurs with Northwest Alaskan Pipeline Company's proposal to blast the trench at separation distance of 60 to 80 feet and to control ground shock by limiting the peak particle velocity to 8 inches per second measured at the ground surface immediately adjacent to the Alyeska pipeline." Thus, this route and the blasting limits for the general case are recognized as acceptable and feasible.

In establishing this route and the blasting limitations for the general case, Northwest reviewed existing literature; correlated published data to its project; analyzed, expanded and incorporated the 1977 test data and SWRI data; compared its general criteria to that of others and consulted experts in the field.

Northwest recognizes that special conditions will develop which depart from the general case previously described. It is Northwest's conclusion that these special cases will not impact the selected route nor the feasibility of the work, merely that specific criteria must be provided for each of the special conditions.

Northwest's solution for blasting in the general case of stable ground conditions has been reviewed by a number of qualified individuals and organizations, including the Federal Energy Regulatory Commission, Department of Transportation, Department of the Interior, House Interior Subcommittee, U.S. Army Corps of Engineers, the Executive Policy Board, explosives company technical representatives, execution contractor representatives, technical consultants, and Alyeska. There has been general agreement that the proposed route in proximity to the existing oil pipeline is technically feasible, and the blasting criteria for the general case have been approved by the Technical Subcommittee of the Executive Policy Board. Alyeska has given implicit approval to the proximity blasting question by offering recommendations for blasting criteria for different distances from the existing oil pipeline, (1) greater than 60 feet, (2) 30 to 60 feet, and (3) less than 30 feet. The feasibility of blasting along the proposed route has been recognized by all responsible concerned parties.

4.7.2 Specific Solutions

4.7.2.1 Ground Rupture Effects, Including Block Motion

It is agreed that there is a need to prevent damage from permanent ground displacements in the form of block motion, opening of weak joints or seams in rock, and similar types of ground rupture or disturbance. In the absence of knowledge of the conditions of a specific site, both Alyeska and Northwest agree that it is conservative to limit the depth of charge emplacement to about 1/4 to 1/5 of the separation distance from the existing oil pipeline (based on earlier conservative recommendations made by Oriard for field application by construction personnel).

In the majority of cases, the conservative solution cited above will not unduly inhibit the advance of the construction work.

4.7.2.2 Flyrock Control

It is agreed by all parties that there is a need to prevent flyrock damage to the existng oil pipeline. This is not a new or unique problem to blasting operations. A great deal of blasting takes place daily in close proximity to various types of structures and other facilities that are far more sensitive to flyrock damage than is the existing oil pipeline. Of course, Northwest will require the necessary flyrock control. It is proposed that the requirements will be presented in the form of specifications and call for a combination of blast design criteria and a protective system to contain any flyrock when blasting takes place in proximity to the existing oil pipeline.

4.7.2.3 Unstable Soil or Rock Masses

It has been expressed that blasting in the vicinity of unstable soil or rock slopes, or loose unfrozen soils which are capable of liquefying may induce damage to nearby facilities.

Field experience and research on these subjects have indicated that high levels of vibration can induce such effects under certain circumstances. However, it has been established that low levels of vibration do not induce these effects.

Potentially unstable slopes, and areas with high liquefaction potential, will be identified along the gas line route. At these locations, it will be specified that specially controlled blasting techniques must be used if blasting is required.

4.7.2.4 Monitoring of Blast Effects

The most suitable way to monitor blasting operations is to record the peak particle velocity of the ground surface motion generated by the blasting. The surface motion is stronger than that at depth, hence is the most conservative point of measurement, as well as being the most convenient. Particle velocity can be measured directly, and can be related to damage criteria established for the various parts of the system or the geological materials, along with any supplemental criteria that may be needed for special circumstances.

Monitoring of blast effects has become so routine that a number of competing instrument manufacturers now offer "standard" instruments for this purpose. Virtually all of these respond directly to the particle velocity of the motion being monitored, since this is the measurement most often required and most generally accepted as a suitable criterion. Some instruments are self-triggering to turn on and off automatically without the need of an operator. Some provide an instantaneous digital readout of the peak particle velocity. Thus, immediate answers are available in the field with instruments that do not require sophisticated training to operate. Such data is easily obtained and technically acceptable.

Northwest plans to use portable, easily operated, high-quality seismographs to monitor the peak particle velocity of ground vibrations generated by the blasting operations when and where such operations would be a matter of reasonable concern to nearby facilities.

4.7.2.5 Loss of Adfreeze Bond of the Vertical Support Members

It has been expressed that ground vibrations generated by nearby blasting may cause a loss of bond between the metal surface of the oil line VSM's (especially those with smooth surfaces) and the surrounding frozen backfill material.

In the normal mode of blasting at a distance of the order of 80 feet, it is expected that wavelengths will be sufficiently large, and vibration levels sufficiently low that this concern would be unwarranted.

4.7.2.6 Structural Response of the Pipeline System

The existing oil pipeline system was designed to withstand stresses induced by earthquakes. Different design earthquakes were used for different parts of the system, according to the geographical location. The route was divided into five different seismic zones, with earthquake design magnitudes varying from 5.5 to 8.5 on the Richter scale, and accelerations from 0.12 g to 0.60 g. (As pointed out by Donovan and Singh, in "Liquefaction Criteria for the Trans-Alaska Pipeline", peak values of acceleration "might range to several times as much" as these values.) Response spectra were developed for the respective earthquakes and the pipeline sections were designed to resist the motions anticipated.

Concern has been expressed about any portion of the blasting energy that might fall into the low-frequency portion of the spectrum, specifically that it not exceed any of the design spectra values below about 10 Hz. It is NWA's opinion that there will not be a significant portion of the blasting energy falling into this portion of the spectrum. An additional consideration is the very short duration of blasting vibrations in comparison to earthquake vibrations. Past experience has indicated that blasting at the level which is planned for this project has not been damaging to structures with strengths and response characteristics comparable to those of the existing oil pipeline.

4.7.2.7 Airblast Overpressures

Airblast overpressures are those pressures (typically expressed as the relative pressure above or "over" atmospheric pressure) which are generated by blasting operations and transmitted through the air to the point of interest. There are several complex variables influencing these air waves, such as the escape of explosive gases directly into the air, flexing of the ground surface at the ground-air contact, mass air movement due to displacement of fragmented rock, other blast-design factors and a variety of factors related to prevailing atmospheric conditions. Some of these air waves fall within the frequency range of human hearing, some do not. In highly populated areas, the question is of some interest because of the many secondary sound effects generated within a typical residence by these air waves (rattling of loose windows and doors, for example) which cause an adverse reaction on the part of the building occupants. Rarely are these pressures of structural concern.

Airblast does not appear to pose a hazard to the existing oil pipeline. When blasting is taking place in proximity to other facilities or features considered to be sensitive to airblast, the overpressures will be limited accordingly. This question is not considered to be a technical problem, but only a matter for routine control in special situations.

4.7.2.8 Sound Levels

Blasting is not ordinarily regarded as a significant source of noise, in the same sense as traffic or machinery, for example, because of the very short duration of blast-generated noise and its infrequent occurrence. Rather, what interest may exist for airwaves generated by blasting is normally related to the peak overpressures rather than noise levels, and the possible direct physical impact of these overpressures rather than physioacoustic effects. For ordinary ditch blasting, the control of flyrock automatically provides a sufficient measure of control for airblast overpressures. In the rare instance that sensitive structures (e.g., those containing large glass areas) should ever be encountered, it is a simple matter to monitor airblast overpressures and to limit the pressures to safe levels. This is done routinely for blasting in urban settings.

4.7.2.9 Blasting Near Streams

Explosive charges detonated in water or near water will transmit pressure pulses through the water to aquatic life in the vicinity. A sufficient amount of data exists from previous projects and research studies to predict both the pressure levels and the effects of these underwater waves. Depending on the type of aquatic life that is known or expected, these pressures can be controlled accordingly.

The experience with the evaluation of blast noises and vibrations on wildlife is much more limited than similar experience related to humans. However, the general results of experience with wildlife is comparable to that of humans and/or domestic animals in the sense that most creatures seem to become desensitized with continued exposure, and/or quickly return to "initial" conditions following the passage of the blasting activity. Some animals become desensitized so quickly that they must be herded away from the blasting area to prevent interference with the work. Northwest has, to date, learned of no experience which would suggest that a significant problem exists with regard to wildlife.

4.7.2.10 Quality Control and Inspection

It has been well established that blasting effects can be controlled to whatever degree is necessary. That is why the basic issue of proximity blasting is not a technical difficulty. Rather, the need of the present case is to provide additional criteria to meet the special cases that might arise along the route and to provide a mechanism for quality control.

Quality control is not a new subject, either in concept or in practice. The concepts and procedures related to sophisticated quality control have evolved over many years of experience with such projects as the construction of nuclear power plants, military facilities, and other well-documented, major projects. The main question is not one of feasibility, but rather an agreement on the degree of control needed and the manner of its implementation.

Quality control must be effective, but should not impede the progress of the work. In the case of blasting procedures, this is relatively simple. An inspector who has even slight familiarity with the explosives products being used can quickly and easily determine conformance with established procedures for blasting.

There seems to be no difference of opinion relative to the feasibility of blasting near other facilities. It is also apparent to most that blasting is the most convenient and expeditious means of excavating the required trench for the pipeline. The remaining concerns only relate to site specific details, philosophies related to the effects of blasting and contractor control during pipeline construction.

4.8 CONTINUING STUDIES

The above mentioned points of interest can be resolved by confirming and refining the data and blasting criteria. The blasting related studies and testing to be performed this year are a means of accomplishing this confirmation or refinement. These programs are briefly described below:

4.8.1 Pipeline Stresses

Northwest's proposed testing program will provide definitive information on pipeline stresses induced by blasting.

The program will include both analytical and experimental procedures. State-of-the-art computer software will be used to model both the blast-induced ground stresses and the pipeline response to those stresses. Computer programs will be modified as the data is gathered so that they can more accurately portray the source, the transmission paths of the energy, and the structural responses generated. Then, additional parametric studies can be conducted to determine the impact of different variables in source, medium or structure parameters. The validated, analytical model will provide the capability to make a reasonable performance prediction for situations not directly tested in the field, and will thus greatly expand the applicability of the tests.

Because of recognized limitations in theory and analytical procedures, it is the opinion of Northwest and its consultants that field confirmation is desirable. This will provide greater assurance that the established criteria are suitable and conservative.

Criteria can be refined for both the above ground and below ground pipeline modes, and will include an evaluation of pipe-soil interaction.

4.8.2 Field Programs

4.8.2.1 Block Motion, Ground Rupture and Instability

It is thought by Northwest and its consultants that previous experience has permitted the development of conservative blasting criteria, as discussed previously. However, the proposed ditch blasting test program will provide opportunities for testing and refining some of these earlier criteria. Blasting tests will include a planned variation in techniques to stimulate varying degrees of rupture, cracking and block motion, in various soil types and permit any necessary refinement of blasting criteria related to these topics.

4.8.2.2 VSM Adfreeze Bond

NWA proposes to perform field tests to evaluate the effect of blasting on the adfreeze bond between the VSMs and the surrounding frozen backfill material.

4.8.2.3 Flyrock Control

The subject of flyrock control is more a question of quality control than of technical analysis. This is well understood by those who are experienced in explosives engineering. Therefore, there is neither a need for an analytical solution nor is there such a solution to be obtained. Rather, Northwest proposes to offer field demonstrations of various blasting techniques and procedures, as a matter of illustration and information for those with less experience, and to use these as a basis for refining the quality control procedures needed to prevent flyrock damage to the existing oil pipeline and/or other facilities that might be encountered along the course of the project.

In principle, flyrock can be controlled by conservative design of the blasting plan. However, in those locations where flyrock damage is deemed a possibility, Northwest will provide suitable containment devices as an additional precaution. The field tests will serve to illustrate various features of different devices and lead to the selection of one or more of those deemed best.

Criteria will be developed to include guidelines for blast designs, and when and how to use containment devices.

4.8.2.4 Blasting Methods

During the course of the proposed testing program, various blasting techniques will be employed and compared to the effects produced. In addition to the evaluations of pipeline and VSM responses, there will be an evaluation of the blasting on the size, shape and condition of the ditch produced by each of the blasting techniques. This information will be used to establish criteria or limitations for blasting in the more sensitive areas, that is, where either the geological conditions or the proximity to existing facilities demand some control of the ditch size and geometry.

4.8.3 Refine Criteria and Develop Specifications

Northwest plans to use the testing program to determine the response of the existing oil pipeline system to vibrations induced by blasting. Northwest plans to investigate this question both theoretically and by actual monitored response of a field model. This response will be compared to the design criteria established earlier. It is expected that this exercise will demonstrate the conservativeness of the limits already established and approved for the general case of stable conditions, and will provide a basis for establishing other limits for special cases that might be encountered.

The testing work planned for this program is a carryover from the 1977 blasting program. It was known that site specific questions would require resolution. After analysis of the data now available and more site specific geotechnical analyses, it is possible to generate useful information that can be readily correlated into the blasting limitation refinement and ultimately into the construction specifications. The programs for this year as presently established offer unique opportunities to utilize several programs to generate data that can be used in this particular concern. Programs requiring ditching in frozen ground (trench stability and construction compatibility) are a good source for blasting data in the various soils to enable gathering of information from a wide variety of conditions.

At the conclusion of the proposed testing program, Northwest and its consultants will refine blasting criteria and develop construction specifications.

4.8.4 Other Continuing Studies

Evaluations and refinements will not terminate at the conclusion of Northwest's testing program. Rather, they will continue throughout the construction period. There will be an ongoing update of the latest research and field experience by Northwest and its consultants, providing a constantly refined state-of-the-art evaluation of the work. Any new knowledge which can increase the safety of the work, improve its efficiency or lower its cost will be considered and evaluated. This includes not only outside research and experience, but an ongoing evaluation of onsite experience on this project. Subjects which will be reviewed and updated include:

- Blasting technology.
- Blasting effects (prediction, measurement and control).
- Analytical modeling (source, medium and structures).
- Adfreeze bonding (nature, behavior, influence of outside forces).

- o Alyeska seismic design criteria in comparison to blasting effects.
- o Geotechnical analyses and evaluation of physical properties and behavior of materials in-situ.
- o Pertinent literature.
- o Distances to existing facilities and depths of excavation.

4.9 POTENTIAL FOR CHANGES

Northwest considers that there is a practical solution for each blasting question that may arise. The various participants in this issue have made it clear that blasting can be safely accomplished within the present constraints of the pipeline routing, even at separation distances less than 30 feet. Site specific instances may occur requiring more restrictive blasting control due to such conditions as short sections of unstable soil, critical fish and wildlife habitat, unique design of adjacent facilities, and others.

It is contemplated that there would be no portions of the pipeline routing that would require significant alignment alterations. Site specific concerns can be relieved by stricter blasting control limitation, adjusting construction scheduling for problematic areas, or slight pipeline relocations. Also, other methods of ditch excavation could be employed if conditions were of a severe enough nature to warrant such an approach.

5.0 RISK ANALYSIS

5.1 STATEMENT OF CONCERN

"Northwest needs to provide a risk analysis concerning the impacts of the gas pipeline on the oil pipeline (and vice versa) with respect to construction activities and pipeline explosions. Northwest should consider using the Alberta blast test to evaluate burial depth and separation distance, since damage to the oil pipeline in the event of an explosion of the gas pipeline will likely be from a direct hit of flying debris."

NOTE: A risk analysis is currently in progress which will address the concerns noted above. The analysis is not yet complete. The analysis is described in two parts. Part A describes the evaluation of risks to the oil pipeline posed by the gas pipeline during construction and evaluation of risks to the gas pipeline posed by the oil pipeline during construction. The second part of DOI's concern, "pipeline explosions," is addressed in Part B which describes the analysis of probabilities of oil or gas pipeline failures which may occur during operation, and the possible effects of such failures.

PART A, PIPELINE CONSTRUCTION ACTIVITIES

5.2 DEFINITION OF ISSUES

One principal concern is the need to assess the risk associated with construction of the gas pipeline in proximity to the oil pipeline. The potential adverse consequences include damage to either pipeline or disruption of the oil pipeline operation. The specific risks to the oil pipeline being considered are: direct pipeline damage, failure of pipeline associated facilities and equipment (vertical support members, bridges, pump stations, block valves, control systems) fire, and vandalism. Also of concern are the risks to the gas pipeline during construction due to operation, maintenance, and repair of the oil pipeline. Each of these specific risks is discussed in the following section.

