UNITED STATES OF AMERICA

Before the

FEDERAL POWER COMMISSION

Volume IV of V
Application of
El Paso Alaska Company
at Docket No. CP75-___
for a
Certificate of Public Convenience
and Necessity

Pursuant to § 7(c) of the
Natural Gas Act

Respecting the
Proposed
Trans-Alaska Gas Project

Dated: September 23, 1974 Filed: September 24, 1974

COPY NO. 0140

2 ENVIRONMENTAL BASELINE

This Section describes the environmental setting of the proposed Alaskan Gas Pipeline, LNG Plant, Alaskan Marine Terminal and LNG Carrier Fleet. The information presented has been derived primarily from published literature, including the Final Environmental Impact Statement for the Trans-Alaskan [Oil] Pipeline (USDI, 1972). Supplemental data were obtained during on-site reconnaissance field studies conducted during 1973 and 1974.

For purposes of this Report, the environmental baseline is considered to be that which exists subsequent to construction of the Trans-Alaskan oil pipeline which consideration results in the projection of potential impacts which are essentially incremental to those associated with the oil pipeline.

Applicant intends to undertake additional biological, geologic, and hydrologic field studies, as necessary, to support final design of the system and to provide a basis for monitoring the environmental effects of construction and operation.

Section 2A
Baseline Environment — Alaska

SECTIONS 2A.1 - 2A.2 - BASELINE ENVIRONMENT

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2A BASELINE ENVIRONMENT - ALASKA

2A.1 INTRODUCTION

This section describes the baseline environment within the State of Alaska at the time of the commencement of field work for the proposed Alaskan Gas Pipeline, LNG Plant and Alaskan Marine Terminal. The marine environment along the trade route of the proposed LNG Carrier Fleet is described in Section 2F following.

2A.2 LAND FEATURES

2A.2.1 Topography and Geology

The proposed Alaskan Gas Pipeline will traverse four major physiographic regions in Alaska: (a) the Interior Plains, (b) the Rocky Mountain System, (c) the Intermontane Plateaus, and (d) the Pacific Mountain System. Descriptions of these regions follow the subdivisions of Wahrhaftig (1965) shown on Figure 2A.2-1.

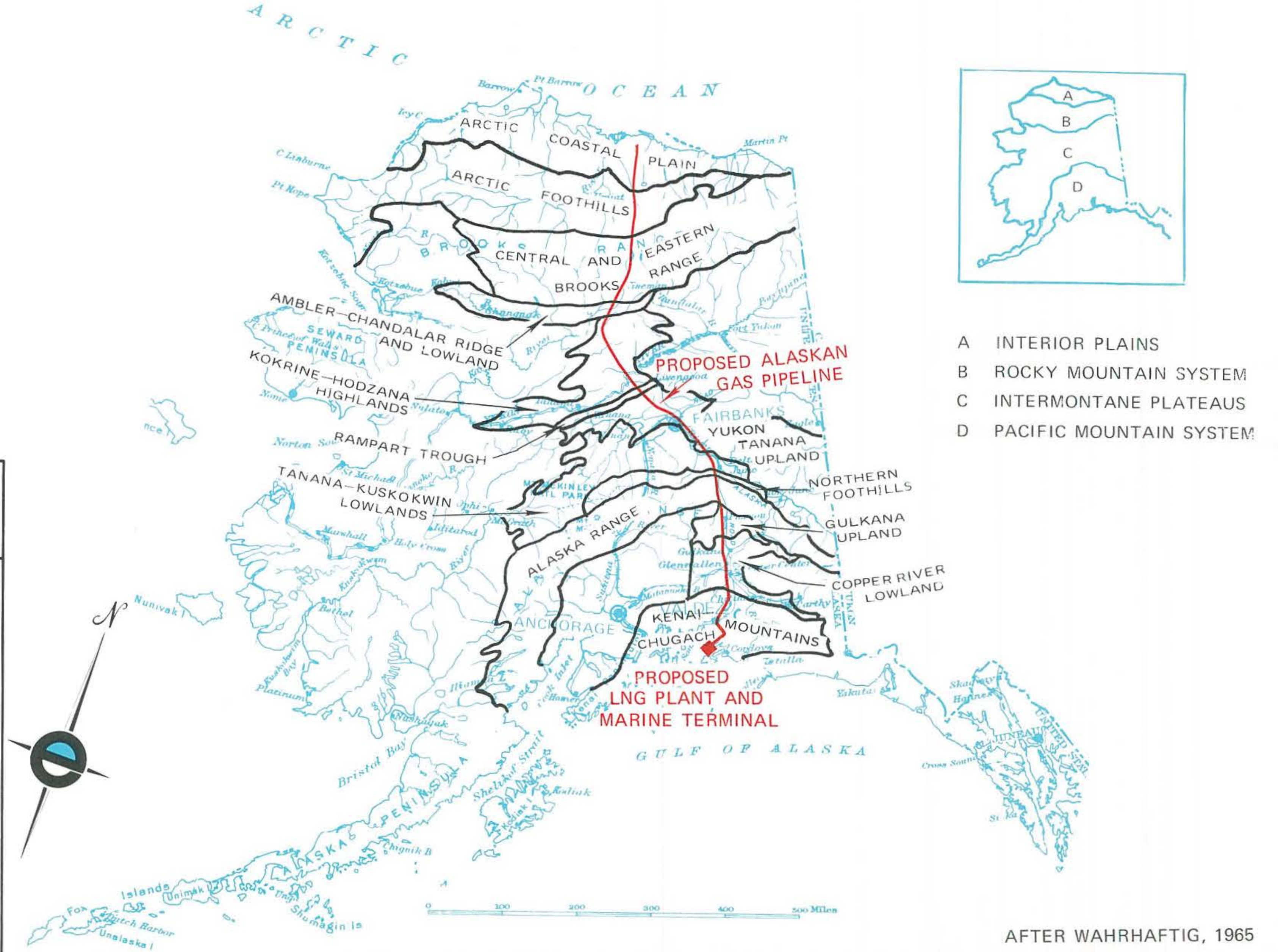
Geologically, the proposed route is exceedingly varied, crossing three major mountain ranges and several intervening broad uplands and alluviated basins. Since little if any detailed information on surface materials existed prior to 1960, most surficial information that follows has been summarized from preliminary engineering geology maps published by the U.S. Geological Survey (USGS)(Ferrians, et al., 1971) and soil maps submitted by Alyeska Pipeline Service Company to the U.S. Department of the Interior (USDI, 1972). Bedrock lithology and general structural trends follow Wahrhaftig's descriptions, with minor revisions where additional information has become available. Virtually all major rock types occur within the proposed corridor, including schists and gneisses, granites, sedimentary and volcanic rocks, and clastic sediments of widely varying character and origin. Ages range from Precambrian to Holocene. The structures within these rocks are varied and, on the whole, complex.

This section presents a summary of the geology and topography of the areas traversed by the proposed pipeline. See Topographic Alignment Sheets in the Appendix for a section-by-section description of topographic and geologic features to be crossed.

2A.2.1.1 Interior Plains

2A.2.1.1.1 Arctic Coastal Plain

Originating at Prudhoe Bay, the proposed gas pipeline will



TRANS-ALASKA GAS PROJECT

PHYSIOGRAPHIC DIVISIONS CROSSED BY PROPOSED PIPELINE ROUTE

FIGURE 2A.2–1

proceed south across the Arctic Coastal Plain to the Arctic Foothills of the Brooks Range. Within these limits the alignment will approach and parallel the Sagavanirktok (Sag) River, remaining in the higher river terraces to a point near its confluence with the Ivishak River.

The Arctic Coastal Plain is the only continuation of the Interior Plains into Alaska. It is an area of very slight relief containing barren arctic tundra which consists of a thin mat of grass, sedges, small ground shrubs, and moss. There are no trees in this area. Scattered low hills rise above the plain in the White Hills section, and pingos (ice-cored hills) provide local relief to the otherwise gently sloping topography. The average slope of the land in most areas is less than 10 feet per mile, and is in a northerly direction.

From Prudhoe Bay south for 250 miles the gas pipeline route is in a zone of continuous permafrost where the active layer ranges from a few inches to a few feet. The relatively flat terrain, coupled with permafrost that extends to depths of more than 1000 feet in some areas, results in poor soil drainage. Thousands of oriented thaw lakes dot the landscape. Their beds are normally silty with some sand and organics present.

The thaw lakes are continually eroding their shorelines, eventually creating outlets by which they drain. Drained lake beds are covered with small ponds. In as little as four years, ice wedges cause the formation of polygonal ground--low relief ridges encircling depressions that collect new ponds. These ponds enlarge, join, and form new lakes, thereby causing continuous changes in the landscape.

Those water bodies that freeze to the bottom each year may be classified as ponds--those that do not, as lakes. In some areas of the Teshekpuk Lake section, lakes and ponds occupy 50 to 75 percent of the land surface. Oxbow lakes are common along major rivers. Rivers follow meandering courses, lace through extensive networks of braided channels, and form broad flood plains. Permafrost is generally not present--at least near the surface--under large lakes and the active flood plains of large rivers.

Soils of the Arctic Coastal Plain generally consist of ice-rich and organic silts mantling gravels and sands. The silts extend to depths of up to 15 feet, thinning to 6 feet or less over the river terrace gravels and along the coast proper. Massive clear and dirty ice is common in these silts. Locally, ice lenses are present in the near surface gravel. The sands and gravels--unconsolidated Quaternary marine sediments--range from 10 to more than 150 feet thick.

The soils are underlain by nearly flat-lying Cretaceous and Lower Tertiary sedimentary rocks. Cretaceous rocks in the subsurface have been folded increasingly with depth, and unconformably overlie older Mesozoic and Paleozoic sandstones, shales, and limestones.

2A.2.1.2 Rocky Mountain System

The Rocky Mountain System in Alaska is represented by the Arctic Foothills and the Brooks Range.

2A.2.1.2.1 Arctic Foothills

Leaving the Coastal Plain, the route enters the foothills of the Brooks Range. In the vicinity of Accomplishment Creek the route diverges from the Sag River drainage in a westerly direction, crossing the upper tributary arms of the Toolik and Kuparuk Rivers, before descending into the Galbraith Lake Basin Area.

The Arctic Foothills consist of rolling plateaus and low, linear mountains. They rise from an altitude of approximately 600 feet on the north to 1200 feet in the south. They have broad, east-trending ridges, separated by intervening tundra plains. Trees are absent along the route.

The low hills above the Sag have bedrock cores mantled with ice-rich silt and gravel. In the upland areas between the Sag River flood plain and Galbraith Lake, the soils consist of moraine sands and gravels containing numerous boulders. In the vicinity of the Kuparuk River crossing, the gravel moraine terminates and resistant frost-shattered sandstones and conglomerates outcrop.

Like the Arctic Coastal Plain, the Arctic Foothills are generally underlain by deep, continuous permafrost. In the moraine areas the granular character of the material indicates a lower ice content; however, the materials in the numerous minor depressions common to this area are expected to be ice-rich and to contain massive ice.

Solifluction and mass wasting in the form of mud flows and landslides are common on the hill slopes in this section. Beaded streams dotted with thermokarst pools are common, as are streams begot by springs at the base of the Brooks Range. The Sag is the principal river in the pipeline corridor; it is typically braided, and is subject to aufeis and spring floods.

Structurally, the northern portion of the Arctic Foothills is composed of Cretaceous sedimentary rocks folded into long anticlines and synclines of the Appalachian type. The southern part is underlain by Devonian to Cretaceous sedimentary rocks and mafic intrusions, all tightly folded and overthrust to the north.

2A.2.1.2.2 Central and Eastern Brooks Range

North of Galbraith Lake, the route will cross to the west side of the basin, traverse an extensive alluvial fan above the lake, and enter the Atigun River Valley. Positioned above the active flood plain in coalescing alluvial fans, the pipeline will proceed up the valley and will cross over Atigun Pass, a narrow steel-walled pass crossing the Continental Divide at an elevation of 4750 feet. The pipeline will then descend to the broad Upper Chandalar River Valley.

After traversing a series of alluvial fans on the east side of the valley, the pipeline will cross the North Fork Chandalar River. Approximately one mile beyond the crossing, the pipeline will descend to the Dietrich River from an escarpment geographically referred to as the Chandalar Shelf.

From below the shelf area, the pipeline will be located on the east side of a major mountain valley system containing the Dietrich River in the upper reaches and the Middle Fork Koyukuk River in the lower reaches. Within this area, the line will traverse approximately 70 miles of coalescing alluvial fans and intermittent river terraces before leaving the valley.

The Brooks Range faces the Arctic Foothills with an abrupt scarp, and similarly rises abruptly above lowlands and low plateaus to the south. The province is a wilderness of rugged, glaciated, east-trending ridges that rise to elevations of 8000 feet. Mountains have cliff-and-bench slopes characteristic of glacially eroded, bedded rocks.

In the Atigun River Valley the fans that form the transition from steep rock walls to broad river flood plains contain subangular sands, gravels, and boulders frequently covered by a thin mantle of wind-blown silt. Evidence of historical mass wasting in the form of landslides and rockslides is present, as is evidence of recent mud and debris flows on the more active fans. On the easterly approach to Atigun Pass, subsurface materials consisting of gravel to boulder size mass wasted rock rubble have accumulated to considerable depths. Within the pass proper, extensive over-steepened cones composed of massive angular talus crowd the bedrock floor.

The low profile fans of the North Fork Chandalar River Valley contain subsurface materials varying from bouldery gravels to silt-rich gravels. Bedrock occurs near the surface within the Chandalar area and outcrops at the escarpment.

Below the Chandalar escarpment, resistant bedrock outcrops below the river terraces and intermittently on the slopes. Solifluction lobes (which result from a slow down-slope flowage of masses of saturated soil derived from the active layer) are located on the slopes above the line.

The entire Brooks Range portion of the route, except in some alluvial plains having groundwater movement, is underlain by continuous permafrost. There is considerable variation in thickness of permafrost because of the differences in the topography, altitude, soil types, soil moisture, and vegetation cover. Silt soils locally contain massive ice, while the coarse alluvial sand and gravel generally is coated with ice. Intergranular voids are locally ice filled.

The Brooks Range, where traversed by the proposed gas pipeline, is composed chiefly of Paleozoic limestone, shale, quartzite, slate, and schist, with some sandstone and conglomerates. The rocks occur in large thrust plates (nappes), thrust to the north during Laramide time. The north front of the range is light-colored, cliff-forming Mississippian limestone. Rocks south of 68°N latitude are metamorphosed, and are generally the same age of those farther north.

2A.2.1.2.3 Ambler-Chandalar Ridge and Lowland

The proposed pipeline will enter this section just south of Coldfoot in the relatively flat area near the confluence of Slate Creek and the Middle Fork Koyukuk River. Near this point the pipeline will traverse Rosie Creek Pass and move down to the flats of the South Fork Koyukuk River, which is a kettle moraine complex with many small lakes.

The Ambler-Chandalar Ridge and Lowland consists of one or two east-trending lines of lowlands and low passes 3 to 10 miles wide and 200 to 2000 feet above sea level, bordered on the north by the abrupt front of the Brooks Range. Along the south is a valley of rolling, rugged ridges, 25 to 75 miles long and 5 to 10 miles wide, rising 3000 to 5000 feet in altitude. Within the lowlands are east-trending ridges 5 to 10 miles long.

Soil conditions are quite variable. Colluvial silts with some gravel deposits mantle bedrock to considerable depths at lower elevations, but become thinner in the higher elevations where bedrock outcrops are common. Wilson Creek Flats contains glacial sand and gravel moraines veneered with silts.

Except for limited areas of thawed gravels in the flood plains of Slate Creek and the South Fork Koyukuk River, permafrost is generally continuous. Silty soils generally have high moisture content, and segregated ice is often found in the form of lenses and seams with massive ice in places.

The hills are mainly greenstone of Mesozoic (?) age. Lowlands are underlain largely by Cretaceous sedimentary rocks folded into anticlines and synclines.

2A.2.1.3 The Intermontane Plateaus

The Intermontane Plateaus system in central Alaska consists of a heterogeneous assemblage of low mountain ranges, rolling uplands, and alluvium-floored lowlands that decline in altitude and relief westward from the Canadian border to the Bering and Chukchi Seas. The proposed pipeline will traverse four sections of the plateau: (a) the Kokrine-Hodzana Highlands, (b) the Rampart Trough, (c) the Yukon-Tanana Upland, and (d) the Tanana-Kuskokwim Lowland.

2A.2.1.3.1 Kokrine-Hodzana Highlands

The Kokrine-Hodzana Highlands consist of even-topped, rounded ridges rising 2000 to 4000 feet in altitude, surmounted by isolated areas of more rugged mountains. In regions discussed previously, the pipeline route generally followed river valleys and drainage channels. Here, however, it passes from one drainage basin to another by traversing low, rounded mountains or hills, following ridge line, and crossing many streams at angles near 90°. Slopes of up to 30 percent are common in the area.

From the north, the pipeline route follows the Grayling Creek drainage, crosses to the west side of Grayling Creek, and enters the Jim River drainage. Descending through a series of terraces, the route crosses the Jim River and traverses a series of colluvial fans before leaving the valley at Prospect Creek. From Prospect Creek the route crosses Bonanza Creek and the Kanuti River before entering the Ray River drainage and crossing the Yukon River.

The broad, open Jim River Valley is an area of discontinuous permafrost, and limited zones of thawed gravel are found in the flood plain proper. Sand and gravel terraces and colluvial gravels are overlain by thick, often organic-rich silt.

Along the route between the Jim River and the Ray River, the terrain consists of a series of lightly forested, east-west trending foothills and narrow ridges. Relatively ice-free silts with occasional gravels cover frequently outcropping granite and schistose bedrock to an average depth of six feet on side slopes and ridge crests. Soil depth is considerable in some drainages; however, most are bedrock controlled, with only shallow soil cover. The surface of the permafrost table is occasionally depressed to depths well below the active layer in the highlands as well as in the major drainage valleys.

Silts, deposited to considerable depths, occur on the slopes and along the flanks of the hills throughout the area. In the lower elevations, well-defined terraces contain sands and gravel overlying bedrock to average depths of twenty feet. The poorly drained areas below the terraces are underlain by silt-rich sands. In the higher elevations of the Fort Hamlin Hills, bedrock outcrops are frequent and soil cover is minimal. The permafrost table is shallow throughout most of the area.

Bedrock is chiefly Paleozoic and Precambrian (?) schist and gneiss, with a northeast structural trend cut by several granitic intrusions. The largest intrusive body is a granitic batholith that forms the Ray Mountains.

2A.2.1.3.2 Rampart Trough

The Rampart Trough is a narrow, structurally-controlled depression with a gently rolling topography 500 to 1500 feet in altitude. The pipeline route crosses a section 6 to 10 miles wide, which is drained by Hess Creek.

Soils in the Rampart Trough include colluvial silt, sand, rock fragments, stream gravel, and reworked, wind-blown silt. Depth to permafrost is variable, depending on terrain and soils. The permafrost table is depressed to depths greater than 20 feet over approximately 50 percent of this segment, while depth of the active layer ranges from one and a half to five feet throughout the area. The fine-grained colluvium and sediments are ice-rich and are easily eroded when thawed.

The Rampart Trough is incised 500 to 2500 feet below highlands on either side. The trough was eroded along a belt of tightly folded, soft, continental coal-bearing rocks of Tertiary age. Hard rock hills and the surrounding uplands are partly metamorphosed sedimentary and volcanic rocks of Mississippian age that strike about N 60° E and are cut by granite intrusions.

2A.2.1.3.3 Yukon-Tanana Upland

From the Rampart Trough to the Fairbanks area, the pipeline route crosses the Yukon-Tanana Upland, located for the most part along forested ridge crests and crossing several east-west trending minor drainages before entering the Tolovana River Valley.

Crossing the wide, lightly-forested Tolovana Valley, the pipeline will ascend the steep valley slope to the ridge line where it will remain, following the natural ridge crests and saddles, crossing the valleys of major east-west trending drainages--including the Tatalina and Chatanika Rivers--before descending into the Tanana River Valley.

The Yukon-Tanana Upland is characterized by rounded, even-topped ridges with gentle side slopes, broad undulating divides, and flat-topped spurs. In the western part, near the proposed pipeline route, these rounded ridges trend east to west, with crest altitudes of

1500 to 3000 feet, rising 500 to 1500 feet above adjacent valley floors. The ridges are surmounted by compact rugged mountains 4000 to 5000 feet high. Valleys in the western part are generally flat, alluvium-floored, and one-quarter to one-half mile wide.

The pipeline route in this segment is underlain by reworked wind-blown silt, colluvium, alluvial silt, sand and gravel, and dune sand. Loess and colluvial silts range from 2 to 15 feet thick on slopes and along the ridges through this area. Loose, wet organic silts occur in low lying areas. In the flood plains of the Salcha River and in the vicinity of Rosa Creek, dense alluvial sands and gravel may be encountered.

Permafrost is discontinuous and locally depressed. Segregated ice occurs as wedges, lenses, and interstitial ice. South of Fairbanks, much of the area is thawed; however, large accumulations of ice are locally present in the reworked silts. In this area, the permafrost table is depressed to depths greater than 25 feet under a large percentage of the pipeline route.

A belt of highly deformed Paleozoic sedimentary and volcanic rocks containing conspicuous limestone units, overthrust and overturned to the north, extends along the north side of the upland. The rest of the upland is chiefly Precambrian (?) schist and gneiss, with scattered, small, ellipitically-shaped granitic intrusions in the northwestern part. Large, irregular batholiths make up much of the southeastern part.

2A.2.1.3.4 Tanana-Kuskokwim Lowland

The Tanana-Kuskokwim Lowland lies between the Yukon-Tanana Upland and the Northern Foothills of the Alaska Range. The pipeline route in the Upland begins at Shaw Creek, passes close to the border of the Lowland in the Fairbanks area (particularly in the vicinity of Moose Creek), then leaves the Lowland south of Fort Greeley. This rather flat area was formed by coalescing outwash fans from the Alaska Range and alluvial deposits of various streams. The corridor is drained primarily by the Tanana River, which the pipeline crosses at the village of Big Delta.

Soils in this segment include ice-rich silts over alluvial gravels from Shaw Creek across the Shaw Creek Flats, frozen loess over bedrock from the southern end of the Shaw Creek Flats to the Tanana River, and generally thawed alluvial gravels and sands from the Tanana River to south of Fort Greeley along the Delta River.

Permafrost is essentially continuous from Shaw Creek to the Tanana River, and discontinuous from the Tanana River to south of Fort Greeley. Ice forms include interstitial ice, massive lenses, and ice wedges in silts overlying alluvial gravels or bedrock.

The Tanana-Kuskokwim Lowland is a broad structural depression north of the Alaska Range. Most of it is covered with surficial deposits, but scattered low hills of granite, ultramafic rocks, and schist rise above the general terrain. Tertiary conglomerate in the foothills of the Alaska Range dips beneath the lowlands in a monocline.

2A.2.1.4 The Pacific Mountain System

The Pacific Mountain System comprises the Northern Foothills of the Alaska Range, the Range itself, the Gulkana Upland, the Copper River Lowland and the Kenai-Chugach Mountains. Elevation varies from near sea level in the lowlands to near 14,000 feet in the mountains. The proposed pipeline, however, will traverse the Range via an interlowland gorge, and will follow relatively low passes through the Chugach Mountains, thereby avoiding most rugged terrain.

2A.2.1.4.1 Northern Foothills

The Northern Foothills of the Alaska Range are flat-topped, east-west trending ridges 2000 to 5000 feet in altitude, 3 to 7 miles wide, and 5 to 20 miles long, separated by rolling lowlands 700 to 1500 feet high and 2 to 10 miles long. Donnelly Dome (3910 feet) is a prominent feature in the area. The pipeline route skirts the Dome through rolling terrain and reaches an elevation of approximately 2650 feet before dropping down into the Delta River Valley. The Delta River, a broad, braided stream, is fed predominantly by glacial melt water from the Alaska Range.

The route follows along the east side of the Delta River Valley crossing glacial till, stratified drift, and limited areas of bedrock. The glacial deposits are commonly frozen, dense, granular deposits overlain by a thin silt layer. These soils generally have a low ice content, though ice-rich soils are present in places. The ridges of the Northern Foothills are mostly crystalline schist and granitic intrusions. Poorly consolidated, Tertiary nonmarine sedimentary rocks underlie the lowlands in synclinal basins.

2A.2.1.4.2 Alaska Range

The Alaska Range is a rugged, glaciated range that includes Mt. McKinley. Mountains in the vicinity of the pipeline route reach elevations of 8500 feet, but the pipeline will pass through the interlowland gorge of the Delta River and thus avoid rugged peaks. Because the Delta River has a fairly narrow, flat channel in the Alaska Range area, a part of the proposed pipeline must follow the side slopes. Several glaciers, including the Black Rapids Glacier, terminate in this gorge, although the Black Rapids is presently receding. Isabel Pass (approximately 3200 feet) is at the boundary of the Alaska Range physiographic section, and is a point of maximum elevation of the pipeline in this area.

Terraces along the route consist of generally unfrozen coarse sands and gravels, mantled in places with organic-rich silts. In short sections where the route leaves the terraces, subsurface materials are dense glacial till over bedrock.

The Alaska Range is a complex synclinorium, with Cretaceous rocks in the center and Paleozoic and Precambrian (?) rocks on the flanks. Many roughly oval granitic stocks and batholiths support groups of high mountains. Tertiary rocks underlie lowlands that trend parallel to the length of the Range. The synclinorium is cut by great longitudinal faults, which are approximately parallel to the trend of the Range, and are marked by lines of valleys and low passes. Scarplets as high as 30 feet can be seen on several longitudinal faults.

2A.2.1.4.3 Gulkana Upland

The Gulkana Upland consists of subdued, east-trending ridges separated by lowlands 2 to 10 miles wide. The ridge crests--3500 to 5000 feet in altitude--are 4 to 15 miles apart, and are cut in intervals of 5 to 15 miles by notches and gaps that were eroded by glacial deposits showing morainal and segment-ice topography. It is through one of these lowlands that the pipeline will pass. Two large, elongated lakes (Summit and Paxson) lie immediately west of the proposed pipeline route, and many smaller lakes are found in the general vicinity.

Soil conditions are highly variable along this segment and consist of glacial till, ice-contact deposits, colluvium, and talus. However, stream gravel and sand are common. Subsurface materials are locally mantled with thin silt and organic soils.

Permafrost is discontinuous. The permafrost table, where present, is often depressed as much as 25 feet below ground. In the vicinity of Summit Lake, permafrost occurs in isolated zones 5 to 25 feet thick, the surfaces of which vary in depth from 0.5 feet to over 10 feet. Segregated ice is generally absent except in silty materials where it takes the form of lenses and seams.

Bedrock in the Gulkana Upland is chiefly greenstone (metamorphosed basalt) with interbedded sediments, both cut by large granitic intrusions. The rocks are of late Paleozoic and Mesozoic age; structures trend eastward. Areas of relatively little relief in the northern part are underlain by poorly consolidated Tertiary sedimentary rocks.

2A.2.1.4.4 Copper River Lowland

At Hogan Hill the pipeline route enters the Copper River Lowland. These lowlands, which contain thick deposits of glaciofluvial and glaciolacustrine materials overlain in areas with wind-blown silts or loess, are relatively flat to gently rolling near Willow Lake and Willow Mountain on the border of the region. Along the pipeline route, the relatively flat terrain is incised by as much as 200 feet by several rivers including the Gulkana, Tazlina, and Klutina.

Lacustrine silt, clay, and sand are the predominant soils along this portion of the route. The lacustrine sediments accumulated to thicknesses of several hundred feet in glacial lakes that filled the basin during Pleistocene time. Fluvial silt, sand and gravel, colluvium, and swamp deposits of peat and organic silt are also present.

Permafrost is generally discontinuous. South of the Klutina River the permafrost table, where it occurs, may be locally depressed more than 30 feet below the surface. The plastic lacustrine silts and clays are poorly drained and contain segregated ice lenses and veins. Massive ground ice may be present in the silts, and the distribution of ice-rich soils is difficult to predict.

Bedrock beneath the northern part is chiefly late Paleozoic and Mesozoic metamorphosed volcanic rock with granitic intrusions. Bedrock beneath the southern part of the basin is primarily easily-eroded Mesozoic sandstone and shale.

2A.2.1.4.5 Kenai-Chugach Mountains

The Kenai-Chugach Mountains form a rugged barrier along the southern coast of Alaska. Segments of high mountains are dominated by extremely rugged east-trending ridges 7,000 to 13,000 feet high. Segments of discrete massive mountains 5 to 10 miles wide and 3000 to 6000 feet high are separated by a system of valleys and passes one-half to one mile wide. The entire range has been heavily glaciated, and the terrain is characterized by horns, aretes, cirques, U-shaped valleys and passes, rock-basin lakes, and grooved and mammillated topography. The coast is indented by fiords and sounds, and ridges extend southward as chains of islands. The north front is an abrupt mountain wall. Surface flow is drained by short swift streams, most of which are glacier fed. All higher parts of the range are buried in ice fields from which valley and piedmont glaciers radiate. Many of the glaciers on the south side of the Mountains end in tidewater.

The pipeline route enters the Chugach Mountains south of Willow Lake and follows the glacially scoured Tonsina, Tiekel, and Tsina Rivers, and the Richardson Highway to Thompson Pass. The topography north of Thompson Pass consists of moderately steep side slopes above river flood plains. South of Thompson Pass some steep rocky slopes are encountered, particularly in Keystone Canyon. Once through the Keystone Canyon area, the pipeline route drops down into the Lowe River flood plain until entering a valley occupied by an unnamed creek just west of Brown Creek. Slopes near the stream are rather gentle until near the head of the valley, which is occupied by a small glacier. To avoid this glacier, the pipeline route traverses some rather steep, talus-coated slopes and then drops down to a stream valley draining into Port Fidalgo. The pipeline route follows this stream to its tidewater delta. From the delta the pipeline will ascend to a high bench area above Port Fidalgo and proceed in a southeasterly direction until descending to the Gravina River flood plain.

Traversing the Gravina River and its flood plain, the pipeline will proceed upstream to the vicinity of Milepost 792 where it will depart to the south and enter the Beartrap Creek Drainage.

Descending Beartrap Creek to Beartrap Bay, the pipeline will follow a route which will be located generally above the southeast shoreline of Beartrap Bay and Port Gravina to a point midway out on Gravina where it will turn south, cross a steep mountain ridge and then descend to a broad open basin area at the LNG Plant site.

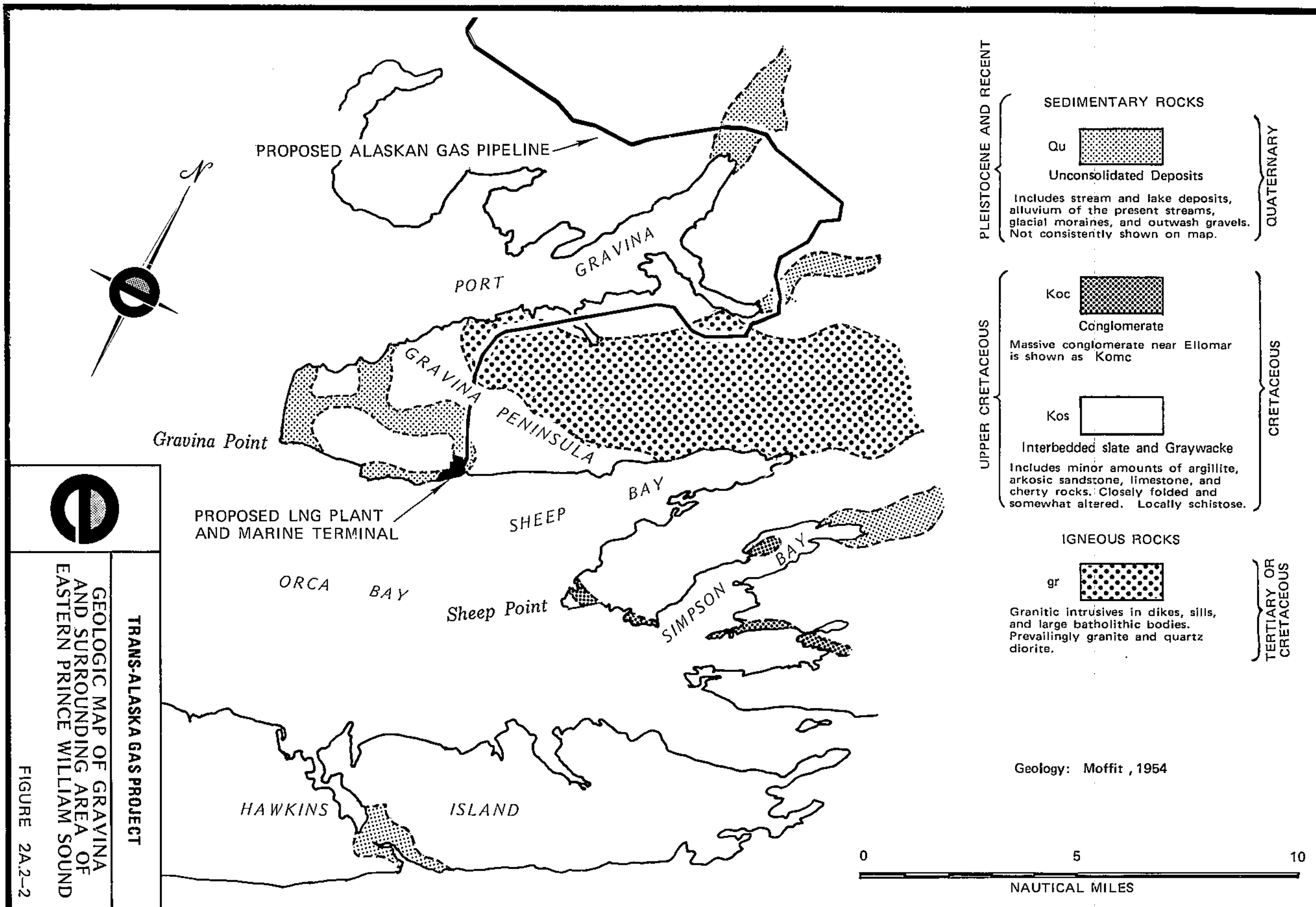
Soils and permafrost conditions are similar to the Copper River Lowland lacustrine silts until the pipeline route leaves the Tonsina River Valley. Ice-rich permafrost generally is not present in this segment of the route, except between Willow Lake and the Little Tonsina River.

South of the Tonsina River the line follows glacially-scoured valley uplands where bedrock is prevalent and river flood plains are underlain by sand and gravel. Bedrock slopes are mantled by alluvial fans and colluvium consisting of silt, sand, gravel, and larger rock fragments. In high passes, extensive deposits of rock rubble containing fragments several feet in diameter have accumulated at the base of near-vertical rock walls. Young, relatively, unmodified moraines are scattered through the area.

The Kenai-Chugach Mountains consist of argillite, graywacke, and greenstone (mostly of Mesozoic age). A belt of Paleozoic and Mesozoic schist, greenstone, chert, and limestone lies along the north edge of the mountains. Granitic intrusions occur near the coast of Prince William Sound. Conspicuous structural lineaments are present. The magnitude and direction of fault displacements are difficult to establish because of the uniform character of the bedrock, and its altered or metamorphosed condition.

2A.2.1.4.6 <u>Gravina</u> (See Figure 2A.2-2)

The LNG Plant site is located on a terrace that slopes gently toward Orca Bay. Site topography is low and rolling, with occasional



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GEOLOGIC MAP OF GRAVINA AND SURROUNDING AREA OF EASTERN PRINCE WILLIAM SOUND

FIGURE 2A.2-2

irregular bedrock knobs and ridges rising above the terrain. Maximum elevations are less than 500 feet. The terrace has been glaciated, and may have subsequently been uplifted.

From a narrow rock beach along the LNG Plant site, the contour of Prince William Sound slopes on a 20 percent grade to a depth of about 25 feet, at which point the grade flattens to about 10 percent. About 1200 feet off-shore the water reaches depths of 50 feet.

Soil cover consists primarily of organic silts and peat. The organic soil is probably less than five feet thick near topographic highs and on steep slopes; however, it may be up to 10 feet thick in some areas. Coarse, granular soils occur in certain places under the organic soils on the terrace. Glaciated valleys adjacent to the site may be underlain by glacial till.

Sediments from a creek known as "Harris Creek" have been deposited in a delta. The delta soils are probably sand and fine gravel. The soils are thin and become finer-grained away from the mouth of Harris Creek.

The predominant rocks of the Prince William Sound area are of marine sedimentary origin. They occur in two units--the Valdez Group and the Orca Group. Granitic intrusives, in the form of sills, dikes, and large batholiths, are also present.

The Valdez Group is of Mesozoic (Jurassic and Cretaceous) age. Graywacke beds of varying thickness are interbedded with thin layers of slate and argillite. The Valdez Group is mildly metamorphosed. Schistosity is well developed in places, but regional schistosity is not present.

The Orca Group of early Tertiary age consists predominantly of slate and graywacke, with rare beds of conglomerate and limestone. Altered basic intrusives and extrusives are subordinate to the sedimentary sequence. The beds of the Orca Group have been complexly folded and faulted. As with the Valdez Group, igneous intrusions have caused some local contact metamorphism.

Granitic instrusives are present in both the Valdez and the Orca Groups. All but one intrusive body occur on the western side of the sound in rocks of the Valdez Group.

Gravina is underlain by sedimentary rocks of the Orca Group and a massive granitic batholith (Figure 2A.2-2). The granite is coarse-grained; feldspar, quartz, and biotite crystals are visibly apparent. Slates and graywacke adjacent to the intrusive granite have been crushed and silicified.

Bedrock exposed along the coastal cliffs is dark gray, thinly-bedded slate that dips steeply to the south and strikes approximately east-west. Inland near the LNG Plant site, bedrock is dominantly dark gray, massive, volcanic rock.

Regional bedrock joint systems and shear zones are expressed in much of the site area as linear trenches eroded below the general land surface. Minor steep drainages are oriented parallel to joint systems, and short segments of larger streams have eroded linear bedrock channels where they cross shear zones.

The slate is jointed and fractured, with 3- to 7-ft. spacing between joints of the major set. Joints in the volcanic rock are poorly expressed.

2A.2.2 Faults, Seismology, and Earthquakes

A large number and variety of major faults have been identified in Alaska. Two general types are present: (a) those with vertical (dip-slip) displacement, and (b) those with predominantly horizontal (strike-slip) displacement. Included in the first group are numerous thrusts and reverse faults in the Brooks Range, in highlands north and south of the Yukon River, and in the Chugach Mountains. Similar structures are also present in the Alaska Range, but are less numerous. In these areas, the faults are related to episodes of Mesozoic or Tertiary mountain building.

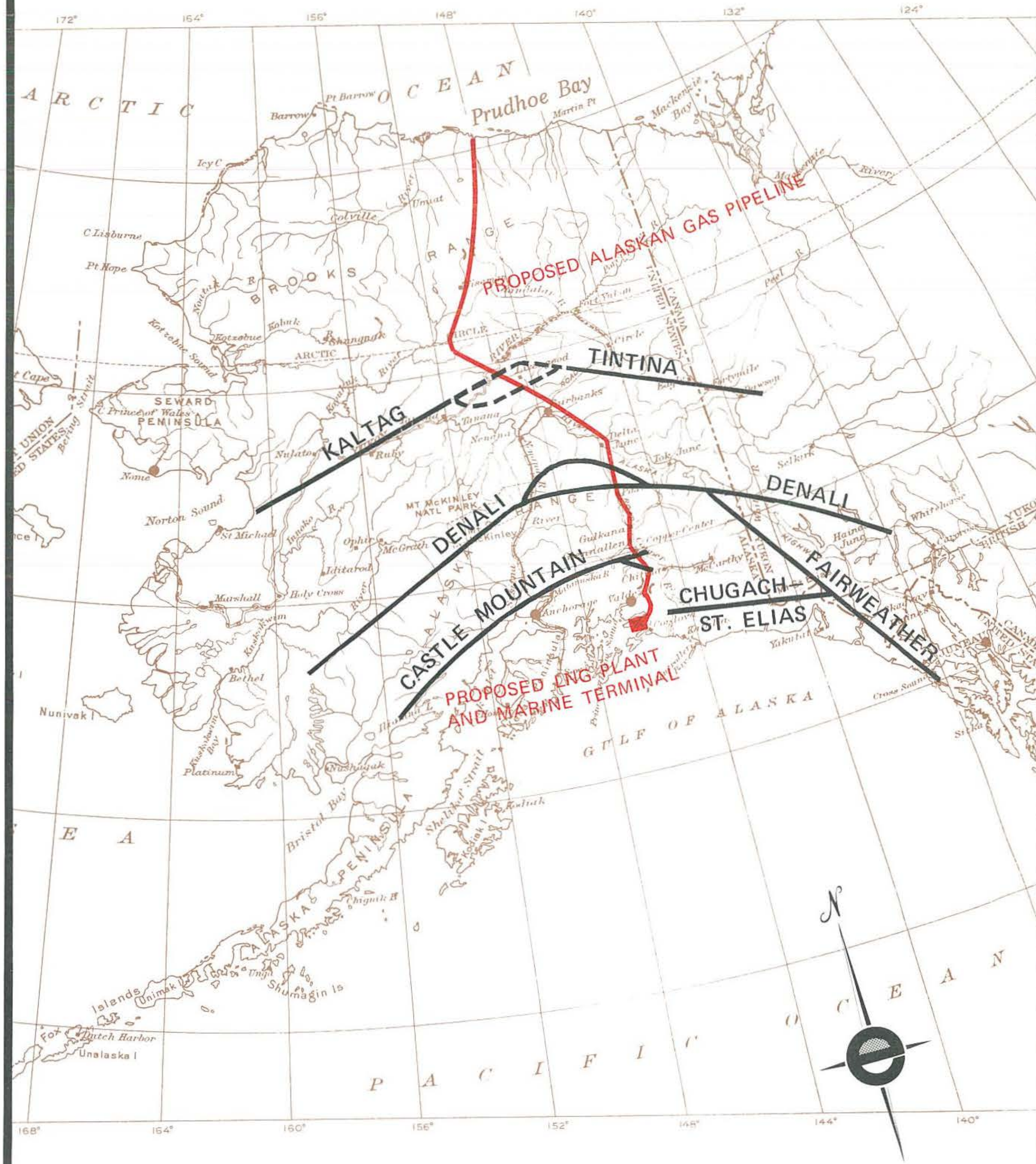
Alaska's major fault systems fall into the second group, those with strike-slip displacement. A number of them are large and probable active, and are likely locations for potential large-magnitude earthquakes.

Altogether, five major fault systems (Figure 2A.2-3) have been mapped that are known or inferred to have had Holocene or historical movement. These are:

(1) Kaltag-Tintina Fault System: Probably a right-lateral fault that may be active. The number and precise location of its branches in central Alaska are unknown.

(2) Denali Fault: A major right-lateral fault, with strong evidence of Pleistocene and Recent activity.

(3) Castle Mountain Fault: A high-angle fault with evidence of both right-lateral and dip-slip displacements (Grantz, 1966). It ends as a series of splay faults on the western margin of the Copper River Lowland.



TRANS-ALASKA GAS PROJECT

FIVE MAJOR FAULT SYSTEMS
OF ALASKA

FIGURE 2A.2–3

(4) Fairweather Fault: A right-lateral strike-slip fault with historical movement and probably the most active fault in Alaska. Although details are poorly known, it is thought to continue to the northwest, joining the Denali Fault in eastern Alaska (Grantz, 1966).

(5) Chugach-St. Elias Fault: A north-dipping reverse fault that cuts Tertiary rocks, and is associated with intense minor folding, overturning, and many lesser faults (Miller, et al., 1959). Some evedence of Holocene dip-slip activity has been reported (Plafker, 1969).

There are other faults that are probably active, but these are smaller and of more limited extent.

The area of the southern two-thirds of the pipeline route has experienced large earthquakes, Richter magnitude 7 or greater (Davis & Echols, 1962). Considering geology, seismic history, and large scale tectonic processes in Alaska, USGS divided the area of the pipeline route into five segments according to relative seismic risk. Each segment was then assigned a maximum probable earthquake magnitude as follows (Page, et al., 1972):

Segment	Richter Magnitude
A. Prudhoe Bay to 67°N	5.5
B. 67°N to Donnelly Dome	7.5
C. Donnelly Dome to Paxson	8.0
D. Paxson to Willow Lake	7.0
E. Willow Lake to Valdez	8.5

The pipeline route intersects several recognized major faults in the active seismic region south of 67°N latitude. Except for the Denali Fault, which displays abundant evidence of large Holocene strike-slip displacement and some vertical movement (Richter & Matson, 1971; Stout, et al., 1973), the possibility of significant future tectonic movement on these faults is essentially unknown at present. Segments B and E are characterized by frequent, sizable earthquakes not yet identified with individual faults.

Based on the distribution of the epicenters of historical earthquakes and known geological relationships, particular source areas for probable earthquakes can be identified. Where these are associated with faults and therefore have restricted width, the term "seismogenic zone" is used.

2A.2.2.1 Kaltag-Tintina Zone

Along the trace of the Kaltag Fault there are scarps developed in Pleistocene and Holocene alluvium (Grantz, 1966). The location of this fault east of the mouth of the Tanana River is obscure. No evidence of lateral movement has been reported. The Tintina Fault to the east shows evidence of late Cretaceous right-lateral offset. The location of the connection between the Kaltag and Tintina is also obscure. Generally, this is an area of low seismicity. The exception is the Rampart earthquake of 1968, and associated aftershock sequence. This group of epicenters defines a narrow north-south band along a straight valley, which strongly suggests an association with a north-south fault (Gedney, et al., 1969).

2A.2.2.2 Denali Zone

The Denali Fault is the longest, most conspicuous fault in Alaska. It can be traced for 840 miles. There is abundant evidence of right-lateral displacement, and a long history of movement, including faulting of Pleistocene and Holocene deposits (Grantz, 1966). Tobin and Sykes (1966) located a number of shallow earthquakes on the fault trace, mostly in the region of the 149 W longitude, approximately 100 miles to the west of the pipeline route. Also, several deeper earthquakes have been located on, or very close to, the fault trace in this same area. There was no known ground breaking associated with any of these earthquakes. Boucher and Fitch (1969), Boucher, et al., (1969), and Page and Lahr (1970), report a high level of microseismic activity, but no slip or creep in three years.

2A.2.2.3 Castle Mountain Zone

The Castle Mountain Fault and its extension to the west, the Lake Clark Fault, are considered by Grantz (1966) to exhibit evidence of right-lateral strike-slip displacement. In addition, there also appears to have been vertical movement, including 3.1 meters of Holocene dip-slip displacement. Tobin and Sykes (1966) located one intermediate and several shallow earthquakes on the fault trace in the Susitna Flat at the head of Cook Inlet.

At the western margin of the Copper River Lowland, a large number of splay faults develop. Not only does the amount of displacement on these fractures lessen toward the east, but maps indicate that many of the individual faults end (Grantz, 1960). Aeromagnetic data implies a few faults continue for a short distance under the sediment of the basin, but no evidence of recent activity exists. On theoretical grounds (Chinnery, 1966), this splay pattern is to be expected at one end of a strike-slip fault. All evidence points to a termination of the fault in this area.

2A.2.2.4 Fairweather Zone

This zone is associated with the Fairweather Fault. Two large-magnitude earthquakes have been recorded in this zone: (a) the Yakutat earthquake of September 10, 1899, with magnitude 8.6, and (b) the Lituya Bay event of July 10, 1958, with magnitude 8.0. In addition, two 8.3-magnitude earthquakes have been reported from the general area. These events, occuring on September 4, 1899, and October 9, 1900, were located two degrees west of the fault at Yakataga. Based on eyewitness reports (Tarr & Martin, 1912), the locality of the earlier event was almost certainly closer to Yakutat Bay than Yakataga. The location of the epicenter of the 1900 earthquake is uncertain, but intensity data suggest the St. Elias Range of the Chugach Mountains (Wood, 1966). On geological grounds, a location in the St. Elias range seems more likely, and therefore it is considered a part of the Fairweather Zone.

The northern extent of the Fairweather Zone is uncertain. Recent mapping has extended it northwestward through Nunatak Fiord and across Hubbard Glacier (Plafker, 1969). Aerial photographical study indicates an active fault along a strike north of the St. Elias Range and east of the Wrangell Mountains that probably joins the Denali Fault (Hamilton & Myers, 1966). Tobin and Sykes (1968) have accurately located two aftershocks of the Lituya Bay event on this same structure. Grantz (1966) reviews the nature of the Fairweather Fault in some detail, and similarly concludes that a continuation northwestward is likely. Finally, there is no evidence to support an alternative location.

A history of late Cenozoic movement is well documented (Page, 1969), and the fault presently exhibits a high level of microseismic activity, but no evidence of slip or creep in two years (Page & Lahr, 1970).

2A.2.2.5 Chugach-St. Elias Zone

The basis for establishing this zone is the probable Holocene movement reported on the Chugach-St. Elias reverse fault (Plafker, 1969). The general level of seismicity is low, and the reported epicenters are widely distributed. Excluding the 1899 and 1900 large-magnitude earthquakes, which appear to be mislocated, the largest event apparently related to this zone is a 1958, magnitude 6.3 earthquake, which occurred along the coast near the eastern end.

Though not strictly in this zone, the active volcanoes of the Wrangell Mountains are potential sources of low-magnitude earthquakes, but present no threat to the pipeline.

A record of earthquake activity in south central Alaska and the surrounding area dates back more than 200 years. Several major earthquakes have occurred during this period. Death and great destruction have been attributed to many of these older shocks, although the area as a whole is sparsely populated even to this day. The destruction frequently resulted from tsunamis accompanying the major shock. Since 1899, seven earthquakes of magnitude 8 or greater have occurred in Alaska. The Good Friday earthquake of 1964 was the only one of these located in the Prince William Sound area. It caused severe damage and major topographic changes in much of south central Alaska. Gravina experienced approximately 4.5 feet of uplift and nearly 30 feet of horizontal displacement to the southeast (US Dept Commerce, 1966b).

Landsliding and subsidence also occurred in south central Alaska during the 1964 eathquake. In some areas of Prince William Sound, soils underwent liquefaction as a result of ground shaking, though none has been reported for Gravina.

The USGS assigned a maximum probable earthquake magnitude of 8.5 to the Alyeska oil terminal site at Valdez. Because of the similarity in the geology, seismic history, and large scale tectonic processes at the site of the proposed LNG Plant and Alaskan Marine Terminal, a similar maximum probable earthquake magnitude could be assigned.

The mechanism of earthquake occurrence in south central Alaska was extensively studied following the 1964 Prince William Sound event. Investigators agree that the quake resulted from movement initiated on a new or reactivated major fault or fault zone beneath Prince William Sound. The nature of the faulting is still somewhat uncertain, although the concept of a primary low-angle thrust fault with the land mass moving toward the Gulf of Alaska fits most of the available data. This concept is also consistent with the plate tectonics theory, which suggests an underthrusting of the ocean floor beneath the continental margin in the vicinity of south central Alaska.

2A.2.3 Glaciation

Of the three major mountain ranges traversed by the proposed pipeline, only the Alaska Range and Chugach Mountains are heavily glaciated and possess possible glacial hazards.

Basically, three types of hazards can be associated with glaciers along the proposed route: (a) glacial surges, (b) outburst flooding from glacier-damned lakes, and (c) the presence of ice-cored moraines.

A surging glacier is one that periodically (every 15 to 100 or so years) exhibits a sudden, brief, large-scale movement. Such glacial surges can be 10 to 100 times faster than normal glacial flow (Post, 1969). Exact mechanisms producing this phenomenon are not well defined; consequently, surges cannot be predicted with any degree of certainty. It is possible, however, to identify certain glaciers that have surged in the past and could again in the future.

Since glaciers are an integral part of the hydrologic regime, streams that originate at glaciers or in heavily glaciated terrain have distinctive run-off characteristics not shown by nonglacial streams. According to Meier (1969), these include:

(1) Peak Flow in midsummer,

(2) Diurnal fluctuations in run-off,

(3) Run-off much more or much less than derived from local, short-term precipitation,

(4) High silt content, and

(5) Outburst floods.

Outburst floods, resulting from the sudden release of ice-dammed waters stored behind, on, or beneath glacial ice, are particularly hazardous and difficult to predict. Even where no lake surface is visible, water stored in or under glaciers may create serious floods. Consequently, any glacier has the potential to produce outburst floods (Post & Mayo, 1971).

The proposed pipeline will pass close to, or across, morainal belts that mark former glacial margins. Some of the more recent terminal or lateral moraines (150 years or younger) may still be ice-cored, and could prove unstable under certain circumstances. Generally, those moraines closest to the proposed pipeline route are related to the oldest of the recent ice advances (circa 1650) and are unlikely to be ice-cored.

In the following sections, glacial hazards along the pipeline route have been identified to the extent possible. For convenience, they are discussed in relation to the mountain ranges in which they occur.

2A.2.3.1 Brooks Range Glaciation

In the vicinity of the proposed pipeline, only a few small glaciers exist. They generally occur on the higher, north-facing slopes. There is no evidence that they present a threat to the proposed pipeline.

2A.2.3.2 Alaska Range Glaciation

The Alaska Range divides the Yukon River Drainage from the Copper and Susitna River Basins. Most of the glaciers here, except those that periodically surge, have been retreating for at least 60 years. A series of terminal moraines and glacial deposits of different ages records ice advances in the central Alaska Range that have reached, or crossed, the pipeline route within the past 300 to 350 years. Minor climatic reversals to wetter and colder conditions, however, could reverse the present recessional trend of these glaciers. Further problems are associated with the tendency for certain glaciers to surge for reasons apparently unrelated to climatic factors alone.

The proposed pipeline will cross the Alaska Range through the Delta and Gulkana River Basins. It is estimated that about 225 square miles, (15 percent) of the total Delta River Drainage Basin is presently glacier covered.

Three glaciers have termini adjacent to the proposed pipeline route. These are the Canwell, Castner, and Black Rapids Glaciers, which have termini at altitudes of 2700, 2500, and 2200 feet, respectively. These glaciers are discussed in more detail below. The Fels Glacier terminus, which at its closest point to the pipeline route is nearly three miles away, lies at an elevation of 3000 feet. Several smaller glaciers in the Delta River Drainage Basin, such as the Gulkana Glacier, terminate at altitudes between 4000 and 5000 feet.

2A.2.3.2.1 Black Rapids Glacier

The Black Rapids Glacier has a history of surging in recent times. A series of multiple looped moraines indicates an alternation of regular and rapid ice flow, corresponding to quiescent and active phases of a surging glacier.

A terminal moraine marking the limit of an ice advance that occurred about 1650, indicates the Black Rapids Glacier crossed the Delta River and the location of the present highway. In a subsequent advance in 1830, the glacier reached the Delta River, crossed it near Suzy Q Creek, and created an ice-dammed lake (Pewe, 1965).

A fresh terminal moraine, still ice-cored, marks the limit of a spectacular surge of the Black Rapids Glacier that occurred in the winter of 1936-37. The glacier advanced four miles, to within one mile of the Richardson Highway--at a rate as great as 200 feet per day.

2A.2.3.2.2 Canwell and Castner Glaciers

Moraines and morainal remnants east of the Richardson Highway record several advances of the Canwell and Castner Glaciers during the past 300 to 350 years. Lichenometric studies on the moraines date two significant glacial advances. During the older advance (circa 1650), the Canwell and Castner Glaciers in places, extended as far as the present highway. A subsequent advance (circa 1830) did not extend as far, although at certain points the ice reached as far as the alignment of the present highway. Ice-cored terminal moraines of the Castner Glacier's 1830 advance lie to the east of the highway at Mile 217 (Pewe, 1965).

The Canwell Glacier has a sinuous moraine ridge that suggests periodic surges on one of its larger tributaries.

2A.2.3.3 Chugach Mountain Glaciation

The Chugach Mountains divide the Copper River Basin on the northeast from a number of small tributaries that flow into Prince William Sound and the Gulf of Alaska to the south. More than 1800 square miles of the western Chugach Mountains are covered by glacial ice, making it one of the most heavily glaciated regions in North America.

North of Port Fidalgo, altitudes of glacier termini are as low as 1000 feet (exceptional), but generally range between 2000 and 2500 feet. On the south side of Lowe River Canyon, glacier termini lie at just over 2000 feet, while on the north side of the canyon several small south-boring glaciers have termini at slightly higher elevations. Along the Tsina River Canyon, northeast of Thompson Pass, glacier termini lie between 3000 and 4000 feet. The Tsina Glacier (two lobes) and Worthington Glacier are exceptions, terminating at altitudes between 2200 and 2300 feet. At the present time, most glaciers in the Chugach Mountains are nearly stable, with some retreating and a few advancing slightly (Meier, et al., 1971). There are several glaciers adjacent to the pipeline route, including the Worthington Glacier and a few unnamed glaciers.

2A.2.3.3.1 Worthington Glacier

The Worthington Glacier lies directly northeast of Thompson Pass. There is no evidence to suggest that it might surge. The present terminus of the glacier lies within one-half mile of the Richardson Highway and three-quarters of a mile from the gas pipeline route, and is currently receding rapidly. Four terminal moraines west of the Richardson Highway mark the limits of former ice advances. The oldest, which abuts the highway, is low, highly dissected, and heavily vegetated. The three inner moraines are prominent arcuate ridges with little dissection and only sparse vegetative cover.

2A.2.3.3.2 Unnamed Glaciers

Between the Lowe River Valley and Gravina, the proposed pipeline will cross a southern portion of the Chugach Mountains through an unnamed pass at (pipeline milepost 775.6) at an elevation of some 2700 feet. On the northern approach, a small, west-flowing valley glacier is encountered close to the pipeline route, its terminus at approximately 2300 feet. The pipeline will cross the flood plain of a meltwater stream emanating from this glacier; however, the danger from outburst flooding is remote, since it appears unlikely that any glacier-dammed lakes exist in the vicinity. The pipeline will cross the ablation moraine in front of the glacier, but no strong evidence has been found that the moraine is ice-cored. The pipeline will, however, skirt the west side of the glacier by way of the lateral moraine, which is recent and suspected of being ice-cored.

To the south, another small, west-flowing glacier terminates close to the pipeline route at approximately 1000 feet. Although the route in some areas is within the flood plain of a stream flowing into Port Fidalgo, there appears to be only the remotest possibility of hazard from a still undetected glacier-dammed lake.

Aerial photography indicates both glaciers have been retreating for at least 50 years and probably as long as 200. Comparison between 1950 and 1973 photographs shows both glaciers have retreated approximately 2000 feet in the past 23 years.

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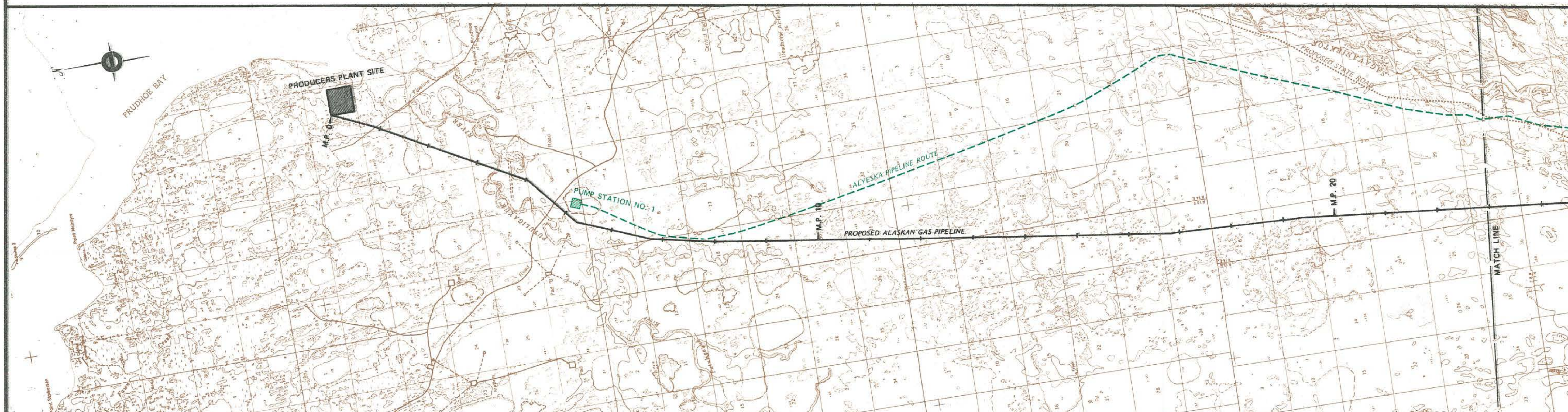
TRANS-ALASKA GAS PROJECT

KEY MAP OF ALASKA

FIGURE 1

OWNERSHIP		U.S.A. (STATE OF ALASKA SELECTION)
TERRAIN		FLAT
VEGETATION		TUNDRA
SPECIAL CONDITIONS	M.P. 0.00	PIPELINE CROSSING; PUTULIGAYUK RIVER CROSSING; ROAD CROSSING; NUMEROUS SWAMPS; M.P. 23.06
GEO-MORPHOLOGY		ARCTIC COASTAL PLAIN. A MONOTONOUS, RELATIVELY FLAT SURFACE CONTAINING NUMEROUS DRAINED AND UN-DRAINED THAW-LAKE BASINS. MINOR FEATURES INCLUDE POLYGONAL GROUND PATTERNS AND OCCASIONAL PINGO DEVELOPMENT
SOILS & BEDROCK	MATCH LINE	LOOSE TO MODERATELY COMPACT, SATURATED SILT RANGING IN THICKNESS FROM 0-10 FEET (AVERAGE THICKNESS 6 FEET) OVERLYING LOOSE, MEDIUM TO COARSE, WELL ROUNDED SAND AND GRAVEL. MATCH LINE
PERMAFROST		CONTINUOUS. ACTIVE LAYER 0-2 FEET (±)
SEGREGATED ICE		CONSIDERABLE. OCCURS AS CRYSTALS, COATING, INCLUSIONS, WEDGES, LENSES, AND SEAMS



PIPELINE SCHEMATIC

PRODUCERS PLANT SITE (M) — M.P. 0.00 — M.P. 3.40 — 42" O.D. x 0.750" W.T. X-65 PIPE — M.P. 19.60 — MATCH LINE M.P. 23.06

CONSTRUCTION DETAIL

PRUDHOE BAY METER STATION

SPECIAL CONSTRUCTION PUTULIGAYUK RIVER CROSSING
LENGTH: 600 FT.
PIPE DEPTH: 8 FT.
1.25 S.G. CONCRETE 520 FT.

M.P. 0.0 TO M.P. 19.3
3 FT. GRANULAR BACKFILL REQ'D. OR ANCHORS

CONSTRUCTION SECTION NO. 1
(2 YEARS)

SITE PREPARATIONS-SUMMER PRIOR TO CONSTRUCTION: PREPARE SOURCES OF MATERIALS, BUILD 5' GRAVEL PAD ON WORK SITES, BUILD ROADS.
RIGHT-OF-WAY-OCT. TO APR.: CLEAR SNOW, BUILD 2' COMPACTED SNOW WORK PAD, STRIP ORGANICS AND STOCK PILE, LEVEL WORK AREA.
LAYING-NOV. THRU MAY: BLAST DITCH LINE, WELD PIPE, EXCAVATE DITCH WITH BACKHOES, PAD DITCH, LOWER-IN, BACKFILL WITH SELECT CONDITIONED MATERIALS, SET VALVES, MAKE TIE-INS.
CLEAN-UP-APR. THRU MAY: RETURN ORGANICS TO DITCH LINE, INSTALL EROSION PROTECTION, REMOVE DEBRIS.

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

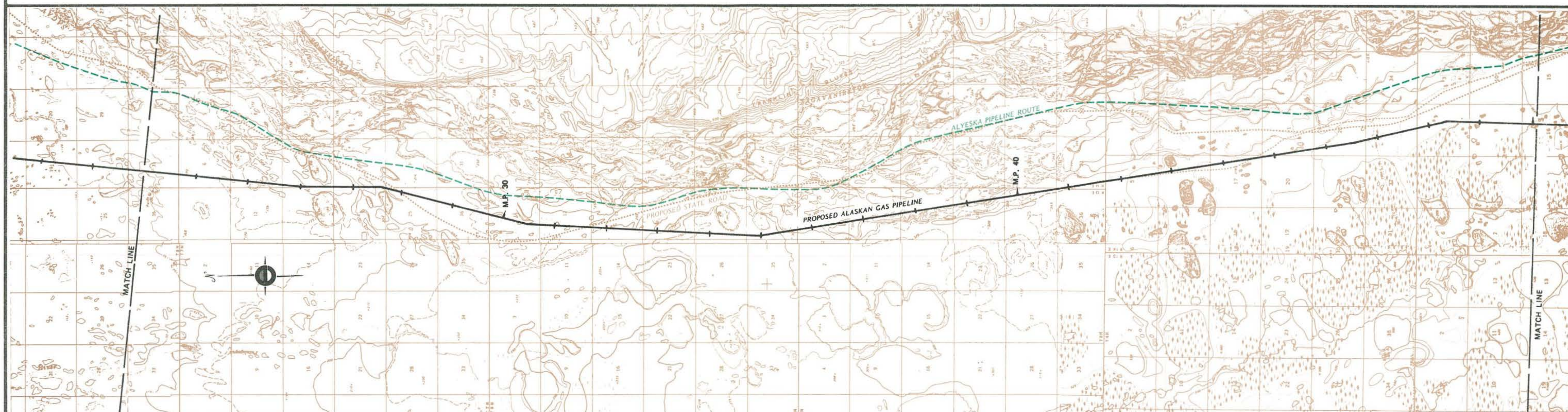
TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

M.P. 0.00 TO M.P. 23.05

FIGURE 2

OWNERSHIP	U.S.A. (STATE OF ALASKA SELECTION)		U.S.A
TERRAIN	FLAT		
VEGETATION	TUNDRA		
SPECIAL CONDITIONS	M.P. 23.05 — ROAD (PROPOSED) CROSSING — ROAD (PROPOSED) CROSSING	NUMEROUS SWAMPS	M.P. 50.10
GEO-MORPHOLOGY	RELATIVELY FLAT, PLAIN, DOTTED BY DRAINED AND UN-DRAINED THAW-LAKE BASINS.	SERIES OF RIVER TERRACES SEPARATED BY SMALL SCARPS	RELATIVELY FLAT PLAIN, DOTTED BY DRAINED AND UNDRAINED THAW LAKE BASINS.
SOILS & BEDROCK	MATCH LINE — LOOSE TO MODERATELY COMPACT, SATURATED ORGANIC RICH SILT RANGING IN THICKNESS FROM 0-10 FEET (AV. THICKNESS 6') OVERLAYING LOOSE, MEDIUM TO COARSE, WELL ROUNDED, MOIST, SAND AND GRAVEL.	LOOSE, MEDIUM TO COARSE, ROUNDED SAND AND GRAVEL UNDERLYING THIN (2 FEET ±) COVER OF ORGANIC RICH, LOOSE, MOIST SILT.	LOOSE TO MODERATELY COMPACT, SATURATED, ORGANIC-RICH SILT RANGING IN THICKNESS FROM 5-10 FEET ± (AVERAGE THICKNESS 5 FEET) OVERLYING LOOSE, MEDIUM TO COARSE SAND AND GRAVEL. — MATCH LINE
PERMAFROST	CONTINUOUS, ACTIVE LAYER 0-2 FEET		
SEGREGATED ICE	CONSIDERABLE. OCCURS AS CRYSTALS, COATING, INCLUSIONS, WEDGES, LENSES, AND SEAMS.		



PIPELINE SCHEMATIC

M.P. 23.05 MATCH LINE

42" O.D. x 0.750" W.T. X-65 PIPE

M.P. 39.20

M.P. 46.5 — 3" GRANULAR BACKFILL REQ'D OR ANCHORS — MATCH LINE M.P. 50.10

CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 1
(2 YEARS)

⊕MATERIAL SITES

0 1 2 3
SCALE IN MILES

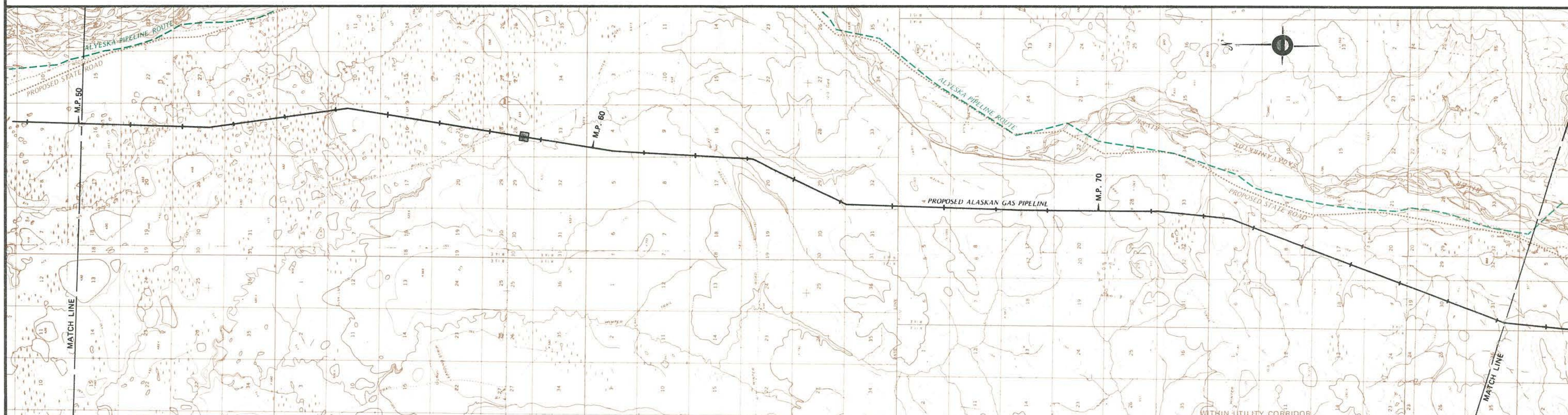
TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

M.P. 23.05 TO M.P. 50.10

FIGURE 3

OWNERSHIP	U.S.A
TERRAIN	FLAT TO GENTLY ROLLING
VEGETATION	TUNDRA
SPECIAL CONDITIONS	M.P. 50.10 — NUMEROUS SWAMPS — SWAMP — M.P. 78.20
GEO-MORPHOLOGY	RELATIVELY FLAT PLAIN, DOTTED BY DRAINED AND UNDRAINED THAW-LAKE BASINS. / UNDULATING RIDGES MODIFIED BY BEADED STREAMS AND OCCASIONAL THAW-LAKE BASINS.
SOILS & BEDROCK	MATCH LINE — LOOSE TO MODERATELY COMPACT SATURATED SILT RANGING IN THICKNESS FROM 5–10 FEET (+) (AVERAGE THICKNESS 6 FEET) OVERLYING LOOSE, MEDIUM TO COARSE SAND AND GRAVEL. / LOOSE, MOIST SILT WITH SOME GRAVEL AND SAND, OVERLYING BEDROCK TO DEPTHS VARYING FROM 0–15 FEET (+). BEDROCK CONSISTS OF SOFT SILTSTONES AND WEAKLY CEMENTED CONGLOMERATES. / LOOSE, MOIST SILT WITH SOME GRAVEL AND SAND, OVERLYING BEDROCK TO DEPTH VARYING FROM 5–15 FEET (+). BEDROCK CONSISTS OF DURABLE SANDSTONES AND CONGLOMERATES. — MATCH LINE
PERMAFROST	CONTINUOUS. ACTIVE LAYER 0–2 FEET IN SOILS, VARIABLE IN BEDROCK.
SEGREGATED ICE	CONSIDERABLE. OCCURS AS CRYSTALS, COATING, INCLUSIONS, WEDGES AND LENSES.



