YUKON RIVER BRIDGE USE
RISK ANALYSIS CRITERIA DEVELOPMENT

by

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EXECUTIVE SUMMARY

I. INTRODUCTION

Pursuant to an agreement with the Pipeline Coordinator, Division of Pipeline Surveillance, the Department of Transportation and Public Facilities contracted with Peratrovich and Nottingham, Inc. for professional services to prepare criteria for the factors to be addressed by Northwest Alaskan Pipeline Company (NWA) in completing studies, including risk analysis, for using the Yukon River bridge as their gas pipeline river crossing. This report develops those criteria. Peratrovich and Nottingham, Inc. will also assist the State in determining the validity of the investigations performed by NWA.

II. BASIS OF RISK CRITERIA

Establishment of risk criteria for the Yukon River Bridge cannot be limited only to an in-depth design analysis of the structure given certain loading parameters. Other criteria considerations such as possible loss of revenue, national energy problems, defense needs, and limitations on North Slope access must also be addressed. Since the Yukon crossing is one of the most crucial elements for access to the North Slope, and probably one of the most difficult links to repair if critically damaged, a contingency system for crossing the Yukon River must also be a part of the criteria used for risk analysis.

III. CONCLUSIONS

This risk assessment must have a dual approach:

1. Risk and Contingency Suitability

2. Risk and Economics

Under both of these categories, a further delineation by design configuration must be made:

A. Oil line and gas line - each on separate structures.

B. One oil line and one gas line on the existing bridge.

C. Two oil lines and one gas line on the existing bridge.

D. One oil line and a contingency for either one oil or gas line on the existing bridge, and one gas line and a contingency for either one oil or gas line on a new structure.

Moreover, evaluation of all factors contributing to risk at the river crossing must be addressed, complete with assessment of the event, planned method of solution, and degree of peril for planned method involving each risk factor.

IV. RECOMMENDATIONS

Northwest Alaskan Pipeline Company must perform a complete study of the Yukon River Bridge which addresses the risk criteria contained in this document. Once NWA has made their conclusions based on these fully defined risk analysis criteria, the State will evaluate NWA's response. From the foregoing, the State will then make the final determination on whether to permit the Yukon River Bridge to be used for the supporting structure of the gas pipeline river crossing.

YUKON RIVER BRIDGE USE
RISK ANALYSIS CRITERIA DEVELOPMENT

INTRODUCTION

First consideration was given to the Yukon River Bridge project in 1970, when Alyeska Pipeline Service Company recognized the serious need for a safe but economical way of crossing the Yukon River with their pipeline, as well as attaining road access to the North Slope. Negotiations with the State of Alaska subsequently produced a joint agreement which initiated planning and engineering work.

Several road alignments were studied (Illustration No. 1), the preferred choice being Alignment No. 5 (one mile downstream from the present bridge), chiefly because this alignment minimized bridge grade to about 2%. In the spring of 1971, State drill crews and geologists began drilling along the intended alignment but encountered dense soil-like material incapable of providing the foundation support desired. Since breakup was rapidly approaching and would terminate drilling from the ice, a new alignment was chosen (Alignment No. 6). Although this alignment was less desirable due to its 6% bridge grade, it offered the probability of a rock foundation. Subsequent borings did indeed reveal rock, with the possibility of some fracture and gouge material (common to many borings taken previously by Alyeska and others). Even though there was some risk that poor rock might be encountered in isolated instances during construction, it was decided this was the best alignment, chiefly because of the great economy gained by using rock for support.

Design began in earnest around the first of June 1971, and the first plan submittal was in September 1971. A delay followed the design phase while Alyeska awaited government permit approval. The bridge construction contract was finally awarded in 1974. During construction, encounter with fractured rock at Pier No. 4 (at the center of the river) caused redesign of that pier footing. Piles were added at the upstream end and the footing size was increased. In October 1975 bridge construction was sufficiently complete for vehicular traffic.

SOILS AND SITE

The 2000-foot wide Yukon River channel is underlain by river-transported gravel from 2 to 40 feet thick over greenstone bedrock with variable fracture. The north floodplain has about 20 feet of frozen silt overlying frozen gravel, while the south bluff abutment area has about 20 feet or more of frozen silt over highly decomposed bedrock. Road grade is Elevation 470 at the south abutment and Elevation 332 at the north abutment, which accounts for the 6% bridge grade.

RIVER FLOW AND ICE

At the time of design, State highway bridges customarily were designed to accommodate 50-year flood recurrence intervals, which for the Yukon River site were estimated at 1,018,000 cfs at Elevation 305. The pipeline project design flood (PDF) was set at 1,600,000 cfs at Elevation 321. With a north floodplain at Elevation 308, a considerable amount of land would be flooded during PDF. Also, the north abutment box girder soffits would be immersed 2 feet during the PDF event.

Ice on the Yukon River can attain a thickness of over 5 feet, but usually is around 30 inches thick at breakup. Ice will move with predictability in huge sheets during annual spring breakup. Bridge design considered 5 feet of ice with 400 psi crushing strength.

The Yukon River transports large volumes of drift, much of it in the form of sizable trees. Drift concentrations up to 80 feet across have been observed at piers. The influence of this phenomena on scour is not known but may be worthy of some investigation using geophysical methods during winter ice cover.

SEISMICITY

Bridge design considered the Yukon River crossing site to be an area of moderate seismic severity. Presence of some highly fractured rock in core samples, thought to be lineament or fault-associated gouge material, suggests some past earthquake action. The appearance of this material, as excavated at Pier No. 4, resembles irregular rocks of various size in a matrix of fine material, some approaching clay size. In the riverbed this formation could be more prone to scour than the parent rock.

ORIGINAL BRIDGE DESIGN CRITERIA

The Yukon River Bridge was designed to support two lanes of AASHTO HS 20 loading, one or two 48-inch diameter crude oil pipelines with allowance for snow and ice, and all dead loads, including a 2-inch epoxy asphalt surface or 5-inch timber deck. In addition, certain components were sized for earthquake, ice or wind design forces or various combinations of forces.

The selected superstructure is a subtly complex orthotropic steel torsionally rigid structure with five basic components. These include two pipeline support bracket assemblies, two box girders and one center deck section. Sections are spliced together with high strength bolts in such a manner that any brittle fracture in one girder will not transmit to the other.

Should a fracture in one girder develop, along with loss of support, the remaining girder is designed to carry all dead loads anticipated at that time without failure. This was accomplished by using torsionally rigid box girders and heavy pier and abutment diaphragms. This reserve capacity could disappear with the imposition of more dead loads (such as additional pipelines, security shields and equipment, etc.).

Thermal movement is large in this structure. Bridge design addressed this and other movements in specific ways that must be accommodated in any added systems.

RISK CRITERIA DEVELOPMENT APPROACH

Establishment of risk criteria for the Yukon River Bridge should not be simplified to the point of merely studying material overstresses under certain loads. Real concerns exist and have been expressed involving loss of revenue, creation of energy problems, possible defense needs and North Slope access. The Yukon River crossing, due to its nature, is probably one of a handful of critical elements along the Alyeska Pipeline Service Company route. If necessary, most parts of the pipeline can be temporarily repaired and put back into service in a few days or less. However, when one of the largest and most difficult rivers in world is involved, repairs could take up to one year or even longer. To compound its crucial nature, the Yukon River Bridge is the only highway link to the North Slope.

For these and other reasons, this risk assessment should be approached in two basic and simultaneous ways:

1. Risk and Contingency Suitability
2. Risk and Economics

Under each of these categories, the following methods of pipeline crossing should be assessed, using ideas shown on Illustrations No. 11 and No. 12.