5.3 CATEGORIES

Each concern identified in 5.2 is further defined and the elements that affect the potential impact for each concern are discussed in this section. Both the probability of the event, and the consequences of the event (system downtime, extent of damage, repair time, etc.) are being considered.

5.3.1 Direct Oil Pipeline Damage

The risks to the oil pipeline directly are identified in this subsection.

Construction equipment impact is a potential mode of oil pipeline damage. This category includes earthmoving equipment, pipe handling equipment, material and personnel transportation equipment (including helicopters) and other associated equipment.

The risk of a joint of pipe impacting the oil line is a concern. Possible scenarios include the pipe sliding freely on grade, impacting the oil line end-on while being manipulated, or being dropped onto the oil line. There is an increased risk of impact at gas pipeline/oil pipeline crossings.

Elements which affect the probability of construction equipment or pipe joints directly impacting the oil pipeline include the following:

- Traffic flow, density of construction traffic
- Proximity of construction activity to the oil pipeline
- Access road layout with respect to the oil line
- The reliability of construction equipment
- Safety procedures employed by construction personnel
- The layout of the safety barrier with respect to the adjacent facilities
- The local terrain
- Weather conditions
- Aufeis formation on access roads or workpads

Excavation blasting occurring during construction of the gas line poses a risk to the oil pipeline due to flyrock, where the oil pipeline is above ground, and due to ground motion, where the pipeline is below ground. The probability of direct damage to the oil pipeline caused by excavation blasting is influenced by the following parameters:

- o Proximity of the excavated ditch to the oil pipeline
- o Blasting procedures and quality control procedures (including crew experience, charge weight, spacing and blasting sequence, length of ditch blasted in a single sequence, type of blast mat)
- o Rock or permafrost properties
- o Configuration of oil line: above or below ground

There is also a risk of terrain instability caused by construction activities; soil slides and erosion are examples. The definition of the risk due to slides or erosion involves incorporation of the following information:

- o Terrain description
- o Soil description: type, water content, loading condition (surcharge)
- o Temperature: seasonal variation, thermal gradient
- o Excavation, from either new or previous construction

At river or stream crossings, the possibility of construction activity causing flooding or ice damming is being considered. Either of these phenomena could pose a risk to the oil pipeline. Moreover, any alteration in terrain drainage characteristics or groundwater characteristics could lead to aufeis formation which, under certain circumstances, may affect the oil pipeline.

The risk of flooding or ice damage is influenced by the following:

- o River crossing design: buried or aerial
- o Construction methods: ditching, backfilling, etc.

- o Time of year

- o Aufeis formation: soil conditions, construction interference with existing drainage paths

5.3.2 Failure of the Oil Pipeline Associated Facilities and Equipment

The risks of failure of the oil pipeline associated facilities and equipment are summarized in the following paragraphs.

The vertical support members (VSMs) could fail as a result of the effects described for the pipeline in 5.3.1 above:

- o Equipment impact

- o Pipe joint impact

- o Excavation blasting; flyrock and ground motion

- o Slides and erosion

- o Flooding, ice and aufeis

The additional risk of thermal degradation of the adfreeze bond is being evaluated.

Elements that affect the risk associated with loss of a VSM are similar to those identified for direct pipeline damage above plus:

- o Shock resistance of the adfreeze bond (blasting effects)

- o Thermal effects on the adfreeze bond caused by nearby excavation, incorporating ditch configuration, ditch proximity, soil type, time of year.

The risk of damage to, or collapse of, the Yukon River bridge due to construction traffic, construction activity on the bridge, or undermining of the abutments must be evaluated. The following elements affect this risk:

- o Construction activity on the bridge: type of equipment, construction procedures

- o Construction traffic on the bridge: weight and number of vehicles

- o Excavation activity: effect on bridge abutment foundation system

Other potential modes of disruption of oil pipeline operation involve pump station failure due to damage to the fuel gas line, inadvertent block valve closure or control and instrumentation system failure. Damage to the fuel gas line could be caused by any of the events similar to those which could damage the belowground oil pipeline.

The risk of direct damage to pump station equipment is expected to be small due to separation of construction activity and the pump stations. Elements that might affect the risks of pump station failure or inadvertent TAPS shutdown are:

- o Fuel gas line location, cover, proximity, and strength
- o Work pad (over gas line) construction procedures and equipment
- o Blasting parameters
- o TAPS control system design
- o TAPS operation and shutdown procedures

5.3.3 Fire

The risk posed to the oil pipeline caused by construction related fire (brush clearing, garbage fires, warming fires, refueling operations) is another concern. The following elements could affect the risk to oil pipeline facilities caused by construction related fire:

- o Construction equipment refueling procedures
- o Brush clearance and disposal procedures
- o "Housekeeping" procedures, warming fires and trash fires
- o TAPS operation procedures, action in the event of a fire

5.3.4 Vandalism and Sabotage

There is a potential for willful damage to oil pipeline related facilities caused by construction personnel or others gaining access to the oil pipeline during construction. The risk to the oil pipeline caused by vandalism and/or sabotage is affected by:

- o Personnel selection procedures
- o Security procedures

5.3.5 Damage to the Gas Pipeline Caused By Operation, Maintenance, and Repair of the Oil Pipeline

There is a risk of damage to the gas pipeline caused by oil pipeline operation, maintenance, and repair. The greatest risks exist during gas line construction prior to backfilling, while the pipe is on skids or in the open trench. The risk posed to the gas pipeline during construction is affected by:

- o TAPS maintenance and repair procedures: frequency, type of equipment
- o Damage-sensitivity of gas pipeline facilities while the pipeline is under construction

Looping of the oil pipeline would pose risks to the gas pipeline (and the existing oil pipeline) similar to those described for gas pipeline construction.

5.4 DATA ACQUISITION

Data required for this risk analysis consists of descriptions of the oil pipeline, the gas pipeline, construction methods, construction experience, pipeline operating experience and blasting experience. Sources of data to be investigated include TAPS design, operation, and construction data; pipeline construction statistics; general construction statistics; existing blasting tests; and construction contractor interviews.

5.4.1 TAPS Data

Available information on TAPS will be reviewed to characterize its vulnerability to gas pipeline construction accidents and to identify TAPS operations which may pose risks to the gas pipeline during construction. As-built design data will be obtained from TAPS drawings, available TAPS reports and pipeline alignment sheets. Procedures for TAPS operations, maintenance and repair will be reviewed. In addition, TAPS construction records, accident reports and construction equipment maintenance data will provide statistical and historical information on pipeline construction activities in the Alaskan environment.

5.4.2 Pipeline Construction Statistics

Statistics for pipeline construction accidents will be obtained through reviews of information compiled by U.S. government agencies and petroleum industry associations. The following potential data sources have been identified:

- Reports of the Office of Pipeline Safety Operations (Department of Transportation)
- Annual Report on the Administration of the Natural Gas Pipeline Safety Act of 1968
- Special Study on Prevention of Damage to Pipelines (National Transportation Safety Board)
- Monthly Pipeline Products Reports of the Division of Oil and Gas Statistics (Department of Energy)
- Interstate Commerce Commission Transport Statistics in the U.S., Part 6, Pipelines

In addition, the American Gas Association and Gas Research Institute are potential industry sources for pipeline construction and operation-related accident statistics.

5.4.3 General Construction Statistics

General statistical information on construction equipment reliability and accidents will be sought from records of the American General Contractor's Association and the Occupational Safety and Health Administration. Additional maintenance and repair records for the types of equipment to be used in the gas pipeline construction will be sought through construction equipment manufacturers.

5.4.4 Existing Blasting Tests

Data from blasting tests will be used to assess the risks posed by flyrock and ground movement. Considerable data are already available from blasting tests conducted by Southwest Research Institute, Northwest Alaskan Pipeline Company, and other industry sources.

5.4.5 Construction Contractor Interviews

It is anticipated that recorded statistical information with regard to some potential construction risks will need to be supplemented by the unrecorded field experience of construction personnel. This information will be obtained through interviews with personnel closely associated with the TAPS pipeline construction and other industry experts.

5.5 ANALYSIS CRITERIA

5.5.1 Levels of Damage

In order to quanitfy the risks to the oil pipeline, it is necessary to identify the various levels of impact which can by hypothesized. For this analysis three levels are defined. They are distinguished by the impact on the TAPS flow of oil.

Level 1: Damage whose repair may be performed without delay or interruption of the oil pipeline flow. This level of damage includes superficial damage to the oil pipeline (e.g., torn or damaged pipeline insulation) which has no impact on the continuous normal flow of oil to the storage facilities at Valdez.

Level 2: Damage or failure resulting in interruption of oil pipeline flow but not delays in shipments from Valdez. This level of damage will result in temporary shutdown of the oil pipeline. It includes damage whose immediate repair is not necessary but which can be accomplished through a scheduled pipeline shutdown. It also includes damage resulting in short-term unplanned pipeline shutdown. In either case, the oil stored at Valdez is not exhausted during the shutdown, so that there is no delay in oil shipments.

Level 3: Damage resulting in interruption of oil pipeline flow and delays in shipments from Valdez. This level of damage is characterized by a pipeline shutdown of sufficient duration as to exhaust the Valdez oil storage.

Some events resulting in Levels 2 and 3 damage may involve a significant spill of oil. The magnitude of the risk associated with construction of the gas pipeline is influenced by the likelihood of such events. Therefore, an additional criterion on significant oil spills will be used in the analysis. All possible events hypothesized will be evaluated with respect to the potential for such spills.

5.5.2 Assessment of Risk

Sequences of events resulting in oil pipeline damage will be constructed. The extent of the resultant damage will be categorized according to the levels outlined in 5.5.1. The probabilities of the occurrence of individual (primary) events will then be statistically combined in order to estimate an overall probability for the occurrence of each of the three levels of damage.

5.5.3 Need for Mitigative Action

The risk assessment will identify the need, if any, for possible action to reduce the probability of a level of damage. It will also identify those factors contributing most significantly to the probability of a level of damage, thereby highlighting mitigative actions which will be most effective in reducing overall risks.

5.6 ANALYSIS PROCEDURES

5.6.1 Study Initiation

At the onset of the risk assessment study, an initiation meeting was held to prepare the work plan, collect data on TAPS and the Northwest pipeline, and develop preliminary hazards and failure modes lists.

5.6.2 Oil Pipeline Structural Resistance Evaluation

The resistance of the oil pipeline, and its support systems, to the type of damage outlined in Section 5.3 will be evaluated. The resistance of the pipeline to direct damage, and the resistance of the VSMs to damage will be evaluated separately.

The resistance of the oil pipeline to the following phenomena will be calculated:

- o Impact (equipment, pipe joint, and projectile)
- o Support loss (erosion or VSM loss)
- o Ground movement (caused by slides)
- o Ground motion (caused by blasting)

The calculations of the effects of ground movement and support loss will be based on beam theory taking into account the existing state of stress of the pipe due to pressure and thermal loading. The available TAPS design data provides most of the information necessary for these calculations.

The resistance of the above ground pipeline to impact will be computed by energy balance techniques. The energy-absorbing properties of the insulation are accounted for. The impact-resistance of pipeline appendages, such as pressure and temperature gauge nipples, will also be evaluated.

The resistance of the below ground pipeline to ground motion caused by blasting will be evaluated on a preliminary basis using simplified techniques. The results of this evaluation will be updated when the results of the blasting evaluation program, described in 4.0, become available.

The resistance of the VSMs to the following phenomena will be calculated:

- o Impact (equipment, pipe joint, projectile)
- o Ground motion (caused by blasting)

The calculation of impact resistance will use TAPS design data and employ energy balance techniques. The possibility of the impact damaging the passive refrigeration system and therefore possibly affecting the adfreeze bond will be considered.

The calculation of resistance to ground shaking will be based on simplifying assumptions of the modes of vibration of the VSM-pipeline system, the shear strength of the adfreeze bond, and the frequency content of ground motion. TAPS design data will be used to the greatest extent possible.

5.6.3 Oil Shipment Interruption Analysis

This task includes an assessment of the probability that an oil line shutdown of finite duration will cause interruption of crude shipments, considering the oil storage and operational capabilities of the Valdez terminal. Data will be collected through reviews of industry records and interviews with government and oil industry personnel. The product of the task will be a probability distribution function of the Valdez stored oil volume to be used in assessing the probability of Level 2 or Level 3 damage.

5.6.4 Failure Modes and Effects Analysis

This task includes a failure modes and effects analysis for each of the risk modes identified in Section 5.2. For each failure or damage mode the analysis will include:

- o Identification of possible event scenarios leading to that failure or damage mode
- o Quantification of the possible effects for each event scenario
- o Characterization of damage, according to the criteria of Section 5.5.1, including estimation of repair times, for each event scenario
- o Determination of possible protective measures which would reduce the probability or mitigate the consequences of each event scenario

5.6.5 Probability Estimate

This task includes estimating probabilities for each event scenario identified through the activities of section 5.6.4. Primary failure rates will be estimated for events in each scenario based on data reviews, physical analysis and judgement. Simple fault trees will be constructed for each scenario.

The DOI concern regarding the relationship of risk and separation distance expressed in the W. M. Toskey letter of June 12, 1980 will be addressed.

5.6.6 Construction Personnel Interviews

In order to gain additional information regarding the construction of TAPS, construction risk probability estimates, and failure modes and effects, personnel interviews will be conducted. The interviews will be conducted in person or by telephone with appropriate personnel representing contractors involved in the construction of the oil pipeline. The collective judgment of these personnel will be used to reinforce and/or modify the failure modes and effects and the probabilities associated with each.

5.6.7 Risk Combination

The probabilities of each failure mode will be combined to derive the overall risk of oil pipeline damage and oil shipment interruption. This will be accomplished by considering the simple fault trees for each scenario, the damage characterization for each scenario, the assigned probabilities and the Valdez oil volume probability distribution function. The result will be probabilities for each level of oil pipeline damage.

5.6.8 Parametric Analysis

Parametric analyses will be used to establish the sensitivity of the risk estimates to individual elements of the fault tree, and to reasonable variances in the assigned probabilities. The overall risk as a function of pipeline separation distance will be investigated. The results will also identify additional information requirements and major contributors to the overall risk.

5.6.9 Assessment of Risk to the Gas Pipeline Due to the Operation, Maintenance and Repair of the Oil Pipeline

This task will determine the probability of damage to the gas pipeline, during construction, due to the operation of the oil pipeline. Failure modes will be identified and will include direct gas pipeline damage, due to:

- o Collision by oil pipeline maintenance or repair equipment, or
- o Oil pipeline burst

Event scenarios will be constructed for each damage mode and damage criteria (e.g., delay in construction, damage to equipment) will be identified. The impact of each scenario will then be assessed and potential protective measures outlined.

Additional data will be needed in order to assign probabilities to each scenario. The data will be obtained through reviews of TAPS maintenance procedures, statistics on oil pipeline failures and repairs, and additional interviews with TAPS maintenance and repair personnel. From this data, primary failure rates will be assigned to each scenario. The probabilities for each failure mode will then be statistically combined to give the overall probability of damage to the gas pipeline.

5.6.10 Documentation

A final report will be written. This report will summarize the results of the study, identify key assumptions that were made, explain limitations associated with the conclusions, and recommend further testing and analysis or protective measures, as appropriate.

5.7 SOLUTION

5.7.1 Expected Results

The risk analysis is currently in progress. It will provide an independent evaluation of the gas pipeline design from the standpoint of pipeline construction risks. The final pipeline design is based on previous pipeline engineering experience, construction experience, current regulatory requirements, engineering analysis, and sound engineering judgement. Because the design was selected from among various alternatives on that basis, the results of the risk analysis are expected to demonstrate that the design is, in general, acceptable.

5.7.2 Unacceptable Results

It is possible that certain specific locations or construction procedures are associated with an unacceptable risk. Such high risk contributions of particular damage modes will be corrected through one or more of the following actions:

- o Construction procedure modifications
- o Design modifications
- o Minor local site specific realignments

These corrective actions are not considered likely to result in substantial changes to the planned design or alignment.