PIPELINE SCHEMATIC

42" O.D. x 0.750" W.T. X–65 PIPE

MATCH LINE M.P. 50.10

M.P. 50.1 – M.P. 59.2
3' GRANULAR BACKFILL REQ'D. OR ANCHORS

CS
M.P. 58.73
M.P. 59.20

COMPRESSOR STATION NO. 1

M.P. 74.73

MATCH LINE M.P. 78.20

CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 1
(2 YEARS)

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

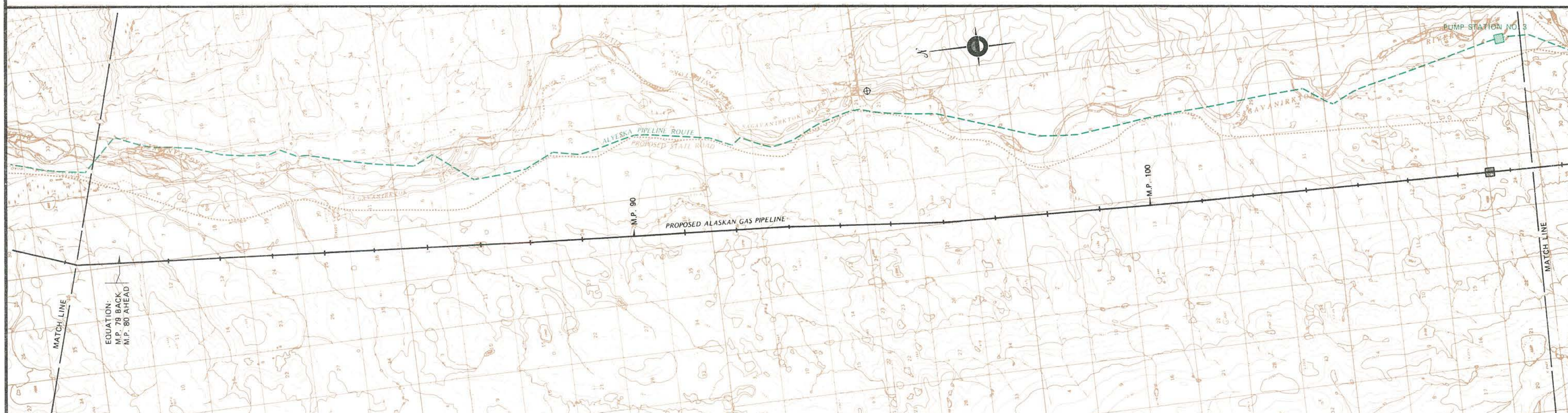
TRANS-ALASKA GAS PROJECT

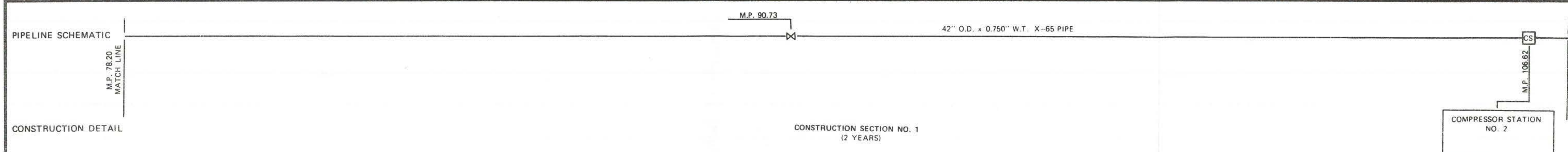
PROPOSED
ALASKAN GAS PIPELINE

M.P. 50.10 TO M.P. 78.20

FIGURE 4

OWNERSHIP		U.S.A.				
TERRAIN		ROLLING				
VEGETATION		TUNDRA				
SPECIAL CONDITIONS	M.P. 78.20		SWAMP		SWAMPS & SMALL STREAM CROSSINGS	M.P. 107.40
GEO-MORPHOLOGY		UNDULATING RIDGES MODIFIED BY BEADED STREAMS AND OCCASIONAL THAW-LAKE BASINS.		GENTLY SLOPING GLACIAL MORAINE MODIFIED BY NUMEROUS PARALLEL STREAMS.		
SOILS & BEDROCK	MATCH LINE	LOOSE, MOIST SILT WITH SOME GRAVEL AND SAND. OVERLYING BEDROCK TO DEPTHS VARYING FROM 5-15 FEET (±). BEDROCK CONSISTS OF DURABLE SANDSTONES AND CONGLOMERATES.		LOOSE TO MODERATELY COMPACT, NON-SORTED SILTS, SANDS AND GRAVEL. OCCASIONAL CONCENTRATIONS OF SAND AND/OR ANGULAR GRAVEL. RANDOM BOULDERS COMMON.		MATCH LINE
PERMAFROST		CONTINUOUS, ACTIVE LAYER 0-2 FEET.				
SEGREGATED ICE		CONSIDERABLE. OCCURS AS CRYSTALS, COATING, INCLUSIONS, WEDGES, LENSES, AND SEAMS.				





⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

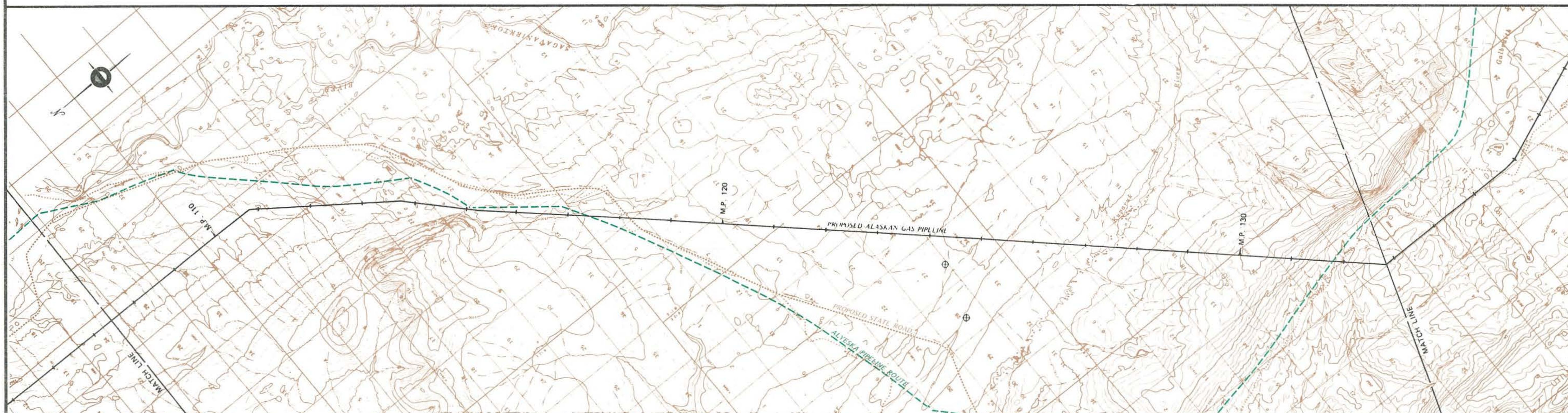
TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

M.P. 78.20 TO M.P. 107.40

FIGURE 5

OWNERSHIP		U.S.A.			
TERRAIN		ROLLING			
VEGETATION		TUNDRA			
SPECIAL CONDITIONS	M.P. 107.40	PIPELINE (PROPOSED) CROSSING; ROAD (PROPOSED) CROSSING		MINOR STREAM CROSSING; PIPELINE (PROPOSED) CROSSING AND ROAD (PROPOSED) CROSSING	M.P. 132.80
GEO-MORPHOLOGY		GLACIAL MORAINE FIELD OF REPEATING, SUBDUED MOUNDS AND DEPRESSIONS.	BROAD GLACIAL MORAINE FIELD, MODIFIED BY SLOPE EROSION.	GENTLY RISING, BROAD, BEDROCK. CONTROLLED FOOTHILLS.	
SOILS & BEDROCK	MATCH LINE	LOOSE TO MODERATELY COMPACT, NON-SORTED SILTS, SANDS AND GRAVEL. OCCASIONAL CONCENTRATIONS OF SAND AND/OR GRAVEL. RANDOM BOULDERS COMMON.		FROST SHATTERED BEDROCK. VENEERED WITH LOOSE SILTS AND SANDS IN DRAINAGES. BEDROCK CONSISTS OF DURABLE CONGLOMERATES AND SANDSTONE.	MATCH LINE
PERMAFROST		CONTINUOUS. ACTIVE LAYER 0–2 FEET (±).			
SEGREGATED ICE		CONSIDERABLE. OCCURS AS CRYSTALS, COATINGS, INCLUSIONS, WEDGES AND LENSES. WEDGES COMMON IN DEPRESSIONS.		CONSIDERABLE. OCCURS AS WEDGES AND LENSES.	



PIPELINE SCHEMATIC

M.P. 107.40 MATCH LINE

M.P. 122.52

42" O.D. x 0.750" W.T. X–65 PIPE

M.P. 131.8 TO M.P. 132.8

3' GRANULAR BACKFILL REQ. OR ANCHORS

MATCH LINE M.P. 132.80

CONSTRUCTION SECTION NO. 1
(2 YEARS)

CONSTRUCTION DETAIL

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

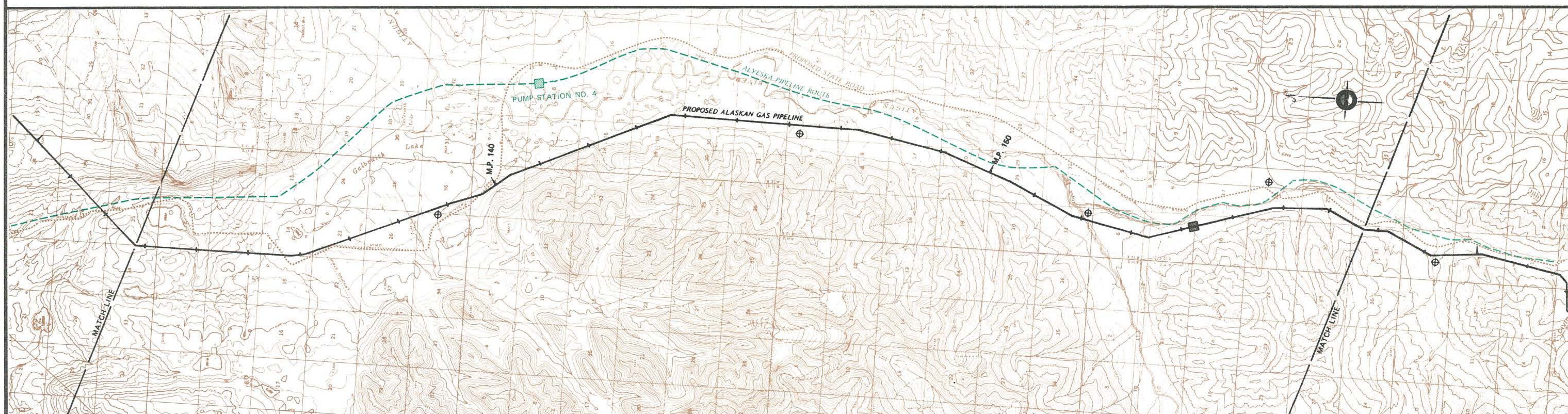
TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

M.P. 107.40 TO M.P. 132.80

FIGURE 6

OWNERSHIP		U.S.A.	
TERRAIN		ROLLING	
VEGETATION		TUNDRA	
SPECIAL CONDITIONS	M.P. 132.80	ROAD (PROPOSED) CROSSING; ROAD (PROPOSED) CROSSING; POTENTIAL SNOW AVALANCHE AREA; GLACIER FORK ATIGUN RIVER CROSSING; SIDEHILL CONSTRUCTION 17% MAX. SLOPE	M.P. 157.70
GEO-MORPHOLOGY		INTER MOUNTAIN LAKE BASIN CONTAINING BROAD, GENTLY SLOPING ALLUVIAL FANS.; BROAD, OVERSIZED RIVER VALLEY FLANKED BY COALESCING ALLUVIAL-COLLUVIAL FANS.; WIDE RIVER VALLEY FLANKED BY COALESCING ALLUVIAL-COLLUVIAL FANS.	
SOILS & BEDROCK	MATCH LINE	LOOSE, WET SILTS OVERLYING GRANULAR, COARSE, ALLUVIUM-COLLUVIUM TO DEPTHS AVERAGING 6 FEET (±).; LOOSE TO MODERATELY COMPACT, COARSE, ANGULAR GRAVEL AND SAND WITH CONSIDERABLE SILT MANTLED BY 3 FOOT (±) LAYER OF SILT. ANGULAR BOULDERS COMMON.	MATCH LINE
PERMAFROST		CONTINUOUS. ACTIVE LAYER 0-2 FEET.; CONTINUOUS. ACTIVE LAYER 2 FEET (±).	
SEGREGATED ICE		CONSIDERABLE. OCCURS AS THICK WEDGES AND RANDOM LENSES.	



PIPELINE SCHEMATIC

MATCH LINE M.P. 132.80

M.P. 138.42

42" O.D. x 0.750" W.T. X-65 PIPE

M.P. 152.00

CS

M.P. 154.23

MATCH LINE M.P. 157.70

CONSTRUCTION SECTION NO. 1 (2 YEARS)

M.P. 137.00

M.P. 132.8 TO M.P. 142.3
3' GRANULAR BACKFILL REQ'D. OR ANCHORS

CONSTRUCTION SECTION NO. 2 (2 YEARS)

SITE PREPARATION–SUMMER PRIOR TO CONSTRUCTION. PREPARE SOURCES OF MATERIALS, (BORROW PITS) BUILD 5' GRAVEL PAD ON WORK SITES, BUILD ROADS.
RIGHT-OF-WAY–MID. OCT. TO APR: CLEAR SNOW, BUILD 2' COMPACTED SNOW WORK PAD, STRIP ORGANICS AND STOCK PILE, LEVEL WORK AREA.
LAYING–NOV. TO EARLY MAY: BLAST DITCH LINE, WELD PIPE, EXCAVATE DITCH WITH BACKHOES, PAD DITCH, LOWER IN, BACKFILL WITH SELECT CONDITIONED MATERIALS, SET VALVES, MAKE TIE-INS.
CLEAN-UP–APR. THRU MAY: RETURN ORGANICS TO DITCH LINE, INSTALL EROSION PROTECTION, REMOVE DEBRIS.

COMPRESSOR STATION NO. 3

CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 1 | CONSTRUCTION SECTION NO. 2

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

TRANS-ALASKA GAS PROJECT

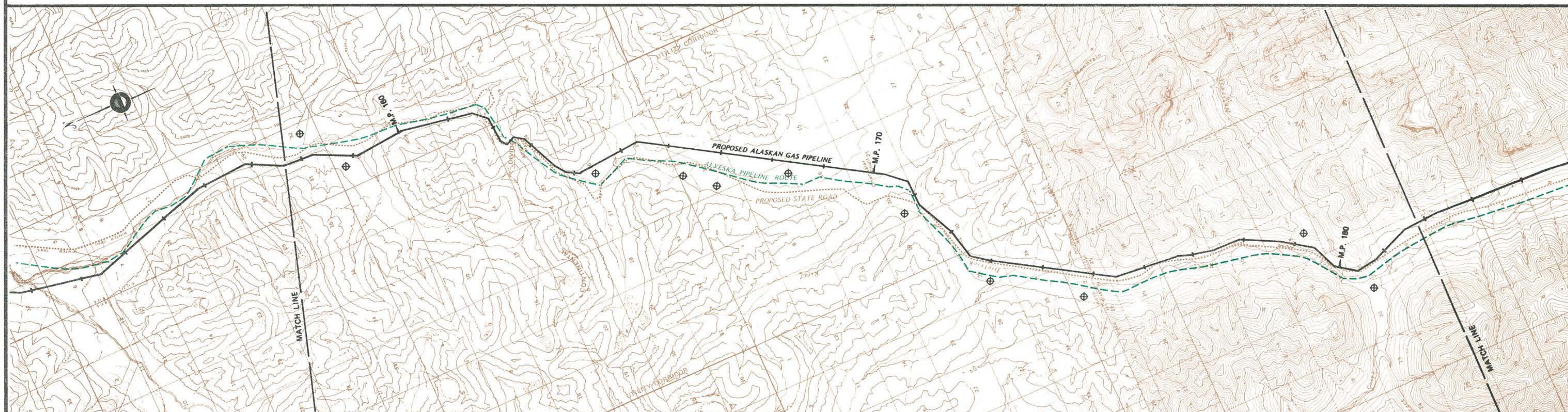
PROPOSED
ALASKAN GAS PIPELINE

M.P. 132.80 TO M.P. 157.70

FIGURE 7

	M.P. 157.70 – M.P. 161.00	M.P. 161.00 – M.P. 164.00	M.P. 164.00 – M.P. 171.00		M.P. 171.00 – M.P. 181.80
OWNERSHIP	USA				
TERRAIN	FLAT TO GENTLY ROLLING	MOUNTAINOUS ATIGUN (DIETRICH) PASS	FLAT		ROLLING W/SOME SIDEHILL CONSTRUCTION.
VEGETATION	THIN LAYER OF TUNDRA	NONE	THIN LAYER TUNDRA		TUNDRA W/BRUSH & SMALL TREES FROM MEDIUM TO SCATTERED DENSITY.
SPECIAL CONDITIONS	SNOW AVALANCHE AREA	STEEP SLOPES AND GRADES PIPELINE (PROPOSED) AND ROAD (PROPOSED) CROSSINGS. CONSIDERABLE ROCK EXCAVATION NECESSARY			STEEP GRADE (CHANDALAR SHELF) SNOW AVALANCHE; SIDEHILL TO 25%; AREA; SIDEHILL TO 21%; NUTIRWIK CREEK CROSSING; SIDEHILL TO 25% (ROCK)
GEO-MORPHOLOGY	WIDE RIVER VALLEY FLANKED BY COALESCING ALLUVIAL & COLLUVIAL FANS	RESTRICTED MOUNTAIN PASS. WELL DEVELOPED, OVER STEEPENED ROCK-TALUS SLIDES AND CONES.	OVERSIZED RIVER VALLEY. WELL DEVELOPED, BROAD ALLUVIAL AND COLLUVIAL FANS COALESCING MID-VALLEY.		RIVER VALLEY WITH COALESCING ALLUVIAL AND COLLUVIAL FANS. FANS ARE FREQUENTLY TRUNCATED BY RIVER CHANNEL. BEDROCK EXPOSED ALONG CHANNEL BENEATH FANS.
SOILS & BEDROCK	DENSE, SAND AND GRAVEL COVERED BY 0–5 FEET OF LOOSE, WET SILT.	HEAVY GRAVEL, BOULDER DEPOSITS WITH NO APPRECIABLE SOIL-COVER. HIGH PASS AREA HAS RESISTANT, FROST-SHATTERED CONGLOMERATE BEDROCK OUT-CROPPING FREQUENTLY.	DENSE SAND AND GRAVEL COVERED BY 0–3 FEET OF LOOSE SILT.	ARGILLITE COVERED WITH 0–11 ' OF LOOSE SILT.	DENSE SILT WITH SOME GRAVEL AND SCATTERED BOULDERS. SLATE AND SANDSTONE APPROACHES SURFACE LOCALLY.
PERMAFROST	CONTINUOUS. ACTIVE LAYER 2 FEET (±)	PERMAFROST SURFACE VARIES 0–20 FEET (±). ACTIVE LAYER 0–6 FEET (±)	CONTINUOUS. ACTIVE LAYER 2 FEET (±).	CONTINUOUS. ACTIVE LAYER 2–4.5 FEET.	CONTINUOUS. ACTIVE LAYER 0–2 FEET (±).
SEGREGATED ICE	LITTLE TO NONE.	NONE	GENERALLY LITTLE TO NONE. LOCALLY CONSIDERABLE.	SOME TO CONSIDERABLE.	LITTLE TO OCCASIONAL. LOCALLY CONSIDERABLE.

M.P. 157.70 MATCH LINE — MATCH LINE M.P. 181.80



PIPELINE SCHEMATIC

42" O.D. x 0.750" W.T. X-65 PIPE — M.P. 170.53 — M.P. 180.00

M.P. 157.70 MATCH LINE — M.P. 161.00 — M.P. 164.00 — M.P. 171.00 — MATCH LINE M.P. 181.80

CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 2 (2 YEARS)

SPECIAL CONSTRUCTION ATIGUN PASS
RIGHT-OF-WAY–SUMMER: CLEAR LOOSE ROCK AND DEBRIS, LEVEL WORK AREA WITH GRAVEL PAD: BLAST DITCH.

CONSTRUCTION SECTION NO. 2 (2 YEARS)

CONSTRUCTION SECTION NO. 2 (2 YEARS)

SITE PREPARATION–SUMMER PRIOR TO CONSTRUCTION; PREPARE SOURCES OF MATERIALS OCT. TO DEC. CLEAR BRUSH AND TREES, BUILD 5' GRAVEL PAD ON WORK SITES.
RIGHT-OF-WAY–MID OCT. TO APRIL CLEAR SNOW, BUILD 2' COMPACTED SNOW WORK PAD, STRIP ORGANICS AND STOCK PILE, LEVEL WORK AREA.
LAYING–NOV. TO EARLY MAY; BLAST DITCH LINE, WELD PIPE, EXCAVATE DITCH WITH BACKHOES, PAD DITCH, LOWER-IN, BACKFILL WITH SELECT CONDITIONED. MATERIALS SET VALVES, MAKE TIE-INS.
CLEAN-UP–APR. THRU MAY; RETURN ORGANICS TO DITCH LINE, INSTALL EROSION PROTECTION, REMOVE DEBRIS.

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

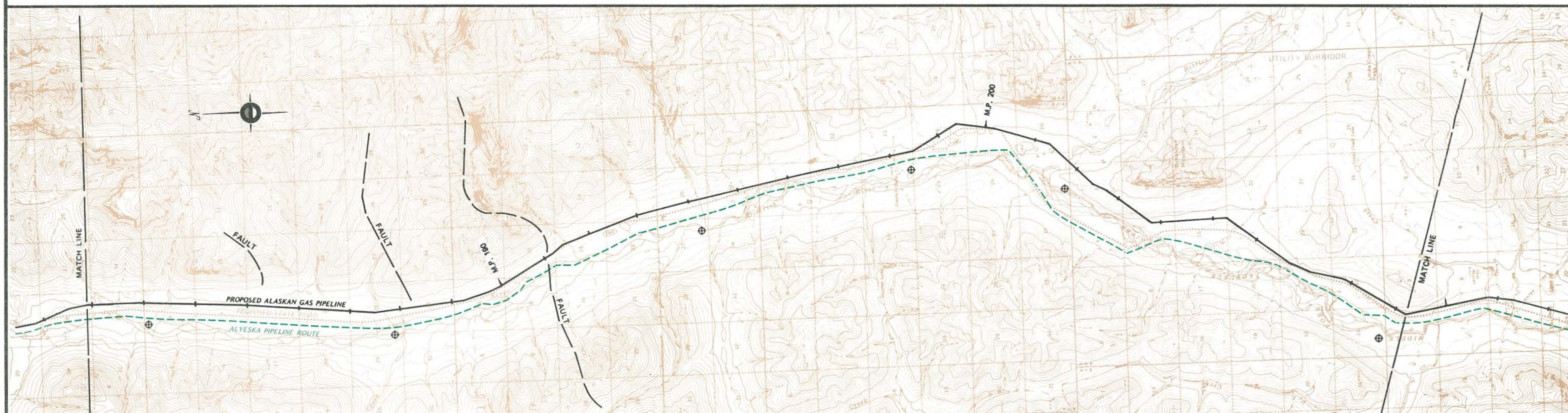
TRANS-ALASKA GAS PROJECT

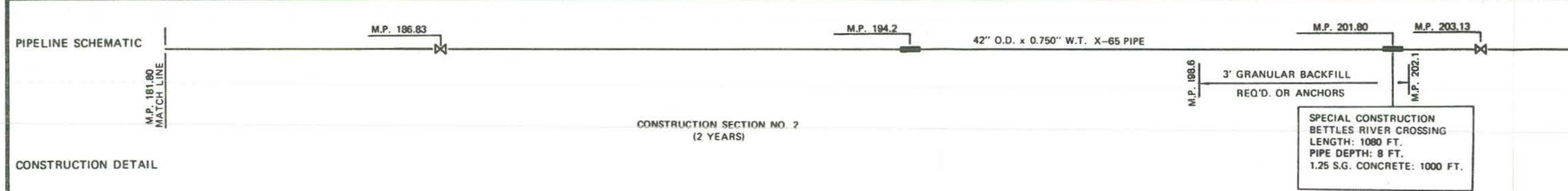
PROPOSED ALASKAN GAS PIPELINE

M.P. 157.70 TO M.P. 181.80

FIGURE 8

OWNERSHIP	USA
TERRAIN	ROLLING; SLIGHTLY ROLLING; ROLLING; FLAT; ROLLING
VEGETATION	TUNDRA; TUNDRA, SCATTERED BRUSH & TREES TO 4" DIA.; DENSE BRUSH & TREES TO 4" DIA.; MEDIUM BRUSH & TREES TO 4" DIA
SPECIAL CONDITIONS	M.P. 181.80 — SNOW AVALANCHE AREA; SOLIFLUCTION LOBES, ROCK GLACIERS AND ROCK TALUS CONES ARE PRESENT AT APPROXIMATE ELEVATION 2000' ON STEEP VALLEY SIDES.; SNOWDEN CREEK CROSSING; BETTLES RIVER CROSSING — M.P. 209.20
GEO-MORPHOLOGY	BROAD RIVER VALLEY FLANKED BY COALESCING ALLUVIAL-COLLUVIAL FANS; BROAD RIVER VALLEY FLANKED BY COALESCING ALLUVIAL-COLLUVIAL FANS. ISOLATED RIVER TERRACES AND MORAINE FIELDS ALONG TOE OF FANS.
SOILS & BEDROCK	MATCH LINE — DENSE, COARSE, ANGULAR TO SUB-ROUNDED SANDS AND GRAVELS WITH CONSIDERABLE SILT. PERCENT SILT INCREASES TOWARD VALLEY AXIS. BEDROCK, COMPOSED OF DURABLE AND METAMORPHOSED SANDSTONES, OUTCROP LOCALLY. BEDROCK STRIKES EAST-WEST, DIPS STEEPLY AND HAS BEEN FAULTED AS DEPICTED.; DENSE, SORTED, ROUNDED, SAND AND GRAVEL UNDERLIES 0-3 FEET (±) OF LOOSE SILT. CONSIDERABLE BOULDERS AND COURSE MATERIAL ALONG FLANKS OF SUKAKPAK MT. — MATCH LINE
PERMAFROST	CONTINUOUS, ACTIVE LAYER 0-2 FEET (±).
SEGREGATED ICE	LITTLE TO OCCASIONAL. LOCALLY CONSIDERABLE. OCCURS AS MASSIVE ICE IRREGULAR LENSES AND SEAMS





⊕ MATERIAL SITES

0 1 2 3 SCALE IN MILES

TRANS-ALASKA GAS PROJECT

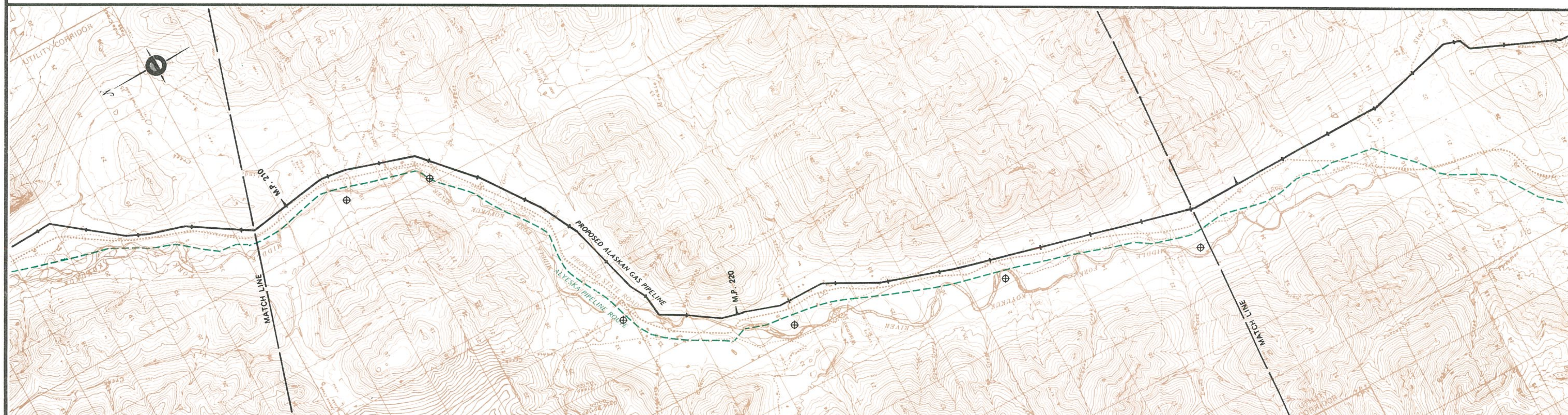
PROPOSED ALASKAN GAS PIPELINE

M.P. 181.80 TO M.P. 209.20

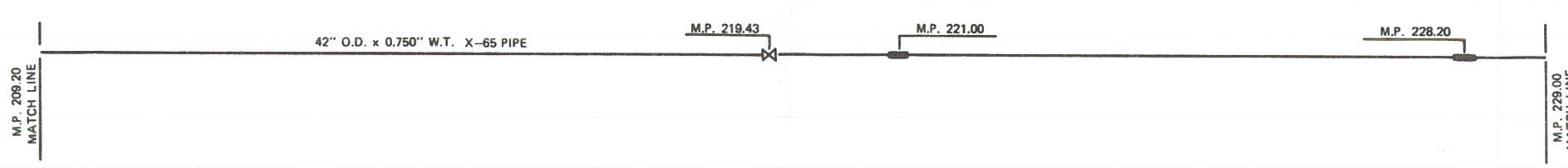
FIGURE 9

OWNERSHIP	U.S.A.		
TERRAIN	ROLLING	SLIGHTLY ROLLING	
VEGETATION	MEDIUM BRUSH & TREES TO 4" DIA.		DENSE LIGHT TIMBER 4" TO 12" DIA.
SPECIAL CONDITIONS	M.P. 209.20; SNOW AVALANCHE AREA; SIDEHILL TO 25%; FLOODPLAIN BURIAL	MINNIE CREEK CROSSING	MARION CREEK CROSSING; M.P. 229.00
GEO-MORPHOLOGY	MODIFIED RIVER TERRACES INTERFACING WITH COLLUVIAL FANS.	GLACIAL KAME TERRACES AND MORAINE FIELDS ON VALLEY FLANKS.	COALESCING ALLUVIAL-COLLUVIAL FANS ON VALLEY FLANKS.
SOILS & BEDROCK	DENSE, SORTED, ROUNDED SAND & GRAVEL UNDERLIES 0-3 FEET (±) OF LOOSE SILT.	DENSE, COARSE, SUB-ANGULAR SAND AND GRAVEL WITH SOME SILT. CONSIDERABLE ANGULAR BOULDERS THROUGHOUT.	DENSE, COARSE, ANGULAR SANDS AND GRAVELS WITH CONSIDERABLE SILT.
PERMAFROST	CONTINUOUS. ACTIVE LAYER 0-2 FEET (±)	CONTINUOUS. ACTIVE LAYER 0-5 FEET (±).	CONTINUOUS. ACTIVE LAYER 0-2 FEET (±).
SEGREGATED ICE	CONSIDERABLE. OCCURS AS MASSIVE ICE LOCALLY AND IRREGULAR LENSES AND SEAMS COMMONLY.		

MATCH LINE



PIPELINE SCHEMATIC



CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 2
(2 YEARS)

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

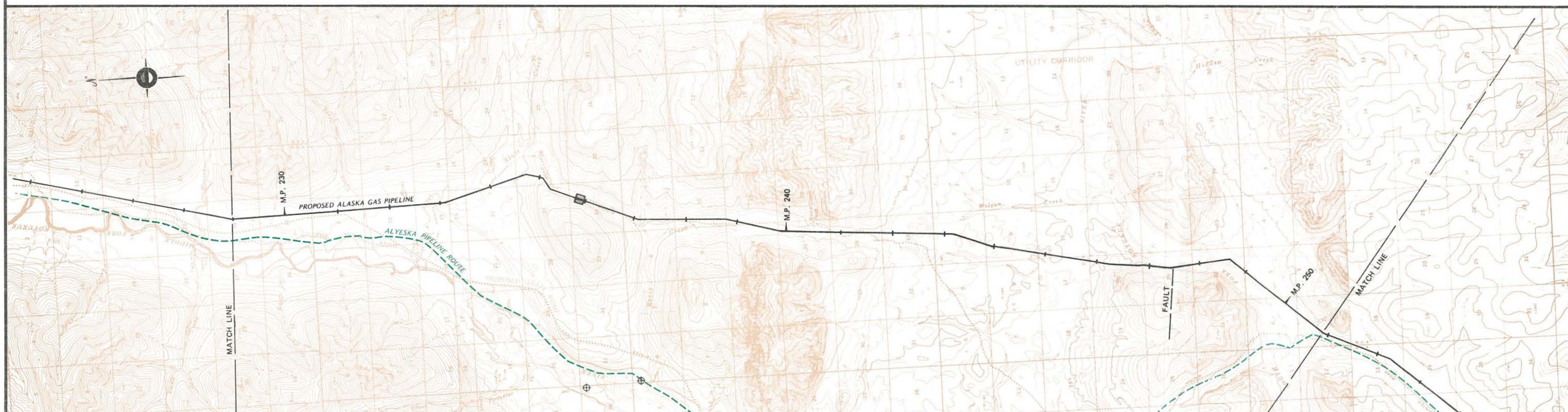
TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

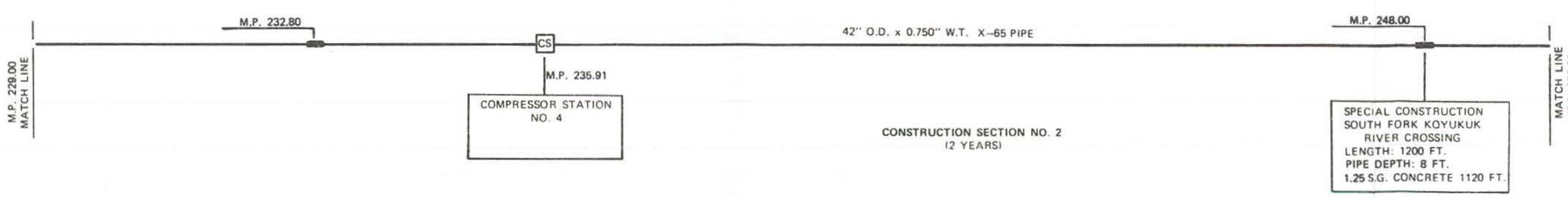
M.P. 209.20 TO M.P. 229.00

FIGURE 10

	M.P. 229.00 –				M.P. 250.90
OWNERSHIP	U.S.A.				
TERRAIN	SLIGHTLY ROLLING	ROLLING		SHARP CHOPPY; FLAT	
VEGETATION	MEDIUM BRUSH AND TREES TO 4" DIA.	MEDIUM LIGHT TIMBER 4" TO 12" DIA.		DENSE LIGHT TIMBER 4" TO 12" DIA.; TUNDRA	
SPECIAL CONDITIONS	SLATE CREEK CROSSING; POTENTIAL SNOW AVALANCHE AREA		RANDOM PEAT DEPOSITS. DEPTH OF PEAT VARIES 5–15 FEET (±).	SIDEHILL CONST.; SOUTH FK. KOYUKUK RIVER CROSSING; POTENTIAL SNOW AVALANCHE AREA	
GEO-MORPHOLOGY	BROAD COLLUVIAL APRON ALONG VALLEY FLANK.	NARROW DRAINAGE DIVIDE	GLACIAL MORAINE FIELD CONSISTING OF REPEATED SUBDUED MOUNDS AND WATER FILLED DEPRESSIONS.	BROAD RIVER VALLEY	
SOILS & BEDROCK	LOOSE SILTS WITH SOME ANGULAR GRAVEL.	LOOSE, WET SILTS WITH SOME ANGULAR GRAVEL. EXPOSED BEDROCK CONSISTS OF DURABLE GREYWACKE.	LOOSE, TO MODERATELY COMPACT, WET SILTS WITH SOME SAND OVERLYING SANDS AND GRAVELS TO DEPTHS 0–10 FEET (±).	LOOSE SILTS WITH SOME ANGULAR GRAVELS.	
PERMAFROST	CONTINUOUS. ACTIVE LAYER 0–2 FEET (±). WITHIN SLATE CK FLOODPLAIN ACTIVE LAYER VARIES 2–15 FEET (±).		CONTINUOUS. ACTIVE LAYER 0–2 FEET (±).		
SEGREGATED ICE	CONSIDERABLE. OCCURS AS MASSIVE ICE LOCALLY AND AS LENSES AND SEAMS COMMONLY.		LITTLE TO SOME. OCCURS AS LENSES & SEAMS.		



PIPELINE SCHEMATIC



CONSTRUCTION DETAIL

⊕ MATERIAL SITES

SCALE IN MILES 0 1 2 3

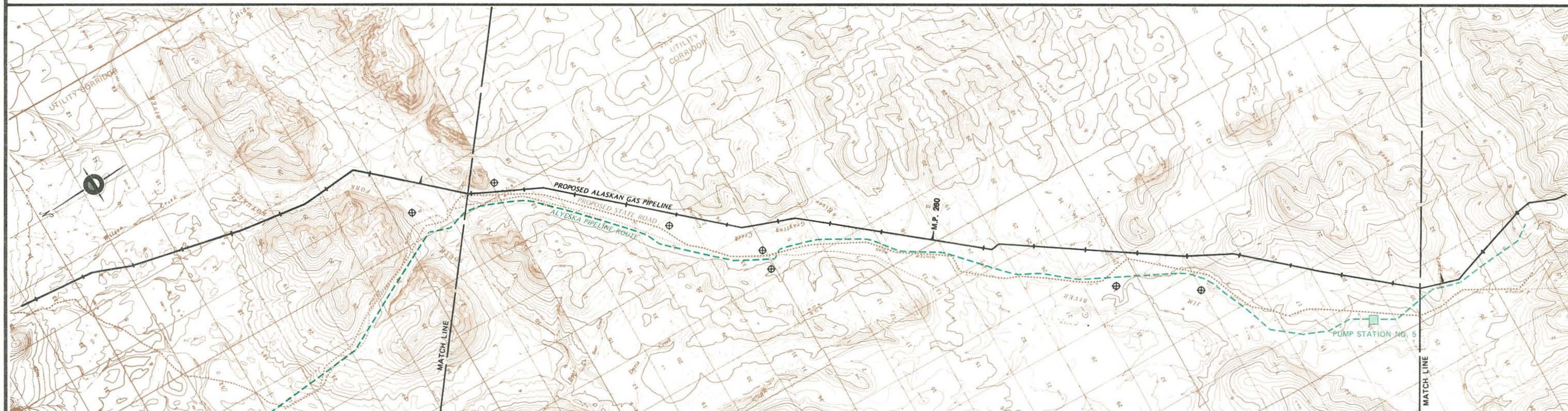
TRANS-ALASKA GAS PROJECT

PROPOSED ALASKAN GAS PIPELINE

M.P. 229.00 TO M.P. 250.90

FIGURE 11

	M.P. 250.90 (Match Line) to Jim River Crossing		Jim River Crossing to M.P. 269.55 (Match Line)
OWNERSHIP	U.S.A.		
TERRAIN	SLIGHTLY ROLLING		
VEGETATION	MEDIUM BRUSH AND TREES TO 4" DIA.	DENSE LIGHT TIMBER 4" TO 12" DIA.	MEDIUM BRUSH AND TREES TO 4" DIA.
SPECIAL CONDITIONS	24" SATURATED ORGANIC LAYER OVER AREA.		JIM RIVER CROSSING
GEO-MORPHOLOGY	RIVER VALLEY WITH COALESCING ALLUVIAL-COLLUVIAL FANS.		BROAD RIVER VALLEY WITH WELL DEVELOPED TERRACES. COLLUVIAL FANS DEVELOPED AROUND BEDROCK OUTLIERS.
SOILS & BEDROCK	LOOSE, WET, ORGANIC SILTS RANGE 8-14 FEET IN DEPTH OVER MODERATELY DENSE GRAVEL WITH SOME SAND.		DENSE, ROUNDED GRAVEL AND SAND UNDERLYING LOOSE SILTS AT DEPTHS OF 3-10 FEET (±).
PERMAFROST	CONTINUOUS. ACTIVE LAYER LESS THAN 1 FOOT.		CONTINUOUS. ACTIVE LAYER 0-2 FEET (±).
SEGREGATED ICE	CONSIDERABLE. OCCURS AS LENSES, SEAMS AND RANDOM MASSIVE ICE.		OCCASIONAL. OCCURS AS CRYSTALS, COATING AND SEAMS.



PIPELINE SCHEMATIC

M.P. 250.90 MATCH LINE — M.P. 255.31 — M.P. 261.20 — 42" O.D. x 0.750" W.T. X-65 PIPE — MATCH LINE M.P. 269.55

M.P. 251.8 — 3' GRANULAR BACKFILL REQ'D. OR ANCHORS — M.P. 256.4

CONSTRUCTION SECTION NO. 2 (2 YEARS)

CONSTRUCTION DETAIL

⊕ MATERIAL SITES

0 1 2 3 SCALE IN MILES

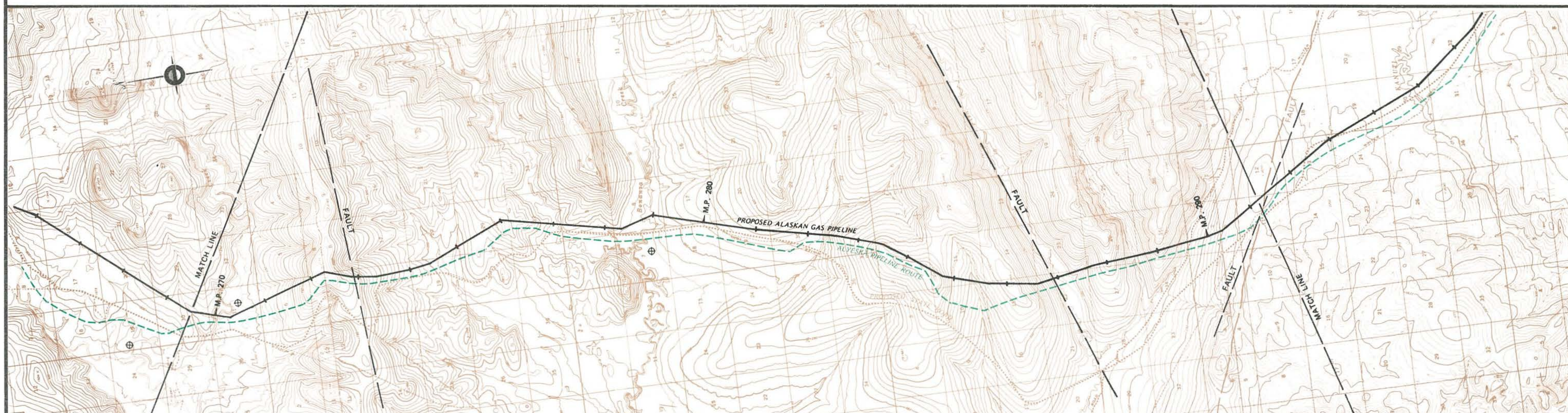
TRANS-ALASKA GAS PROJECT

PROPOSED ALASKAN GAS PIPELINE

M.P. 250.90 TO M.P. 269.55

FIGURE 12

OWNERSHIP		U S A		
TERRAIN		ROLLING		
VEGETATION		MEDIUM BRUSH AND TREES TO 4" DIA	SCATTERED BRUSH AND TREES TO 4" DIA	
SPECIAL CONDITIONS	M.P. 269.55	OCCASIONAL DEEP 3-11' (+) PEAT DEPOSITS PROSPECT CREEK CROSSING; NO. FK. BONANZA CREEK STREAM CROSSING; BONANZA CREEK STREAM CROSSING	FISH CREEK STREAM CROSSING; WELL DEVELOPED SOLIFLUCTION LOBES	M.P. 291.20
GEO-MORPHOLOGY		REPEATING EAST-WEST TRENDING RIDGES. DRAINAGE IS BEDROCK CONTROLLED		
SOILS & BEDROCK	MATCH LINE	COMPETENT GRANITE BEDROCK WITH SHALLOW (0-8 FEET) SILT COVER. / DENSE, ROUNDED, SANDS AND GRAVELS BECOME SILT RICH ON SLOPES	SCHISTS AND RELATED METAMORPHIC BEDROCK WITH SHALLOW (4-7 FEET) SILT COVER ON SLOPES AND RIDGES DEPTH OF SILT VARIES FROM 1 TO 20+ FEET IN CREEKS.	MATCH LINE
PERMAFROST		CONTINUOUS ACTIVE LAYER 0-2 FEET ON NORTH FACING SLOPE, 0-6 FEET (+) SOUTH FACING SLOPE.	PERMAFROST SURFACE DEPRESSED LOCALLY BELOW ACTIVE LAYER 2-6 FEET (+).	
SEGREGATED ICE		LITTLE TO NO ICE GENERALLY. ISOLATED AREAS OF CONSIDERABLE ICE SEAMS AND LENSES.		



PIPELINE SCHEMATIC

M.P. 269.55 MATCH LINE — M.P. 270.00 — M.P. 274.71 — M.P. 277.10 — M.P. 278.80 — 42" O.D. x 0.750" W.T. X-65 PIPE — M.P. 287.00 — MATCH LINE M.P. 291.20

CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 2 | CONSTRUCTION SECTION NO. 3

CONSTRUCTION SECTION NO. 3
(2 YEARS)

SITE PREPARATIONS–SUMMER PRIOR TO CONSTRUCTION: PREPARE SOURCES OF MATERIALS.
OCT. TO DEC.: CLEAR BRUSH AND TREES, BUILD 5' GRAVEL PAD ON WORK SITES, BUILD ROADS.
RIGHT-OF-WAY–MID. OCT. TO APR.: CLEAR SNOW, BUILD 2' COMPACTED SNOW WORK PAD, STRIP ORGANICS AND STOCK PILE, LEVEL WORK AREA.
LAYING–NOV. THRU APRIL: BLAST DITCH LINE, WELD PIPE, EXCAVATE DITCH WITH BACKHOES, PAD DITCH, LOWER-IN, BACKFILL WITH SELECT CONDITIONED MATERIALS, SET VALVES, MAKE TIE INS.
CLEAN UP–MAR. & APRIL: RETURN ORGANICS TO DITCH LINE, INSTALL EROSION PROTECTION, REMOVE DEBRIS.

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

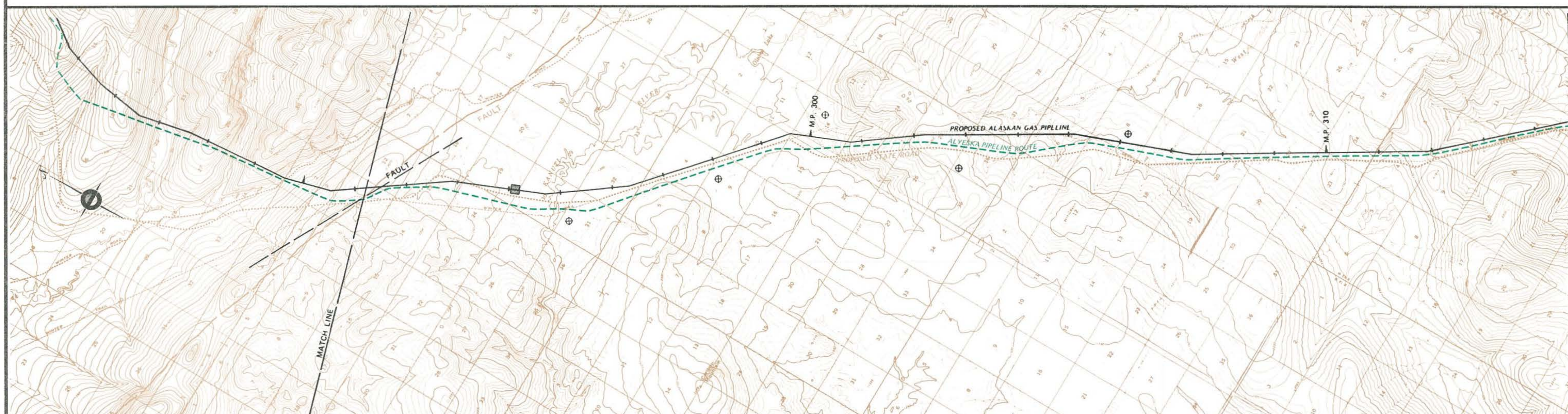
TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

M.P. 269.55 TO M.P. 291.20

FIGURE 13

OWNERSHIP	USA				
TERRAIN	ROLLING	SLIGHTLY ROLLING	ROLLING		
VEGETATION	SCATTERED BRUSH & TREES TO 4" DIA	TUNDRA	MEDIUM BRUSH & TREES TO 4" DIA	MEDIUM BRUSH & TREES TO 12" DIA	
SPECIAL CONDITIONS	M.P. 291.20 — ROAD (PROPOSED) CROSSING; ROAD (PROPOSED) CROSSING; KANUTI RIVER CROSSING				M.P. 314.70
GEO-MORPHOLOGY	REPEATING EAST WEST TRENDING RIDGES DRAINAGE BEDROCK CONTROLLED				
SOILS & BEDROCK	MATCH LINE — GRANITES AND RELATED IGNEOUS ROCK BENEATH 3 10 FEET OF LOOSE SAND WITH SOME SILT AND ANGULAR GRAVEL COBBLES AND BOULDER TO 20 FEET (±) LOCALLY.	SCHISTS AND RELATED METAMORPHIC ROCK BENEATH 6 15 FEET (±) OF LOOSE SILT AND SAND WITH SOME ANGULAR GRAVEL			MATCH LINE
PERMAFROST	PERMAFROST SURFACE DEPRESSED LOCALLY BELOW ACTIVE LAYER ACTIVE LAYER 1 4 FEET.				
SEGREGATED ICE	LITTLE TO OCCASIONAL GENERALLY ISOLATED AREAS OF CONSIDERABLE ICE SEAMS AND LENSES				



PIPELINE SCHEMATIC

M.P. 291.20 MATCH LINE

CS

M.P. 294.90

M.P. 294.18

42" O.D. x 0.750" W.T. X-65 PIPE

M.P. 310.08

MATCH LINE M.P. 314.70

CONSTRUCTION DETAIL

COMPRESSOR STATION NO. 5

SPECIAL CONSTRUCTION
KANUTI RIVER CROSSING
LENGTH. 280 FT.
PIPE DEPTH: 5 FT.
1.25 S.G. CONCRETE 200 FT.

CONSTRUCTION SECTION NO. 3
(2 YEARS)

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

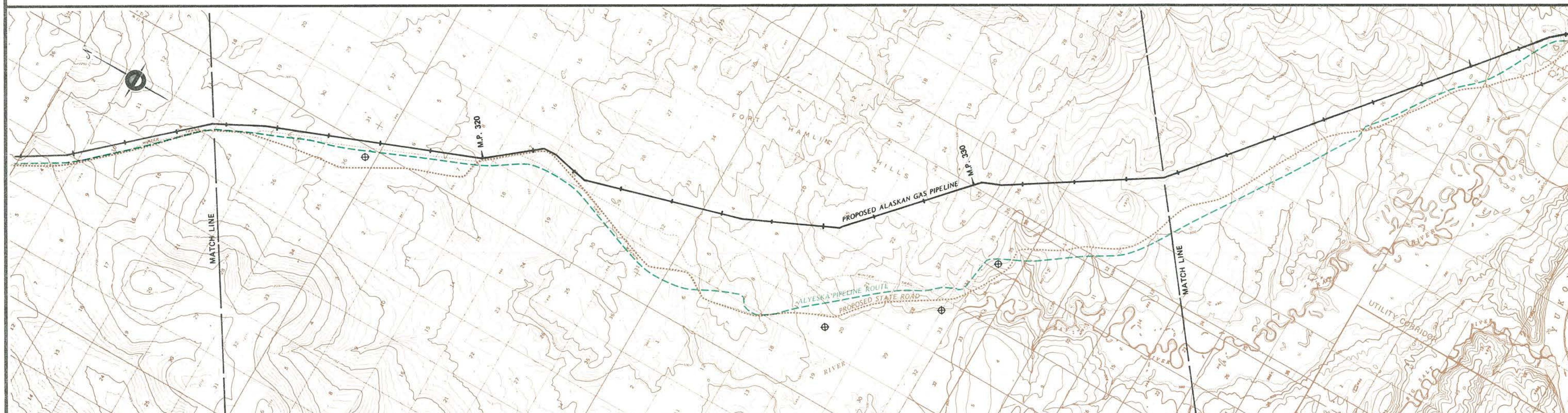
TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

M.P. 291.20 TO M.P. 314.70

FIGURE 14

	M.P. 314.70 – M.P. 333.70
OWNERSHIP	U.S.A.
TERRAIN	ROLLING
VEGETATION	MEDIUM BRUSH & TREES TO 12" DIAMETER / MEDIUM BRUSH & TREES TO 4" DIAMETER / MEDIUM BRUSH & TREES TO 12" DIAMETER
SPECIAL CONDITIONS	M.P. 314.70 … M.P. 333.70
GEO-MORPHOLOGY	AN EXTENSIVE BROAD BASIN ENCROACHED BY BEDROCK RIDGES.
SOILS & BEDROCK	MATCH LINE / LOOSE COLLUVIAL SILTS WITH SOME ANGULAR GRAVELS AND BOULDERS. / GRANITE BEDROCK BENEATH 2–6 FT. OF LOOSE SILT. / MODERATELY DENSE SAND AND GRAVEL TERRACES WITHIN EXTENSIVE SILT DEPOSITS / GRANITE BEDROCK BENEATH 1.5–6.0 FT. (±) OF LOOSE SILT, SAND & ANGULAR GRAVEL. / SCHIST BEDROCK BENEATH 6–15 FT. (±) OF LOOSE SILT. / LOOSE COLLUVIAL SILTS WITH SOME ANGULAR GRAVELS AND BOULDERS. / MATCH LINE
PERMAFROST	CONTINUOUS. ACTIVE LAYER 0–2 FEET
SEGREGATED ICE	LITTLE TO NO VISIBLE ICE. / CONSIDERABLE. OCCURS AS LENSES & SEAMS. / LITTLE TO NO VISIBLE ICE. / LITTLE TO SOME. OCCURS AS LENSES & SEAMS.



PIPELINE SCHEMATIC

M.P. 314.70 MATCH LINE — M.P. 325.98 — 42" O.D. x 0.750" W.T. X–65 PIPE — MATCH LINE M.P. 333.70

CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 3
(2 YEARS)

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

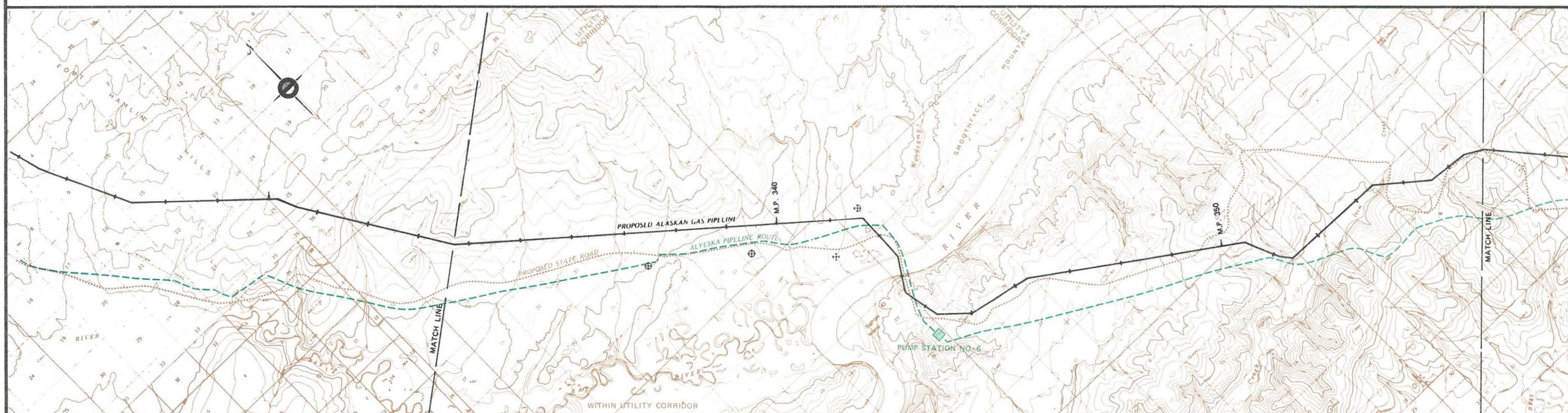
TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

M.P. 314.70 TO M.P. 333.70

FIGURE 15

OWNERSHIP	USA
TERRAIN	ROLLING; SLIGHTLY ROLLING; MOUNTAINOUS; ROLLING
VEGETATION	MEDIUM BRUSH & TREES TO 12" DIA; MEDIUM BRUSH & TREES TO 4" DIA.; DENSE BRUSH & TREES TO 12" DIA; DENSE BRUSH & TREES TO 4" DIA; MEDIUM BRUSH & TREES TO 4" DIA
SPECIAL CONDITIONS	M.P. 333.70; PIPELINE (PROPOSED) CROSSING ROAD (PROPOSED) CROSSING; YUKON RIVER CROSSING; ROAD (PROPOSED) CROSSING PIPELINE (PROPOSED) CROSSING; ROAD CROSSING; ISOM STREAM CROSSING; ROAD CROSSING; M.P. 355.80
GEO-MORPHOLOGY	GENTLE COLLUVIAL SLOPES OCCUPYING TRANSITION FROM UPLAND RIDGES TO VALLEY FLOOR; HIGH LEVEL SURFACE MODIFIED BY EAST-WEST TRENDING STREAMS
SOILS & BEDROCK	MATCH LINE; LOOSE COLLUVIAL SILTS; LOOSE TO MODERATELY DENSE SILTS; MATCH LINE
PERMAFROST	CONTINUOUS ACTIVE LAYER 0 2 FEET (+); DISCONTINUOUS PERMAFROST SURFACE MAY BE DEPRESSED LOCALLY BELOW ACTIVE LAYER; CONTINUOUS. ACTIVE LAYER 0 2 FEET (+)
SEGREGATED ICE	LITTLE TO NONE; CONSIDERABLE OCCURS AS LENSES, SEAMS AND MASSIVE ICE; OCCASIONAL OCCURS AS LENSES, SEAMS AND LOCAL MASSIVE ICE



PIPELINE SCHEMATIC

M.P. 333.70 MATCH LINE — M.P. 341.88 — M.P. 342.9 — 42" O D x 0.750" W T x 65 PIPE — M.P. 353.60 — MATCH LINE M.P. 355.80

CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 3 (2 YEARS)

SPECIAL CONSTRUCTION DESIGN IS BASED UPON THE ACQUISITION OF ADDITIONAL PIPELINE RIGHTS AND INSTALLATION OF PIPE ON THE YUKON HIGHWAY BRIDGE

⊕ MATERIAL SITES

0 1 2 3 SCALE IN MILES

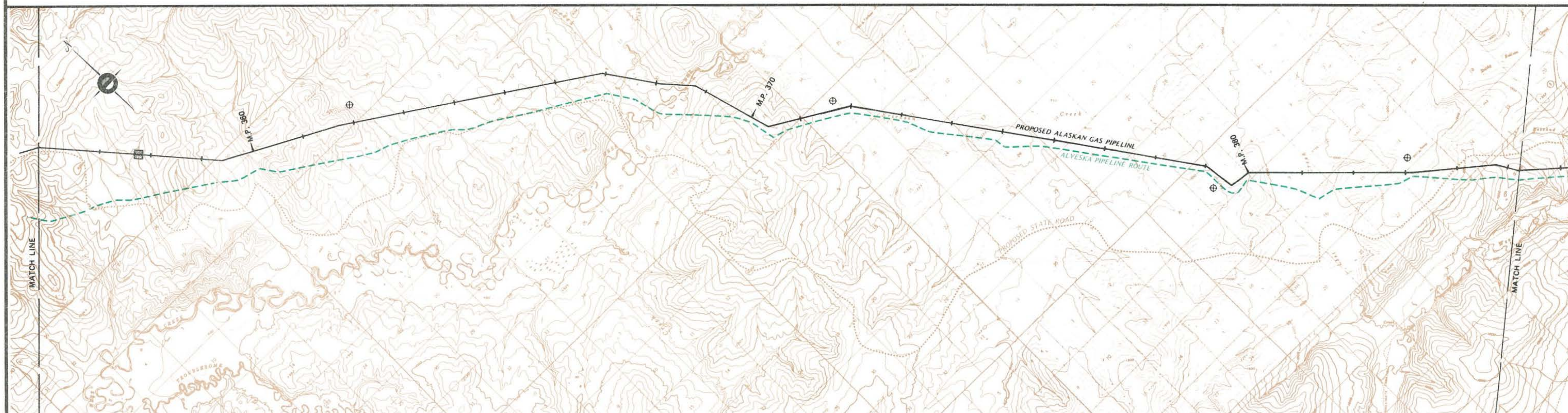
TRANS-ALASKA GAS PROJECT

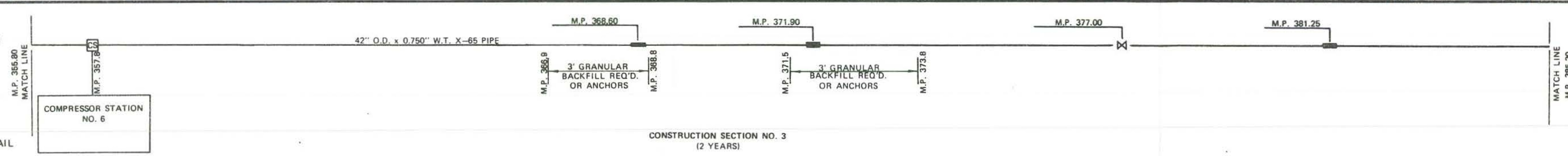
PROPOSED ALASKAN GAS PIPELINE

M.P. 333.70 TO M.P. 355.80

FIGURE 16

OWNERSHIP	USA
TERRAIN	ROLLING · SHARP & CHOPPY · ROLLING
VEGETATION	MEDIUM BRUSH & TIMBERS TO 4" DIAMETER · MEDIUM BRUSH & TREES TO 12" DIAMETER · DENSE BRUSH & TREES TO 4" DIAMETER MEDIUM LIGHT TIMBER 4" TO 12" DIAMETER · DENSE BRUSH & TREES TO 4" DIAMETER SCATTERED LIGHT TIMBER 4" TO 12" DIAMETER · DENSE BRUSH & TREES TO 4" DIAMETER MEDIUM LIGHT TIMBER 4" TO 12" DIAMETER
SPECIAL CONDITIONS	M.P. 355.80 · SWAMPS: HESS CREEK STREAM CROSSING · SWAMPS: ERICKSON CREEK CROSSING · LOST CREEK CROSSING · ROAD (PROPOSED) CROSSING · M.P. 385.20
GEO-MORPHOLOGY	UPLAND RIDGES MODIFIED BY GENTLE TO STEEP WALLED STREAM VALLEYS
SOILS & BEDROCK	MATCH LINE · LOOSE SANDS AND SILTS WITH SOME ANGULAR GRAVELS. BEDROCK BENEATH 6–8 FT. (±) OF COVER ON RIDGE TOPS. · LOOSE, WET SILTS WITH SOME ANGULAR GRAVELS AND SAND. CONSIDERABLE ORGANIC RICH SILTS IN LOW LYING AREAS. BEDROCK BENEATH 3–10 FT. (±) OF COVER ON RIDGES ABOVE ELEVATIONS 1000 (±). · MATCH LINE
PERMAFROST	DISCONTINUOUS. PERMAFROST TABLE DEPRESSED TO DEPTHS GREATER THAN 20 FEET OVER 50% OF THIS SEGMENT · ACTIVE LAYER 1.5–5 FEET
SEGREGATED ICE	LITTLE TO OCCASIONAL. OCCURS AS LENSES AND SEAMS. · CONSIDERABLE. OCCURS AS LENSES AND SEAMS. MASSIVE ICE OCCURS ON NORTH AND SOUTH FACING SLOPES.





CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 3
(2 YEARS)

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

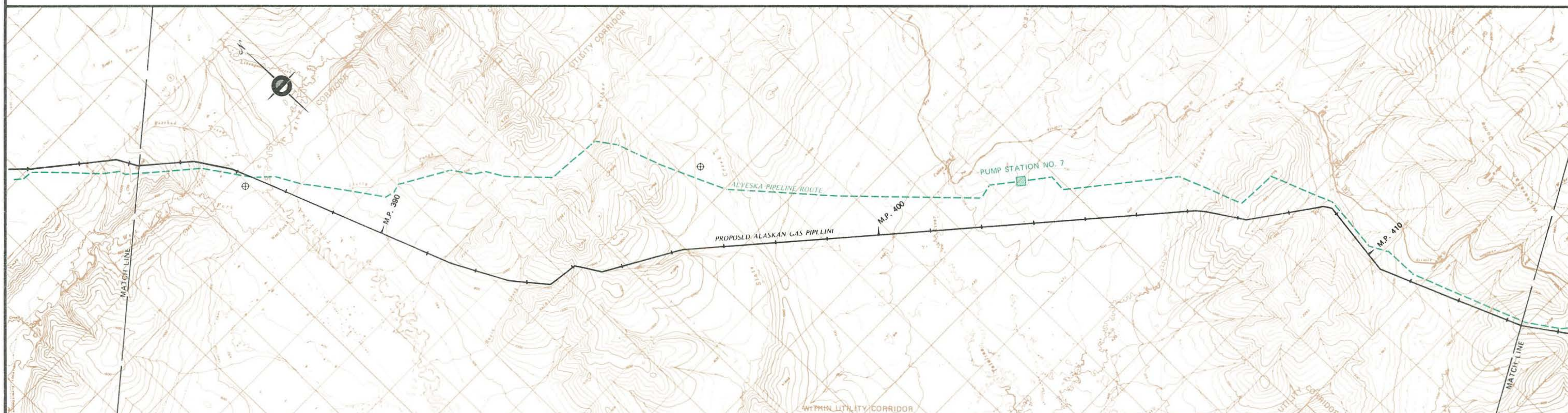
TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

M.P. 355.80 TO M.P. 385.20

FIGURE 17

OWNERSHIP	U.S.A.						
TERRAIN	ROLLING	FLAT	ROLLING	SLIGHTLY ROLLING	ROLLING		
VEGETATION	DENSE BRUSH & TREES TO 4" DIAMETER	MEDIUM LIGHT TIMBER 4" TO 12" DIAMETER	DENSE BRUSH & TREES TO 4" DIAMETER	DENSE LIGHT TIMBER 4" TO 12" DIAMETER	MEDIUM BRUSH & TREES TO 4" DIAMETER		
SPECIAL CONDITIONS	M.P. 385.20	ROAD CROSSING	PIPELINE PROPOSED CROSSING; SWAMPS	TOLOVANA RIVER CROSSING; SWAMPS	SLATE CREEK CROSSING	TATALINA RIVER CROSSING & SWAMPS	GLOBE CREEK CROSSING & SWAMPS; AGGIE CREEK CROSSING; M.P. 413.30
GEO-MORPHOLOGY	NORTHEAST-SOUTHWEST TRENDING RIDGES AND VALLEYS.						
SOILS & BEDROCK	MATCH LINE	MODERATELY DENSE ANGULAR SAND AND GRAVEL.	LOOSE, WET SILTS.	WEATHERED SLATE BEDROCK UNDER 2-15 FEET GRANULAR SOIL COVER.	LOOSE, MODERATELY DENSE SILT AND SAND.	MATCH LINE	
PERMAFROST	DISCONTINUOUS. PERMAFROST TABLE DEPRESSED BELOW 20 FEET OVER 50% OF THIS SEGMENT. ACTIVE LAYER VARIES FROM 1-4 FEET (+) IN LEVEL, NON FORESTED AREAS.						
SEGREGATED ICE	LITTLE TO SOME. OCCURS AS LENSES AND SEAMS.	LITTLE TO SOME. OCCURS AS LENSES AND SEAMS. LOCAL MASSIVE ICE ON NORTH FACING SLOPES.					