A. Oil Line and Gas Line each on separate structures

B. One Oil Line and one Gas Line on the existing bridge

C. Two Oil Lines and one Gas Line on the existing bridge

D. One Oil Line on the existing bridge with provision for one contingency Oil or Gas Line, and one Gas Line on a new structure with provision for one contingency Oil or Gas Line

RISK

The following list of items contributing to risk at the Yukon River Crossing should be addressed, complete with:

1. Assessment of the event
2. Planned method of solution
3. Risk of planned method

LIST OF RISK FACTORS

- Wind
- Lightning
- Flood
- River Scour
- Ice and Drift
- Earthquake
- Slope Stability
- Permafrost Deterioration
- Temperature Extremes
- Thermal Movement
- Aircraft Collision
- Vehicle Collision
- Marine Collision
- Vandalism
- Sabotage
- Excess Dead Load
- Excess Vehicular Loads
- Bridge Metal Brittle Fracture
- Bridge Metal Brittle Fracture From Chilled Gas Leak
- Pipeline Weld or Material Flaws

- Gas Line Crack Propagation
- Gas Line Explosion
- Pipeline Leakage
- Pressure Surge or Over Pressure
- Pipeline Related Construction
- Non-Pipeline Related Construction
- Future Construction in Bridge Vicinity
- Pipeline Maintenance Activity
- Bridge Maintenance Activity
- Corrosion

CONTINGENCY SUITABILITY

Contingency suitability can best be assessed in a simple "yes or no" format, after all detailed arguments are presented for the following questions (risk items previously listed are to be addressed as appropriate):

1. Is there any potential for adverse impact on U.S. energy needs with this solution?

2. Will the potential for adverse impact on U.S. energy needs be decreased with this solution?

3. Is another method available with less potential for adverse impact on U.S. energy needs?

4. Will this solution add weight that may negate the existing structure's contingency design for loss of one girder?

5. Will this solution add weight on the existing bridge which may limit future overload highway transportation to the North Slope and thus impact shipping efficiency?

6. Will this solution add weight on the existing bridge that may limit possible defense access need?

ECONOMICS

Most capital expenditure decisions made today involve the cost of doing business related to annual cost, life cycle cost, or other costing methods. Since use (or non-use) of the Yukon River Bridge will impact initial expenditures, an analysis of various alternatives is necessary, using some form of common ground cost comparison that recognizes interest and inflation.

Some items requiring input are complex and perhaps subjective, but nevertheless are economic factors that could influence a decision. Annual cost of insuring against certain events may be a viable approach in some of these cases.

ECONOMIC FACTORS

- Capital investment, including engineering, planning, administrative and construction costs
- Security costs
- Maintenance and operation costs
- Physical loss of oil and gas
- Environmental impact cost of spills
- Economic loss due to oil and gas operation shutdown
- Economic loss due to load-limited Haul Road traffic
- Economic loss due to Haul Road shutdown
- National energy impact losses due to shutdown
- Defense impact losses due to Haul Road shutdown

ANALYSIS

Once all factors have been defined, they should be utilized with each crossing method identified in order to arrive at a bottom line economic cost that accurately reflects both Costs and Cost of Risks.

These findings should be summarized, along with Risk and Contingency Suitability, with the final statement being a recommendation for the best method of crossing the Yukon River with additional pipelines.

All methods, assumptions, costs, rates, physical site data verifying conditions, etc., should be carefully documented and presented as backup for the conclusions.

ILLUSTRATION COMMENTARY

No. 1

The Yukon River Bridge crossing was studied in great detail during planning phases, as evidenced by this illustration which shows various alignments and soil boring locations. Topography and variable soils at other locations led to selection of Alignment No. 6.

This crossing predominantly featured a bedrock foundation structure, an economic must for design of piers in heavy ice flows. Permafrost existed at each bridge abutment and was a design consideration.

Construction at River Pier No. 4 later uncovered fractured bedrock. Pier modifications were required in the form of added piling on the upstream side and footing enlargement.

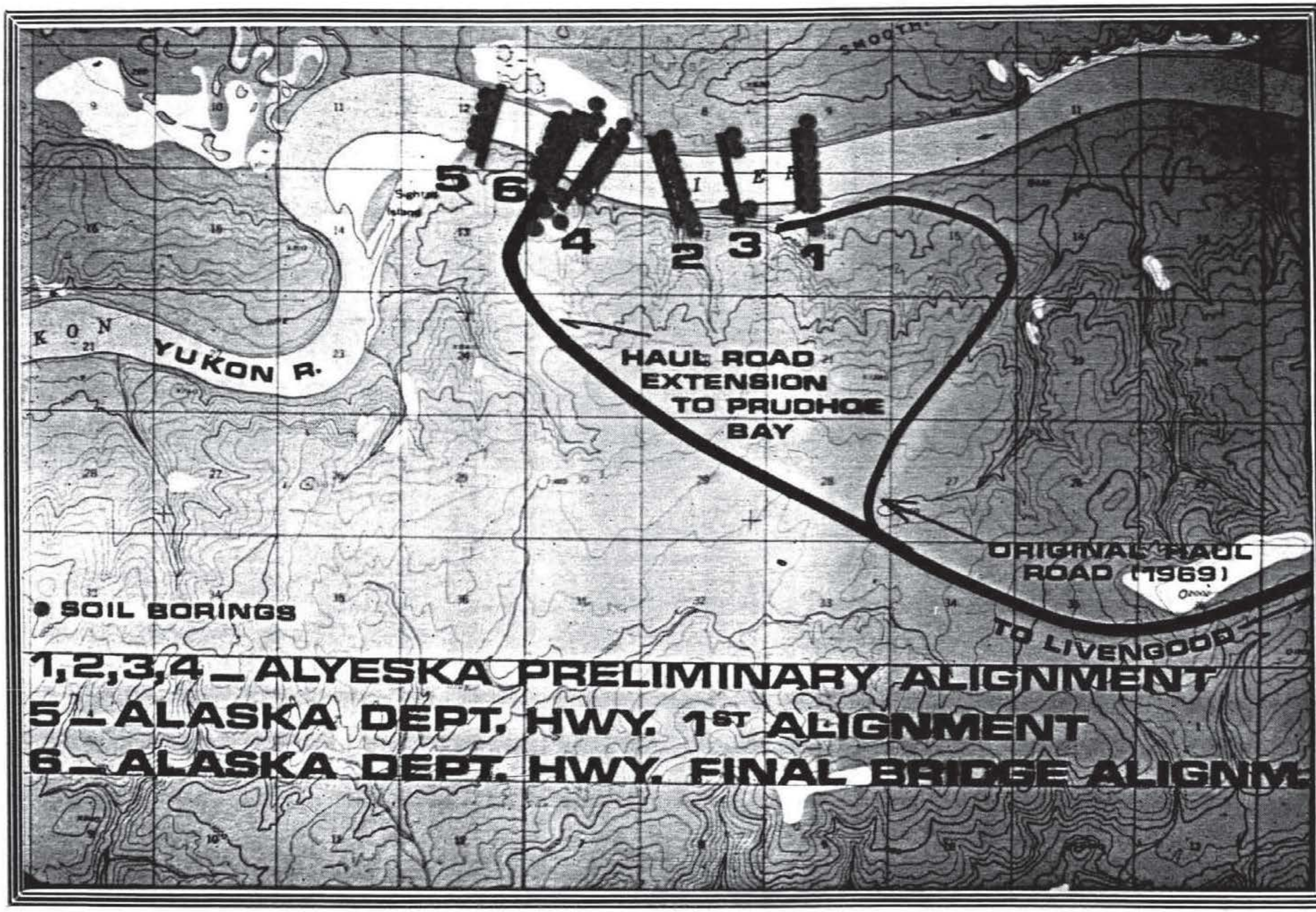


ILLUSTRATION No. 1

ILLUSTRATION COMMENTARY

No. 2

This photo taken in the construction period shows typical ice run during spring breakup. Shown on the left is the partially complete bridge superstructure.