5.8 Continuing Studies

Numerous field test programs will be conducted during 1980 to obtain data pertinent to the design of the gas pipeline and auxiliary facilities. It is expected that results from these programs will provide additional input data to support and supplement this risk analysis program.

5.8.1 Hydrological Field Programs

- o Unusual Floods
- o Pre-breakup Survey
- o Breakup Survey
- o Low-Level Stream Photography
- o Stream Geometry
- o Groundwater Observation

5.8.2 Pipeline Design Field Programs

- o Ditch Stability and Blasting Tests
- o Construction Compatibility Tests

- o Yukon Bridge Study

5.8.3 Civil Design Field Programs

- o Delta North Material Sites
- o Access Road Location and Survey
- o Pipeline Route Survey
- o Workpad Assessment
- o Atigun Pass Study

5.8.4 Geotechnical Field Programs

- o Ice Dam Testing for Cross-Drainage
- o Slope Stability/Liquefaction
- o Soil Deformation and Resistance
- o Ground Temperature Measurements
- o Drilling Program

5.9 Potential for Changes

The results of the continuing studies described in 5.8 will serve to improve the accuracy of the risk analysis and also may modify the risks associated with specific damage modes. Design changes required to satisfy criteria other than risk will cause changes in the basis of the risk analysis. Modifications in construction procedures will also cause changes in the basis of the risk analysis. The analysis will be updated to account for all such changes.

PART B, PIPELINE OPERATION ACCIDENTS

5.2 DEFINITION OF ISSUES

The risk of an accident during operation in one pipeline which causes damage to the other pipeline is a second DOI concern. Operations period risks are vastly diminished from those risks during construction. However, accidents which could cause such damage are: gas pipeline failure (leak or rupture); internal ignition in the gas pipeline and consequent rupture and fire; and oil pipeline failure (leak or rupture). These types of failures and the elements affecting the risks are discussed in Section 5.3.

This part of the analysis is being limited to evaluation of the effects of accidents involving each pipeline upon the other pipeline. In assessing the risk under each of the categories, impact of externally-initiated events of vandalism and sabotage will be taken into account. The risks to both pipelines associated with construction of additional pipelines, looping of the gas or oil pipelines, or major repair of the gas or oil pipelines are identical to those being evaluated in Part A of this analysis. The mutual risks to each pipeline associated with routine surveillance, maintenance and minor repairs is expected to be very small due to the frequency, amount of equipment, and qualifications of personnel involved.

5.3 CATEGORIES

Each of the events identified in 5.2 are discussed in this section.

5.3.1 Gas Pipeline Failure

The risk of a gas pipeline accident damaging the oil pipeline is affected by the individual probabilities of the following events:

- Pipeline leak or rupture
- Flying debris

- o Ignition and Fire
- o Debris impacting oil pipeline
- o Fire engulfing oil pipeline
- o Fire damaging oil pipeline or associated facilities

The design and construction practices minimize the probability of a leak or rupture. External sources are for the most part responsible for pipeline failures.

The probability of creation of flying debris is dependent upon whether the accident is a leak or a rupture, and whether, if a leak, the resulting gas pocket ignites. The debris will comprise backfill material and may include surrounding soil material and/or pipe material.

The probability of fire engulfing the oil pipeline depends upon the proximity of the pipelines and the prevailing winds. The probability of fire damaging TAPS depends on the wind direction, proximity of the pipelines and duration of the fire.

5.3.2 Internal Ignition in Gas Pipeline

The probability of sufficient oxygen to permit internal ignition being present in the gas pipeline during operation is insignificant. There is a possibility of a volatile mixture occuring during purging and packing. The probability of such a mixture igniting is being evaluated. The effects of internal ignition would be similar to those described for gas pipeline failure and fire described in 5.3.1.

5.3.3 Oil Pipeline Failure

The risk of an oil pipeline accident damaging the gas pipeline is affected by the individual probabilities of the following events:

- o Pipeline leak or rupture
- o Oil ignition
- o Fire approaching gas pipeline

The probability of an oil pipeline leak is affected by the same elements as the probability of a gas pipeline leak described in 5.3.1.

The probability of fire approaching the gas pipeline is governed by the drainage and wind direction. For a short duration fire, the effect on the below ground gas line will be minimal, but for longer duration, a significant possibility of gas pipeline failure arises.

5.4 DATA ACQUISITION

Data regarding pipe failure mechanisms and their probability of occurrence come from Department of Transportation statistics and operating records of the pipeline industry.

5.4.1 Department of Transportation

The Department of Transportation Office of Pipeline Safety Statistics has compiled records of pipeline failures in the United States. Accident report data (event type, existence of fire or debris, pipeline elevation and size) have been recorded on magnetic tape. The relevant data on this tape are currently being processed.

5.4.2 Industry Operating Records

The statistical data of the Department of Transportation is being supplemented by the available operating records of gas transmission companies. Much of this operations data is included in the Department of Transportation statistics.

Additional data, not included in the DOT statistics, comes from the operating experience of Canadian pipeline companies (Alberta Gas Trunk Line, Alberta Natural Gas) and other foreign pipeline operations.

5.4.3 Burst Tests

Available burst test data, from programs conducted by Northwest and the Canadian Arctic Gas Study Group, do not provide information pertinent to establishing probabilities of pipeline failures. These data do, however, supply information for pipeline crack progagation.

5.5 ANALYSIS CRITERIA

Three levels of damage to the pipelines are defined.

Level 1: Damage whose repair may be performed without delay or interruption of the oil pipeline flow.

Level 2: Damage resulting in interruption of oil pipeline flow but not delays in shipments from Valdez.

Level 3: Damage resulting in interruption of oil pipeline flow and delays in shipments from Valdez.

As before, sequences of events resulting in pipeline damage, due to adjacent pipeline failure will be constructed and the resultant damage categorized according to the above damage levels. Probabilities assigned to primary failure modes will then be combined to establish overall probabilities for each level of damage. Potential mitigative actions to reduce the overall risk will be identified if necessary

5.6 ANALYSIS PROCEDURE

5.6.1 Analysis Initiation

The analysis was initiated by identifying sources of data related to the mechanisms and probabilities for large diameter pipeline failure (see section 5.4). In addition, potential failure modes to be considered in the study were listed (see section 5.2).

5.6.2 Failure Modes and Effects Analysis

Event scenarios leading to each of the potential failure modes will be constructed. For each event scenario, potential damage will be quantified and characterized according to the damage criteria of section 5.5. The damage assessment will consider pipeline design features, such as material specifications and wall thickness. Also, for each scenario the time required for the repair of damage will be estimated and possible protective measures identified.

5.6.3 Probability Estimate

Probabilities for the occurrence of pipeline failures will be estimated from a review of the Department of Transportation pipeline safety statistics and industry operating records. Probabilities for seismic events will be assigned from U.S. Geological Survey data and from NWA data.

Overall damage probabilities will be estimated by combining probabilities for each pipeline failure/leak scenario. Parametric analyses will then be used to establish bounds on the risk analysis through examination of the effects of reasonable variations in the assigned primary failure probabilities and to examine the dependence of the risk on pipeline separation distance.

5.6.4 Documentation

Results of the analysis of risk due to pipeline failures will be documented in a final report. The report will discuss analysis assumptions, list input data and identify analysis limitations. Finally, the report will contain recommendations for protective measures to reduce overall damage risk, if necessary.

5.7 SOLUTION

5.7.1 Expected Results

The risk analysis is currently in progress. It will provide an independent evaluation of the gas pipeline design from the standpoint of pipeline failures during operation. The final pipeline design is based on previous pipeline engineering experience, construction experience, current regulatory requirements, engineering analysis, and sound engineering judgement. Because the design was selected from among various alternatives on that basis, the results of the risk analysis are expected to demonstrate that the design is, in general, acceptable.

5.7.2 Unacceptable Results

It is possible that certain specific locations or procedures are associated with an unacceptable risk. Such high risk contributions of particular damage modes will be corrected through one or more of the following actions:

- Procedure modifications
- Design modifications

These corrective actions are not considered likely to result in substantial changes to the current design or alignment.

5.8 CONTINUING STUDIES

Field test programs planned for 1980 will provide additional data to support the design of the gas pipeline. Programs which will provide information to confirm or extend the present risk analysis of pipeline failures include:

- o Construction compatibility tests
- o Yukon Bridge study
- o Soil deformation and resistance tests

5.9 POTENTIAL FOR CHANGES

The results of the 1980 field test program will provide additional data; the risk analysis will be updated to include these data. The pipeline material and welding specifications are not yet definite; the risk analysis will be updated when the final specifications become available. Changes in the design of the pipeline or construction procedures will have an effect on the risk analysis; the analysis will be updated when these changes occur.

6.0 SEISMIC

6.1 STATEMENT OF CONCERN

"The design criteria should locate and analyze active faults and should include appropriate values for ground motion and duration of seismic shaking of such earthquakes."

6.2 DEFINITION OF ISSUES

6.2.1 Location of Active Faults

In accordance with the Federal stipulations to safeguard the integrity of the completed pipeline, information on active faults that may be crossed by the pipeline will be incorporated into the pipeline design. Location of active faults is necessary in order to delineate the sections of pipeline where fault crossing design is to be applied and to avoid the siting of compressor stations in these zones in accordance with the stipulations.

6.2.2 Analysis of Faults

Site-specific design of the pipeline to resist failure at active fault crossings requires site-specific information on fault parameters (see Section 6.3.1) in order to select and design the appropriate mitigative mode (see Section 6.6.1).

For purposes of the above studies, the term significant fault has been used and is defined as an active fault crossed by the pipeline route. Further, a candidate significant fault is defined as either:

- o An active fault or a lineament that exhibits geomorphic features characteristic of active faults at a distance from the pipeline route but cannot be traced across the pipeline route, or does not exhibit characteristics of active faulting where crossed by the pipeline route:

- o A lineament or fault associated with microseismic activity:

- o A previously mapped bedrock fault of unknown activity that is crossed by the pipeline route:

- o A combination of these factors.

6.2.3 Ground Motion Values

Earthquake ground motion values are needed for seismic design of aboveground and below-ground structures. Ground motion values are also necessary for geotechnical terrain stability assessment, including slope and thaw plug stability and liquefaction.

For below ground pipe, it is considered that the pipe deforms with the ground, and the strain in the ground will be transmitted to the pipe without attenuation. Consequently, the strain (and resulting stress) in the pipe is determined predominantly by ground velocity and to a much lesser extent by ground acceleration.

For aboveground pipe and structures, somewhat lower ground motion values are appropriate which take into account the various energy absorption mechanisms, both in the ground and in the element, including radiation of energy into the ground from the responding element. Ground motion values are used to construct response spectra for seismic design of aboveground pipe and facilities.

Accordingly, values of ground motion are needed, consistent with the stipulated earthquake magnitudes distributed along the pipeline route.

6.2.4 Duration of Seismic Shaking

Duration of seismic shaking is used in conjunction with corresponding ground motion values to assess seismic settlement, slope stability and liquefaction potential of soils (discussed in Section 3, Geotechnical) and in arriving at spectrum-compatible time histories of earthquake ground motion. These time histories are used for developing in-structure response spectra of aboveground facilities and for analysis of seismic strains in buried pipe.

6.3 CATEGORIES

6.3.1 Characteristics of Fault Parameters

For design at active fault crossings, the following questions regarding fault parameters have to be addressed:

- What is the probability of surface displacement along the fault during the operational life of the pipeline (recurrence interval)?

- What is the probability that surface displacement will take place at the pipeline (fault length and location and rupture length)?

- How much surface displacement is likely (displacement per event)?

- Over how wide a zone is the surface displacement likely to occur (fault zone width)?

- What is the geometry of the fault relative to the pipeline (fault trend, dip of fault plane)?

- What is the displacement geometry likely to be (fault type)?

6.3.2 Seismic Zones

The route is subdivided into seismic zones as specified in the draft stipulations (Enclosure A). The pipeline design criteria consider these guidelines (see Section 6.5.1).

6.3.3 Foundation Conditions

Design values as outlined in Dr. Newmark's draft report (see Section 6.4.3, Reference 6) are given for effective accelerations, velocities and displacements for two types of foundation or soil conditions:

- Rock, permafrost or limited depth of sediment over rock

- Deep sediments

6.4 DATA ACQUISITION

6.4.1 Necessary Data

In addition to borehole logs of soil strata, the following seismic data are needed for design:

- Earthquake magnitude

- Ground acceleration, velocity and displacement values

- Fault morphology, fault movement parameters and fault location

- Estimates, based upon geologic data, of maximum earthquakes that may be associated with faults in the region surrounding the ANGTS corridor.

- Probabilistic analysis of ground motion values, at points along the pipeline, based upon magnitude-distance attenuation relationships.

6.4.2 Data Acquired to Present

6.4.2.1 Delta Junction to Canadian Border

Data for seismic design has been obtained from:

- Review of available geoseismic literature, data, and research.

- Acquisition and analysis of satellite, aerial and low-sun-angle photographs encompassing an area within a 150-km distance of the pipeline route.

- Aerial and ground reconnaissance of selected lineaments and faults identified from the above information.

No significant faults have been positively identified in the pipeline corridor between Delta Junction and the Canadian border from the above data and studies. Eight candidate significant faults and 250 lineaments were studied in the area encompassing the pipeline route. These have been reduced to three candidate significant faults in proximity to the pipeline route in this area. They are the Alaska Range front, Mansfield Creek fault and Tok River lineaments. Further study (see Section 6.8) is designed to determine whether or not these are significant faults.

Maximum estimated earthquake magnitudes that may be associated with faults in the region were developed (see Section 6.4.3, Reference 3) to confirm the stipulated earthquake magnitude and as input to the earthquake engineering consultant for use in establishing ground motion values. The magnitude estimates are conservative and are based upon fault parameters including fault length, length of previous ruptures, type and amount of displacement, and rate of displacement. This information was derived from the acquired regional geologic data cited above, where available.

6.4.2.2 Delta Junction to Prudhoe Bay

A review (see Section 6.4.3, Reference 2) has been completed of available geoseismic literature; pertinent, available non-proprietary geologic data; and current research in geology, seismology, and geophysics by selected researchers at the U.S. Geological Survey, the Alaska Geological and Geophysical Surveys, and the University of Alaska.

6.4.2.3 Earthquake Engineering Consultant

Dr. N. M. Newmark has been retained as earthquake engineering consultant to the project. He was selected for his internationally-recognized expertise and because he developed the seismic criteria used previously for TAPS. Dr. Newmark is also serving as earthquake engineering consultant to Foothills and has prepared the seismic criteria for that portion of the system.

He has prepared preliminary seismic design criteria (see Section 6.4.3, Reference 6) based upon the above-cited geoseismic information and other factors, including his previous work for oil and gas pipelines in Alaska and Canada, and considering the design criteria for TAPS and other gas pipelines. His criteria recommendations are described in FERC Exhibit Z-9.0, Section 3.3, Seismic Design Criteria. Ground motion values are provided in FERC Exhibit Z-9.1, Table 1-1 and procedures to provide for fault motions are discussed in Exhibit Z-9.1, Paragraph 1.14.5. It is Newmark's stated opinion that since his preliminary recommended design bases were established using limited data available to define the seismic hazard, they are purposely more conservative than they might be when further planned field studies and other investigations are completed.

Dr. Newmark has been serving as consultant to the project since September 1979. In early 1980, Dr. Newmark was forced to reduce his project activity for health reasons and requested that his long-time associate, Dr. R. P. Kennedy of Structural Mechanics Associates, represent him at meetings regarding seismic criteria.

6.4.3 Bibliographic References

1. Identification of Candidate Significant Faults in the Delta Junction-Yukon Territory Border Section of the Alaska Natural Gas Transportation System Corridor, Woodward-Clyde Consultants, January 22, 1979.

2. ANGTS Fault Study, Review of Data, Alaska Natural Gas Transportation Corridor, Prudhoe Bay to Delta Junction Alaska. Woodward-Clyde Consultants, March 28, 1980.

3. ANGTS Fault Study, Estimates of Earthquake Magnitudes, Delta Junction to the Yukon Territory Border, Woodward-Clyde Consultants, March 31, 1980.