PIPELINE SCHEMATIC

M.P. 385.20 MATCH LINE — M.P. 387.70 — 42" O.D. x 0.750" W.T. X-65 PIPE — M.P. 396.20 — M.P. 397.40 — M.P. 401.25 — M.P. 405.70 — M.P. 411.80 — M.P. 413.00 — MATCH LINE M.P. 413.30

M.P. 386.3 — 3' GRANULAR BACKFILL REQ'D. OR ANCHORS — M.P. 388.5

CONSTRUCTION SECTION NO. 3 (2 YEARS)

CONSTRUCTION SECTION NO. 3 | CONSTRUCTION SECTION NO. 4

CONSTRUCTION DETAIL

⊕ MATERIAL SITES

0 1 2 3 SCALE IN MILES

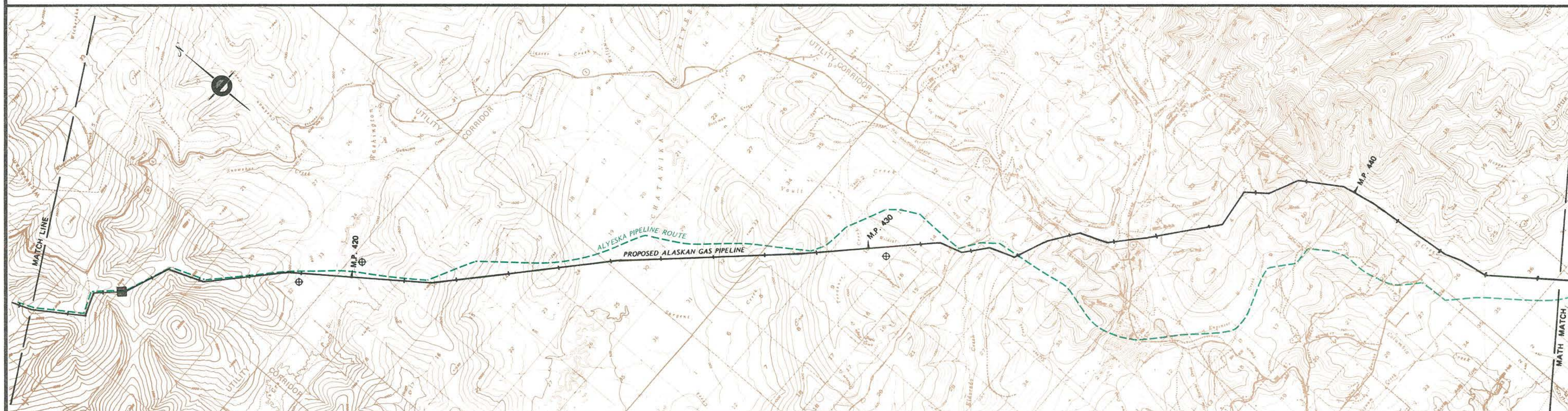
TRANS-ALASKA GAS PROJECT

PROPOSED ALASKAN GAS PIPELINE

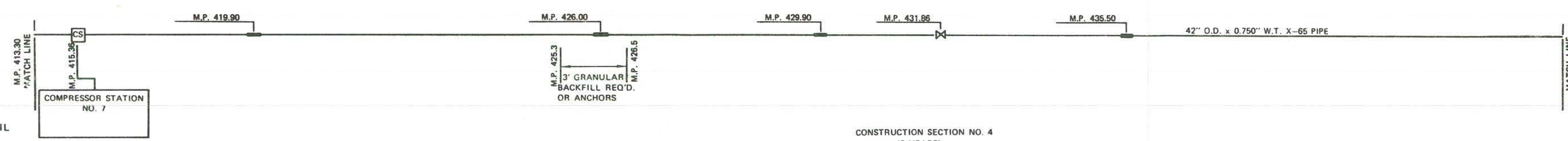
M.P. 385.20 TO M.P. 413.30

FIGURE 18

OWNERSHIP	U.S.A. / M.P. 427.95 / STATE OF ALASKA
TERRAIN	ROLLING / FLAT / ROLLING / SLIGHTLY ROLLING
VEGETATION	MEDIUM BRUSH & TREES TO 4" DIA. / DENSE BRUSH & TREES TO 4" DIA. DENSE LIGHT TIMBER 4" TO 12" DIA. / MEDIUM BRUSH & TREES TO 4" DIA.
SPECIAL CONDITIONS	M.P. 413.30 / WASHINGTON CREEK CROSSING / SWAMPS / CHATANIKA RIVER CROSSING / TREASURE CREEK CROSSING / MURPHY DOME RD. CROSSING / PIPELINE (PROPOSED) CROSSING / ELLIOTT ROAD CROSSING / STEESE ROAD CROSSING / GOLDSTREAM CREEK CROSSING / ROAD CROSSING / CHENA-HOT SPRINGS RD. CROSSING / M.P. 444.40
GEO-MORPHOLOGY	SERIES OF NORTHEAST-SOUTHWEST TRENDING RIDGES AND VALLEYS.
SOILS & BEDROCK	MATCH LINE / RIDGES CONSIST OF WEATHERED BEDROCK COVERED BY 5-15 FEET SILT. LOWLANDS AND CREEKS CONTAIN LOOSE, WET SILTS WITH SOME ORGANICS. / WEATHERED BEDROCK COVERED WITH 2-4 FEET OF LOOSE SILT WITH SOME ANGULAR GRAVEL. / DENSE SAND & GRAVEL LOCALLY WITH LOOSE COBBLE BOULDER TAILINGS. / WEATHERED BEDROCK COVERED WITH 2-4 FEET OF LOOSE SILT WITH SOME ANGULAR GRAVEL. / LOOSE MOIST TO WET SILT. / MATCH LINE
PERMAFROST	PERMAFROST SURFACE VARIES FROM 0.5-25 FEET (+). ACTIVE LAYER VARIES FROM 0.5-2.5 FEET IN LEVEL, NON-FORESTED AREAS. / DISCONTINUOUS, PERMAFROST SURFACE BELOW 40 FEET. ACTIVE LAYER VARIES FROM 0.5-2.5 FEET IN LEVEL, NON-FORESTED AREAS. / DISCONTINUOUS, PERMAFROST SURFACE VARIES FROM 0.5-40 FT. (+) ACTIVE LAYER VARIES FROM 0.5-2.5 FEET IN LEVEL, NON-FORESTED AREAS.
SEGREGATED ICE	LITTLE TO SOME. OCCURS AS LENSES AND SEAMS. LOCAL MASSIVE ICE DEVELOPS ON SLOPES. / LITTLE TO SOME. OCCURS AS LENSES AND SEAMS.



PIPELINE SCHEMATIC



CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 4
(2 YEARS)

SITE PREPARATIONS-SUMMER PRIOR TO CONSTRUCTION; PREPARE SOURCES OF MATERIALS OCT. TO DEC. CLEAR BRUSH AND TREES, BUILD 5' GRAVEL PAD ON WORK SITES.
RIGHT-OF-WAY-MID OCT. TO MAR. CLEAR SNOW, BUILD 2' COMPACTED SNOW WORK PAD. STRIP ORGANICS AND STOCK PILE, LEVEL WORK AREA.
LAYING-NOV. TO MID APRIL; BLAST DITCHLINE, WELD PIPE, EXCAVATE DITCH IN FROZEN SILTS WITH DITCHING MACHINE, EXCAVATE DITCH IN FROZEN GRAVELS WITH BACKHOES, PAD DITCH, LOWER-IN, BACKFILL WITH SELECT CONDITIONED MATERIALS, SET VALVES, MAKE TIE-INS.
CLEAN UP-MAR. & APRIL, RETURN ORGANIC TO DITCHLINE, INSTALL EROSION PROTECTION, REMOVE DEBRIS.

⊕ MATERIAL SITES

0 1 2 3 SCALE IN MILES

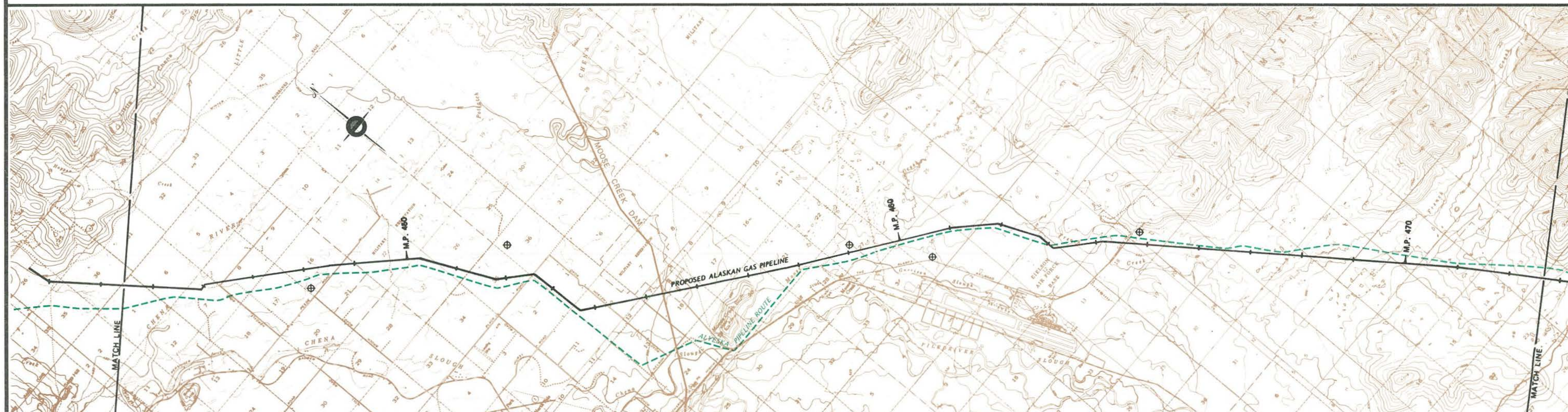
TRANS-ALASKA GAS PROJECT

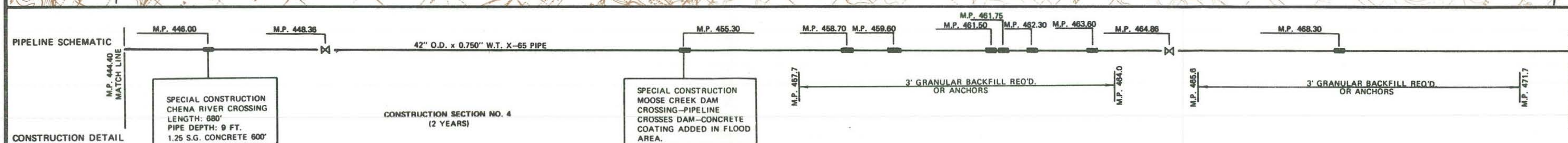
PROPOSED ALASKAN GAS PIPELINE

M.P. 413.30 TO M.P. 444.40

FIGURE 19

OWNERSHIP	STATE OF ALASKA — M.P. 447.60 — U.S.A. — M.P. 451.30 — VARIED — M.P. 459.20 — U.S.A. (AIR FORCE) — M.P. 469.60 — U.S.A.
TERRAIN	SLIGHTLY ROLLING — FLAT
VEGETATION	MEDIUM BRUSH AND TREES TO 4" DIA. — DENSE BRUSH AND TREES TO 4" DIA.
SPECIAL CONDITIONS	M.P. 444.40 — CHENA RIVER CROSSING — NORDALE ROAD CROSSING — PEEDE ROAD CROSSING — PLACK RD. CROSSING — NELSON RD. CROSSING — MOOSE CREEK DAM — 6 MINOR STREAM CROSSINGS — PIPELINE (PROPOSED) CROSSING — ROAD CROSSING — MINOR STREAM CROSSING — M.P. 472.70
GEO-MORPHOLOGY	EXTENSIVE RIVER FLOODPLAIN
SOILS & BEDROCK	MATCH LINE — MODERATELY DENSE SILT RANGING IN THICKNESS FROM 0–10 FEET OVER DENSE SAND, — LOOSE, WET, ORGANIC-RICH SILT RANGING IN THICKNESS FROM 0–5 FEET OVER DENSE SAND — MODERATELY DENSE SILT — MODERATELY DENSE SILT WITH 5 FEET OF ORGANIC-RICH SILT COVER. — MATCH LINE
PERMAFROST	DISCONTINUOUS, PERMAFROST SURFACE (IF PRESENT) IS 40 FEET (+) ACTIVE LAYER VARIES FROM 0–2.5 FEET IN LEVEL NON-FORESTED AREAS. — PERMAFROST SURFACE VARIES FROM 0–2.5 FEET (+) ACTIVE LAYER VARIES FROM 0–2.5 FEET IN LEVEL, NON-FORESTED AREAS. — DISCONTINUOUS, PERMAFROST SURFACE VARIES FROM 0–2.5 FEET (±) — ACTIVE LAYER VARIES FROM 0–2.5 FEET (±) IN LEVEL NON-FORESTED AREAS.
SEGREGATED ICE	LITTLE TO NONE — OCCASIONAL TO CONSIDERABLE. OCCURS AS LENSES, SEAMS AND MASSIVE ICE.





⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

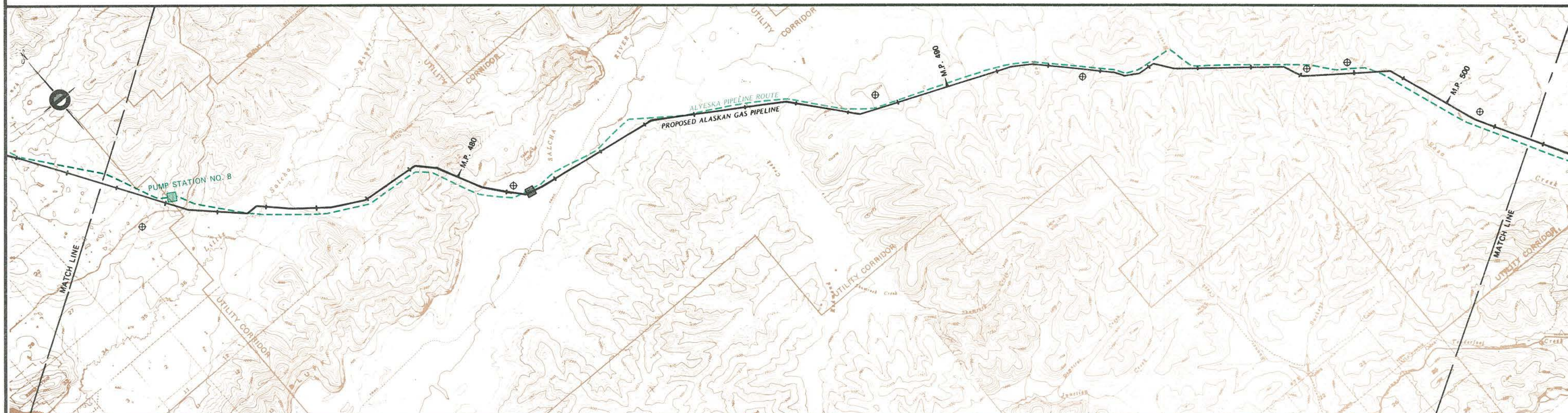
TRANS-ALASKA GAS PROJECT

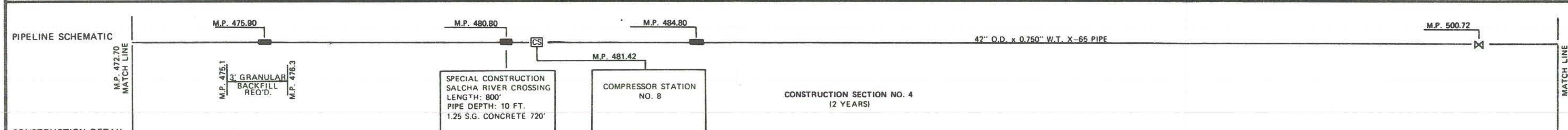
PROPOSED
ALASKAN GAS PIPELINE

M.P. 444.40 TO M.P. 472.70

FIGURE 20

OWNERSHIP	STATE OF ALASKA · M.P. 473.50	U.S.A.
TERRAIN	ROLLING · FLAT · SHARP & CHOPPY · SLIGHTLY ROLLING · ROLLING · SHARP & CHOPPY · WASHBOARD	
VEGETATION	DENSE BRUSH & TREES TO 4" DIA. DENSE LIGHT TIMBER 4" TO 12" DIA. · MEDIUM BRUSH & TREES TO 4" DIA. · DENSE BRUSH & TREES TO 4" DIA. · MEDIUM BRUSH & TREES TO 4" DIA	
SPECIAL CONDITIONS	M.P. 472.70 · PIPELINE (PROPOSED) CROSSING · LITTLE SALCHA RIVER CROSSING · SALCHA RIVER CROSSING · PIPELINE (PROPOSED) CROSSING · REDMOND CREEK CROSSING · PIPELINE (PROPOSED) CROSSING · M.P. 501.80	
GEO-MORPHOLOGY	EAST-WEST TRENDING SUBDUED RIDGES AND WELL DEVELOPED FLOOD PLAINS	
SOILS & BEDROCK	MATCH LINE · DENSE, MOIST SILTS. METAMORPHIC BEDROCK COVERED BY 0-2 FEET SILT ON RIDGE CRESTS. · LOOSE, WET, ORGANIC-RICH SILT · MODERATELY DENSE SAND & GRAVEL · MODERATELY DENSE, MOIST, SILT WITH TRACE TO LITTLE SAND, METAMORPHIC BEDROCK COVERED BY 0-2 FEET LOOSE SILT ON RIDGE CRESTS. SADDLES CONTAIN ORGANIC, RICH, LOOSE, WET SILTS. · LOOSE, MOIST TO WET SILT · LOOSE TO MODERATELY DENSE SAND · MATCH LINE	
PERMAFROST	DISCONTINUOUS. PERMAFROST SURFACE VARIES FROM 0-25 FEET (+). ACTIVE LAYER VARIES FROM 0-2.5 IN LEVEL, NON-FORESTED AREAS. · DISCONTINUOUS. PERMAFROST SURFACE VARIES FROM 1-3 FEET. ACTIVE LAYER VARIES FROM 0-2.5 FEET IN LEVEL, NON FORESTED AREAS.	
SEGREGATED ICE	SOME TO CONSIDERABLE. OCCURS AS LENSES AND SEAMS. · LITTLE TO SOME. OCCURS AS LENSES AND SEAMS. · NONE	





⊕ MATERIAL SITES

0 1 2 3 SCALE IN MILES

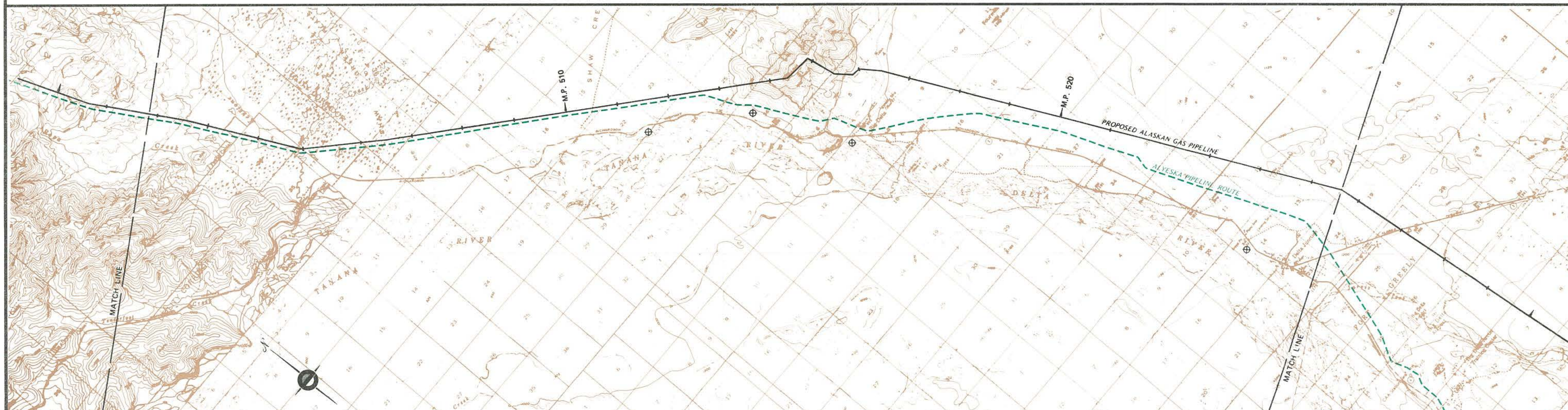
TRANS-ALASKA GAS PROJECT

PROPOSED ALASKAN GAS PIPELINE

M.P. 472.70 TO M.P. 501.80

FIGURE 21

OWNERSHIP	U.S.A. (M.P. 503.35) STATE OF ALASKA (M.P. 504.80) U.S.A. (M.P. 506.00) STATE OF ALASKA
TERRAIN	SLIGHTLY ROLLING; FLAT; ROLLING; SLIGHTLY ROLLING
VEGETATION	SCATTERED BRUSH & TREES TO 4" DIA. TUNDRA.; DENSE BRUSH & TREES TO 4" DIA. DENSE LIGHT TIMBER 4" TO 12" DIA.
SPECIAL CONDITIONS	M.P. 501.80; SHAW CREEK CROSSING; MINOR STREAM CROSSING; TANANA RIVER CROSSING; M.P. 525.60
GEO-MORPHOLOGY	EXTENSIVE FLOOD PLAIN.
SOILS & BEDROCK	MATCH LINE; LOOSE TO MODERATELY DENSE SAND; LOOSE, WET ORGANIC SILT; LOOSE, WET, ORGANIC-RICH SILTS COVERING SAND AND GRAVEL TO DEPTH OF 2.5–10 FEET (±).; METAMORPHIC BEDROCK COVERED BY 2–10 FEET OF LOOSE SILT; LOOSE SILTS WITH SOME SAND COVERING SAND AND GRAVEL TO DEPTHS OF 6–10 FEET (±).; DENSE, ROUNDED, SAND AND GRAVEL OCCASIONALLY COVERED BY LOOSE, WET SILT TO DEPTHS OF 5–15 FEET (±).; MATCH LINE
PERMAFROST	DISCONTINUOUS. PERMAFROST SURFACE VARIES FROM 1–2 FEET. ACTIVE LAYER VARIES FROM 0–2 FEET IN LEVEL, NON-FORESTED AREAS.; DISCONTINUOUS PERMAFROST SURFACE (IF PRESENT) 25 FEET (+), ACTIVE LAYER VARIES FROM 0–2' IN LEVEL, NON FORESTED AREAS; DISCONTINUOUS PERMAFROST SURFACE VARIES FROM 1–25 FEET (+). ACTIVE LAYER VARIES FROM 0–2 FEET IN LEVEL, NON FORESTED AREAS.
SEGREGATED ICE	LITTLE TO OCCASIONAL. OCCURS AS CRYSTALS, COATING, SEAMS AND MASSIVE ICE.; LITTLE, OCCURS AS CRYSTALS, COATINGS AND SEAMS.



PIPELINE SCHEMATIC

M.P. 501.80 MATCH LINE — M.P. 504.80 — 42" O.D. x 0.750" W.T. X-65 PIPE — M.P. 516.3 — M.P. 520.02 — MATCH LINE M.P. 525.60

CONSTRUCTION SECTION NO. 4 (2 YEARS)

SPECIAL CONSTRUCTION
TANANA RIVER CROSSING
LENGTH: 1080 FT.
PIPE DEPTH: 14 FT.
1.25 S.G. CONCRETE 1000 FT.

CONSTRUCTION DETAIL

⊕ MATERIAL SITES

0 1 2 3 SCALE IN MILES

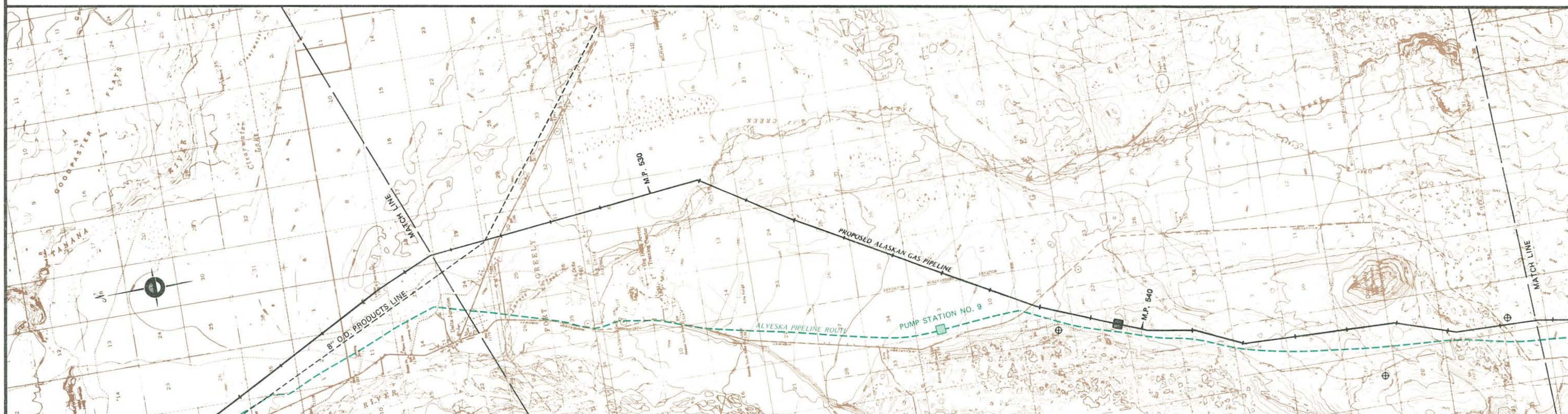
TRANS-ALASKA GAS PROJECT

PROPOSED ALASKAN GAS PIPELINE

M.P. 501.80 TO M.P. 525.60

FIGURE 22

OWNERSHIP	STATE OF ALASKA / U.S.A. MILITARY RESERVATION / U.S.A. / U.S.A. MILITARY RESERVATION / U.S.A.
TERRAIN	SLIGHTLY ROLLING / FLAT / SLIGHTLY ROLLING / ROLLING
VEGETATION	DENSE BRUSH & TREES TO 4" DIA. DENSE LIGHT TIMBER 4" TO 12" DIA. / DENSE BRUSH & TREES TO 4" DIA. / MEDIUM BRUSH & TREES TO 4" DIA. / TUNDRA
SPECIAL CONDITIONS	M.P. 525.60 / 8" PRODUCTS LINE CROSSING / ALASKA HWY. CROSSING / JARVIS CREEK CROSSING / RICHARDSON HWY. CROSSING / MINOR STREAM CROSSING / RICHARDSON HWY. CROSSING / M.P. 547.50
GEO-MORPHOLOGY	
SOILS & BEDROCK	MATCH LINE / MODERATELY DENSE SAND AND GRAVEL WITH NUMEROUS COBBLES AND BOULDERS. / MODERATELY DENSE SAND WITH SOME SILT AND GRAVEL. OCCASIONAL POCKETS OF LOOSE, WET ORGANIC SILT TO 8 FEET (±). / LOOSE, MOIST TO WET SILT WITH SOME SAND COVERING SAND AND GRAVEL TO DEPTHS OF 0–10 FEET (±). / MATCH LINE
PERMAFROST	DISCONTINUOUS, PERMAFROST SURFACE (IF PRESENT) 25 FEET (+). ACTIVE LAYER VARIES FROM 1–6 FEET. / DISCONTINUOUS, PERMAFROST SURFACE VARIES FROM 1–10 FEET. ACTIVE LAYER VARIES FROM 1–6 FEET. / PERMAFROST SURFACE VARIES FROM 1–2 FEET. ACTIVE LAYER VARIES FROM 1–2 FEET. / PERMAFROST SURFACE (IF PRESENT) 25 FEET (+). / SEE NEXT SHEET
SEGREGATED ICE	NONE / LITTLE TO NONE / SOME TO CONSIDERABLE. OCCURS AS CRYSTALS, LENSES, AND SEAMS / NONE



PIPELINE SCHEMATIC

M.P. 525.60 MATCH LINE

M.P. 531.25

42" O.D. x 0.750" W.T. X–65 PIPE

CS

M.P. 539.45

COMPRESSOR STATION NO. 9

CONSTRUCTION SECTION NO. 4 (2 YEARS)

MATCH LINE M.P. 547.50

CONSTRUCTION DETAIL

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

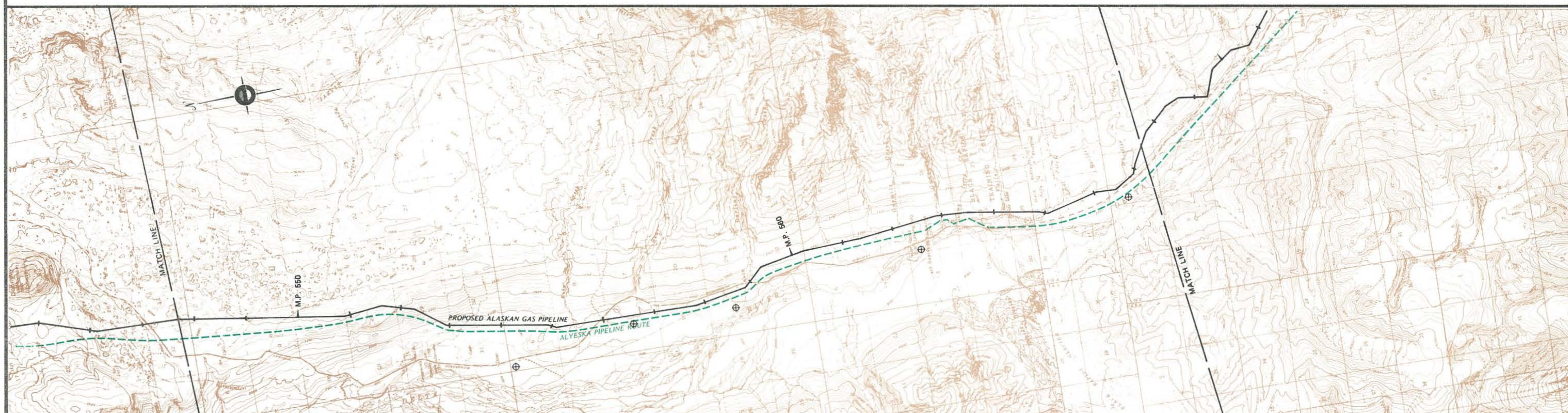
TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

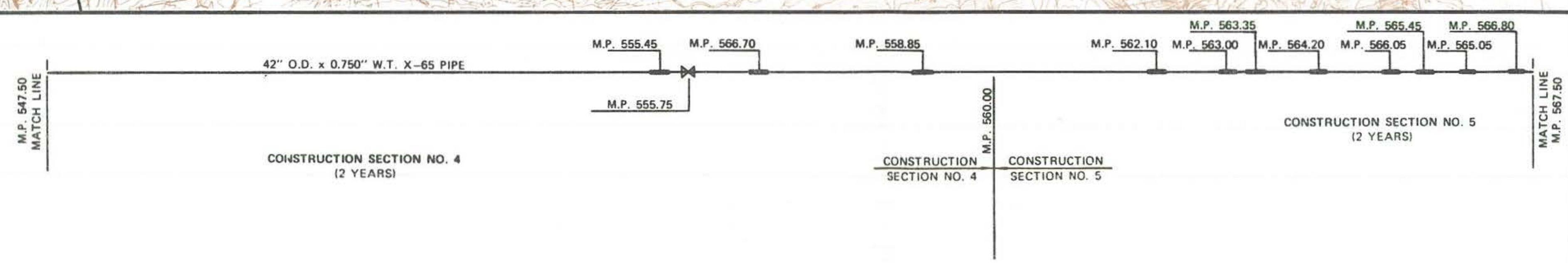
M.P. 525.60 TO M.P. 547.50

FIGURE 23

OWNERSHIP	U.S.A.				
TERRAIN	ROLLING	SHARP CHOPPY	SLIGHTLY ROLLING		
VEGETATION	SCATTERED BRUSH & TREES TO 4" DIA.	MEDIUM BRUSH & TREES TO 4" DIA.	TUNDRA	OPEN COUNTRY	
SPECIAL CONDITIONS	M.P. 547.50	RUBY CREEK CROSSING; RICHARDSON HWY CROSSING; BEAR CREEK CROSSING	DARLING CREEK CROSSING; RICHARDSON HWY. CROSSING	SNOW AVALANCHE AREA. ONE MILE CREEK CROSSING; 2 MINOR STREAM CROSSING; FALLS CREEK CROSSING; 3 MINOR STREAM CROSSING; WHISTLER CREEK CROSSING	M.P. 567.50
GEO-MORPHOLOGY	MORAINE FIELD OF SUBDUED RIDGES AND DEPRESSIONS. DEPRESSIONS ARE OFTEN UNDRAINED.	RIVER TERRACES AND FLOODPLAINS.	DENUDED VALLEY UPLAND DEEPLY INCISED BY NUMEROUS MOUNTAIN STREAMS.		
SOILS & BEDROCK	MATCH LINE	MODERATLY DENSE, WET, SILT	SAND, GRAVEL AND SILT COVERED BY 5–15 FEET (+) OF ORGANIC RICH WET SILT.	MODERATELY DENSE SAND AND GRAVEL.	DURABLE SCHIST BEDROCK WITH OCCASIONAL THIN (0–10 FEET ±) VENEER OF GRANULAR ALLUVIUM -COLLUVIUM. MATCH LINE
PERMAFROST	DISCONTINUOUS, PERMAFROST SURFACE 1–6 FEET. ACTIVE LAYER VARIES FROM 1–2 FEET IN LEVEL, NON-FORESTED AREAS.	DISCONTINUOUS, PERMAFROST SURFACE VARIES FROM 3–12 FEET (±). ACTIVE LAYER VARIES FROM 1–6'.	D. PERMAFROST SURFACE (IF PRESENT) 25 FEET (+).	DISCONTINOUS, PERMAFROST PROBABLY NEAR SURFACE IN UPLAND AREAS. ACTIVE LAYER 0–2'.	
SEGREGATED ICE	LITTLE TO SOME OCCURS AS CRYSTALS, LENSES AND SEAMS.	NONE	NONE		



PIPELINE SCHEMATIC



CONSTRUCTION DETAIL

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

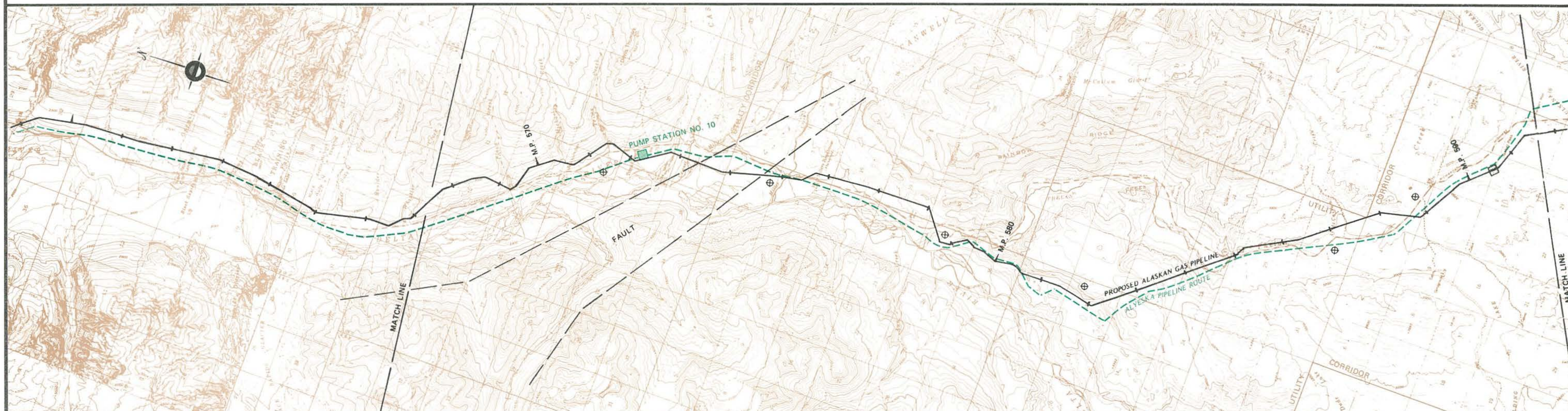
TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

M.P. 547.50 TO M.P. 567.50

FIGURE 24

OWNERSHIP	U.S.A. — M.P. 575.60 — STATE OF ALASKA — M.P. 578.10 — U.S.A.
TERRAIN	SLIGHTLY ROLLING / SHARP CHOPPY / ROLLING / WASHBOARD / SHARP CHOPPY / ROLLING
VEGETATION	OPEN COUNTRY / MEDIUM BRUSH & TREES TO 4" DIA. / DENSE BRUSH & TIMBER TO 4" DIA. / SCATTERED BRUSH & TREES TO 4" DIA. / OPEN COUNTRY
SPECIAL CONDITIONS	M.P. 567.50 — SNOW AVALANCHE AREA: FLOOD CREEK CROSSING; MICHAEL CREEK CROSSING; TRIMS CREEK CROSSING / RICHARDSON HWY CROSSING & PIPELINE (PROPOSED) CROSSING / DENALI FAULT ZONE: MILLER & CASTNER CREEK & STREAM CROSSINGS / RICHARDSON HIGHWAY CROSSING / PHELAN CREEK CROSSING NO. 1 / PIPELINE (PROPOSED) CROSSING / PIPELINE (PROPOSED) CROSSING / PHELAN CREEK CROSSING NO. 2 / RICHARDSON HIGHWAY CROSSING / PHELAN NO. 3 AND A MINOR CROSSING / RICHARDSON HIGHWAY CROSSING / PIPELINE (PROPOSED) CROSSING — M.P. 591.80
GEO-MORPHOLOGY	DENUDED VALLEY UPLAND DEEPLY INCISED BY NUMEROUS MOUNTAIN STREAMS. / GLACIAL OUTWASH FANS AND MORAINE FIELDS. / UPLAND GLACIATED PLATEAU INCISED BY VIGOROUS STREAMS.
SOILS & BEDROCK	MATCH LINE — DURABLE SCHIST BEDROCK WITH OCCASIONAL THIN (0–10 FEET) VENEER OF GRANULAR ALLUVIUM COLLUVIUM. / DENSE, ROUNDED TO SUB ANGULAR GRAVEL AND SAND WITH CONSIDERABLE COBBLES AND BOULDERS. / DENSE SILT WITH SOME GRAVEL. / MODERATELY DENSE, ANGULAR GRAVEL AND SAND FREQUENTLY COVERED WITH 3–10 FEET OF ORGANIC MATTER. / DENSE, ANGULAR TO SUBROUNDED SAND AND GRAVEL FREQUENTLY COVERED WITH 0–3 FEET OF LOOSE SILT. — MATCH LINE
PERMAFROST	DISCONTINUOUS, PERMAFROST SURFACE VARIES FROM 0.5–10 FEET (±). ACTIVE LAYER VARIES FROM 0–2' IN FLAT, NON-FORESTED AREAS. / DISCONTINUOUS, PERMAFROST (IF PRESENT) 25 FEET (+). ACTIVE LAYER VARIES FROM 0–2' IN FLAT, NON-FORESTED AREAS.
SEGREGATED ICE	LITTLE TO CONSIDERABLE. OCCURS AS CRYSTALS, LENSES AND SEAMS. / NONE



PIPELINE SCHEMATIC

M.P. 567.50 MATCH LINE — M.P. 569.25 — M.P. 570.45 — M.P. 571.50 — M.P. 571.70 — M.P. 573.1 — M.P. 573.4 — M.P. 575.1 — M.P. 575.85 — M.P. 578.50 — 42" O.D. x 0.750" W.T. X–65 PIPE — M.P. 584.50 — M.P. 587.20 — M.P. 588.40 — CS — M.P. 590.53 — MATCH LINE M.P. 591.80

CONSTRUCTION SECTION NO. 5 (2 YEARS)

CONSTRUCTION DETAIL

M.P. 567.50 – M.P. 571.70	SPECIAL CONSTRUCTION SUMMER SEASON WHISTLER CREEK TO TRIMS CREEK BLAST DITCH IN ROCK SIDE SLOPES AND BURY PIPE FOR PROTECTION AGAINST SNOW SLIDES
M.P. 571.70 – M.P. 575.85	SPECIAL CONSTRUCTION DENALI FAULT ZONE 42" O.D. x 1.08" W.T. X–65 PIPE SLOPE SIDES OF DITCHES CONCRETE 5000 FT. AND BACKFILL WITH COARSE GRAVEL
M.P. 578.50	SPECIAL CONSTRUCTION PHELAN CREEK CROSSING NO. 1 LENGTH: 1600 FT. PIPE DEPTH: 5 FT. 1.25 S.G. CONCRETE: 1520 FT.
M.P. 584.50	SPECIAL CONSTRUCTION PHELAN CREEK CROSSING NO. 2 LENGTH: 2400 FT. PIPE DEPTH: 5 FT. 1.25 S.G. CONCRETE: 2320 FT.
M.P. 590.53	COMPRESSOR STATION NO. 10

⊕ MATERIAL SITES

0 1 2 3 SCALE IN MILES

TRANS-ALASKA GAS PROJECT

PROPOSED ALASKAN GAS PIPELINE

M.P. 567.50 TO M.P. 591.80

FIGURE 25

OWNERSHIP		U.S.A. (to 601.90); 608.30 – U.S.A.
TERRAIN		ROLLING; SHARP CHOPPY; ROLLING
VEGETATION		OPEN COUNTRY; MEDIUM BRUSH COVERAGE; SCATTERED BRUSH & TREES TO 4" DIA.
SPECIAL CONDITIONS	591.80	GULKANA RIVER CROSSING; RICHARDSON HIGHWAY CROSSING; PIPELINE (PROPOSED) CROSSING; FISH CREEK CROSSING; M.P. 613.30
GEO-MORPHOLOGY		GLACIAL MORAINE FIELD OF SUBDUED RIDGES AND DEPRESSIONS DEVELOPED ON A BROAD INTER-MONTANE PLATEAU.
SOILS & BEDROCK	MATCH LINE	DENSE GRAVEL WITH SOME SAND, NUMEROUS COBBLES AND BOULDERS. SILT DEPOSITS 3–10 FEET THICK IN DEPRESSIONS.; DENSE SAND WITH SOME SILT AND GRAVEL. LOCAL ORGANIC DEPOSITS TO 6 FEET (±).; MATCH LINE
PERMAFROST		DISCONTINUOUS, PERMAFROST THROUGH THIS AREA OCCURS AS ISOLATED ZONES 5–25 FEET THICK, THE SURFACE OF WHICH VARIES FROM 0.5–10 FEET (±) BELOW EXISTING GROUND ELEVATION. ACTIVE LAYER VARIES FROM 0–2 FEET IN FLAT, NON-FORESTED AREAS.
SEGREGATED ICE		LITTLE TO NONE.

PIPELINE SCHEMATIC

M.P. 591.80 MATCH LINE

M.P. 592.60 — M.P. 598.00 — 42" O.D. x 0.750" W.T. X-65 PIPE — M.P. 607.43

MATCH LINE M.P. 613.30

CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 5
(SUMMER CONSTRUCTION)
SITE PREPARATIONS–SUMMER PRIOR TO CONSTRUCTION: PREPARE SOURCES OF MATERIALS, LEVEL AND GRADE WORK SITES, BUILD ROADS.
RIGHT-OF-WAY–JUNE TO SEPT. CLEAR BRUSH AND TREES, GRADE, LEVEL.
LAYING–JUNE TO SEPT. BLAST ROCK AND EXCAVATE WITH BACKHOES, PAD DITCH, WELD, LOWER-IN, BACKFILL, SET VALVES, MAKE TIE-INS.
CLEAN-UP–SEPT. INSTALL EROSION PROTECTION, REMOVE DEBRIS.

⊕ MATERIAL SITES

0 1 2 3 SCALE IN MILES

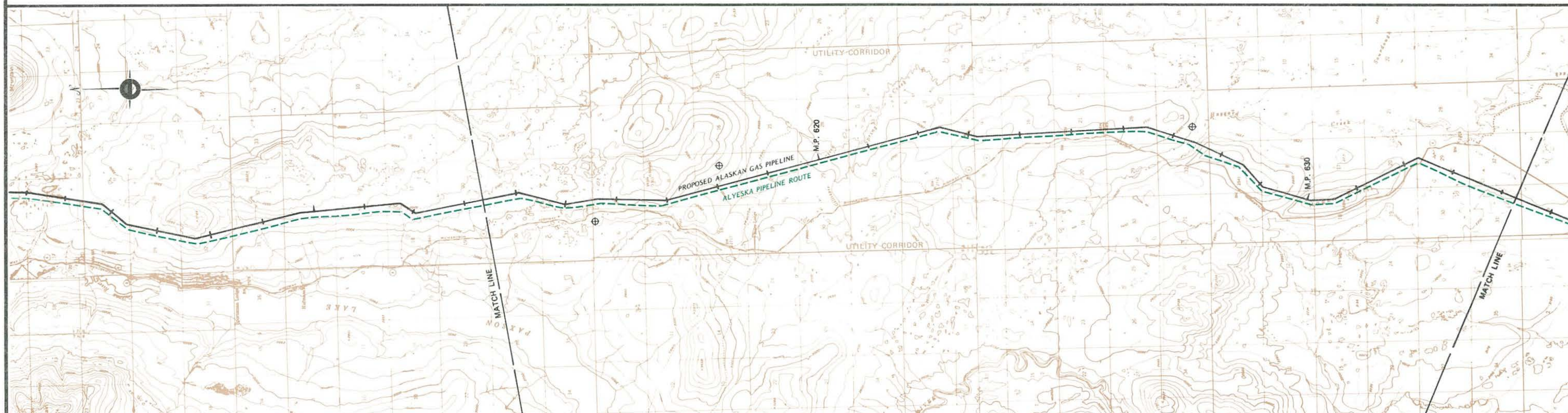
TRANS-ALASKA GAS PROJECT

PROPOSED ALASKAN GAS PIPELINE

M.P. 591.80 TO M.P. 613.30

FIGURE 26

OWNERSHIP		U.S.A.
TERRAIN		ROLLING; FLAT
VEGETATION		SCATTERED BRUSH & TREES TO 4" DIA.
SPECIAL CONDITIONS	M.P. 613.30	3 MINOR STREAM CROSSINGS; MINOR STREAM CROSSING; RICHARDSON HIGHWAY CROSSING; M.P. 634.40
GEO-MORPHOLOGY		PLATEAU WITH REMNANT BEDROCK HILLS SURROUNDED BY MORAINES AND LACUSTRINE SILTS.
SOILS & BEDROCK	MATCH LINE	MODERATELY DENSE SANDS AND SILTS; SANDS AND GRAVELS; SILTS, SANDS, AND GRAVELS. / SILT AND CLAY / MODERATELY DENSE SANDS AND SILTS; SANDS AND GRAVELS; SILTS, SANDS AND GRAVEL DEPTH TO DURABLE GRANITE BEDROCK VARIES FROM 3–15 FEET (+) THROUGH THIS AREA. MATCH LINE
PERMAFROST		DISCONTINUOUS, PERMAFROST NOT PRESENT IN SOME AREAS. WHERE PRESENT PERMAFROST SURFACE VARIES FROM 2–25 FEET (+). ACTIVE LAYER VARIES FROM 0–2 FEET. IN FLAT, NON-FORESTED AREAS.
SEGREGATED ICE		LITTLE TO OCCASIONAL. OCCURS AS LENSES AND SEAMS.



PIPELINE SCHEMATIC

M.P. 613.30 MATCH LINE — M.P. 620.20 — M.P. 620.60 — M.P. 620.75 — M.P. 624.33 — M.P. 627.50 — 42" O.D. x 0.750" W.T. X–65 PIPE — MATCH LINE M.P. 634.40

CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 5
(2 YEARS)

SITE PREPARATIONS–SUMMER PRIOR TO CONSTRUCTION: PREPARE SOURCES OF MATERIALS. OCT. TO DEC. CLEAR BRUSH AND TREES, BUILD 5' GRAVEL PAD ON WORK SITES.
RIGHT-OF-WAY–MID OCT. TO MAR. CLEAR SNOW, BUILD 2' COMPACTED SNOW WORK PAD STRIP ORGANICS AND STOCK PILE, LEVEL WORK AREA.
LAYING–NOV. TO MID APRIL: BLAST DITCHLINE, WELD PIPE, EXCAVATE DITCH IN FROZEN GRAVEL WITH BACKHOES, PAD DITCH, LOWER IN, BACKFILL WITH SELECT CONDITIONED MATERIALS, SET VALVES, MAKE TIE-INS.
CLEAN-UP–MAR. AND APR. RETURN ORGANICS TO DITCHLINE, INSTALL EROSION PROTECTION REMOVE DEBRIS.

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

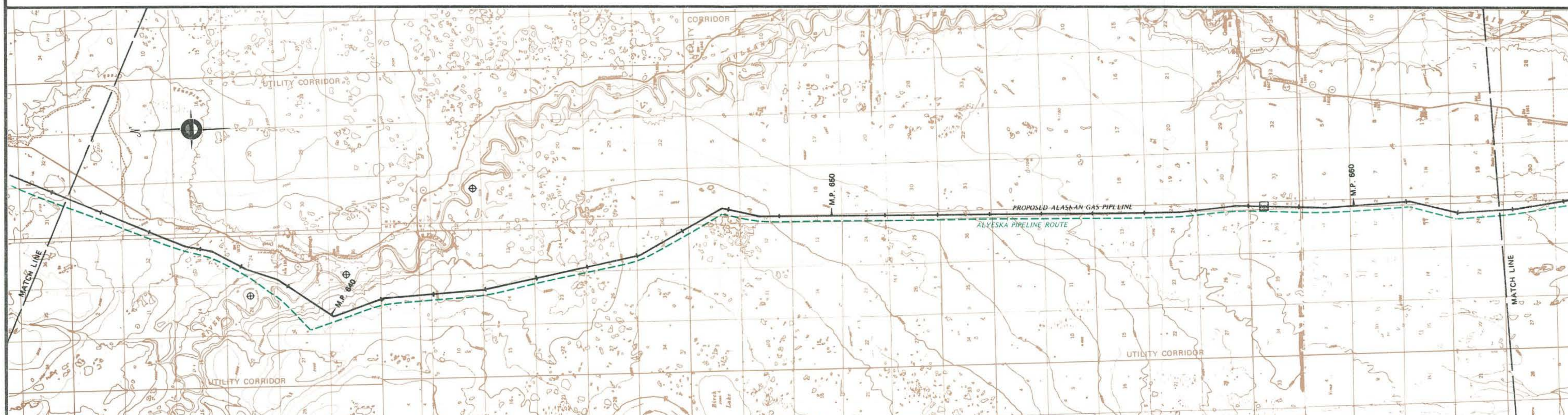
TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

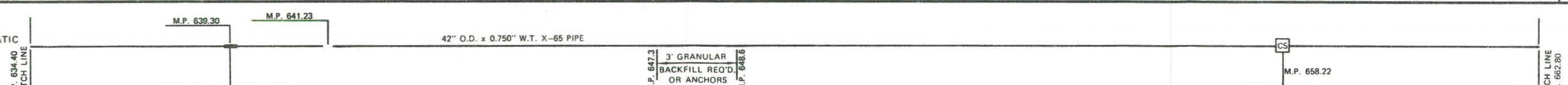
M.P. 613.30 TO M.P. 634.40

FIGURE 27

OWNERSHIP	U.S.A.		
TERRAIN	FLAT		
VEGETATION	DENSE BRUSH & TREES TO 4" DIA.	MEDIUM BRUSH & TREES TO 4" DIA	DENSE BRUSH & TREES TO 4" DIA.
SPECIAL CONDITIONS	M.P. 634.40 — GULKANA RIVER CROSSING — M.P. 662.80		
GEO-MORPHOLOGY	INTER-MONTANE BASIN AREA CONTAINING EXTENSIVE GLACIO FLUVIAL AND GLACIO LACUSTRINE SEDIMENTS.		
SOILS & BEDROCK	MATCH LINE — SILT WITH SOME CLAY TO CLAY WITH SOME SILT. LOCAL DEPOSITS OF SAND & GRAVEL WITH SOME SILT. — MATCH LINE		
PERMAFROST	DISCONTINUOUS, PERMAFROST SURFACE VARIABLE. GENERALLY SURFACE IS AT 5 FEET (±). LOCALLY SURFACE EXTENDS TO 25 FEET (+). ACTIVE LAYER VARIES FROM 2–5 FEET IN LEVEL. NON-FORESTED AREAS		
SEGREGATED ICE	AREAS OF MASSIVE SEGREGATED ICE	CONSIDERABLE LOCALLY. OCCURS AS CRYSTALS, LENSES, SEAMS AND MASSES	



PIPELINE SCHEMATIC



CONSTRUCTION DETAIL

SPECIAL CONSTRUCTION
GULKANA RIVER CROSSING
LENGTH: 680 FT.
PIPE DEPTH: 10 FT.
1.25 S.G. CONCRETE: 600 FT.

CONSTRUCTION SECTION NO. 5
(2 YEARS)

COMPRESSOR STATION NO. 11
SEE FIGURE 20 FOR DETAILS

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

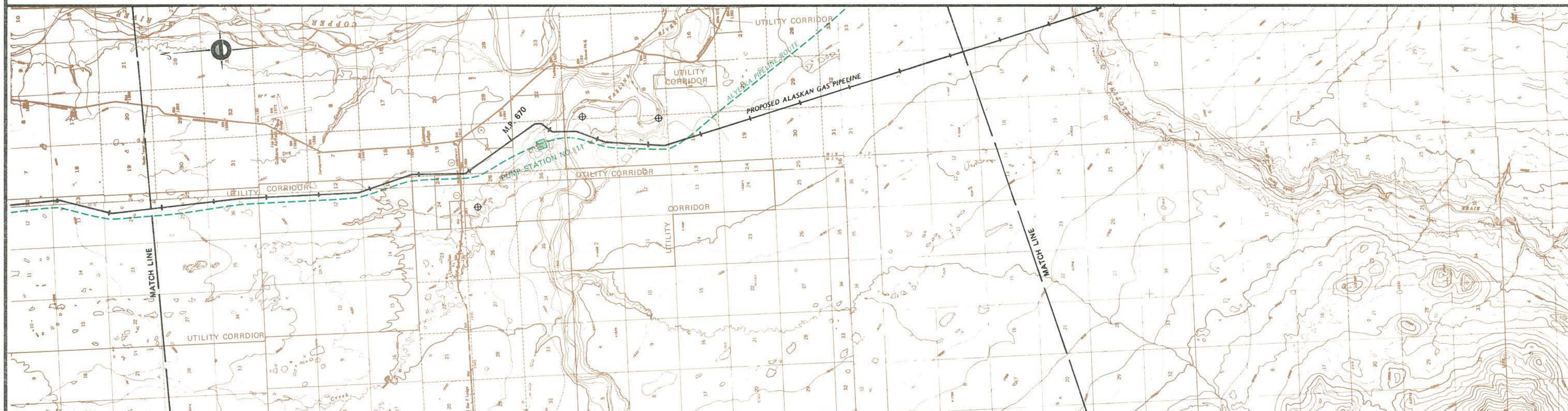
TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

M.P. 634.40 TO M.P. 662.80

FIGURE 28

OWNERSHIP		U.S.A. M.P. 667.55 STATE OF ALASKA M.P. 668.90 U.S.A. M.P. 669.70 STATE M.P. 670.10 U.S.A M.P. 671.35 STATE OF ALASKA	
TERRAIN		FLAT	
VEGETATION		DENSE BRUSH & TREES TO 4" DIA. / MEDIUM BRUSH & TREES TO 4" DIA.	
SPECIAL CONDITIONS	M.P. 662.80	GLENN HIGHWAY CROSSING; TAZLINA RIVER CROSSING; PIPELINE (PROPOSED) CROSSING	M.P. 679.26
GEO-MORPHOLOGY		INTERMONTANE BASIN AREA CONTAINING EXTENSIVE GLACIO-LACUSTRINE SEDIMENTS.	
SOILS & BEDROCK	MATCH LINE	SILT WITH SOME CLAY TO CLAY WITH SOME SILT. LOCAL DEPOSITS OF SANDED GRAVEL WITH SOME SILT.	MATCH LINE
PERMAFROST		DISCONTINUOUS. PERMAFROST SURFACE VARIABLE. GENERALLY SURFACE IS AT 5 FEET (+). LOCALLY SURFACE EXTENDS TO 25 FEET (+). ACTIVE LAYER VARIES FROM 2–5 FEET IN LEVEL, NON-FORESTED AREAS.	
SEGREGATED ICE		CONSIDERABLE LOCALLY. OCCURS AS CRYSTALS, LENSES, SEAMS, AND MASSES.	



PIPELINE SCHEMATIC

MATCH LINE M.P. 662.80 — 42" O.D. x 0.750" W.T. X–65 PIPE — M.P. 673.92 — MATCH LINE M.P. 679.25

M.P. 671.40

SPECIAL COSNTRUCTION
TAZLINA RIVER
CROSSING
AERIAL CROSSING

CONSTRUCTION SECTION NO. 5
(2 YEARS)

CONSTRUCTION DETAIL

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

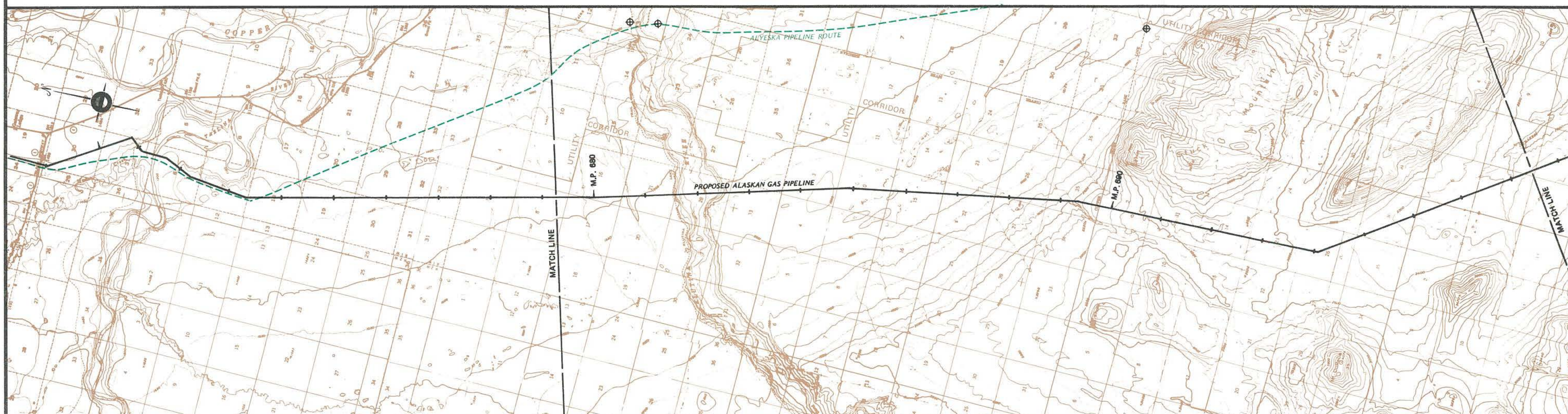
TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

M.P. 662.80 TO M.P. 679.25

FIGURE 29

	M.P. 679.25 to M.P. 698.50
OWNERSHIP	VARIED
TERRAIN	FLAT / ROLLING
VEGETATION	MEDIUM BRUSH & TREES TO 4" DIA. / DENSE BRUSH & TREES TO 12" DIA.
SPECIAL CONDITIONS	M.P. 679.25 — KLUTINA RIVER CROSSING — M.P. 698.50
GEO-MORPHOLOGY	INTERMONTANE BASIN AREA CONTAINING EXTENSIVE GLACIO-FLUVIAL AND GLACIO-LACUSTRINE SEDIMENTS. / SADDLE IN BEDROCK RIDGE WITH COLLUVIAL APRONS ON APPROACHES.
SOILS & BEDROCK	MATCH LINE — SILTS WITH SOME CLAY TO CLAY WITH SILT LOCAL DEPSOITS OF SAND AND GRAVEL WITH SOME SILT. / LOOSE, ANGULAR GRAVEL, SAND AND SILT. CONSIDERABLE ANGULAR COBBLES AND SCATTERED BOULDERS LOCALLY. — MATCH LINE
PERMAFROST	DISCONTINUOUS. PERMAFROST SURFACE VARIABLE. GENERALLY SURFACE IS AT 5 FEET (±). LOCALLY SURFACE EXTENDS TO 25 FEET (+). ACTIVE LAYER VARIES FROM 2–5 FEET IN LEVEL, NON-FORESTED AREAS. / DISCONTINUOUS, PERMAFROST SURFACE VARIES FROM 5–25 FEET (+) INTERMITTENTLY. ACTIVE LAYER VARIES FROM 2–5 FEET IN FLAT, NON-FORESTED. / DISCONTINUOUS, PERMAFROST SURFACE AT 5 FEET GENERALLY.
SEGREGATED ICE	CONSIDERABLE LOCALLY. OCCURS AS CRYSTALS, LENSES, SEAMS, AND MASSES. / CONSIDERABLE LOCALLY, OCCURS AS CRYSTALS, LENSES AND MASSES.



PIPELINE SCHEMATIC

M.P. 679.25 MATCH LINE

M.P. 682.05

42" O.D. x 0.750" W.T. X–65 PIPE

M.P. 689.62

MATCH LINE M.P. 698.50

SPECIAL CONSTRUCTION
KLUTINA RIVER CROSSING
LENGTH: 1080 FT.
PIPE DEPTH: 5 FT.
1.25 S.G. CONCRETE: 1000 FT.

CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 5
(2 YEARS)

⊕MATERIAL SITES

SCALE IN MILES: 0 1 2 3

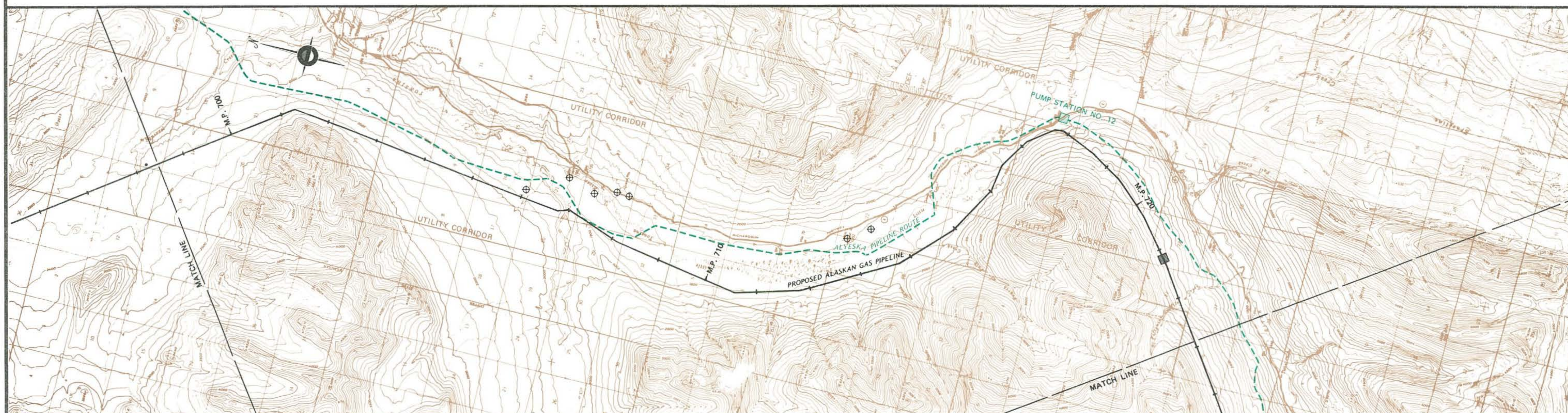
TRANS-ALASKA GAS PROJECT

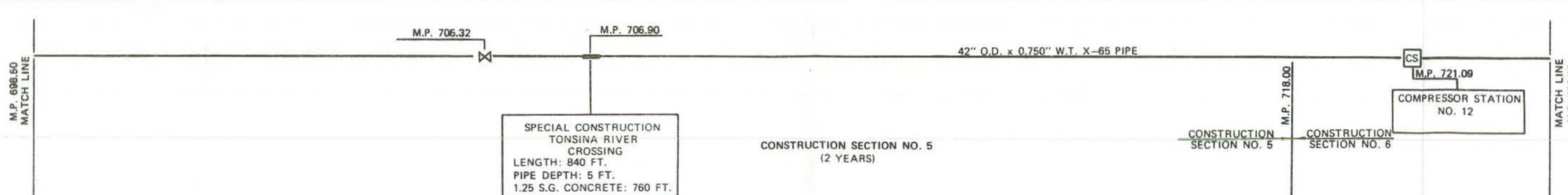
PROPOSED
ALASKAN GAS PIPELINE

M.P. 679.25 TO M.P. 698.50

FIGURE 30

OWNERSHIP		U.S.A.				
TERRAIN		ROLLING			MOUNTAINOUS	
VEGETATION		DENSE BRUSH & TREES TO 12"	DENSE BRUSH & TREES TO 4" DIA.		DENSE BRUSH & TREES TO 12" DIA.	
SPECIAL CONDITIONS	M.P. 698.50	TONSINA RIVER CROSSING	AREA OF POTENTIAL AVALANCHING.	AREA OF STRONG SOLIFLUCTION EVIDENCE	AREA OF POTENTIAL AVALANCHE.	M.P. 722.90
GEO-MORPHOLOGY		GLACIATED RIVER VALLEY WITH COALESCING ALLUVIAL-COLLUVIAL FANS.			GLACIALLY SCOURED VALLEY UPLAND	
SOILS & BEDROCK	MATCH LINE	LOOSE ANGULAR GRAVEL, SAND, AND SILT. CONSIDERABLE ANGULAR COBBLES AND SCATTERED BOULDERS.			DURABLE GRAYWACKE BEDROCK MANTLED BY 0-5 FEET OF SAND, SILT, GRAVEL AND COARSE ANGULAR TALUS.	MATCH LINE
PERMAFROST		DISCONTINUOUS. PERMAFROST SURFACE AT 5 FEET GENERALLY	SPORADIC. PERMAFROST SURFACE VARIABLE 5-50 FEET (±).	ACTIVE LAYER 2-5 FEET IN LEVEL, NON-FORESTED AREAS	NON-PERMAFROST AREA.	
SEGREGATED ICE		SOME TO CONSIDERABLE. OCCURS AS CRYSTALS, LENSES AND WEDGES.	LITTLE TO NONE.		NONE	





⊕ MATERIAL SITES

0 1 2 3 SCALE IN MILES

TRANS-ALASKA GAS PROJECT

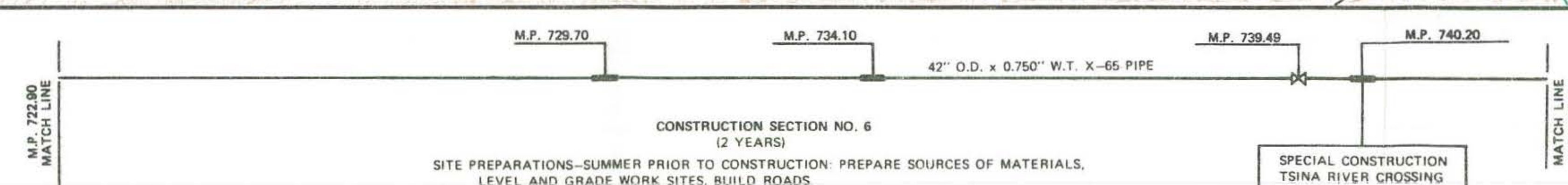
PROPOSED ALASKAN GAS PIPELINE

M.P. 698.50 TO M.P. 722.90

FIGURE 31

OWNERSHIP	U.S.A. — U.S.A
TERRAIN	MOUNTAINOUS — ROLLING — MOUNTAINOUS
VEGETATION	DENSE BRUSH & TREES TO 4" DIA.
SPECIAL CONDITIONS	M.P. 722.90 — AREA OF POTENTIAL AVALANCHING: PIPELINE (PROPOSED) CROSSING; RICHARDSON HIGHWAY CROSSING; TIEKEL NO. 1 CROSSING; PIPELINE (PROPOSED) CROSSING; TIEKEL NO. 2 CROSSING; RICHARDSON HIGHWAY CROSSING; PIPELINE (PROPOSED) CROSSING; PIPELINE (PROPOSED) CROSSING; RICHARDSON HIGHWAY & PIPELINE (PROPOSED) CROSSINGS; TSINA RIVER CROSSING — M.P. 743.80
GEO-MORPHOLOGY	GLACIALLY SCOURED VALLEY UPLAND. — RESTRICTED VALLEY FLOODPLAIN WITH SCATTERED REMNANT TERRACES. ALLUVIAL FANS WELL-DEVELOPED ON VALLEY FLANKS. — GLACIALLY SCOURED VALLEY UPLAND WITH RECENTLY DEVELOPED ALLUVIAL-COLLUVIAL FANS.
SOILS & BEDROCK	MATCH LINE — DURABLE GRAYWACKE BEDROCK MANTLED BY 0-5 FEET OF SAND, SILT, GRAVEL AND COARSE ANGULAR TALUS. — DENSE SAND AND GRAVEL WITH SOME SILT. FREQUENT COBBLES AND BOULDERS. — DURABLE GRAYWACKE BEDROCK MANTLED BY THIN (0-5 FEET) COLLUVIUM. — MATCH LINE — DURABLE GRAYWACKE BEDROCK MANTLED BY 0-5 FEET OF SAND, SILT, GRAVEL AND COARSE ANGULAR TALUS.
PERMAFROST	NONE
SEGREGATED ICE	NONE

PIPELINE SCHEMATIC



CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 6
(2 YEARS)

SITE PREPARATIONS–SUMMER PRIOR TO CONSTRUCTION: PREPARE SOURCES OF MATERIALS, LEVEL AND GRADE WORK SITES, BUILD ROADS.
RIGHT-OF-WAY–JUNE TO SEPT.: CLEAR BRUSH AND TREES; GRADE, LEVEL, AND GRAVEL FILL WHERE NEEDED FOR WORK PAD.
LAYING–JUNE TO TO SEPT.: PREDOMINANTLY ROCK DITCH IN MOUNTAINOUS TERRAIN. BLAST, EXCAVATE DITCH WITH BACKHOES, BEND SINGLE JOINTS, WELD PIPE, PAD DITCH, LOWER IN, BACKFILL, SET VALVES, MAKE TIE-INS.
CLEAN UP–SEPT. AND OCT.: INSTALL EROSION PROTECTION, REMOVE DEBRIS.

SPECIAL CONSTRUCTION
TSINA RIVER CROSSING
LENGTH: 400 FT.
PIPE DEPTH: 5 FT.
1.25 S.G. CONCRETE: 320 FT.

⊕ MATERIAL SITES

0 1 2 3 SCALE IN MILES

TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

M.P. 722.90 TO M.P. 743.80

FIGURE 32

OWNERSHIP	M.P. 743.80	U.S.A. / M.P. 759.45 / STATE OF ALAKSA / M.P. 760.50 / U.S.A. / M.P. 762.30 / STATE OF ALASKA / M.P. 762.85 / U.S.A. / M.P. 767.30 / STATE OF ALASKA
TERRAIN		WASHBOARD / MOUNTAINOUS / ROUGH-MOUNTAINOUS / FLAT / SHARP & CHOPPY
VEGETATION		DENSE BRUSH & TREES TO 4" DIA. / OPEN / DENSE BRUSH & TREES TO 4" DIA. / OPEN / MEDIUM TIMBER TO 12" DIA.
SPECIAL CONDITIONS	M.P. 743.80	AREA OF POTENTIAL AVALANCHING: RICHARDSON HWY. CROSSING; TSINA RIVER; RICHARDSON HWY. CROSSING / RICHARDSON HIGHWAY CROSSING / PIPELINE (PROPOSED) CROSSING / SHEEP CREEK CROSSING / TUNNEL; RICHARDSON HWY CROSSING; TUNNEL / LOWE RIVER CROSSING / PIPELINE (PROPOSED) CROSSING / M.P. 767.80
GEO-MORPHOLOGY		GLACIALLY SCOURED VALLEY UPLAND WITH RECENTLY DEVELOPED ALLUVIAL-COLLUVIAL FANS. / BROAD GLACIATED VALLEY WITH WELL-DEVELOPED TERRACES / STEEP WALLED NARROW CANYON / BROAD RIVER FLOOD PLAIN WITH WELL DEVELOPED TERRACES.
SOILS & BEDROCK	MATCH LINE	DURABLE GRAYWACKE BEDROCK MANTLED BY 0-5 FEET OF SAND, SILT, GRAVEL AND COARSE ANGULAR TALUS. / ALTERNATING AREAS OF SURFACE BEDROCK AND ALLUVIUM-COLLUVIUM CONSISTING OF SUBROUNDED SAND, SILT AND GRAVEL. / DENSE ROUNDED GRAVELS WITH SOME SAND AND SILT. / DURABLE METAMORPHOSED GRAYWACKE AND RELATED BEDROCK. / DENSE ROUNDED GRAVELS WITH SOME SAND AND SILT. / MATCH LINE
PERMAFROST		NONE
SEGREGATED ICE		NONE

PIPELINE SCHEMATIC

M.P. 743.80 MATCH LINE — 42" O.D. x 0.750" W.T. X-65 PIPE — MATCH LINE M.P. 767.80

M.P. 746.9 – M.P. 747.6: SPECIAL CONSTRUCTION TSINA RIVER ROCK APRON AND RIP RAP TO PREVENT EROSION

CONSTRUCTION SECTION NO. 6 (2 YEARS)

M.P. 757.40: SPECIAL CONSTRUCTION SHEEP CREEK CROSSING LENGTH: 480 FT. PIPE DEPTH: 7 FT. 1.25 S.G. CONCRETE: 400 FT.