Channel width at this location is about 2000 feet, with a uniform upstream channel capable of forming significant river ice. Design recognized 5 feet of 400 psi ice as an ice loading possibility. Normal ice thickness as breakup appears to be about 30 inches, although shore ice can be much thicker.

The left side (north) shows a low flood plain characterized by frozen silty soils overlying frozen gravel. The right side (south) shows a bluff composed of frozen silt overlying deteriorated soil-like bedrock.

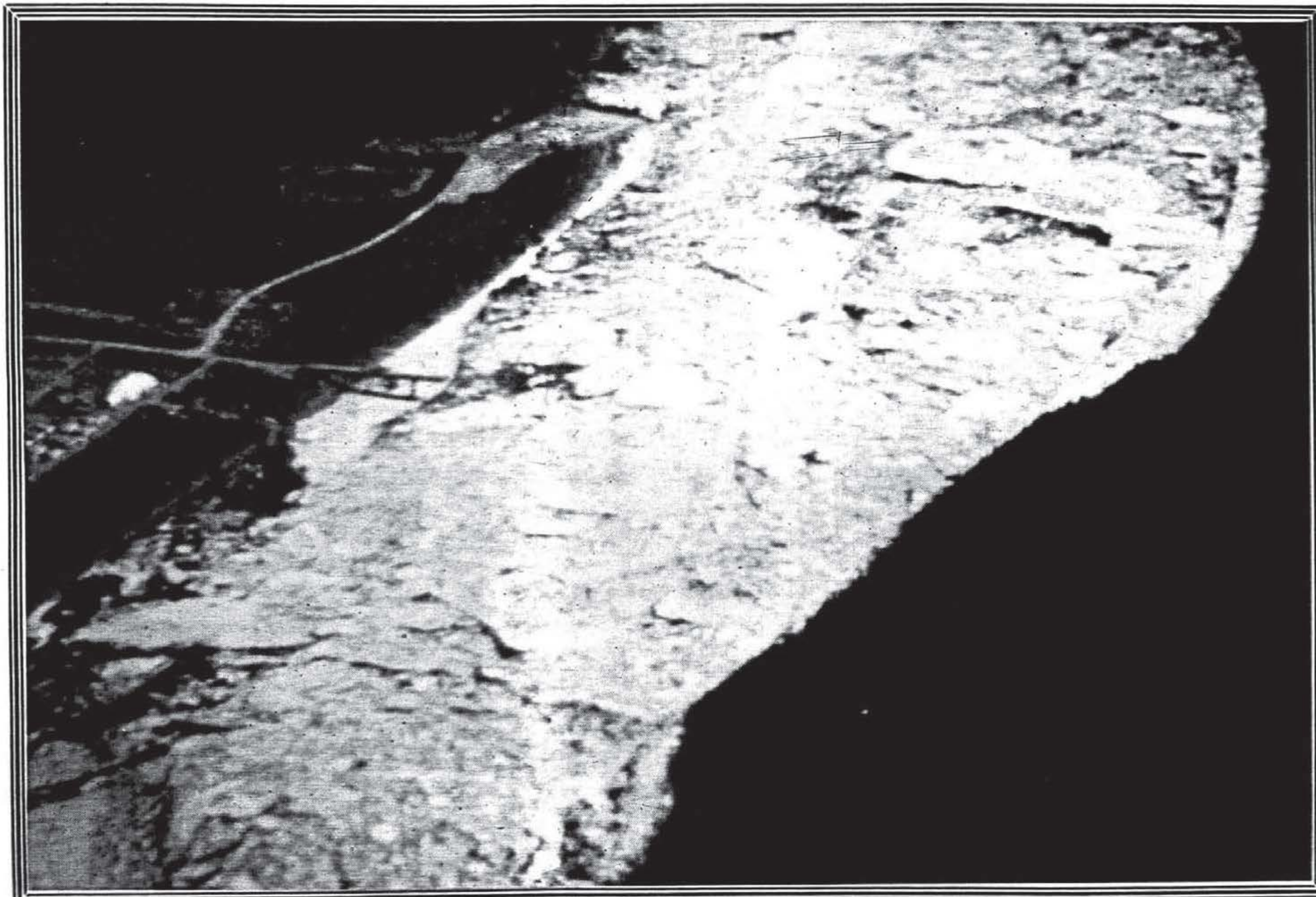


ILLUSTRATION No. 2

ILLUSTRATION COMMENTARY

No. 3

This photo shows drift accumulation ± 80 feet wide at a river pier, and the bridge underside with catwalks and other details.

Drift accumulation of this nature can increase foundation scour potential. Assessment of foundation performance using geophysical methods during winter ice cover would help address this potential and confirm performance to date.

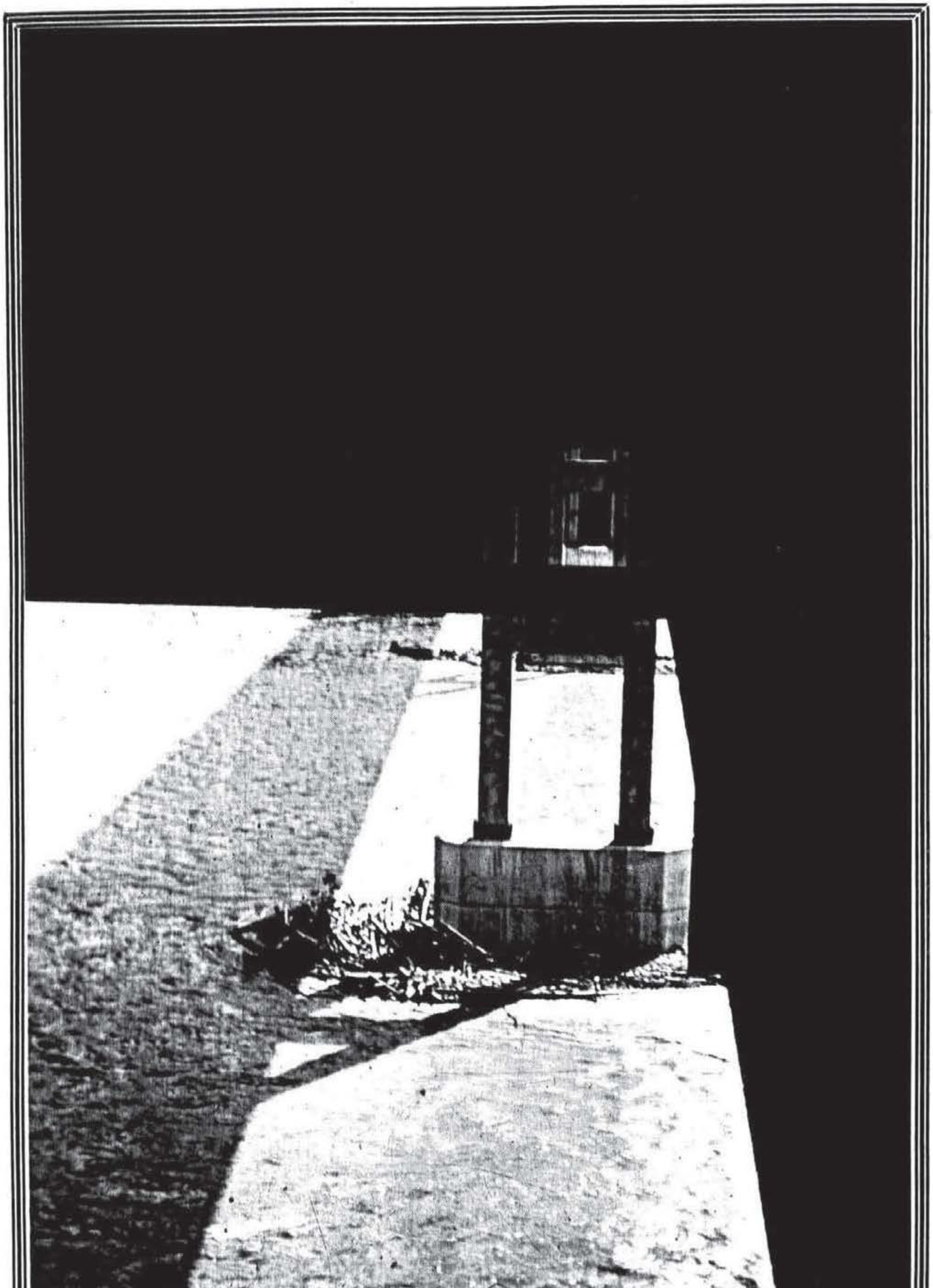


ILLUSTRATION No. 3

ILLUSTRATION COMMENTARY

No. 4

This photo of the completed bridge looks south. Readily apparent on the horizon is a $\pm$ 40-foot cut in frozen silt. Some deterioration of this cut has been noted during bridge inspection, which demonstrates the critical nature of future design and construction on or around this land form.