4. Interpretation of Low-Sun-Angle Aerial Photographs of Candidate Significant Faults, ANGTS Corridor Delta Junction to the Yukon Territory Border, Woodward-Clyde Consultants, January 29, 1980.

5. Potential Fault Crossings along the Alaska Natural Gas Transportation Corridor, Delta Junction, Alaska to the Yukon Territory Border, Woodward-Clyde Consultants, January 29, 1980.

6. Rough Draft Seismic Design Criteria for ANGTS Pipeline Project, N. M. Newmark, February 28, 1980.

6.5 DESIGN CRITERIA

6.5.1 Stipulations

Department of Interior Stipulations form the bases for the seismic design. These Stipulations are as follows:

> "3.2.1.1 The PIPELINE shall be designed by appropriate application of modern, state-of-the-art, seismic design procedures to protect the PIPELINE from the effects (including seismic shaking, ground deformation and earthquake-induced mass movements) of earthquakes distributed along the route as follows:

ZONE	RICHTER MAGNITUDE
Canadian/Alaska Border to Big Delta	6.5
Big Delta to 67 deg. N	7.5
67 deg. N to Prudhoe Bay	5.5

"3.2.2.1 Prior to applying for a NOTICE TO PROCEED for any CONSTRUCTION SEGMENT, the COMPANY shall satisfy the FEDERAL INSPECTOR that all recognizable or reasonably inferred faults or fault zones along the alignment within that segment have been identified and delineated and any risk of major PIPELINE damage resulting from fault movement and ground deformation has been adequately assessed and provided for in the design of the PIPELINE SYSTEM for that segment. Evaluation of said risk shall be based on geologic, geomorphic, geodetic, seismic, and other appropriate scientific evidence of past or present fault behavior and shall be compatible with the design earthquakes tabulated in Stipulation 3.2.1.1 and with observed relationships between earthquake magnitude and extent and amount of deformation and fault slip within the fault zone."

"3.2.2.2 Minimum design criteria for a segment of the PIPELINE SYSTEM traversing a fault zone that is interpreted by the FEDERAL INSPECTOR as active shall be: (1) that the PIPELINE resist failure resulting in line rupture from maximum, anticipated horizontal and/or vertical displacement in the foundation material anywhere within the fault zone during the life of the PIPELINE; and (2) that no storage tank or compressor station be located within the fault zone unless otherwise approved by the FEDERAL INSPECTOR".

6.6 DESIGN PROCEDURES

6.6.1 Active Fault Crossings

At each active fault crossing zone, the pipeline burial mode will be modified as necessary, to mitigate the effects on the pipeline of abrupt differential ground displacements. These displacements have the effects of applying soil pressures normal to the pipe in the horizontal and/or vertical directions, depending upon the faulting geometry and the direction of postulated fault motion. The pipe is also stretched or compressed, depending upon the angle at which the pipeline intersects the fault.

Knowing fault parameters and the limits of stress and strain allowed in the pipe, site-specific crossing designs will be carried out. Geotechnical input is also required in the form of soil load/displacement functions appropriate to each design mitigation configuration and applicable to the site-specific geotechnical conditions.

Fault crossing designs will focus on permitting the pipeline to move relative to the soil such that the pipeline can safely accommodate the fault movement. Design considerations include:

- o Providing limited soil resistance to pipe movement
- o Using heavy walled pipe
- o Avoiding strain concentrators
- o Adjusting local fault crossing angle to avoid large compressive strains.
- o Providing proper anchorage

Active fault crossing designs, covering a broad range of capabilities to mitigate fault offsets from near zero to more than the largest anticipated values, will be evaluated. These special designs will incorporate:

- o Fault geometry
- o Amount and direction of motion
- o Crossing angle
- o Soil load/displacement characteristics
- o Pipeline material behavior
- o Internal pipe pressure
- o Operating and other environmental stress effects

In order to keep pipeline strains within acceptable limits, very minor pipeline alignment local adjustments may be necessary at active fault crossings to optimize the fault crossing angle.

6.6.2 Fault Crossing Alternatives

Depending upon the magnitude of fault motion, local soil properties and the other factors cited above, the final fault crossing design will be selected from the following, listed in order of increasing fault-motion mitigation capability:

- o Conventional burial
- o Shallow burial with selected, low shear strength granular backfill, shallow side slopes, and with or without artificially-enhanced slip planes
- o Buried pipeline protected by oversize sacrificial conduit
- o Embankment
- o Reroute to avoid active fault crossing

6.6.3 Seismic Shaking - All Locations

Maximum effective earthquake ground motion values have been determined by N. M. Newmark for the three stipulated seismic zones. Values have been established for foundation or soil conditions including rock, permafrost, limited depth of sediment over rock and deep sediments.

The analysis of aboveground segments of pipeline and support structures and facilities will use the design response spectra defined by N. M. Newmark. The effects of wave propagation over long elevated spans will be studied. In transition zones where the pipeline changes from elevated to buried, analysis models will include below-ground segments of sufficient length to develop virtual anchors.

Strain and stress in the buried pipeline that are due to propagating seismic waves (shaking effect) will be calculated using minimum wave propagation velocities for various soils quoted by N. M. Newmark. Analysis will consider straight buried pipe and buried pipe at bends. The evaluation will consider the following parameters:

- o Seismic zone
- o Seismic wave propagation velocity and direction

- Foundation soil type
- Ditch backfill and surrounding soil stiffness effects, including frost bulb effects
- Bend type
- Bend radius and angle

The above analyses will be used to develop design guides for final segment-by-segment design verification of the pipeline.

Additional site-specific analyses will be made as necessary for special cases such as tight multiple bend configurations at road crossings, TAPS and other pipeline crossings, entries to compressor stations, sections of cased pipe where direct soil support to the pipe is prevented, and at intermediate traps, valves, and T-junctions. Effects of anchors on the seismic response of the pipeline will also be investigated.

Total stresses (seismic shaking plus fault motion plus operating and other environmental stress effects) will be determined for acceptance in accordance with the criteria defined in Exhibit Z-9.1, Section 1.14.5, Analysis of Earthquake Effects.

6.7 SOLUTION

The design of the pipeline at an active fault crossing is dependent upon the geometry of the fault motion.

The orientation of a fault can be described in terms of the strike of the fault and the dip of the fault plane. In reality a fault embraces a zone which does not conform to strict geometric forms.

The fault motion is described in terms of dip slip and strike slip. The magnitude of these parameters have to be established before any effort is made in the design of a fault crossing.

Woodward-Clyde Consultants are carrying out a comprehensive study to locate possible active faults along the proposed route of the Northwest Alaskan Pipeline. Their conclusion reported to NWA January 29, 1980 identified only three candidate significant faults proximate to the pipeline between Delta Junction and the Alaska-Yukon Territory Border.

Data available to date indicate that none of the three candidate significant faults are active.

Should any of the candidate significant faults be determined to be active, design of the fault crossing, to ensure pipeline integrity, would be carried out.

Seismic shaking and ground movement without faulting is not expected to pose any hazard to the pipeline. Buried pipe is considered to move with the ground in the event of an earthquake and thus will have the same longitudinal strain imposed in it as the ground. This argument is valid as long as the material surrounding the pipe maintains contact and its stability. However, if the surrounding soil loses its contact or stability, e.g., it undergoes liquefaction, the pipe could experience additional strain. Slope stability and soil liquefaction and their influence upon pipeline integrity has been dealt with in detail under Section 3.0, Geotechnical.

Preliminary elastic analysis of seismic response of typical straight and bend configurations under average soil conditions and the highest seismic zone has indicated peak strains well within design limits.

Field investigations and literature research carried out so far have not located any active faults in the vicinity of the pipeline route.

6.8 CONTINUING STUDIES

6.8.1 Delta Junction to Yukon Border

A summer field program is underway to investigate whether the three candidate significant faults (see Section 6.4.2.1) are or are not active faults and, if so, to evaluate the relevant fault parameters for design. The program includes:

- Studying and mapping the geological and geomorphic features pertinent to an assessment of faults and possible faults that trend near or across the route.

- Studying the geological history of the faults to include seeking materials appropriate and applying age dating techniques or palynological analysis.

- o Identifying specific locations for and conducting geophysical surveys, including seismic refraction, gravity, and magnetic measurements.

- o Excavating and logging of trenches across faults, if appropriate

- o Writing final report.

6.8.2 Delta Junction to Prudhoe Bay

A computerized literature search has identified 1,175 published references of potential interest. Discussions with Alaska Geological and Geophysical Survey, University of Alaska and U.S. Geological Survey personnel are ongoing to identify current work that they are doing which can be used by the project. In addition, negotiations are underway to acquire the Alyeska Pipeline Service Company Fault Study of 1974. These data will be evaluated and updated and a field program will be organized for 1981 should it be appropriate to expand on the work.

6.8.3 Prudhoe Bay to Yukon Border

Continued studies that are underway for the entire route are as follows:

- o Develop statistical and probabilistic procedure to establish active fault crossing design parameters.

- o Develop time histories of earthquake ground motion.

- o Finalize N. M. Newmark seismic design criteria.

- o Complete statistical study of ground motion values at stations along the pipeline route. (This is an extension of similar work performed for Foothills by the Canadian Mines and Resources Division.)

- o Exchange of technical data with Foothills Pipe Lines (South Yukon) Ltd.

- o Develop final seismic analysis/design techniques for use in mile-by-mile design of the pipeline.

- o Ongoing review with USGS.

6.9 POTENTIAL FOR CHANGES

6.9.1 Active Fault Locations

The three candidate significant faults from Delta-South will be investigated in detail during the summer of 1980. Should any of these faults prove to be active faults, no delays in design would be expected nor is rerouting necessary since the design mode is related to known field conditions.

The Delta-North preliminary review has been completed and negotiations are in progress which will lead to acquiring the Alyeska Fault Study. Field work for this portion of the route is scheduled for 1981 and no delays in design are expected should any active faults be found.

6.9.2 Fault Parameters

Both the field work and probabilistic studies should be completed by summer 1981 and no delays in design are anticipated.

6.9.3 Confirmation of N. M. Newmark's Recommended Ground Motion Values

No delay in design should occur in this procedure.

6.9.4 Application of Ground Motion Values

The preliminary values presently developed and used indicate that no adverse effect should develop that would delay the design effort or cause rerouting since these preliminary values were conservatively selected.

6.9.5 Application of Fault Crossing Data to Design

A preliminary review of the entire route indicates that should it be determined there are active faults which require special design, the mitigative methods would be site-specific and with little adverse impact on the final design.

Several mitigative measures are being developed which will give the design team optional solutions for the fault parameters at each site.

Rerouting is not considered a necessary mitigative measure at this time; however, minor route alignment at a specific active fault crossing site may be required.

It is felt that the state-of-the-art for designing fault crossings is such that there is no need for a fallback position for designing, constructing, and operating the pipeline.

7.0 DITCH STABILITY

7.1 STATEMENT OF CONCERN

"The elevated TAPS pipeline is used in areas of fine-grained soils that are known to be excessively ice-rich and contain large masses of ground ice. Alyeska has avoided ditching in these areas by their use of the elevated pipeline. Therefore, no factual data exist as to the stability of these materials in relation to trenching. In those areas of ice-rich overburden in which the TAPS line was buried in underlying thaw stable sediments, the ditch walls in the overburden were so unstable that many delays and extra costs were incurred during construction. These same sensitive buried areas have required considerable maintenance since construction (e.g., miles 10-14 along the TAPS alignment).

Longitudinal thaw ponds have formed along the outer margin of some sections of the TAPS workpad, particularly north of the Brooks Range. It is in just this area that Northwest plans to extend the TAPS workpad and to construct the ditch. The excess water from such ponds will affect the constructibility and trafficability of the new workpad, compound the problem of water in the trench, accelerate thawing of permafrost in the Northwest ditch during and after construction, create more ground settlement in the first four years, and result in more intensive frost action during freeze back around the chilled gas line."

7.2 DEFINITION OF ISSUES

There are three main issues associated with the ditch stability problem:

- Sloughing of the ditch wall during construction
- Thaw ponds and permafrost degradation near or along the TAPS workpad during construction
- Thaw prior to start up.

7.2.1 Sloughing of the Ditch During Construction

When ice-rich soils in the ditch are exposed to warm air and sunlight, the ice in the soil melts and the resultant water flows to the bottom of the ditch carrying soil particles with it. The natural creation and transportation of this sloughed material to the ditch bottom results in the exposure of additional frozen soil, which accelerates the thawing of the ditch sides and bottom. The problems created by this condition are:

- Widening of the top of the ditch which creates side boom reach problems
- "In-ditch" working room and condition problems
- Requirements for larger backfill quantities.

7.2.2 Thaw Ponds and Permafrost Degradation Near or at the TAPS Workpad

In areas of ice-rich soils, the TAPS workpad has induced substantial thawing of these soils under and near the edges of the workpad. These soils have low shear strength and high moisture contents and can aggravate the degradation of a ditch excavated near them. Consequently, in areas where this condition exists and the ditch for the gas pipeline is near the TAPS workpad, excessive sloughing of the ditch may occur.

7.2.3 Thaw Prior to Startup

Construction disturbance may cause some thawing of the permafrost at the bottom and sides of the backfilled ditch prior to startup. In very high ice-rich soils, this may cause water to saturate the ditch. The magnitude of the problem will depend on the type of soil and on the thickness of the thaw bulb around the pipe. This is a transitory condition which will stop when the soil is refrozen.

7.3 CATEGORIES

The stability of the ditch during construction is affected by several factors. The most important factors identified are:

- Soil ice content
- Soil type

- Construction period
- Length of time the ditch is left open
- Availability of water.

7.3.1 Soil Ice Content

The thickness and areal extent of soils with high ice content control the magnitude of potential ditch instability in a particular area. In addition, the selection of a mitigative solution depends on the amount of ice present in the soil.

7.3.2 Soil Type

The type of soil helps to classify the degree of ditch instability along the alignment. For instance, in those areas known to have thaw stable frozen or unfrozen soils or frozen gravels, construction could be scheduled without regard to ditch stability considerations. In addition, the thaw strain used to estimate thaw settlement must include consideration of the soil type at each particular area.

7.3.3 Construction Period

Construction during cold weather will generally satisfy ditch stability concerns. However, the warm ambient air and solar radiation will cause problems for fringe shoulder month and summer construction periods.

7.3.4 Length of Time the Ditch is Left Open

The magnitude of the ditch instability problem is proportional to the length of time the unprotected ditch is exposed to above freezing temperatures.

7.3.5 Availability of Water

The presence of water accelerates the thawing process. Water may enter the ditch from a variety of sources including flow in the active layer and thaw ponds near the TAPS workpad.

7.4 DATA ACQUISITION

7.4.1 Data Necessary

The necessary data are thermal state of the soil, ice content, mean ambient temperature and environmental impact.

7.4.2 Data Acquired to Present

Approximately 80 percent of the required data has already been obtained from the following sources and has been used to assess the potential for ditch instability along the pipeline alignment.

- Alyeska VSM logs
- Alyeska ditch logs
- Borehole data
- Resistivity surveys
- Terrain unit maps
- Aerial photographs

7.5 DESIGN CRITERIA

The solution of the ditch instability problem will have the following criteria:

- thermal state of the soil
- ice content
- mean ambient air temperature
- topography
- environmental concerns

7.5.1 Thermal State of the Soil

Only frozen soils were considered for evaluation of the ditch instability problem.

7.5.2 Ice Content

The amount of ice in the soil is used to assess the potential severity of the ditch instability problem. The severity of the problem is based on thaw strain which is a direct function of ice content. Ditch instability has been categorized as low, 0-10 percent thaw strain; medium, 10-20 percent thaw strain; and high above 20 percent thaw strain. In addition, if a soil has a thaw strain value of 20 percent or more, a dormant period thaw problem must be mitigated with an effective solution. Categories of ditch instability are seen in Exhibit Z-9.1, Paragraph 4.8.2.5.

7.5.3 Mean Ambient Air Temperature

Ambient air temperature is one of the criteria used to categorize ditch stability problems. Only ambient temperatures above freezing will cause a problem.

7.5.4 Topography

Terrain with a cross slope will have a higher potential for ditch wall instability than level terrain, particularly on the uphill side where ditch spoil will be placed. The effect of ground slope is discussed further in Exhibit Z-9.1, Paragraph 4.8.2.5.