M.P. 757.89

M.P. 760.95: SPECIAL CONSTRUCTION NORTH TUNNEL LENGTH: 2330 FT. SIZE: 9' x 9'

M.P. 762.40: SPECIAL CONSTRUCTION SOUTH TUNNEL LENGTH: 1800 FT. SIZE: 9' x 9'

M.P. 764.20: SPECIAL CONSTRUCTION LOWE RIVER CROSSING LENGTH: 4080 FT. PIPE DEPTH: 7 FT. 1.25 S.G. CONCRETE: 4000'

CONSTRUCTION DETAIL

⊕ MATERIAL SITES

0 1 2 3 SCALE IN MILES

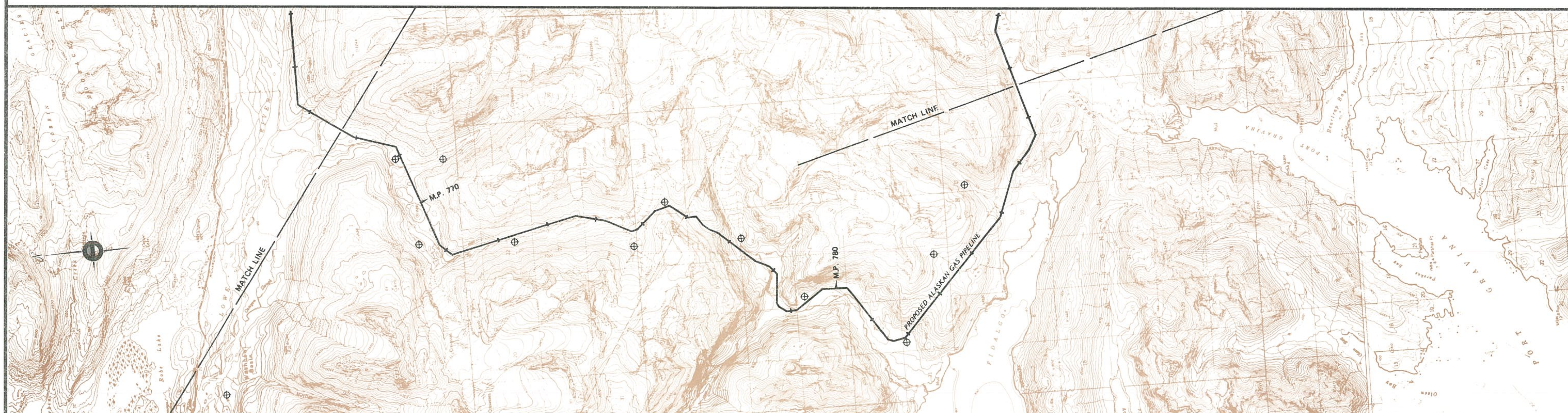
TRANS-ALASKA GAS PROJECT

PROPOSED ALASKAN GAS PIPELINE

M.P. 743.80 TO M.P. 767.80

FIGURE 33

OWNERSHIP	U.S.A.				M.P. 775.95	U.S.A. FOREST SERVICE				
TERRAIN	SHARP & CHOPPY	WASHBOARD	ROUGH	FLAT	SHARP CHOPPY	MOUNTAINOUS	ROUGH	ROLLING	SHARP CHOPPY	ROLLING	SHARP CHOPPY
VEGETATION	DENSE MEDIUM TIMBER TO 12" DIA.	MEDIUM BRUSH & TIMBER TO 4"	OPEN	DENSE, MEDIUM, TIMBER 4"–12" DIA.	OPEN TO MED. BRUSH & TREES TO 4" DIA.	DENSE MEDIUM TIMBER 12"–14" IDA.	MEDIUM TIMBER 12" TO 14" DIA.	DENSE TIMBER 12"–14" DIA.		
SPECIAL CONDITIONS	M.P. 767.80	MOUNTAINOUS AREA–STEEP SLOPES–ROCK–TALUS ZONES AND POSSIBLE AVALANCHE AREAS.	M.P. 787.70							
GEO–MORPHOLOGY	NARROW GLACIATED DRAINAGES, DIVIDES AND RELATIVELY BROAD INTRA-MONTANE VALLEYS.									
SOILS & BEDROCK	MATCH LINE	DURABLE METAMORPHASED GRAYWACKE AND RELATED BEDROCK WITH THIN, 0–1.5 FEET, SOIL COVER.	LOOSE TO MODERATELY DENSE ANGULAR GRAVEL, COBBLES, BOULDERS WITH SOME SILT. COLLUVIUM AND TALUS.	DURABLE METAMORPHIC BEDROCK FREQUENTLY COVERED WITH LARGE DIAMETER BOULDERS AND COBBLES. ROCK GLACIERS, TALUS AND UNMODIFIED MORAINE DEPOSITS LOCAL.	MODERATELY DENSE SILT AND GRAVEL WITH SOME SAND.	DURABLE METAMORPHASED GRAYWACKE AND RELATED BEDROCK, BENEATH 4 FEET (+) OF ORGANIC SILT.	MATCH LINE			
PERMAFROST	NONE									
SEGREGATED ICE	NONE									



PIPELINE SCHEMATIC

M.P. 767.80 MATCH LINE

M.P. 776.29

42" O.D. x 0.750" W.T. X–65 PIPE

M.P. 786.7

WEIGHT COATING OR ANCHORS

MATCH LINE M.P. 787.70

NOTE: PIPELINE SCHEMATIC REPRESENTS ACTUAL PIPE DISTANCE.

CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 6
(2 YEARS)

⊕ MATERIAL SITES

0 1 2 3
SCALE IN MILES

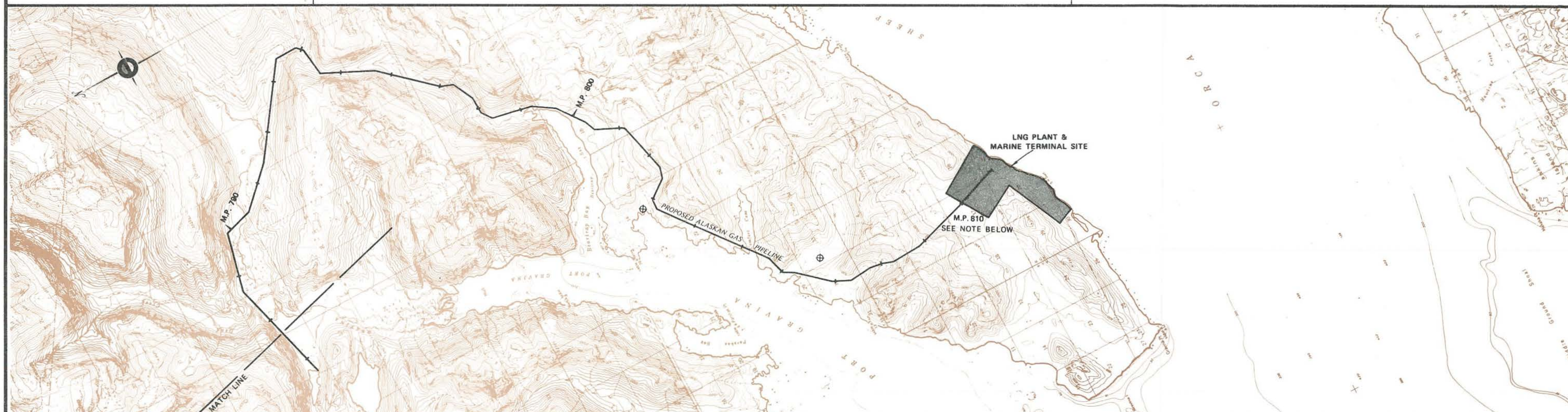
TRANS-ALASKA GAS PROJECT

PROPOSED
ALASKAN GAS PIPELINE

M.P. 767.80 TO M.P. 787.70

FIGURE 34

OWNERSHIP	U.S.A. FOREST SERVICE
TERRAIN	ROLLING / SHARP CHOPPY / SLIGHTLY ROLLING / SHARP & CHOPPY / WASHBOARD SHARP & CHOPPY / SHARP & CHOPPY / WASHBOARD / MOUNTAINOUS / WASHBOARD / MOUNTAINOUS / FLAT
VEGETATION	SCATTERED MED. TIMBER 12 - 14" DIA. / DENSE TIMBER 12" - 14" DIA. / MEDIUM BRUSH & TIMBER 4" DIA. / DENSE TIMBER 12"-14" DIA. / MED. TIMBER 12" - 14" DIA. / MED. TIMBER 4" - 12" DIA. / DENSE TIMBER 12" - 14" DIA. / DENSE TIMBER 4" - 12" DIA. / DENSE TIMBER 12" - 14" DIA. / DENSE BRUSH & TREES TO 4" DIA. / MEDIUM BRUSH & TREES 4" - 12" DIA. / MEDIUM BRUSH & TREES TO 4" DIA. / OPEN
SPECIAL CONDITIONS	M.P. 787.70 / DEAD CREEK CROSSING / SPAN / GRAVINA RIVER CROSSING / MOUNTAINOUS STEEP GRADES AND SIDEHILLS / SPAN / SPAN / AREA OF POTENTIAL AVALANCHING / COMFORT COVE CROSSING
GEO-MORPHOLOGY	NARROW GLACIATED DRAINAGES, DIVIDES AND RELATIVELY BROAD INTRA-MONTANE VALLEYS.
SOILS & BEDROCK	MATCH LINE / DENSE GRAVELS WITH SOME SAND AND SILT FREQUENTLY COVERED BY 3-12 FEET (±) ORGANIC SILT / DURABLE METAMORPHOSED GRAYWACKE AND SLATE INTRUDED BY GRANITE DIKES, SILLS AND BATHOLITHIC BODIES / GRAVEL AND SILT WITH LITTLE SAND / LOOSE SAND AND GRAVEL / LOOSE SAND AND GRAVEL
PERMAFROST	NONE
SEGREGATED ICE	NONE



PIPELINE SCHEMATIC

M.P. 787.70 MATCH LINE — M.P. 788.40 — M.P. 790.30 — M.P. 791.0 — WEIGHT COATING OR ANCHORS — M.P. 793.90 — M.P. 794.69 — 42" O.D. x 0.750" W.T. X-65 PIPE — M.P. 805.10 — M.P. 810.00 — M.P. 810.20

SPECIAL CONSTRUCTION COMFORT COVE CROSSING LENGTH: 900 FT. PIPE DEPTH: 6 FT.

LNG PLANT METER STATION

NOTE:
1. EQUATION AT M.P. 80 MAKES TOTAL LENGTH 809.20 MILES.
2. PIPELINE SCHEMATIC REPRESENTS ACTUAL PIPE DISTANCE.

CONSTRUCTION DETAIL

CONSTRUCTION SECTION NO. 6
(2 YEARS)

⊕ MATERIAL SITES

0 1 2 3 SCALE IN MILES

TRANS-ALASKA GAS PROJECT

PROPOSED ALASKAN GAS PIPELINE

M.P. 787.70 TO M.P. 810.20

FIGURE 35

SECTION 2A.3 - CLIMATE AND AIR QUALITY

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SECTION 2A.3

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SECTION 2A.3

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2A.3 CLIMATE AND AIR QUALITY

In traversing Alaska from the Arctic Ocean to Prince William Sound, the proposed pipeline will encounter a variety of climatic extremes (Searby, 1968; EDS, 1967-1973). In the interior of the state, temperatures may range from 100°F to -80°F. Winds up to 100 mph may be encountered in mountain passes (Thom, 1968). Precipitation ranges from almost desert conditions on the North Slope (four to ten inches of water equivalent annually) to maritime conditions at the southern part of the route (over 100 inches of water equivalent annually) (NWS, 1973a). In higher elevations of the Chugach Mountains, annual snowfall may range from 400 to 1000 inches (NWS, 1973b)

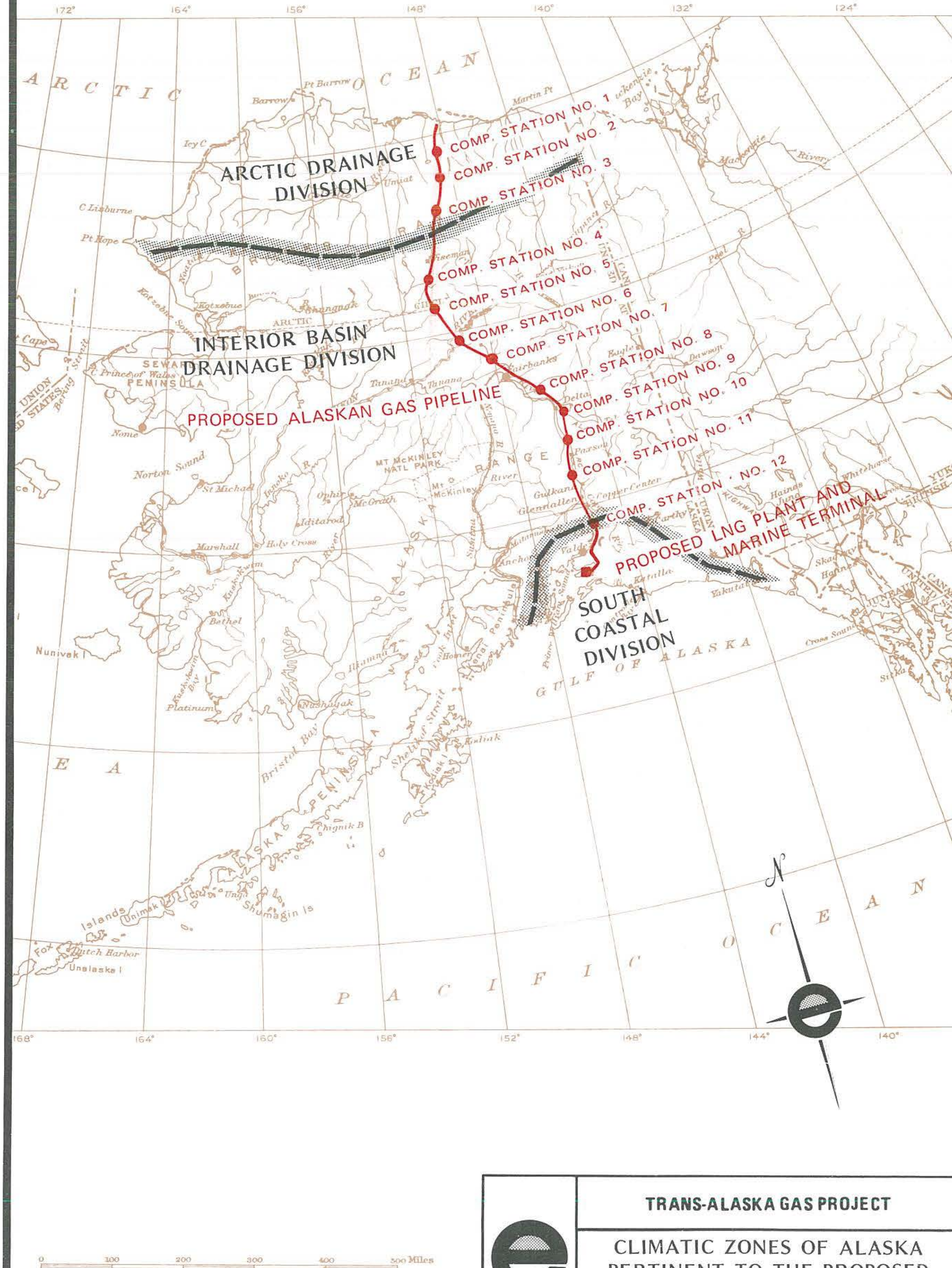
The principal mountain ranges divide Alaska into three climatic divisions, herein designated: (a) Arctic Drainage Division, (b) Interior Basin Division and (c) South Coastal Division (Fahl, 1973). Figure 2A.3-1 shows the geographic boundaries of each zone. The similarities in parameters within climatic divisions and the differences among zones are shown in Table 2A.3-1, as are the effects of latitude and altitude. Conditions generally become milder as one moves south, and stations at higher elevations have lower annual temperatures and higher precipitation levels (see Anaktuvuk Pass, Thompson Pass--Table 2A.3-1). A transitional zone lies between the Alaska Range and the Kenai-Chugach Mountains, but it is largely confined to the Cook Inlet-Susitna Valley area. The climate of the Copper River Basin is more similar to the Interior Division than to the transitional zone.

Freeze data for selected Alaskan stations are given in Table 2A.3-2. Both mean (Searby, 1968) and normal (EDS, 1973a) dates of spring and fall freeze threshold temperatures are presented. Although the probability of the temperature falling below a certain threshold on any given day between normal dates is less than 50 percent, the probability that the threshold will be reached or exceeded at least once between normal dates is high. Adding normal dates to the usual assemblage of mean dates allows further predictability of freezing and subfreezing temperatures during the summer months.

2A.3.1 Air Quality

Although few data are available for the predominantly uninhabited areas to be crossed by the proposed gas pipeline, air quality in these regions is considered high. The exceptions are due to summer forest fires, wind-blown dust, and dust raised by caribou herds.

Some air quality data are available for Fairbanks from the National Air Surveillance Network (NASN) of the Environmental Protection



TRANS-ALASKA GAS PROJECT

CLIMATIC ZONES OF ALASKA PERTINENT TO THE PROPOSED GAS PIPELINE

FIGURE 2A.3–1

TABLE 2A.3-1

COMPARATIVE CLIMATIC DATA FOR SELECTED ALASKAN STATIONS

STATION	ELEVATION (feet)	TEMPERATURE (°F) JANUARY DAILY MAX.	JANUARY DAILY MIN.	JULY DAILY MAX.	JULY DAILY MIN.	ANNUAL	RECORD HIGHEST	RECORD LOWEST	PRECIPITATION (inches) NORMALS WETTEST MONTH	NORMALS DRIEST MONTH	NORMALS ANNUAL TOTAL	EXTREMES EXTREME WETTEST MONTH	EXTREMES EXTREME DRIEST MONTH	EXTREMES MAXIMUM IN 24 HR	SNOW, SLEET, HAIL JANUARY MEAN	SNOW, SLEET, HAIL SEASONAL MEAN	SNOW, SLEET, HAIL MAXIMUM IN 24 HR
ARCTIC ZONE:																	
BARROW	31	-8.0	-21.3	44.3	33.0	9.3	78	-56	1.04	0.17	4.89	2.81	0.00	1.00	2.3	29.1	15.0
BARTER IS.	39	-8.5	-21.9	45.5	34.5	10.1	75	-59	1.28	0.23	7.05	4.91	T	2.23	5.9	46.0	17.0
UMIAT	337	-11.8	-30.6	63.8	43.2	10.3	85	-63	1.20	0.11	5.71	2.26	T	1.01-2.50	3.4	33.2	4.2
BROOKS RANGE:																	
ANAKTUVUK PASS	2100	-7.5	-22.2	60.8	40.7	13.4	91	-56	1.65	0.50	10.65	4.28	0.00	1.58	6.2	63.1	
INTERIOR ZONE:																	
BETTLES	666	-5.3	-21.1	68.2	47.5	21.3	92	-68	2.77	0.62	14.18	5.91	0.00	1.93	10.0	76.3	19.0
WISEMAN	1286	-2.4	-19.8	68.4	45.6	21.8	89	-65	1.97	0.20	9.20			2.05	11.4	82.8	31.0
INDIAN MT	1230	0.6	-12.1	64.6	47.5	23.2	88	-65	4.27	0.89	19.92	8.08	0.03	2.16	15.7	99.1	24.7
FAIRBANKS	436	-2.2	-21.6	71.8	49.6	25.7	99	-66	2.19	0.33	11.22	6.88	0.00	3.42	10.7	70.4	20.1
EIELSON	547	-2.8	-19.7	69.9	50.4	25.3	93	-64	2.51	0.60	14.93	7.47	T	3.61	12.6	74.6	14.2
TRIMS CAMP	2408	12.2	-5.2	62.9	43.2	26.0	86	-57	5.40	1.85	44.68	11.66	0.10	4.75	31.6	332.9	
SUMMIT	2401	7.9	-4.8	60.2	43.8	25.5	89	-45	3.30	0.67	20.06	6.74	T	2.79	13.7	119.4	28.0
GULKANA	1570	1.9	-16.4	68.1	45.6	26.8	91	-65	1.84	0.22	11.11	4.34	0.00	2.06	7.5	47.0	10.6
CHUGACH MOUNTAINS:																	
THOMPSON PASS	2700	12.7	1.5	57.7	40.7	27.6	75	-39	10.97	1.87	82.51	37.46	0.42	6.62	71.1	582.8	62.0
COASTAL ZONE:																	
VALDEZ	49	25.3	11.0	60.1	45.2	36.0	87	-28	7.74	2.70	59.31	18.74	T	5.10	56.3	244.5	43.0
CORDOVA	41	31.6	14.5	60.3	46.1	38.2	87	-33	13.53	4.67	92.53	27.72	0.08	7.92	25.0	124.7	22.9

STATION	RELATIVE HUMIDITY (percent) JANUARY (ALASKA STANDARD TIME) 0200	JANUARY 0800	JANUARY 1400	JANUARY 2000	JULY 0200	JULY 0800	JULY 1400	JULY 2000	WIND SPEED, MEAN HOURLY (mph) JAN.	WIND SPEED JULY	FASTEST MILE	ANNUAL MEAN NUMBER OF DAYS SUNRISE TO SUNSET CLEAR	PARTLY CLOUDY	CLOUDY	PRECIP. 0.01 IN. OR MORE	SNOW 1.0 IN. OR MORE	THUNDER-STORMS	DENSE FOG	TEMPERATURE MAX. 70° AND ABOVE	MAX. 32° AND BELOW	MINIMUM 0° AND BELOW
ARCTIC ZONE:																					
BARROW	65	66	65	65	94	91	87	91	11.3	11.6	58	58	53	188	74	8	*	65	*	324	169
BARTER IS.	68	68	68	68	93	89	86	89	14.3	10.6	81	49	66	195	93	13	*	74	*	311	167
UMIAT	77	78	76	77	91	77	63	76	7.0	7.0	47+	51	72	197	106	11	1	26	13	291	179
BROOKS RANGE:																					
ANAKTUVUK PASS																			8	286	170
INTERIOR ZONE:																					
BETTLES	67	61	65	67	87	70	52	63	5.8	6.6	50	85	88	192	105	29	6	7	35	248	140
WISEMAN																			33	254	129
INDIAN MT	67	68	67	67	78	74	60	62	6.3	5.5	62				126	41	4		22	235	113
FAIRBANKS	67	68	68	68	78	68	50	56	2.7	6.4	60	66	83	216	103	22	5	20	52	227	122
EIELSON									2.0	4.3	60				106	27			41	231	119
TRIMS CAMP											60+								17	251	96
SUMMIT	68	68	69	68	89	77	60	71	15.1	7.8	48	65	76	224	139	44	7	15	9	251	86
GULKANA	67	68	66	68	84	70	46	57	5.1	8.2	52	68	88	209	89	17	5	18	30	239	107
CHUGACH MOUNTAINS:																					
THOMPSON PASS																			*	249	52
COASTAL ZONE:																					
VALDEZ									4.3	3.5	65				170				4	207	15
CORDOVA	83	82	81	83	92	86	80	84	4.6	4.1	55-63	51	52	262	215	35	2	12	8	189	18

* LESS THAN ONE-HALF

T = trace

Source: EDS, 1941-1973; 1970

TABLE 2A.3-2

FREEZE DATA FOR SELECTED ALASKAN STATIONS

STATION	32°F[1/]						28°F[1/]						24°F[1/]						20°F[1/]					
	Normal date of last spring occurrence	Mean date of last spring occurrence	Mean date of first fall occurrence	Normal date of first fall occurrence	Mean No. of days between dates	Normal No. of days between dates	Normal date of last spring occurrence	Mean date of last spring occurence	Mean date of first fall occurrence	Normal date of first fall occurrence	Mean No. of days between dates	Normal No. of days between dates	Normal date of last spring occurrence	Mean date of last spring occurrence	Mean date of first fall occurrence	Normal date of first fall occurrence	Mean No. of days between dates	Normal No. of days between dates	Normal date of last spring occurrence	Mean date of last spring occurrence	Mean date of first fall occurrence	Normal date of first fall occurrence	Mean No. of days between dates	Normal No. of days between dates
ARCTIC ZONE																								
Barrow	(7-5)	6-28	7-5	8-26	7	51	6-12	6-19	8-4	9-14	46	93	6-2	6-10	9-5	9-23	87	112	5-25	6-3	9-26	9-30	115	127
Barter Island	6-25	6-29	7-10	9-3	11	69	6-9	6-15	8-13	9-17	59	99	5-30	6-5	9-11	9-25	98	117	5-22	5-25	9-24	10-2	122	132
INTERIOR ZONE																								
Bettles	5-16	5-25	8-22	9-15	89	121	5-9	5-15	9-11	9-23	119	136	5-4	5-7	9-16	9-30	132	148	4-29	5-2	9-23	10-6	144	159
Indian Mt.		5-28	8-24		88			5-18	9-3		108			5-8	9-20		135			5-4	9-25		144	
Fairbanks	5-9	5-20	9-1	9-21	104	134	5-2	5-9	9-12	9-29	126	149	4-25	4-29	9-25	10-6	149	163	4-19	4-23	10-2	10-12	162	175
Eielson AFB		5-16	9-2		109			5-4	9-14		133			4-28	9-24		149			4-20	9-28		161	
Trims Camp		6-17	8-2		46			6-3	8-17		75			5-18	8-29		103			5-14	9-20		129	
Summit	5-23	6-3	8-26	9-17	84	116	5-14	5-20	9-13	9-26	116	134	5-5	5-10	9-19	10-3	132	150	4-28	5-1	9-23	10-11	145	165
Gulkana	5-15	6-2	8-19	9-19	78	126	5-5	5-17	9-3	9-28	109	145	4-26	5-1	9-17	10-6	139	162	4-18	4-25	9-25	10-13	153	177
COASTAL ZONE																								
Valdez		5-21	9-14		116			5-5	10-3		151			4-25	10-20		178			4-13	10-30		200	
Cordova	4-29	5-28	9-14	10-15	109	168	4-16	5-13	9-28	10-28	138	194	4-5	4-24	10-16	11-12	175	220	3-23	4-15	10-28	12-3	196	254

[1/]Freeze threshold temperature

Source: Searby, 1968; EDS, 1973a

Agency (Alaska DEC, 1972). This information is presented in Table 2A.3-3. From August 1967 to June 1969 an air quality study was conducted at four sampling sites at Eielson Air Force Base, 26 miles southeast of Fairbanks (Alaska DEC, 1972). The data are presented in Table 2A.3-4.

The high atmospheric stability found in the Interior Division is manifested by the frequency of surface-based inversions. According to Benson and Weller (1970), surface-based nighttime inversions occur in the Interior more than 60 percent of the time year-round, though in December and January they occur more than 80 percent of the time, both day and night. For the months of November through April, Benson and Weller (1970) found that surface-based inversions occurred on 82 percent of the nights, and that they had an average height of 510 meters and an average temperature gradient of 3.1°C/100 meters. During the period May through October, inversions occurred on 67 percent of the nights, averaging 300 meters in height, with temperature gradients averaging 1.6°C/100 meters. In the very lowest air layer--ground surface to 50 meters--temperature gradients as great as 30°C/100 meters were found, whereas in the layer from two to four meters, gradients greater than 1°C/meter were measured (Benson, 1970).

Fairbanks, which is a representative Interior Division station, has high atmospheric stability--especially in winter--and because of its relatively large population (greater metropolitan area, about 40,000), numerous sources of pollution. Carbon monoxide (CO) and particulate matter are the principal pollutants (Benson, 1970; Holty, 1973; Gilmore & Hanna, 1974; MacKenzie & Arnold, 1974), with lead and halogens less serious (Winchester, et al., 1967). According to Holty (1973), average particulate and CO levels frequently exceed the EPA's primary national air quality standards, with particulate lead concentrations about triple the available urban averages.

2A.3.1.1 Ice Fog

A phenomenon peculiar to arctic and subarctic regions is ice fog. Whereas normal fogs are concentrations of water droplets, ice fogs are one step beyond--the water has frozen. This climatic condition is precipitated by three factors: (a) a temperature lower than -25°F, (b) a source of water and (c) particulates in the air that form nuclei for droplet and ice particle formation. A common misconception equates ice fog with air pollution, but some of the worst pollution episodes in Fairbanks occur at temperatures above -25°F (MacKenzie & Arnold, 1974). High volumes of vapor emissions from vehicles, heating systems, power stations, and industries combined with high volumes of particulates from the same sources make any area susceptible to ice fog when the temperature is below -25°F and a ground-based inversion restricts vertical motion.

Ice fog, like any intense fog, severely reduces visibility. In Fairbanks the situation is worsened by increased particulate emissions that color the fog a murky gray. Sunlight, for all practical purposes, disappears during periods of intense fog.

TABLE 2A.3-3

AIR QUALITY DATA FOR FAIRBANKS

Pollutant	Location[1]	Start Date	End Date	Number Samples	24-Hr Max $\mu g/m^3$	Arith. Mean $\mu g/m^3$	Geo. Mean $\mu g/m^3$	Geo. Std. Dev.
TSP[2]	Fairbanks NASN	1/67	12/67	23	767		124	2.84
	3rd & Cushman	1/68	12/68	24	715		157	2.15
		1/69	12/69	24	867		175	2.21
		1/70	11/70	21	511			
SO_2		1/67	12/67	41	107	9		1.97
		1/68	12/68	22	22	8		1.69
		1/69	12/69	25	28	9		1.54
NO_2		1/67	12/67	39	224	75		1.76
		1/68	12/68	21	269	96		1.64
		1/69	12/69	23	233	68		2.04
		1/70	12/70	11		87		
Oxidant		1/68	12/68	21	30	13.9		
		1/69	12/69	9	18	12.0		
		1/70	6/70	4	17	11.5		

1/ Height of sampler inlet 3 feet above ground level
2/ TSP = Total Suspended Particulates

Source: NASN (Alaska DEC, 1972)

TABLE 2A.3-4

AIR QUALITY DATA FOR EIELSON AIR FORCE BASE
(Sampling Period: 08/25/67 to 06/11/69)

Pollutant	Location [1]	Number Samples	24-Hr Max $\mu g/m^3$	Arith. Mean $\mu g/m^3$	Geo. Mean $\mu g/m^3$	Geo. Std. Dev.
TSP [2]	Eielson AFB	23	178	67	56	2.06
SO_x	Guardhouse	26	4	0.18	--	--
NO_x		25	78	19.3	13	2.93
TSP	Eielson AFB	22	468	114	73	2.64
SO_x	Warehouse	25	4	0.52	--	--
NO_x		22	67	13.7	7.4	2.96
TSP	Eielson AFB	23	336	111	83	2.21
SO_x	Chapel	24	13	0.76	--	--
NO_x		23	60	18.6	12	2.98
TSP	Eielson AFB	21	135	57	43	2.33
SO_x	Officers' Club	23	12	0.63	--	--
NO_x		24	29	7.8	5.1	2.75

1/ Height of sampler inlet 5 feet above ground level
2/ TSP = Total Suspended Particulates

Source: Arctic Health Research Center (Alaska DEC, 1972)

Ice fog is not restricted to urban areas. Hot springs, even caribou herds, cooling ponds and construction equipment are all adequate sources of vapor emissions. Lacking winds to dissipate it, ice fog often is confined to narrow stretches, or patches, along highways and around industrial plants where it remains *in situ* until such time as the inversion lifts.

The ambient air quality standards set by the State of Alaska correspond to the secondary National Air Standards (Alaska DEC, 1972). Table 2A.3-5 is a summary of the National Air Standards, with both primary and secondary standards listed. The federal secondary standards (except for the three-hour standards) for SO_x have been revised to correspond with the primary standards, and a similar revision in the Alaskan Standards has been proposed. State of Alaska and local standards for water vapor emissions under conditions conducive to ice fog formation are proposed.

2A.3.2 Climatic Divisions

2A.3.2.1 Arctic Drainage Division

The North Slope of Alaska is characterized by long, cold winters and short, cool summers. It is a semiarid zone, where annual precipitation varies between 4 and 10 inches (NWS, 1973a). The mean high temperature for winter is between -50°F and -60°F, and for summer is between 60°F and 75°F (Sealby, 1968). In winter this division is dominated by a surface-based inversion, which is only briefly broken by passing storms (Wilson, 1967; 1969). Pressure gradients are generally higher here than in the Interior though because of the treeless, relatively smooth terrain, their frictional effects are reduced. Thus, high winds are experienced on the coast, especially in winter. Blowing, drifting snow frequently occurs. The Brooks Range effectively blocks any intrusion of warm air from the south, both in winter and summer (Fahl, 1973). Warm air is advected through the Bering Strait, but loses much of its warmth before it reaches the North Slope. In summer a semi-permanent front oscillates irregularly between the Brooks Range and the Beaufort Sea (Barry, 1967). When it lies north of the coast, all areas may experience warming, and even the coastal areas have reached 75°F on occasion. Frequently the front lies near the coast, bringing fog, rain, and snow (Fahl, 1973). The Arctic Ocean has a pronounced effect on the North Slope's climate, moderating it in all seasons. Toward the Arctic Foothills, colder temperatures in winter (-60°F to -65°F) and warmer temperatures in summer (75°F to 85°F) are experienced.

Although the Arctic Division is quite large, only a few stations have kept records for any length of time (EDS, 1941-1973). Barrow, the farthest north station in this zone, has the longest record, extending back some 50 years. Barter Island, on the coast near the eastern ege of this zone, has a record of approximately 25 years. Several other stations have kept records for shorter periods, *e.g.*, Umiat in the center of the zone on the Colville River. In the past ten years, additional data have been accumulated from numerous oil field

TABLE 2A.3-5

SUMMARY OF NATIONAL AIR STANDARDS

Pollutant	Time of Average	Primary Standard 1/	Secondary Standard 1/
Particulate matter	Annual (Geometric Mean)	75 µg	60 µg
	24 Hour	260 µg 2/	150 µg 1/
SO_x (measured as SO_2)	Annual (Arithmetic Mean)	80 µg(0.03ppm)	
	24 Hour	365 µg(0.14ppm) 2/	
	3 Hour	--	1300 µg (0.5ppm) 2/
CO	8 Hour	10 mg(9ppm) 2/	Same as Primary
	1 Hour	40 mg(35ppm) 2/	Same as Primary
Hydrocarbons (nonmethane measured as CH_4)	3 Hour (6 to 9 a.m.)	160 µg(0.24ppm) 2/	Same as Primary
NO_2	Annual (Arithmetic Mean)	100 µg(0.05ppm)	Same as Primary
Oxidants (measured as O_3)	1 Hour	160 µg(0.08ppm) 2/	Same as Primary

1/ Concentration in weight per cubic meter (corrected to 25°C and 760 mm of Hg)
2/ Concentration not to be exceeded more than once per year

camps and airstrips, primarily in the center of the region. Table 2A.3-6 gives the normals, means, and extremes for both Barrow and Barter Island.

EDS data (1967-1973) from Happy Valley Camp (approximately 69°N latitude, 149°W longitude, at about 1000 feet elevation) and supplementary, longer-term data from Barrow, Barter Island, and Umiat (EDS, 1941-1973) have been used to derive the estimated climatic parameters for an inland North Slope location. Tables 2A.3-7, 8 and 9 give temperature, precipitation, and wind data, respectively. Because of the higher elevation of this location, compared to the coastal stations of Barrow and Barter Island, temperatures are slightly more extreme, i.e., colder in midwinter and warmer in midsummer. Estimated precipitation totals are higher. Also, because of the more irregular terrain in this area, wind speeds will probably be less than those experienced on the coast.

Anaktuvuk Pass, located approximately in the middle of the Brooks Range, has the longest climatic record of any Brooks Range station (EDS, 1970). Table 2A.3-10 gives a summary of normals, means, and extremes at that station. Stations located at higher elevations, such as Atigun Pass, would probably receive more precipitation and experience colder temperatures than Anaktuvuk Pass.

Climatic conditions at Atigun Pass might be mirrored to some extent by those observed at McCall Glacier in the eastern Brooks Range. There, observations have been made both on the glacier surface and on the adjacent lateral moraine at elevations of 7500 feet and 5700 feet, respectively (Fahl, 1973; Wendler et al., 1974). Though few data have been collected for winter months, data from six summers give a fairly good representation of the summer climate there. Extreme temperatures of 65°F and -60°F seem likely at such elevations. Based on precipitation records at McCall Glacier, annual measurements between 10 and 20 inches seem likely for Atigun Pass. Based on upper air soundings at Barrow and Barter Island, temperatures below -40°F were not anticipated at McCall Glacier. However, the surface-based inversions observed at Barrow and Barter Island which allowed the extremely cold temperatures to develop, must also form at other elevated stations, especially if pressure gradients are weak, since minimum temperatures below -40°F were frequently observed at McCall Glacier (Wendler et al., 1974). When pressure gradients are strong, though, wind speeds in passes and high valleys can be high, because of channeling.

2A.3.2.2 Interior Basin Division

The Interior Division lies for the most part between the Brooks and Alaska Ranges. However, as pointed out above, the Copper River Basin is more properly classified in this zone. The Interior has a typical continental climate, though somewhat more severe than continental climates found at lower latitudes. The winters are cold and long and the summers are warm and short. Typical winter temperatures range from 0°F to -20°F, with extremes to -60°F and, occasionally, -70°F (Searby, 1968). Summertime temperatures range from 50°F to 70°F, with

TABLE A.3-6

NORMALS. MEANS. AND EXTREMES

Station: BARROW, ALASKA — WILEY POST-WILL ROGERS AIRPORT — Standard time used: ALASKAN — Latitude: 71° 18' N — Longitude: 156° 47' W — Elevation (ground): 31 feet

Month	Temperature: Normal Daily maximum	Normal Daily minimum	Normal Monthly	Extremes Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)
(a)	(b)	(b)	(b)	52		52		(b)
J	-9.4	-23.0	-16.2	35	1963	-53	1951	2517
F	-12.2	-24.4	-18.3	32	1960	-56	1924	2332
M	-8.1	-21.1	-14.6	33	1967	-52	1971+	2468
A	7.4	-7.0	.2	42	1936	-42	1924	1944
M	23.5	13.3	18.4	45	1927	-18	1922	1445
J	37.5	28.7	33.1	70	1942	4	1969	957
J	44.9	33.3	39.1	78	1927	22	1936	803
A	42.7	33.1	37.9	76	1968	20	1925+	840
S	33.8	27.2	30.5	62	1957	1	1957	1035
O	21.4	11.8	16.6	43	1954	-32	1970	1500
N	5.3	-6.7	-.7	39	1937	-40	1948	1971
D	-5.0	-17.4	-11.2	34	1932	-55	1924	2362
YR	15.1	4.0	9.6	78	JUL. 1927	-56	FEB. 1924	20174

Month	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	52		52		51		52	52		52	
J	0.18	1.04	1962	0.00	1939+	0.70	1937	2.3	11.9	1962	5.4	1962
F	0.17	0.81	1959	0.00	1936	0.36	1959	2.2	9.4	1944	3.6	1959
M	0.11	1.49	1963	0.00	1928	0.71	1963	1.9	15.8	1963	7.1	1963
A	0.11	1.36	1963	0.00	1938	0.42	1963	2.2	15.4	1963	4.2	1963
M	0.12	0.81	1933	T	1939+	0.30	1969+	2.0	12.9	1933	4.5	1923
J	0.36	1.15	1955	T	1937+	0.82	1955	0.5	6.6	1933	2.9	1954
J	0.77	2.44	1922	T	1937	0.86	1954	0.7	9.0	1922	6.0	1922
A	0.90	2.81	1963	T	1934	0.83	1960	0.7	4.0	1969	2.5	1936
S	0.64	1.56	1958	0.01	1969	0.56	1959	3.1	12.9	1972	5.0	1950
O	0.50	1.65	1925	0.12	1936+	1.00	1926	7.1	21.2	1925	15.0	1926
N	0.23	1.15	1965	T	1936+	0.41	1925	3.7	19.0	1925	6.0	1925
D	0.17	0.76	1967	0.00	1936+	0.26	1930	2.7	9.7	1925	5.0	1922
YR	4.26	2.81	AUG. 1963	0.00	JAN. 1939+	1.00	OCT. 1926	29.1	21.2	OCT. 1925	15.0	OCT. 1926

Month	Relative humidity Hour 02 (Local time)	Hour 08	Hour 14	Hour 20	Wind &: Mean speed	Prevailing direction	Fastest mile Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset
(a)	28	28	28	28	42	14	13	13			31
J	65	66	65	65	11.3	ESE	49	09	1962		#
F	63	64	63	63	11.0	E	48	08	1970		5.2
M	64	64	66	65	11.2	ENE	58	27	1960		4.9
A	73	74	74	73	11.5	NE	40	25	1961		5.8
M	88	88	85	87	11.7	ENE	39	25	1968		8.4
J	94	92	89	91	11.4	E	35	23	1961		7.9
J	94	91	87	91	11.6	E	35	23	1961		8.1
A	95	94	89	93	12.5	E	36	23	1963+		8.9
S	92	92	89	92	13.1	E	44	31	1970		9.2
O	85	85	85	85	13.3	E	55	27	1963		8.7
N	77	76	76	76	12.6	E	54	26	1966		#
D	68	68	68	68	11.3	E	44	09	1960		#
YR	80	79	78	79	11.9	E	58	27	MAR. 1960		

Month	Mean number of days: Sunrise to sunset Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures Max. ‡ 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below	** Average daily solar radiation - langleys
(a)	38	38	38	52	28	52	31	52	52	52	52	
J	3	2	3	4	1	0	2	0	31	31	29	
F	12	6	10	4	1	0	1	0	28	28	27	
M	14	7	10	3	*	0	1	0	31	31	30	
A	10	7	13	4	1	0	3	0	29	30	23	
M	3	5	23	4	*	0	8	0	26	31	4	
J	4	6	20	4	*	*	12	*	5	24	0	
J	3	7	21	8	*	*	13	*	*	14	0	
A	2	3	26	10	*	*	11	*	2	16	0	
S	1	3	26	9	1	0	5	0	14	26	0	
O	2	4	25	11	2	0	4	0	29	31	6	
N	4	3	11	6	1	0	3	0	30	30	21	
D	0	0	0	5	1	0	2	0	31	31	29	
YR	58	53	188	74	8	*	65	*	257	324	169	

Sun below horizon continuously November 19 to January 23. Data entered in columns headed "Clear, Partly Cloudy, and Cloudy" in both tables are for period sun above horizon.
Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows:
Maximum monthly snowfall 26.5 in April 1916.

NORMALS, MEANS, AND EXTREMES

Station: BARTER ISLAND, ALASKA — BARTER ISLAND AIRPORT — Standard time used: ALASKAN — Latitude: 70° 08' N — Longitude: 143° 38' W — Elevation (ground): 39 feet

Month	Temperature: Normal Daily maximum	Normal Daily minimum	Normal Monthly	Extremes Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)
(a)	(b)	(b)	(b)	23		25		(b)
J	-9.9	-23.6	-16.8	39	1962	-51	1962	2536
F	-13.3	-25.9	-19.6	34	1962+	-59	1950	2369
M	-7.7	-22.1	-14.9	36	1967	-50	1961	2477
A	8.6	-6.8	.9	43	1958	-38	1971	1923
M	25.9	15.5	20.7	52	1964	-16	1964	1373
J	39.1	29.3	34.2	67	1961	15	1965	924
J	47.5	35.0	41.3	75	1967	24	1967	735
A	45.2	34.7	40.0	72	1957	24	1971+	775
S	36.0	28.2	32.1	64	1950	4	1970	987
O	22.6	11.7	17.2	46	1969	-23	1970	1482
N	6.5	-6.1	.2	37	1950	-51	1948	1944
D	-3.7	-17.1	-10.4	35	1963	-51	1961	2337
YR	16.4	4.4	10.4	75	JUL. 1967	-59	FEB. 1950	19862

Month	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	24		24		24		24	24		24	
J	0.40	4.08	1962	0.01	1959	2.25	1962	5.9	35.0	1962	14.8	1962
F	0.35	2.53	1955	T	1965+	1.22	1955	3.1	15.3	1955	3.8	1970
M	0.20	1.44	1967	T	1968+	0.55	1967	2.9	15.0	1967	5.5	1967
A	0.17	1.22	1963	T	1968	0.44	1963	2.5	12.2	1963	4.4	1963
M	0.25	1.51	1967	T	1948	0.76	1954	3.1	11.1	1954	7.6	1954
J	0.51	2.09	1956	0.06	1969	1.15	1956	1.5	7.3	1968	5.1	1968
J	0.88	3.01	1971	0.15	1958	1.64	1971	0.4	2.5	1959	2.2	1964
A	1.05	3.40	1955	0.16	1958	1.11	1955	1.5	7.4	1969+	3.4	1956
S	0.94	4.91	1954	0.07	1969	2.23	1954	6.3	35.8	1954	17.0	1954
O	0.84	3.62	1954	0.12	1969	1.98	1954	9.5	32.1	1954	16.0	1954
N	0.40	1.50	1950	0.04	1960	0.43	1954	5.6	14.9	1950	5.0	1967
D	0.29	1.17	1949	T	1960	0.55	1949	3.7	12.9	1965	5.2	1949
YR	6.28	4.91	SEP. 1954	T	APR. 1968+	2.25	JAN. 1962	46.0	35.8	SEP. 1954	17.0	SEP. 1954

Month	Relative humidity Hour 02 (Local time)	Hour 08	Hour 14	Hour 20	Wind &: Mean speed	Prevailing direction	Fastest mile Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset
(a)	25	25	25	25	23	15	16	16			24
J	68	68	68	68	14.3	W	75	23	1957		#
F	67	67	67	68	14.1	W	62	27	1962		5.3
M	67	67	68	67	13.6	W	77	28	1969		5.7
A	74	74	75	75	12.2	W	52	27	1963		6.1
M	87	86	84	86	12.3	E	55	26	1968		8.3
J	92	89	87	90	11.3	ENE	38	27	1970+		7.8
J	93	89	86	89	10.6	ENE	40	25	1963		7.8
A	94	91	88	92	11.7	E	44	27	1969+		8.6
S	92	90	88	91	13.1	E	78	27	1957		8.6
O	84	84	83	84	14.4	E	58	27	1963		8.3
N	75	74	74	74	14.9	E	81	26	1970		#
D	68	68	69	68	14.0	E	72	27	1961		#
YR	80	79	78	79	13.0	E	81	26	NOV. 1970		

Month	Mean number of days: Sunrise to sunset Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures Max. ‡ 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below	Average daily solar radiation - langleys
(a)	24	24	24	23	24	23	24	25	25	25	25	
J	3	3	8	6	2	0	2	0	31	31	29	
F	10	6	12	5	1	0	1	0	28	28	28	
M	10	8	13	5	1	0	1	0	31	31	30	
A	8	8	14	6	1	0	3	0	29	30	23	
M	3	5	23	7	1	0	7	0	24	31	3	
J	3	7	20	6	*	*	12	0	4	23	0	
J	3	9	19	9	*	*	15	*	*	9	0	
A	1	7	23	11	1	0	16	*	1	11	0	
S	2	4	24	10	2	0	10	0	11	25	0	
O	2	5	24	13	3	0	4	0	29	31	7	
N	4	4	15	8	2	0	3	0	30	30	20	
D	0	0	0	6	1	0	1	0	31	31	29	
YR	49	66	195	93	13	*	74	*	249	311	167	

May-December 1948 data considered in extracting extremes of monthly precipitation.
Sun below horizon continuously November 24 to January 17.
Yearly totals of data entered in columns headed "Clear, Partly Cloudy and Cloudy" in both tables are for period sun above horizon.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09-East, 18-South, 27-West, 36-North, and 00-Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

** The National Weather Service considers the accuracy of solar radiation data questionable; therefore, publication is suspended pending determination of corrected values.

Source: EDS, 1941-1973

TABLE 2A.3-7

EXTRAPOLATED TEMPERATURE DATA (°F) INLAND NORTH SLOPE LOCATION 1/

Month	Normals				Extremes		Mean Number of Days			
							Max		Min	
	Max	Min	Avg	HDD 2/	Max	Min	>70°	<32°	<32°	<0°
January	-5	-23	-14	2437	31	-52	0	31	31	29
February	-8	-28	-18	2335	26	-57	0	28	28	27
March	-2	-22	-12	2387	30	-52	0	31	31	29
April	12	-13	0	1962	34	-46	0	29	30	28
May	33	11	22	1324	54	-9	0	13	30	6
June	56	30	43	654	81	22	7	0	11	0
July	63	36	50	471	79	29	16	0	4	0
August	55	33	44	654	70	20	2	1	13	0
September	39	21	30	906	72	3	1	9	24	0
October	22	2	12	1649	41	-31	0	27	31	17
November	8	-13	-2	2016	35	-37	0	28	30	25
December	-6	-25	-15	2496	48	-51	0	30	31	26
Annual	22	1	12	19291	81	-57	26	227	294	187

1/ Happy Valley Camp Data: 11/70 - 9/72
2/ HDD = Heating Degree Days

Source: EDS, 1941- 1973; 1969 - 1973

TABLE 2A.3-8

EXTRAPOLATED PRECIPITATION DATA INLAND NORTH SLOPE LOCATION

	Rain				Snow				Mean Number of Days	
	1/ Normal Total	2/ Max Monthly	2/ Min Monthly	2/ Max 24 Hour	3/ Mean Total	2/ Max Monthly	2/ Max 24 Hour	2/ Greatest Depth	3/ Precip ≥ 0.01 inch	3/ Snow ≥ 1.0 inch
January	0.43	4.08	0.00	2.25	6	35	15	37-48	7	2
February	0.35	2.53	0.00	1.22	4	15	4	37-48	6	1
March	0.37	1.44	0.00	0.71	4	15	7	37-48	5	1
April	0.41	1.50	0.00	0.44	5	14	4	37-48	7	1
May	0.42	1.51	T	0.76	3	11	8	37-48	7	1
June	0.64	2.09	T	1.15	2	7	5	25-36	7	*
July	1.69	3.01	T	1.64	T	9	6	2	9	*
August	2.34	3.40	T	1.11	1	7	3	2	13	*
September	1.36	4.91	0.01	2.23	6	36	17	13-24	10	2
October	0.86	3.62	0.12	1.98	12	32	16	13-24	13	3
November	0.55	1.50	T	0.43	9	15	6	13-24	9	2
December	0.40	1.17	0.00	0.55	6	13	5	25-36	9	1
Annual	9.84	4.91	0.00	2.25	58	36	17	37-48	102	14

1/ Arctic Stations, 1941 - 1970 normals (x 1.2)
2/ Barrow, Barter Island, and Umiat
3/ Syntheses of Barter Island and Umiat Data

* Less than one-half

T = Trace

Source: EDS, 1941 - 1973; 1967 - 1973; 1973b

TABLE 2A.3-9

EXTRAPOLATED WIND DATA INLAND NORTH SLOPE LOCATION 1/

Month	Average Wind Speed (mph)	Prevailing Directions: Primary Dir	Primary Freq	Secondary Dir	Secondary Freq	Calms	Max Winds (mph) 1-Min Speed	1-Min Dir	Gust Speed	Gust Dir
January	7.0	W	41.0	WSW	14.1	16.4	>47	WNW		
February	7.6	W	42.6	WSW	13.9	15.2	>47	W		
March	5.7	W	33.0	E	11.9	19.9	>25	W		
April	6.9	W	26.1	E	11.2	16.3	>32	W		
May	8.3	E	29.4	NE	14.4	9.2	>25	E		
June	8.4	E	24.6	NE	18.0	8.7	>32	E		
July	7.0	E	16.3	NE	14.8	14.6	>25	WSN		
August	6.4	E	14.5	NE	11.1	16.7	>25	WNW		
September	6.5	E	16.0	NE	15.3	16.1	>25	E		
October	5.1	W	13.3	E	12.6	27.9	>25	NE		
November	6.3	W	22.8	WSW	10.9	23.7	>32	WSW		
December	6.0	W	34.5	WSW	11.6	18.2	>47	W		
Annual	6.8	W	20.3	E	14.2	16.9	>47	W		

1/ Umiat

Source: EDS, 1941 - 1973; 1967 - 1973

TABLE 2A.3-10

CLIMATOLOGICAL DATA SUMMARY FOR ANAKTUVUK PASS

Location: Latitude 68°10', Longitude 151°46', Altitude 2100 feet

	Temperature (°F)								Precipitation Totals (Inches)										Wind		Mean Number of Days				
	Means			Extremes								Snow and Sleet										Temperatures			
																						Max		Min	
Month	Daily Maximum	Daily Minimum	Monthly	Record Highest	Year	Record Lowest	Year	Mean Degree Days	Mean	Greatest Daily	Year	Mean	Maximum Monthly	Year	Greatest Daily	Year	Greatest Depth on Ground	Year	Mean Hourly Speed MPH	Prevailing Direction	Precipitation .10 Inch or More	70° and Above	32° and Below	32° and Below	0° and Below
1/	9	9	9	9		9		No Data	6	6		5	5		No Data	No Data	No Data	No Data	No Data	No Data					
J	-7.5	-22.2	-14.9	25	1955	-56	1967		0.52	0.30	1955	6.2	12.3	1967							2	0	31	31	29
F	-7.3	-21.1	-14.2	29	1959	-47	1957		0.51	0.50	1954	4.8	9.0	1955							2	0	28	28	26
M	0.9	-15.1	-7.1	37	1958	-43	1967		0.62	0.50	1955	7.9	18.0	1955							1	0	31	31	26
A	13.3	-5.3	4.0	45	1957	-38	1960		0.72	0.50	1959+	7.2	17.5	1959							1	0	27	30	17
M	39.2	20.7	30.0	63	1958	-9	1954		0.50	0.60	1955	4.1	15.0	1955							2	0	8	29	2
J	57.6	36.6	47.1	81	1967	-1	1967		1.38	1.58	1958	0.3	2.0	1955							5	3	0	9	0
J	60.8	40.7	50.8	91	1967	26	1956		1.40	0.80	1961	T	T	1957+							6	5	0	4	0
A	53.6	36.8	45.2	75	1960	21	1960		1.65	0.50	1959	0.7	3.0	1955							5	*	*	9	0
S	38.9	24.8	31.9	63	1957	-2	1957		1.15	0.60	1960	7.1	17.0	1954							4	*	8	23	1
O	14.9	2.1	8.5	45	1959	-24	1966		0.93	0.40	1954	10.8	20.5	1961							3	0	29	31	12
N	0.7	-12.6	-6.0	35	1967	-40	1969		0.61	0.40	1954	7.7	20.0	1954							2	0	30	30	27
D	-8.9	-22.3	-15.6	26	1955	-45	1955		0.66	0.50	1955	6.6	15.0	1955							2	0	31	31	30
Anl	21.4	5.3	13.4	91	1967	-56	1967		10.65	1.58	1958	63.1	20.5	1961							35	8	223	286	170

1/Period of record, years (through 1969)

*Less than one-half

+ - Also on earlier dates, months, or years

T - Trace, an amount too small to measure

Note: Accuracy of snowfall data is questionable because of the limited amount of data available

Source: EDS, 1970

extremes in the 80's and occasionally the 90's (Searby, 1968). Precipitation is low, ranging from 10 to 40 inches per year (NWS, 1973a). Precipitation is distributed fairly evenly throughout the year, with a maximum occurring in the summer (Searby, 1968).

In winter, long periods of cold, stable air occasionally are broken by cyclonic disturbances coming from the south or west. At times, such disturbances are strong enough to destroy the surface-based inversion, and winter temperatures above freezing may then be experienced.

Summer months are pleasant. Convective activity is common, but violent thunderstorms are rare and tornadoes are unknown. By late July or August, large scale cyclonic patterns evolve causing increased cyclonic activity. Heavy rains then occur, and are occasionally intense enough to cause severe flooding. The most recent such occurrence was in August, 1967, in the Tanana River Valley. Fairbanks received 80 percent of its normal annual precipitation between mid-July and mid-August (EDS, 1941-1973). In one 24-hour period, 30 percent of the normal annual precipitation (3.44 inches) was reported (EDS, 1973b).

Although the interior of Alaska is usually thought of as lowlands, uplands constitute a considerable percentage of the area. Indian Mountain, Trim's Camp, and Summit are examples of upland stations. Trim's Camp is located in the wide valley leading from the Tanana River watershed through the Alaska Range into the Copper River Basin; the top elevation in this crossing is slightly above 3000 feet at Isabell Pass. Climatic conditions at Isabell Pass are similar to those at Trim's Camp. Taken together, conditions throughout this traversal may be considered climatically similar to general upland conditions elsewhere in the Interior Division.

Bettles, Fairbanks, Summit, and Gulkana are all first order Interior Division weather stations, with Bettles, Fairbanks, and Gulkana representative of lowland locations. Normals, means, and extremes at these stations are given in Tables 2A.3-11 and 12.

Data from Wiseman, Bettles, and the Alyeska's Coldfoot Camp were used to compile Tables 2A.3-13, 14 and 15, which give estimated temperature, precipitation, and wind conditions, respectively, for a compressor station location on the south slope of the Brooks Range.

Tables 2A.3-16, 17 and 18 give temperature, precipitation, and wind conditions, respectively, for Indian Mountain (U.S. Air Force AWS, 1971). Indian Mountain is considered most representative of an upland location for the central Interior Division, though it is about 100 miles west of the pipeline route.

Data from Eielson Air Force Base (26 miles southeast of Fairbanks) were used to extrapolate conditions for a compressor station location in that vicinity (U.S. Air Force AWS, 1957). Tables 2A.3-19, 20 and 21 give estimated temperature, precipitation, and wind conditions, respectively.

NORMALS, MEANS, AND EXTREMES

Station: BETTLES, ALASKA BETTLES FIELD Standard time used: ALASKAN Latitude: 66° 55' N Longitude: 151° 31' W Elevation (ground): 644 feet

Month	Temperature – Normal ∅ – Daily maximum	Daily minimum	Monthly	Extremes – Record highest	Year	Record lowest	Year	Mean heating degree days, 1951-1968	Precipitation – Normal total ∅	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	22		22			(b)	22		22		22	
J	-5.3	-21.1	-13.2	42	1961	-68	1971	2434		2.60	1957	T	1961	0.98	1962
F	1.0	-16.5	-7.8	37	1968	-60	1968	2070		2.94	1964	0.11	1972+	0.74	1959
M	12.9	-10.0	1.5	44	1965	-56	1964	1981		3.60	1963	T	1960	0.87	1963
A	31.7	9.2	20.5	56	1969	-25	1955	1374		1.88	1965	0.01	1969	0.56	1962
M	51.6	31.7	41.7	83	1960	-10	1952	738		1.18	1971	0.04	1959	0.48	1971
J	67.2	46.1	56.2	92	1969	27	1960	255		3.59	1965	T	1959	1.93	1958
J	68.2	47.6	57.9	92	1955	29	1955	226		5.42	1963	0.00	1959	1.46	1970
A	60.9	42.9	51.9	85	1960	22	1968	388		5.91	1963	0.41	1958	1.87	1951
S	48.2	31.7	40.0	79	1957	5	1957	747		4.13	1951	0.31	1958	1.31	1954
O	26.6	13.3	20.0	53	1969+	-32	1970	1442		3.32	1972	0.20	1967	1.32	1972
N	5.8	-8.6	-1.4	38	1952	-51	1956	1977		3.85	1967	0.15	1960	0.65	1955
D	-4.3	-20.0	-12.2	38	1960	-59	1957	2424		1.97	1970	0.13	1964	0.65	1967
YR	30.4	12.1	21.3	92	JUN. 1969+	-68	JAN. 1971	16056		5.91	AUG. 1963	0.00	JUL. 1959	1.73	JUN. 1958

Month	Snow, Ice pellets – Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity – Hour 02 (Local time)	Hour 08	Hour 14	Hour 20	Wind & – Mean speed	Prevailing direction ¢	Fastest mile % – Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset %	Mean number of days – Sunrise to sunset % – Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more $	Snow, Ice pellets 1.0 inch or more	Thunderstorms %	Heavy fog %	Temperatures Max. – 90° and above ‡	Max. – 32° and below	Min. – 32° and below	Min. – 0° and below	Average daily solar radiation - langleys
(a)	21	22		22		2	4	3	3	6	5	4	4			3	3	3	3	13	4	4	4	21	21	21	21	
J	10.0	31.4	1957	19.0	1965	67	61	65	67	5.8	NNW	30	11	1970		4.1	17	5	9	6	2	0	1	0	30	31	28	
F	9.4	29.5	1964	7.4	1959	65	60	59	66	7.1	NNW	25	08	1970		6.0	9	4	15	6	3	0	0	0	28	28	24	
M	10.0	30.4	1963	8.0	1955	64	58	55	62	7.3	NNW	29	08	1971		6.1	10	3	16	7	4	0	0	0	29	31	23	
A	8.2	23.6	1965	10.0	1970	75	63	62	69	7.5	NNW	26	36	1972		6.4	5	12	13	4	2	0	*	0	16	30	9	
M	1.5	12.0	1952	6.7	1952	71	61	46	51	7.4	NNW	31	11	1970		6.4	6	10	15	6	1	*	*	1	1	15	*	
J	T	T	1967+	T	1967+	73	58	44	48	6.8	NNW	28	01	1970		6.5	5	11	14	8	0	1	*	13	0	*	0	
J	0.0	0.0		0.0		87	70	52	63	6.6	SSE	26	23	1969		8.1	1	8	22	9	0	4	1	14	0	*	0	
A	0.1	2.6	1969	2.6	1969	86	80	61	73	6.1	SSE	29	36	1969		7.9	3	7	21	14	*	*	2	5	0	2	0	
S	1.4	9.4	1968	5.6	1972	78	73	54	69	6.6	NNW	25	03	1971+		6.2	8	7	15	10	1	0	*	*	1	15	0	
O	11.2	28.3	1972	9.0	1955	76	78	74	78	6.2	NNW	25	24	1970		7.6	5	6	20	11	6	0	2	0	21	29	7	
N	11.8	41.6	1967	9.7	1970	70	72	71	71	6.0	NNW	38	26	1970		6.4	7	8	15	9	5	0	1	0	29	30	20	
D	12.7	31.2	1970	11.0	1954	66	65	64	66	6.4	NNW	40	24	1970		5.6	9	5	17	9	7	0	*	0	31	31	26	
YR	76.3	41.6	NOV. 1967	19.0	JAN. 1965	73	67	59	65	5.7	NNW	40	24	DEC. 1970		6.5	85	88	192	105	29	6	7	35	189	248	140	

NORMALS, MEANS, AND EXTREMES

Station: FAIRBANKS, ALASKA INTERNATIONAL AIRPORT Standard time used: ALASKAN Latitude: 64° 49' N Longitude: 147° 52' W Elevation (ground): 436 feet

Month	Temperature – Normal – Daily maximum	Daily minimum	Monthly	Extremes – Record highest	Year	Record lowest	Year	Normal heating degree days (Base 65°)	Precipitation – Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	9		9		(b)	(b)	21		21		21	
J	-.8	-21.4	-11.1	38	1965	-61	1969	2359	0.89	1.92	1957	0.01	1966	0.58	1968
F	9.5	-15.3	-2.9	43	1970	-56	1968	1901	0.52	1.75	1966	0.07	1958	0.97	1965
M	23.5	-5.7	8.9	51	1970	-46	1964	1739	0.40	2.10	1963	T	1968	0.92	1963
A	42.1	16.6	29.4	63	1969	-21	1964	1068	0.25	0.84	1967	T	1969+	0.31	1965
M	59.1	35.1	47.1	81	1954	-1	1964	555	0.71	1.67	1955	0.07	1957	0.88	1955
J	71.1	45.6	58.4	96	1969	37	1970+	222	1.39	3.52	1955	0.19	1966	1.52	1955
J	71.7	47.6	59.7	89	1968	37	1964	171	1.84	4.35	1962	0.40	1957	1.53	1962
A	65.3	43.2	54.3	85	1966	30	1965	332	2.20	6.20	1967	0.40	1957	3.42	1967
S	53.9	33.3	43.6	90	1963	11	1972	642	1.10	3.05	1960	0.15	1968+	1.21	1954
O	35.4	17.0	26.2	65	1969	-15	1965	1203	0.85	1.84	1970	0.09	1954	0.68	1970
N	13.4	-5.6	3.9	46	1970	-43	1964	1833	0.60	3.32	1970	T	1953	0.84	1970
D	2.1	-17.5	-7.7	42	1969+	-56	1964	2254	0.54	2.29	1970	T	1969	1.25	1968
YR	37.2	14.4	25.8	96	JUN. 1969	-61	JAN. 1969	14279	11.29	6.20	AUG. 1967	T	DEC. 1969+	3.42	AUG. 1967

Month	Snow, Ice pellets – Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity – Hour 02 (Local time)	Hour 08	Hour 14	Hour 20	Wind & – Mean speed	Prevailing direction	Fastest mile – Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days – Sunrise to sunset – Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures Max. – 90° and above ‡	Max. – 32° and below	Min. – 32° and below	Min. – 0° and below	Average daily solar radiation - langleys **
(a)	21	21		21		9	9	9	9	21	12	21	21			21	21	21	21	21	21	21	21	9	9	9	9	
J	10.7	26.3	1957	9.4	1968	67	68	68	68	2.7	N	29	27	1954		5.9	10	6	15	7	3	0	5	0	31	31	29	
F	10.6	43.1	1966	20.1	1966	64	64	62	65	3.9	N	33	27	1953		6.7	7	5	15	8	3	0	2	0	26	28	23	
M	7.5	29.6	1963	12.6	1963	64	63	53	61	4.9	N	40	22	1970		6.0	9	7	15	6	3	0	1	0	22	31	19	
A	3.9	11.1	1967	4.9	1962+	55	60	48	55	6.5	N	31	23	1965		5.9	6	7	17	5	1	0	*	0	7	23	3	
M	0.8	4.7	1964	4.5	1964	66	53	33	45	7.6	N	31	29	1955		7.0	4	10	17	6	*	*	*	2	*	9	*	
J	T	T	1953+	T	1953+	69	58	40	46	6.1	SW	30	21	1971		7.3	3	10	17	10	0	2	*	19	0	0	0	
J	0.0	0.0		0.0		78	68	50	56	6.4	SW	29	09	1937		7.6	3	8	20	12	0	2	1	20	0	0	0	
A	T	T	1967+	T	1969+	82	77	53	67	6.0	N	34	27	1954		7.9	2	7	22	13	0	1	2	9	0	1	0	
S	1.2	7.8	1972	7.0	1972	77	73	51	66	6.0	N	29	21	1971		7.3	5	6	19	9	*	*	1	1	*	10	0	
O	9.5	24.2	1961	7.6	1970	77	77	65	74	5.4	N	40	25	1958		8.0	3	6	22	10	4	0	2	0	17	28	4	
N	13.0	54.0	1970	14.6	1970	74	74	73	74	4.0	N	35	25	1970		6.9	7	3	18	10	4	0	1	0	28	30	18	
D	13.2	33.5	1963	14.7	1968	69	69	68	69	3.1	N	37	24	1970		6.9	7	6	18	3	4	0	4	0	30	31	26	
YR	70.4	54.0	NOV. 1970	20.1	FEB. 1966	71	67	56	62	5.3	N	40	22	MAR. 1970+		7.0	66	33	216	103	22	3	20	32	162	227	122	

∅ For period September 1963 through the current year.
Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 99 in July 1919; lowest temperature -66 in January 1934; maximum monthly precipitation 6.88 in August 1930; minimum monthly precipitation 0.00 in February 1919; maximum monthly snowfall 65.6 in January 1937.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1963.
‡ ≦ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "Ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09-East, 18-South, 27-West, 36-North, and 00-Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

** The National Weather Service considers the accuracy of solar radiation data questionable; therefore, publication is suspended pending determination of corrected values.

¢ April 1950 through 1954 and January 1969 to date when available.
$ Available data for 1943-1953 and January 1969 to date.

% Data incomplete from time to time due to less than full time operation of the station.