Risk of slope failure with increased excavation is an important factor in all future design and assessment.

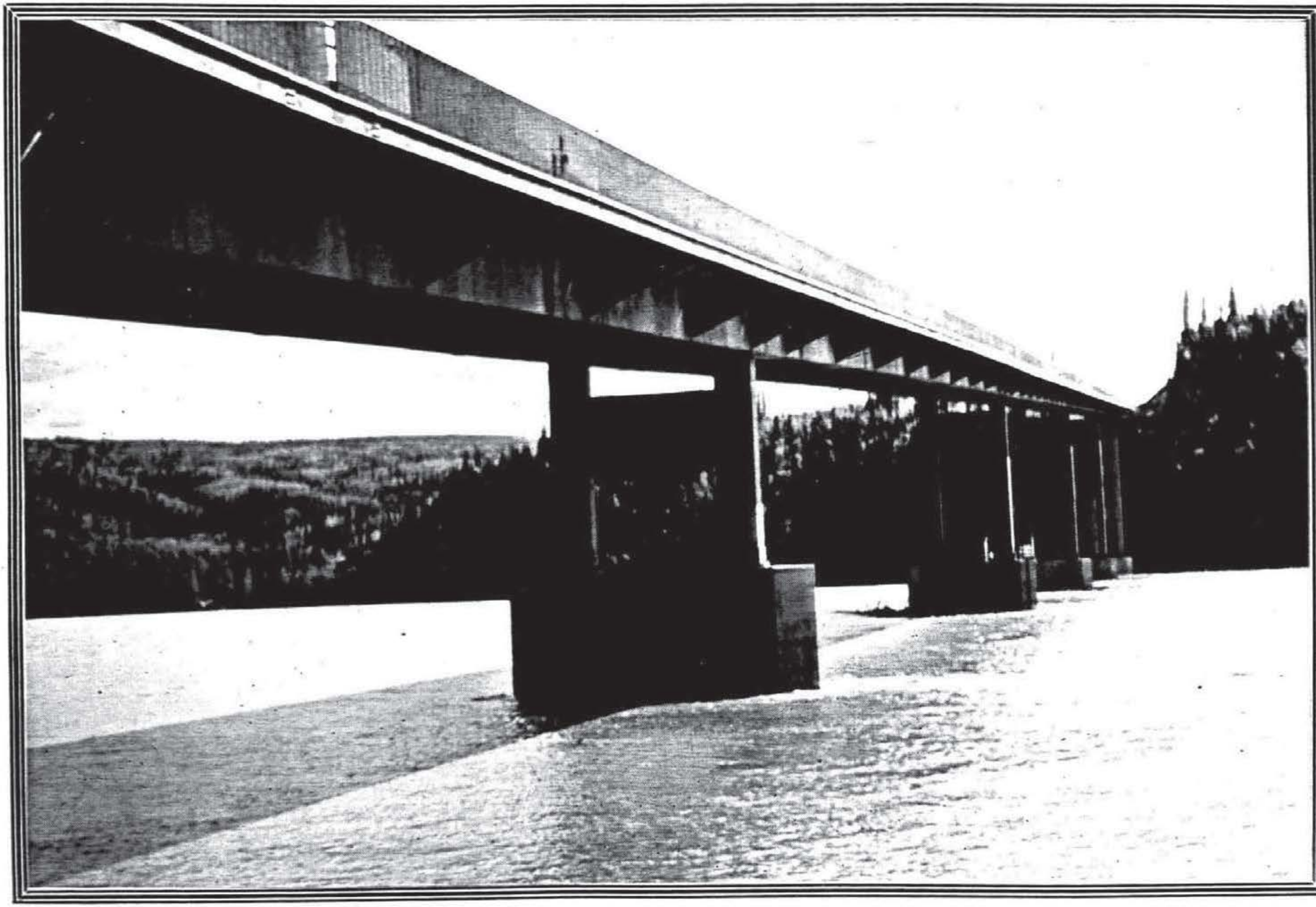


ILLUSTRATION No. 4

ILLUSTRATION COMMENTARY

No. 5

This illustration shows major components of the Yukon River Bridge; specifically exterior pipeline supports, torsionally rigid box girders and pier diaphragm used to resist torsion.

Design of this system considered loss of one girder (by damage from aircraft impact, brittle fracture, etc.) without loss of the bridge superstructure under design dead load. Torsional consideration in design made this criteria a reality and influenced the choice of superstructure.