7.5.5 Environmental Concerns

Environmental disturbance caused by ditching in permafrost is to be kept to a minimum by the use of mitigative measures.

7.6 DESIGN PROCEDURES

The design procedures include:

- o Identify the alignment sheets having areas where potential ditch instability exists. Based on an evaluation of the permafrost condition, perform a segment-by-segment analysis of areas with potential ditch stability concerns and mark them on the alignment sheets.

- o Use thaw strain criteria as a basis, and delineate those segments that will have excessive settlement if thawed.

- Evaluate and apply mitigative measures to the areas of concern. Part of the evaluation is thermal analyses to determine the anticipated thaw of the ditch during the dormant years.

7.6.1 Alternatives from which Solutions were Selected

The following list identifies all the alternatives considered in choosing the solutions for ditch stability problems.

- Shoulder-month construction
- Special mitigative modes for the dormant years
- Extending the shoulder-month construction period into the winter months
- Use of ditch wall insulation
- Artificial protection from the sun
- Removing ice rich soils.

7.7 SOLUTION

7.7.1 Solution for the Construction Period Concern

The optimum solution selected to minimize ditch stability problems during construction consists of selecting the proper construction period. Areas underlain by ice-rich soils have been scheduled to be excavated during the shoulder months. There are 383 miles currently identified on the alignment sheets as areas of potential ditch instability concern during the construction period.

Some of those segments indicated as ditch instability problems on the alignment sheets are areas of sporadic permafrost and soils with low thaw strain. Therefore, the total length of the alignment which will have construction constraints due to ditch instability is greater than the total length of concerns during the dormant years. Shoulder months are:

Section Limits (Mileposts)	Spring Shoulder Months (Begin January 15) End Dates		Fall Shoulder Months (End December 15) Begin Dates	
	Civil	Pipeline	Civil	Pipeline
Section 1				
0-110	May 1	May 15	Oct. 15	Nov. 1
110-132	Apr. 15	May 1	Oct. 15	Nov. 1
Section 2				
132-175	Apr. 15	May 1	Oct. 15	Nov. 1
175-230	May 1	May 15	Oct. 15	Nov. 1
Section 3				
230-376	May 1	May 15	Nov. 1	Nov. 15
Section 4				
376-504	Apr. 1	Apr. 15	Nov. 15	Dec. 1
Section 5				
504-624	Apr. 1	Apr. 15	Nov. 15	Dec. 1
Section 6				
624-743	Apr. 1	Apr. 15	Nov. 15	Dec. 1

7.7.2 Solution for the Dormant Period Concern

Mitigative ditch modes, Type IIA and IIB, have been developed and applied to the alignment to prevent ditch thaw during the dormant years for those soils with very high ice contents (thaw strains over 20 percent).

- Subtype "A" will utilize insulation board ranging in thickness from 1-1/2 to 3-1/2 inches covered by a protective berm to maintain the ditch materials in a frozen state prior to startup. This mode of construction is an extension of the workpad and will limit the amount of excavation needed in frozen ground.

- Subtype "B" will use a 5-inch thick insulation board and will be employed in permafrost regions that have a deeper active layer (south of Brooks Range). Again, the purpose will be to prevent the disturbed materials in the ditch sidewalls from thawing prior to startup. The insulation board for Subtype B will be located as close to the active layer depth as practical.

There are 139 miles of Type IIA ditch and 95 miles of Type IIB ditch. The modes are further discussed in Exhibit Z-9.1, Paragraph 1.5.

7.7.3 Rationale for Selecting the Above Solutions

Utilizing the techniques outlined above, NWA is confident that no problems will be encountered in areas of ice-rich soils and that no delays or extra costs will be incurred. Furthermore, since the construction will be carried out in shoulder months, the excess water in the thaw ponds is not expected to significantly affect the constructibility or trafficability of the new workpad. Also, the cold ambient temperatures during the shoulder months minimize water in the ditch or the thawing of permafrost while the ditch is open during construction. By placing insulation board over the pipe in the ditch, the maintenance of a frozen environment during the dormant period minimizes ground settlement.

7.7.4 Status of the Alternative Solutions

The following brief discussions describe the rationale for rejecting the alternate solutions and, in some cases, the remaining potential for the use of some of the alternatives.

- Extending the shoulder months into the winter months - Winter construction is known to be possible. However, this has been discarded due to the problems and cost associated with winter construction in the arctic.

- Use of ditch wall insulation - Open ditch mitigative measures, such as spraying the ditch walls with foam insulation or blasting with delayed excavation, are conceptual at this time and are currently under investigation as discussed in Section 7.8.

7.8 CONTINUING STUDIES TO SUPPORT DESIGN

The following studies are being performed to support the design and to develop alternative solutions: ditch stability field tests, thermal analyses, and an evaluation of the TAPS workpad.

7.8.1 Ditch Stability Field Tests

A field testing program is currently planned to assess the effectiveness of various mitigative measures for ditch instability and to observe the degree of ditch degradation as a function of lapsed time for an open ditch. There are six test sites planned for this study. One site, which will be tested this year, will be used to assess mitigative measures. The additional five sites, which will be tested in 1981, will be used for the degradation vs. lapsed time observations.

- The 1980 Program - The one test site in this summer's program will have two ditches excavated in variable/ high ice content frozen silts. One ditch will be oriented North-South, and the second ditch will be oriented East-West. The ditches will be segmented into equal length sections and the different mitigative measures will be applied to those sections. One section in each ditch will not have any mitigative measures applied. This will be used as the control section.

  The mitigative measures that will be used include: spray foam on the ditch walls and bottom, insulation board on the ditch walls, board insulation covering the ditch, a technique of drilling and shooting with delayed excavation, plywood panels on the ditch walls, plywood covering the ditch and a white fabric panel covering the ditch or the ditch walls.

  The data gathered at the site will be ice content, soil type, visual observation and notes, photographs, daily temperatures, cross-section survey of the ditch with time and particular information regarding each mitigative measure as to ease of application, cost, and any other specific problems.

- The 1981 Program - Five test sites will be investigated in 1981. The sites are different with respect to soil type and relief. The soils at all sites are ice-rich. This portion of the test program will not investigate mitigation measures. Rather, it will supply information regarding the rate of degradation of an unprotected open ditch.

  At least two ditches will be opened at each test site. One will be oriented North-South, and the other will be oriented East-West. The ditches will be left open and the melting and erosion of the ditch will be observed with time.

The data gathered at the sites will be ice contents, soil type, relief of the land, ditch aspect (N-S, E-W), visual observations and notes, photographs, daily temperatures, and cross-section surveys of the ditch with time.

7.8.2 Thermal Analyses

Thermal analyses were performed to verify the effectiveness of the Type IIA and IIB mitigative ditch modes used in those areas where thawing during the dormant years would be a problem. If it is decided to use an alternative mitigative measure for ditch stability wherein insulation is used, the thermal effect it will have on the soils in and around the ditch will be analyzed.

7.8.3 Evaluation of TAPS Workpad

There will be a site reconnaissance study performed this summer to evaluate the TAPS workpad. This study will be done in conjunction with Alyeska Pipeline Service Company. The primary objective of this reconnaissance is to gather data for workpad design. However, locations of severe thermal degradation and thaw ponds created by the existence of the TAPS workpad will be gathered. These data will supplement information already known about the alignment soil conditions and may result in a change in the length or location of potential ditch instability segments.

7.9 POTENTIAL FOR CHANGES

As a result of the studies mentioned in Section 7.8, the effectiveness of various mitigative measures for ditch instability and the condition of the TAPS workpad will be ascertained. Some of the alternative mitigative modes will be used if appropriate. If the mitigative measures are seen to be ineffective, the fall-back solution will be to keep problem areas in the shoulder month construction schedule.

8.0 TAPS CROSSINGS AND HIGHWAY CROSSINGS

8.1 STATEMENT OF CONCERN

"The gas pipeline alignment should be reviewed to minimize TAPS and Yukon-River-to-Prudhoe-Bay-Highway crossings."

8.2 DEFINITION OF ISSUES

8.2.1 TAPS Crossings

There is a concern that the construction of the gas line in the immediate vicinity of TAPS increases the risk of damage to TAPS. During operation of the gas pipeline, should any rupture occur in the vicinity of a TAPS crossing, there will be a risk of damage to TAPS. Any maintenance or repair operations performed in the vicinity of TAPS crossings present a potential risk of damage to TAPS.

8.2.2 Highway Crossings

There is a concern that construction of highway crossings will result in hazards to the highway during the construction and operational phases.

8.3 CATEGORIES

The location of pipeline and road crossings must be balanced with the following constraints:

8.3.1 Route Constraints

The primary constraint which determined the route location was to maximize usage of existing utility corridors. Secondary constraints in routing are:

- o The gas line originates at Prudhoe Bay on the west side of TAPS
- o The gas line must cross the Yukon River bridge on the west side of TAPS

- o The gas line must cross TAPS in order to be on the east side to follow the Alaska Highway south and east of Delta.

8.3.2 Geotechnical Constraints

Both TAPS and the state have requested that the gas line be located downslope of their facilities. A decrease in the number of TAPS and road crossings decreases the ability to totally optimize the gas line location to remain downslope of TAPS and roads.

Cross slopes and soil stability determine which side of TAPS and the road is most desirous for routing the gas line.

8.3.3 Hydrological Constraints

A decrease in the number of TAPS and road crossings decreases the ability to optimize stream crossing locations (i.e., upstream or downstream of existing facilities including TAPS and roads).

8.3.4 Environmental Constraints

A decrease in the number of TAPS and road crossings decreases the ability to optimize the gas line location as it relates to wildlife habitats, wetlands and other environmental concerns.

8.3.5 Compressor Station Locations

A decrease in the number of TAPS and road crossings decreases the ability to optimize compressor station locations.

8.3.6 Construction Constraints

A decrease in the number of TAPS crossings decreases the ability to maximize use of the existing TAPS workpad.

A decrease in the number of TAPS crossings may decrease the number and extent of accessible gas line segments and thereby can increase material haul distances and inconvenience of construction access.

A decrease in the number of TAPS and road crossings decreases the ability to optimize the gas line location due to inability to select locations available on the offside of TAPS or the road.

8.4 DATA ACQUISITION

8.4.1 Data Necessary

Detail surveys of each TAPS and road crossing are necessary to get accurate location and topographic mapping.

A minimum of one borehole will be drilled at each TAPS and road crossing. Where TAPS is in the buried mode, extra borings will be required because of changed conditions due to the warm pipe. Borehole sampling will provide necessary data on the in-situ aspects of the soil and thawed/frozen conditions at each crossing location.

8.4.2 Data Acquired to Present

8.4.2.1 Aerial photography and mapping have been acquired as follows:

- o Colored aerial photography of 1:24,000 scale
- o Mapping available includes U.S. Geological Survey mapping (1:63,360), photo mosaic mapping (1"=1,000'), and topographic mapping with photographic background (1"=500').
- o Low level oblique photography.

8.4.2.2 Borehole Data as follows:

- o Alyeska and Northwest borehole data for 22 of the 23 TAPS crossings and for 23 of the 32 road crossings.

8.4.2.3 VSM Logs

- o Alyeska VSM logs for 13 of the 23 TAPS crossings and for 2 of the road crossings.

8.4.2.4 Alyeska Trench Logs

- o Alyeska trench logs for 10 of the 23 TAPS crossings and for 7 of the road crossings.

8.4.2.5 Terrain Unit Maps

- o Terrain unit maps cover all TAPS and road crossings.

8.5 DESIGN CRITERIA

- o The number of crossings of TAPS and roads must be minimized within the constraints listed in Section 8.3.
- o Where the gas line is routed immediately adjacent and parallel to existing facilities, including TAPS and roads, the gas line will be located on the downslope side of the adjacent facility.
- o The gas line will be routed so as to minimize environmental impact.
- o The gas line will be routed so as to avoid geotechnical hazards where possible.
- o The gas line will be routed so as to keep construction costs minimal.
- o The gas line will be routed so as to provide relative ease of access for operation and maintenance activities.

8.6 DESIGN PROCEDURES

The following procedures have been used in preparing Enclosure B:

- o Apply route constraints.
- o Assess the route for environmental, geotechnical, and construction desirability.
- o Maintain route in existing facilities corridor, keeping virgin territory reroutes to a minimum.

- Locate compressor stations to minimize TAPS crossings unless station locations have overriding technical, geotechnical and/or environmental requirements.

- Accept resultant highway crossings resulting from previous action.

8.7 SOLUTION

8.7.1 Reduction in TAPS Crossings

In accordance with the procedures in preceding Section 8.6, the number of TAPS crossings was reduced from sixty-five to twenty-three. It should be noted that in the following crossing summary, the mileposts of the remaining twenty-three crossings are as shown on the "Pipeline Construction" alignment sheets, revision 1 (January 1980 route), and the mileposts of the deleted crossings are those of May, 1979.

TAPS Crossing No. 1

In DOI reroute No. 3, the TAPS crossing which was at MP91.3 has been relocated to MP96.0. This crossing is required to permit descent of the ice cut hill in the vicinity of MP97 and to locate the gas line on the downslope side of TAPS at MP98.6.

TAPS Crossings No. 2 & 3

NWA's position to reroute through virgin territory between MP108.3 and MP115.1 to pass west of Pump Station No. 3 results in two TAPS crossings at the start and finish of this reroute and places the gas line back on the east side of TAPS to be able to join later the west side of the Prudhoe Bay Road.

TAPS Crossings No. 4 & 5

At MP132.4 and MP148.0, TAPS crossings are required to locate the gas line on the west side of the aboveground TAPS for accessibility. The crossing at MP148.0 is also required for the line to join with DOI reroute No. 6, which was adopted for geotechnical and environmental reasons.

TAPS Crossings No. 6, 7, 8, 9, & 10

The next five TAPS crossings are required to provide ample work room to facilitate construction in the tight work areas of the Atigun River floodplain, across the Atigun Pass, and along the Chandalar Shelf. The first of these at MP165.8 locates the gas line on the west side of the Atigun River. The next at MP171.6 is required to locate the line on the east side of TAPS to climb the north side of Atigun Pass. The line crosses back to the west side of TAPS at MP172.2 to climb the remainder of the north side of the pass to the summit, and to locate the line between TAPS and the Prudhoe Bay road. At MP174.5, the line crosses TAPS at a point which optimizes the use of the existing TAPS workpad and locates the line on the east side of TAPS to provide the clearance required to descend Chandalar Shelf. The last of these crossings at MP181.9 locates the gas line on the west side of TAPS to join with DOI reroute No. 7 which passes through the environmentally sensitive "White Spruce" area.

TAPS Crossings No. 11 & 12

The next TAPS crossing at MP197.8 starts DOI reroute No. 8 which is required for geotechnical and environmental reasons, and to avoid the deep channel of the Dietrich River. In order to improve the crossing of the Dietrich River in this reroute, it is necessary to cross TAPS again at MP205.7.

TAPS Crossing No. 13

At MP215.4 the gas line crosses TAPS to get away from the floodplain of the Middle Fork Koyukuk River and its associated geotechnical and environmental concerns, and to locate eventually next to the west side of the Prudhoe Bay Road.

TAPS Crossing No. 14

Again at MP227.7, in order to cross the Middle Fork Koyukuk and Hammond Rivers, and to remain with TAPS, it is necessary to have a TAPS crossing.

TAPS Crossing No. 15

The next TAPS crossing at MP235.0 is required to have the line join with DOI reroute No. 11. This reroute eliminates the necessity of having TAPS crossings at MP234.7, MP237.7, MP240.4, MP242.4, and MP244.9, and avoids the environmental and hydrological problems associated with construction in the Middle Fork Koyukuk River floodplain.

TAPS Crossing No. 16

DOI reroute No. 12 requires that a TAPS crossing be moved from MP252.0 to MP254.0. This crossing is required to put the gas line on the west side of TAPS to optimize use of the existing TAPS workpad.

TAPS Crossing No. 17

At MP264.2 the line crosses TAPS so as to locate the gas line on the east side of TAPS to permit access to the line and to optimize use of the existing TAPS workpad.