Source: EDS, 1941-1973

TABLE 2A.3-12

NORMALS, MEANS, AND EXTREMES

Station: SUMMIT, ALASKA SUMMIT AIRPORT Standard time used: ALASKAN Latitude: 63° 20' N Longitude: 149° 08' W Elevation (ground): 2401 feet

Month	Temperature: Normal ∅ Daily maximum	Normal ∅ Daily minimum	Normal ∅ Monthly	Extremes: Record highest	Year	Record lowest	Year	Mean heating degree days, 1941-1967.	Precipitation: ∅ Normal total	Maximum monthly	Year	Minimum monthly	Year	$ Maximum in 24 hrs.	Year	Snow, Ice pellets: Mean total	Maximum monthly	Year	$ Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	32		32		27	(b)	32		32		32		30	31		32	
J	7.9	-4.8	1.6	44	1945	-45	1971	1928		3.38	1948	0.09	1945	0.80	1948	13.7	64.8	1948	14.9	1948
F	13.5	-0.4	6.6	45	1942	-45	1947	1638		4.31	1951	T	1950	2.79	1951	16.4	44.5	1951	28.0	1964
M	19.4	3.0	11.2	49	1961	-35	1971	1696		4.53	1946	0.07	1961+	1.67	1646	15.1	59.1	1946	18.1	1946
A	32.9	14.1	23.5	57	1956	-30	1944	1248		4.45	1966	0.06	1944	0.97	1963	8.8	28.7	1970	9.7	1963
M	45.7	29.1	37.4	76	1960	-14	1945	859		2.66	1966	0.04	1949	0.96	1946	4.3	17.4	1958	7.5	1946
J	58.0	39.9	49.0	89	1961	25	1947	480		4.45	1949	0.41	1942	2.22	1967	0.7	8.4	1970	5.9	1970
J	60.2	43.8	52.0	81	1961+	32	1970+	400		5.58	1959	1.17	1955	1.95	1948	0.4	9.7	1970	9.7	1970
A	56.0	41.1	48.6	81	1968	20	1955	505		6.74	1944	0.70	1941	2.10	1944	0.5	9.0	1955	6.0	1955
S	47.1	32.6	39.9	75	1957	6	1956	750		6.55	1942	0.29	1969	2.07	1944	4.9	21.5	1958	14.0	1955
O	30.4	17.5	24.0	59	1969	-12	1965	1271		3.79	1952	0.12	1967	1.24	1963	18.9	54.8	1970	12.6	1970
N	15.7	3.7	9.7	44	1962+	-29	1948	1662		4.85	1952	0.06	1963	1.30	1964	18.3	75.1	1967	21.9	1970
D	9.2	-3.4	2.9	42	1969+	-43	1961	1931		4.63	1951	0.24	1945	1.09	1967	17.4	50.7	1970	27.4	1970
YR	33.0	18.0	25.5	89	JUN. 1961	-45	JAN. 1971+	14368		6.74	AUG. 1944	T	FEB. 1950	2.79	FEB. 1951	119.4	75.1	NOV. 1967	28.0	FEB. 1964

Month	Relative humidity: Hour 02 (Local time)	Hour 08	Hour 14	Hour 20	Wind &: @ Mean speed	Prevailing direction	Fastest mile: Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	† Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures Max. ‡ 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below	Average daily solar radiation - langleys
(a)	5	5	5	5	8	5	5	5			5	5	5	5	17	5	5	5	31	31	31	31	
J	68	68	69	68	15.1	NE	44	05	1968		5.1	13	6	12	9	4	0	1	0	30	31	20	
F	76	76	77	77	11.9	NE	35	05	1969+		7.0	6	5	17	10	7	0	2	0	26	28	15	
M	76	76	71	73	11.1	NE	48	10	1971		6.2	9	6	16	10	5	0	2	0	27	31	14	
A	80	76	66	74	7.6	NE	33	08	1971		7.3	4	8	18	7	4	0	2	0	14	30	3	
M	83	71	60	69	7.7	W	28	07	1969		7.6	2	9	20	7	2	0	1	*	1	22	*	
J	84	72	55	64	8.3	SW	29	22	1970+		7.9	2	7	21	12	*	3	1	3	0	2	0	
J	89	77	60	71	7.8	SW	30	10	1972+		8.1	1	8	22	16	*	3	1	5	0	*	0	
A	88	80	60	75	7.4	SW	26	24	1970		8.3	2	6	23	18	0	*	1	1	0	2	0	
S	85	81	59	76	7.5	NE	32	23	1972		7.3	5	6	19	16	3	*	1	*	1	14	0	
O	83	84	75	81	8.0	NE	35	23	1970		7.7	4	6	21	14	8	0	2	0	18	30	2	
N	79	79	78	78	11.3	NE	39	25	1970		7.2	7	4	19	9	5	0	1	0	27	30	12	
D	76	76	74	76	12.7	NE	44	11	1970		6.3	10	5	16	11	6	0	1	0	30	31	19	
YR	81	76	67	73	9.7	NE	48	10	MAR. 1971		7.2	65	76	224	139	44	7	15	9	173	251	86	

NORMALS, MEANS, AND EXTREMES

Station: GULKANA, ALASKA GULKANA INTERMEDIATE FIELD Standard time used: ALASKAN Latitude: 62° 09' N Longitude: 145° 27' W Elevation (ground): 1572 feet

Month	Temperature: Normal ∅ Daily maximum	Normal ∅ Daily minimum	Normal ∅ Monthly	Extremes: Record highest	Year	Record lowest	Year	Mean heating degree days, 1943-1967.	Precipitation: ∅ Normal total	Maximum monthly	Year	Minimum monthly	Year	$ Maximum in 24 hrs.	Year	Snow, Ice pellets: Mean total	Maximum monthly	Year	$ Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	30		30		25	(b)	30		30		30		30	30		27	
J	1.9	-16.4	-7.3	46	1948	-60	1947	2229		1.56	1943	0.06	1971	0.76	1958	7.5	21.4	1943	7.5	1947
F	14.7	-6.9	3.9	46	1943	-65	1947	1750		1.65	1968	0.04	1943	0.48	1948	5.8	12.6	1968	6.9	1953
M	28.1	0.8	14.5	49	1965	-48	1972+	1593		1.32	1972	T	1950	0.78	1972	4.8	23.4	1944	10.6	1972
A	41.8	18.5	30.2	67	1958	-42	1944	1068		0.82	1945	0.00	1954	0.78	1961	1.8	6.3	1970	3.0	1963+
M	55.1	32.5	43.8	85	1960	5	1964	663		1.51	1967	T	1950	1.25	1946	0.5	5.0	1945	4.0	1945
J	66.0	42.4	54.2	90	1969	28	1950	327		4.07	1962	0.08	1946	1.51	1945	T	T	1963+	T	1963+
J	68.1	45.6	56.9	91	1953	29	1970	245		3.05	1972	0.71	1955	2.04	1972	0.0	0.0		0.0	
A	64.3	42.1	53.2	85	1957	20	1948	363		4.19	1947	0.40	1963	2.01	1971	0.1	4.0	1955	4.0	1955
S	53.7	33.5	43.6	72	1963	7	1946	639		4.34	1951	0.07	1969	2.06	1951	1.1	6.4	1970	4.0	1972
O	35.7	17.8	26.8	65	1969	-23	1958	1175		2.42	1965	0.11	1967	1.15	1959	7.7	22.7	1965	8.3	1959
N	13.8	-1.6	6.1	48	1964+	-44	1948	1749		4.11	1956	0.07	1964	0.80	1943	8.7	36.2	1956	8.3	1950
D	3.0	-13.1	-5.1	44	1943	-58	1964	2179		3.07	1955	0.07	1972+	0.99	1955	9.0	30.0	1955	10.0	1946
YR	37.2	16.3	26.8	91	JUL. 1953	-65	FEB. 1947	13980		4.34	SEP. 1951	0.00	APR. 1954	2.06	SEP. 1951	47.0	36.2	NOV. 1956	10.6	MAR. 1972

Month	Relative humidity: Hour 02 (Local time)	Hour 08	Hour 14	Hour 20	Wind &: @ Mean speed	Prevailing direction	Fastest mile %: Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	† Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	% Thunderstorms	% Heavy fog	Temperatures Max. ‡ 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below	Average daily solar radiation - langleys
(a)	3	5	5	5	8	5	5	5			5	5	5	5	15	5	5	5	30	30	30	30	
J	67	68	66	68	5.1	N	52	04	1971		4.7	15	4	12	8	2	0	*	0	29	31	25	
F	78	76	72	76	5.6	N	35	19	1970		7.0	6	4	18	5	2	0	1	0	24	28	19	
M	76	74	60	69	6.5	WNW	35	15	1970		6.0	9	7	15	5	2	0	2	0	18	30	16	
A	75	65	49	60	8.6	SE	46	18	1970		6.8	5	10	15	3	2	0	*	0	4	29	2	
M	76	59	40	53	8.8	SE	29	17	1972+		7.2	3	10	18	5	*	1	*	1	*	15	0	
J	75	59	40	48	8.8	SE	38	15	1971		7.4	2	10	18	8	0	2	0	10	0	1	0	
J	84	70	46	57	8.2	SE	40	15	1971		7.2	4	9	18	13	0	2	1	13	0	*	0	
A	84	74	48	66	8.0	SE	30	16	1970		7.4	3	9	19	11	0	1	2	6	0	3	0	
S	82	77	52	72	7.6	SE	31	04	1972		6.8	6	7	17	10	1	0	3	*	*	14	0	
O	83	85	71	81	6.3	SE	46	19	1970		7.8	3	7	21	8	4	0	4	0	11	28	4	
N	83	84	83	84	4.8	N	33	17	1969		7.5	5	4	21	7	3	0	3	0	26	30	17	
D	70	76	75	75	3.6	N	40	17	1969		6.7	7	7	17	8	2	0	2	0	29	31	24	
YR	78	72	58	67	6.8	SE	52	04	JAN. 1971		6.9	68	88	209	89	17	5	18	30	142	239	107	

∅ Climatological standard normals have not been established for this station.
Record mean values for temperature and precipitation appear on the next page.

(a) Length of record, years, based on January data. Other months may be for more or fewer years if there have been breaks in the record.
(b) Climatological standard normals (1931-1960).
* Less than one half.
\+ Also on earlier dates, months, or years.
T Trace, an amount too small to measure.
Below zero temperatures are preceded by a minus sign.
The prevailing direction for wind in the Normals, Means, and Extremes table is from records through 1954.
‡ ≥ 70° at Alaskan stations.

Unless otherwise indicated, dimensional units used in this bulletin are: temperature in degrees F.; precipitation, including snowfall, in inches; wind movement in miles per hour; and relative humidity in percent. Heating degree day totals are the sums of negative departures of average daily temperatures from 65° F. Cooling degree day totals are the sums of positive departures of average daily temperatures from 65° F. Sleet was included in snowfall totals beginning with July 1948. The term "ice pellets" includes solid grains of ice (sleet) and particles consisting of snow pellets encased in a thin layer of ice. Heavy fog reduces visibility to 1/4 mile or less.

Sky cover is expressed in a range of 0 for no clouds or obscuring phenomena to 10 for complete sky cover. The number of clear days is based on average cloudiness 0-3, partly cloudy days 4-7, and cloudy days 8-10 tenths.

Solar radiation data are the averages of direct and diffuse radiation on a horizontal surface. The langley denotes one gram calorie per square centimeter.

& Figures instead of letters in a direction column indicate direction in tens of degrees from true North; i.e., 09 - East, 18 - South, 27 - West, 36 - North, and 00 - Calm. Resultant wind is the vector sum of wind directions and speeds divided by the number of observations. If figures appear in the direction column under "Fastest mile" the corresponding speeds are fastest observed 1-minute values.

$ For calendar day prior to 1968.
@ Record for 1950-1954 and January 1968 to date.
† Record for 1943-1952 and January 1968 to date.

% Data incomplete from time to time due to less than full time operation of the station.

Source: EDS, 1941-1973

TABLE 2A.3-13

EXTRAPOLATED TEMPERATURE DATA (°F) SOUTH SLOPE BROOKS RANGE LOCATION

Month	Normals 1/ Max	Normals 1/ Min	Normals 1/ Avg	Normals 1/ HDD	Extremes 2/ Max	Extremes 2/ Min	Mean Number of Days 3/ Max >70°	Mean Number of Days 3/ Max <32°	Mean Number of Days 3/ Min <32°	Mean Number of Days 3/ Min <0°
January	-6.3	-22.1	-14.2	2455	42	-74	0	30	31	28
February	1.2	-16.3	-7.6	2032	37	-60	0	28	28	24
March	13.3	-9.6	1.9	1957	44	-58	0	29	31	23
April	31.7	9.2	20.5	1335	56	-32	0	16	30	9
May	49.8	29.9	39.9	778	83	-10	1	1	15	*
June	64.2	42.1	53.2	360	92	27	13	0	*	0
July	64.0	43.3	53.7	361	92	29	14	0	*	0
August	56.5	38.5	47.5	542	85	22	5	0	2	0
September	44.0	27.5	35.8	876	79	5	*	1	15	0
October	23.0	9.7	16.4	1507	53	-35	0	21	29	7
November	3.0	-11.4	-4.2	2076	38	-52	0	29	30	20
December	-6.1	-21.8	-14.0	2449	38	-59	0	31	31	26
Annual	28.2	9.9	19.1	16728	92	-74	35	189	248	140

1/ Bettles Data: 1951 - 1970, modified slightly
2/ Bettles Data: 1951 - 1972 or Coldfoot Data: 1970 - 1972
3/ Bettles Data: 1951 - 1972

* Less than one-half

Source: EDS, 1941 - 1973; 1967 - 1973

TABLE 2A.3-14

EXTRAPOLATED PRECIPITATION DATA (°F) SOUTH SLOPE BROOKS RANGE LOCATION

	Rain				Snow				Mean Number of Days	
Month	Normal Total	Max Monthly	Min Monthly	Max 24 Hour	Mean Total	Max Monthly	Max 24 Hour	Greatest Depth	Precip ≥1.0 inch 1/	Snow ≥1.0 inch 1/
January	0.72	2.60	T	0.98	10.0	31.4	19.0	38	6	2
February	0.77	2.94	0.11	0.74	9.4	29.5	7.4	80	6	3
March	0.82	3.60	T	0.87	10.0	30.4	8.0	80	7	4
April	0.63	1.88	0.01	0.56	8.2	23.6	10.0	46	4	2
May	0.62	1.18	0.04	0.48	1.5	12.0	6.7	32	6	1
June	1.22	3.59	T	1.93	T	T	T	0	8	0
July	1.79	5.42	0.00	1.46	0.0	0.0	0.0	0	9	0
August	2.77	5.91	0.41	1.87	0.1	2.6	2.6	4	14	*
September	1.78	4.13	0.31	1.31	1.4	9.4	5.6	5	10	1
October	1.23	3.82	0.20	1.32	11.2	28.3	9.0	38	11	6
November	0.81	3.85	0.15	0.65	11.8	41.6	9.7	36	9	5
December	0.82	1.97	0.13	0.65	12.7	31.2	11.0	38	9	7
Annual	14.18	5.91	0.00	1.93	74.8	41.6	19.0	80	105	29

1/ Wiseman Data
* Less than one-half
T = Trace

All data for Bettles, Alaska, except where noted. Normals are for 1941 - 1970 period. Other values are for period of record, viz., 1951 - 1972.

Source: EDS, 1941 - 1973; 1967 - 1973; 1973b

TABLE 2A.3-15

EXTRAPOLATED WIND DATA SOUTH SLOPE BROOKS RANGE LOCATION

Month	Average Wind Speed (mph)	Prevailing Directions				Calms	Max Winds (mph)			
		Primary		Secondary			1-Min		Gust	
		Dir	Freq	Dir	Freq		Speed	Dir	Speed	Dir
January	5.8	N					31	NW		
February	7.1	N					25	E		
March	7.3	N					29	E		
April	7.5	N					32	NNW		
May	7.4	N					31	ESE		
June	6.8	S					28	N		
July	6.6	S					29	SW		
August	6.1	S					29	N		
September	6.6	N					25	NNE		
October	6.2	N					30	ENE		
November	6.0	N					38	W		
December	6.4	N					50	SW		
Annual	6.7	N					50	SW		

1/ Wiseman Data

Source: EDS, 1941 - 1973; 1967 - 1973

TABLE 2A.3-16

EXTRAPOLATED TEMPERATURE DATA (°F) UPLAND LOCATION - CENTRAL INTERIOR DIVISION

	Normals				Extremes 1/		Mean Number of Days			
							Max		Min	
Month	Max	Min	Avg	HDD	Max	Min	≥70°	≤32°	≤32°	≤0°
January	0.6	-12.1	-5.8	2195	36	-65	0	30	31	25
February	1.7	-14.3	-5.9	1985	32	-47	0	28	28	23
March	14.4	-2.7	6.0	1829	38	-46	0	28	31	17
April	30.3	12.9	21.9	1293	57	-28	0	17	28	5
May	49.3	32.5	41.2	738	72	-2	1	2	14	*
June	65.1	45.9	55.7	279	88	32	9	0	*	0
July	64.6	47.5	56.3	270	85	30	9	0	*	0
August	58.7	43.2	51.2	428	80	26	3	0	1	0
September	46.7	32.7	40.0	750	74	9	*	2	13	0
October	27.3	16.8	22.2	1327	52	-17	0	21	28	4
November	9.0	-2.6	3.3	1851	36	-39	0	29	30	15
December	-0.6	-16.4	-7.7	2254	36	-56	0	30	31	24
Annual	30.6	15.3	23.2	15198	88	-65	22	187	235	113

1/ Indian Mountain Data: 1953 - 1958; 1963 - 1970
* Less than one-half

Source: U.S. Air Force AWS, 1971

TABLE 2A.3-17

EXTRAPOLATED PRECIPITATION DATA UPLAND LOCATION - CENTRAL INTERIOR DIVISION

	Rain				Snow				Mean Number of Days	
Month	Normal Total	Max Monthly	Min Monthly	Max 24 Hour	Mean Total	Max Monthly	Max 24 Hour	Greatest Depth	Precip ≥0.01 inch	Snow ≥1.0 inch
January	1.34	5.04	0.04	2.16	15.7	50.3	24.7	64	9	6
February	1.10	3.88	0.11	0.80	14.6	39.0	10.9	≥64	10	7
March	1.28	4.58	0.04	1.35	12.9	44.9	13.5	65	9	5
April	0.96	3.63	0.04	1.55	11.4	43.7	19.4	69	8	4
May	0.89	1.57	0.34	0.76	1.6	≥7.0	7.0	30	8	1
June	1.55	4.03	0.13	1.90	T	0.5	0.3	T	10	0
July	2.55	5.23	0.21	1.22	0.0	0.0	0.0	0	14	0
August	4.27	8.08	1.72	1.81	0.1	0.9	0.9	T	16	0
September	2.52	4.90	0.45	1.84	2.9	16.1	10.3	10	12	1
October	1.36	4.37	0.48	1.32	14.4	47.6	19.5	≥16	12	7
November	0.94	2.24	0.03	0.65	11.1	22.5	9.1	27	10	5
December	1.16	3.22	0.09	1.02	14.4	40.9	13.8	42	10	5
Annual	19.92	8.08	0.03	2.16	99.1	50.3	24.7	69	126	41

T = Trace

Source: U.S. Air Force AWS, 1971

TABLE 2A.3-18

EXTRAPOLATED WIND DATA UPLAND LOCATION - INTERIOR BASIN DIVISION

		Prevailing Directions					Max Winds (mph)			
	Wind Speed	Primary		Secondary			1-Min		Gust	
Month	(mph)	Dir	Freq	Dir	Freq	Calms	Speed	Dir	Speed	Dir
January	6.3	ENE	12.3	E	7.9	46.4	52	E	61	E
February	6.4	ENE	10.7	E	9.0	42.2	46	ENE	76	NE
March	6.1	ENE	12.5	E	9.9	37.4	62	ENE	55	WNW
April	6.7	ENE	14.2	NE	9.7	25.2	38	NE	38	WNW
May	7.0	NE	12.0	ENE	11.6	19.4	32	SW	46	N
June	6.3	NW	12.5	W	10.8	19.7	25	W	32	NE
July	5.5	W	13.9	SW	11.7	25.0	26	WSW	33	ENE
August	5.1	SW	10.2	W	10.1	32.5	40	NE	29	NE
September	6.1	NE	11.5	ENE	11.1	30.0	30	NE	46	NE
October	6.7	ENE	15.7	NE	12.7	36.0	35	NE	55	NE
November	6.2	ENE	12.5	NE	9.5	44.1	40	NE	51	NE
December	5.8	ENE	10.6	NE	7.8	50.0	58	WNW	59	NE
Annual	6.2	ENE	10.3	NE	7.9	33.7	62	ENE	76	NE

Source: U.S. Air Force AWS, 1971

TABLE 2A.3-19

EXTRAPOLATED TEMPERATURE DATA (°F) VICINITY EIELSON AFB

	Normals				Extremes		Mean Number of Days			
							Max		Min	
Month	Max	Min	Avg	HDD	Max	Min	≥70°	≤32°	≤32°	≤0°
January	-2.8	-19.7	-11.3	2365	48	-66	0	31	31	29
February	6.2	-15.5	-4.7	1952	50	-60	0	26	28	23
March	23.8	-3.0	10.4	1693	56	-56	0	22	31	19
April	39.3	18.2	28.8	1086	75	-32	0	7	28	3
May	56.4	36.4	46.4	577	92	-1	2	*	9	*
June	68.2	47.4	57.8	216	96	26	19	0	0	0
July	69.9	50.4	60.2	149	99	29	20	0	0	0
August	65.2	45.3	55.2	304	90	19	9	0	1	0
September	53.8	34.5	44.2	624	85	7	1	*	10	0
October	32.7	16.8	24.7	1249	68	-28	0	17	28	4
November	10.7	-5.1	2.8	1866	54	-54	0	28	30	18
December	-3.0	-18.6	-10.8	2350	58	-62	0	30	31	26
Annual	35.1	15.6	25.3	14431	99	-66	52	162	227	122

* Less than one-half

Source: U.S. Air Force AWS, 1957; EDS, 1941 - 1973

TABLE 2A.3-20

EXTRAPOLATED PRECIPITATION DATA VICINITY EIELSON AFB

	Rain				Snow				Mean Number of Days	
Month	Normal Total	Max Monthly	Min Monthly	Max 24 Hour	Mean Total	Max Monthly	Max 24 Hour	Greatest Depth	Precip ≥0.01 Inch	Snow ≥1.0 Inch
January	1.03	8.95	.01	1.18	12.6	40.1	11.3	41	7	3
February	0.77	2.80	.00	0.75	11.0	33.5	14.2	54	8	3
March	0.69	4.96	T	0.80	8.3	31.4	8.0	48	6	3
April	0.60	3.07	T	0.80	4.9	14.7	6.1	37	5	1
May	0.83	2.33	T	0.87	0.9	6.0	2.9	3	6	*
June	1.73	4.69	.25	1.36	T	T	T	0	10	0
July	2.51	7.19	.16	2,07	0.0	0.0	0.0	0	12	0
August	2.38	9.17	.53	3.61	T	T	T	0	13	0
September	1.48	7.48	.12	1.29	2.3	12.4	5.0	4	9	*
October	1.07	4.53	T	2.14	9.6	28.6	7.8	12	10	4
November	0.89	6.20	T	0.74	12.8	47.1	8.4	28	10	4
December	0.95	3.05	T	0.80	12.4	32.1	11.3	33	8	4
Annual	14.93	9.17	.00	3.61	74.6	47.1	14.2	54	103	22

* Less than one-half
T = Trace

Source: U.S. Air Force AWS, 1957; EDS, 1941 - 1973

TABLE 2A.3-21

EXTRAPOLATED WIND DATA VICINITY EIELSON AFB

Month	Average Wind Speed (mph)	Prevailing Directions: Primary Dir	Primary Freq	Secondary Dir	Secondary Freq	Calms	Max Winds (mph): 1-Min Speed	1-Min Dir	Gust Speed	Gust Dir
January	2.0	S	4.5	SE	4.3	55.2	39	SW	42	
February	2.3	W	5.4	SE	5.3	54.3	60	SW	78	
March	3.2	SE	6.5	W	5.8	41.4	58	WSW	62	
April	5.0	W	8.8	SE	8.6	26.7	39	WSW	42	
May	5.3	W	9.5	NE	7.0	22.5	35	NE	40	
June	5.4	W	12.7	SW	8.1	20.7	36	SW	>36	
July	4.3	W	11.7	SW	7.7	27.4	29	WSW	>29	
August	3.9	SW	8.6	W	8.5	31.4	40	W	>40	
September	3.5	SE	8.8	SW	6.5	37.8	35	S	60	
October	3.0	SW	5.9	SE	5.1	43.6	30	E	82	
November	2.0	SE	4.9	N	4.6	61.1	32	ESE/W	53	
December	1.8	SE	4.9	S	4.5	59.7	37	E	40	
Annual	3.5	W	6.4	SE	6.3	40.5	60	SW	82	

Source: U.S. Air Force AWS, 1957; EDS, 1941 - 1973

Thompson Pass, located at the divide of the Chugach Mountains at an elevation of 2700 feet, represents the extreme climate that occurs in the higher elevations. Table 2A.3.2-22 gives the normals, means, and extremes of climatic conditions (EDS, 1970). The mean annual snowfall is 583 inches, but in the winter of 1952-53, 975 inches were recorded. A one-day fall of 62 inches was measured in February 1964. The mean annual snowfall at the unnamed pass (pipeline milepost 775.6) is unknown, but probably ranges between 400 and 800 inches (NWS, 1973b).

2A.3.2.3 South Coastal Division

The South Coastal Division to the south of the Chugach Mountains is maritime (Searby, 1968). Conditions are much more moderate than in the Interior Basin Division. The nearness of the Pacific Ocean plays a dominant role in the climate of this Division. Temperatures are cooler in the summer and warmer in the winter, and extremes are less severe than in the Interior Basin Division. The precipitation level is much higher, as is the annual snowfall, even though the duration of the snow season is shorter than in the Interior Basin Division. Table 2A.3-23 gives the normals, means, and extremes for Valdez; Table 2A.3-24 gives them for Cordova. This Division experiences a climate that is severe by temperate latitude standards.

Since the LNG Plant site is only 15 miles northwest of Cordova, that station's climatology is the most representative of any station in the South Coastal Division. However, conditions in Cordova can be significantly different from those at Cordova Airport (Table 2A.3-25), especially with respect to precipitation. It is seen that the annual precipitation there is slightly more than twice that of Cordova Airport. Because the LNG Plant site is located on the north side of Orca Bay, with no mountains to buffer prevailing winds (east to southeast--the situation at Cordova), annual precipitation totals at the site are estimated to be about 120 inches, which is intermediate to Cordova and the Cordova Airport values. Temperatures at the LNG Plant site are estimated to be comparable to those at Cordova and Cordova Airport. Since snowfall in this region is strongly temperature dependent, annual totals at the LNG Plant site should also be comparable to the Cordova figures. The wind regime at the LNG Plant site will be somewhat different than that of the Cordova Airport, because of differences in exposure. Mean wind speeds should be higher at the site than at Cordova Airport, since it is located directly on the coast, whereas Cordova Airport is inland about six miles. The distribution of wind directions is also different at the LNG Plant site compared to Cordova Airport, because of the general northeast-to-southwest orientation of the coastline and the more open exposure at the site. When all of these considerations are taken into account, a reasonable estimate of the climatic conditions at the LNG Plant site can be made. Tables 2A.3-26, 27 and 28 give such data.

Temperature data are slightly modified Cordova data, and precipitation data are combined and modified data from both Cordova and Cordova Airport. The wind data have been interpolated from 4 years of

TABLE 2A.3-22

CLIMATOLOGICAL DATA SUMMARY FOR THOMPSON PASS

Location: Latitude 61°07', Longitude 145°44', Altitude 2700 feet

	Temperature (°F)								Precipitation Totals (Inches)										Wind		Mean Number of Days				
	Means			Extremes								Snow and Sleet										Temperatures			
																						Max		Min	
Month	Daily Maximum	Daily Minimum	Monthly	Record Highest	Year	Record Lowest	Year	Mean Degree Days	Mean	Greatest Daily	Year	Mean	Maximum Monthly	Year	Greatest Daily	Year	Greatest Depth on Ground	Year	Mean Hourly Speed MPH	Prevailing Direction	Precipitation .10 Inches or More	70° and Above	32° and Below	32° and Below	0° and Below
[a]	15	15	15	15		15		15	15	15		16	16		16						13	14	14	14	14
J	12.7	1.5	7.1	44	1961	-30	1964		6.90	4.26	1958	71.1	170.2	1958	42.4	1958					10	0	29	30	17
F	17.2	7.0	12.1	48	1968	-28	1968		9.36	5.42	1953	107.5	346.1	1964	49.3	1952					11	0	26	28	9
M	23.6	11.2	17.4	48	1967	-28	1964		7.16	4.32	1963	68.4	133.8	1963	42.5	1962					10	0	25	31	5
A	36.5	21.5	29.0	54	1960	-10	1964		5.99	4.20	1959	57.2	133.4	1959	42.0	1959					8	0	9	28	1
M	40.2	27.0	33.6	62	1953	0	1964		1.87	1.20	1952	15.3	45.9E	1956	9.4	1956						0	1	27	*
J	54.1	36.2	45.2	68	1952	29	1952		1.95	1.15	1952	T	T	1955	T	1955						0	0	8	0
J	57.7	40.7	49.2	75	1952	37	1952		4.03	1.71	1952	0.0	0.0		0.0		No Data	No Data	No Data	No Data		0	5	0	0
A	54.6	41.7	48.2	68	1952	31	1952		4.63	1.40	1953	0.0	0.0		0.0							0	0	2	0
S	46.8	33.5	40.2	58	1953	20	1956		9.08	2.50	1956	8.9	33.8	1956	26.3	1956						0	1	8	0
O	32.3	23.3	27.8	51	1953	-3	1958		10.48	4.80	1965	60.4	126.2	1965	46.0	1956					12	0	11	28	*
N	21.2	5.4	23.3	42	1952	-23	1963		10.09	6.50	1961	89.0	204.8	1952	36.0	1967					13	0	24	29	6
D	13.4	3.5	8.5	42	1961	-39	1964		10.97	6.62	1967	105.0	225.8	1955	62.0	1955					13	0	29	30	14
Anl	34.2	21.1	27.6	75	1952	-39	1964		82.51	6.62	1967	582.8	346.1	1964	62.0	1955					77	0	160	249	52

[a] Period of record, years (through 1969)

*Less than one-half

+ - Also on earlier dates, months, or years

T - Trace, an amount too small to measure

E - Estimated

Note: This is a seasonal station, operated by the State of Alaska Highway Department during winter months. Their purpose is to keep the roads open for travel. Considering the heavy snowfall this is a difficult task. Entries for the months of May through September represent only one to two years data and should not be considered as long term averages.

Source: EDS, 1970

TABLE 2A.3-23

CLIMATOLOGICAL DATA SUMMARY FOR VALDEZ

Location: Latitude 61°08', Longitude 146°15', Altitude 60 feet

Month	Temperatures (°F) Normal Daily Maximum	Temperatures (°F) Normal Daily Minimum	Temperatures (°F) Normal Monthly	Temperatures (°F) Extremes Record Highest	Year	Record Lowest	Year	Normal Degree Days	Precipitation Totals (Inches) Normal Total	Maximum Monthly	Year	Minimum Monthly	Year	Maximum in 24 Hours	Year	Snow and Sleet Mean Total	Snow and Sleet Maximum Monthly	Year	Snow and Sleet Maximum in 24 Hours	Year	Greatest Depth on Ground	Year	Mean Number of Days Precipitation .10 Inch or More	Temperatures Max 70° and Above	Temperatures Max 32° and Below	Temperatures Min 32° and Below	Temperatures Min 0° and Below
[a]	[b]	[b]	[b]	56		56		[b]	[b]	54		54		54		48	48		48				14	48	48	55	55
J	25.3	11.0	18.2	55	1963	-24	1951	1451	5.78	15.17	1949	0.41	1914	3.07	1954	56.3	127.8	1949	32.5	1948	115	1924	9	0	23	31	6
F	29.2	14.3	21.8	59	1923	-28	1947	1210	4.88	16.09	1953	0.23	1950	4.00	1928	47.2	174.5	1928	43.0	1928	120	1924	9	0	17	28	3
M	34.4	17.6	26.2	57	1965	-11	1918	1203	3.70	13.55	1930	0.40	1943+	3.30	1960	36.7	117.1	1930	25.0	1927	132	1928	8	0	10	31	1
A	43.4	26.4	34.9	68	1965	4	1910	903	2.96	10.11	1941	T	1948	2.36	1915	13.1	40.0	1956	17.0	1930	135	1929	8	0	1	26	0
M	51.8	34.5	43.1	78	1910	6	1964	679	3.48	8.12	1956	0.36	1920	1.80	1961+	2.1	22.0	1949	12.0	1949	40	1949	8	*	0	9	0
J	58.9	42.0	50.4	87	1953	27	1961	438	2.61	6.59	1955	0.46	1934	1.66	1914	0.0	0.0		0.0		2	1947	8	1	0	*	0
J	60.1	45.2	52.7	84	1911	33	1957+	381	4.72	11.51	1958	0.88	1916	2.41	1930	T	T	1953+	T	1953+	0		11	2	0	0	0
A	59.8	43.5	51.6	84	1911	29	1913	415	6.48	13.63	1939	0.34	1967	2.97	1932	0.0	0.0		0.0		0		13	1	0	*	0
S	53.6	38.5	46.0	82	1910	14	1946	570	8.38	18.74	1912	0.71	1967	3.71	1949	0.1	4.0	1956	2.0	1956+	1	1956	13	0	0	4	0
O	43.5	31.0	37.2	69	1954	5	1935	862	7.95	17.23	1936	2.22	1947	3.00	1965	8.4	41.0	1956	35.0	1956	35	1956	12	0	1	18	0
N	32.1	20.3	26.2	59	1936	-10	1963	1164	6.27	17.38	1952	0.32	1909	4.30	1956	31.0	131.0	1956	26.0	1956	67	1956	10	0	13	29	1
D	26.2	13.2	19.7	54	1966	-18	1917	1404	5.15	16.66	1928	0.14	1917	5.10	1955	49.6	150.7	1928	30.0	1955	76	1955	10	0	22	31	4
Anl	43.2	28.1	35.7	87	1953	-28	1947	10680	62.37	18.74	1912	T	1948	5.10	1955	244.5	174.5	1928	43.0	1928	135	1929	119	4	87	20.7	15

[a]Period of record, years (through 1967)

[b]Climatological Standard Normals (1931-1960)

+ - Alson on earlier dates, months, or years

*Less than one-half

Source: EDS, 1970

TABLE 2A.3-24

CLIMATOLOGICAL DATA SUMMARY FOR CORDOVA

Location: Latitude 60°32', Longitude 145°45', Altitude 25 feet

	Temperature (°F)								Precipitation Totals (Inches)										Wind		Mean Number of Days				
	Means			Extremes								Snow and Sleet										Temperatures			
																						Max		Min	
Month	Daily Maximum	Daily Minimum	Monthly	Record Highest	Year	Record Lowest	Year	Mean Degree Days	Mean	Greatest Daily	Year	Mean	Maximum Monthly	Year	Greatest Daily	Year	Greatest Depth on Ground	Year	Mean Hourly Speed MPH	Prevailing Direction	Precipitation .10 Inch or More	70° and Above	32° and Below	32° and Below	0° and Below
[a]	9	9	9	9		9			9	9		6	6		6		6				9	9	9	9	9
J	31.9	20.6	26.3	58	1961	-4	1969		10.90	6.00	1958	13.2	32.0	1956	13.0	1963	74	1956			10	0	15	27	1
F	34.8	22.8	28.8	48	1963	-2	1956		8.86	4.30	1957	24.3	39.5	1956	14.0	1956	71	1956			10	0	8	25	*
M	38.8	24.0	31.4	51	1957	-13	1956		9.09	3.39	1961	17.7	48.5	1959	11.0	1959	74	1956			10	0	4	27	1
A	45.3	31.1	38.2	62	1958	18	1965		8.76	4.78	1965	13.2	59.0	1956	9.0	1956	95	1956			10	0	0	19	0
M	52.8	37.3	45.1	73	1969	22	1965		17.49	5.70	1961	T	T	1969	T	1969	32	1956			14	*	0	3	0
J	59.4	44.2	51.8	78	1959	32	1965		7.42	6.18	1965	0.0	0.0		0.0		0				8	2	0	*	0
J	61.0	48.0	54.5	77	1960	35	1964		13.54	9.05	1958	0.0	0.0		0.0		0				12	2	0	0	0
A	61.2	48.0	54.6	81	1957	35	1964		13.12	6.12	1958	0.0	0.0		0.0		0				11	2	0	0	0
S	55.2	43.0	49.1	72	1964	29	1956	No Data	20.39	5.06	1957	T	T	1956	T	1956	0		No Data	No Data	12	*	0	1	0
O	46.5	34.1	40.3	64	1969	16	1957		21.72	8.03	1965	3.6	19.5	1966	12.0	1966	16	1966			17	0	*	12	1
N	38.1	28.3	33.2	55	1957	6	1956		18.79	5.46	1956	11.3	44.0	1956	11.0	1956	31	1956			18	0	5	20	0
D	33.6	21.6	27.6	52	1969	-23	1964		17.60	14.13	1955	33.4	70.5	1957	30.0	1955	57	1955			15	0	13	26	1
Anl	46.6	33.6	40.1	81	1957	-23	1964		167.68	14.13	1955	116.7	70.5	1957	30.0	1955	95	1956			147	6	45	160	4

[a]Period of record, years (through 1969)

*Less than one-half
+ - Also on earlier dates, months, or years
T - Trace, an amount too small to measure
Source: EDS, 1970

TABLE 2A.3-25

LATITUDE 60° 30' N
LONGITUDE 145° 30' W
ELEVATION (ground) 41 FEET

NORMALS, MEANS, AND EXTREMES

CORDOVA, ALASKA
MILE 13 AIRPORT
1963

Month	Temperature: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal degree days	Precipitation: Normal total	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Sleet: Mean total	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)	(b)	(b)	(b)	20		20		(b)	(b)	21		21		20		20	20		20	
J	31.6	14.5	23.1	58	1961	-27	1947	1299	6.10	14.21	1949	0.72	1950	2.66	1948	25.0	64.3	1949	13.7	1949
F	35.2	17.1	26.2	52	1963	-33	1947	1086	4.64	13.22	1953	1.07	1950	3.42	1954	22.5	38.3	1956	13.1	1951
M	38.2	19.9	29.1	52	1954	-24	1956	1113	3.84	10.57	1947	1.03	1943	3.56	1949	24.5	69.7	1962	22.9	1959
A	44.2	28.1	36.2	65	1958	- 9	1944	864	4.32	8.71	1952	0.08	1948	2.80	1956	11.2	61.2	1956	14.0	1956
M	51.7	35.6	43.7	77	1947	20	1949+	660	5.06	10.04	1944	1.91	1957	2.80	1961	1.4	18.5	1949	10.8	1949
J	58.1	42.3	50.2	79	1959	29	1955+	444	3.48	9.47	1959	0.69	1957	2.79	1950	0.0	0.0		0.0	
J	60.3	46.1	53.2	84	1946	34	1954+	366	6.27	17.78	1952	3.02	1946	6.60	1952	0.0	0.0		0.0	
A	60.5	44.2	52.4	80	1957	30	1948	391	8.06	20.25	1942	4.29	1948	3.94	1961	0.0	0.0		0.0	
S	55.0	39.1	47.6	71	1956	20	1956	.522	12.51	27.72	1951	4.32	1955	7.92	1951	T	T	1958+	T	1958+
O	47.7	31.9	39.8	70	1950	11	1945	781	11.90	26.63	1952	5.82	1950	6.29	1952	2.6	12.9	1950	7.2	1953
N	38.5	23.6	31.1	55	1962+	-17	1948	1017	8.02	21.13	1952	1.46	1955	4.48	1951	10.3	47.9	1956	12.7	1948
D	32.9	18.2	25.6	50	1962	-19	1948	1221	6.78	20.78	1943	2.19	1942	4.66	1955	27.2	70.8	1957	18.1	1957
YR	46.2	30.1	38.2	84	JUL. 1946	-33	FEB. 1947	9764	80.98	27.72	SEP. 1951	0.08	APR. 1948	7.92	SEP. 1951	124.7	70.8	DEC. 1957	22.9	MAR. 1959

Month	Relative humidity: 2:00 A.M. AST	8:00 A.M. AST	2:00 P.M. AST	8:00 P.M. AST	Wind: Mean hourly speed	Prevailing direction	Fastest mile: Speed	Direction	Year	Pct. of possible sunshine	Mean sky cover sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Sleet 1.0 inch or more	Thunderstorms	Heavy fog	Temperatures: Max.: 70° and above	Max.: 32° and below	Min.: 32° and below	Min.: 0° and below
(a)	17	18	18	18	14	19					18	18	18	18	20	18	18	18	18	18	18	18
J	83	82	81	83	4.6	E					7.3	6	5	20	17	7	0	2	0	14	29	6
F	84	83	77	82	4.8	E					7.3	6	4	18	15	7	0	1	0	8	26	4
M	84	82	74	79	5.0	E					7.1	7	5	19	15	6	0	1	0	5	29	2
A	86	78	70	80	5.4	ESE					7.4	6	4	20	15	3	0	1	0	*	24	0
M	90	79	72	80	5.3	ESE					8.3	3	4	24	19	*	0	1	*	0	10	0
J	89	81	76	81	4.7	SW					8.4	2	5	23	17	0	*	1	2	0	1	0
J	92	96	80	84	4.1	E					8.7	2	4	25	19	0	*	1	3	0	0	0
A	93	88	79	85	3.8	E					8.2	3	5	23	19	0	*	2	3	0	*	0
S	91	88	78	86	5.1	E					8.3	3	4	23	20	0	*	1	*	0	5	0
O	88	88	77	83	5.6	E					8.0	4	4	23	21	1	*	*	*	*	16	0
N	87	87	83	85	5.3	E					7.9	4	4	22	18	3	*	*	0	7	23	1
D	85	85	84	85	5.1	E					7.9	3	4	22	19	8	*	1	0	12	27	5
YR	88	84	78	83	4.9	E					7.9	51	52	262	215	35	2	12	8	46	139	18

Data for July-December 1942 considered in extracting maximum and minimum monthly precipitation extremes. Data for January-May 1955 and June-December 1956 considered in computing means of 2:00 a.m. Relative Humidity, Mean Hourly Wind Speed and in extracting Prevailing Wind Directions.
Means and extremes in the above table are from the existing location. Annual extremes have been exceeded at prior locations as follows: Highest temperature 87 in July 1914; maximum monthly precipitation 49.63 in September 1912; minimum monthly precipitation 0.04 in December 1933; maximum monthly snowfall 98.5 in January 1910.

(a) Length of record, years.
(b) Climatological standard normals based on the period 1931-1960.

Source: EDS, 1941-1973

TABLE 2A.3-26

EXTRAPOLATED TEMPERATURE DATA (°F) LNG PLANT SITE

	Normals				Extremes		Mean Number of Days			
							Max		Min	
Month	Max	Min	Avg	HDD	Max	Min	≥70°	≤32°	≤32°	≤0°
January	31	21	26	1209	58	-4	0	15	27	1
February	34	22	28	1036	48	-2	0	8	25	*
March	39	25	32	1023	51	-13	0	4	27	1
April	46	31	38	795	62	18	0	0	19	0
May	53	37	45	620	73	22	*	0	3	0
June	58	43	51	435	78	32	2	0	*	0
July	61	48	54	326	80	35	2	0	0	0
August	61	48	54	326	81	35	2	0	0	0
September	56	42	49	480	72	29	*	0	1	0
October	47	34	41	760	64	16	0	*	12	0
November	39	28	34	945	55	6	0	5	20	0
December	33	23	28	1147	52	-23	0	13	26	1
Annual	47	34	40	9100	81	-23	6	45	160	4

* Means less than one-half

Source: EDS, 1970

TABLE 2A.3-27

EXTRAPOLATED PRECIPITATION DATA LNG PLANT SITE

	Rain				Snow				Mean Number of Days	
Month	Normal Total	Max Monthly	Min Monthly	Max 24 Hour	Mean Total	Max Monthly	Max 24 Hour	Greatest Depth	Precip ≥0.01 Inch	Snow ≥1.0 Inch
January	9.60	22	2	4.20	25	64	14	74	17	7
February	9.00	18	4	4.20	23	40	14	71	15	7
March	7.92	21	2	4.20	25	70	23	74	15	6
April	7.44	23	*	3.90	11	61	14	95	15	3
May	8.16	19	3	4.30	1	19	11	32	19	*
June	6.00	12	1	4.40	0	0	0	0	17	0
July	7.68	19	3	8.40	0	0	0	0	19	0
August	10.20	23	4	5.30	0	0	0	0	19	0
September	14.40	26	7	7.80	T	T	T	0	20	0
October	15.84	33	8	7.70	3	20	12	16	21	1
November	12.12	25	2	5.40	10	48	13	31	18	3
December	11.64	31	4	8.80	27	71	30	57	19	8
Annual	120.00	33	*	8.80	125	71	30	95	215	35

* Less than one-half
T = Trace

Source: EDS, 1941 - 1973; 1970

TABLE 2A.3-28

PERCENT FREQUENCY OF WIND BY SPEED (KNOTS) AND DIRECTION (DEGREES)
LNG PLANT SITE, 1959 - 1962 (ANNUAL)

Speed	Wind Direction												
	0-2	3-5	6-8	9-11	12-14	15-17	18-20	21-23	24-26	27-29	30-32	33-35	TOTAL
0-10	2.9	5.9	6.2	4.4	2.8	1.7	2.7	2.0	1.7	2.6	2.5	2.1	37.5
10-20	1.8	6.2	10.1	5.2	3.3	1.5	2.1	1.6	1.7	2.8	1.5	2.0	39.8
20-30	.1	2.2	5.9	3.4	1.7	.3	.2	.1	.1	.5	.2	.4	15.2
30-40	0.0	.3	2.1	2.4	.4	.0	0.0	0.0	0.0	.0	.0	.0	5.2
40-50	0.0	.0	.5	1.0	.1	.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
50-60	0.0	0.0	.1	.3	.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.5
60-70	0.0	0.0	.0	.1	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1
TOTAL	4.7	14.5	25.0	16.8	8.4	3.6	5.1	3.7	3.5	5.9	4.2	4.5	5631

the 6-hourly weather reports for areas surrounding Gravina, taken between January 1959 through December 1963.

This 4-year data base has also been used to determine the recurrence interval of extreme winds. The following table gives several extrapolated values:

Recurrence Interval (yrs)	1-Hour Average Speed (kts)	1-Minute Average Speed (kts)
25	88	118
50	90	122
100	92	125

The analysis indicates that these winds will blow from 060° to 130°.

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Section 2A.4
Water Resources

SECTION 2A.4 - WATER RESOURCES

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2A.4 WATER RESOURCES

This section discusses surface water and groundwater hydrology, existing water quality, and present water use along the proposed Alaskan Gas Pipeline route, as well as at the LNG Plant site.

The discussion of surface water hydrology includes a general summary of existing conditions and available, quantitative information on average and extreme stream flows. Also presented is a discussion of existing hydrologic hazards that might affect the proposed Alaskan Gas Pipeline and LNG Plant.

Streamflow characteristics were derived primarily from published USGS records for the State of Alaska. Some data for water year 1973 (October 1972 - September 1973) were used, but they were considered provisional since they were unpublished. Where streamflow data did not exist, extrapolated data from areas similar to those under study were used. Stream flows are reported in units of cubic feet per second (cfs), or cubic feet per second per square mile of contributing drainage basin (cfsm).

Hydrologic hazards are identified on a regional or basin-wide basis. In general, such hazards include icings, outburst flooding from glacier-dammed lakes, ice-jam flooding, and scour associated with these events.

The term "icing" describes a variety of phenomena of arctic or subarctic regions. In this Report, icing is defined as a mass of surface ice formed by successive freezing of sheets of water that may seep from the ground, from a river, or from a spring (Carey, 1973). River icings are formed from waters of the river itself. This type of icing generally builds up over existing river ice, and may grow to exceed the limits of the river channel, extending into the flood plain. Ground icings are formed on a ground surface as a result of some obstruction to normal groundwater flow. Spring icings are simply formed by water flowing from a spring. Icings may damage or prevent access to roads, bridges, buildings, and other structures.

Lakes may exist behind, on top of, within, or beneath glaciers. Some of these lakes drain occasionally, causing floods of exceptionally large magnitudes. Some of these "outburst floods" occur at regular periods (e.g., once every three years), while others may occur without warning at any time of the year. All glacier-fed streams have the potential to outburst flood, even though no lake is visible on the glacier surface, or no history of previous floods exists.

Ice jams and flooding may also occur in major rivers in Alaska in the spring, since river ice (usually several feet thick) does not always break up uniformly and may accumulate in unfrozen reaches in areas of constrictions, or in the shallows.

Channel scour, shifting of stream channels and lateral erosion occur continuously throughout a flood plain; however, these processes can be greatly accelerated as a result of the previously-mentioned hydrologic extremes. Icings or ice jams may temporarily block main channels of flow, causing new channels to form elsewhere on the flood plain. Major floods, including outburst floods, may cause channel scour and subsequent deposition to unusual depths. In many streams, bed materials are more resistant to scour than are bank areas, especially when the beds are protected by a channel armor layer. This is especially true in meandering streams. During floods, water tends to erode upstream-facing margins of meanders and deposit materials on the opposite margins. Occasionally, flows breach the necks of meanders and form new channels.

Groundwater conditions along the route of the proposed Alaskan Gas Pipeline are highly variable because of the inconsistencies in soils, topography, precipitation, and permafrost. The groundwater potential has not been explored or developed in most areas along the pipeline route, except in the Tanana River Basin near Fairbanks. For these reasons, the following discussion of groundwater is presented on a regional basis. Also, characteristics of groundwater hydrology in areas of continuous and discontinuous permafrost will be discussed, since conditions in these areas are unique when compared to conditions in areas where permafrost is absent.

Prior to oil and gas discoveries at Prudhoe Bay, little water quality data had been collected, particularly north of Fairbanks. But in 1969, the U.S. Environmental Protection Agency (EPA) and USGS began gathering chemical-physical data from a number of streams in the Utility Corridor through which the trans-Alaska oil pipeline and the proposed Alaskan Gas Pipeline will pass. The EPA information remains unpublished, though permission has been granted to use such data from selected streams to help characterize water quality along the route of the proposed gas pipeline. Few data exist for the area between the Lowe River and Gravina.

The route of the proposed pipeline comprises numerous aquatic systems, from ponds and muskeg to deep mountain lakes, from small intermittent streams to large rivers. The water quality characteristics of these waters are herein described using existing literature, and since data have not been collected for all water bodies along the route, or at the LNG Plant site, inferences have been drawn to characterize certain types of water bodies. For example, streams are classified as to their water quality as: (a) clear water streams, (b) brown water streams, and (c) glacial streams. Brown water streams drain boggy areas and have relatively high color because of organic leachates. Glacial streams carry relatively large suspended sediment loads during summer, but normally become clear water streams during winter.

Because of the wide variety of geologic, topographic, and climatological conditions along the route of the proposed pipeline, the water resources have been arbitrarily separated into four drainage areas (Figure 2A.4-1). They are (from north to south):

(1) Arctic Slope Drainage,
(2) Yukon River Drainage,
(3) Copper River Drainage, and
(4) Prince William Sound Drainage.

Major river basins (greater than 1000 square miles) traversed by the proposed pipeline are presented in Table 2A.4-1.

Approximately 532 streams will be crossed by the pipeline, one-third of which flow intermittently.

2A.4.1 Arctic Slope Drainage

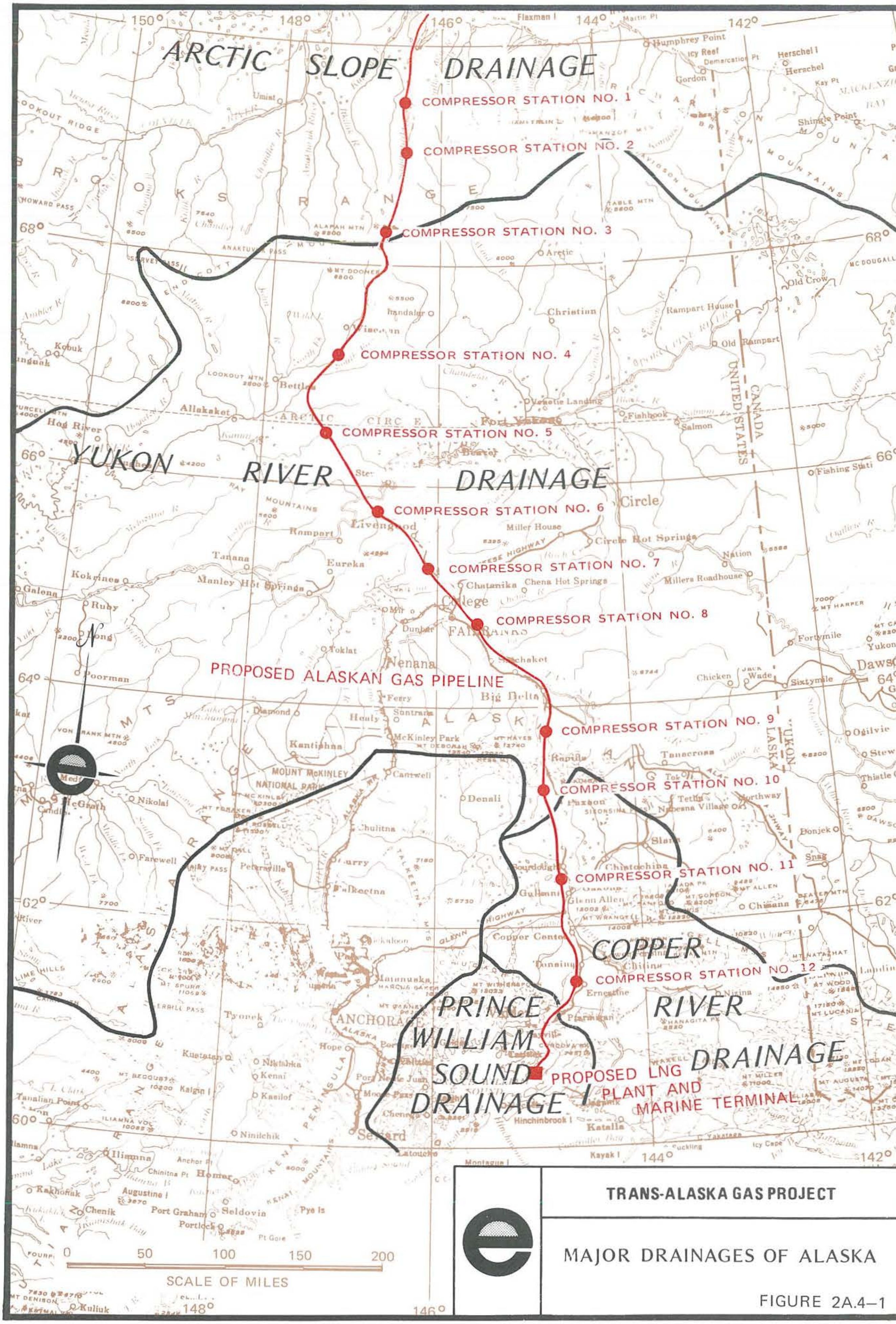
The Arctic Slope Drainage is bounded by the Arctic Ocean and Beaufort Sea on the north, and by the Brooks Range on the south. It is divided into: (a) the Arctic Coastal Plain, (b) Arctic Foothills, and (c) Brooks Range (Wahrhaftig, 1965).

The Arctic Coastal Plain is dominated by thousands of shallow lakes and ponds, a number of wide, braided rivers, and many small streams that meander extensively. In spring the Plain transforms into a vast marsh, with only isolated spots above water. The Foothills contain swift, braided rivers, and a few thaw and morainal lakes. Rock-basin lakes are scattered through the mountains. The major rivers of the Arctic Slope Drainage originate in the Brooks Range, and flow generally north.

The proposed pipeline will cross parts of four drainage basins within the Arctic Slope Drainage: (a) the Putuligayuk River, (b) the Kuparuk River, (c) the Colville River, and (d) the Sagavanirktok (Sag) River (Figure 2A.4-2). There will be about 135 streams crossed, including a number of intermittent watercourses.

2A.4.1.1 Surface Water Hydrology and Hydrologic Hazards

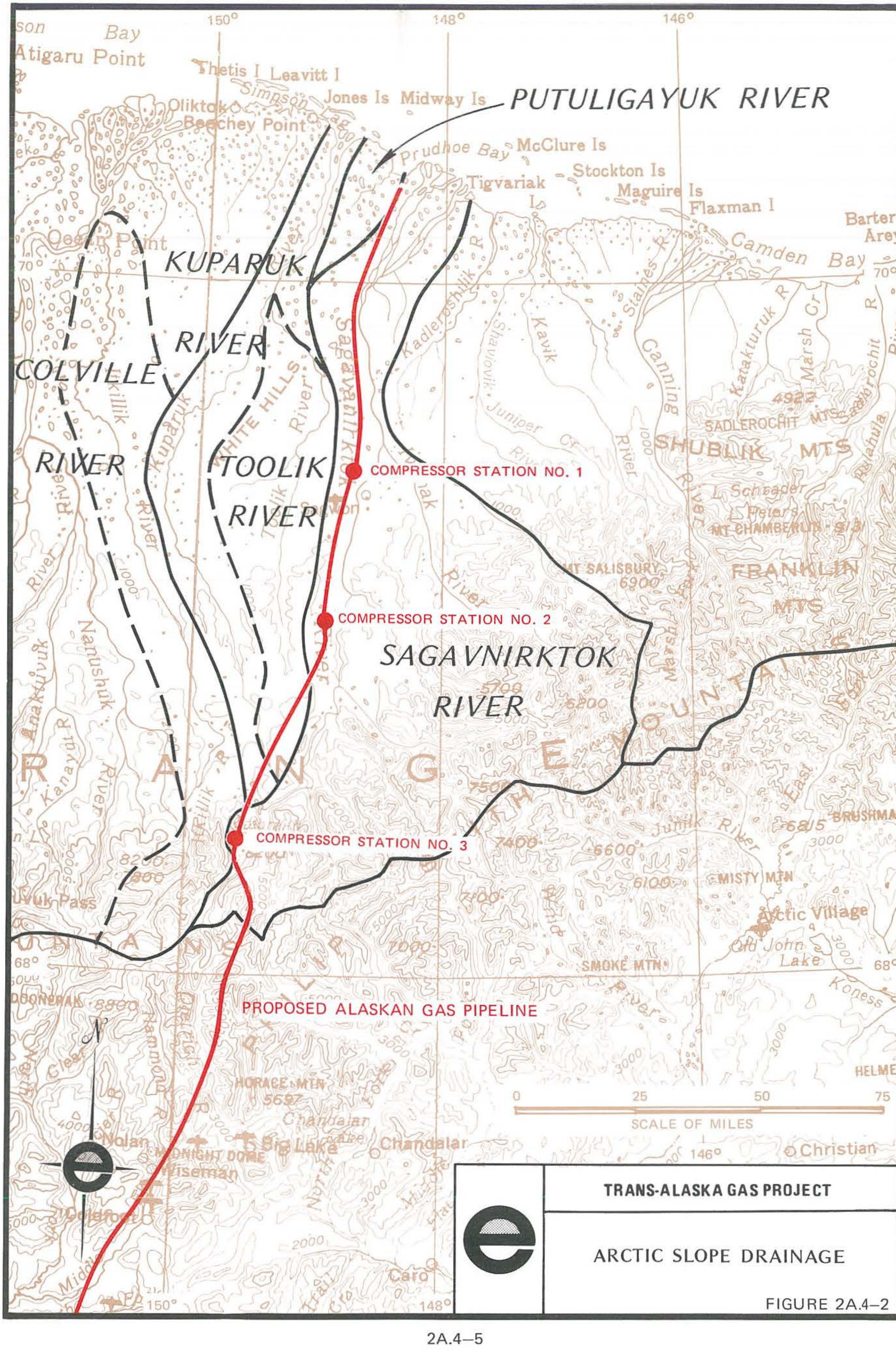
The hydrology of the Arctic Slope Drainage is dominated by high flow in the spring, a gradual decrease in flow throughout the summer, and a virtual cessation of flow during the winter. The magnitude of spring flow depends primarily on the amount and timing of snow melt. Normally, river breakup occurs first in the Arctic Foothills in early to mid-May, then progresses downstream, reaching the Coastal Plain by late May or early June. During the initial stages of breakup, the active layer is generally frozen to the surface; consequently, most water released by snow melt reaches the river channels over the surface.



TRANS-ALASKA GAS PROJECT

MAJOR DRAINAGES OF ALASKA

FIGURE 2A.4–1



TRANS-ALASKA GAS PROJECT

ARCTIC SLOPE DRAINAGE

FIGURE 2A.4–2

TABLE 2A.4-1

MAJOR DRAINAGE BASINS TRAVERSED
BY THE PROPOSED ALASKAN GAS PIPELINE

Drainage	Total Drainage Area (sq mi)
Arctic Slope Drainage	
Sagavanirktok River	5,360
Kuparuk River	3,560
Toolik River	1,140
Colville River	23,500
Itkillik River	1,800
Yukon River Drainage	
Yukon River	327,600
Chandalar River	9,900
North Fork Chandalar River	1,500
Koyukuk River	32,400
Middle Fork Koyukuk River	1,800
South Fork Koyukuk River	1,500
Kanuti River	3,000
Dall River	1,000
Hess Creek	1,200
Tanana River	44,000
Tolovana River	2,500
Chatanika River	1,400
Chena River	2,000
Salcha River	2,170
Delta River	1,500
Copper River Drainage	
Copper River	24,400
Gulkana River	1,980
Tazlina River	2,450
Prince William Sound Drainage	
(none > 1000 sq mi)	

During early breakup flooding, bottom-fast ice protects the river channel from scour. As flow increases, this ice is lifted and carried downstream. During the recession of the spring flood, ice is likely to become stranded, thus increasing the likelihood of ice jamming, localized flooding, and erosion.

Flows generally decline throughout the summer, though some fluctuations occur from rainstorms. Stream responses from summer storms vary widely because of intricate tundra relief. In a study of a small watershed in the Coastal Plain (Brown, et al., 1968), run-off was found to vary from 1 percent to 70 percent of the total precipitation for individual summer storms. Most streams in the region freeze solid during the winter months, and surface flow ceases in all but the largest.

Lakes are especially prevalent in the Coastal Plain, and in some regions may account for 80 percent of the total surface area (Brown, et al., 1968). These lakes generally range from 2 to 20 feet in depth, and are rectangular or oval in shape. Because of prevailing winds, the lakes exhibit an orientation of their longitudinal axis of approximately N 15° W (Wahrhaftig, 1965). During spring breakup, such lakes act as natural catchments for melt water, and often flood beyond their normal shorelines. Lake levels decrease following breakup, often to levels below their outlet elevation, and may become stagnant.

Springs are reported in the Foothills in parts of the Sag River Basin. Many of these springs produce flow year-round and contribute to icing conditions during the winter months. River icing conditions also are reported for most of the length of the Sag River, as well as for portions of the Kuparuk River (USGS, 1969a).

Several years' streamflow data are available from USGS for most major basins in the Arctic Slope Drainage to be traversed by the proposed pipeline. A summary of these data are presented in Table 2A.4-2. Other reports are available for nearby regions, from which regional variations of flow may be derived.

Studies of a small glacial stream in the eastern Brooks Range indicate mean annual run-off rates of 0.8 cfsm (Wendler, et al., 1972). Stream-flow records for the Putuligayuk, Kuparuk, and Sagavanirktok indicate mean annual flow rates of 0.2, 0.5 and 0.8 cfsm, respectively (USGS, 1972, 1974a, 1974b). These rates reflect flow conditions which exist, respectively, in the Coastal Plain, Foothills, and Brooks Range. The Colville River, which receives flow from all three regions of the Arctic Slope Drainage, is estimated to produce a mean annual run-off of 0.5 cfsm. The above data are in general agreement with mean annual flow rates of less than 0.5 cfsm to near 2.0 cfsm (Feulner, et al., 1971). It has been estimated that approximately 50 percent of the total annual precipitation ends up as surface run-off (Brown, et al., 1968).

Available data for the Arctic Slope Drainage indicate the mean annual daily maximum discharge rates range from near 30 cfsm in the Coastal Plain to near 10 cfsm in the mountains. Mean annual peak run-off rates reported are as much as 50 cfsm in the region. The mean annual low flow for the entire region is reported at less than 0.1 cfsm

TABLE 2A.4-2

SUMMARY OF SURFACE WATER DATA FOR SELECTED STREAMS
ALONG THE PROPOSED ALASKAN GAS PIPELINE
ARCTIC SLOPE DRAINAGE

Stream	Drainage Area (sq mi)	Period of Record (years)	Average Discharge (cfs)	Maximum Flow [1/] Date	Maximum Flow [1/] Discharge (cfs)	Minimum Flow [2/] Date	Minimum Flow [2/] Discharge (cfs)
Putuligayuk River near Prudhoe Bay	176	2(1971-72)	43	Jun 6, 1971	4,980 [3/]	No flow during some winter months	
Kuparuk River near Deadhorse	3130	2(1972-73)	1630	Jun 8, 1973	77,200 [3/]	Jan 1/May 3-72 Dec 26/May 31-73	10
Sagavanirktok River near Sagwon	2208	2(1971-72)	1760	Jun 8, 1971	22,000 [3/]	Mar 21/May 14-71	1.6

1/ Maximum peak flow
2/ Minimum daily flow
3/ Maximum daily flow

Source: USGS, 1972, 1974a, and 1974b

(Feulner, et al., 1971). Most streams in the region, however, have no surface flow during at least part of the winter.

Discharges from springs on the Arctic Slope Drainage vary considerably with location and, to a lesser extent, with season. Discharges from major springs flowing into the Ivishak River, a tributary of the Sag River, are reported to range from 4.2 cfs to 36.5 cfs (Childers, et al., 1973).

The erosion and deposition of sediments in the Arctic Slope Drainage has not been studied extensively. It is, however, suspected that these processes will occur during periods of peak flow, primarily during spring breakup. As an example, it was estimated that in 1962 approximately 75 percent of the annual sediment load of the Colville River was transported during a three-week period in June (Walker, 1973). Once the bottom-fast ice is lifted off the channel, the bed becomes susceptible to scour. Lateral erosion and channel shifting are especially noticeable in the larger rivers. Many of the rivers deposit their sediments to form deltas where they flow into lagoons or bays in the Arctic Ocean. The largest of these deltas is the more than 200-square-mile Colville River delta (Walker, 1973).

2A.4.1.2 Groundwater Hydrology

The Arctic Slope Drainage is an area of continuous permafrost, which may extend to great depths beneath the surface. Groundwater may occur above, within, or beneath the permafrost.

Intersticial water may exist within permafrost if the water is saline, even though by definition the soil is permafrost. Prediction of the occurrence of this water is difficult.

In areas of continuous permafrost, groundwater is usually found beneath it. It may or may not be brackish, depending upon availability of freshwater recharge, groundwater flow rates, and other factors. Where permafrost extends to great depths, groundwater is usually saline, or high in mineral content, since permafrost tends to form an impermeable barrier to prevent fresh water from percolating downward. In many cases, water from wells drilled in permafrost flows under artesian pressure, since permafrost confines the aquifer in much the same way an impermeable rock or soil stratum does. Artesian water is only found in comparatively young sedimentary formations (Jurassic and Tertiary), and in volcanic formations of Jurassic, Cretaceous, and Tertiary age (Chernyshey, 1928).

Where permafrost is discontinuous, free water may occur as entrapped water, as artesian or nonartesian water beneath the permafrost, and between permafrost areas as either artesian or nonartesian water. Water in holes drilled through the permafrost will usually rise to the level of the water table in the area where permafrost is absent.

Depending on the depth to the top of the permafrost, and upon drainage and supply conditions, groundwater that does not freeze during the winter may occur above the permafrost layer, especially if the permafrost is degrading such that the permafrost table becomes deeper with time. Where drainage is impeded by slope and soil conditions during the summer months, a perched water table at or near the ground surface may be created if the permafrost is close to the ground surface, thereby creating marshy or swampy conditions such as are found on the North Slope.

Groundwater in permafrost regions may also be located under lakes and rivers deep enough that they do not freeze solid each winter. Groundwater resources have not been developed or explored to any significant extent in the Arctic Slope Drainage, or in the vicinity of the pipeline route. The entire region, except where underlain by deep lakes or rivers, is underlain by continuous permafrost. Underneath the rivers, shallow aquifers may exist. The principal recharge source then would be the river itself, and the direction of groundwater flow would be in the general direction of the regional slope.

At Umiat on the Colville River (to the west of the pipeline route), oil test wells within 1750 feet of the river revealed that permafrost extended up to 800 feet deep into bedrock. Water-bearing, unfrozen sandy gravel was found within the terrace deposits. Large supplies of groundwater are available from unfrozen alluvium beneath the river; smaller quantities are available from alluvium beneath the lakes that do not freeze to the bottom in winter and from local unfrozen zones in the terrace alluvium near the river (Williams, 1970).

2A.4.1.3 Water Quality

The principal parameters of water quality include dissolved oxygen, pH, temperature, nutrients, suspended solids, turbidity, and color. Ranges and seasonal variations of these parameters are discussed for various water bodies.

Topographic and climatologic conditions greatly affect the physical and chemical water quality characteristics of tundra lakes and ponds. An ice cover isolates these water bodies from outside influences for nine or ten months of the year. Lakes and ponds usually freeze over by mid- to late-September, remaining so until late June or July (Brewer, 1958; Sater, 1969); shallow water bodies freeze solid each winter. Seasonal temperature variation was described by Brewer (1958) in a study of Imikpuk Lake near Barrow. Immediately after freeze-up, the water temperature rose to about 2°C, probably because of radiant energy. The temperature dropped to about 0°C after the first snowfall, then rose slightly to about 1.5°C, apparently because of conduction from the mud bottom. During the winter the water cooled to between 0 and 0.6°C. The maximum water temperature during the summer varied from 8 to 12°C. Shallow tundra lakes may reach 15°C, and ponds may reach 18°C (Hobbie, 1973) at the height of the warming period. The maximum temperatures of mountain lakes are about 10 to 12°C (Howard & Prescott, 1971), and most deep lakes will warm to 6 to 8°C in the average summer (Hobbie, 1973).

Arctic lakes are normally at, or near, complete saturation of dissolved oxygen during the open water season and in the fall (Howard & Prescott, 1971). This is due to the low level of biological activity (Sater, 1969). From mid-winter to breakup, dissolved oxygen decreases, often to levels less than 5 mg/l (Howard & Prescott, 1971); severe deoxygenation may take place under ice so that some waters become anaerobic (Hobbie, 1973).

In general, the fresh waters of the North Slope uninfluenced by the ocean are dilute calcium bicarbonate waters (Kalff, 1968). During summer, lakes and ponds near the coast have higher salt levels than those farther inland, since salt spray is delivered inland by storms (Howard & Prescott, 1971). Salt concentrations also fluctuate seasonally. Low dissolved solids concentrations in tundra ponds and lakes occur during breakup (Sater, 1969). Salts in ponds and small lakes become somewhat concentrated during summer, owing to evaporation (Hobbie, 1973), and become more concentrated during winter, largely because of solids rejection during freezing (Sater, 1969; Hobbie, 1973). The concentrations of inorganic ions (except nutrients) in North Slope fresh waters is similar to the concentrations in temperate waters (Hobbie, 1973). In two tundra ponds studied in the summer of 1964 by Kalff (1968), conductivity ranged from 132 to 248 μmhos/cm at 25°C (standard reporting temperature), and from 126 to 273 μmhos/cm at 25°C in six lakes. Conductivity would have undoubtedly been higher if measured under the ice during winter.

In ponds and lakes, pH generally ranges from slightly below neutral to about 8.0 (Howard & Prescott, 1971). Kalff (1968) measured pH ranges of 6.7 to 8.4 in six lakes, and 6.7 to 7.2 in two ponds. Alexander and Coulon (1973), in a study of Lake Ikroavik (4-1/2 miles southeast of Barrow), measured a pH range of 6.3 to 6.9 during the summers of 1970 and 1971.

Nutrients in arctic waters are present in small quantities (Sater, 1969; Hobbie, 1973). Phosphate concentrations are low in lakes and ponds (Barsdate, 1971; Hobbie, 1973), whereas nitrate concentrations are low in lakes and high in ponds (Hobbie, 1973). Although tundra waters have low nutrient concentrations, the levels are similar to levels found in uncontaminated surface waters of temperate regions (Kalff, 1968). In a study of six lakes and two ponds during the summer of 1964, Kalff (1968) reported phosphate (PO_4) as ranging from 0.002 to 0.018 mg/l in lakes and from 0.002 to 0.019 mg/l in ponds. In the same study, nitrate (NO_3) ranged from less than 0.01 to 0.02 mg/l in lakes and from 0.05 to 0.17 mg/l in ponds. Barsdate (1971) reported that nitrate ranged from less than 1 μg/l to 90 μg/l in three ponds studied during the summers of 1970 and 1971.

Snow cover limits light to arctic waters during winter, and turbidity and color limit it during summer. Wind mixing keeps particulates suspended in ponds and shallow lakes (Sater, 1969; Hobbie, 1973), and deeper lakes remain relatively turbid owing to glacial flour brought in by glacial streams, or by streams passing through morainic material (Hobbie, 1973).

Tundra water color is a result of the leaching of organic material, which is enhanced by poor drainage on the Coastal Plain. Also, the bottom sediments of tundra ponds are highly organic (Hobbie, 1971). Livingstone (1963) measured color as high as 250 platinum-cobalt (Pt) units in small tundra pools, and Kalff (1968) measured a color range of 20 to 30 Pt units in six lakes, but noted that lakes usually contain 10 to 30 Pt units of color.

Water quality characteristics of sampled streams in the Arctic Slope Drainage are presented in Table 2A.4-3. The Sag River represents a clear water stream, although it reveals minor glacial influence. Happy Valley Creek is an example of a brown water stream, and Chamberlin Creek is a glacial stream. Chamberlin Creek is outside the route of the proposed gas pipeline, but is presented since it is the only glacial stream in the Arctic Slope Drainage for which water quality data have been obtained. Though a number of tributaries of the Atigun River are glacial streams, no quality data exist for them.

The above streams exhibit good water quality. The pH of the Sag River is generally between 7.5 and 8.0, whereas in Happy Valley Creek it is usually close to neutral. Chamberlin Creek had a pH of 6.5 to 6.6 in the summer of 1958 (Rainwater & Guy, 1961).

An annual temperature range of 0 to 17°C has been measured for the above streams. The maximum temperatures are 1°C in Chamberlin Creek (Rainwater & Guy, 1961), 8°C in Happy Valley Creek (EPA, 1973), and 17°C in the Sag River (USGS, 1972). Dissolved oxygen usually remains high in the Sag and in Happy Valley Creek because of relatively low temperatures and biological activity.

Nutrients are generally low in arctic streams. According to Hobbie (1973), phosphorous concentrations are always low, but nitrate may be high. Nitrate concentrations are usually lower than 0.20 mg/l in the Sag; nitrate was absent from Chamberlin Creek during the study by Rainwater and Guy (1961).