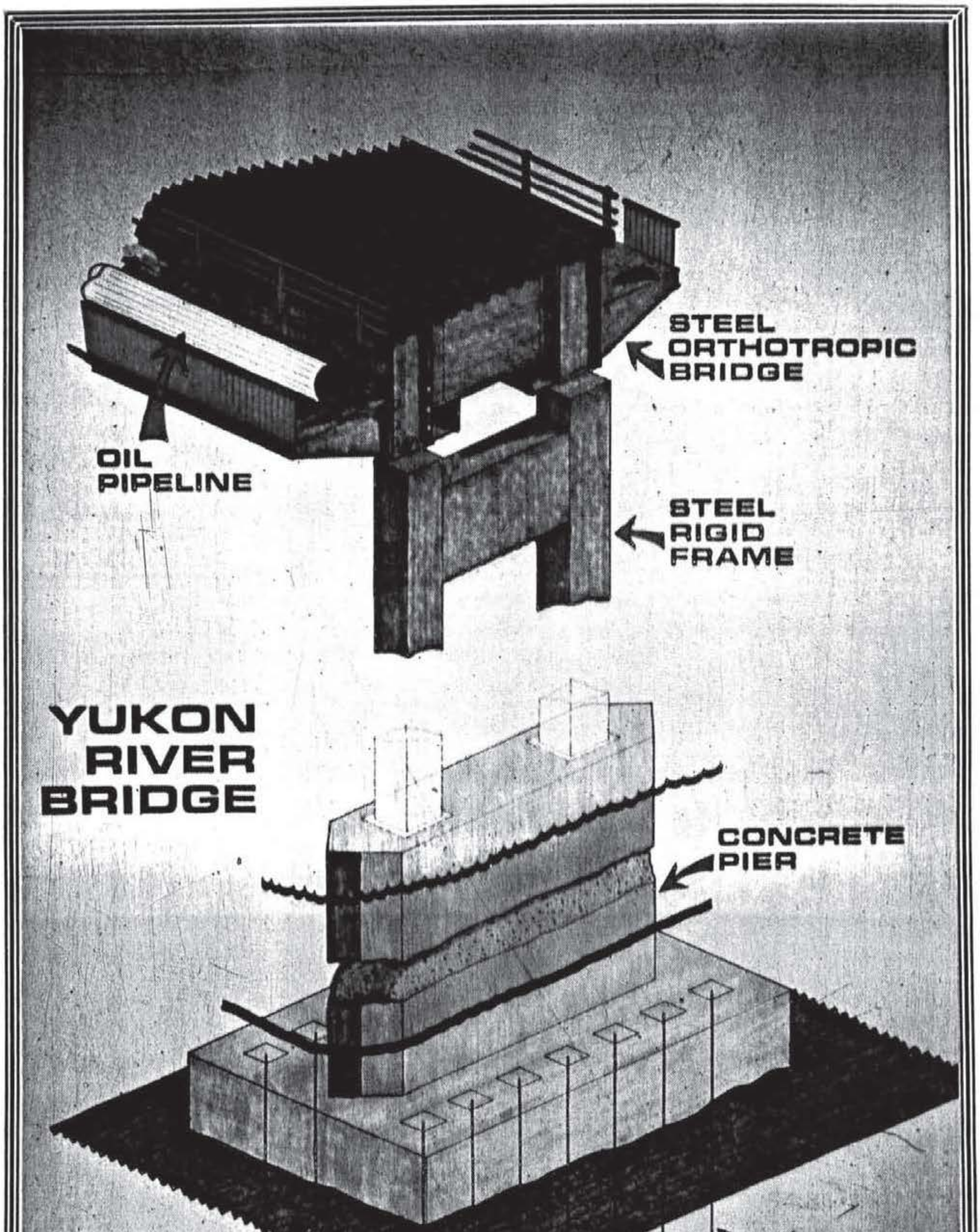


ILLUSTRATION No. 5

ILLUSTRATION COMMENTARY

No. 6

This photo further illustrates box girder construction and shows various details. The view also shows the north floodplain, composed of frozen silts overlying frozen gravel.

Project design flood levels are calculated to submerge box girder soffits by two feet at the north abutment.

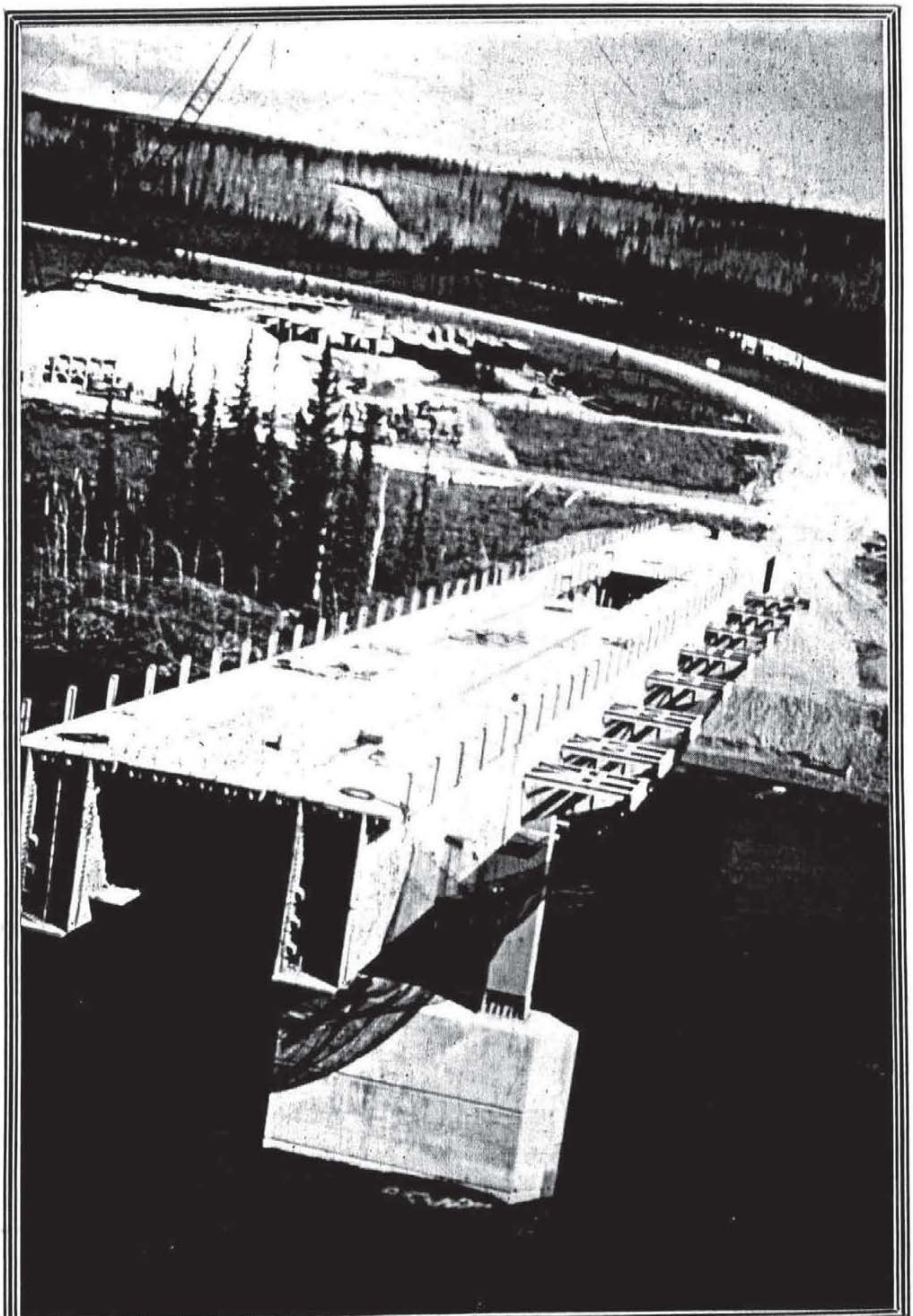


ILLUSTRATION No. 6

ILLUSTRATION COMMENTARY

No. 7

This photo shows the relative scale of oil pipeline supports and the oil line as constructed. A 4-foot roadway barrier rail can be seen at the top, while a 5-foot screen rail partially obscures the pipeline from a frontal view.

Since this photo was taken, various security devices and covers have been added, with some increase in dead load.