Two more TAPS crossings at MP274.5 and MP285.2 are eliminated by DOI reroute No. 13 which avoids hydrological and environmental concerns in the Jim River area and by-passes TAPS Pump Station No. 5.

Crossings of TAPS at MP292.5 and MP296.7 have been eliminated by rerouting the gas line between these points from the west side of TAPS to the east and away from TAPS for geotechnical reasons. Similarly, crossings at MP305.6 and MP309.0 have been deleted.

TAPS Crossing No. 18

The next TAPS crossing is necessary to put the gas line on the west side of TAPS prior to the Yukon River bridge crossing at MP361.5. In order to minimize double pad extensions and new routing, the crossing has been located at MP338.9.

Two TAPS crossings at MP345.4 and MP347.2 have been eliminated by rerouting the gas line between these points. Instead of following the TAPS workpad on the east side of TAPS, the line is now located on the west side away from TAPS, utilizing new and double workpad.

TAPS Crossing No. 19

The next TAPS crossing at MP362.7 must remain to allow TAPS to enter Pump Station No. 6 while the gas line passes to the east of the station. This permits the gas line to rejoin TAPS on the east side, which is required to enable access to the gas line for the next six miles.

TAPS crossings at MP368.4 and MP369.7 have been eliminated by moving the gas line between these points from the TAPS workpad on the west side of TAPS to the east and away from TAPS.

TAPS Crossing No. 20

The next TAPS crossing at MP375.1 locates the gas line on the west side of TAPS which is required for access to the line between this point and MP403.1.

Crossings of TAPS at MP376.8 and MP378.7 have been eliminated by rerouting the gas line between these points from the east side of TAPS, to the west and away from TAPS for geotechnical reasons. Similarly, crossings at MP385.9 and MP387.9, MP397.3 and MP401.2, MP402.6 and MP403.6, MP405.2 and MP405.8, MP409.5 and MP410.5, MP412.1 and MP413.7, and MP415.2 and MP416.1 have been deleted.

TAPS Crossing No. 21

The next TAPS crossing at MP425.2 is required to put the gas line east of TAPS so as to make use of the TAPS workpad, to avoid a TAPS segment where snowpad construction was used, and to remain away from TAPS in the Globe Creek area near MP429.

Crossings of TAPS at MP437.1 and MP438.2 have been eliminated by rerouting the gas line between these points from the west side of TAPS, to the east and away from TAPS for geotechnical reasons. Similarly, crossings at MP442.7 and MP444.8, MP447.5 and MP448.6, MP461.7 and MP464.2, and MP480.1 and MP482.0 have been deleted.

TAPS Crossing No. 22

The next TAPS crossing at MP487.0 remains to take advantage of the TAPS workpad on the west side of TAPS, to bypass TAPS Pump Station No. 8 on the west side, and to enable joining the GVEA right-of-way, which is located west of TAPS at MP499.

TAPS Crossing No. 23

Reroute to the GVEA causes the TAPS crossings at MP520.2 and MP523.0 to be deleted, and the crossing at MP534.5 which was required to leave finally the gas line east of TAPS has been shifted to MP528.2. This crossing permits the gas line to rejoin the GVEA route after a short (4 mile) section of paralleling TAPS.

8.7.2 Effect on Road Crossings

Elimination of TAPS crossings has not affected the number of road crossings. DOI reroutes eliminated six road crossings and added three for a net decrease of three. Compressor station locations added seven crossings and the overall net change is an increase from 28 to 32 crossings.

8.7.3 Minimum TAPS Crossings

The 23 crossings of TAPS represent the optimum minimum number of crossings required properly to satisfy all concerns along the route.

8.8 CONTINUING STUDIES

A study for a tunnel under Atigun Pass is being made, considering two alternatives: a tunnel of approximately 2.5 miles; and, a tunnel of approximately 0.75 miles.

8.9 POTENTIAL FOR CHANGES

Use of a tunnel under Atigun Pass could potentially reduce the number of TAPS crossings. The number of TAPS and road crossings could be reduced by major reroutes; however, those reroutes would decrease the use of existing facilities.

10.0 FISH AND WILDLIFE HABITAT

10.1 STATEMENT OF CONCERN

"NAPLINE must demonstrate how they intend to mitigate impacts to fish and wildlife habitats; for example, riparian and wet and moist tundra (wetlands)."

NOTE: The response to Concern No. 11 is discussed concurrently with Fish and Wildlife Habitat in Concern No. 10. See Enclosure 11 which contains the quotation of Concern No. 11.

10.2 DEFINITION OF ISSUES

NWA recognizes that the construction, operation, and maintenance of the gas pipeline has the potential to create detrimental effects to fish and wildlife populations and the habitats which sustain them. It is NWA's objective to avoid such impacts or, where adverse effects cannot be avoided entirely, to minimize them to the greatest extent feasible.

Issues relating to fish, wildlife, and their habitats were identified by NWA based on the direct experience of many staff members (with the TAPS project), through numerous discussions with agency personnel, and through NWA's continuing field studies and information reviews.

The issues, and selected examples of their causes, are summarized below.

10.2.1 Fish

- o Blockage to fish passage by stream crossings, drainage structures and river training structures, flow alterations, velocity barriers, streambed disturbance, ice bulb formation, and aufeis effects.
- o Siltation of fish spawning beds and rearing areas by erosion resulting from drainage structures, workpad construction, material mining, bank degradation, road construction, and such construction methods as vegetation clearing and ditching.
- o Disturbance or destruction of fish overwintering areas by ice-bulb formation, aufeis effects, water withdrawal, and construction activities.

- Deterioration of surface water and groundwater quality by contaminant release from point sources (camp wastewater, hydrotest water) and non-point sources (oil spillage, leachates from landfills, soil erosion).

10.2.2 Endangered Species

- Disturbance to peregrine falcon hunting habitat and reproduction by any project activity.

10.2.3 Birds

- Disturbance to non-endangered raptor nesting by any project activity.
- Impacts to wetland areas by flow blockage or diversion, erosion effects, vegetation or soil disturbance, or the introduction of hazardous substances.
- Local disruption of wetland bird nesting, rearing, and molting by any project activity, particularly summer construction.
- Interference with sandhill crane staging and roosting, especially through disturbances at alluvial bars and islands during spring and fall migration.

10.2.4 Mammals

- Blockage of free passage of big game mammals by open ditches, strung pipe, protective barriers, mining operations, and other temporary or permanent features.
- Disturbance to caribou, moose, or Dall sheep food sources or reproduction by construction activities or compressor station operation.
- Attraction of animals to food or food wastes at construction camps or along pipeline spreads.

10.3 CATEGORIES

The following categories are used within this section to organize discussion of the issues.

- o Habitat - the specific set of environmental conditions which support a particular species.
- o Population - the individuals of a single species found within a certain area.
- o Passage - the ability of animals to traverse disturbed areas.

10.4 DATA ACQUISITION

The following subsections discuss data acquisition for fish, endangered species, birds, and mammals. Data requirements are first identified, followed by a discussion of the extent to which these requirements have been fulfilled.

10.4.1 Fish

10.4.1.1 Identification of Data Requirements

NWA's baseline fisheries program has focused on determining where fish occur along the route, how the habitat is used, and what seasonal sensitivities exist. The biological information necessary to satisfy NWA's objective of minimizing impacts to fish sensitive streams is as follows:

- o Fish streams
- o Seasonal species and sex/age composition
- o Spawning areas
- o Overwintering areas
- o Upstream swimming velocities
- o Habitat requirements
- o Migration periods
- o Water quality

10.4.1.2 Status of Data Acquisition

NWA fisheries studies and literature searches began in 1976 with four studies which analyzed the fisheries of the Tanana River, its tributaries, and other points along the route south of Delta. Two supplemental studies were conducted during 1977 and 1978; the first was a fall and winter survey of the upper Tanana River drainage (including chemical and biological data), and the second, completed in 1978, was an update of prior field studies conducted from Delta to the Canadian border.

In 1979 an integrated program was initiated to more comprehensively address fisheries along the entire route centerline on a multi-seasonal basis. A 1980/1981 sequel to this effort is now underway.

The baseline fisheries data now amassed are adequate for the siting of most permanent and temporary facilities. However, NWA is continuing site-specific investigations to obtain additional data necessary to refine the development of ancillary facilities such as material sites, access roads, spoil disposal sites, and landfills. These data are also being used for the design of drainage structures.

10.4.2 Endangered Species

10.4.2.1 Identification of Data Requirements

Two subspecies of peregrine falcon, the Arctic peregrine falcon (*Falco peregrinus tundrius*) and the American peregrine falcon (*F.p. anatum*), are protected under the 1973 Endangered Species Act (as amended) as well as by the draft stipulations. This is the only endangered species along the pipeline route.

The following information is necessary to develop protection strategies for the peregrine falcon:

- Nest site locations
- Hunting behavior
- Sensitive periods
- Nesting and feeding habitat

10.4.2.2 Status of Data Acquisition

Studies of peregrine falcons along the route have been conducted by NWA and by government agencies. In 1977, investigators from the University of Alaska conducted literature reviews and performed limited field observations for NWA. Field studies in 1979 determined the status of all active and historical peregrine nesting sites along the pipeline route and also identified potential nesting habitat.

Preconstruction studies are continuing in 1980, including a survey along the length of the route for the identification of presently unknown nest sites, and an information and status review involving a continuing analysis of existing published and unpublished reports, studies, and interviews with biologists involved in peregrine behavior studies.

Nest site locations are the critical data requirement. There is a good degree of certainty that all currently active and potential nesting areas are now known. The present extent of baseline data on this species is adequate to develop an effective protection strategy.

10.4.3 Birds

10.4.3.1 Identification of Data Requirements

The following information on birds is necessary to develop effective protection strategies:

Waterfowl

- High quality wetland habitat
- Nesting, rearing, molting, and staging areas
- Sensitive periods
- Relative abundance

Sandhill Cranes

- Migration zones and periods
- Migratory staging and roosting areas
- Relative abundance

Raptors

- o Species present
- o Nest sites and status
- o Sensitive periods

Sharp-tailed Grouse

- o Courtship habitat
- o Reproductive period

10.4.3.2 Status of Data Acquisition

Prior to NWA studies in 1977, little was known about the Tetlin-Northway wetlands with regard to waterfowl use. In light of the importance of this area (now the Tètlin National Wildlife Refuge), NWA has given it highest priority for wetland bird studies.

During May through November 1977, University of Alaska researchers conducted field surveys of wetland birds along the proposed NWA pipeline route from Tetlin Junction to Little Scottie Creek, concentrating on those wetlands most likely to be impacted by pipeline construction. This study documented habitat utilization, estimated the size and composition of the wetland bird population, and determined the productivity of nearby wetland habitats. Additional field studies were conducted for NWA by the University in April 1979, concentrating on the Scottie Creek, Desper Creek, and Gardiner Creek areas. This work provided additional data on seasonal densities of wetland birds and habitat productivity.

Two-thirds of the world's population of lesser sandhill cranes migrate through interior Alaska. To provide baseline data about crane movements along the gas pipeline corridor, NWA initiated fall migration studies in 1976 and continued the program in the fall of 1977, fall and spring of 1978, and spring of 1979. The results of this work identify the route and timing of migration and influences thereon, as well as delineate ground utilization areas.

NWA has conducted extensive raptorial bird studies. These studies determined the status of known active and historical nesting sites of gyrfalcons and other cliff-nesters, the locations of previously unknown tree nests, and distribution, density, and seasonal habitat utilization.

During the summer of 1977, NWA sponsored studies in the upper Tanana River Valley to determine upland bird density and habitat utilization along the portion of the route in interior Alaska. In addition, NWA completed a review of the available literature regarding sharp-tailed grouse, the principal upland bird species likely to be affected by construction activity. This suggested that no long-term adverse impacts on the grouse will occur. As a result, no further studies of the species are now planned.

The baseline bird data already collected are considered adequate to develop effective protection strategies. However, in the case of waterfowl, NWA recognizes the need to expand its data base to encompass further information on waterfowl nesting, rearing, molting, and staging areas.

10.4.4 Mammals

10.4.4.1 Identification of Data Requirements

The following information is necessary to develop effective protection strategies:

- Late winter distribution and spring movement of caribou within the pipeline corridor
- Characterization of caribou corridor crossing sites
- Bison spring movements and corridor crossing sites.
- Wintering, lambing areas, and corridor crossing locations of Dall sheep; and the number and age/sex composition of sheep using these locations
- Spring distribution and habitat use of canids and ursids, emphasizing the area between Fairbanks and the Canadian border
- Factors influencing human-carnivore interactions

10.4.4.2 Status of Data Acquisition

An information review has been completed on the potential for project-mammal interactions. Spring field studies have been completed on bison, caribou, Dall sheep, and large carnivores. An analysis of potential problems relating to human-carnivore interactions is currently underway.

Final reports documenting the results of these investigations are due before the end of 1980.

10.5 CRITERIA

Environmental standards for project construction and operation are contained in the President's Decision, legislation, state and federal rules and regulations and draft stipulations. Compliance with these standards is facilitated by the development of environmental criteria specific to project activities.

Criteria application to date has primarily involved avoidance of the environmentally sensitive features revealed through baseline data acquisition. Avoidance has been achieved by means of route, construction schedule, construction method modification, and by site selection activities. In the future, additional specific criteria will be formulated in concert with completion of the final, site-specific design.

10.5.1 Fish

Design criteria will protect fish populations from direct or induced mortality. Similarly, adverse modification or disturbance of fish habitats will be minimized. When disturbance to fish and key fish habitat cannot be avoided, mitigative measures will be employed. Except for unavoidable temporary blockages, access by fish to key habitats will be maintained by assuring fish passage through any structures placed by the project in fish streams.

Project activities will be scheduled to take advantage of seasonal changes in the utilization of waterbodies by fish. Seasonal terrestrial sensitivities (including thermal, soil, and biological sensitivities of adjacent habitat and hydrologic regimes) will also be considered when determining the optimum timing of project activities potentially affecting fish.

Site-specific methods for mitigating the effects of construction in fish streams will be developed based on environmental analysis of the final design. These methods will be employed in all cases where the construction schedule cannot be altered to avoid sensitive time periods, or the route realigned to avoid key fish habitat.

10.5.2 Endangered Species

The pipeline route and siting of permanent, temporary, and ancillary facilities will be designed to prevent the destruction or alteration of peregrine falcon nesting sites and hunting habitat. Engineering design restrictions will also be implemented to prevent disturbances to the peregrine falcon. All design features will ensure that normal nesting, fledging, and predation occur without disruption or alteration.

No activities in the vicinity of active peregrine falcon nests will occur during the nesting and fledging period. Potential disturbances to nesting birds by aircraft and transient vehicular traffic will also be prevented by enforcing stringent operating procedures.

Construction planning will protect nesting and hunting habitat, including all active or historical nesting areas and known prey habitat in the vicinity of those nesting areas. Construction methods will also be utilized which avoid damage or disturbance to individual peregrine falcons and their prey, including the introduction of hazardous compounds into the food chain.

10.5.3 Birds

Pipeline routing and facility siting will minimize intrusion into wetland bird, sandhill crane, upland gamebird, and raptor habitat. Equipment specifications will be prepared to limit adverse impacts to bird populations and their habitat caused by exhaust emissions, noise, and surface water or groundwater quality degradation. Procedures will be implemented to ensure the environmentally safe storage, handling, use, and disposal of potentially hazardous contaminants. Civil design will avoid or minimize adverse impacts to wetland and riparian habitat caused by erosion or flow alteration.

Wherever feasible, construction activities will be scheduled to avoid key habitats during the breeding, nesting, feeding, and molting of wetland birds. Sandhill crane migration and roosting areas, and raptor nesting and fledging areas will be avoided when birds are present in these areas.

Construction methods will be employed which prevent significant siltation, scouring, flow blockage or diversion, and water level alterations within streams and wetlands. Procedures will be formulated during the construction period to avoid the release of hazardous contaminants which might harm bird populations or habitat. Blasting will be avoided near key habitat areas during sensitive periods. Habitat destruction due to vegetation clearing will be minimized; restoration and revegetation procedures will be developed to facilitate the reestablishment of avian habitat to preconstruction productivity levels.