The amounts of solids vary considerably between glacial and nonglacial streams. Conductivity is low in Chamberlin Creek, but high in the Sag River. Suspended solids follow the opposite trend, since glacial streams transport larger sediment loads than do nonglacial streams. The latter generally transport less than 100 mg/l of suspended sediment, with the highest concentration occurring during spring breakup or during periods of heavy rainfall (Feulner, et al., 1971). Glacial streams transport their highest sediment loads in mid- to late-summer at the height of the melt season. Chamberlin Creek, for example, had a suspended sediment concentration of 2820 mg/l on August 5, 1958 (Rainwater & Guy, 1961). Turbidity in glacial and nonglacial streams varies the same as suspended sediment. Table 2A.4-3 shows turbidity is high in Chamberlin Creek during the summer. The low value (20 JTU) in August is undoubtedly a result of freezing weather reducing glacial thaw. Turbidity in nonglacial streams of the Arctic Slope Drainage can be expected to be less than 70 JTU (Jackson Turbidity Units).

TABLE 2A.4-3

WATER QUALITY OF THREE STREAMS IN THE ARCTIC SLOPE DRAINAGE

Sample Date	Temp. °C	pH	Dissolved Oxygen mg/l	Dissolved Oxygen % Sat.	Conductivity, μmhos at 25°C	Nitrate, NO_3-N mg/l	Color, Pt Units	Suspend. Solids, mg/l	Turbidity, JTU	Source
Sagavanirktok River Near Prudhoe Bay (LAT 70°11'40", LONG 148°06'40")										
05/07/69	0.2	--	--	--	1604	1.24	5	--	--	USGS, 1971c
Sagavanirktok River at Sagwon (LAT 69°22'00", LONG 148°43'30")										
05/02/69	0.2	8.0	--	--	905	0.00	5	--	--	USGS, 1971c
08/14/70	13.0	8.1	--	--	170	0.09	0	--	--	USGS, 1971d
09/03/70	5.0	8.0	--	--	188	0.05	0	4	--	USGS, 1971d
09/06/70	--	8.0	--	--	219	0.05	5	--	--	USGS, 1971d
Sagavanirktok River Near Sagwon (LAT 69°05'20", LONG 148°45'10")										
11/15/70	0.0	7.3	9.0	63	190	--	--	--	--	N&K, 1973 1/
11/15/70	--	8.1	--	--	230	0.16	0	--	--	USGS, 1972
03/17/71	--	8.3	--	--	291	0.07	10	--	--	USGS, 1972
04/17/71	0.5	7.9	--	--	298	0.20	--	--	--	USGS, 1972
06/05/71	8.0	7.6	--	--	122	0.05	0	76	--	USGS, 1972
06/05/71	8.0	7.8	11.8	103	120	--	--	--	--	N&K, 1973
08/12/71	--	8.3	--	--	217	0.00	10	--	--	USGS, 1972
08/12/71	5.6	8.1	11.2	92	50	--	--	--	--	N&K, 1973
09/09/71	2.0	8.1	--	--	213	0.05	0	3	--	USGS, 1972
10/16/71	0.0	8.3	13.8	97	270	--	--	--	--	N&K, 1973
03/17/72	0.5	8.0	8.4	--	270	--	--	--	--	N&K, 1973
06/22/72	9.0	8.4	11.0	97	140	--	--	--	--	N&K, 1973

1/ Nauman and Kernodle

TABLE 2A.4-3 (Continued)

Sample Date	Temp. °C	pH	Dissolved Oxygen mg/l	Dissolved Oxygen % Sat.	Conductivity, μmhos at 25°C	Nitrate, NO_3-N mg/l	Color, Pt Units	Suspend. Solids, mg/l	Turbidity, JTU	Source
Happy Valley Creek (LAT 69°09'05", LONG 148°51'00")										
08/13/71	6.1	7.2	11.2	93	<50	--	--	--	--	N&K, 1973
10/15/71	0.0	7.3	13.3	94	60	--	--	--	--	N&K, 1973
06/21/72	10.7	7.0	10.2	94	21	--	--	--	--	N&K, 1973
08/13/72	9.3	6.8	10.6	94	21	--	--	--	--	N&K, 1973
09/08/72	5.3	6.9	11.7	87	38	--	--	--	--	N&K, 1973
Chamberlin Creek (800 feet downstream from Chamberlin Glacier)										
07/07/58	--	--	--	--	12	--	--	265	--	R&G, 1961 2/
07/14/58	--	--	--	--	11	--	--	616	--	R&G, 1961
07/28/58	--	--	--	--	12	--	--	758	--	R&G, 1961
08/03/58	--	--	--	--	15	--	--	84	--	R&G, 1961
08/10/58	1	--	--	--	14	--	--	85	80	R&G, 1961
08/17/58	1	--	--	--	20	--	--	131	150	R&G, 1961
08/26/58	1	--	--	--	24	--	--	60	70	R&G, 1961
08/28/58	--	--	--	--	60	--	--	2	20	R&G, 1961

2/ Rainwater and Guy

The quality of groundwater in the Arctic Slope Drainage is probably best in alluvium beneath rivers. Shallow groundwater in these areas is of the calcium bicarbonate type, usually with less than 250 mg/l of dissolved solids. Dissolved solids probably become more concentrated with depth. Formation tests of a well between Umiat Lake and the Colville River showed an increase in dissolved solids and chloride concentrations with depth. The water contained 1031 mg/l dissolved solids and 173 mg/l chloride between 102 and 345 feet, but contained 3188 mg/l dissolved solids and 1176 mg/l chloride at a depth of 6212 feet (Williams, 1970). Saline groundwater, mainly of the sodium chloride type, is common below permafrost on the Coastal Plain, Brackish or saline water occurs at great depth in the Foothills (Williams, 1970). Groundwater beneath lakes in the Coastal Plain may contain dissolved organic material (Williams, 1970). The temperature of groundwater in the Arctic Slope Drainage rarely exceeds 1 to 1.5°C.

2A.4.1.4 Water Use and Waste Disposal

Until recently, water usage and waste disposal in the Arctic Slope Drainage were attributed to a few scattered villages and small scientific and geological exploratory installations. Surface supplies (lakes and streams during summer, snow during winter) were relied upon for water, and wastes were discarded on the surface.

Since the discovery of oil and gas at Prudhoe Bay, a number of work camps have been established. Water is still obtained from surface supplies, and is distributed by truck. One company has installed an infiltration gallery in the Sag River to supply its main camps, though distribution to other camps is still by truck. At one drilling camp studied by Damron (1972), the average usage was 35 gallons per capita per day (gpcpd), and at the main camp the average water usage was 53 gpcpd. Wastes from the main camps were treated by either extended aeration activated sludge or by physical-chemical means, prior to being discharged to rivers, lakes, or ponds. Wastes from most drilling camps are presently discharged to sumps.

2A.4.2 Yukon River Drainage

The Yukon River Drainage lies entirely within the Yukon River Drainage Basin, bounded by the Brooks Range to the north and the Alaska Range to the south.

Between the borders of this Drainage are high mountains, plateaus and foothills, and alluvial river valleys. The water resources are as varied as the topography. Streams from the Brooks Range flow south into a lowland area north of the Kokrine-Hodzana Highlands. Thaw lakes are present, as they are on the Yukon River Flood Plain. Oxbow lakes occur in the flood plains of many streams in lowland areas. Scattered thaw lakes are present in the Yukon-Tanana Upland between the Yukon River and Big Delta. The lowlands south of Big Delta and the foothills north of the Alaska Range also contain a few thaw lakes. Scattered rock-basin lakes and small ponds occur within the Alaska Range.

Approximately 426 miles of pipeline will traverse this Drainage, with a total of about 281 stream crossings. A number of these streams flow intermittently. Major tributary basins to be traversed by the proposed pipeline are presented in Figures 2A.4-3 and 3a.

2A.4.2.1 Surface Water Hydrology and Hydrologic Hazards

The hydrology of the Yukon River Drainage varies considerably. North of the Yukon River, the pipeline route is drained primarily by the Koyukuk River system, while the Tanana River system drains it to the south. Streams within these major tributary drainages may be classified as either glacial or nonglacial, and their flow characteristics vary accordingly.

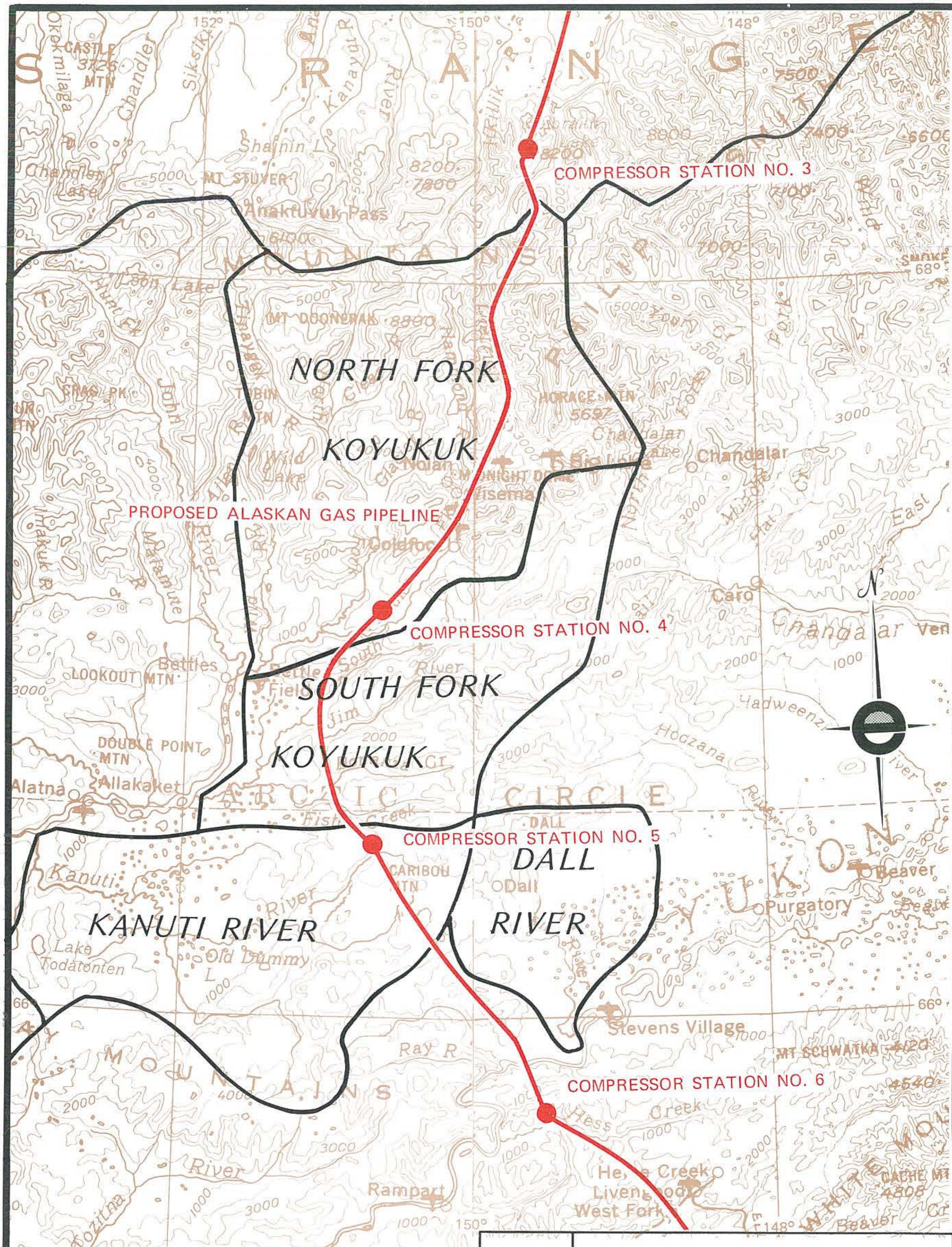
Glacial streams are most prevalent among the southern tributaries of the Tanana River. These tributaries usually achieve peak flows during the late summer months as a result of rapid glacial melt and high precipitation, with lesser peaks in the spring from snow melt or ice jam flooding. Nonglacial streams usually exhibit highest flows in the spring because of rapid snow melt, but they may also have high flows in the late summer or early fall because of high precipitation. All streams in the Yukon River Drainage in the vicinity of the proposed pipeline have low flows in the late winter when most precipitation is stored as snowpack and base flow is lowest.

Some streamflow records exist for the Drainage south of the Yukon River, but are poor to nonexistent north of the Yukon. A summary of available streamflow data is presented in Table 2A.4-4. Estimates of the magnitudes and frequencies of floods in the Yukon River Basin are uncertain because of the lack of historical stream flow records.

Mean annual run-off rates average about 0.5 to 1.0 cfsm in the lowlands and basins north of the Tanana River, and approximately 1 cfsm to more than 4 cfsm in the upland regions in the Alaska Range (Feulner, et al., 1971).

Annual run-off varies widely. One report (Anderson, 1970) indicates that nonglacial stream run-off varies more annually than glacial stream run-off. As an example, 16 years of streamflow record for the Chena River (a nonglacial stream) indicate annual flow variations of 47 to 173 percent of mean annual conditions. Based on 14 years of record for the Nenana River at Healy (a glacial stream), flows range from 86 to 128 percent of mean annual flows. The low variability of flows in glacial streams can, in part, be attributed to the regulatory effects of ice storage (Anderson, 1970).

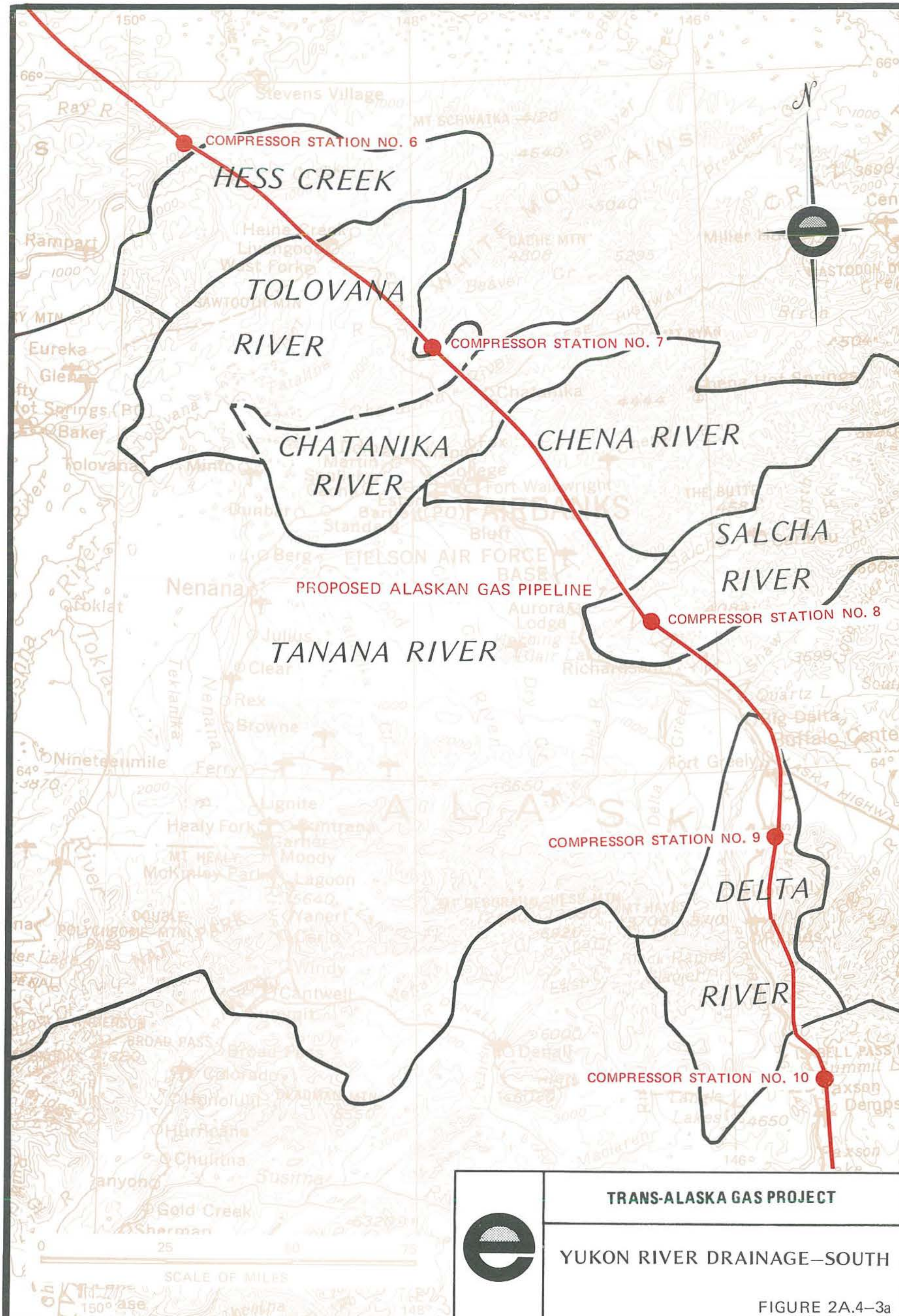
Mean annual peak run-off rates range from near 10 cfsm in the valley lowlands to upwards of 50 cfsm in the Brooks and Alaska Ranges. River icings and ice jam flooding make the entire region flood-prone (Feulner, et al., 1971).



TRANS-ALASKA GAS PROJECT

YUKON RIVER DRAINAGE—NORTH

FIGURE 2A.4–3



TRANS-ALASKA GAS PROJECT

YUKON RIVER DRAINAGE—SOUTH

FIGURE 2A.4–3a

TABLE 2A.4-4

SUMMARY OF SURFACE WATER DATA FOR SELECTED STREAMS
ALONG THE PROPOSED ALASKAN GAS PIPELINE
YUKON RIVER DRAINAGE

Stream	Drainage Area (sq mi)	Period of Record (Years)	Average Discharge (cfs)	Maximum Flow[1] Date	Maximum Flow[1] Discharge (cfs)	Minimum Flow[2] Date	Minimum Flow[2] Discharge (cfs)
Yukon River at Kaltag	296,000	10(1957-66)	216,500	Jun 22, 1964	1,030,000	Apr 1-15, 1959	19,000
Koyukuk River at Hughes	18,700	12(1961-72)	15,160	Jun 6, 1964	266,000	Apr 1-15, 1967	200
Middle Fork Koyukuk River near Wiseman	1,426	2(1971-72)	350	Jun 24, 1971	6,860	Mar-Apr 15, 1972	0.5
Wiseman Creek at Wiseman	49.2	2(1971-72)	21.8	Jun 6, 1971	590	3/	0
South Fork Koyukuk River							
Jim River near Bettles	465	2(1971-72)	488	Aug 25, 1972	8,670	Feb 2-Apr 15, 1972	5.4
Yukon River at Ruby	259,000	15(1957-71)	169,900	Jun 20, 1964	970,000	Mar 1-Apr 15, 1959	17,000
Tanana River at Nenana	27,500	10(1963-72)	24,350	Aug 18, 1967	186,000	Nov 16-30, 1963	4,800
Chena River at Fairbanks	1,980	23(1949-71)	1,507	Aug 15, 1967	74,400	Feb 1-28, 1953 Mar 1-31, 1958	120

1/Maximum peak discharge

2/Minimum daily discharge

3/No flow recorded during some winter months

TABLE 2A.4-4 (Continued)

SUMMARY OF SURFACE WATER DATA FOR SELECTED STREAMS
ALONG THE PROPOSED ALASKAN GAS PIPELINE
YUKON RIVER DRAINAGE

Stream	Drainage Area (sq mi)	Period of Record (Years)	Average Discharge (cfs)	Maximum Flow[1/]		Minimum Flow[2/]	
				Date	Discharge (cfs)	Date	Discharge (cfs)
Salcha River near Salchaket	2,170	24(1949-72)	1,773	Aug 14, 1967	97,000	Mar 1-31, 1953	60
Delta River Phelan Creek near Paxson	12.2	6(1967-72)	70.6	Aug 13, 1967	2,320	Jan 1-May 6, 1967 Feb 19-May 4, 1969	1.0
Tanana River at Big Delta	13,500	8 (1948-52) (1950-57)	14,950	Jul 29, 1949	62,800	Apr 7, 1957	3,720
Yukon River at Rampart	199,400	12(1956-67)	128,500	Jun 15-16, 1964	950,000	Mar-Apr, 1956	9,000
Hess Creek near Livengood	622	2(1971-72)	208	Jul 1,1970	5,910	Dec 5, 1970 Apr 6, 1971	0.5
Chandalar River near Venetie	9,330	9(1964-72)	4,848	Jun 9, 1968	62,800	3/	0

1/Maximum peak discharge

2/Minimum daily discharge

3/No flow recorded during some winter months

Sources: USGS-1957, 1958a, 1958b, 1960a, 1960b, 1961, 1962, 1964, 1967, 1968a, 1969b, 1970b, 1971b, 1971d, 1972, and 1974a

Mean annual monthly flows range from less than 0.1 cfsm to 0.2 cfsm. Many basins produce no surface flow during some winter months; however, this is not necessarily restricted to the smaller streams, as indicated by records for the Chandalar River near Venetie. Flow records for the 9330-square-mile drainage above Venetie indicate no surface flow during several winter months for a number of years of record.

A number of geothermal springs are reported in basins traversed by the pipeline route in the vicinity of the Yukon River. Included is one in the Kanuti River Basin and two in the Ray River Basin north of the Yukon River. A number of springs are also reported in regions south of the Yukon, including the Tolovana and Chena River Basins (Ogle, 1974). Such springs may produce local icing conditions during the winter.

Hydrologic hazards of the region include icings, ice-jam flooding, glacier-outburst flooding, and scour associated with flooding.

During the winter, streams in the Yukon River Drainage often freeze to their channel bottom over most of their width. Continued discharge through these channels constricted by freezing builds up pressure, which is often relieved as discharge breaks out of the channel. River icings are formed as the water freezes on the surface. These icings may rise five times the depth of the channel above the surface of the water, and often extend into the river flood plains (Benson, 1973). Most larger streams in the portion of the Yukon River Drainage to be traversed by the proposed gas pipeline are reportedly subject to river icings (Price, 1973). Specific problem areas include the Dietrich-Middle Fork Koyukuk Rivers (USGS, 1969a) and the Delta River (Carey, 1973).

Prior to spring breakup, most streams within the region have a solid ice cover, and many are frozen solid or have extensive icings. If the snow melt process is gradual, river ice will melt gradually. If, on the other hand, snow melt progresses more rapidly than channels can be cleared of ice, extensive flooding may result. Ice jams at later phases of breakup can cause further flooding. Ice-jam flooding is generally restricted, however, to larger streams such as the Yukon and Tanana Rivers.

Small glacier-dammed lakes are reported in, or at the margins of several glaciers near the route of the proposed pipeline through the Alaska Range, including the Black Rapids, Castner, Canwell, and Gulkana Glaciers, all of which provide surface flows to the Delta River (Post & Mayo, 1971). Based upon analysis of aerial photos of these lakes, it is probable that intense outburst floods of short duration occur in the downstream drainages of these glaciers at least once a year. A stream gage below the Gulkana Glacier has recorded outburst flooding at three-day intervals during one particular period (Mayo, personal communication, 1974). For this reason, the Delta River and applicable tributaries should be considered as having potential for moderate to severe outburst flooding from glacier-dammed lakes.

Many larger rivers such as the Dietrich, Tanana, and Delta have wide, braided channels in their upland areas. Beds in these streams are typically composed of unconsolidated alluvial materials ranging from sand to boulders. Flood plains are typically overlain by silts. Such channels are susceptible to both scour and channel shifting during periods of high flows, especially during ice-jam flooding. Other major streams such as the Tolovana, Chatanika, Chena, and Salcha Rivers may meander extensively in their lowland reaches. In these streams, downstream migration of meanders and lateral erosion can create substantial channel changes. As an example, it has been estimated (Brice, 1971) that in less than 20 years, portions of the Salcha River have migrated nearly 300 feet because of lateral erosion in the vicinity of the Alyeska oil pipeline crossing.

2A.4.2.2 Groundwater Hydrology

Groundwater conditions vary greatly in the Yukon River Drainage, as do permafrost conditions, soil, topography, and surface run-off. Along the pipeline route north of the Yukon and in the Yukon-Tanana Upland, permafrost is almost continuous, although this region is considered to be in the discontinuous zone. Areas without permafrost occur along rivers and streams and certain south-facing slopes. Groundwater resources in these regions have not been thoroughly explored.

Groundwater within the discontinuous permafrost zone occurs principally in alluvial deposits. Some major basins, such as the Tanana River Basin, where unconsolidated deposits as much as 825 feet thick near Fairbanks and 2000 feet thick south of Minto are frozen to a maximum known depth of 270 feet, contain reserves of groundwater adequate to meet any foreseeable need. Withdrawal of groundwater in the Tanana River Basin near Fairbanks is estimated to be 2.8 million gallons per day (mgd). Yields from 1000 to 3000 gallons per minute (gpm) from depths of less than 200 feet are commonly available from properly developed wells in the alluvium of the Tanana River and its tributaries. Within these aquifers, the local distribution of permafrost is affected by the history of river migration and by proximity of bodies of surface water. The older flood plain terraces, in areas remote from rivers and lakes, are underlain by thicker and more continuous permafrost than are the younger terraces and the flood plain adjacent to the stream (Williams & van Everdingen, 1973).

In areas of discontinuous permafrost, principal recharge occurs through the unfrozen zones underlying streams. Losses from stream flow in Jarvis Creek near Big Delta average 10 cfs per linear mile of channel. Dingman, et al., (1971) found that the groundwater outflow from the basin of the Delta River averaged 1105 cfs, or 717 mgd, over the entire year, and that most of the recharge occurred by seepage from the Delta River and Jarvis Creek between the front of the Alaska Range and the mouth of the streams.

The direction of groundwater movement in the alluvial flood plain deposits of the river valleys is generally parallel to the direction of stream flow, whereas direction of movement in the adjacent terraces, alluvial fan deposits, and upland deposits is, in general, parallel to the surface slopes. The direction of movement in confined zones within the alluvium or bedrock aquifers, and within fracture or joint systems within bedrock, is independent of surface features.

Discharge of groundwater from principal alluvial aquifers along the pipeline route occurs largely as base flow discharge to streams. Groundwater is also discharged through springs, lakes, and wetlands, and directly by evapotranspiration from shallow groundwater reservoirs. Water under sufficient hydrostatic head may in some cases burst through permafrost or frozen layers and cause icings.

Discharge from wells in most areas is of minor significance. The amount of groundwater available is a function of many factors. Probable groundwater conditions as a function of soil or land form in the Tanana River Basin listed by Anderson (1970) are given in Table 2A.4-5. Some of the generalizations also apply to the same soils and land forms found in other river basins along the proposed pipeline, especially in the discontinuous permafrost zone.

In the Yukon-Tanana Upland, groundwater may be found beneath streams and in Birch Creek schist beneath the permafrost, as well as in individual fractures and fracture zones containing abundant vein quartz and quartzite members (Cederstrom, 1963). Water is recharged to bedrock aquifers through unfrozen loess and weathered rock on hilltops and upper slopes, and from alluvial aquifers in the valleys and on lower slopes. The water table in bedrock near the summits of narrow ridges is as much as 490-feet deep, but artesian wells on some lower slopes are drilled through unfrozen silt and gravel, or frozen bedrock, into confined bedrock aquifers. Water levels in wells in bedrock are determined largely by the rock structure and the geometry of the fracture systems. Cederstrom (1963) noted that the potentiometric surface of the confined aquifers in bedrock apparently flattens above the upper limit of permafrost on hillsides, and that the water level in wells in bedrock above the upper limit of permafrost is apparently related to the height to which permafrost extends up slope. However, both flowing and nonflowing artesian wells in bedrock occur above the upper limit of permafrost.

For the Tanana River Basin, which drains a large area of the Yukon River Drainage, more information is available concerning groundwater supplies because of greater development of the groundwater resources. Cederstrom (1963) and Anderson (1970) have made studies of the occurance and availability of groundwater resources in the Basin. The following discussion is taken from Anderson's studies.

In the Tanana Basin, groundwater occurs under both unconfined and artesian conditions. Unconfined groundwater generally is found in unconsolidated alluvium in the valleys, and in fractured bedrock beneath high slopes and ridges. Artesian conditions generally occur in the lower slopes where permeable beds are confined by permafrost or by impermeable sedimentary beds. Along the lower hill slopes,

TABLE 2A.4-5

PROBABLE GROUNDWATER CONDITIONS AS RELATED TO LAND FORM OR SOIL TYPE IN THE TANANA BASIN (FROM ANDERSON, 1970)

Geologic Unit	Surface Drainage, Infiltration, and Permeability	Probable Groundwater Conditions
Flood plain alluvium	Surface drainage poor to moderate because of low relief; infiltration moderate to good, except where covered by silt or underlain by permafrost; permeability moderate to good	Groundwater availability good because of extensive saturated thickness and abundant recharge. Yields of 1000 to 3000 gpm (gallons per minute) generally available from depths of less than 200 feet. Static water levels less than 50 feet, but depth to permeable sediments as great as 400 feet
Alluvial fans	Surface drainage moderate to good; infiltration moderate to good; permeability moderate to good	Groundwater availability good because of extensive saturated thickness and abundant recharge. Yields up to 3000 gpm generally available from depths less than 200 feet. Locally, the depth to water is greater than 400 feet near the mountain fronts or in the deeply dissected fans of the major streams, and recharge is limited in the areas furthest removed from the major streams
Alluvial silt and sand	Surface drainage poor because of low relief; infiltration poor because of silt and permafrost; permeability poor to moderate	Groundwater availability poor to moderate because of low permeability. Unit grades to more permeable sediments at depths greater than 100 feet. Yields up to 1000 gpm generally available from depths less than 200 feet
Eolian silt	Surface drainage good; infiltration moderate to good; permeability poor	Groundwater availability poor because of limited saturated thickness and low permeability. Unit generally less than 200 feet thick
Sand dunes	Surface drainage good on slopes, poor in depressions, infiltration moderate to good, except where covered by silt or underlain by permafrost; permeability poor to moderate	Groundwater availability assumed to be poor to moderate because of limited saturated thickness and recharge. Unit generally less than 200 feet thick
Undifferentiated alluvial, colluvial or eolian sand and silt	Surface drainage poor because of low relief; infiltration poor because of silt and permafrost; permeability poor	Groundwater availability poor because of low permeability. Unit generally less than 200 feet thick
Glacial moraines	Surface drainage good on slopes, poor in depressions; infiltration and permeability ranges from poor to good depending upon soil texture and permafrost	Groundwater availability poor to moderate because of limited saturated thickness and low permeability. Unit generally less than 400 feet thick
Sedimentary bedrock	Surface drainage good; infiltration poor to moderate; primary permeability poor, secondary permeability in faults and fractures poor to moderate	Unit has no wells. Groundwater availability assumed equal or better than for igneous and metamorphic bedrock
Igneous and metamorphic bedrock	Surface drainage good to excellent; infiltration poor to moderate; primary permeability poor, secondary permeability in faults and fractures poor to moderate	Groundwater availability poor to moderate because of limited saturated thickness and low permeability. Yields less than 50 gpm at depths from 100 to 200 feet

flowing artesian wells are common.

The most important source of groundwater is seepage from streams, though direct infiltration of precipitation also contributes. In areas where streams leave the mountains and cross the fans, the water table is generally deep, and much water percolates downward through permeable material. The area of major recharge is along the south side of the valley where the major rivers cross alluvial fans.

The direction of regional groundwater flow generally parallels surface drainage. In areas where influent tributaries debouch from the Alaska Range, groundwater mounds form under the channels and the water flows away from the axis of the tributary. The water table slope is generally less than the land surface slope, but in a similar direction.

Water level fluctuations in the Tanana Basin are related principally to seasonal changes in recharge and discharge, and range from a few inches to more than 50 feet per year. The greatest seasonal fluctuation has been recorded in wells near Delta Junction. The distance of the observation wells from influent streams largely controls the time and magnitude of seasonal changes. Wells within an immediate area of recharge, such as at the Delta Junction Alaska Communication System, have large fluctuations. On flood plains and low terraces where the groundwater is shallow, the surface streams alternately gain and lose flow. Water level fluctuations in flood plains and low terraces show more correlation with surface water levels than with local precipitation, as shown by the record of the observation well at Fort Wainwright at Fairbanks. The fluctuations also are more variable than those in wells on alluvial fans. Water level fluctuations in bedrock respond to snow melt recharge, but the changes usually are small.

Most of the groundwater moves out of the basin by underflow through alluvium and by contributing to stream flow. Only a small part of the groundwater discharge is by pumping from wells (less than 15 mgd) and evapotranspiration in the present stage of development of the basin.

As discussed previously, enough groundwater is available in some areas of the Tanana River Basin to meet all foreseeable future needs. In the most favorable areas of development, which include the alluvium and glacial outwash deposits of the Tanana River and its major tributaries, yields from 1000 to 3000 gpm from depths of less than 200 feet are commonly available from properly developed wells. The maximum recorded depth to water-bearing sediments because of overlying impermeable silt is 427 feet while it is 265 feet because of permafrost. Both wells are in the Fairbanks area. The static water levels after well completion were less than 20 feet from the land surface.

In coarse and fine alluvium in areas of limited recharge, yields greater than 50 gpm could be developed at depth less than 500 feet, based on available data. Along the flanks of the Alaska

Range, in the central part of the basin, geologic mapping indicates that the sediments are coarse. However, meager groundwater data indicate that the depth to water is commonly greater than 300 feet, and that the groundwater supplies may be small because of the limited recharge.

In the sedimentary, igneous, and metamorphic bedrock complexes, extensive development has occurred only in the Fairbanks area. Yields are less than 50 gpm from wells that range in depth from less than 50 to more than 550 feet.

2A.4.2.3 Water Quality

Water quality of lakes has been measured in widely scattered areas of the Yukon River Drainage. Likens and Johnson (1968) measured quality characteristics in lakes located in the Yukon Flats, near Fairbanks, and at Northway (along the Tanana River near the Alaska-Yukon border). Water chemistry of these low altitude lakes is similar--generally alkaline with calcium, magnesium, sodium, and bicarbonate as dominant ions. Surface water temperatures were measured as high as 22.3°C, but typically range between 14 and 18°C during summer.

A series of alpine lakes (Tangle Lake system) in the southern extreme of the Yukon River Drainage was studied by Barsdate and Alexander (1971). They found that the lakes contained calcium bicarbonate water, with low to moderate hardness and relatively abundant nutrients (phosphorus and nitrate). Alkalinity, dissolved solids, and particulate matter were usually low. Surface temperatures reached 17°C in late July, and summer pH levels typically range between 7.5 and 8.5. Dissolved oxygen concentrations are usually high in surface waters, but may become lower in deeper waters.

Quality characteristics of three streams in the Yukon River Drainage are presented in Table 2A.4-6. The Chatanika River represents one of the few large clear water streams in this Drainage. Hess Creek, although relatively large, exemplifies a brown water stream. The Delta River is glacial. All such streams generally exhibit high quality water. Temperatures and pH levels are within expected limits of natural streams, and dissolved oxygen concentrations remain high during the ice-free period. Dissolved solids concentrations are generally low, as are nutrient levels. Color in the Chatanika and Delta Rivers is low compared to the relatively high levels in Hess Creek. Although unmeasured, suspended solids in the Delta River during summer are expected to be significantly higher than in the Chatanika River and Hess Creek, as reflected by the high turbidity levels measured by EPA (1973).

Quality data on groundwater in the Yukon River Drainage is rather sparse except for in the area near Fairbanks. Generally, groundwater of interior Alaska is calcium bicarbonate water with a dissolved solids content ranging from 200 to 300 mg/l (Feulner, et al., 1971). Groundwater temperatures range from 0 to 4°C in the Tanana Basin (Feulner, et al., 1971), and average 1.7°C in potable

TABLE 2A.4-6

WATER QUALITY OF THREE STREAMS IN THE YUKON RIVER DRAINAGE

Sample Date	Temp. °C	pH	Dissolved Oxygen mg/l	Dissolved Oxygen % Sat.	Conductivity, µmhos at 25°C	Nitrate NO_3-N, mg/l	Phosphate, Ortho, mg/l	Color, Pt Units	Suspend. Solids, mg/l	Turbidity, JTU	Source
Chatanika River (200 feet downstream from Elliott Highway)											
08/07/70	10.0	7.2	10.1	89	101	0.16	--	--	--	6.0	Peterson, 1973
08/20/70	10.5	7.1	9.6	86	121	0.11	0.01	--	--	12	Peterson, 1973
09/03/70	8.5	7.0	9.4	80	115	0.14	--	--	--	0.0	Peterson, 1973
09/16/70	4.5	7.1	9.1	70	110	0.23	--	--	--	12	Peterson, 1973
10/07/70	1.0	7.0	11.4	80	125	0.24	--	--	--	0.0	Peterson, 1973
11/11/70	0	6.7	7.2	49	83	0.31	0.01	--	--	0.0	Peterson, 1973
01/12/71	0	6.5	7.8	53	155	0.34	0.01	5	31.0	4.0	Peterson, 1973
03/16/71	0	6.8	9.5	65	142	0.38	0.01	5	26.0	3.0	Peterson, 1973
04/23/71	0	7.3	10.4	71	131	0.32	0.01	5	7.8	3.5	Peterson, 1973
06/04/71	7.0	6.8	10.6	87	51	0.15	0.05	35	28.0	23	Peterson, 1973
07/01/71	9.5	7.5	10.2	89	90	0.06	0.82	--	--	--	Peterson, 1973
07/16/71	10.0	7.6	9.4	83	86	0.16	0.01	25	19.0	2.2	Peterson, 1973
09/10/71	7.0	7.2	10.8	89	108	0.16	0.01	20	2.0	2.0	Peterson, 1973
10/15/71	0	7.5	11.6	79	114	0.18	0.01	10	1.6	2.0	Peterson, 1973
Chatanika River At Alyeska Pipeline Crossing											
06/14/71	--	7.7	--	--	90	0.14	--	5	--	--	USGS, 1972
08/10/71	--	7.1	--	--	95	0.18	--	20	--	--	USGS, 1972
Hess Creek Near Livengood (LAT 65°39'55", LONG 149°05'47")											
07/21/70	10.5	6.9	--	--	78	0.32	--	100	72	--	USGS, 1972
09/15/70	--	7.2	--	--	89	0.47	--	50	--	--	USGS, 1972

TABLE 2A.4-6 (Continued)

Sample Date	Temp. °C	pH	Dissolved Oxygen mg/l	Dissolved Oxygen % Sat.	Conductivity, µmhos at 25°C	Nitrate NO_3-N mg/l	Phosphate, Ortho, mg/l	Color, Pt Units	Suspend. Solids, mg/l	Turbidity JTU	Source
09/15/70	3.0	7.2	11.5	87	98	--	--	--	--	--	N&K, 1973[1/]
11/17/70	--	7.6	--	--	132	0.11	--	40	--	--	USGS, 1972
11/17/70	0.0	--	6.0	42	95	--	--	--	--	--	N&K, 1973
05/06/71	0.3	7.3	13.0	91	60	--	--	--	--	--	N&K, 1973
06/14/71	10.5	7.6	--	--	104	0.07	--	60	--	--	USGS, 1972
06/14/71	10.6	7.1	8.6	77	115	--	--	--	--	--	N&K, 1973
07/15/71	7.0	7.2	--	--	65	0.18	--	140	170	--	USGS, 1972
07/16/71	8.0	7.3	--	--	72	0.11	--	130	79	--	USGS, 1972
08/10/71	--	7.3	--	--	62	0.20	--	110	--	--	USGS, 1972
08/10/71	9.0	7.6	10.2	89	68	--	--	--	--	--	N&K, 1973[1/]
08/11/71	--	6.6	--	--	64	0.29	--	110	368	--	USGS, 1972
09/14/71	4.5	7.4	--	--	109	0.09	--	100	3	--	USGS, 1972
10/14/71	0.2	7.3	13.2	92	150	--	--	--	--	--	N&K, 1973
03/14/72	0	7.5	0.0	0	--	--	--	--	--	--	N&K, 1973
05/29/72	6.9	7.1	11.0	92	<50	--	--	--	--	--	N&K, 1973
07/30/72	17.3	7.5	7.9	83	118	--	--	--	--	--	N&K, 1973
09/28/72	2.3	7.5	10.7	79	106	--	--	--	--	--	N&K, 1973
Delta River (Adjacent to Mile 230 Richardson Highway)											
08/17/69	6.0	8.4	11.0	88	203	0.06	0.02	1	--	94	EPA, 1973
09/19/69	4.2	8.4	12.4	95	240	0.02	0.02	1	--	26	EPA, 1973
07/13/70	3.8	8.1	12.2	90	165	0.07	0.01	1	--	180	EPA, 1973
03/29/71	0.1	7.3	18.6	128	3600	2.45	0.03	2	--	1	EPA, 1973

1/ Nauman and Kernodle

well water at Fairbanks (Williams, 1970). The quality of groundwater near Fairbanks ranges from good to poor. Cederstrom (1963) characterized it as being an alkaline, moderately hard to hard, calcium bicarbonate water. Depending upon its specific location, groundwater near Fairbanks can contain objectionable quantities of iron, manganese, and nitrate.

2A.4.2.4 Water Use and Waste Disposal

Water is used at widely scattered locations throughout the Yukon River Drainage for domestic, industrial, military, agricultural, and placer-mining purposes. Military installations and the larger communities primarily use groundwater, whereas smaller communities may use either surface or groundwater for water supply. Feulner, *et al.*, (1971) estimate that approximately 12 mgpd are used in this drainage. The majority of this use, of course, occurs in the Tanana Basin.

Wastes are typically discharged into cesspools or septic tanks in the smaller communities and in areas of Fairbanks not served by the community disposal system. Three waste treatment plants are presently operated in the Fairbanks area--primary plants at Fort Wainwright and Fairbanks, and a secondary plant at College. Effluents from these plants are discharged to the Chena River at a point downstream of the proposed pipeline crossing.

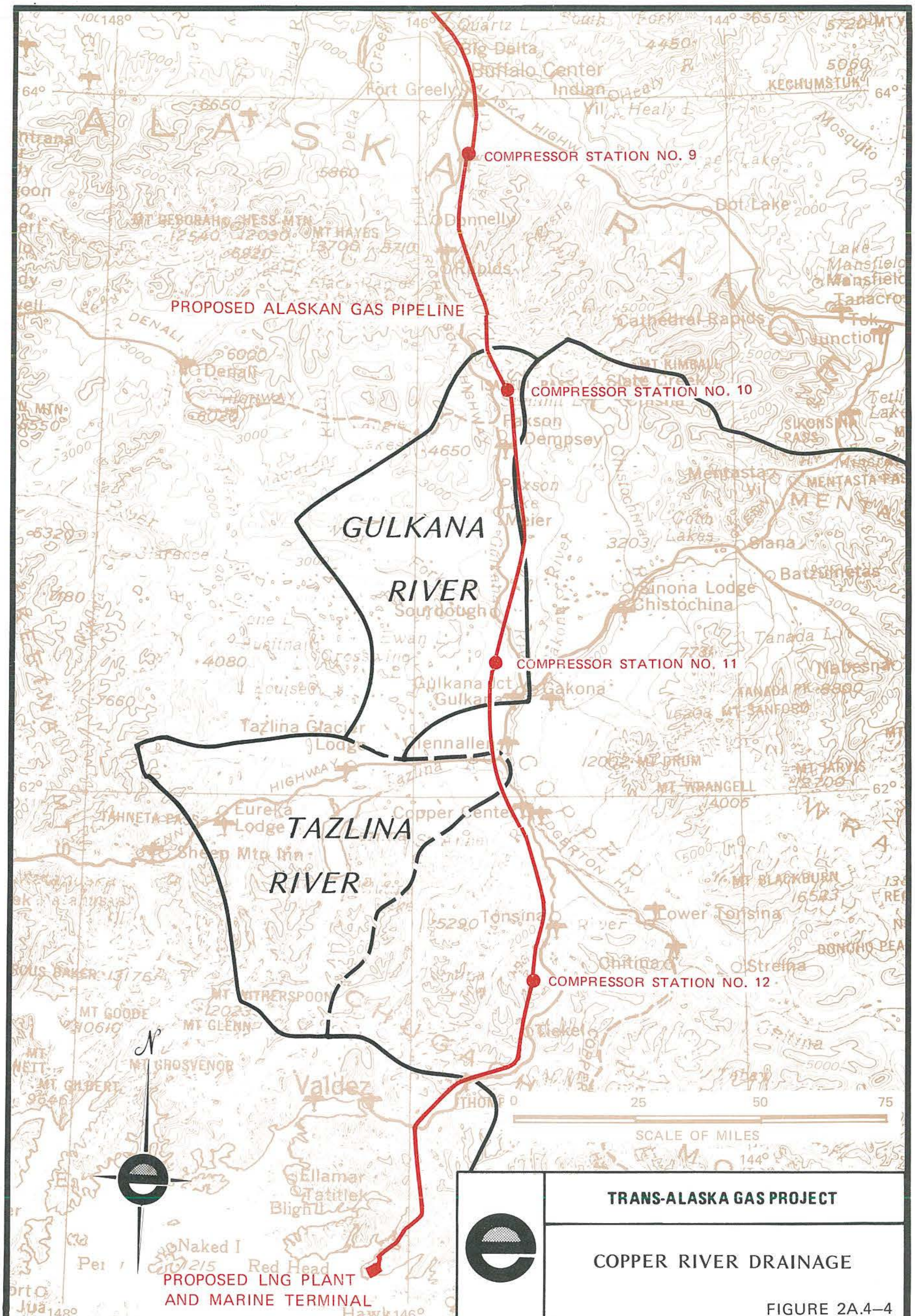
2A.4.3 Copper River Drainage

The Copper River Drainage is bounded by the Alaska Range to the north and by the Chugach Mountains to the south and east. The proposed pipeline will traverse mountain, upland, and lowland terrain in the Copper River Drainage. Numerous long, narrow rock-basin lakes, and irregular lakes in some morainal areas, are located in the Gulkana Upland. The Copper River Lowland is dotted with thaw lakes. Large, morainal lakes occur along the north margin of the Chugach Mountains. The entire region has been extensively glaciated.

Approximately 156 miles of pipeline will traverse this Drainage, crossing 76 streams, a few of which are intermittent. Most larger basins traversed (Figure 2A.4-4) flow eastward directly into the Copper River, which flows south into the Gulf of Alaska.

2A.4.3.1 Surface Water Hydrology and Hydrologic Hazards

The hydrologic cycle of the Copper River Drainage is dominated by high flows, beginning with spring breakup and continuing throughout the summer and early fall. Most larger tributaries in the region are glacier-fed, and peak flows in these streams generally occur in late summer or early fall, usually as a result of rapid glacial melt and high precipitation. Nonglacial streams generally exhibit their peak flows in the spring from snow melt, though occasionally in late



TRANS-ALASKA GAS PROJECT

COPPER RIVER DRAINAGE

FIGURE 2A.4–4

summer during periods of maximum precipitation, Peak flows may be attenuated slightly by large lakes located within the Gulkana, Tazlina, Klutina, and Tonsina River basins,

By late fall, surface flows on all streams diminish rapidly and base flow prevails. Low flows persist throughout the winter, generally reaching the lowest levels in March. Many smaller streams freeze solid during the winter.

Streamflow records are available from USGS and others (Fuelner, et al., 1971) for most major tributaries in the Copper River Drainage to be traversed by the proposed Alaskan Gas Pipeline, and are presented in Table 2A.4-7.

Mean annual stream flows range from less than 0.5 cfsm in the Copper River Lowland to 4 cfsm in the higher regions of the Alaska Range and the Chugach Mountains. Mean annual peak run-off is similarly reported to range from near 10 cfsm in the lowlands to 50 cfsm in the mountains (Feulner, et al., 1971). Maximum peak flows reported at stream gages on major tributaries range from 10.3 cfsm on the Klutina River near Tonsina, to 22.7 cfsm on the Tazlina River near Glennallen. Peak flow rates of 52.3 cfsm have been reported on a small, unnamed tributary of Ptarmigan Creek in the Chugach Mountains near Valdez (Childers, 1970). Mean monthly low flows are reported as being less than 0.5 cfsm over the entire region (Feulner, et al., 1971).

Hydrologic hazards to be expected along the pipeline route through the Copper River Drainage include outburst flooding from glacier-dammed lakes, river icings, and ice-jam flooding.

At least three streams along the route have a potential for dangerous outburst flooding--the Tazlina, Klutina, and Tsina Rivers (Post & Mayo, 1971). The Tazlina reportedly experiences glacier outburst flooding every two to four years, and at least four major glacier-dammed lakes at its headwaters present flood hazards to the lowlands. The Tsina, a tributary of the Tiekel River, is reported to have flooded from glacier outburst in 1915 and again possibly in 1919. The Klutina River is also capable of such flooding, though it has no history of doing so.

River icings are reported to occur on some major streams such as the Tazlina River (Carey, 1973) and the Tiekel River (Price, 1973). Whether river icings occur at the outlets of the major lakes in the region is unknown. If so, it is possible that outburst floods could result as lake waters melt through their blocked outlets,

Floods resulting from ice jams may occur in larger tributaries during spring breakup. The channels in the rivers of this Drainage fill with ice several feet thick each winter, and at the time of breakup the increased flow piles up large quantities of ice so that the channels become blocked and overflow their banks (U.S. Army Corps of Engineers, 1950).

TABLE 2A.4-7

SUMMARY OF SURFACE WATER DATA FOR SELECTED STREAMS ALONG THE PROPOSED ALASKAN GAS PIPELINE COPPER RIVER DRAINAGE

Stream	Drainage Area (sq mi)	Period of Record (years)	Average Discharge (cfs)	Maximum Flow [1/]		Minimum Flow [2/]	
				Date	Discharge (cfs)	Date	Discharge (cfs)
Copper River near Chitna	20,600	16(1956-71)	36,560	Jul 15, 1971	265,000	Mar 1-31, 1956	2,000
Tonsina River at Tonsina	420	21(1951-72)	852	Jun 17, 1962	8,490	Mar 1-15, 1957	60
Squirrel Creek at Tonsina	70.5	7(1966-72)	31.0	Jun, 1964	1,200	Apr 1-10, 1967	9
Klutina River at Copper Center	880	17(1951-67)	1,686	Jun 29, 1953	9,040	Apr 1-30, 1955	110
Tazlina River near Copper Center	2,670	22(1950,52-72)	4,085	Aug 14, 1962	60,700	Mar 31-Apr 18, 1971	150
Gulkana River at Sourdough	1,170	1(1973)	1,210	May 16, 1973	7,260 [3/]	Jan 11-Apr 25, 1971	300

1/ Maximum peak flow

2/ Minimum daily flow

3/ Maximum daily flow

Sources: USGS-1957, 1958a, 1958b, 1960a, 1960b, 1961, 1962, 1964, 1967, 1968a, 1969b, 1970b, 1971b, 1971d, 1972, 1974a, and 1974b

Most major streams in the region are glacier-fed, and are generally braided channels with steep gradients and broad flood plains. Bed materials generally consist of unconsolidated materials ranging in size from sands to boulders. Such channels are susceptible to scour and lateral erosion. Braided streams may undergo channel changes from major floods.

2A.4.3.2 Groundwater Hydrology

The Copper River Basin is almost totally within the discontinuous permafrost region. Distribution of permafrost becomes quite sporadic in the southern part of the Drainage along the pipeline route.

Development of groundwater resources in the area has been slight. However, several wells in the Copper River Lowland have encountered potable water in permeable unconsolidated deposits interbedded with impermeable glaciolacustrine and glacial deposits. Permeable beds in wells 303, 321, 330, and 443 at Gulkana airfield between the reported base of frozen ground and the static level of saline water are dry, probably because the potentiometric surface of the saline water has dropped in response to canyon cutting by the Copper River, and the beds have not been recharged by fresh water (Williams, 1970).

2A.4.3.3 Water Quality

Water quality information is not available for the numerous thaw lakes in the Copper River Lowland, or for the large morainal lakes along the northern margin of the Chugach Mountains. Paxson and Summit Lakes in the Gulkana Upland are the only lakes with quality information in this Drainage (Table 2A.4-8).

The quality of water in Paxson and Summit Lakes is good. Nutrient concentrations are low, dissolved oxygen is high, and the range of pH is normal for natural waters. Both lakes have soft water, low alkalinity concentrations and low conductivity levels. Carbonate hardness predominates.

Water quality characteristics of three streams in the Copper River Drainage are presented in Table 2A.4-9. Squirrel Creek is one of the few clear water streams in this Drainage. The Little Tonsina River is one of the few brown water streams in the segment of the Copper River Drainage to be traversed by the proposed pipeline. The Gulkana River is a brown water stream in its lower reaches, but is a glacial stream above Summit Lake. The Tonsina River is presented to characterize a glacial stream. Other glacial streams include the Copper, Klutina, and Tazlina Rivers.

The water quality of Squirrel Creek, the Little Tonsina River, and the Tonsina River is good. Nitrate-nitrogen ranges from 0.0 to 0.38 mg/l in these streams, the percentage saturation of dissolved oxygen is usually above 85 percent, and pH ranges from 6.8 to 8.4. Color is generally below 50 Pt Units, except during breakup when it rises to

TABLE 2A.4-8

PHYSICAL-CHEMICAL CHARACTERISTICS OF PAXSON AND SUMMIT LAKES

Site	Date	Dissolved Oxygen ppm	pH	Total Alkalinity $CaCO_3$ ppm	Total Hardness $CaCO_3$ ppm	Conductivity µmhos at 25°C	NO_3-N ppm	Ortho PO_4-P ppm
Paxson Lake								
Near Inlet								
03' Surface	08/02/70	9.8	8.1	53	--	118	0.02	0.01
36' Mid-depth	08/01/70	9.8	8.0	54	--	118	0.02	0.01
72' Bottom	08/01/70	8.2	7.6	55	--	123	0.02	0.01
03' Surface	03/16/71	10.6	7.2	56	61.1	140	0.14	0.01
36' Mid-depth	03/16/71	10.2	7.1	54	59.8	144	0.14	0.01
72' Bottom	03/16/71	10.1	7.2	50	56.9	140	0.40	0.01
Mid-Lake								
03' Surface	08/02/70	9.8	7.8	54	--	125	0.01	0.01
05' Surface	10/23/63*	8.1*	7.4*	64*	--	--	--	0.03*
46' Mid-depth	08/02/70	9.3	7.6	54	--	123	0.02	0.01
03' Surface	03/15/71	10.9	7.2	55	59.4	150	0.27	0.01
46' Mid-depth	03/15/71	11.5	7.0	39	57.7	140	0.06	0.01
Near Outlet								
03' Surface	08/02/70	10.0	7.8	54	--	125	0.01	0.01
36' Mid-depth	08/02/70	9.0	7.6	54	--	125	0.01	0.01
03' Surface	03/16/71	12.8	7.3	56	59.4	148	0.37	0.01
36' Mid-depth	03/16/71	11.0	7.4	53	60.0	141	0.04	0.01
Summit Lake								
Near Inlet								
03' Surface	08/03/70	10.1	7.8	41	--	83	0.02	0.01
82' Bottom	08/03/70	10.4	7.6	40	--	81	0.02	0.01
03' Surface	03/16/71	11.7	7.3	38	41.2	102	0.05	0.01
82' Bottom	03/16/71	11.6	7.3	38	37.5	96	0.59	0.03
Mid-Lake								
03' Surface	03/17/71	12.8	7.3	20	39.6	102	0.09	0.008
05' Surface	10/23/63*	9.4*	7.8*	59*	--	--	--	--
32.5 Mid-depth	03/17/71	11.9	7.4	20	40.0	103	0.01	0.007
Near Outlet								
03' Surface	08/03/70	10.5	7.7	40	--	81	0.02	0.01
03' Surface	03/16/71	12.5	7.3	43	42.5	115	0.10	0.01

NOTE: Data from Stewart, K., 1974. Data with * taken from Van Wyhe & Peck, 1968, PO_4 values from Van Wyhe converted to PO_4-P.

TABLE 2A.4-9

WATER QUALITY OF THREE STREAMS IN THE COPPER RIVER DRAINAGE

Sample Date	Temp °C	pH	Dissolved Oxygen mg/l	Dissolved Oxygen % Sat	Conductivity, μmhos at 25°C	Nitrate, NO_3-N mg/l	Phosphate, Ortho, mg/l	Color, Pt Units	Suspend. Solids, mg/l	Turbidity, JTU	Source
Squirrel Creek at Tonsina (LAT 61°40'05", LONG 145°10'26")											
07/23/67	13	7.0	--	--	192	0.07	--	10	14	--	USGS, 1968b
09/18/67	7	8.0	--	--	187	0.18	--	10	13	--	USGS, 1968b
10/12/67	1	8.0	--	--	193	0.23	--	5	--	--	USGS, 1969c
03/06/68	--	8.0	--	--	180	0.18	--	40	--	--	USGS, 1969c
05/06/68	0	7.2	--	--	94	0.11	--	150	--	--	USGS, 1969c
05/21/68	5	6.9	--	--	68	0.14	--	120	--	--	USGS, 1969c
05/21/69	4.0	7.8	--	--	92	0.11	--	50	86	--	USGS, 1971c
04/10/70	0	7.5	--	--	222	0.00	--	5	6	--	USGS, 1971d
05/13/70	5.5	7.6	--	--	98	0.07	--	50	68	--	USGS, 1971d
07/07/70	8.5	7.8	--	--	137	0.05	--	10	5	--	USGS, 1971d
08/19/70	9.5	7.6	--	--	180	0.00	--	5	2	--	USGS, 1971d
09/26/70	--	7.9	--	--	176	0.05	--	5	--	--	USGS, 1971d
09/26/70	3.5	--	12.1	97	160	--	--	--	--	--	N&K, 1973 1/
10/02/70	3.0	8.0	--	--	178	0.02	--	5	2	--	USGS, 1972
12/03/70	0	8.1	--	--	183	0.07	--	0	6	--	USGS, 1972
12/03/70	0	7.4	13.8	95	175	--	--	--	--	--	N&K, 1973
03/15/71	0.5	7.8	--	--	199	--	--	--	10	--	USGS, 1972
04/06/71	0.3	8.4	13.5	99	192	--	--	--	--	--	N&K, 1973
05/24/71	3.5	7.7	--	--	107	--	--	--	--	--	USGS, 1972
06/03/71	5.0	7.3	--	--	111	--	--	--	17	--	USGS, 1972

1/ Nauman and Kernodle

TABLE 2A.4-9 (continued)

WATER QUALITY OF THREE STEAMS IN THE COPPER RIVER DRAINAGE

Sample Date	Temp. °C	pH	Dissolved Oxygen mg/l	Dissolved Oxygen % Sat.	Conductivity, µmhos at 25°C	Nitrate, NO_3-N mg/l	Phosphate, Ortho, mg/l	Color, Pt Units	Suspend. Solids, mg/l	Turbidity, JTU	Source
					Squirrel Creek at Tonsina (LAT 61°40'05", LONG 145°10'26") (continued)						
07/09/71	10.0	7.6	--	--	126	0.02	--	20	4	--	USGS, 1972
07/23/71	--	8.0	--	--	156	0.00	--	0	--	--	USGS, 1972
07/23/71	8.7	7.7	--	--	150	--	--	---	--	--	N&K, 1973
08/21/71	--	--	--	--	--	0.02	--	--	--	--	USGS, 1972
08/25/71	8.0	7.9	--	--	180	--	--	--	57	--	USGS, 1972
09/26/71	2.0	8.0	--	--	172	0.02	--	5	--	--	USGS, 1972
09/26/71	2.5	8.2	13.6	106	180	--	--	--	--	--	N&K, 1973
02/14/72	0.1	7.4	--	--	200	--	--	--	--	--	N&K, 1973
					Little Tonsina River Near Tonsina						
08/18/69	5.5	7.6	13.3	105	99	0.01	0.01	4	--	2	EPA, 1973
09/21/69	5.1	7.5	11.8	92	103	0.02	0.02	6	--	2	EPA, 1973
07/10/70	6.9	7.4	11.2	92	66	0.03	0.01	5	--	6	EPA, 1973
09/27/70	2.4	--	12.7	102	110	--	--	--	--	--	N&K, 1973 1/
12/02/70	0	6.9	8.4	64	130	--	--	--	--	--	N&K, 1973
03/31/71	0.2	7.4	11.1	79	153	0.11	0.01	3	--	1	EPA, 1973
04/06/71	0.5	8.0	11.2	85	128	--	--	--	--	--	N&K, 1973
05/26/71	1.0	7.6	--	--	69	0.38	--	--	--	--	USGS, 1971d
07/23/71	5.4	6.8	--	--	45	--	--	--	--	--	N&K, 1973
09/21/71	5.0	7.9	--	--	99	0.02	--	10	--	--	USGS, 1971d

1/ Nauman and Kernodle

TABLE 2A.4.9 (continued)

WATER QUALITY OF THREE STEAMS IN THE COPPER RIVER DRAINAGE

Sample Date	°C	pH	Dissolved Oxygen mg/l	Dissolved Oxygen % Sat	Conductivity, μmhos at 25°C	Nit-trate, NO_3-N mg/l	Phos-phate, Ortho, mg/l	Color, Pt Units	Suspend. Solids, mg/l	Turbi-dity, JTU	Source
Little Tonsina River Near Tonsina											
09/21/71	5.0	7.9	10.1	87	110	--	--	--	--	--	N&K, 1973
02/14/72	0.1	--	--	--	140	--	--	--	--	--	N&K, 1973
05/25/72	1.5	7.3	11.0	86	79	--	--	--	--	--	N&K, 1973
07/26/72	7.6	7.4	10.9	101	65	--	--	--	--	--	N&K, 1973
09/21/72	0.8	7.5	11.1	86	85	--	--	--	--	--	N&K, 1973
Tonsina River at Tonsina (LAT 61°39'50", LONG 145°10'50")											
11/03/59	0.5	7.3	--	--	86	0.09	--	10	24	--	USGS, 1962
12/03/59	0	7.5	--	--	98	0.05	--	0	12	--	USGS, 1962
12/14/59	--	6.9	--	--	116	0.45	--	0	--	--	USGS, 1962
04/09/60	--	7.3	--	--	123	0.09	--	0	--	--	USGS, 1962
04/20/60	--	7.5	--	--	122	0.05	--	20	3	--	USGS, 1962
10/24/60	--	7.0	--	--	85	0.05	--	10	--	--	USGS, 1965
04/08/61	--	7.3	--	--	125	0.05	--	10	--	--	USGS, 1965
04/17/61	--	7.6	--	--	121	0.05	--	5	--	--	USGS, 1965
08/23/67	--	7.3	--	--	66	0.25	--	5	--	--	USGS, 1968b
09/18/67	12.7	7.0	--	--	69	0.16	--	20	60	--	USGS, 1968b
10/12/67	2.0	7.4	--	--	80	0.25	--	5	--	--	USGS, 1969c
03/06/68	0	7.7	--	--	97	0.09	--	15	--	--	USGS, 1969c
05/22/68	3.0	7.3	--	--	74	0.14	--	45	--	--	USGS, 1969c
09/02/70	--	7.3	--	--	71	0.23	--	5	--	--	USGS, 1971d
09/17/70	8.0	7.6	--	--	73	0.09	--	10	--	--	USGS, 1971d

1/ Nauman and Kernodle

levels of 100 Pt units and higher. Measured temperature ranges of these streams are 0 to 13°C in Squirrel Creek, 0 to 7.6°C in the Little Tonsina River, and 0 to 19°C (USGS, 1965) in the Tonsina River. Temperature data for the Tonsina River are more extensive than for the other streams, which suggests that maximum temperatures for Squirrel Creek and the Little Tonsina River may be higher if sampled more often in July and August. Conductivity in these streams displays the typical seasonal variation; high values occur during breakup, followed by low values during summer, then increasing values prior and subsequent to freeze-up. Conductivity (in μmhos at 25°C) ranges of these streams are 68 to 222 (Squirrel Creek), 45 to 153 (Little Tonsina River) and 66 to 125 (Tonsina River). Data on suspended solids in Squirrel Creek, although sparse, indicate low concentration. No suspended solids data exist for the Little Tonsina River. Suspended solids concentrations in the Tonsina River have ranged from 3 to 127 mg/l (USGS, 1962; USGS, 1965; USGS, 1966; USGS, 1971a). This range is significantly lower than expected for a glacial stream. Tonsina Lake, however, is located between the glacier and the sample location. This lake probably acts as a settling basin, trapping a large percentage of the solids. The Klutina and Tazlina Rivers, also have lakes located between their glaciers and the pipeline route.

Information on the chemical quality of groundwater in the Copper River Drainage is sparse. Feulner, et al., (1971) reported that water from shallow wells (less than 150 to 200 feet deep) in the Glennallen area is generally of the calcium bicarbonate type with a dissolved solids content of 383 mg/l, while deeper wells generally contain sodium chloride- or sodium calcium bicarbonate-type water, with dissolved solids concentrations as high as 2400 mg/l. The dissolved solids concentration of a spring near Glenallen was measured at 14,500 mg/l (Feulner, et al., 1971). The temperature of groundwater is usually 3 to 4°C.

Groundwater was sampled near Paxson on June 18, 1968 (USGS, 1969c). The water was of the calcium bicarbonate type, with a dissolved solids concentration of 160 mg/l, and a pH of 7.9. The water was moderately hard (106 mg/l).

2A.4.3.4 Water Use and Waste Disposal

There is only limited use of water for water supply and waste disposal along the pipeline route in the Copper River Drainage. The communities in this area are small, and few have a community water supply or waste disposal system. The Alaska Highway Department has a number of maintenance camps in the area, and a few hunting and fishing lodges are also present.

In general, surface waters are not used for water supply or waste disposal. Groundwater is used for water supply, and septic tanks and privies are the primary recepticles of wastes. Because the quality of groundwater is generally poor in the Glennallen area, a number of people truck water to their homes from wells having better quality water.

2A.4.4 Prince William Sound Drainage

The Prince William Sound Drainage is bounded by the Chugach Mountains to the east and north, and by Prince William Sound to the west and south (Figure 2A.4-5). The entire region is characterized by U-shaped glaciated valleys surrounded by steep mountains. The area to be traversed by the proposed pipeline has numerous short, swift streams, but few lakes.

The major stream basins are the Lowe River and Gravina River Basins. A total of 40 stream crossings will be required for this 56-mile portion of the pipeline.

Harris Creek flows through the LNG Plant site, but no lakes are present.

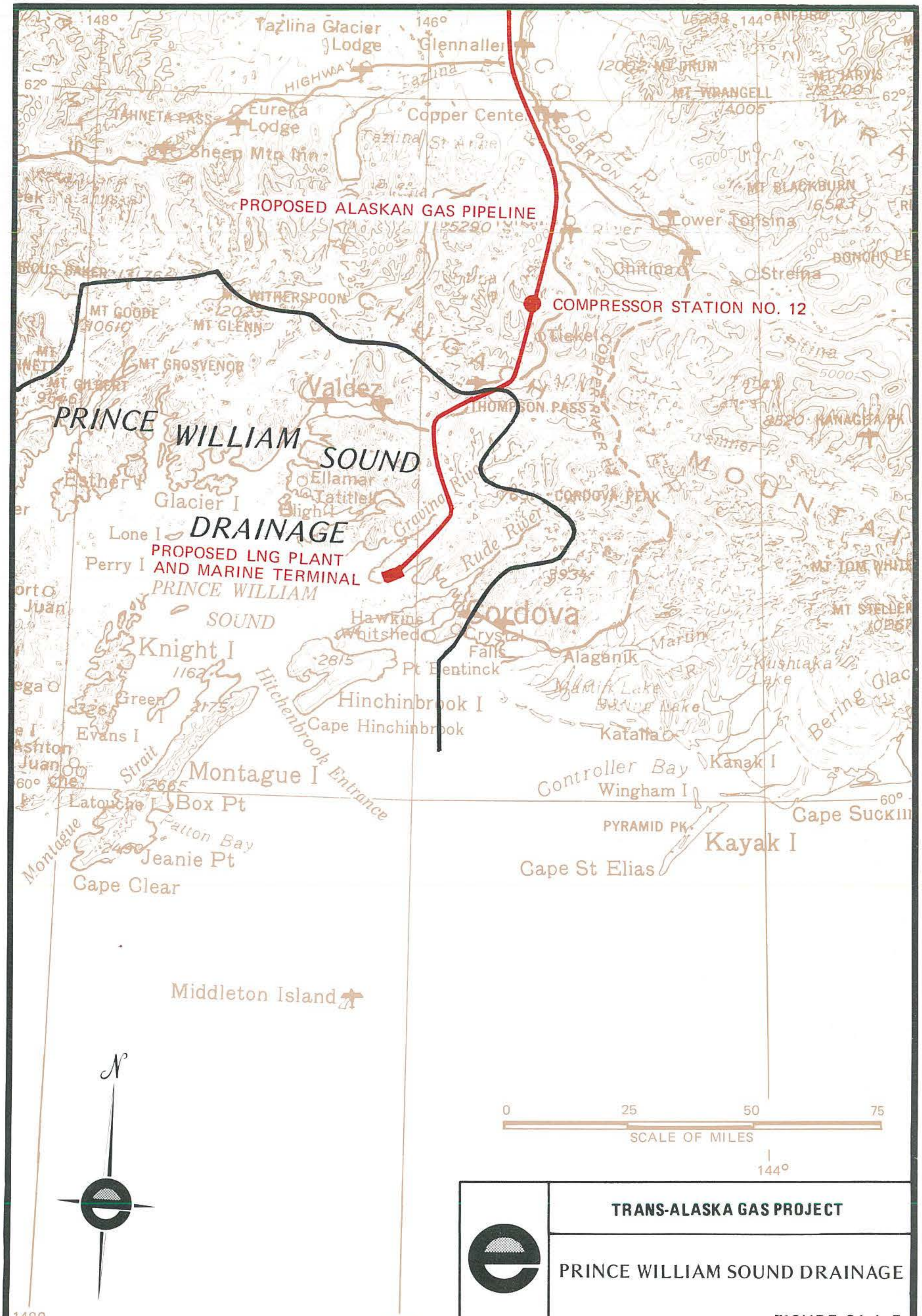
Water resources data do not exist for Harris Creek, and there is no data on groundwater at the Gravina Site. Therefore, the hydrology and hydrography of the area have been inferred from available data in the vicinity. Surface water hydrology and water quality data were taken from West Fork Olsen Bay Creek, which flows into Port Gravina at a point nine miles north of the LNG Plant site.

2A.4.4.1 Surface Water Hydrology

Streamflow records for the Prince William Sound Drainage provide some information on annual and seasonal variability, and represent a base from which certain regional characteristics can be derived. However, streamflow records for all streams in the Drainage to be traversed by the proposed pipeline are either fragmentary or nonexistent. Most information must be drawn by analysis and transposition of data on the few drainage basins in the region that have been gauged by USGS. A summary of these records is presented in Table 2A.4-10.

The hydrology of the Prince William Sound Drainage is dominated by high flows lasting from spring breakup to winter freeze-up. High flows may occur in spring due to rapid snow melt. Flows then increase rapidly, with peaks occurring in late summer or fall, coinciding with periods of maximum precipitation and glacial melt. By November, surface flows diminish and base flow prevails. Flows generally reach a minimum by March, and many smaller streams may exhibit no flow from freeze-up in October or November until the following spring breakup.