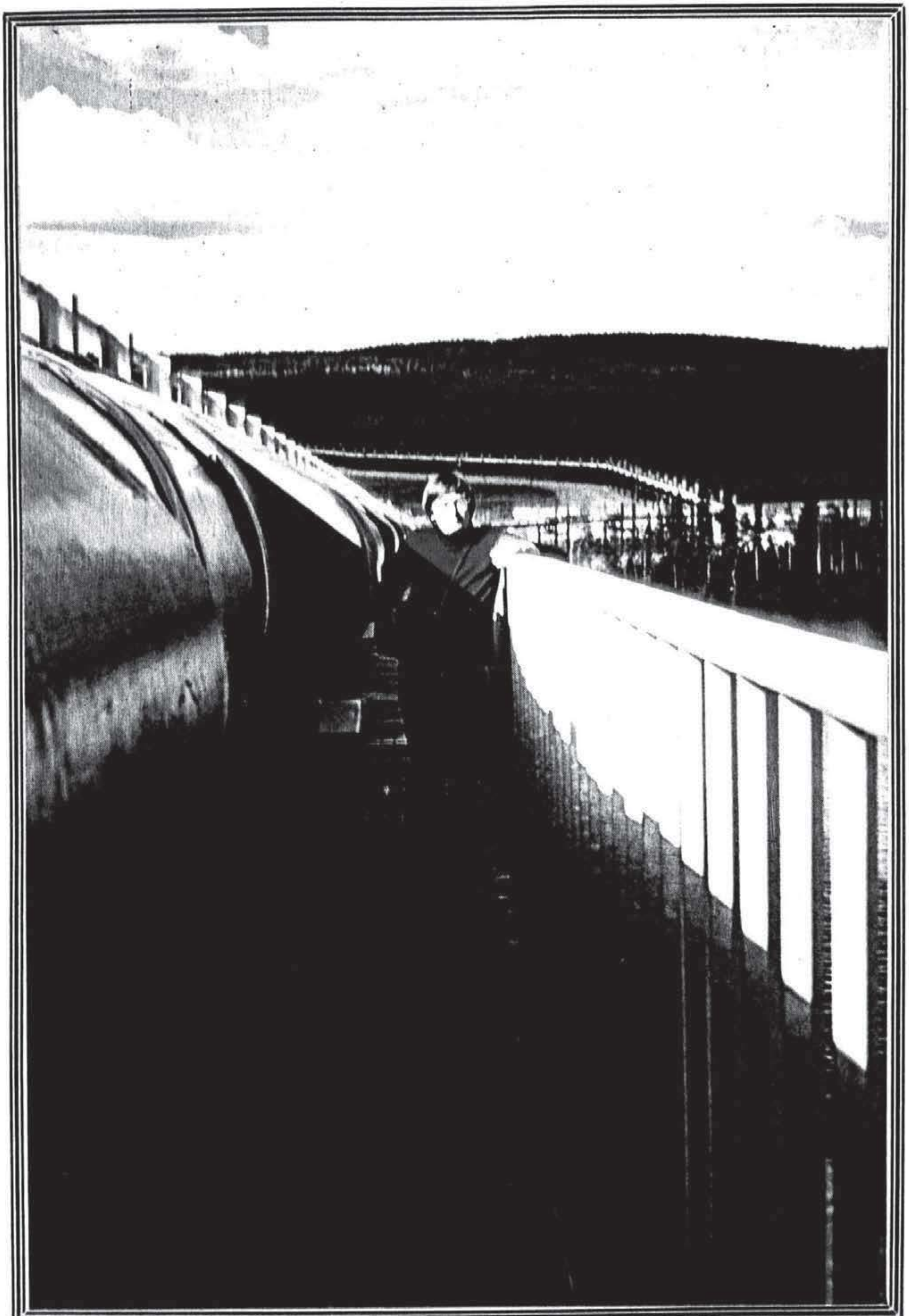


ILLUSTRATION No. 7

ILLUSTRATION COMMENTARY

No. 8

The bridge shortly after pipeline completion is shown here. Most geometrical features can be seen. Future oil line supports are visible on the left.

Presently a temporary timber wearing surface covers the orthotropic steel deck surface. Eventually, after most construction is finished, a suitable permanent surface (such as epoxy asphalt) is planned.

ILLUSTRATION No. 8

ILLUSTRATION COMMENTARY

No. 9

This winter view illustrates the significant drop in river water level and shows relatively easy access over the ice.

Some experimental ice force measurements have been taken, and more are currently being planned, using river piers.

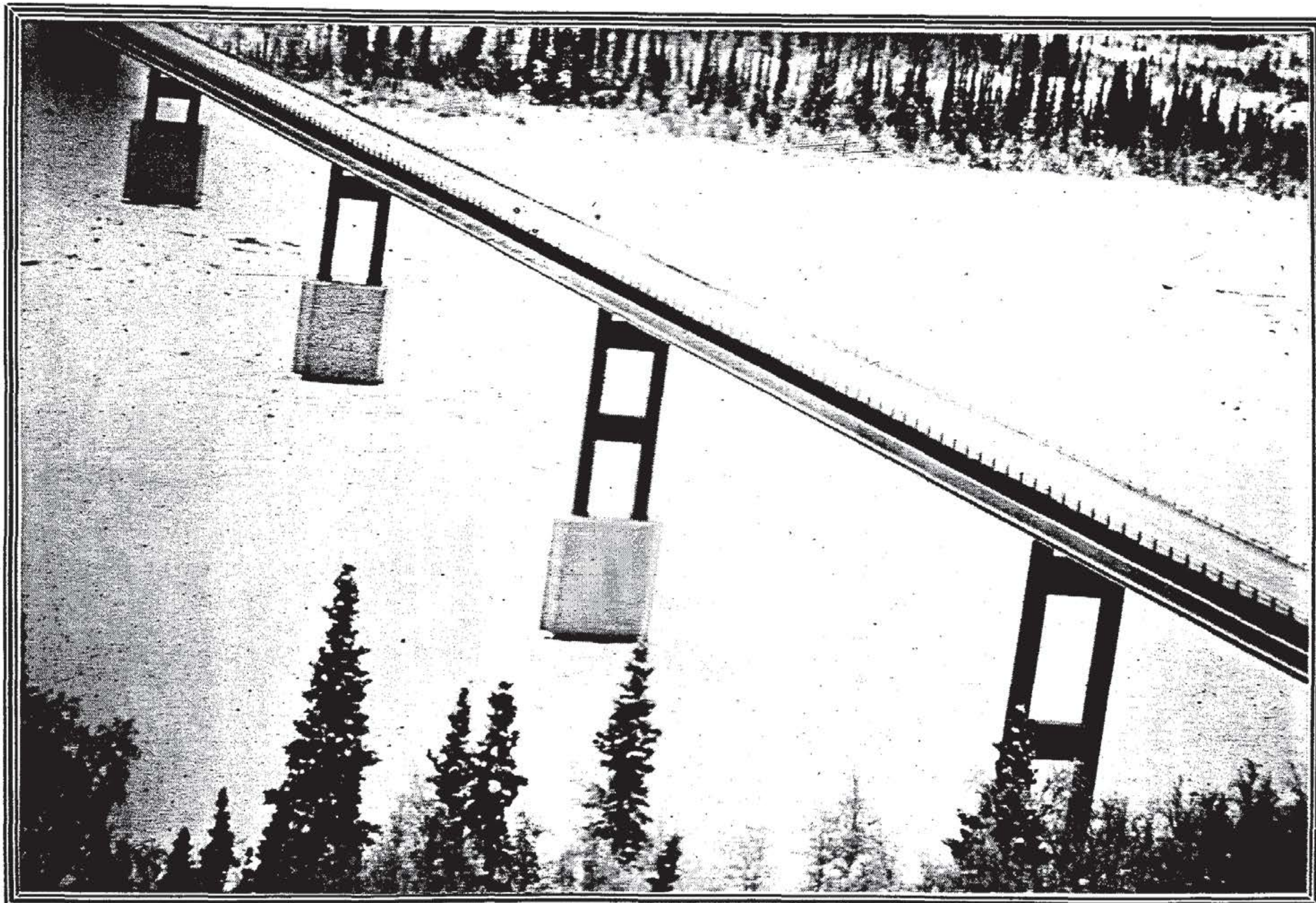


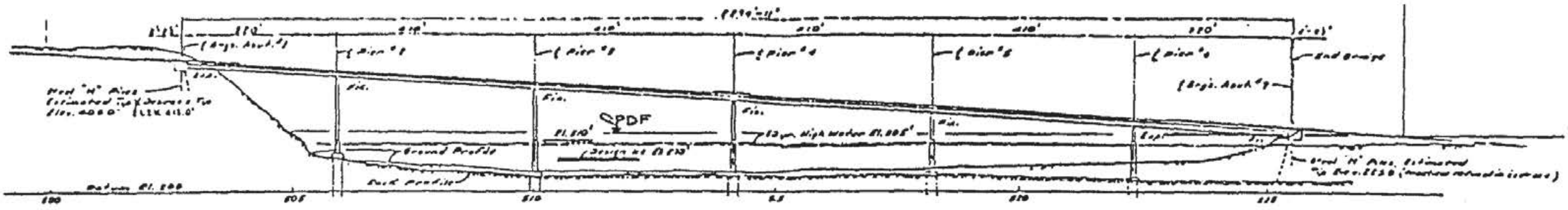
ILLUSTRATION No. 9

ILLUSTRATION COMMENTARY

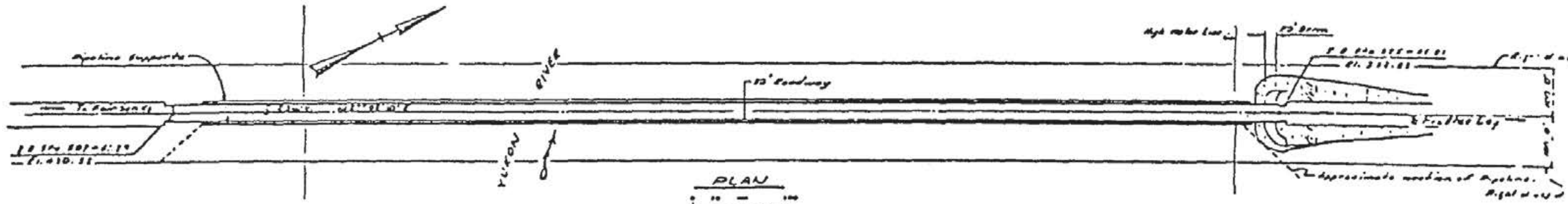
No. 10

This illustration displays various dimensions and shows PDF (Project Design Flood) volumes and levels. Here PDF is noted as "Standard Project Discharge."