10.5.4 Mammals

Design criteria will be established to protect mammal populations. Similarly, destruction or alteration of key mammal habitats will be avoided. Except for unavoidable temporary impediments to free movement of big game, access by mammals to their key habitats will be maintained through or around project facilities and structures.

Project activities will be scheduled to take advantage of the seasonal use of key habitats by mammals. Habitat juxtaposition, seasonal sensitivity and use by mammals will also be considered when establishing optimum schedules for project activities which may affect mammals.

Site-specific methods for mitigating the effects of construction in key mammal habitat will be implemented following environmental analysis of the final design.

10.6 DESIGN PROCEDURES

NWA will ensure that engineering design, construction planning, and construction methods incorporate effective protection strategies to avoid or minimize potentially detrimental effects on fish, wildlife, and their habitats. This objective is achieved through an environmental engineering program progressing from early design through construction and post-construction monitoring.

10.6.1 Project Analysis

The development of protection strategies begins with the overall review of project activities and of the sequence in which they will occur. The planned activities are evaluated with respect to their potential to produce adverse effects to fish and wildlife and their habitats. It is determined what activities are capable of creating potentially detrimental impacts and require structuring to avoid or minimize such impacts.

10.6.2 Data Acquisition and Review

The specific types of data required to structure engineering design and construction planning to avoid adverse effects are identified, with advice from state and federal agency representatives. Studies are then designed in consultation with agency personnel and conducted to fill the data gaps.

10.6.3 Protection Strategies

As data are acquired and reviewed, they are used to support the interaction of environmental specialists with design and construction engineers. Through this process, protective measures are developed to avoid or lessen potential adverse impacts in a manner consistent with sound engineering practice.

Interactions with project engineers focus on the issues identified in Section 10.2. Types of interactions are:

- o Direct participation in facilities siting
- o Preparation of environmental assessments for proposed material sites, access roads, storage yards, airstrips, disposal sites, and landfills
- o Direct participation in fish passage structure design and material site mining plan development
- o Input to design criteria for camp incinerators and animal-resistant fencing; potable water extraction, treatment, storage, and distribution systems; liquid waste collection, storage, treatment, and disposal; solid waste collection, storage, incineration, and disposal; and fuel storage and distribution systems
- o Preparation of or contributions to plans and programs required by the draft stipulations.

10.6.4 Review of Design Products

NWA reviews all criteria, plans, programs, and schedules to ensure that they adequately incorporate protective measures specifically addressing the issues identified in Section 10.2. Where further refinement is necessary, design products receive continuing development and repeated review by NWA until appropriate design features are achieved to ensure satisfactory impact avoidance or mitigation.

10.6.5 Environmental Protection Plan

The application for government approval to construct will contain an Environmental Protection Plan providing an environmental assessment of the project containing a description of the protection measures, and describing planned environmental monitoring.

10.6.6 Monitoring

NWA will monitor performance against the protection measures during the construction phase of the project.

10.7 SOLUTIONS

Avoidance is the most effective means of resolving planning conflicts between engineering design and environmentally sensitive features. The route was selected by NWA to minimize impacts to undisturbed wildlife habitat by following active utility and transportation corridors. The route has been adjusted to the maximum practical extent to avoid sensitive fish and wildlife populations and habitat.

However, avoidance of key habitat or populations by selection of alternative sites or routes is not always technically or economically feasible. In these cases, baseline information on the seasonal distribution of wildlife species is used to schedule construction activities during periods of low sensitivity. In addition, proposed site-specific construction methods are assessed against criteria based on the ecological requirements of the species to be affected. Solutions to potential conflicts with each of the major taxonomic groupings are individually discussed in the following subsections.

10.7.1 Fish

Solutions for mitigating impacts to fisheries resources must be based on synthesis of:

- o Knowledge and analysis of the distribution, composition, and survival requirements of the fish found in the pipeline corridor,
- o Analysis of the types of impacts that may be generated by the constructon of a large diameter pipeline system, and

- Identification of the specific sources of those impacts, namely the individual project components and activities.

10.7.1.1 Fish Habitat

The biological, physical, and chemical integrity of fish habitat can be maintained by protecting the existing hydrologic regime, suitable water quality, and existing streambed conditions.

Where fish habitat cannot be avoided, pipeline and civil designs limit changes in surface and subsurface hydrology to protect fish. Water quality is maintained by pipeline system designs to control the entry of undesirable substances into surface waters. Comprehensive plans are being developed pursuant to the draft stipulations addressing project activities that could affect water quality: e.g., erosion and sediment control, liquid waste management, hazardous substances control, and stream crossings design.

Civil and pipeline designs minimize direct intrusion of the pipeline or its related facilities into fish habitat and develop protective measures for habitats potentially influenced by project activities. Fish stream crossings will be designed on a site-specific basis.

Where spatial avoidance of fish habitat is not practicable, in-stream activities are scheduled for the least sensitive periods for each stream. However, conditions in adjacent terrestrial areas, such as other biological sensitivities, susceptibility of adjacent soils to thermal disruption, and hydrologic conditions have necessitated that some streams be crossed at sensitive times.

10.7.1.2 Fish Populations

Pipeline and civil design solutions for the protection of fish habitat also have direct bearing on fish survival, particularly in the maintenance of the quantity, quality, and seasonal availabilty of water. Pipeline and civil designs are assessed with respect to the sensitivities of life history stages to project activities. The results of these assessments are reflected in spatial or temporal avoidance of fish.

Where spatial avoidance cannot be achieved, temporal avoidance of fish presence is chosen wherever practicable. Avoidance is based on a priority ranking of sensitivities of the fish to the type of disturbance expected.

Where avoidance of fish is not possible, construction techniques are being refined to minimize or avoid damage to fish stocks as a result of project activities.

10.7.1.3 Fish Passage

Where fish passage is required, pipeline design includes suitable drainage structures. Culverts or bridges are the preferred structures. Fish stream crossings will include provisions for fish passage.

The planned aerial crossings pose no impediment to fish passage. Other fish stream crossings are being designed to reestablish preconstruction hydrologic conditions to the maximum extent practicable in the post-construction phase. NWA's structures will be compatible with existing drainage structures along the route.

Ancillary facilities such as mining sites are being defined to limit their intrusion into fish habitat and thereby reduce interference with fish passage.

Schedules for in-stream construction of the pipeline and completion of civil work have been developed to minimize conflict with fish migrations. Some temporary blockage of fish movements is anticipated.

When temporal or spatial avoidance of fish migrations during construction is not possible, techniques such as fluming or channel diversions will be employed to minimize interruption of fish passage.

10.7.2 Endangered Species

10.7.2.1 Peregrine Falcon Habitat

NWA emphasizes avoidance as the key strategy for preventing detrimental impacts to peregrine falcon nesting and hunting habitat.

The pipeline route has been selected to avoid known historical or active peregrine falcon nesting sites. Moreover, the route has been planned to avoid, wherever feasible, productive habitat for wetland birds, which constitute a major source of prey for the peregrine falcon.

The siting of compressor stations and construction camps has also emphasized avoidance of disturbances to peregrine falcon nesting and hunting habitat. This principle continues to guide the selection of sites for material mining, access roads, spoil disposal sites, landfills, storage yards, and other ancillary facilities.

Construction methods are planned to avoid any significant detrimental effect on peregrine falcon habitat. Active nesting areas will be avoided by pipeline construction.

Disturbed area restorative measures are designed to facilitate the reinvasion of native plants and, ultimately, prey habitat.

10.7.2.2 Peregrine Falcon Populations

As emphasized above, the pipeline route and facilities sites are located to avoid known historical or active peregrine falcon nesting areas. Procedural guidelines are also designed to prevent the release of hazardous contaminants into the environment.

To further ensure that interference with nesting or hunting peregrine falcons is avoided, the project strictly controls the confidentiality of information regarding specific nest locations. In addition, field surveys to monitor the status of known nest sites and to identify new sites are limited, through the use of data from other surveys, including state and federal agency studies.

The pipeline route and sites of temporary, permanent, and ancillary facilities are placed to avoid peregrine falcon nesting areas. In addition, construction scheduling avoids activities in the vicinity of nest sites during the nesting and fledging period. Therefore, disturbances are avoided both spatially and temporally. These constraints, coupled with the census of active nest sites, should prevent significant adverse impacts to the peregrine falcon.

10.7.3 Birds

10.7.3.1 Bird Habitat

Habitat avoidance is the primary protection strategy for minimizing adverse impacts to birds. The pipeline route has been selected to avoid key habitats such as highly productive wetlands supporting waterbirds and raptors, and alluvial islands providing roosting sites for sandhill cranes. Facility siting is also guided by environmental analyses, including data reviews and field investigations. Environmental specialists participate in the design effort on a close and active basis to ensure proper consideration and incorporation of environmental concerns to protect habitat.

Project environmental specialists with technical training and experience in Alaska participate actively in the civil design program, ensuring the establishment and incorporation of proper design criteria for the avoidance of such potential problems as siltation, scouring, flow blockage, ponding, and flow diversion in riparian and wetland habitats. Drainage structure design utilizes year-round hydrologic, geotechnical, and biological data from preconstruction field investigations.

Careful scheduling is necessary to avoid or minimize construction through important avian habitats during sensitive periods. Since 1977, NWA has been conducting field investigations and information reviews to identify significant wetland bird, sandhill crane, sharp-tailed grouse, and raptor habitat areas along the proposed pipeline route, and the timing of their occupancy. Data from these and other pertinent study reports are continually analyzed, and the results are used to define sensitive periods and establish "windows" for construction through productive avian habitats such as the Tetlin-Northway wetlands and the North Slope coastal plain.

Wetlands provide important habitat for waterfowl, shorebirds, sandhill cranes, and raptors. Therefore, they are receiving high-priority attention from NWA during construction planning. This emphasis is reinforced by NWA's awareness that wetlands are particularly vulnerable to construction impacts.

NWA's planning calls for shoulder month construction through wetland areas wherever feasible. The protection to vegetation and substrata afforded by frozen conditions and snow cover will be a significant mitigative feature. The proper installation of drainage structures, including equalization culvert systems, will assist in preventing adverse impacts relating to erosion and flow alteration in riparian and wetland habitat.

Alluvial bars provide important roosting locations for sandhill cranes during spring and fall migrations. Construction will avoid gravel mining at sites which cranes are known to occupy.

NWA's study of the sharp-tailed grouse indicates that construction is unlikely to produce detrimental effects on courtship areas or other grouse habitat. In fact, clearing and revegetation procedures may actually enhance grouse occupancy of the proposed pipeline corridor.

10.7.3.2 Bird Population

Design features emphasize the protection of bird populations through avoiding adverse impacts to habitat. However, many design objectives and criteria will also prevent direct harm to individuals and populations.

Staging areas utilized by wetland birds and sandhill cranes, as well as principal raptor nesting areas and high-density waterfowl nesting, rearing, molting, and feeding areas, are largely avoided by route design and facilities siting.

Construction scheduling avoids or minimizes activities in areas where large concentrations of waterfowl, sandhill cranes, and raptors occur during the migration, reproduction, and molting periods. Construction scheduling emphasizes the protection of wetlands during the late spring, summer, and early fall months of waterfowl occupancy. Disturbances of productive waterfowl nesting areas such as the Tetlin-Northway wetlands are minimized during the nesting and molting periods of approximately May 15-August 10 and July 1-September 1, respectively.

Construction methods are planned so that significant habitat damage will be avoided. Route selection which avoids major staging, nesting, rearing, and molting areas, coupled with construction scheduling during non-sensitive "windows", largely prevents direct construction impact to bird populations. In riparian and wetland areas, proper drainage structure installation will prevent flow blockage or diversion, maintain normal water levels, and minimize turbidity impacts.

The handling, use, and disposal of petroleum products and other hazardous substances will be strictly controlled in compliance with applicable DOI stipulations. Contingency plans for effective spill response procedures now in effect are being refined to cover the broad range of construction-related activities.

10.7.4 Mammals

10.7.4.1 Mammal Habitat

Protection of key mammal habitat is being achieved through careful routing of the pipeline. Examples of key habitat include but are not limited to Dall sheep lambing and mineral licks, riparian willow bars on the North Slope that support wintering moose, and habitat providing similar niches for other big game mammals.

Destruction of habitat through the development of material sites will be minimized by selecting sites of relatively low importance to big game. This is being accomplished through an analysis of available habitat using the output of the NWA-sponsored habitat evaluation program. These data, combined with the results of field inspections of exploratory material sites, will be correlated with the distribution and abundance of mammals. In instances where damage to important habitat is unavoidable, restoration will use native species wherever possible. This technique eventually will reestablish the original habitat conditions.

Pipeline facilities including compressor stations, construction camps, and ancillary access roads, disposal sites and landfills are sited to avoid key habitats wherever possible. Moreover, construction activities such as ditching, pipe stringing, clearing, blasting, and mining will be conducted to avoid or minimize adverse impacts to mammals.

Wetland habitats important to mammals are being protected by scheduling construction during the shoulder months. This generally is the period of least sensitivity. In instances where summer construction is unavoidable, construction restrictions including erosion and siltation control, cross drainage equalization, and limited use of all-terrain vehicles will be imposed.

10.7.4.2 Mammal Populations

Construction schedules are developed to avoid sensitive periods in the life cycles of mammals.

The habituation and attraction of mammals to human activities are being avoided through fencing of fly camps, construction camps, and compressor stations. Procedures for controlled handling and prompt incineration of putrescible food wastes and disposal of all other potential mammal attractants are followed. No putresible food wastes will be landfilled in remote areas. Environmental briefings will be administered to aid in creating an awareness among construction employees for the need to avoid unnecessary and potentially hazardous interaction with mammals. Additionally, state game regulations which prohibit the feeding of certain mammals are enforced.

Aircraft overflights are restricted to avoid unnecessary disturbance and stress upon selected mammal populations.

10.7.4.3 Mammal Passage

The buried gas pipeline allows long-term free passage of mammals.

Site selection of ancillary facilities considers mammal concentrations, major migration and movement routes, and breeding, rearing, and feeding areas. There are construction strategies that permit "windows" for passage thru the construction zone. These include soft plugs in the ditch and double stringing.

Construction through mammal habitat is being scheduled to avoid sensitive periods.

10.8 CONTINUING STUDIES

NWA has acquired most of the baseline biological information needed to develop an environmentally sound design. Studies scheduled for 1980 and 1981 are intended to complete the data base with regard to the information indicated in Section 10.4 to be outstanding. The following is a description of this work.

10.8.1 Fish

The 1980/1981 fisheries program consists of field investigations to continue baseline data gathering in the small number of streams potentially affected by the project where available fishery data is yet inadequate. Similar to past studies, key habitats such as spawning, rearing, or overwintering areas are to be noted, as are observed migrations. Stream features or conditions affecting fish utilization such as impassable natural or artificial barriers are also to be recorded.

10.8.2 Endangered Species and Birds

10.8.2.1 Peregrine Falcons and Other Raptors

The 1980 raptor studies are a continuation of baseline studies performed by NWA. An aerial survey of the entire route and proposed ancillary facilities, such as material sites, access roads, and compressor station sites, was conducted this spring prior to leaf-out to locate tree nests. Efforts focused on the Yukon River to the Canadian border segment and emphasized the identification of nesting habitat utilized by raptors other than peregrines. Also recorded were the locations of any previously unidentified peregrine nests.

In addition to the field work, a review of existing published and unpublished reports, ongoing studies, and interviews with specialists in raptor behavior will be conducted. The review will describe likely nesting habitat for non-peregrine species and delineate such habitat along the pipeline. This review will cover the following specific topics:

- Habitat use, nesting behavior, territoriality, distribution, and related information for raptors found in Alaska along the gas pipeline route with emphasis on "low density" species.

- Nesting chronologies for species not previously covered.

- Available information on raptor hunting behavior (with emphasis on peregrine falcons) and habitat preference.

Finally, peregrine falcon monitoring at the Sagavanirktok, Tanana, and other known peregrine nest sites will be continued in July, 1980 to determine their status. These surveys will also be continued during construction. These studies will determine nest occupancy of active and historical nest sites as well as identification of new sites. A primary purpose of the studies is to update those restrictions that are based upon the presence of the birds.

In addition to the tasks outlined above, consultation with the USFWS will continue regarding peregrine falcon restrictions currently under consideration.