With the exception of the Gravina and Lowe River Basins, most basins are generally small and their streams discharge directly into Prince William Sound. Streams in the region are typically short, with very steep gradients, braided channels, and wide flood plains. Most are glacier-fed, and can be expected to have a rapid response to summer and fall storms.



TRANS-ALASKA GAS PROJECT

PRINCE WILLIAM SOUND DRAINAGE

FIGURE 2A.4–5

TABLE 2A.4-10

SUMMARY OF SURFACE WATER DATA FOR SELECTED STREAMS ALONG THE PROPOSED ALASKAN GAS PIPELINE PRINCE WILLIAM SOUND DRAINAGE

Stream	Drainage Area (sq mi)	Period of Record (years)	Average Discharge (cfs)	Maximum Flow [1/]		Minimum Flow [2/]	
				Date	Discharge (cfs)	Date	Discharge (cfs)
Lowe River near Valdez	201	1(1972)	1441	Jul 13, 1972	9840	Feb 11-Mar 15, 1972	55
Solomon Gulch	19	8(1949-56)	144	Sep 4, 1951	2420	Feb 20-Mar 3, 1954	0
West Fork Olsen Bay Creek near Cordova	4.78	8(1965-72)	31.6	Sep 12, 1972	1080	Mar 5-21, 1966	0.5
Eyak River Power Creek near Cordova	20.5	25(1948-72)	246	Sep 25, 1949	5540	Apr 29, 1950	13

1/ Maximum peak discharge

2/ Minimum daily discharge

Sources: USGS-1957, 1958a, 1958b, 1960a, 1960b, 1961, 1962, 1964, 1967, 1968a, 1969b, 1970b, 1971b, 1971d, 1972, and 1974a

Mean annual monthly low flows generally occur between January and April. Flow rates range from 1.7 cfsm in Power Creek near Cordova (glacial stream) to 0.3 cfsm in the Lowe River near Valdez (glacial stream). Many smaller streams may freeze solid during these months.

Mean annual peak flows in glacial streams range from near 150 cfsm at Power Creek to near 50 cfsm at the Lowe River. Peak flows may exceed 250 cfsm. West Fork Olsen Bay Creek, the only nonglacial stream in the region having continuous flow records, has a mean annual peak flow of near 160 cfsm and a maximum observed flow rate of 215 cfsm. Peak flows usually occur from August to October; however, small coastal basins such as that of West Fork Olsen Bay Creek have experienced peak annual flows in February and March, probably due to rains.

Mean annual flows for the eastern Prince Williams Sound streams are reported from 12 cfsm near the Gulf of Alaska to 4 cfsm near Valdez (Feulner, et al., 1971). According to existing streamflow data, nonglacial streams appear to exhibit slightly lower mean annual flow rates than do glacial streams.

Only one stream along the pipeline route in the Drainage is reported to be subject to outburst flooding (Post & Mayo, 1971). Sheep Creek, a tributary of the Lowe River, has flooded on a number of occasions as a result of subglacial draining of small lakes at its headwaters. As an example of the magnitude of these events, in 1948, 20 feet of boulders, gravel, and other debris were deposited at the site of an old highway bridge.

River icings reportedly occur in portions of the Lowe River below Keystone Canyon (Price, 1973). Icing conditions on other tributaries are unknown.

Stream basins on Gravina Peninsula are generally less than five square miles in size and drain directly into either Port Gravina to the north or Sheep and Orca Bays to the south. Mountains that divide the basins on the western end of the peninsula seldom exceed 2500 feet and contain no glaciers. Lowland regions between the mountains are poorly drained, with occasional marshes, ponds, and some small lakes.

The LNG Plant site lies partially within the six square mile Harris Creek Basin, with the remainder inside a narrow, poorly drained strip of land to the west. Surface waters in both regions flow in a southerly direction toward Orca Bay.

Published information is not available for any streams on Gravina Peninsula. Flow conditions in Harris Creek have been estimated on the basis of published records for West Fork Olsen Bay Creek (Table 2A.4-11). Based on these data, stream flow is expected to be highly variable in Harris Creek. High flows may occur both in the spring from snow melt and in the fall from rainfall. Flows should gradually decrease throughout the late fall and winter, with lowest flows typically occurring from January to March, when most precipitation is stored as snowpack. Occasionally during periods of above-

TABLE 2A.4-11

SUMMARY OF STREAMFLOW RECORDS FOR WEST FORK OLSEN BAY CREEK[1/]

Month	Mean Monthly Discharge Minimum (cfs)	Maximum (cfs)	Average (cfs)	Average (cfsm)
January	1.4	23.1	6.7	1.4
February	1.5	44.3	12.4	2.6
March	2.0	25.8	11.9	2.5
April	10.0	50.9	22.0	4.6
May	35.8	66.4	49.3	10.3
June	42.6	97.8	58.4	12.2
July	27.7	82.1	42.3	8.8
August	14.1	76.2	47.2	9.9
September	18.0	109	51.8	10.8
October	19.5	58.3	36.3	7.6
November	6.4	42.3	23.3	4.9
December	3.6	39.5	13.3	2.8
Annual			31.6	6.6

1/ Drainage area: 4.78 square miles
Period of record: September 1964 to September 1972

Sources: USGS-1967, 1968a, 1969b, 1970b, 1971b, 1971c, 1972 and 1974a freezing temperatures, winter precipitation may occur as rainfall and induce high flows.

Estimates for the mean monthly discharges for the Harris Creek Basin, as well as average and extreme mean monthly flows for West Fork Olsen Bay Creek, are presented graphically in Figure 2A.4-6. Estimates were derived from areal run-off rates of the latter.

2A.4.4.2 Groundwater Hydrology

The Prince William Sound Drainage is free of permafrost, except possibly in certain isolated areas at higher elevations. Principal aquifers in the area occur in the unconsolidated alluvium and glacial outwash deposits along streams and valleys, and in the fractures and joints in bedrock.

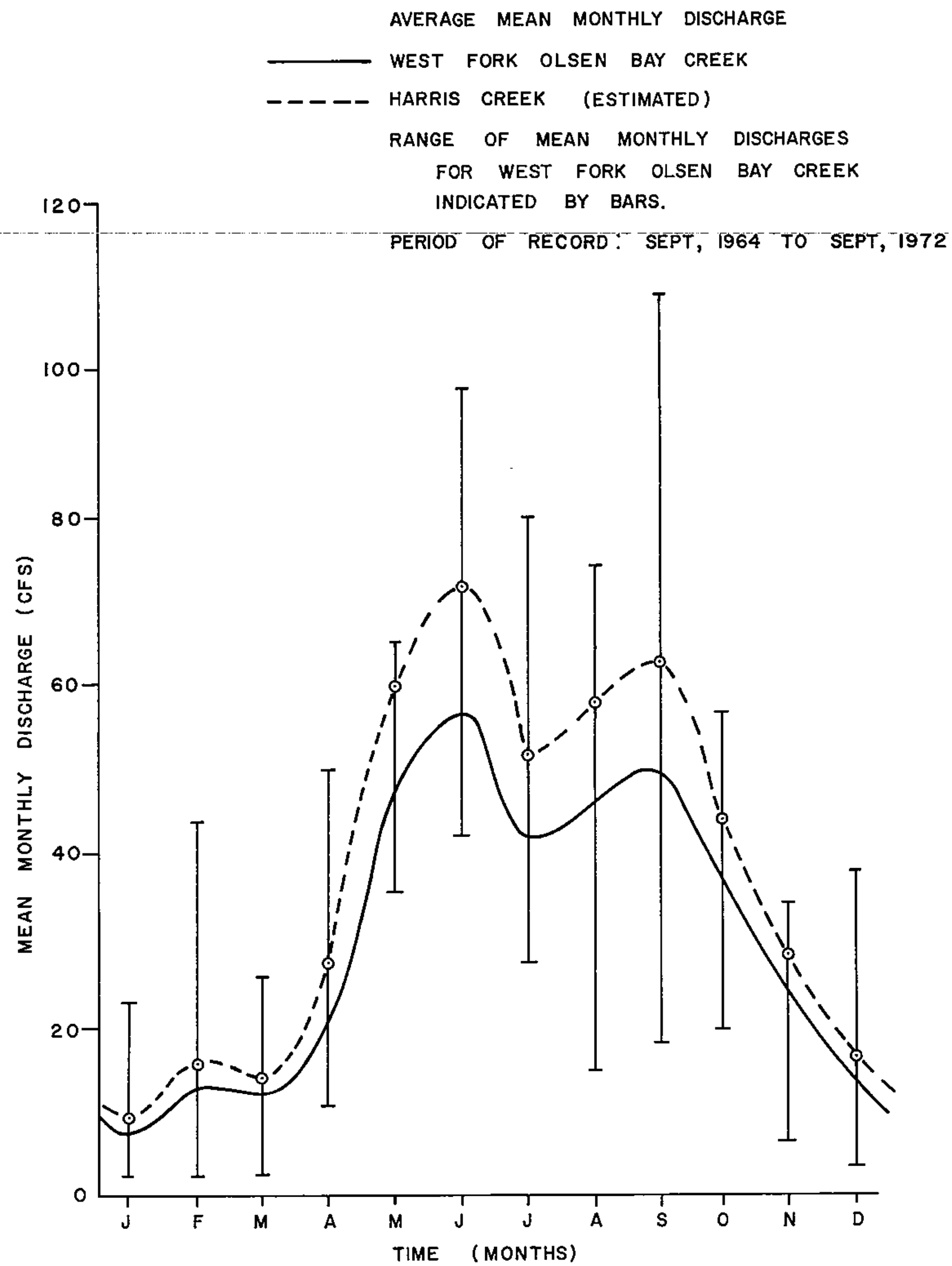
Recharge of these groundwater basins occurs through infiltration from streams and precipitation through the soil. Movement of groundwater follows the slope of the topography, and discharge occurs in the form of springs into streams, at the base of the slope, or into the Sound itself. Discharge through wells is insignificant.

The City of Valdez obtains water from two wells in alluvial gravels beneath the townsite. The water source is directly recharged from infiltration of run-off water from adjacent mountains north of town and perhaps, in part, by underflow of Mineral Creek. The wells, which are pumped at rates of approximately 500 to 1000 gpm, appear to have negligible drawdowns, although almost no data are available.

No published information exists concerning distribution and movement of groundwater near the LNG Plant site. Discussion of this topic is therefore based upon interpretation of regional maps and aerial photographs, and upon general knowledge of the area.

The mountains surrounding the Site are characterized by near-surface or exposed bedrock overlain by a veneer of glacial and organic deposits. These mountains are not expected to contain significant quantities of groundwater. Lowland regions in the Harris Creek Basin and at the Site may contain relatively thick deposits of organic soils. Water tables in these lowland areas are expected to be within a few feet of the surface.

The movement of groundwater in the soil system is generally parallel to the surface slopes. Groundwater basin divides are believed to coincide with topographic divides. Most recharge to the groundwater system in the lowland areas is probably in the vicinity of the interface with the mountains. Most precipitation on the lowlands is expected to enter the surface water system; however, some minor quantities of water may infiltrate through the relatively impervious surface soils to recharge the groundwater system. Discharge from the groundwater system either enters Harris Creek as surface flow, or flows directly into Orca Bay.



TRANS-ALASKA GAS PROJECT

MEAN MONTHLY DISCHARGES FOR WEST FORK OLSEN BAY CREEK AND HARRIS CREEK

FIGURE 2A.4-6

It is reported that groundwater systems in the Prince William Sound region generally produce from 10 to 100 gpm (Feulner, et al., 1971). Clean alluvial gravels and outwash deposits may provide groundwater in quantities in excess of 1000 gpm. Subsurface conditions in the vicinity of the LNG Plant site have not been determined sufficiently to make predictions of groundwater availability at the present time.

2A.4.4.3 Water Quality

The proposed Alaska Gas Pipeline will pass within one mile of seven lakes between Thompson Pass and the LNG Plant site. One lake is located near Thompson Pass, four are located along the southwest margin of the Chugach Mountains, and two are on Gravina Peninsula. No water quality data exist for these lakes, but it is assumed they are of high quality.

Examples of clear water streams include two streams which terminate as Bridal Veil Falls and Horsetail Falls, and flow into the Lowe River. The Robe River is a brown water stream, and the Lowe River is a glacial stream. No water quality information exists for clear or brown water streams in the Drainage.

The Lowe River is a high quality stream. Table 2A.4-12 presents data which indicate low levels of conductivity, nutrients, color, and turbidity, a high percentage saturation of dissolved oxygen, and a pH range considered to be normal for unpolluted freshwater streams. Although data on suspended solids are not available, concentrations can be expected to be quite high during the middle or late summer, which is normal for glacial streams.

Groundwater in the coastal lowlands is a calcium or sodium bicarbonate water having a low dissolved solids content, such as at Valdez, where a dissolved solids content of 110 mg/l has been measured (Feulner, et al., 1971). Temperatures of groundwater usually remain between 3 to 4°C (Feulner, et al., 1971).

Since specific water quality data are lacking for Harris Creek, data from West Fork Olsen Bay Creek are used to characterize its water quality. Temperature data exist for water years 1965 through 1971 (USGS, 1966; 1968b; 1969c; 1971a; 1971c; 1972). The minimum water temperature reaches the freezing point on many days between January and March, and the maximum temperature of 8 to 9°C is reached in July or August. The maximum temperature measured has been 9.5°C, which occurred on August 2, 1969 (USGS, 1971c). Suspended solids were measured at 1 mg/l on June 4, and July 24, 1971, and conductivity on these dates was 21 and 16 μmhos, respectively (USGS, 1972). On June 4, 1971, pH was 7.1 (USGS, 1972). These sparse data indicate good water quality, and it is assumed that Harris Creek would exhibit similar characteristics.

TABLE 2A.4-12

WATER QUALITY OF THE LOWE RIVER IN THE PRINCE WILLIAM SOUND DRAINAGE

Sample Date	Temp., °C	pH	Dissolved Oxygen (mg/l)	% Sat.	Conductivity, μmhos at 25°C	Nitrate (mg/l)	Phosphate (mg/l)	Color Pt Units	Turbidity (JTU)	Source
					Lowe River Near Valdez					
08/13/69	3.6	8.0	12.4	94	100	0.11	0.01	1	22	EPA, 1973
09/22/69	5.1	7.6	11.6	91	118	0.13	0.01	0	5	EPA, 1973
07/09/70	4.7	7.6	12.6	98	90	0.14	0.01	1	56	EPA, 1973
09/25/70	2.0	7.3	--	--	119	0.09	--	0	--	USGS, 1971d
09/25/70	1.9	8.7	11.7	84	120	--	--	--	--	N&K, 1973[1/]
12/02/70	0	7.8	--	--	142	0.32	--	0	--	USGS, 1972
12/02/70	0	7.2	13.2	90	125	--	--	--	--	N&K, 1973
04/01/71	0.7	7.5	12.6	88	144	0.32	<0.01	2	1	EPA, 1973
02/16/72	0.1	7.6	--	--	190	--	--	--	--	N&K, 1973

1/ Nauman and Kernodle

Groundwater in the coastal lowlands (temperatures ranging from 3 to 4°C) is a calcium or sodium bicarbonate water, such as at Valdez and Cordova (Feulner, et al., 1971). Dissolved solids in wells have been measured at 110 mg/l at Valdez and 140 mg/l at Cordova (Feulner et al., 1971). Water from shallow wells is usually low in iron and other mineral content, whereas water from deeper wells exceeds the U.S. Public Health Service limit for chloride, sulfate, magnesium, or a combination of chloride and sulfate (Feulner, et al., 1971). The quality of groundwater at the LNG Plant site will probably be good, unless the aquifer is affected by deposits of organic material or salt water intrusion.

2A.4.4.4 Water Use and Waste Disposal

For all practical purposes, neither surface nor groundwater resources are being drawn upon at the present time along the pipeline route in the Prince William Sound Drainage. Likewise, no wastes are being discharged to surface waters. The largest communities in this Drainage obtain water from the ground (Valdez) or from a lake (Cordova); however, neither lies with the corridor.

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Section 2A.5
Oceanography

SECTION 2A.5 - OCEANOGRAPHY

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SECTION 2A.5

SECTION 2A.5

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2A.5 OCEANOGRAPHY

Prince William Sound is a semi-enclosed body of water separated from the Gulf of Alaska by several major and minor islands. Hinchinbrook Entrance and Montague Strait are the principal entrances (Figure 2A.5-1). Prince William Sound has an irregular coastline, with many long, deep fiords penetrating the Chugach Mountains, some of which culminate at or near tidal glaciers. Though average depths are 800 feet, portions of the Sound may exceed 2500 feet.

Orca Bay lies on the east side of the Sound; it is approximately 33 miles long, has a mouth 13 miles wide, and is separated from the Gulf of Alaska by Hawkins and Hinchinbrook Islands. Maximum water depths range from 700 feet near the head to 300 feet at the mouth. Outside Orca Bay, depths plunge to more than 1000 feet. Though it is not shaped like a typical fiord, Orca Bay still exhibits many fiord characteristics, such as steep side slopes and fairly flat bottom contours. Port Gravina, Sheep Bay, and Simpson Bay empty into Orca Bay.

2A.5.1 Physical Oceanography

Published information on the physical oceanography of Orca Bay near the Gravina Peninsula is limited. Most information herein is based on data for other coastal areas in south central Alaska, extrapolated to reflect conditions that may be expected at the LNG Plant site.

2A.5.1.1 Tides

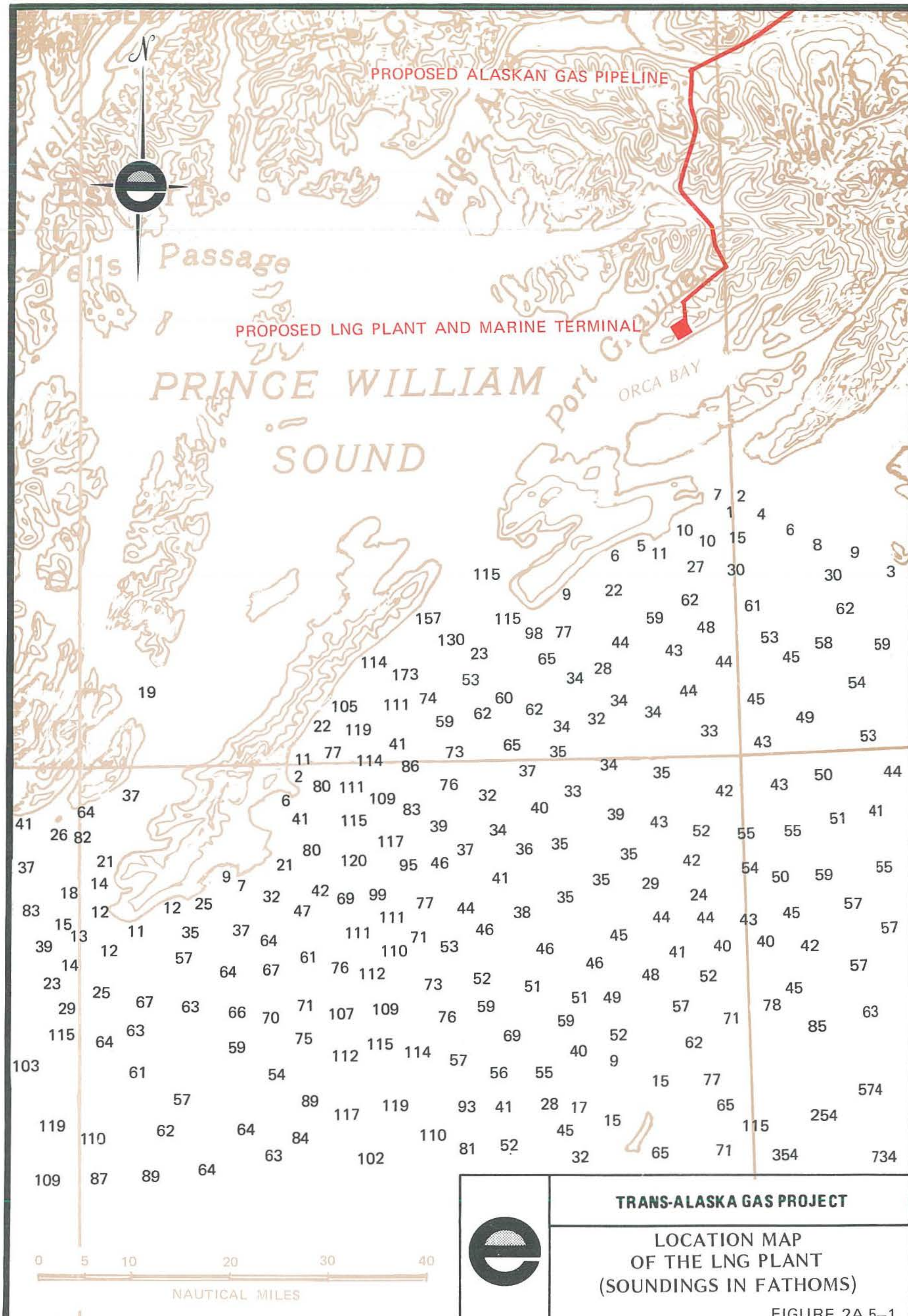
Tidal information for the proposed Alaska Marine Terminal is based on extrapolation of records from tidal stations located within the vicinity of Gravina (Figure 2A.5-2). Only Comfort Cove and Cordova have been surveyed since the 1964 earthquake, and only at Cordova is a continuous tidal gage currently operating.

Extrapolated tidal elevations at the LNG Plant site are presented in Table 2A.5-1.

2A.5.1.2 Currents

Density, wind drift, and tidal currents may be expected off the LNG Plant site.

Density currents are caused by density variations in a body of water (usually resulting from spatial variations in the water mass of



TRANS-ALASKA GAS PROJECT

LOCATION MAP
OF THE LNG PLANT
(SOUNDINGS IN FATHOMS)

FIGURE 2A.5–1

TABLE 2A.5-1

LNG PLANT SITE TIDE DATA[1/]

Tidal Plane	Elevation[2/]
Extreme High Water	17.0
Highest Astronomical Tide	15.2
Mean Higher High Water	11.9
Mean High Water	10.9
Mean Tide Level	6.2
Mean Low Water	1.4
Lowest Astronomical Tide	-3.6
Extreme Low Water	-5.0

[1/] Extrapolated from National Ocean Survey Bench Mark reports (Dames & Moore, 1973a).

[2/] Elevations in feet above Mean Lower Low Water.

Definitions

Extreme High Water: The height of the highest tides resulting as a combination of both meteorological and astronomical effects.

Highest Astronomical Tide: The height of the highest tides in the absence of meteorological effects.

Mean Higher High Water: The average height of the higher high waters. The higher high water is the highest high water for diurnal tides.

Mean High Water: The average height of the high waters.

Mean Tide Level: The water elevation exactly between the elevations of mean high water and mean low water.

Mean Lower Low Water: The average height of the lower low waters. The lower low water is the height of the lowest low water for diurnal tides.

Lowest Astronomical Tide: The height of the lowest tide in the absence of meteorological effects.

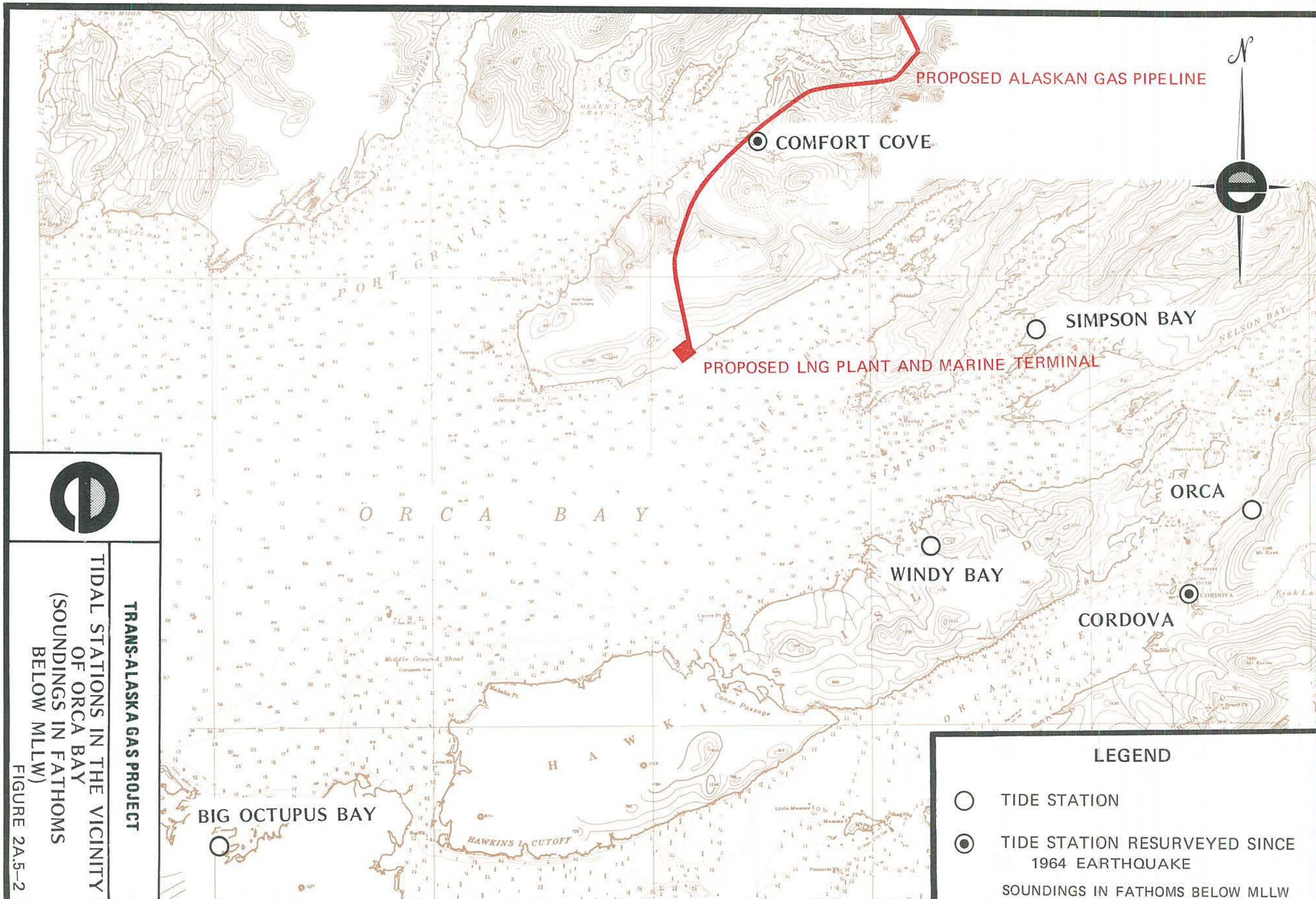
Extreme Low Water: The height of the lowest tide resulting as a combination of both meteorological and astronomical effects.

temperature, sediment, salinity, or a combination thereof). This situation occurs as fresh water flows into an estuary or fiord, since fresh water, which generally possesses a lower density than saline ocean water, tends to flow near the surface. The resulting net movement of water is a flow of fresh water seaward near the surface and a flow of saline water in the lower layers toward the freshwater source. The magnitude of density currents will depend upon the bathymetry of Orca Bay and the locations and magnitudes of freshwater inflows. The major source of fresh water to Orca Bay nearest the LNG Plant site is the Rude River, 20 miles east. Density currents caused by freshwater inflows to Orca Bay are more likely to occur in periods of high summer run-off. Lack of any detailed salinity and temperature data for near-site waters precludes sophisticated calculation of the magnitude and direction of density currents.

Wind drift currents occur when strong winds flow over the surface of a water body. Shear stresses develop at the air-water interface, which tend to drag the near surface water in the direction of the winds. The resultant currents tend to deepen as the wind continues to blow. Generally, these currents are insignificant below a depth of five feet. Their magnitude is commonly approximated at two to four percent of the wind speed; as would be expected, the currents travel in the same direction as the wind (Wiegel, 1964). In the vicinity of Gravina Point, wind drift currents would probably come from the east or west to southwest, coinciding with prevailing winds, and normally not exceeding one foot per second (fps). During storms, wind drift currents may attain speeds of three fps.

Tidal currents simply result from variations in the tides. They are commonly reversible, with inflows toward the head of a bay during a flood tide, and outflows seaward during the ebb tide. In Prince William Sound, tidal currents reverse direction approximately every six hours. Under normal conditions, current magnitude varies with tide stage. Under storm conditions, currents may develop that are considerably more severe than the usual tidal currents. For example, surface currents can increase if the direction of the storm-induced wind drift currents coincides with the direction of tidal currents.

In the absence of meteorological effects, tidal currents within Orca Bay are assumed to travel approximately parallel to the Bay's longitudinal axis; flood currents are expected to travel in an easterly direction, ebb currents westerly. Some data are available for the area near Salmo Point at the east end of Hawkins Island (Figure 2A.5-2). Tidal Current Tables (U.S. Natl. Ocean Survey, 1973) indicate that currents to the northwest of Salmo Point are too weak and variable to be predicted. Similar conditions have been observed at the LNG Plant site. Flood tide currents traveled in an easterly or northeasterly direction, (while ebb tide currents, which were generally higher, traveled in a westerly and southwesterly direction), paralleling Sheep Bay's longitudinal axis. A maximum speed of 1.3 fps was measured.



TRANS-ALASKA GAS PROJECT

TIDAL STATIONS IN THE VICINITY OF ORCA BAY (SOUNDINGS IN FATHOMS BELOW MLLW)

FIGURE 2A.5–2

It appears possible that a 2 fps tidal current could occur at the Gravina Site during either a flood or ebb tide; it is assumed that this current would be fairly uniform with depth. Average speeds are probably less than 1 fps.

2A.5.1.3 Waves

Published information on wave conditions is available for the Gulf of Alaska (U.S. Naval Weather Service Command, 1970), but is lacking for the Orca Bay region of Prince William Sound. Wave conditions near Gravina have therefore been estimated from the 4-year wind data (given in Table 2A.3-28) using the revised Sverdrup-Munk-Bretschneider (SMB) method ({US} Coastal Eng. Research Center, 1966). The October to April distribution of number of events and the average percentage occurrence of significant wave height (average of one-third of highest waves) versus hours duration are presented in Table 2A.5-2 and Table 2A.5-3, respectively. These tabulations do not include those waves from the north and northwest owing to the somewhat sheltered nature of the site. The May to September conditions are presented in Table 2A.5-4. Table 2A.5-2 shows that 25.8 percent of the time in the winter the significant wave height equals or exceeds 4 feet and 6.5 percent of the time the significant wave height equals or exceeds 6 feet. Table 2A.5-4 shows that during the summer half of the year, the same heights occur an order of magnitude less frequently.

Calculations using the revised SMB equations indicate that for a 100-year storm wind, significant wave height may reach 12.5 feet for easterly winds and 14.5 feet for southeasterly winds. This latter value yields a maximum wave of 24.5 feet at the LNG Plant site. These values significantly exceed the 15-ft. maximum wave heights reported in Prince William Sound by Cordova fishermen (Craig, 1973).

2A.5.1.4 Tsunamis

Tsunamis and seiching often associated with seismic activity have been reported on several occasions within Prince William Sound. Tsunamis occurred in 1899, 1908, 1911, 1925, and 1964 (Cox & Pararas-Carayannis, 1969). With the exception of the 1964 event, records for these occurrences are poor.

The Good Friday Earthquake (1964) and the resulting tsunamis and seiches of March 27-28, 1964, are of particular interest because of their magnitude and degree of documentation. The exact mechanisms that caused the earthquake have been discussed by a number of investigators. Wilson and Torum (1968) suggest that extreme oceanic tides may have been part of the triggering mechanisms of the earthquake, since it occurred during a spring tide (when the tidal range is at a maximum). In Prince William Sound the tides were at their lowest on the tidal cycle, while in Cook Inlet, tides were at their peak. The Cook Inlet region generally subsided as a result of the earthquake, whereas Prince William Sound underwent an uplift.

TABLE 2A.5-2

AVERAGE NUMBER OF EVENTS THAT EXCEEDED SPECIFIED VALUES OF WAVE HEIGHT AND DURATION, GRAVINA POINT, ALASKA

(October - April, 1959-1962)

Initial Direction	Wave Height (ft)	Hours Duration 6	12	18	24	30	36	42	48
050°-110°	≥4	22.2	14.8	7.8	3.5	2.2	1.2	0.8	0.5
	≥6	5.2	2.2	0.5	0.2	-	-	-	-
	≥8	1.5	0.2	-	-	-	-	-	-

Initial Direction	Wave Height (ft)	Hours Duration 6	12	18	24	30	36	42	48
120°-210°	≥4	1.5	0.8	-	-	-	-	-	-
	≥6	0.5	0.2	-	-	-	-	-	-

Initial Direction	Wave Height (ft)	Hours Duration 6	12	18	24	30	36	42	48
220°-260°	≥4	2.0	0.2	-	-	-	-	-	-
	≥6	0.8	-	-	-	-	-	-	-

All Directions	Wave Height (ft)	Hours Duration 6	12	18	24	30	36	42	48
	≥4	25.8	15.8	7.8	3.5	2.2	1.2	0.8	0.5
	≥6	6.5	2.5	0.5	0.2	-	-	-	-
	≥8	1.5	0.2	-	-	-	-	-	-

TABLE 2A.5-3

PERCENT PROBABILITY OF EQUIVALENT DURATIONS OF WAVES
EXCEEDING SPECIFIED VALUES OF HEIGHT AND DURATION
GRAVINA POINT, ALASKA
(October - April, 1959-1962)

Initial Direction	Wave Height (ft)	Hours Duration							
		6	12	18	24	30	36	42	48
050°-110°	≥4	6.2	5.4	3.7	2.2	1.6	1.0	0.7	0.5
	≥6	1.0	0.6	0.2	0.1	-	-	-	-
	≥8	0.2	0.1	-	-	-	-	-	-

Initial Direction	Wave Height (ft)	Hours Duration							
		6	12	18	24	30	36	42	48
120°-210°	≥4	0.4	0.2	-	-	-	-	-	-
	≥6	0.1	0.1	-	-	-	-	-	-

Initial Direction	Wave Height (ft)	Hours Duration							
		6	12	18	24	30	36	42	48
220°-260°	≥4	2.6	0.1	-	-	-	-	-	-
	≥6	0.1	-	-	-	-	-	-	-

All Directions	Wave Height (ft)	Hours Duration							
		6	12	18	24	30	36	42	48
	≥4	6.9	5.6	3.7	2.2	1.6	1.0	0.7	0.5
	≥6	1.2	0.7	0.2	0.1	-	-	-	-
	≥8	0.2	0.1	-	-	-	-	-	-

TABLE 2A.5-4

AVERAGE NUMBER OF EVENTS THAT EXCEEDED SPECIFIED VALUES OF WAVE HEIGHT AND DURATION, GRAVINA POINT, ALASKA (May - September, 1959-1962)

Wave Height (ft)	Hours Duration 6	12	18	24	30	36	42	48
≥4	9.0	2.2	1.5	-	-	-	-	-
≥6	1.2	-	-	-	-	-	-	-

PERCENT PROBABILITY OF EQUIVALENT DURATIONS OF WAVES EXCEEDING SPECIFIED VALUES OF HEIGHT AND DURATION GRAVINA POINT, ALASKA, (May - September, 1959-1962)

Wave Height (ft)	Hours Duration 6	12	181	24	30	36	42	48
≥4	2.1	0.4	0.3	-	-	-	-	-
≥6	0.2	-	-	-	-	-	-	-

The earthquake generated both a main tsunami and local, smaller waves. The main tsunami wave, with an average period of 1.8 hours, resulted from large land displacements along a 500-mile front of the gulf coast of Alaska. This wave, with an initial height of 30 to 60 feet, was propagated mainly along a northwest-to-southeast orientation. The immediate effect was a general outflow of water from Prince William Sound.

During the earthquake, a number of local tsunamis resulted from submarine sliding of loosely consolidated deltaic materials. These waves ranged from 30 to 40 feet high, with periods of 3 to 5 minutes, and caused severe damage to Valdez, Whittier, and Seward. At Port Valdez, a run-up of 170 feet was measured (Plafker, et al., 1969). Figure 2A.5-3 shows a general distribution of the larger destructive local waves that occurred throughout Prince William Sound, along with known locations of submarine landsliding. Shorelines damaged by waves with run-up heights in excess of 40 feet above lower low water are indicated by an X, and numbers indicate the measured maximum run-up height. A solid triangle points out locations of known submarine landsliding. Other waves in western Prince William Sound may have been generated by local submarine faulting.

Wave damage to the Orca Bay area was somewhat lessened because the earthquake occurred during a period of low tidal levels and because the area was uplifted 4 to 6 feet. The sequence of events at Gravina can be inferred from records at Cordova. It is believed that there was an initial drawdown of water, followed by a series of waves (probably generated locally) with periods of one-half hour to one hour and maximum heights of 10 feet. The Gravina Site was probably hit by several 20 to 30 foot waves from the main tsunamic activity in the hours following the earthquake (Dames & Moore, 1973b). High run-ups are suspected to have occurred when the crest of a major tsunami coincided with the crest of the high spring tides. At Cordova, this resulted in wave run-ups as high as 34 feet above mean sea level (Pflaker, et al., 1969).

2A.5.1.5 Ice

Prince William Sound is considered to be essentially ice free the entire year, as is Orca Bay. Local fishermen report that sheet ice may occur at the head of Orca Bay and extend westward in quantity sufficient to impede the passage of small vessels through the Orca Bay narrows. This ice can probably be attributed to freezing of freshwater inflows from the Rude River at the head of Nelson Bay (see Figure 2A.5-2). It is estimated that sheet ice will rarely extend farther west than Simpson Bay, or exceed more than six inches in thickness. Ice could occur similarly at the heads of both Simpson and Sheep Bays, though it is not expected to extend past the entrances to these bays and its thickness will probably be less than several inches.

Some shore ice may develop in the intertidal zone at the Gravina Site; however, it is not expected to attain any significant thick ness.

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GENERALIZED DISTRIBUTION OF LARGER DESTRUCTIVE WAVES OF THE 1964 EARTHQUAKE

FIGURE 2A.5–3

Icebergs from tidal glaciers are common in northern and western Prince William Sound, but there are no known reports of them in Orca Bay.

2A.5.2 Chemical Oceanography

Baseline data on salinity, temperature, dissolved oxygen, pH, nutrients, and other parameters in Orca and Sheep Bays are quite limited. Oceanographic data on Prince William Sound are practically nonexistent. Two reports exist that describe Port Valdez and Valdez Arm (Hood, et al., 1973) and the northern Gulf of Alaska (Rosenberg, 1972). Sample locations of data presented in these reports are shown in Figure 2A.5-4. It is inappropriate to infer oceanographic conditions at the proposed Alaska Marine Terminal from these data, since Port Valdez is an enclosed bay, and the Gulf of Alaska is open ocean. Oceanographic conditions at the proposed Alaska Marine Terminal, which is to be located on a semi-enclosed bay, are likely to differ considerably from Port Valdez and the Gulf of Alaska.

2A.5.2.1 Salinity

Spatial and temporal variations of salinity within Orca Bay will be influenced by tides, winds, freshwater inflows, and the availability of oceanic waters. Maximum salinities will occur in the late winter when freshwater inflows are minimal, while minimum salinities will occur in the late summer coinciding with periods of maximum freshwater inflows.

It is expected that salinities will increase rapidly with depth from the surface to about 30 feet, and then increase only gradually in the remaining water column. Surface salinities are likewise expected to increase with distance from the heads of bays and other points of freshwater inflows.

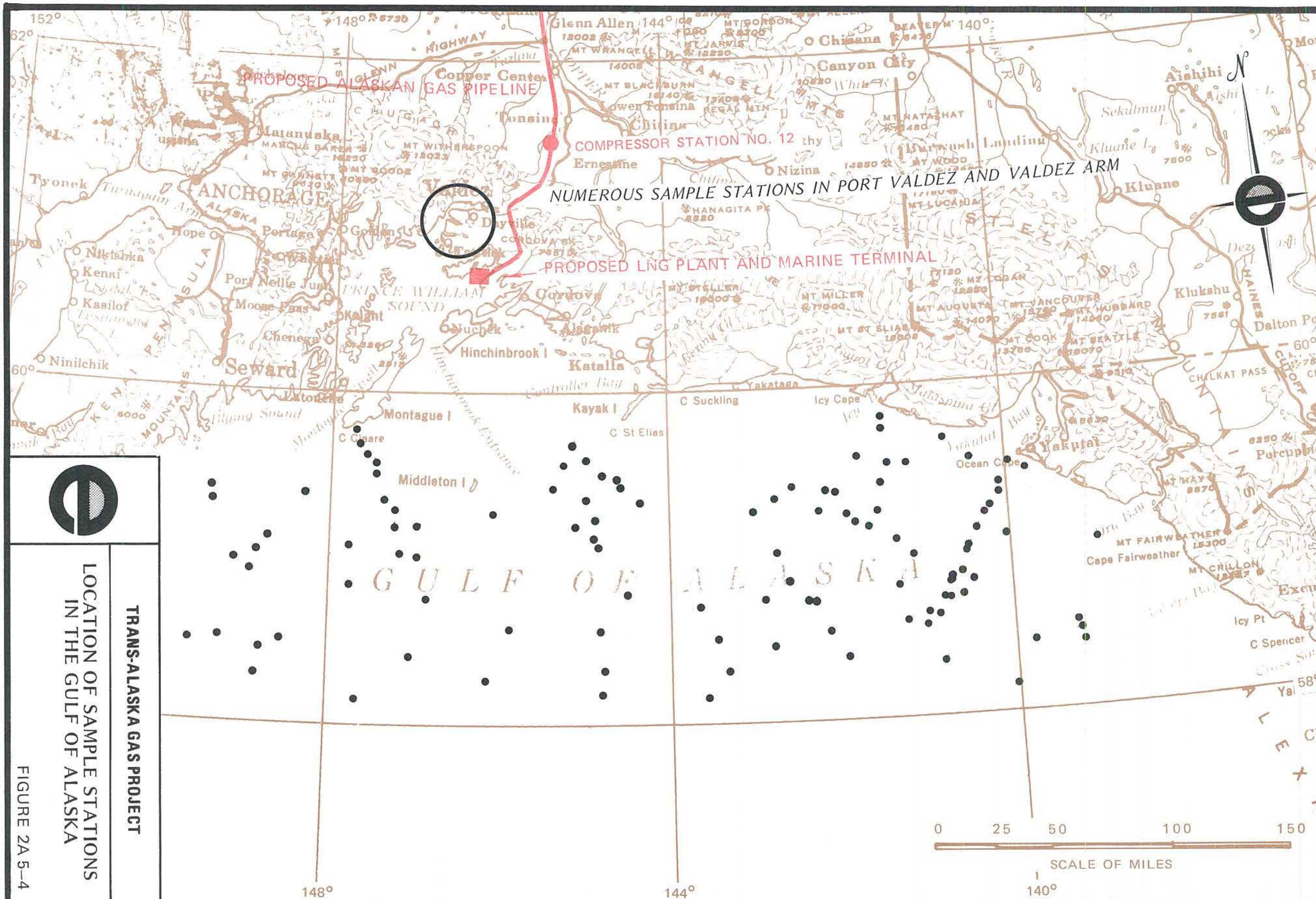
Little information is available for actual ranges of salinity occurring within Orca Bay. Some preliminary information is available from an oceanographic reconnaissance survey in September, 1973, and is summarized below:

TABLE 2A.5-5

SALINITIES AT OFFSHORE LNG PLANT SITE (PARTS PER THOUSAND)[3/]

	Minimum	Average	Maximum	No. Observations
Surface	25.4	27.6	31.1	9
Mid-Depth	29.2	30.1	30.9	3
Bottom	30.5	30.9	31.1	3

[3/] Measurements taken offshore from the LNG Plant site in approximately 60 feet of water.



TRANS-ALASKA GAS PROJECT

LOCATION OF SAMPLE STATIONS IN THE GULF OF ALASKA

FIGURE 2A 5–4

2A.5.2.2 Temperature

Sufficient information on water temperatures is not available to determine spatial and temporal variations of temperatures within Orca Bay. It is expected, however, that maximum surface temperatures will occur during middle or late summer when solar heating is greatest. Surface temperatures might be slightly lower near freshwater inflows from glacier-fed streams. Water temperatures will reach a minimum during the winter months.

Some preliminary information is available from an oceanographic survey conducted in September, 1973. These data are summarized below, and indicate a thermal gradient.

TABLE 2A.5-6

WATER TEMPERATURES (°C) AT OFFSHORE LNG PLANT SITE 4/

	Minimum	Average	Maximum	No. Observations
Surface	10.0	10.4	10.7	9
Mid-Depth	10.7	10.8	11.0	3
Bottom	10.2	10.4	10.6	3

4/Measurements taken offshore of the LNP Plant site in approximately 60 feet of water.

2A.5.2.3 Dissolved Oxygen

Generally, dissolved oxygen in the surface waters of the Gulf of Alaska approaches saturation, which is about 6.0 mg/l (Longerich & Hood, 1972). Since the concentration of dissolved oxygen is predominately dependent upon salinity, temperature, and biological activities it could vary greatly among the bays of Prince William Sound.

2A.5.2.4 pH

Sea water is usually alkaline, having a pH of 8.0 or slightly higher at the surface and decreasing with depth. Areas like Sheep Bay that have freshwater inputs normally exhibits increased pH values seaward. Orce Bay may exhibit a narrow range of pH near 8.0.

2A.5.2.5 Nutrients

Bay waters may exhibit significant variations in nutrient paramaters, depending on concentrations in river waters entering the bays and on local conditions. Coastal waters of southeast Alaska have been found to contain rather high amounts of silica in the surface waters (Sharma, 1970). Hood (1969) found comparatively high concentrations of ammonia, nitrite, and nitrate in Valdez Arm and Port Valdez. Areal and seasonal variations of nutrients near the proposed Alaskan Marine Terminal are unknown.

2A.5.2.6 Other Chemical Parameters

Although not directly applicable to Orca Bay, it is interesting to note the rather wide ranges of certain components of sea water found in various southeast Alaskan fiords. Table 2A.5-6 presents ranges for various parameters measured in surface waters, bottom waters, and interstitial waters (water in the sediment). These large variations could also be found in Orca Bay.

TABLE 2A.5-6

RANGES OF VARIOUS COMPONENTS OF SEA WATER

	Surface Water	Bottom Water	Interstitial Water
Na, ppm	6000-8800	7400-8800	8400-8700
Mg, ppm	650-1100	1060-1080	800-1700
K, ppm	220-350	340-425	330-360
Ca, ppm	200-380	350-380	236-450
Sr, ppm	3.0-5.0	9.0-15.5	9.0-12.0
Li, ppm	0.108-0.17	0.17-0.34	0.15-0.19

Source: Longerich & Hood, 1972

2A.5.3 Circulation and Flushing

The circulation patterns of Orca Bay are unknown at this time; however, generalizations can be made, based upon observations in other regions of Alaska.

Fiords in Prince William Sound are classified positive, since they receive more water as run-off and direct precipitation than they do by saline input from the ocean. The typical circulation in these fiords is a seaward movement of less saline surface waters and a landward movement of more saline deeper layers. This circulation is sufficient to maintain, or at least periodically renew, waters within Orca Bay.

Fiords in northern latitudes also exhibit a general counterclockwise circulation of surface waters because of the Coriolis effect. This circulation pattern is also expected to be enhanced by larger freshwater inflow on the northern margins of Orca Bay at the heads of the tributary bays.

The mixing and flushing characteristics of Orca Bay are not known at this time because of a lack of adequate meteorologic, hydrologic, and oceanographic information. It is expected, however, that vertical mixing will increase with distance from the head of Orca Bay, and will be more rapid during the winter when freshwater inflows are minimal.

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SECTION 2A.6 - SPECIES AND ECOSYSTEMS

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2A.6 SPECIES AND ECOSYSTEMS

This Section is divided into three parts, according to the three relatively distinct climatic, physiographic, and biological regions crossed by the proposed Alaskan Gas Pipeline (Figure 2A.6-1).

The Arctic Drainage Division (Section 2A.6.1) extends from the Beaufort Sea to the Continental Divide in the Brooks Range. The Interior Basin Division (2A.6.2) extends from the Brooks Range south to Thompson Pass in the Chugach Mountains, and includes the "transitional zone" of the Copper River Drainage Division of Johnson and Hartman (1969), and Arkin (1972). The South Coastal Division (2A.6.3) extends from Thompson Pass to the southern terminus of the gas pipeline at the LNG Plant at Gravina, and thence to the departure point of ships from Alaskan coastal waters, at Hinchinbrook Entrance.

For each Division, species and ecosystems are described for each major environment--terrestrial, aquatic, and marine--in functional, dynamic terms. The Species and Communities subsections describe plant communities, and includes a lengthy table of the known plant and animal species. The Abiotic Characteristics subsection briefly treats the soils and weather as these aspects influence the biota. The terrestrial, aquatic, and marine environments are then described in functional dynamic sequence, from Primary Production (green plants) through Consumption (herbivores, carnivores), Decomposition, and Systems Dynamics (the interworking of the previous three). Wildfire is an important aspect in the Terrestrial Environment; thus, it is treated sequentially in that subsection, following Decomposition. Regional Systems Interactions are discussed at the conclusion of each of the three major Divisions.

To frame an example, the brown lemming (lemmus trimucronatus) is listed in Appendix A (Arctic Drainage Division Species List), as one of the many mammals found in that region. The brown lemming is subsequently identified as the principal functional herbivore, or consumer, utilizing primary production of green plants. The lemming's unique role is important in understanding how the ecological system of the region operates, why other species are present or absent from the system, and what can be expected when the system is disturbed. If lemmings shared the role of herbivore with a species of grasshopper, each would be taken from an entirely different faunal inventory list (mammals vs. insects), but would be assigned a similar role in ecosystem functioning.

The functional dynamic approach to describing ecological systems differs from the static, natural history cataloging of biota. In addition to asking, "What is that species?", the functional dynamic approach asks, "What does that species do in the system?". In addition to identifying the rare and endangered species, it also identifies sensitive and vital biological processes, without regard for population sizes.

TRANS-ALASKA GAS PROJECT

BIOTIC DIVISIONS OF ALASKA PERTINENT TO THE PROPOSED ALASKAN GAS PIPELINE

FIGURE 2A.6–1

A general conceptual model helps to frame this discussion (Figure 2A.6-2). Basically, two commodities circulate through any ecological system: energy and matter.

Energy is captured in photosynthesis by primary producers (mainly green plants). A fraction of that energy is passed up the food chain to consumers--first to herbivores, then to carnivores. Death and waste products represent energy transfer to decomposers (or in many Alaskan situations, to wildfire). Decomposers utilize this energy, and function chiefly in returning nutrients to the system for reuse by primary producers.

The earth is an open system with respect to energy. Incoming energy is re-radiated at each step of biological transfer. Along with energy, matter flows through the ecosystem. The lithosphere and biosphere, however, form a closed system with respect to matter. For all practical purposes, materials (nutrients and water) are cycled repeatedly in a series of closed loops without net gain from, or loss to, outer space. These cycles are commonly referred to as "biogeochemical cycles."

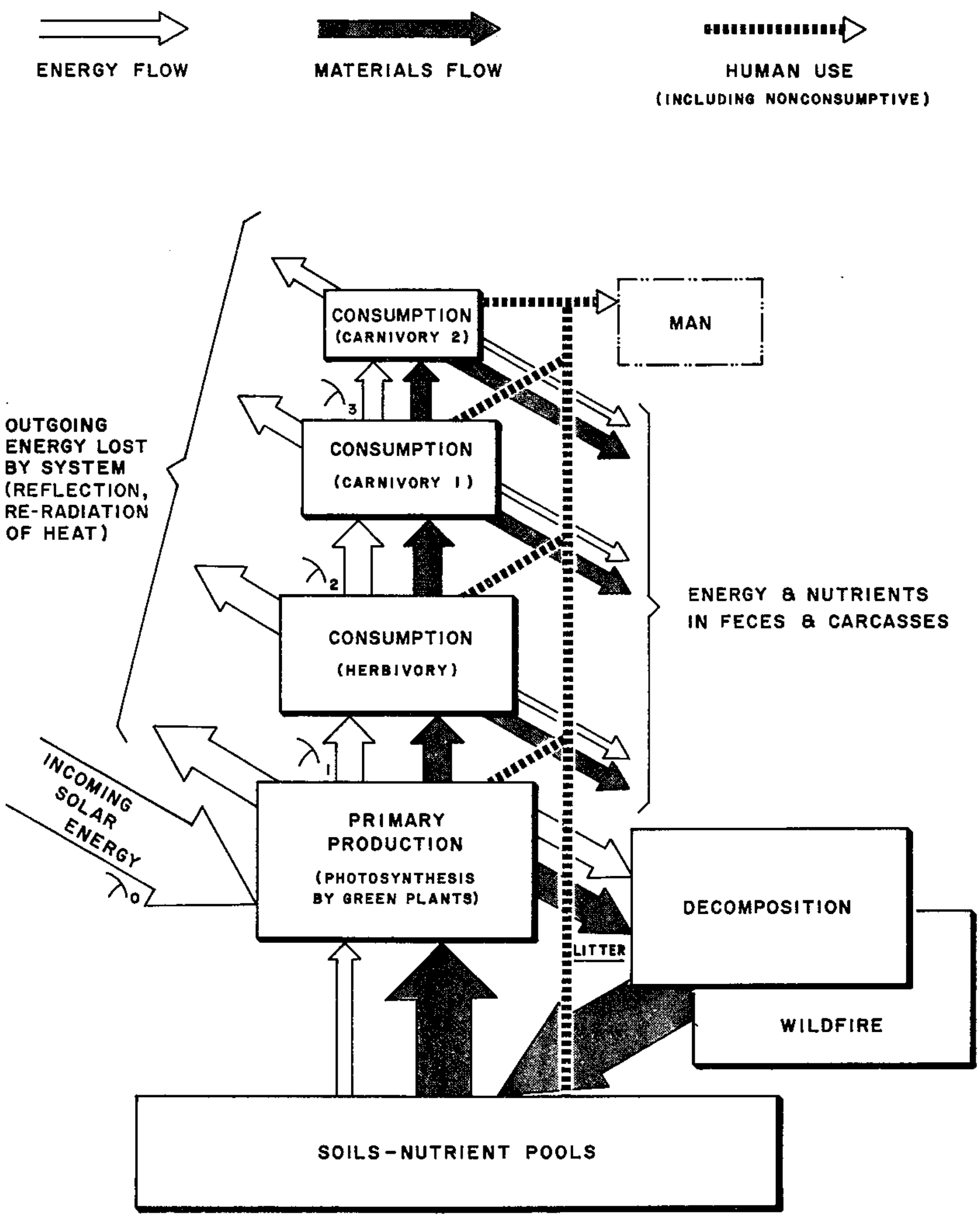
An important feature of the functional-dynamic model is that it permits analysis of biotic transfers to and from man at each trophic level (Figure 2A.6-2). By being deliberately nonspecific about units of measure for the commodities involved in human interaction with the ecosystem, nonconsumptive human uses, such as recreation, can be identified along with consumptive uses, such as agriculture, fishing, and hunting.

The functional-dynamic framework is in keeping with present ecological systems analysis, used by the International Biological Program (cf Bowen, 1972). The conceptual models of functional-dynamic ecology, by stressing biotic transfers, productivity, and turnover rates, should permit the prediction of impact and perturbation at all levels of the system.

Repeated natural disturbances of biotic systems are characteristic of Alaskan communities, as elsewhere. Where possible, the known natural recovery steps, or successional stages, following such disturbances as wildfire, floods, and glaciation, will be examined for their value in subsequent predictions of impact.

2A.6.1 Arctic Drainage Division

The North American Arctic has been the focus of intensive ecological research in the last several years. As a consequence of both government (International Biological Program, Ecosystems Analysis) and industry-inspired research in this and comparable regions, new data have accumulated at an unprecedented rate since the preparation of the Alyeska Environmental Impact Statement (USDI, 1972). The rapid developments in arctic ecology have generated complete reappraisals of the dynamics of the region. Remaining abreast of the development of such concepts as "fragility of the tundra," "limiting factors," and "effects of disturbance," is both necessary and bewildering, because synthesis of ideas and information is still under way, and much of what has been written is preliminary (Bliss, 1972).



TRANS-ALASKA GAS PROJECT

FUNCTIONAL DYNAMIC MODEL OF TERRESTRIAL ECOLOGICAL SYSTEMS FOR ALASKA

FIGURE 2A.6-2

2A.6.1.1 Species and Communities

Arctic Drainage Division vegetation is dominated by chamaephytes and hemicryptophytes (Bliss, 1971), which make it appear continuous with little complexity. Phytosociological classification attempts, however, have shown that such a view is untenable, because the effects of relief, both macro and micro, and substrate dynamics on tundra vegetation are profound (Johnson, 1969). This is especially true of the triadic relationship of permafrost, cryopedogenic processes, and vegetation.

Superimposed on the plant community mosaic of North Slope vegetation are two general phytogeographical patterns: (a) a decrease in species numbers as latitude increases (Bliss, 1956; Spetzman, 1959; Britton, 1957), and (b) predominance of graminiform (grass-like) species and concurrent decrease in woody forms with increasing latitude (Clebsch & Shanks, 1968; Britton, 1957; Batten & Murray, in preparation). This leads to a change from sedge-grass communities near the Beaufort Sea Coast to tussock-heath communities in the southern portion of the Arctic Drainage Division. The change is gradual, implying control by climatic variables.

Correlations between floristic data and mean monthly temperature sums for the growing season support the contention that there are different zones of arctic vegetation related to climatic severity. On the North Slope, two zones are recognized: (a) a coastal zone, and (b) an inland zone extending to the crest of the Brooks Range. A severe maritime climate characterizes the coastal zone, while the inland zone is characterized by a more continental climate (Polunin, 1951; Young, 1971).

Topographic and historical diversities generate a community mosaic within climatic macropatterns (Bliss, 1956; Spetzman, 1959; Britton, 1957; Johnson, 1969). A discussion of regional vegetation within the physiographic provinces of Wahrhaftig (1965) is therefore useful.

The following is taken from the Final Environmental Impact Statement for the Proposed Trans-Alaska (Oil) Pipeline (USDI, 1972).

Coastal Plain Vegetation

> The vegetation blanketing the 50-mile wide coastal plain south of Prudhoe Bay is simple in composition and form. The coastal plain is strikingly uniform, exhibiting little relief. Most of the soils are poorly drained sandy silts. Because of this uniformity in the physical environment, most of the vegetation consists of nearly continuous sedge sod, forming a wet sedge meadow. The grass-like sedges and associated grasses grow to heights of six inches along the coast and to a foot or more inland. The sedge meadow is composed primarily of one species (<u>Carex aquatilis</u>), but others are present. These, along with the few other sedges, some grasses, and herbaceous plants, grow in the wet depressions of ice-wedge polygons.....
>
> The uniformity is broken by different kinds of vegetation on low, peat ridges, and in areas of active sand dunes. Low, woody, heath species (<u>Vaccinium</u> sp, <u>Ledum palustre</u>), mountain avens (<u>Dryas integrifolia</u>) and matted willows (<u>Salix</u>

arctica, Salix reticulata) that range from one to three inches high grow with sedges on low peat ridges that rise only a few inches above the polygonal depressions.

Foothills Vegetation

Cottongrass-dwarf birch-heath vegetation covers hundreds of square miles of the gently rolling foothills south of the mouth of Ivishak River. The tussock-forming cottongrass (Eriophorum vaginatum, subsp. spissum) predominates and is responsible for the unique appearance of the country. The sites characterized by cottongrass tussocks are somewhat better drained than wet sedge meadow sites and water is present at the surface most years only through early June. The tussocks range from 2 to 18 inches in height, 6 to 15 inches in diameter, and are evenly spaced at intervals of 6 to 18 inches. Woody plants, dwarf birch (Betula nana), blueberrys (Vaccinium uliginosum), lingonberry, (Vaccinium vitis-idaea), bearberry (Arctostaphylos alpina), Labrador tea (ledum palustre), and cloudberry (Rubus chamaemorus) grow in sphagnum moss in the intervening spaces among the tussocks. . . .

The vegetation on sand and gravel bars of the braided Sagavanirktok River, where the bars are frequently disturbed, is sparse at best. The plants that do start to grow are commonly destroyed by floating ice in spring, icings that persist on the flood plain well into July, and frequent channel shifting.

Two species of shrubby willow grow on young alluvial terraces that are underlain by coarse sandy gravel and sand, and along the banks of older terraces. One species, Alaska willow, (Salix alaxensis) grows to heights of four to eight feet. The other, Salix pulchra, is smaller. On the lower terraces, the bases of the shrubs have been buried by recently deposited alluvium. Much of the flooded surface is bare, but scattered grasses, sedges, scouring rush, grass-of-parnassus, bearberry, and vetch are present among the willows. Similar vegetation is present in an irregular, discontinuous band up to 10 feet wide along the banks of higher, older terraces. These surfaces are flooded infrequently, or not at all, and the ground surface is underlain by one to two inches of humus. Here, too, tiny, prostrate willows, netted willow (Salix reticulata) and arctic willow (Salix arctica) are common and grow to heights of one to three inches.

Toward the upland on old alluvial terraces, the vegetation is composed of low prostrate plants, and dwarf heath shrubs six inches to two feet tall. . . .

Alluvial fans and colluvium deposits in the vicinity of Franklin Bluffs and below steep slopes southward are kept bare of vegetation by active erosion and physical instability. . . .

North Slope-Brooks Range Vegetation

Four types of vegetation characterize the proposed route along the Atigun River to the Continental Divide. These are stream bank shrub, which is similar to that along streams in the foothills, matted sod, sedge meadow, and rock desert. Although balsam poplar trees (Populus balsamifera) are scattered along the river bottom, they only locally exceed 20 feet in height. Thus, they have forms similar to the larger willow shrubs, which are the predominant plant on the flood plain.

Along the Atigun River between its junction with the Sagavanirktok River and Galbraith Lake, the vegetation on level and gently sloping surfaces underlain by sedimentary rocks and on old moraines, consists of tightly matted sod. Low willows, small heaths, other woody plants, grasses, sedges, herbaceous plants and lichens are among the many species comprising the sod. These plants grow only to heights of two to three inches. In rocky areas, taller Arctic willow and blueberry shrubs reach heights of three feet and form relatively dense thickets. On lower parts of slopes near Galbraith Lake where water stands at the surface in summer, the vegetation consists of sedge meadow. Because of the gentle slopes, movement caused by freezing and thawing has pushed the sod and underlying peat into ridges 6-12 inches high that are roughly parallel to the contour, giving the landscape the appearance of terraced slopes.

The steep, rocky, valley slopes and ridges, small alluvial fans, and colluvium deposits in the Atigun River Canyon and Endicott Mountains are nearly bare of plants. Locally scattered, matted woody plants and tufts of grass grow where some amount of fine mineral soil and organic matter has accumulated and physical disturbance has ceased momentarily, or is reduced in intensity. This is called rock desert and is described by others (Britton, 1957, pp 37-38; Porsild, 1951; Sigafoos, 1952, pp 482-483; Spetzman, 1959, pp 28-30). (Vol 2, pp 118-123).

Arctic vegetation has been classified by several investigators (Batten & Murray, in preparation), but the most applicable systems of nomenclature belong to Johnson, et al., (1966) and Wielgolaski (1972). Because of the greater applicability of Johnson, et al., (1966) (Batten & Murray, in preparation), their system will be followed in descriptions of major plant communities.

Habitat characteristics and dominant species of the communities discussed are presented in Table 2A.6-1.

2A.6.1.1.1 Strand Communities

These characterize coastal beach ridges, reefs, and spits (Britton, 1957). Because of coastal erosion and plant succession, their extent is slight. They occupy xeric (very dry) habitats (Britton, 1957)--the most severe being ridge crests. Between ridges lie both mesic (moderately moist) and hydric (very moist) sites.

TABLE 2A.6.1

HABITAT CHARACTERISTICS AND DOMINANT SPECIES
ARCTIC DRAINAGE DIVISION

Plant Community	Topographic Position	Moisture	Soil Type	Dominant Species	Reference
STRAND COMMUNITIES (Small extent, restricted to coastal barrens)	Recent beach ridge tops, reefs, and spits	Well drained	Regosols (marine sands and gravels)	PLANTS *Honckenya peloides* *Mertensia maritima* *Lathyrus maritima* *Cochlearia officinalis arctica* *Puccinellia phryganodes* *Oxytropis nigrescens*	Britton, 1957
				ANIMALS *Charadrius semipalmatus*, (Various shorebirds and waterfowl in migration) *Alopex lagopus innuitus*	
	Depressions in recent beach ridge systems	Wet	Hydrosols	PLANTS *Alopecurus alpinus* *Arctophila fulva* *Dupontia fischeri* *Calamagrostis neglecta*	
			Bog soils	PLANTS *Dupontia fischeri* *Cochlearia officinalis arctica* *Carex aquatilis* *Saxifraga hirculus*	
				ANIMALS Collembola, Chironomidae, Tipulidae; *Calidris bairdii*, *Sterna paradisea* *Stercorarius*, spp, *Larus*, spp	

TABLE 2A.6-1 (continued)

Plant Community	Topographic Position	Moisture	Soil Type	Dominant Species	Reference
	Exposed ridges on emergent strands (old beach ridges and spits)	Xeric	Regosols (marine sands and gravels)	PLANTS *Salix rotundifolia* *S. phlebophylla* *Cassiope tetragona* Lichens and Mosses prominent	
				ANIMALS *Tipulidae* *Calidris alpina* *Pluvialis dominica* *Lemmus trimucronatus* *Nyctea scandiaca* *Alopex lagopus*	
	Depressions between emergent strands	Wet	Bog soils	PLANTS *Carex aquatilis* *Poa arctica*	
				ANIMALS Chironomidae, Collembola *Calidris melanotos*	
SAND DUNES (Throughout region, often near rivers	Usually slightly elevated above surrounding terrains (very limited extent)	Xeric	Regosols (dune sands)	PLANTS *Anemone parviflora* *Antennaria angustata* *Armeria maritima* *Dryas integrifolia* *Silene acaulis*	Britton, 1957
				ANIMALS Aranei *Citellus undulatus* *Rangifer tarandus* (during insect attack)	White et al, 1974

Plant Community	Topographic Position	Moisture	Soil Type	Dominant Species	Reference
ERODING BLUFF (Throughout the North Slope)	Often on river bluffs such as the Franklin Bluffs	Xeric	Variable--often a lithosol or regosol	PLANTS *Oxyria digyna* *Potentilla hyparactica* *Papaver radicatum* *Petasites frigidus* *Saxifraga* spp Mosses	Britton, 1957
GRAVEL BAR & BENCH COMMUNITIES (Successional communities)	Flood Plains Less than 1.5 m above normal river level	Well drained	Regosols--gravels, sands silts	PLANTS *Crepisnana* *Erigeron purpuratus* *Artemesia tilesii* *A. alaskana* *Oxytropis* spp Mosses	Bliss & Cantlon, 1957
	Gravel bars higher in elevation than about 1.5 m	Well drained	Regosols--gravels, sands silts	PLANTS *Salix alaxensis* *S. arbusculoides* *S. glauca* *Lupinus arcticus* *Oxytropis* spp *Hedysarum mackenzii* *H. alpinum americanum* *Artemisia tilesii* *A. alaskana*	
	Gravel bars greater than 1.5 m above river level	Moist	Regosols to meadow tundra soils	PLANTS *Salix alaxensis* *S. arbusculoides* *S. glauca* *Equisetum arvense* *Pyrola grandiflora* *Drepanocladus uncinatus* *Lupinus arcticus*	

TABLE 2A.6-1 (continued)

Plant Community	Topographic Position	Moisture	Soil Type	Dominant Species	Reference
				Deschampsia caespitasa *Hierochloe adorata*	
ERIOPHORUM-CAREX WET MEADOW (Dominant community of the Arctic Coastal Plain. It covers approximately 50% of the province)	Lowest river terraces	Moist	Meadow tundra soils	PLANTS *Alnus crispa* *Salix pulchra* *S. glauca desertorum* *S. arbusculoides* *Carex aquatilis* *Hylocomium alaskanum* *Vaccinium uliginosum* *Eriophorum vaginatum spissum* *Empetrum nigrum* *Lupinus arcticus* *Cetraria* spp	
				ANIMALS *Lagopus lagopus* *Numenius phaeopus* *Turdus migratorius* *Lanius excubitor* *Wilsonia pusilla* *Zonotrichia leucophrys* *Citellus undulatus* *Alces alces* *Vulpes fulva*	
	Poorly drained lowlands depressions on moderately drained sites	Wet	Bog soils	PLANTS *Carex aquatilis* *C. chordorrhiza* *Dupontia fischeri* *Eriophorum scheuzeri*	Spetzman, 1959

TABLE 2A.6-1 (continued)

Plant Community	Topographic Position	Moisture	Soil Type	Dominant Species	Reference
				ANIMALS Saprovorous insects (Tipulidae, Chironomidae) Collembola; Shorebirds: 6-10 spp *Nyctea scandiaca* *Stercorarius*, spp *Lemmus trimucronatus* *Mustela nivalis*	
ERIOPHORUM TUSSOCK Southern Teshekpuk Lake Section, White Hills Section, Arctic Foothills to 3000 feet. It is the dominant community of the Foothills.	Uplands and lower slopes of higher foothills	Moist	Uplands tundra soils	PLANTS *Eriophorum vaginatum spissum* *Arctagrostis latifolia* *Poa arctica* *Carex biglowii* *Betula nana exilis* *Empetrum nigrum* *Ledum palustre decumbens* *Polygonum bistorta plumosum*	Spetzman, 1959
				ANIMALS [Collembola, Aranei (lycosidae)] *Calidris melanotos* *Calcarius lapponicus* *Passerculus sandwichensis* *Corvus corvax* *Microtus oeconomus* *Rangifer tarandus*	
DRYAS FELL-FIELDS (Dominant community of Brooks Range Province)	Ridges between 2000 and 4000 feet in elevation	Xeric	Lithosols--Arctic brown (shallow phase)	PLANTS *Dryas octopetala* *Arctagrostis latifolia* *Calamagrostis purpurescens* *Festuca brachyphylla* *Hierochloe alpina* *Carex misandra*	Spetzman 1959

TABLE 2A.6-1 (continued)

Plant Community	Topographic Position	Moisture	Soil Type	Dominant Species	Reference
				C. scirpoidea *Kobresia myosuroides* *Empetrum nigrum* *Loiseleuria procumbens* *Salix reticulata* *S. rotundifolia* *Oxytropis* spp *Pedicularis lanata* Lichens	
	South-facing rubble slopes	Xeric	Regosol	PLANTS *Androsace ochotensis* *Draba* spp *Hierochloe alpina* *Kobresia* spp *Oxytropis nigrescens* *Antennaria* spp *Erigeran* spp *Potentilla* spp	
	North-facing rubble slopes	Moist	Regosol	PLANTS *Dryas octopetala* *Saxifraga bronchialis funstonii* *S. davurica grandipetala* *S. eschscholtzii* *S. serpyllifolia* *S. tricuspidata* *Cassiope tetragona* *Vaccinium uliginosum* Mosses	
				ANIMALS *Aquila chrysaetos* *Lagopus mutus* *Calidris bairdii*	

TABLE 2A.6-1 (continued)

Plant Community	Topographic Position	Moisture	Soil Type	Dominant Species	Reference
				Eremophila alpestris *Anthus spinoletta* *Citellus undulatus* *Ursus arctos* *Rangifer tarandus* *Ovis dalli*	
OUTCROP AND TALUS COMMUNITIES (not common) (Higher elevations of foothills and mountains)	Steep Slopes	Xeric	Lithosol	PLANTS *Saxifraga caespitosa sileneflora* *S. davurica grandipetala* *S. flagellaris* *S. oppositifolia* *S. punctata nelsoniana*	Britton, 1957
				ANIMALS *Oenanthe oenanthe* *Aquila chrysactos* *Falco peregrinus* *Buteo lagopus* *Ovis dalli* *Marmota caligata*	

Recent beach ridges have a thin covering of plants because of: (a) ice shoving during winter and spring storms, and (b) severe storms sweeping the beaches, removing and depositing large volumes of sand and gravel. Old beach ridges are less subject to scouring and therefore have a more complete vegetative cover.