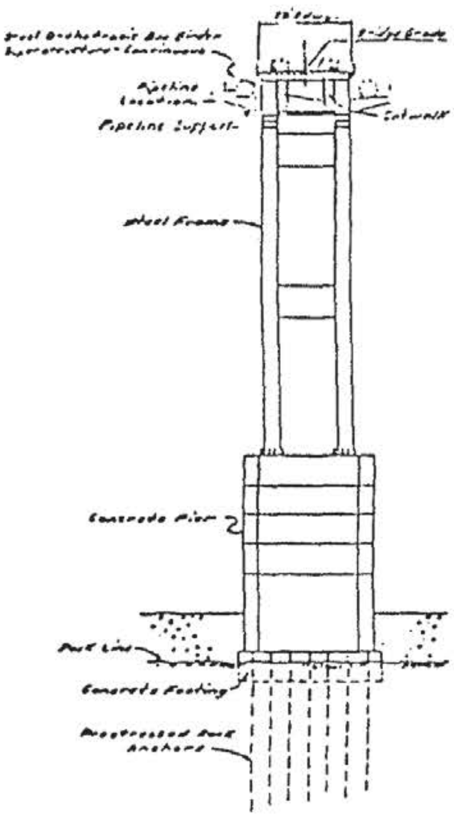
The profile shows various relevant features such as rock level, bridge slope and flood levels. Note that PDF levels extend over the north approach road and for a considerable distance over the north flood-plain.



ELEVATION



PLAN



TYPICAL SECTION

HYDRAULIC SUMMARY
DRAINAGE AREA —— 199,400 SQ. MI.
DESIGN FREQUENCY —— 50 YEAR
DESIGN DISCHARGE —— 1,015,000 CFS
DESIGN HIGH WATER ELEV. —— 305'
STANDARD PROJECT DISCHARGE —— 1,600,000 CFS
HIGH WATER ELEVATION —— 321'
FREQUENCY —— 500 YEAR (APPROX.)

ILLUSTRATION No. 10

YUKON RIVER BRIDGE

GENERAL LAYOUT

ILLUSTRATION COMMENTARY

No. 11

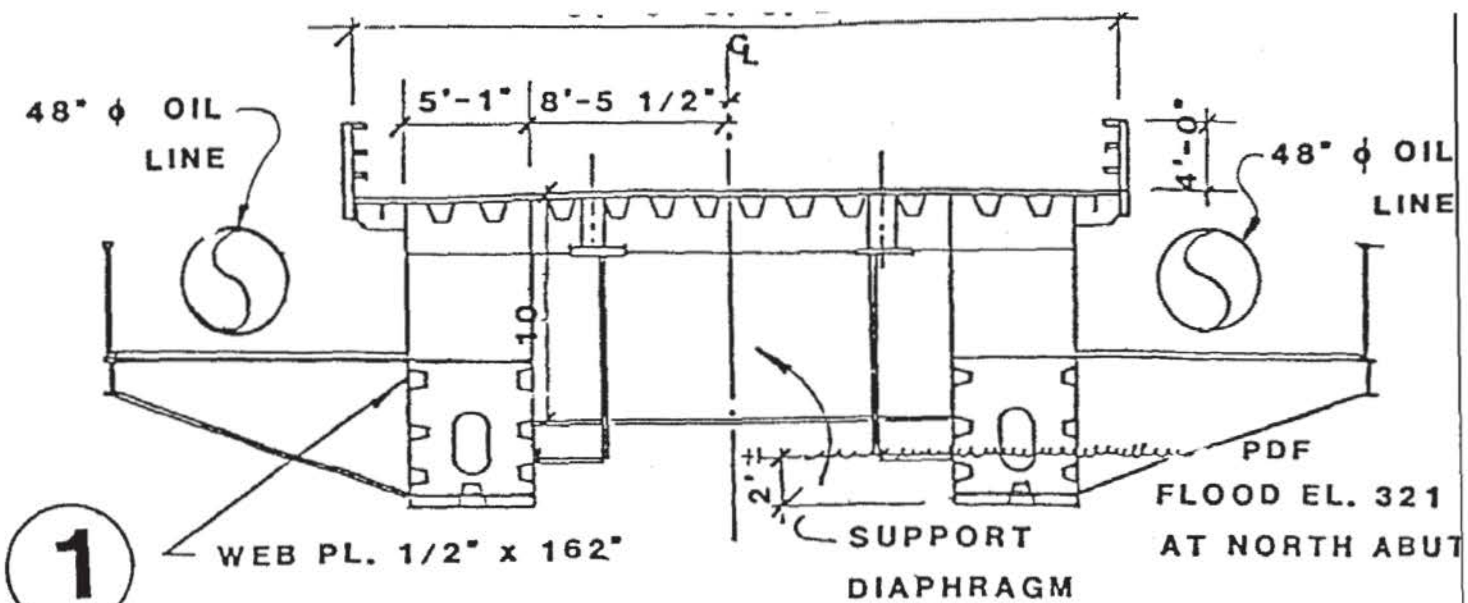
This illustration presents three possible ways that a gas line and oil line or lines may occupy the Yukon River Bridge.

Method No. 1 follows the original design, with 48-inch diameter oil lines on each side. This method was originally selected because of constructability, ease of maintenance, and accessibility during emergencies.

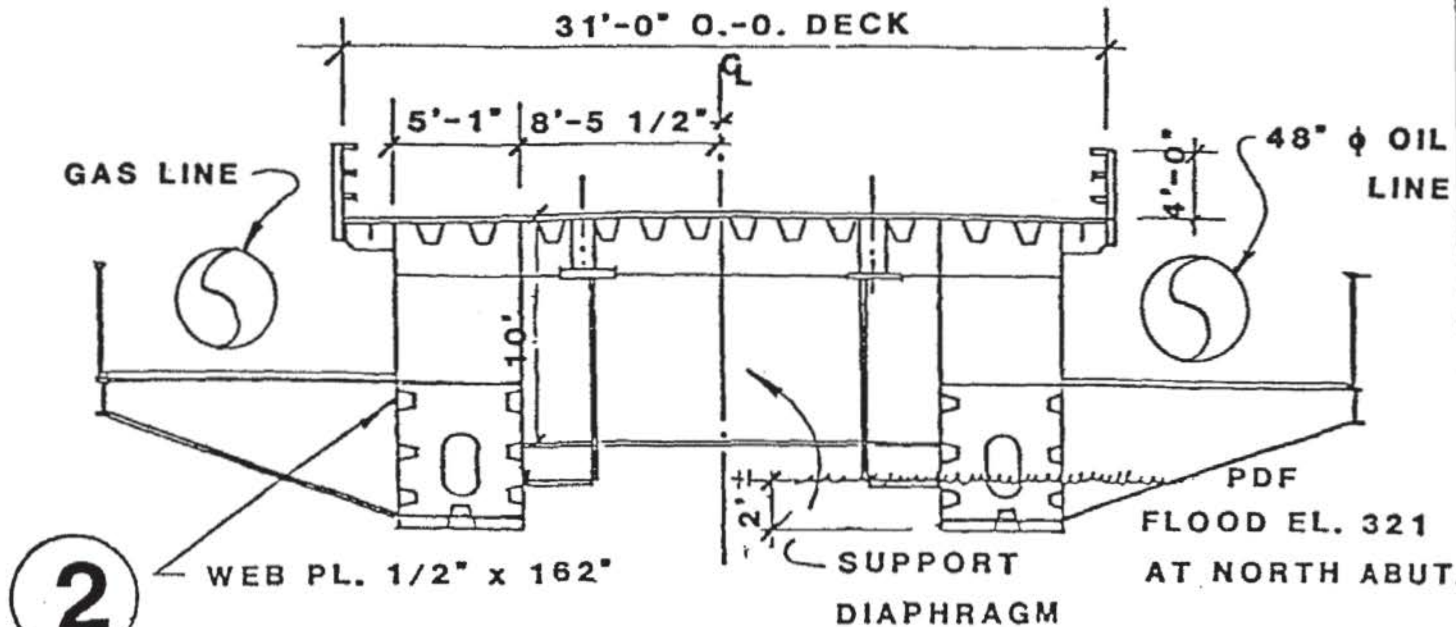
Previously a method of suspending a pipeline under the bridge deck was examined but rejected for reasons just the opposite of the preceding statement.