10.8.2.2 Waterfowl

The 1980 waterfowl program will occur during summer and fall. The summer study, from Delta to TAPS Pump Station No. 3, will identify breeding, nesting, rearing, and molting areas and census populations. The fall study will identify staging areas and relative abundance along the pipeline route.

10.8.2.3 Sharp-tailed Grouse

A review is now underway of available data on habitat and behavioral patterns of the sharp-tailed grouse. A determination of the flexibility and adaptability of the sharp-tailed grouse to anticipated effects of pipeline construction and maintenance will result from this review.

10.8.2.4 Mammals

The 1980 mammal program includes an ongoing effort to monitor the Central Arctic Caribou Herd, including migration routes, seasonal concentration areas, and calving grounds. This program will determine project impacts to the caribou as well as aid in delineating possible mitigation. Personnel from the Alaska Department of Fish and Game are conducting this program.

10.9 PROBABILITY OF CHANGES

No changes are expected in the present route, project design, construction schedule, or construction methods as a result of new data from continuing fish and wildlife studies.

11.0 FISH AND WILDLIFE POPULATION

11.1 STATEMENT OF CONCERN

"NAPLINE must demonstrate how they intend to mitigate impacts to fish and wildlife populations; for example, construction timing which avoids impacts to sensitive fish streams."

Note: The response to Concern No. 11 is discussed concurrently with Fish and Wildlife Habitat in Concern No. 10.

12.0 EROSION CONTROL AND VEGETATION

12.1 STATEMENT OF CONCERN

"NAPLINE must demonstrate that erosion control and vegetation practices are integral parts of the pipeline and that the ones proposed are the best state of the art".

12.2 DEFINITION OF ISSUES

12.2.1 Erosion control and vegetation, or more precisely, revegetation concerns must be considered in all phases of design development, construction activities, and maintenance activities. The design must address general as well as site specific technical, environmental, construction, operation and economic needs and must be clearly identified on construction plans.

12.2.2 NWA must demonstrate that the erosion control and revegetation practices incorporated into project documents are the best state of the art by subjecting them to comparison to the practices of the American Association of State Highway and Transportation Officials (AASHTO), Cold Regions Research and Engineering Laboratory (CRREL), the Highway Research Board (HRB), the Environmental Protection Agency (EPA) and other applicable agencies or groups. The technical basis for design solutions must be presented. All practices must be utilized with appropriate updating based on arctic engineering experiences and new technical methods.

12.3 CATEGORIES

Facets of the project that require erosion control and revegetation considerations follow.

12.3.1 Preconstruction Phase

- o Route and access road location.
- o Clearing boundaries and seasonal restrictions.
- o Material and disposal site location and design.

- Temporary facility location and design.
- Visual impact assessment.
- Construction zone cross-section selection.
- Drainage structure selection and design.
- Erosion control feature selection and design.
- Final grading design.
- Revegetation design.

12.3.2 Construction Phase

- Clearing and grading operations.
- Mining operations.
- Workpad and access road construction.
- Bridge construction.
- Ditch maintenance.
- Drainage structure construction.
- Breakup preparations.
- Spoil disposal operations.
- River crossing and floodplain construction.

12.3.3 Cleanup Phase

- Permanent drainage structure construction.
- Final grading operations.
- Visual impact treatment.
- Revegetation operations.

12.3.4 Operations and Maintenance Phase

- Final access plan.
- Maintenance requirements and grading methods.
- Snow and ice removal and disposal methods.

12.4 DATA ACQUISITION

Data necessary to address erosion control and revegetation concerns and the status of each follows.

12.4.1 Topographic Data

Topographic data are needed for assessing erosion potential as a function of ground slopes, and for the location of drainage structures.

12.4.1.1 Mapping and Aerial Photography

- Topographic mapping of entire project area has been acquired from the USGS in the form of 1:63,360 and 1:24,000 scales topographic maps.
- Aerial photo mosaic maps of the project area have been prepared in 1:6,000 scale with 10-foot contour intervals and 1:12,000 scale.
- Color and black and white stereo-aerial photography at 1:24,000 and 1:36,000 scales.
- Low level oblique photography.

12.4.1.2 Route Survey Data

- Centerline survey data include centerline profile and cross-sections. Data will also include location, skew, outline and inlet/outlet elevations of drainage structures.
- Similar survey data will be acquired for new or refurbished access roads, storage yards, new camps, and airfields.

- Survey data for cross drainage, streams and rivers will include horizontal and vertical control. Topographic and stream data will be sufficent for drainage design (refer to Section 9.0 of this document).

12.4.2 Hydrologic Data

Hydrologic data needed for assessing erosion potential as a function of water flows must include:

- Pipeline Design Flood (PDF) is a flood derived by applying the most severe precipitation or snowmelt conditions which can reasonably be expected. These flood data in combination with the survey data are required in the design of erosion control structures at river and major stream crossings (refer to Enclosure B, Exhibit Z-9.1, Volume VII, Design Manual).

- Frequency Design Flood (FDF) is a flood with an excedance frequency of 50 years. These flood data in combination with the survey data are required in the design of drainage structures, and erosion control structures (refer to draft stipulations 2.4.1.3 and 3.4.3.1 and Enclosure B, Exhibit Z-9.1, Volume VII, Design Manual).

12.4.3 Geotechnical Data

The geotechnical data needed for assessing revegetation and erosion potential as a function of soil conditions must include:

12.4.3.1 Soil Erosion Code (SEC)

- A Soil Erosion Code has been developed which classifies soils by their particle size distribution, their thermal state, and groups them according to their susceptibility to erosion. This classification is described in Enclosure B, Exhibit Z-9.1, Volume VII, Design Manual.

- The classifications correspond to the Unified Soil Classification (USC). Both the SEC and USC classifications appear on the design drawings.

12.4.3.2 Workpad Assessment Program

The program for assessment of the conditions of the TAPS workpad, proposed to be shared by NWA, consists of field reconnaissance during 1980. In addition to geotechnical aspects, erosion characteristics, especially at cross drains, are under assessment.

12.4.3.3 Field Drilling Program

Borehole programs continue to verify soils information used as a basis for the design and the SEC code. Borings are being made along the pipeline centerline, new airfields, new camps, compressor station sites, and at areas of suspected slope instability.

12.4.3.4 TAPS Geotechnical Data

12.4.4 Environmental Data

The environmental data are needed to assess erosion control and revegetation needs as a function of habitats, populations, growing conditions and aesthetics, and must include:

12.4.4.1 Fish and Wildlife Data

Fish and wildlife concentrations and seasonal habitat, movement routes and general guidelines for sensitive periods are necessary for the scheduling of construction activities. Refer to Section 10 of this enclosure.

12.4.4.2 Visual Resource Data

Visual impact assessment data are required as input to the selection of access roads and material and disposal site locations to avoid, when possible, costly restoration requirements for mitigation. A visual resource program is planned to provide the project with guidance necessary to minimize adverse impacts on visual resources (Enclosure B, Exhibit Z-1.1, Volume III).

12.4.4.3 Revegetation Data

Data on seed and fertilizer mixes, and application rates and seasons are required. Data from all possible sources are being compiled. In addition, a field program is planned to study the TAPS revegetation status to gain further input (Enclosure B, Exhibit Z-1.1, Volume III, and the Environmental Engineering Manual).

12.5 DESIGN CRITERIA

12.5.1 Stipulations

Design criteria for erosion control and revegetation have been developed in accordance with draft stipulations, Enclosure A.

12.5.2 Erosion Control

Erosion control practices are incorporated into all elements of design. Construction plans will provide for control of erosion, sediment production, transport, and deposition to allowable levels. They must also provide for minimum disturbance of natural waters and minimum effect on the thermal regime of the soil.

12.5.3 Revegetation

Revegetation practices are incorporated in design and construction plans. Areas which have been graded, filled, or otherwise disturbed in the course of construction or related activities will be restored to satisfactory conditions during and subsequent to completion of construction. Such restoration will include finish grading, permanent erosion control and drainage structure construction, revegetation, and other measures which may be required to leave the affected area physically stable, minimizing natural change which will occur in the topography or drainage patterns before native vegetation reclaims the disturbed area.

12.5.4 Criteria Summary

Outline criteria for erosion control and revegetation are summarized as follows:

- o Minimize clearing
- o Minimize grading and gravel removal
- o Minimize visual impact

- o Minimize soil erosion
- o Minimize drainage interruption
- o Establish plant cover on disturbed areas, except active floodplains.

12.6 DESIGN PROCEDURES

Application of erosion control and revegetation design criteria has been included in the design in Enclosure B. The methodology applied to resolve the issues of erosion control and revegetation is presented as described herein.

12.6.1 Location of Route and Project Selection

To the extent possible and consistent with project requirements, route and project facility locations have been selected which:

- o Allow or preserve buffer strips of undisturbed land adjacent to streams, lakes, and wetlands.
- o Minimize crossings of streams and wetlands.
- o Minimize disturbance of stream banks and activities which disturb fish habitat including spawning beds, rearing areas, and overwintering areas.
- o Minimize alteration of stream patterns or other stream or groundwater hydrology such as the creation of ponding or draining of lakes.
- o Minimize thermal disturbance and mass soil movement on cut slopes.

12.6.2 Soil Classification for Erosion Control

The soil erosion classification system is utilized to identify and classify the various soils. Application of erosion control design and procedures will be in accordance with this classification system.

12.6.3 Siltation Control

Siltation of natural waters will be minimized by the use of:

- o Location of facilities
- o Settlement basins
- o Water bars (tranverse pad levees)
- o Ditch checks
- o Filters
- o Silt curtains
- o Surface protection (mulches and mat binders)
- o Revegetation.

12.6.4 Slope Protection

Slope angles are designed to maximize stability and minimize erosion considering classification, characterization, and hydrologic conditions. Concentrated flow is not allowed over cut and fill slopes, except where such slopes are specifically protected by an appropriate erosion control structure. Lined let-down structures are employed if stream or culvert flow must pass over cut or fill slopes. Levees are planned to intercept stream or sheet flow and are designed to minimize head cutting. Suitable thermal erosion control measures are employed where cuts in ice-rich materials are necessary.

12.6.5 Thermal Erosion Control

Thermal erosion is minimized by:

- o Locating facilities
- o Providing adequate embankment insulation or thickness
- o Providing drainage to minimize ponding adjacent to embankments
- o Preserving organic mats above cuts
- o Using diversion levees
- o Providing ditch checks at toe of slopes

- Insulating erodable areas
- Mulching erodable areas.

12.6.6 Cross Drainage Design

12.6.6.1 Methods

Workpad and road cross drainage is facilitated by:

- Culverts
- Low water crossings (LWCs)
- Nontrafficable channels
- Undisturbed natural channels
- Bridges, both permanent and temporary.

12.6.6.2 Structure Type

Structure type is based upon:

- Traffic requirements
- Fish passage requirements
- Habitat protection
- Small craft passage requirements
- In-situ soil conditions
- Proximity to existing facilities
- Embankment thickness
- Construction zone geometry
- Grades and cross slopes
- Discharge and velocity.

12.6.6.3 Structure Design

Selection of designs includes:

- Study of data collected regarding performance of TAPS and adjacent road drainage structures.
- Site-specific field evaluation and survey to select structure location, slope, and skew, to best conform with existing channel.
- Evaluation of underlying soils to design depth of over excavation.
- Confirmation of underlying soils during over excavation.
- Checking for compatibility with adjacent existing structures.
- Assurance of FDF flow passage and 5-year flood fish passage (Section 9).
- Use of temporary culverts as necessary in LWC's to reduce erosion during heavy construction traffic, primarily intended for fish streams.
- Use of plunge basins as necessary to control outflow erosion (Section 9).

12.6.7. Channels and Ditches

12.6.7.1 Channels and Drainage Ditches

Channels and ditches are designed to provide drainage. Where required, channels are lined to resist erosion at design flow conditions. Channel linings include coarse gravel, cobbles, riprap, or gabions.

12.6.7.2 Velocity Control Measures

Ditch checks are designed to reduce flow velocity and to control sedimentation. Plunge (or stilling) basins are designed for areas where the discharge to natural streams has a greater velocity than the limiting velocity of the natural material.

12.6.8 Material and Disposal Site Design

Material and disposal sites are selected and designed to minimize erosion and subsequent revegetation efforts. This will be accomplished by:

- o Study of geotechnical data indicating sites of greatest material promise and elimination of small sites of questionable promise and greatest erosion or revegetation sensitivity.
- o Study of hydrologic data to minimize impact on drainage and to determine the extent and depth of mining allowable before undesirable erosion would result.
- o Study of aerial photography and exploration plans in terms of terrestrial and aquatic biology and visual impact.
- o Placing of spoil in abandoned portions of upland material sites wherever possible.
- o Storage of suitable spoil for later use as revegetation material.

12.6.9 Erosion Control Feature Design

Selection and design of erosion control features is determined by:

- o Study of data collected regarding performance of TAPS and Prudhoe Bay Road erosion control practices and structures and incorporation of practices deemed successful.
- o Review state of the art structures and practices endorsed by government agencies and other available current technology and incorporation of practices deemed usable.
- o Study of aerial photography, including high level photography and low altitude oblique photography, to establish drainage basins and flow patterns. (Section 9 of this report).

- o Evaluation of site-specific data to identify soil type, flows and slope data to determine erosion potential.

- o Selection of most appropriate means to temporarily reduce flows to acceptable levels and desired configuration.

- o Selection of most appropriate means to permanently reduce flows to acceptable levels and desired configuration.

12.6.10 Erosion Control During Construction

12.6.10.1 Concise plans must be prepared for stream diversions necessary for pipe burial in floodplains, mining sites or bridge pier excavation.

12.6.10.2 Cross drainage where there is open ditch will be handled in the plans as follows:

- o Flows will be blocked or intercepted and passed across the open ditch in thaw unstable or highly erodible soils or when accommodating a fish stream.

- o Flows will be intercepted by ditch plugs and discharged from the ditch in thaw stable and erosion resistant soils at intervals to avoid discharge erosion at the end of the ditch.

12.6.10.3 Adequate plunge basins (or similar energy dissipaters) will be provided to prevent erosion during discharge of hydrostatic test water.

12.6.10.4 Silt curtains for streams shall be available to control erosion as necessary to allow drainage structure installation or pipe ditching operation to proceed through or in sensitive aquatic habitats during critical periods.

12.6.10.5 Control of sediment from run-off of ice-rich thaw unstable soil is to be accommodated by:

- o Properly designed spoil disposal sites

- Adequate containment basin for settlement and overflow, or infiltration of melt water into the ground.

12.6.11 Revegetation

12.6.11.1 Revegetation Phases

- Temporary revegetation consists of measures which control erosion or siltation during construction.

- Permanent revegetation measures are specified for slope stabilization and rehabilitation. Permanent revegetative measures are implemented in order to minimize erosion and visual impact and to encourage the reinvasion of native species.

12.6.11.2 Revegetation Measures

The following revegetation measures are used:

- Surface preparation of designated areas in order to leave soil in a rough and friable condition.

- Application of fertilizer at suitable rates consistent with soil type and condition.

- Temporary seeding is applied when the surface will be disturbed in the future. Fast establishing grasses are used for temporary seeding.

- Selected permanent seed mixes may consist of perennial grasses chosen for their similarity to native grasses and suitability to the climate.

- Application of surface protection where needed, to retain moisture, dissipate raindrop energy and hold the seed in place.

12.6.11.3 Revegetation Scheduling

Revegetation measures will be scheduled for implementation and hardening-off during the growing season, or during positive dormancy in the winter.

12.7 SOLUTION

NWA will provide erosion control and revegetation by developing final designs and specifications. These plans and specifications will contain details for compliance and contractor implementation. Special practices will be developed if the need for them becomes apparent.

12.8 CONTINUING STUDIES

The following studies and data acquisition will continue to support the selected solution.

12.8.1 Topographic Data

- o Route survey.
- o Streams and rivers survey.

12.8.2 Hydrologic Data

12.8.3 Geotechnical Data

- o Workpad assessment program.
- o Field drilling program.

12.8.4 Environmental Data

- o Fish and wildlife field programs.
- o Visual resource assessment field programs.
- o Restoration and revegetation field programs.

12.9 POTENTIAL CHANGES

Reroutes are not expected as a result of any erosion control or revegetation problems.