Method No. 2 is similar to Method No. 1 in that dead load is not increased and desirable access features are present.

Method No. 3 could eventually carry three pipelines on the bridge. Although additional dead load (dead weight plus product) may not appear to cause significant superstructure overstresses, the contingency safety criteria of having only one girder support all dead loads may be negated.



TYPICAL SECTION



TYPICAL SECTION

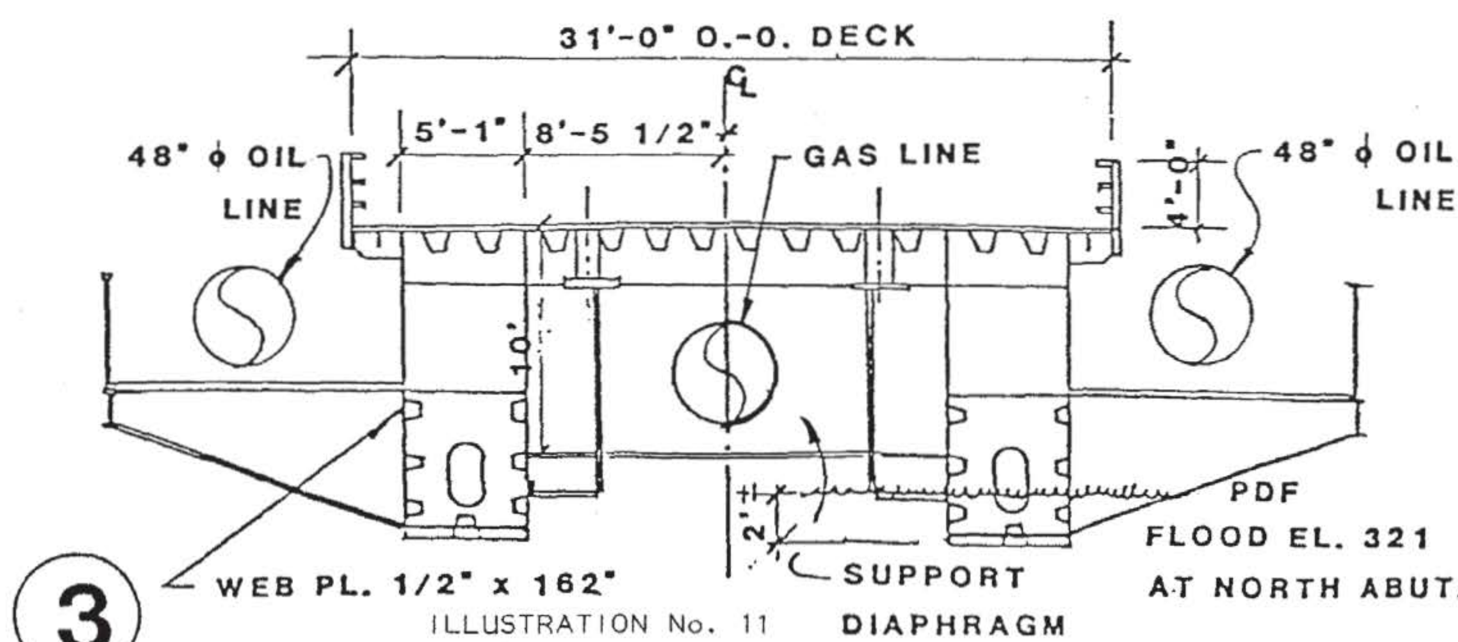


ILLUSTRATION No. 11

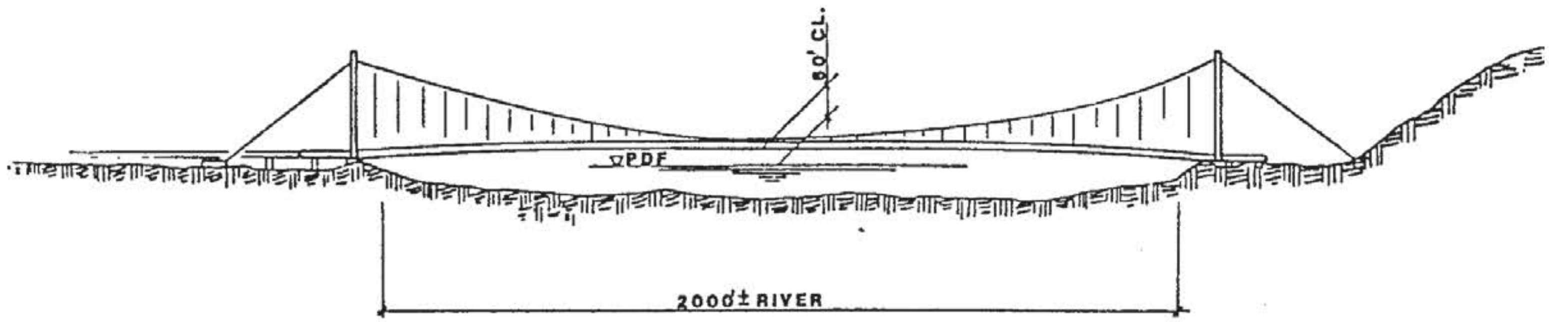
TYPICAL SECTION

ILLUSTRATION COMMENTARY

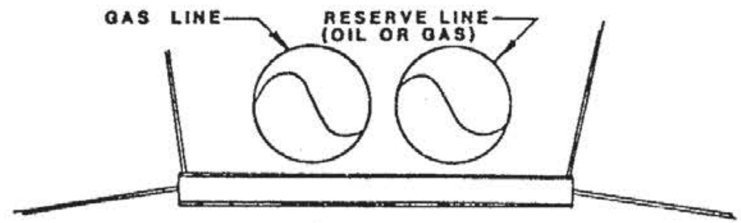
No. 12

This illustration suggests an alternative to a single bridge crossing which may be consistent with published government concerns regarding the vulnerability of the pipeline to damage and the lack of contingency systems. Loss of a structure such as the Yukon River Bridge for any reason could require possibly one to two years for replacement. This method, with proper location, could assure a minimum pipeline down time for either oil or gas transmission.

This concept is presented as a basis for economic and risk comparisons for all combinations of systems. By comparing economics and risks jointly, a more meaningful final decision can be achieved.



SCHEMATIC ELEVATION



TYPICAL SECTION

ILLUSTRATION No. 12