2A.6.1.1.2 Sand Dunes

These are found to a limited extent throughout the Arctic Coastal Plain. Dune habitats are typically xeric, but many tundra species, such as grasses, Saxifraga spp, and Pedicularis spp, occupy them nonetheless. Several forbs unique to dunes set them off floristically from other Coastal Plain communities.

2A.6.1.1.3 Eroding Bluff

These communities depend upon substrate stability. In such areas exists a depauperate assemblage of vascular taxa and mosses, with the extent of plant cover increasing with slope stability.

2A.6.1.1.4 Gravel Bar and Bench Communities

These form a successional sequence, which may arbitrarily be divided into four communities:

(1) A pioneer stage characterized by perennial herbs;

(2) A vigorous willow stage dominated by the feltleaf willow, Salix alexensis;

(3) A zone of deteriorating feltleaf willow with increasing cover of low greenleaf willows, mosses, and herbs; and

(4) An alder-willow-heath type that grades into Eriophorum-Carex wet sedge meadow or Eriophorum tussock communities on wet sites.

Pioneer stages tend to have low plant cover values (plant cover increases in later stages). Closed "climax vegetation" exists on older river terraces.

2A.6.1.1.5 Eriophorum-Carex Wet Sedge Meadows

These cover about half the area of the Arctic Coastal Plain and one-quarter of the Arctic Foothills (Spetzman, 1959), the dominant community of the Teshekpuk Lake section, and of secondary dominance in the White Hills section and Arctic Foothills.

This community's habitat is associated with saturated, peaty soils on flat, poorly drained lowlands, margins of flood plains, and lake shores (Spetzman, 1959). Frost polygons, 50 feet or more in diameter, characterize these areas (Britton, 1957).

2A.6.1.1.6 Eriophorum Tussock Communities

These characterize elevated southern parts of the Arctic Coastal Plain and Arctic Foothills. They are associated with fairly well-drained soils, which suffer moderate to intense frost action (Spetzman, 1959).

2A.6.1.1.7 Dryas Fell-fields

These dominate elevations of 2000 to 4000 feet in the Brooks Range. They occupy ridge tops and rubble slopes with shallow, well-drained lithosols.

Vegetative cover is sparse and of low stature, a few inches high, and composed primarily of Dryas octopetala and lichens. The remaining flora consists of grasses, dry land sedges, shrubs, and herbs. Variants of the general theme are relative to exposure differences (Spetzman, 1959).

The approximate distribution of North Slope community types along the proposed Alaskan Gas Pipeline route is given in Table 2A.6-2, and an extensive listing of species and communities found in the Arctic Drainage Division is presented in Appendix A hereto.

Because of the flexibility of animal interactions and the importance of mobility to much of the northern fauna, it is difficult to construct "animal community" patterns analogous to plant communities. Population interactions of consumers are, instead, treated as trophic relations in subsequent subsections. A few key species of consumers are indicated in association with the tabular presentations of plant community types in Appendix A, but these are by no means exhaustive lists.

2A.6.1.2 Abiotic Characteristics

2A.6.1.2.1 Meteorology

The climatic severity of the Arctic is well known. Terrestrial and aquatic biological systems operate on a brief annual "pulse" of primary production that occurs between June and August. The ultimate factor controlling primary productivity here, as elsewhere, is incident radiation (Weller & Cubley, 1972). Available light depends on the annual solar cycle, on the effects of snow and ice cover, and on local conditions such as cloud cover and, in lakes, turbidity and wind disturbance of water surfaces.

Because snow melt and commencement of tundra production are delayed in much of the region until near the summer solstice, 50 percent of the annual solar radiation is largely unavailable for carbon fixation (Tieszen, 1971). Though the sun remains above the horizon for several

TABLE 2A.6-2

DISTRIBUTION OF ARCTIC DRAINAGE DIVISION COMMUNITIES

Milepost Start	Milepost End	Miles	Plant Community	Area Affected By Pipeline Right-of-Way Acres	Area Affected By Pipeline Right-of-Way Hectares
0	16	16.00	*Eriophorum-Carex* Wet Sedge Meadow	291	118
16	51	35.00	*Eriophorum* Tussock	636	258
51	59	8.00	*Eriophorum-Carex* Wet Sedge Meadow	145	59
59	127.25	68.25	*Eriophorum* Tussock	1245	504
127.25	127.75	0.50	Gravel Bar and Bench	9	4
127.75	160.00	32.25	*Eriophorum* Tussock	586	237
160.00	162.50	2.50	*Dryas* Fell-field	45	18

weeks following the solstice, the angle of incidence is quite low much of the time.

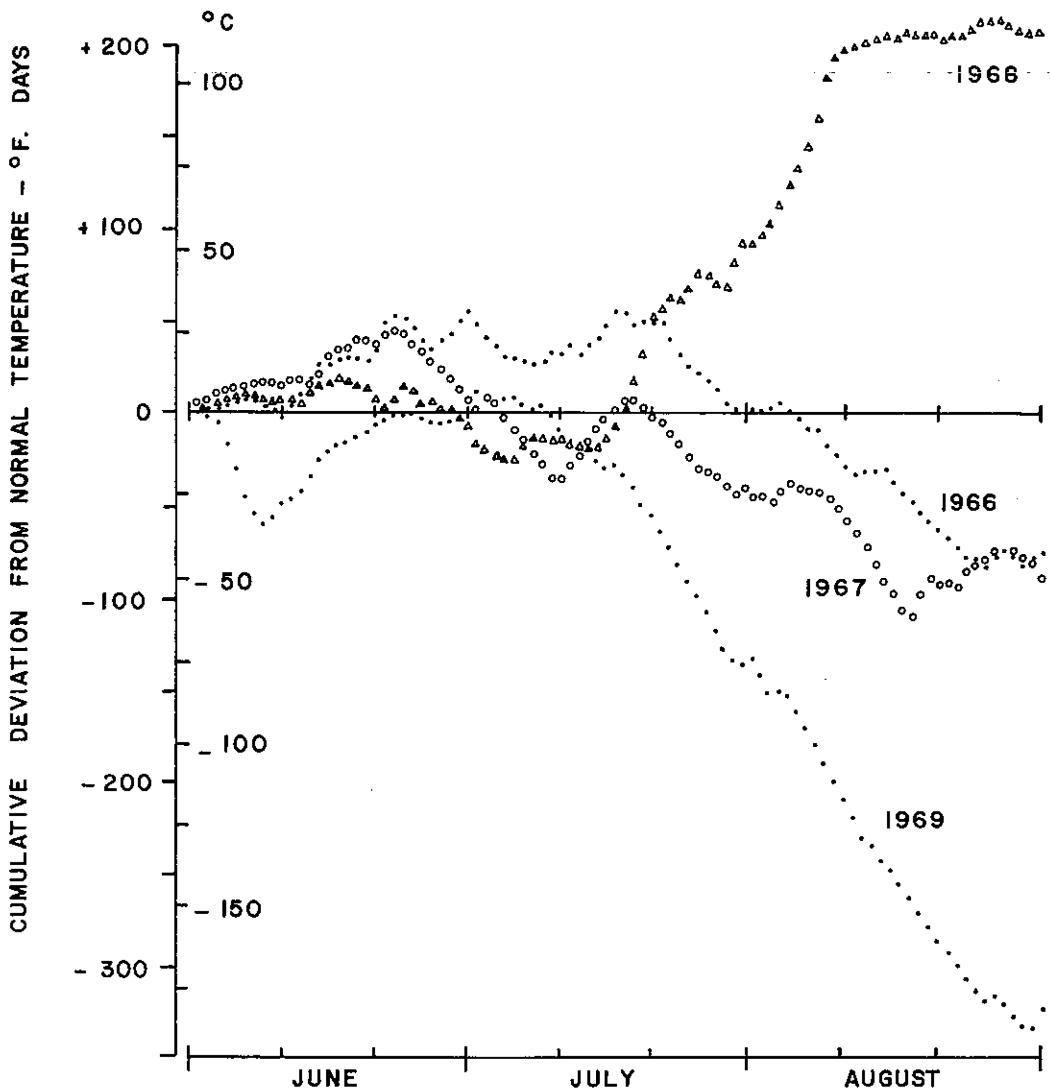
Rates and timing of snow melt, especially on the Coastal Plain, are determined largely by ambient temperatures, which are in turn affected by ice conditions on the Beaufort Sea. Depth of snow on ice is a vital factor to biological production in lakes and ponds, since 8.25 cm of loose, fluffy snow transmits approximately 18 percent of the incident light received (Howard & Prescott, 1971). In light transmission, the quality of the ice is as important as its thickness. On deep arctic lakes, the ice tends to be bubble-free and clear. Thus, a 50 percent reduction in incident intensity requires a thickness of 347 cm of clear ice, but only 20 cm of the bubbly ice found on shallow lakes (Hobbie, et al., 1972).

In much of this region, air temperatures typically oscillate about a mean slightly above freezing during the biologically active season. Periods of subfreezing weather put a stop to terrestrial primary production and much of secondary production. Aquatic production is less affected. Seasons of abnormal temperatures result in wide excursions of overall biological production, which statistically correspond most closely to the parameter of cumulative deviations from normal temperature (Figure 2A.6-3). Poikilotherms, such as fishes and soil arthropods, grow and develop slowly in cold waters and soils (MacLean, in press; Kalff, 1970; Hobbie, 1973). Arctic homeotherms must expend considerable energy to maintain stable body temperature--energy that might otherwise be available for secondary production (i.e., growth and reproduction) (cf Irving, 1972; Norton, 1973; West & Norton, in press).

Precipitation is less than 40 cm per year in all of this region, and less than 25 cm per year in much of it. Most of the precipitation occurs as snowfall. In the summer, dense fogs are frequent along the northern coast.

The availability of water, along with ambient air temperature, distinguishes tundra systems from those of other biomes, as shown in Figure 2A.6-4. The moisture content of the soil in the Arctic Drainage Division ranges from very dry to completely saturated. Local conditions vary according to topography and drainage. For example, the microrelief associated with polygonal, or patterned, ground in the Arctic Coastal Plain causes dramatic variation over a few centimeters of horizontal distance in parameters such as soil moisture, soil nutrients, pH, temperature, and depth of the active layer (Tedrow & Cantlon, 1958; MacLean & Pitelka, 1971). In consequence of physical processes such as leaching action, biotic communities also vary dramatically over short distances into what MacLean (1969) terms a fine-grained mosaic.

The interplay of nonliving (abiotic) and living elements of terrestrial systems in this region may be such that continual and repetitive natural disturbance is a general feature of the aboveground and below ground environments. Frost action, soil creep on slopes, wildfire, and grazing activities by various herbivores, are examples of such disruptive forces (Hopkins & Sigafoos, 1950; Tedrow & Cantlon, 1958; Wein & Bliss, 1973). This natural tendency toward repeated perturbation tends to rejuvenate natural systems at random intervals by restoring them to an earlier seral stage.



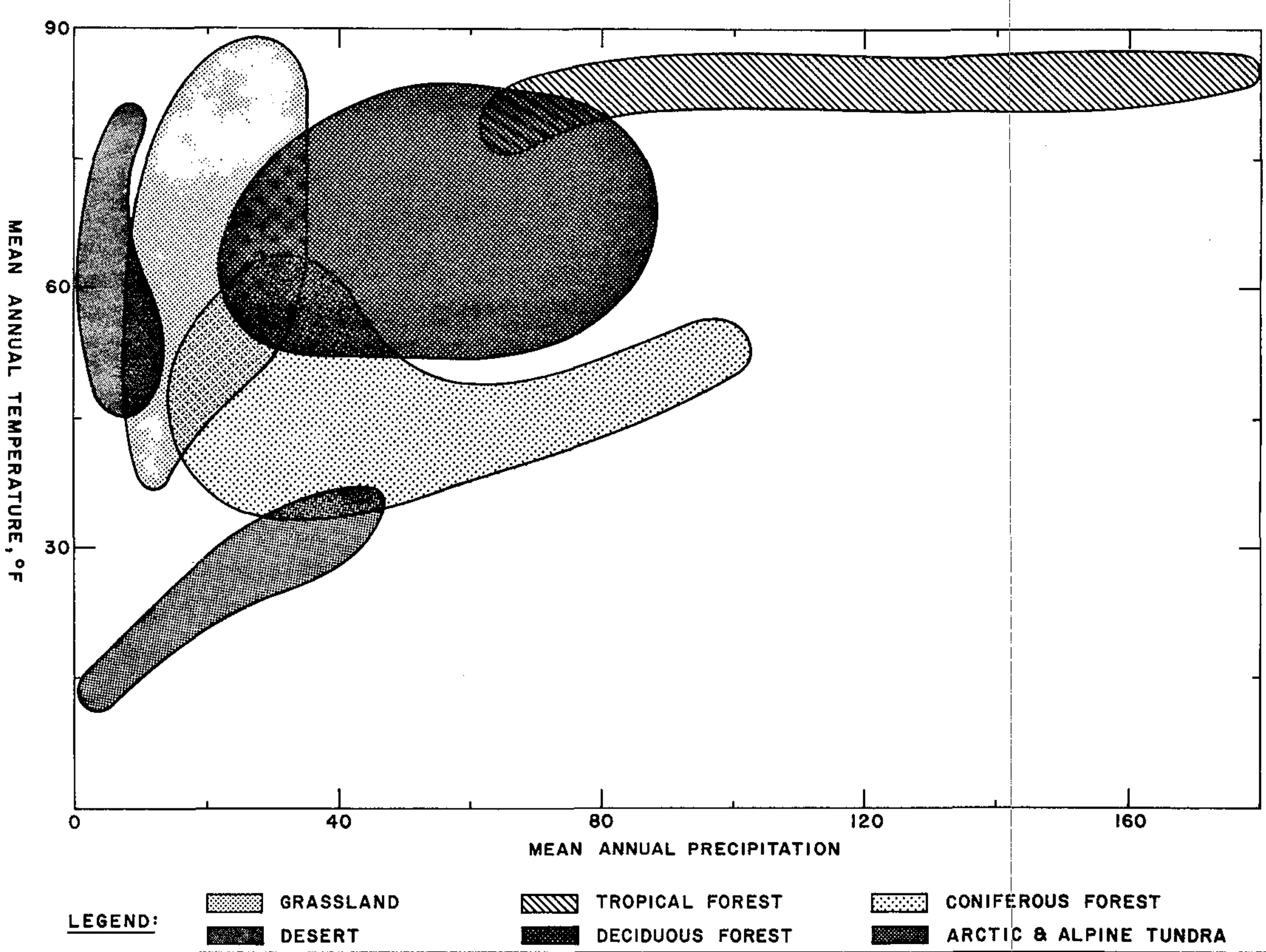
REF: MacLEAN & PITELKA, 1971

TRANS-ALASKA GAS PROJECT

SEASONAL TEMPERATURE CONDITIONS IN SUMMER MONTHS AT BARROW, ALASKA, 1966–1969

FIGURE 2A.6–3

REF: BOWEN, 1971 (MODIFIED FROM TREWARTHA, 1954)



TRANS-ALASKA GAS PROJECT

MAJOR BIOMES vs. ANNUAL PRECIPITATION AND TEMPERATURE

FIGURE 2A.6-4

2A.6.1.2.2 Soils

Arctic soils form a hydrologic series. Hydromorphic bog, half bog, meadow tundra, and upland tundra soils are underlain by permafrost at shallow depths. Increased depth of active layer and drainage give rise to arctic brown soils. Decreased depth to bedrock is associated with the shallow phase of arctic brown soil and lithosols where soil development is minimal. On transported parent materials, minimal development leads to regosol formation. These relationships are shown in Figure 2A.6-5.

As in any region, arctic soil formation, plant community structure and function, and decomposition are components of a dynamic system. The distinguishing feature of arctic soils in this respect is their modification by permafrost and cryopedogenic processes.

Permafrost forms an impervious layer at varying depths below the soil surface; consequently, drainage is impeded. The most severely hydric conditions are associated with level topography and shallow annual thaw depth--a shallow active layer. As the active layer increases in depth and drainage improves, soil-forming processes are stimulated. Thus, where depth to permafrost is minimal, soils formation is minimal.

In association with permafrost and hydric conditions are cryopedogenic processes such as ice wedge, ice lense, and frost boil formation. These processes churn and break up profiles, inhibiting the formation of well-defined soils.

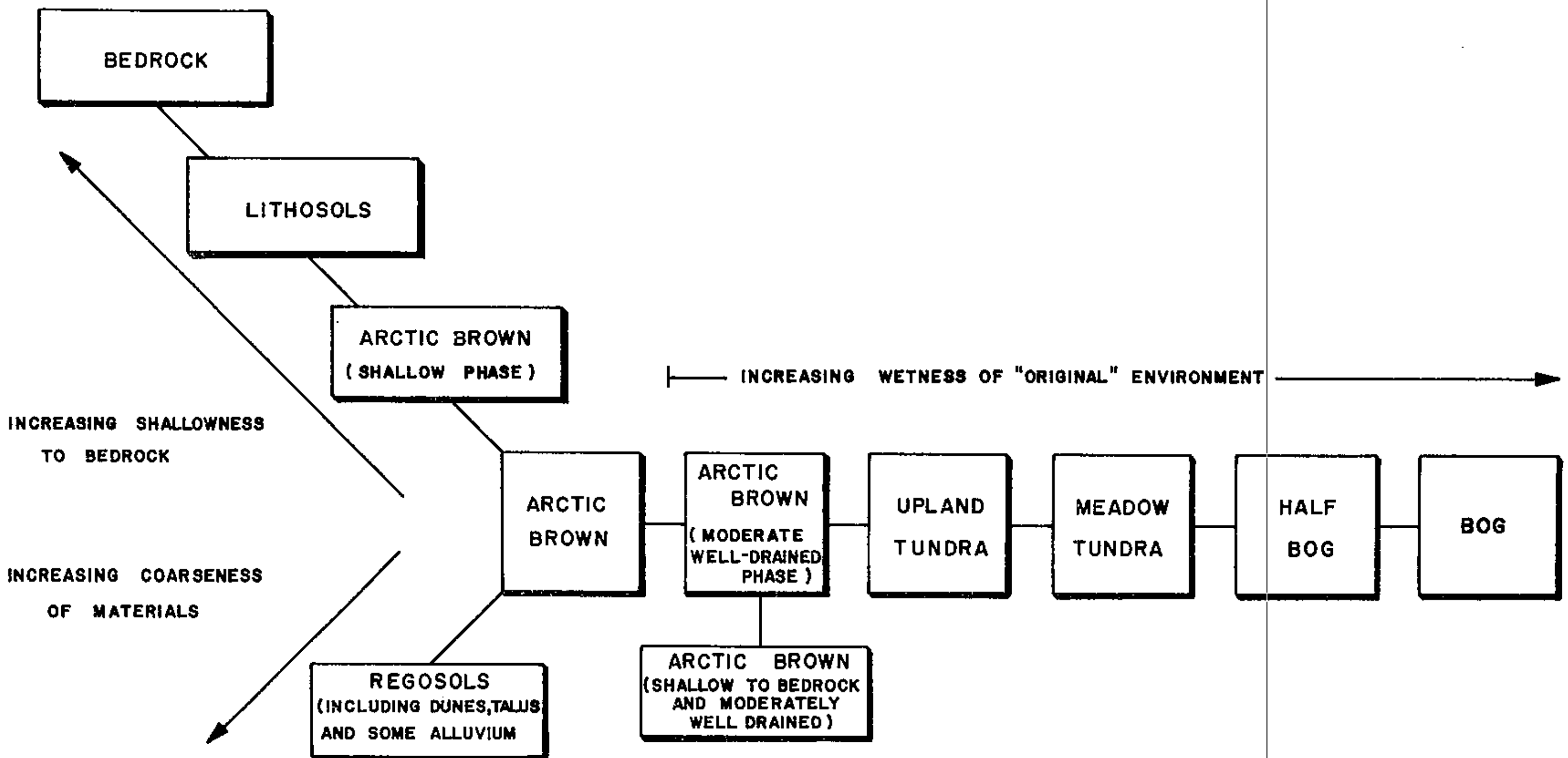
A moisture gradient is created that is reflected in a continuum of plant communities running from marsh types to barrens. The plants, however, help preserve permafrost by decreasing albedo and producing organic matter which insulates the soil. On wet sites, closed swards of grasses and sedges produce a thick mat of plants, which resists heat and moisture transfer and thereby preserves cool, hydric conditions. On dry sites, a more open vegetation allows greater thaw depth and drainage; thus, uplands tend to exhibit more rapid soil formation. These plant-soil relations are presented in Figure 2A.6-6.

The moisture gradient also affects decomposition, which in turn alters soil formation and plant community structure. Where organic mats retard warming, decomposition processes are relatively slow. This allows development of acidic peat, which further insulates permafrost. Thus cool, acid conditions enhance permafrost formation, which in turn leads to plant communities that form the thick organic mats responsible for a shallow active layer. On warm, dry sites, peat does not occur, and soils can develop at the maximum rates observed on the North Slope.

Bog soils are extensive on the Coastal Plain, covering 25 to 50 percent of the Teshekpuk Lake section. In the southern Coastal Plain and Foothills, they are restricted to swales, wide terraces and level uplands. They are rare in the Brooks Range.

The associated vegetation is commonly an Eriophorum-Carex meadow (Tedrow & Cantlon, 1958). This community is typical of hydric peats with

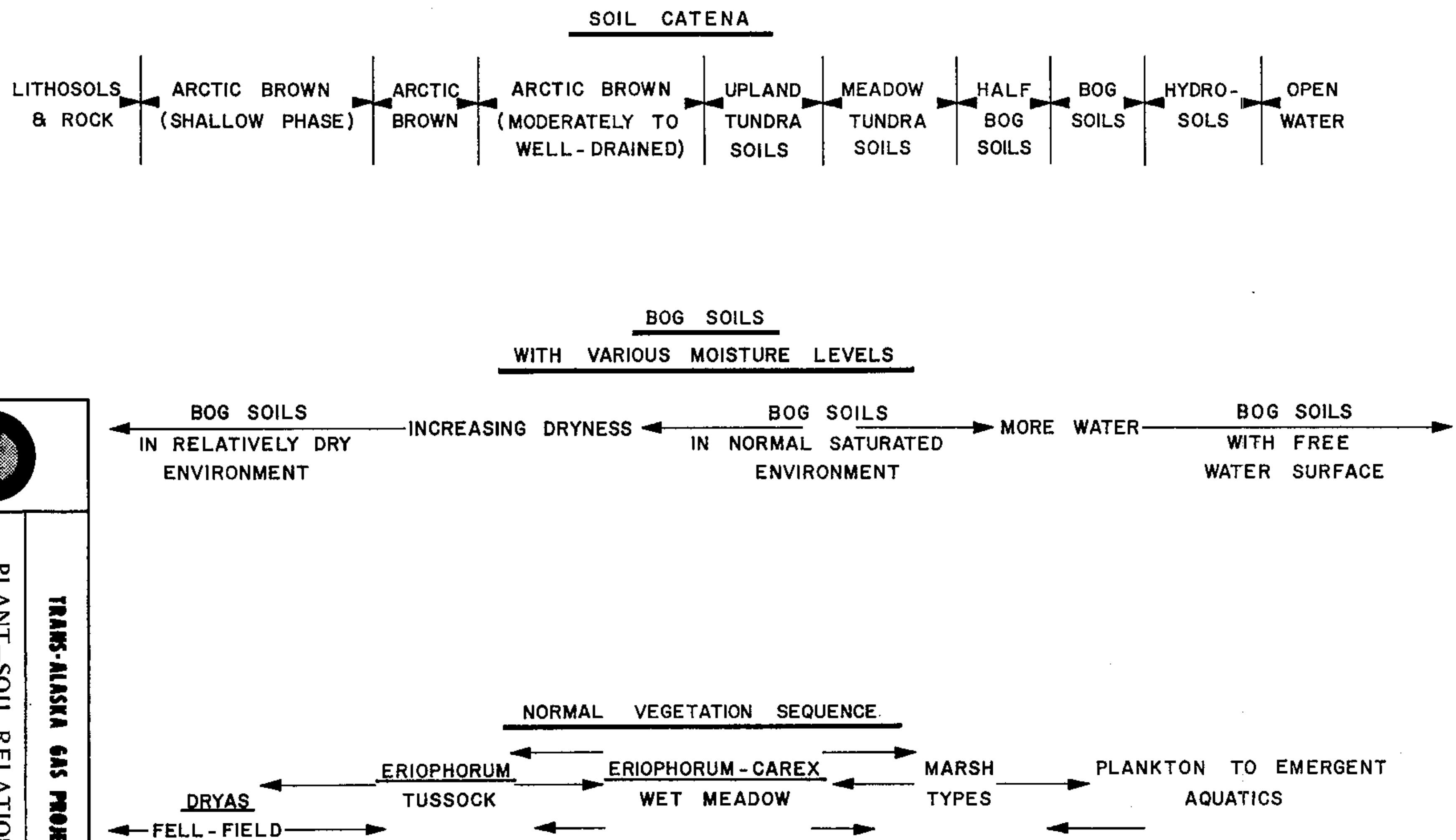
REF: TEDROW & CANTLON, 1958



TRANS-ALASKA GAS PROJECT

DEVELOPMENTAL SEQUENCE OF ARCTIC SOILS

FIGURE 2A.6-5



REF: CANTLON & TEDROW, 1958

TRANS-ALASKA GAS PROJECT

PLANT–SOIL RELATIONSHIPS IN THE ARCTIC DRAINAGE DIVISION

FIGURE 2A.6–6

an acid reaction. Where soil is derived from carbonate-rich parent materials, pH values increase (Tedrow & Cantlon, 1958).

Half bog soils are found on moderately drained sites throughout the North Slope. Less hydric than bog soils, they retain acid reactions and high organic content. Again, soil pH may be altered by calcareous (lime-rich) parent materials. Associated vegetation types are *Eriophorum-Carex* wet meadows and *Eriophorum* tussock communities (Tedrow & Cantlon, 1958).

Tundra soils have two variants: (a) meadow tundra on wet sites in association with *Eriophorum-Carex* wet meadows, and (b) upland tundra soils on better drained sites in association with *Eriophorum* tussock communities (Douglas & Tedrow, 1960). These are the most common soils of the North Slope, particularly in the Foothills.

Tundra soils result from two processes: (a) low temperature gleization accompanied by acid leaching, and (b) physical displacement of soil particles by frost processes such as solifluction and ice wedging. The first produces a profile with acid conditions at the surface, and increasing pH with depth. The second disrupts the profile (Douglas & Tedrow, 1960).

A silty texture characterizes tundra soils. This is correlated with rock grain size. Textural variants, clays or loamy sands, are related to clay-rich parent materials or eolian deposits respectively. The typical structure of tundra soils is poorly developed, large and blocky, with smooth faces and sharp angles. This structure is caused by formation and degradation of thin ice lenses (Douglas & Tedrow, 1960). Though acid surficial soils are common, some alkaline soils are present in areas of carbonate-rich parent materials. In slightly acid parent materials, base saturation of surface horizons is 25 to 50 percent (Brown & Tedrow, 1958; Douglas & Tedrow, 1960). Cation exchange capacity varies with organic matter distribution and acidity stratification (Douglas & Tedrow, 1960).

Arctic brown soils are well drained. They are found on narrow ridges, kames, lateral moraines and dunes where the active layer is two to four feet deep (Drew, et al., 1958). Consequently, they occupy only small areas (about one percent of the North Slope), with the greatest frequency being in the Foothills (Britton, 1957).

These soils develop a solum to a depth of 20 inches. A range in textures is present, but sandy loams predominate. Clay is usually in greatest quantity at the surface and decreases slightly with depth. An acid condition (pH values as low as 3.5) is usually present at the surface, with pH values increasing at depth.

Minerology of arctic brown soil indicates that a low order of weathering takes place in the solum, including lateration of feldspars to clay-like substances. Organic matter studies show carbon to nitrogen ratios of 15 to 20. The degree of weathering is even less in the arctic brown soil, shallow phase. Thus it may be considered an "immature" arctic brown soil.

Associated vegetation forms a continuum from Eriophorum tussock communities on poorly developed, hydric variants of arctic brown soils to Dryas fell-fields on the shallow phase. This plant continuum typifies the transition from hydric, permafrost-rich soils to well-drained, low-ice-content soils.

Lithosols are found on ridge tops and rock outcrops where soil development is negligible. Associated vegetation is outcrop and talus communities.

Regosols are "immature" soils derived from transported parent materials. They are found on beaches, dunes, gravel bars, and talus. Soil development is negligible. Associated plant communities include strand, dune, gravel bar and bench communities, and communities of outcrops and talus.

2A.6.1.2.3 Water

Summer sea temperatures in the Beaufort Sea near Prudhoe Bay usually range between 0.3°C and 1.7°C. Drift ice may be present during summer, depending upon melting and wind direction; the latter occasionally blows pack ice on shore, in which case the sea temperature will be near 0°C. The ice-free period generally occurs from late June through September. Freeze-up in lakes and rivers occurs in October, and breakup comes in June. Seasonal surface water temperatures parallel ambient air temperatures and solar radiation. The amplitude of variation in water is less than in air, but shallow lakes and ponds can undergo large daily shifts in temperature. Groundwater, present only in thawed areas beneath lakes and rivers, has a temperature of below 1°C.

Conductivity, an approximate measure of the dissolved solids in water, varies seasonally, with the highest values appearing during winter and lowest values during spring run-off. Conductivity values ranging from 50 to 300 μmhos/cm at 25°C are common. Exclusion of mineral salts and dissolved solids during ice formation causes high concentrations of these components in the unfrozen waters underlying the ice. High salinity in fresh waters along the coast can occur from storms carrying salt spray inland.

Data on suspended solids concentrations in streams of the Arctic Drainage Division are sparse. Seasonal variations of this parameter, however, indicate low values during winter, high values during summer, and the highest values of the annual cycle during breakup. Suspended solids concentrations during summer will normally be less than 100 mg/l. Glacial streams, of course, will carry more suspended sediment than non-glacial streams. Turbidity is an important factor limiting productivity, especially in rivers and streams.

Lake and stream pH values generally range between 7.5 and 8.5, but in some waters occasionally fall slightly below 7.0. Dissolved oxygen during ice-free periods usually ranges above 10 mg/l, with percentage saturation usually greater than 90 percent. Dissolved oxygen values under ice probably range widely from zero to above 10 mg/l. Low values are wide spread in rivers, and are an important influence on existing biota.

The nutrient poverty associated with lakes and streams in the Arctic is a reflection of nutrient levels in the soils. Controlling factors include poor development of soils, low rates of microbial decomposition of organic matter in the soils, and low rates of precipitation. In addition, a complex relationship exists between lake and pond sediments and nutrient cycling. Nutrient levels are often related to thermal cycles and circulation patterns, especially in deeper lakes.

2A.6.1.3 Terrestrial Environment

2A.6.1.3.1 Primary Production

Tundra is unproductive 70 to 90 percent of the year, and therefore net annual primary production of tundra ecosystems is lower than any other terrestrial ecosystem, except that of an extremely arid desert.

Annual aboveground production ranges from 3 $g/m^2/yr$ in high Arctic regions to 242 $g/m^2/yr$ in the sub-Arctic. Most values fall in the range of 40 to 128 $g/m^2/yr$ (Bliss, 1962). Since arctic Alaska is within the low Arctic, annual production of this region is in the higher portion of the range.

Variability of production within the Arctic Drainage Division is related to variation in community type. As discussed in subsection 2A.6.1.1, physiographic provinces within this division are characterized by different community types. Over the range of phytosociological variability, a pattern in standing crop of aboveground phytomass is apparent.

At Barrow (a Coastal Plain site), yearly production ranges from 78 to 190 g/m^2 of aboveground phytomass. Umiat (a Foothills site) produces about 60 g/m^2 of aboveground phytomass (Bliss, 1962). No data are available for the Brooks Range, but because of the severe alpine environment, productivity may be similar to the extremely low figures given for high Arctic regions--that is, 3 g/m^2.

These values imply an increase in production of aboveground phytomass with increasing dominance of graminiform species. Thus, given the phytogeographic patterns of the North Slope (subsection 2A.6.1.1), it may be expected that graminiform-dominated communities typical of the Coastal Plain, and tussock communities characteristic of the Foothills, are the most productive regarding dry matter accumulation, whereas the fell-fields characteristic of the Brooks Range are the least productive.

On the North Slope, aboveground annual production of dry phytomass is about 86 g/m^2 in *Eriophorum-Carex* wet sedge meadows, dominant communities of the Coastal Plain. *Eriophorum* tussock communities, characteristic of the Foothills, have an annual aboveground standing crop of 95 g/m^2, while xeric fell-fields produce 35 g/m^2 dry phytomass annually (Tieszen & Johnson, 1968).

Variation in community production is related to community structure. These differences may be related to the distribution of biomass among taxa, the primary breakdown being among: (a) vascular plants, (b) bryophytes, and (c) lichens. The secondary breakdown among life forms of the dominating vascular component is: (a) woody forms, (b) forbs, and (c) monocotyledons.

From south to north there is an increase in the importance of monocots and a decrease in the importance of woody forms with respect to distribution of aboveground phytomass. This would be expected on the basis of floristic gradients (subsection 2A.6.1.1). There is also a concomitant increase in the bryophyte component and decrease in the vascular and lichen components. These relations are given in tabular form in Table 2A.6-3.

A characteristic of tundra vegetation is the great proportion of standing crop that lies underground. Annual below ground production in sedge or sedge-grass meadows ranges from 130 to 360 g/m^2 (Dennis & Johnson, 1970). Ratios of live-aboveground to live-below ground standing crop are generally 1:5 to 1:11 (Dennis & Johnson, 1970; Wielgolaski, 1972), with live roots accounting for about 50 to 60 percent of the total root biomass (700 to 1800 g/m^2), (Dennis & Johnson, 1970). Maximum root development typically occurs in the upper 10 cm (Dennis & Johnson, 1970).

Ratios of total aboveground to total below ground biomass in the low Arctic are lowest in wet meadows (from 1:10 to 1:20), (Bliss, 1970; Dennis & Johnson, 1970) and higher in *Eriophorum* tussock communities. If this trend continues, then vegetation of the Brooks Range may approach ratios found in polar desert communities (Aleksandrova, 1970). These trends and production rates of shoots and roots suggest that low arctic environments may be more limiting for shoots than roots (Bliss, 1970; Dennis & Johnson, 1970).

While annual production of tundra is quite low, daily production during the short, cold growing season of 30 to 75 days is comparable to some herbaceous communities of temperate regions (Billings & Mooney, 1968; Bliss, 1971, Bliss, *et al.*, 1973). The range of aboveground production given by Bliss (1962) is 0.05 g/m^2/day on extremely xeric, high arctic sites to 3.73 g/m^2/day for favorable sites at Point Barrow. Where available, for graminoid communities, photosynthetically available radiation, length of growing season, and plant caloric data show daily productivity of 0.9 to 1.9 g/m^2 and the efficiency of net primary production of 0.20 to 0.45 percent for the growing season in Alaska (Bliss *et al.*, 1973).

For the vascular plant component, aboveground phytomass varies yearly. Commencement of growth in the spring is rapid. At Barrow, production through the majority of the growing season (mid-June through early August) is approximately a linear function of time. Productivity ranges from 1.5 g/m^2/day to 1.8 g/m^2/day during this phase. In early August, 15 to 30 days prior to the end of the growing season, productivity drops to zero. After this, aboveground productivity becomes negative, approximately -0.66 g/m^2/day (see Figure 2A.6-7) (Dennis & Tieszen, 1972).

This pattern of growth is typical of tundra vegetation (Bliss, 1956; 1962; Billings & Bliss, 1959; Holway & Ward, 1965; Fonda & Bliss,

TABLE 2A.6-3

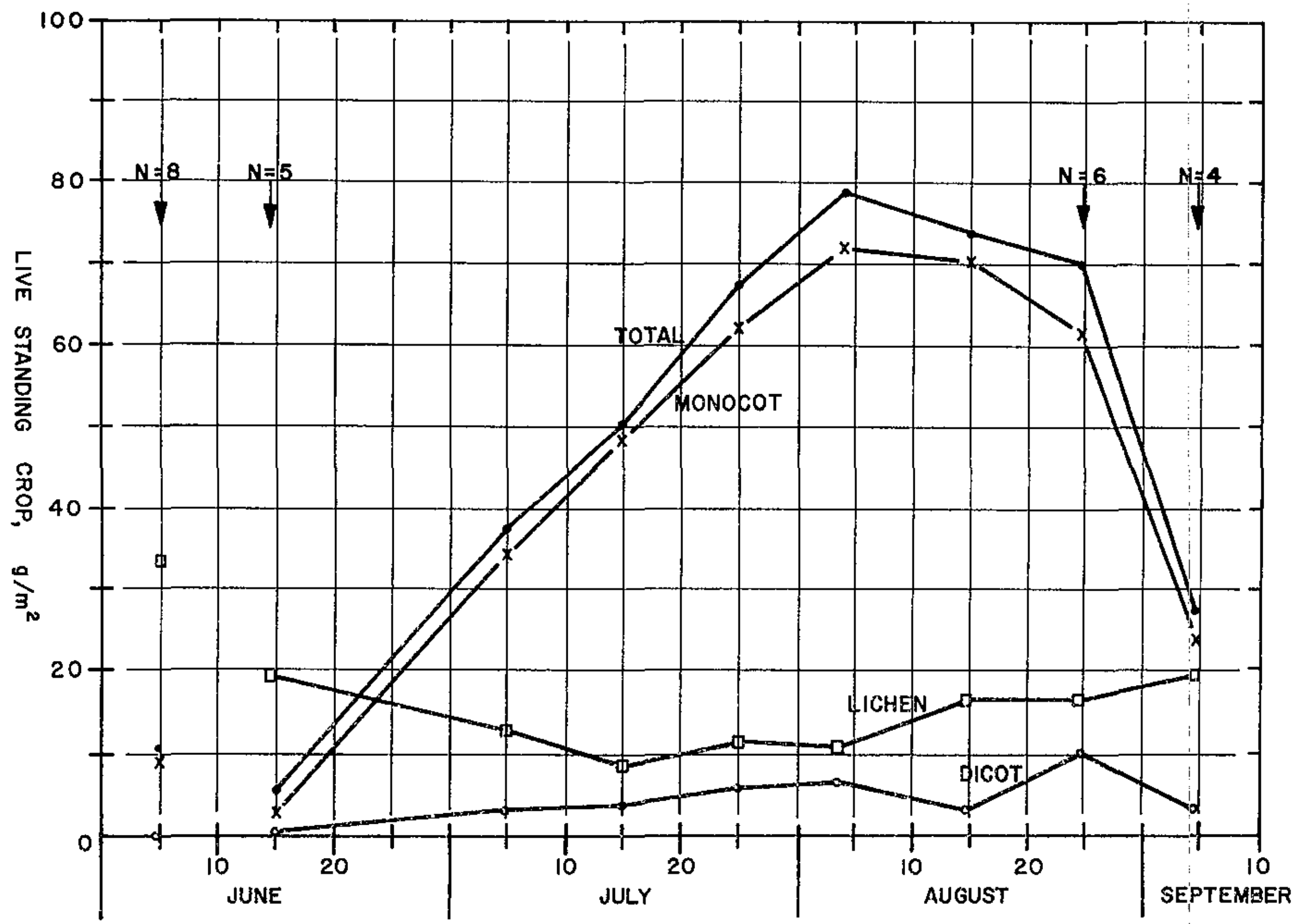
DISTRIBUTION OF BIOMASS AMONG GROWTH FORMS AND TAXA IN TUNDRA PLANT COMMUNITIES

	% of total vascular plants (aboveground living)			% of total aboveground living biomass		
	Woody	Forbs	Monocot.	Vas-cular	Bryoph.	Lichens
Shrub meadows	≥50	≥10-15	≤40	≥50	≤40-50	≤10
Eriophorum tussock	≤50	≥10	≤90	≥50 Norm.	≤40-50	≤10 Norm.
Fell-field	≥80-90	≤10-15	≤10	≤90 Norm.	≤40 Norm.	≥10
Eriophorum-*Carex* wet meadow	≤50	≤10	≥40-50	≤50	≥45-50	≤5

after Wielgolaski, 1972

N = NUMBER OF MEASUREMENTS TAKEN TO ARRIVE AT ARITHMETIC MEAN.

N = 10 UNLESS OTHERWISE INDICATED.



REF: DENNIS & TIESZEN, 1972

TRANS-ALASKA GAS PROJECT

SEASONAL PROGRESSION OF MEAN LIVE STANDING CROP, 1971

FIGURE 2A.6-7

1966; Dennis & Johnson, 1970; McCown & Tieszen, 1972; Tieszen, 1972; Bliss, et al., 1973). It corresponds to a period of rapid carbon fixation followed by a period of net translocation of photosynthate to actively growing roots and rhizomes and to below ground storage organs (rhizomes).

The dynamics of underground production are poorly understood (Dennis & Tieszen, 1972). A possible pattern might be a decrease in below ground phytomass during the period of positive aboveground production, followed by a period of increasing below ground phytomass and growth, concurrent with negative aboveground production. This would imply that below ground photosynthate stores are used during the rapid, spring aboveground growth phase and that these stores are replaced during the senescence of aboveground parts.

Key factors in low levels of arctic plant production are nutrients, low soil and air temperatures, and low plant and soil water potentials.

It has long been recognized that cold tundra soils are deficient in available nutrients, especially nitrogen (Bliss, 1971). Haag (1973) has shown that in a low arctic, wetland sedge and upland willow-birch-dwarf heath shrub communities, available nitrogen limits protein content and dry matter production, while phosphorous does not. Nitrogen is metabolized into organic compounds at low temperatures, while phosphorous metabolism is limited by low soil temperature and low available nitrogen, factors that limit nucleoprotein formation (Bliss et al., 1973).

In very cold soils, however, phosphorous and potassium become limiting. "Cold phosphorous" seems to be more limiting than "cold potassium" (Bliss, 1971). Thus, as soil temperatures are lowered, the availability of nutrients becomes a limiting factor for plant growth.

Fertilization experiments have supported these hypotheses concerning nutrient limitation. In Canada and Alaska, addition of nitrogen and phosphorous to both peat and mineral soil stimulates plant growth (Bliss, 1971; Van Cleve & Manthei, 1972).

Evidence that lowering soil temperature will decrease productivity is also available. The addition of a small plastic greenhouse above the soil surface significantly increased plant dry weight, soil temperature, and soil moisture on Devon Island (Bliss, 1971). This effect is well known to gardeners in interior Alaska where plastic mulches are commonly used to increase garden productivity. The importance of increasing soil temperature for plant growth was found by McCown (1973) in work with the effects of hot oil pipelines on plant growth in cold-dominated soils.

Within a tundra system, especially a low arctic one such as the North Slope, the increment of nutrients within the mineral soil in relation to the nutrient pool of the surface peats (often 5 to 20 cm) and the standing vegetation may be quite low. This, coupled with slow below ground (some 5 to 10 years) and aboveground (some 3 to 5 years) turnover times suggests that the organic horizons of bog and tundra soils serve as a nutrient sink, which has a low release rate. This sink and its nutrient release rate may be expected to control primary productivity.

It is now known that natural disturbance to this peat horizon, in the form of lemming grazing and rooting, releases nutrients from the sink by reducing plant cover, which reduces the albedo of the tundra surface and thus allows greater warming of the soil and consequent increase in decomposition and nutrient release. In addition, a flush of nutrients from fecal matter and urine associated with dense lemming populations short-circuits the slow turnover times for aboveground and below ground plant parts. This disturbance ultimately leads to a period of increased primary productivity (Schultz, 1964).

It is not presently known to what extent other natural or man-made disturbances affect primary productivity. The green color of tractor trails on the North Slope, and the increase in productivity following tundra fire (Bliss, in preparation) imply that such perturbations may be of major importance to nutrient cycling, and hence increasing primary production, in tundra systems. With increasing human activity, studies to determine the role of disturbance in primary productivity will become of utmost importance.

2A.6.1.3.1.1 Arctic Plant Reproduction Strategies

Tundra plants are capable of growth and reproduction at temperatures just above freezing. Under such conditions, sexual reproduction is often replaced by asexual forms such as apomixis, vivipary, or various kinds of vegetative reproduction. All polar and alpine angiosperms (except for annuals) have these characteristics in common (Billings & Mooney, 1968).

Annuals, which must rely completely on seeds for reproduction, are rare in tundra environments. The general lack of heat in summer is not conducive to the evolution of annuals, which require considerable heat for maturity and seed set (Bliss, 1973).

Seed reproduction in perennial plants is strongly influenced by growing season temperature. Some arctic growing seasons may be so cold that flowering and fruiting are seriously hampered, and little or no viable seed is produced. However, in other growing seasons, some plants have abundant seed crops, though such seeds usually do not ripen before the onset of winter. Indeed, they may not ripen at all during the year of flowering, and fruits may become dormant, go through the winter, and ripen the following summer (Sorensen, 1941).

Because of the early onset of winter, one might anticipate finding almost universal seed dormancy as a protective mechanism, but this is not the case. Amen (1966) reported that of some 60 tundra species previously studied, about 40 percent showed dormancy.

Once germination requirements have been met, the next critical stage is seedling establishment. In tundras, even less is known about this stage than is known about germination requirements. The limited data, however, indicate that seedling mortality is high (Bliss, 1971).

Billings and Mooney (1968) give several reasons why years may elapse between episodes of successful seedling establishment of a species in a given tundra location:

(1) The temperature must be warm enough for germination to take place;

(2) This must occur early enough in the summer to allow time for good growth before the return of temperatures constantly below freezing, and in some years these come unusually early;

(3) The seedlings must not be exposed to drought in the latter half of the summer before the root system has penetrated to a reliable water supply; and

(4) Needle ice activity must be limited.

Once seedlings have established and grown to maturity, further population is contingent upon production of viable reproductive structures, seeds, or vegetative reproductive structures.

Seed production may or may not follow pollination, depending upon whether the weather remains favorable. At higher latitudes and altitudes, years when any seeds are produced become fewer, and even in relatively good years the amount of viable seeds may be low. This effect becomes more pronounced as environmental severity increases (Bliss, 1956).

Another possible limitation to seed production is related to nutrient balance. Chapin (personal communication) has noticed that in the case of *Eriophorum vaginatum* subsp *spissum*, addition of phosphorus and potassium enhances seed production.

As sexual seed production decreases and becomes unreliable in the most severe environments, vegetative reproduction seems to increase. Apomixis is particularly prevalent in tundra environments, as are vivipary and layering (Billings & Mooney, 1968). The principal means of vegetative reproduction is, however, by rhizomes. This is especially common in dwarf heath shrubs, grasses, and sedges (Bliss, 1971).

2A.6.1.3.2 Consumption

Many ecological features of the North Slope are so unusual as to be alien to ready understanding. This generalization applies to the physical, and to the unseen subtle biological factors in the environment. It even applies to the more visible consumers--those species generally included under the popular heading of "wildlife."

One unusual feature of tundra consumers is their mobility and widespread migratory tendency. Over a hundred bird species may be encountered in summer, but most of these are absent from the tundra in winter. Mammal movements are to a great extent seasonal movements. Caribou generally move out of the region, to winter south of the Brooks Range. Many arctic foxes move out onto the Beaufort Sea ice in winter. Even indigenous man has traditionally been mobile (nomadic) in this part of the world, capitalizing on cyclic and noncyclic changes in the availability of biological resources. This mobility, and large year-to-year variations in so many ecological variables, makes generalizations or predictions dubious without many years exposure to the vagaries of arctic ecology (cf MacLean & Pitelka, 1971).

The regional trophic dynamics are unique because of the paucity of herbivores, and the simultaneous relative importance of the saprovore-based food chain. Each of these separate chains--herbivore-based, and saprovore-based--has primary consumers and carnivores associated with it.

Herbivory is practiced by relatively few insect species, several birds (waterfowl and ptarmigan), to a minor extent by granivorous birds (Lapland longspurs, snow buntings and other finches), and by a number of mammals. Mammals are the most important herbivorous determinants of systems function, and include the brown lemming and other rodents, barren-ground caribou, a limited number of moose, Dall sheep, and (formerly) the musk ox.

In general, the diversity, or number, of herbivore species in the community increases north to south in the Arctic Drainage Division. At Barrow, for example, only the brown lemming is a significant herbivore. The lemming's well-known but unexplained density fluctuations (often by factors of 1000, Pitelka, 1972) provoke marked changes in the abundance of carnivorous species preying upon this rodent. Through this one herbivore, energy is passed along to an array of predatory birds and mammals: snowy owls, short-eared owls, three species of jaegers, least weasels, and arctic foxes. When lemmings are not sufficiently abundant, these predatory species are virtually absent in many seasons over large areas of tundra. Such dramatic changes in mammal and bird populations become less pronounced farther south, as the herbivore specie diversity broadens. The consequences of a whole segment of the ecosystem depending on one or a few herbivores are limited species diversity and dramatic changes of abundance in carnivores. Moreover, these carnivores may shift their predation to another food chain, as discussed below.

Caribou using the region during part of the year probably number nearly 350 thousand animals (R. LeResche, personal communication; cf Hemming, 1971). Mobility and migration are important to these animals for constantly renewing their foraging habitats, for getting to and from appropriate wintering range and calving areas, and for escaping or reducing insect attack by seeking snow patches or windswept exposures in early summer.

The Sag River marks the approximate boundary between two major herds of the North Slope--the Arctic Herd (250,000 animals) and the Porcupine Herd (100,000 animals). Apparently some animals of both herds use the Dietrich-Atigun-Sagavanirktok systems for seasonal movements (Hemming, 1971). The numbers of animals using this pass system in spring and fall varies in different years, but in recent years some 10,000 animals have moved through this area (LeResche, personal communication). The major calving areas for the Porcupine Herd are to the east of Prudhoe Bay, between the Canning River and Demarcation Point, within the boundaries of the Arctic National Wildlife Range.

Dall sheep occur in the Brooks Range, along both sides of the Atigun River, and, like caribou, depend on mobility to capitalize on locally available resources. One such resource is mineral licks. All sheep herds so far investigated in Alaska make use of mineral seeps, particularly following calving. Daily lick use in spring involves ingestion of mud thought to contain physiologically important cations. Secondarily, licks seem to be an important social focal point in population dynamics (W. Heimer, personal communication). In the Arctic Drainage Division, an important series of mineral licks lies just north of the Brooks Range divide, on the Atigun River near Galbraith Lake. Sheep, and to a lesser extent caribou and moose, cross the Atigun Valley to visit these licks (Linderman, 1972; Price, 1973).

The total extirpation of the musk ox from Alaska by the middle of the last century through over-hunting (Matthiessen, 1959; Alaska Dept. Fish & Game, 1973a) left a functional gap of unknown importance in the picture of herbivory on the North Slope. Quite probably, they primarily ate vascular plants, including grasses, sedges, willows, and ericacious (heath) species, and only fed on moss and lichens to a minor extent (Tener, 1965). Reintroductions of musk oxen to former range on the North Slope (Barter Island) have taken place since 1968 (Alaska Dept. Fish & Game, 1973b). The results and success of this operation are presently indeterminate.

Saprovory exists to a major degree in the tundra, perhaps because it fills the functional vacuum left by the paucity of herbivores. The saprovore-based food chain crosses the imaginary boundary between consumption and decomposition. Even the brown lemmings contribute significantly to the decomposition process, by changing living and standing dead vegetation into litter and feces, subject to decomposer attack. But the workhorses of the saprovore picture are the assorted soil invertebrates that live in the rich, organic, peaty soils. These organisms include enchytraeid worms, larval dipterous insects of the families Tipulidae and Chironomidae, Acarina, and Collembola. Very high densities of these saprovores develop because of coexistence of several year classes of larvae with life cycles lasting longer than one year (MacLean, in press) and the generally low turnover rate (productivity to biomass ratio) of invertebrates in cold soils. Such dense populations support several species of carnivorous soil arthropods and the diverse fauna of aboveground insectivores, most notably shorebirds. The shorebirds in this region number 28 species, an important exception to the basic biogeographic observation that species diversity declines with latitude. These birds are uniquely adapted for probing the soil for the underlying invertebrates, hence for securing enough energy to support the high energy costs of breeding in cold environments. These shorebirds attain breeding densities of 80 to 100 pairs/km^2 or more on the Coastal Plain (cf Norton, 1973; Norton, *et al*., in press).

The saprovore chain culminates in higher carnivory, often by the same species that crop the herbivores, such as owls, jaegers, foxes, and weasels. In years of lemming abundance, the presence of one or more of these carnivores leads to widespread predation on shorebird eggs and young (Norton, 1973). One shorebird, the Eskimo curlew, is rare and endangered, quite possibly extinct (USDI, 1973). Its former breeding range was the Mackenzie Lowlands and perhaps the northeastern corner of Alaska. If there are surviving individuals, they would most likely occur in this region during spring and fall migrations.

Carnivory is widely distributed among taxonomic groups of terrestrial invertebrates and vertebrates. Ecologists know little about invertebrate carnivores, and in any event, it is generally among vertebrates (mammals and birds) that top carnivores are found. Because of their location at the top of a food pyramid, mammals and birds are vulnerable to the progressive concentration of nonmetabolizable toxic compounds. The successive transfer steps through the trophic system may increase concentrations of such compounds by several orders of magnitude. Harmful effects on reproductive biology of carnivorous birds (eggshell thinning, nonviable young) is manifested in some species or groups, but not in others. Jaegers and owls apparently do not show susceptibility to reproductive failure, while many hawks, eagles, and falcons are threatened with steadily declining populations and extinction.

Top carnivores include the cliff-nesting raptors, especially noted for breeding along the Colville River. In this region, the gyrfalcon, Peregrine falcon, and rough-legged hawk coexist. The Peregrine Falcon now appears to be in serious danger of extinction in certain locations, as its reproductive success has been falling steadily since 1966, while the levels of pesticide residues in both prey and falcon tissues have risen correspondingly, due to exposure throughout their annual migratory flyways (Cade & Fyfe, 1970; Cade, et al., 1971). Although it supports a lower density of breeding raptors, the Sagavanirktok and Atigun drainage systems do support some nesting (Price, 1973); non-nesting birds of these three species may be expected to use habitats of middle and high elevations, as far north as Franklin Bluffs, within 25 miles of Prudhoe Bay. Both the gyrfalcon and rough-legged hawks appear to be reproducing satisfactorily in this region (Cade, et al., 1971), despite intrinsically less stable numbers and breeding densities than the Peregrine. Cade and coworkers believe that the availability of nesting cliffs is a limiting factor on the abundance of these species. Peregrines are primarily bird hawks, preying on waterfowl, passerines, shorebirds, and a few mammals, in decreasing order of proportional representation in the diet (Cade, et al., 1968). Gyrfalcons more typically depend on the availability of both ptarmigan species.

Eskimos in this region are, by tradition and choice (even today), dependent upon biotic productivity for a substantial share of their food, utensils, and clothing. Two ecological traditions (less definable as ethnic groups) have dominated biotic resource use. The coastal Eskimo tradition (Taremiut) depends on marine mammals--bowhead whale, walrus, and seals--waterfowl, fisheries, and caribou, in approximately that order of importance. The inland Eskimo tradition (Nunamiut) revolves primarily around the caribou, supplemented by berries, fish, and a small component of marine mammal products.

Relative numbers of adherents to these two ecological traditions have fluctuated, repeatedly interchanged, coalesced at temporarily flourishing localities, and again separated in the last 100 years (Federal Field Committee, 1968). Despite the introduction of modern firearms, western clothing, health care, and wage-based economic opportunities, inland and coastal Eskimos have not abandoned many of their subsistence resource usage patterns. This resiliency demonstrates preferences for native foods, continued superiority of skins for use in clothing, umiaks, and certain kinds of rope. The adoption of introduced technology by

Eskimo has been eclectic; those items and methods currently used in hunting are generally a combination of native and introduced, which maximize the efficiency and mobility of subsistence hunting.

A combination of subsistence life and wage work seems to be attractive to Eskimos in permanent settlements at Point Hope, Wainwright, Barrow, Kaktovik, and Anaktuvuk Pass (cf Sater, 1969). The sociology, economy, and ecology of these communities thus interact to a greater degree than in most regions of the United States. The Federal Field Committee (1968) concluded that the Eskimo would not voluntarily abandon subsistence consumption patterns in the face of expanded industrial development in the region. This conclusion suggests an impending resource squeeze because the resident Eskimos are experiencing a doubling of population every 20 years in the North American Arctic, including Greenland (Sater, 1968). Allowing for emigration, and assuming that per capita consumption of wildlife will decline, the growth rate of these people can be expected to confront the limited productivity of arctic ecosystems in the future. The effects of the Alaskan Native Claims Settlement Act (ANCSA) in prompting or discouraging Eskimo reliance on biotic resources in the Arctic Drainage Division remain to be seen, as the Eskimos assume a larger share of directing the stewardship over arctic lands.

2A.6.1.3.3 Decomposition

Organic decomposition rates in tundra soils are low. The explanation of this basic observation, and the effect of slow rates of decomposition on the whole system are essential to appreciating arctic ecology, and to predicting system alterations following disturbance.

Optimum incubation conditions for most microbial activity are warm and moist. Aboveground atmospheric conditions in the arctic are cold and dry. This contrast helps to explain the severe rate limitations upon organic decomposition. In addition, the arena of biological activity is limited in time by the short summer, and in extent by the shallow active layer over permanently frozen ground. Mineral nutrients are locked up to a large extent in underlying frozen mineral soils, and become available only during occasional seasons of greater-than-average thaw depths, or after certain forms of perturbation. Although soil organisms in the arctic demonstrate certain adaptations to these adverse conditions, the number of decomposer taxa is strictly limited.

The most intensive relevant studies of decomposition in Alaskan arctic tundra are the current U. S. Tundra Biome efforts. Benoit, et al., (1972) characterized high latitude peaty soils typical of the Arctic Coastal Plain by four features:

(1) The large organic litter compartment,

(2) Immobility of much of the nitrogen in above- and below ground dead compartment,

(3) The general paucity of available essential minerals, and

(4) Slow mineral flux rates of soil of micro-organisms.

A further characterization of soil microbiota on the Arctic Coastal Plain is detailed in Table 2A.6-4.

Decomposition rates and characteristics of soil microflora elsewhere than Barrow are not as well known. Prudhoe Bay bog soils, in contrast to those at Barrow, may be alkaline (Bilgin & Douglas, 1972).

Better-drained soils of upland tundra, slopes of the Foothills, and of Brooks Range proper are even less well studied as to decomposer function. It is to be expected that lateral transport of nutrients through run-off and drying of the vegetative mat become increasingly dominant features of decomposition dynamics.

In summary, decomposition in arctic systems is a limiting process; much organic matter is tied up in dead, undecomposed litter. The net accumulation of peat in bogs, and the accompanying low primary and secondary productivity of bog systems, represents a failure of the decomposition process. A slow rate of nutrient recycling depresses turnover rates in the functional compartments of primary production and consumption, with two important exceptions. The first exception is that of the development of an important saprovore-based food chain (subsection 2A.6.1.3.2). The second exception in wildfire (subsection 2A.6.1.3.4) which, in a sense, substitutes for "inadequate" decomposition.

2A.6.1.3.4 Wildfire

The significance of fire in unforested high latitude regions is just beginning to be appreciated (Barney & Comiskey, manuscript; Wein & Bliss, 1973). Fires in arctic tundra may go unnoticed because of a lack of observers. Moreover, there are few single-stemmed plants to indicate (by scarring) a recent fire. As a consequence of revegetation, fire boundaries disappear quickly and cannot be detected by aerial photography after several years.

It had long been assumed (but not demonstrated) that a scarcity of combustible fuels, the general presence of ice-rich permafrost, and low evaporation potentials, all acted to prevent fire. On the other hand, alpine tundra in interior Alaska is subject to extensive wildfire, from both lightning above timberline and extensions of forest wildfires (Barney, 1969; Wein & Bliss, 1973). There is every reason to suppose that wildfire is and has been an integral part of the ecological systems functioning in North Slope tundra, although perhaps to a lesser extent than is the case in interior Alaska taiga.

Two fundamental effects of fires need review. First are their effects in determining species compositon in plant communities. Fire is probably one of the processes instrumental in altering soil moisture and temperature regimes (by destruction of litter), and thereby maintaining the occurrence and productivity, for example, of *Eriophorum* tussocks (Wein & Bliss, 1973). The second effect to be analyzed concerns range quality, particularly for barren-ground caribou. Lichens and other cryptogams are particularly prone to total elimination by fire and smoke, in tundra (Wein & Bliss, 1973) and in taiga (Viereck, 1973), and may require

TABLE 2A.6-4

CHARACTERISTICS OF WET TUNDRA SOIL MICROFLORA

1. THE INORGANIC NITROGEN COMPARTMENT IS AMMONIA-DOMINATED. Nitrifying bacteria are present but rare. Laboratory soil perfusion studies and enrichment cultures under optimum conditions demonstrated a weak NO_2^- and NO_3^- yielding potential after two months of incubation. The activity detected could have been due to heterotrophic nitrification or the weak activity of chemoautotrophs. Many bacteria of the pseudomonadaceae group were isolated, which can produce NH_4^+ from various amino acids or urea; these bacteria appear to be active in mineralization reactions.

2. SULFATE PRODUCTION FROM CHEMOAUTOTROPHIC SULFUR BACTERIA IS RARE. *Thiobacilli* spp. were not detected, or were rare. Sulfate-reducing bacteria were present on the wetter sites but only traces of sulfide were detected on site 2.

3. IRON-OXIDIZING BACTERIA ARE ABUNDANT IN SURFACE HORIZONS. Chemoautotrophic bacteria which can oxidize Fe^{+2} are rare, but a variety of heterotrophs incorporate Fe^{+3} into their cell sheaths.

4. ALGAE ARE ABUNDANT AND PLAY A CRITICAL ROLE IN THE NITROGEN CYCLE. As much as 10^5 cells/g dry wt soil were detected by the Most Probable Number method in a variety of media. The algae are most abundant in polygon troughs, especially in years when standing water occurs; green algae and diatoms are common. *Nostoc commune* appears as a large mat and plays a critical role in the nitrogen cycle (see Alexander, 1972).

5. CO_2 IS THE MAJOR END PRODUCT OF DECOMPOSITION BUT CH_4 PRODUCTION CAN BE SIGNIFICANT. Methane production is not a major end product of decomposition on the intensive site, but when decomposition is stimulated on the wet meadow, or if bog soils are examined, then methane may be a major product. A large protion of the bacterial flora is facultative in response to oxygen. In the buried peat layers the activity of strict anaerobes is indicated from high direct microscopic counts, low aerobic plate count, low concentration of soil oxygen and significant quantities of ATP.

6. THE NUMBER OF BACTERIAL TAXA IS LIMITED. The chemoheterotrophic bacterial population consists largely of gram negative rods. *Bacillus*, *Arthrobacter*, *Micrococcus*, *Mycobacterium*, *Brevibacterium* and actinomycetes are rarely isolated.

7. THE YEAST POPULATION IS HIGH. The yeast population is often as high as 10^6 cells/g dry wt soil. The role of these organisms in decomposition processes is not known.

(from Benoit, et al., 1972)

up to 100 years to reestablish. Since caribou depend on lichens to some extent, this is a serious consideration, and many studies have indicated that extensive loss of winter range follows wildfire, particularly in the Canadian sub-arctic (Scotter, 1971). Skoog's (1968) analysis of caribou diets in Alaska, however, led him to challenge the long-standing belief that fires destroyed caribou range. This question will require closer examination, and the possibility of basic differences in caribou biology between Alaskan and Canadian herds must be entertained. (For a current review, see Viereck, 1973).

2A.6.1.3.5 Systems Dynamics

The preceding sections have repeatedly cited constraints and limitations upon biotic processes in terrestrial environments of the Arctic Drainage Division. These limitations are fundamentally related to the limited productivity and reduced species diversity characteristic of this region. Ecologists have long regarded arctic ecosystems as simple in trophic structure, and therefore unstable, or "fragile," in the face of perturbations (cf Dunbar, 1968; Sater, 1969; Bliss, 1970).

The perception undoubtedly springs from confusion surrounding the concepts of stability, diversity, and fragility. Stability of an ecosystem can have two meanings: (a) nonoscillation of components of the system, and (b) the ability to absorb perturbations without collapse of the system, (Dunbar, 1973). The tundra clearly is not stable in the sense of nonoscillation. It is stable in the sense that it absorbs natural perturbations without dysfunction. Does this kind of stability mean that the tundra is not fragile? Dunbar (1973) thinks that such is the case, because the tundra is so vast, and local extirpations can be replaced by immigration of biota from other regions of the tundra. To put Dunbar's conclusion in different perspective, mobility is vital to the resiliency and productivity of tundra systems. The point here is to deemphasize the physical vastness, and to emphasize the importance of biotic mobility.

Despite the inherent danger of ecological dysfunction arising from low species diversity and instances of all biotic transfers being channeled through a single species (as in localities where only the brown lemming performs herbivory), there is mounting evidence that terrestrial arctic ecosystems and communities are well acquainted with, and adjusted to, disturbance. Natural disturbance-recovery cycles occur continuously. The freeze-thaw cycle disrupts the soil and results in the "patterned ground" phenomenon and continual species replacements and displacements as microhabitats change. Oriented lakes move across the land surface, eroding old basins and forming new ones. Caribou movements, where concentrated, may inflict serious disturbance to the vegetative mat by trampling. Lemmings in peak abundance periods may ravage the aboveground and below ground plant parts over extensive areas. Tundra wildfires may act as shortcuts to the decomposition process, destroying some species associations, but fostering conditions favoring others. Likewise, the array of processes associated with run-off--erosion, deposition, flooding, soil creep on slopes, slumping, and soil slides--act constantly on the arctic landscape and its biota.

Most natural perturbations are limited in their intensity. Tundra fires, for example, kill aboveground portions of plants, leaving in tact enough of the below ground portions to permit revegetation largely from rhizomes of native species (Bliss & Wein, 1972b). Fires also act to increase the depth of thaw, affording greater volume for root exploration and nutrient uptake by surviving species, resulting in greater nutrient availability, at least temporarily, and a vigorous vegetative recovery.

Although perturbation-recovery phenomena are complex, it is essential to characterize the natural perturbations in tundra systems as "releasing phenomena" to a large extent. That is, they generally do not force the system to start all over again from the status of a biological desert, but act mainly to unlock a portion of the essential nutrients that tend to be tied up as a result of slow organic decomposition. Survivors or surviving parts of the system can capitalize on this local resource availability.

Exceptions to these generalizations about the mildness of natural disturbance, including erosion, beach weathering, and dune migration, all serve to demonstrate that the recovery of the biota over bare mineral soils is extremely slow. These exceptions, coupled with recent recognition of the long-term destructive effects of equipment operation on poorly drained tundra underlain by ice-rich permafrost (cf Hok, 1969), have added weight to the simplistic argument that tundra systems are fragile (cf Dunbar, 1973).

The probability that continuous moderate perturbations are an integral part of tundra ecological systems raises the question of what these systems would be like in the absence of such perturbation. Perhaps they would be even less productive than they are now. The prospect of large influence by the extractive industries in arctic Alaska would be less frightening, to the degree that industrial disturbance can be held within the qualitative and quantitative range of natural disruptive phenomena.

2A.6.1.4 Aquatic Environment

Two basic sources exist for descriptions of aquatic ecosystems in the Alaskan arctic: (a) the ecological study in progress by the Tundra Biome section of the U. S. International Biological Program (IBP), and (b) studies generated by proposed construction of the oil pipeline, carried out by federal and state agencies, and by Alyeska Pipeline Service Company. The former concerns ponds at Barrow and the construction of a mathematical model to describe energy relations in an entire pond community. The latter has emphasized fishes, particularly in the Sagavanirktok River drainage, and most of it is unpublished. Additional information is scattered through reports that have appeared in scientific literature since the 1950's, but most of the reports deal with primary productivity and zooplankton life histories in the arctic, and are fairly limited in scope. Information on flowing waters is almost nonexistent.

Arctic aquatic ecosystems exhibit two particular biological characteristics: (a) extremely low primary productivity, and (b) low species diversity. The result of low primary productivity is an absolute limit on secondary productivity, since all animals depend on primary production for required energy. Nutrient limitation, low light levels during winter months (further reduced by snow and ice cover), and low water temperatures, even in summer, apparently control primary productivity. In rivers and streams, turbidity may be important. Low species diversity, which is apparently caused by a small number of niches available to arctic organisms, results in simplified food webs.

2A.6.1.4.1 Primary Production

The productivity of arctic waters is considerably less than the most oligotrophic lakes of northern temperate latitudes. Production is virtually nonexistent for the period November through February. Adaptation by phytoplankton to extremely low light levels often allows measurable photosynthesis shortly before and after these dates. With the disappearance of snow cover, photosynthesis may proceed at fairly high rates under the ice in deep lakes. In some cases, peak productivity occurs under the ice (Hobbie, 1966: Howard & Prescott, 1971). Nearly all primary production takes place from the end of April to the end of September, and rates of production are quite low during this short season.

In the summer, low nutrient levels are the chief limitation placed on primary productivity (Hobbie, 1973: Kalff, 1970). Phosphate appears to be the nutrient in shortest supply. Nitrate may be critically limited in lakes, but less so in ponds and rivers. Trace metals and vitamins may be limited during periods of increased photosynthesis (Hobbie, 1973; Kalff, 1970; 1971). Nutrient levels in the Colville River and its tributaries are generally higher than in adjacent lakes and ponds, indicating that primary productivity is lower in rivers. The turbidity of rivers, however, makes productivity measurement difficult.

Primary production may be broken into three categories, representing phytoplankton, benthic algae, and vascular plants (epiphyton have not been described). Phytoplankton have traditionally been taken as the measure of productivity of a water body (Frey & Stahl, 1958; Hobbie, 1966; Howard & Prescott, 1971; Kalff, 1967a), but their contribution to total production depends on the particular situation. In shallow lakes or ponds where sufficient light penetrates to the bottom, and where sediment conditions are favorable, the contribution of benthic algae may be much greater than that of phytoplankton. Where a pond supports a shore fringe of vascular plants, their contribution may also be relatively great. In deeper lakes, or in shallow lakes with sediments lacking in organic matter, benthic production may be absent; additionally, the shore fringe of vascular plants occupies a small proportion of lake area (it may be absent because of ice scouring), thereby making phytoplankton the major producers for these systems.

The dominant phytoplankton populations that develop in the spring are adapted to low light conditions. As the available light increases with snow and ice melt, the populations tend to sink from near the ice-water interface to a lower depth, thereby maintaining the most favorable light level. A new population, adapted to a higher light intensity, frequently develops immediately beneath the ice, resulting temporarily in two zones of maximum photosynthesis (Kalff, 1970).

After ice disappears, distribution of planktonic organisms will be fairly uniform, since stratification is rare. Until freeze-up, productivity peaks roughly follow incident light curves.

The species composition of phytoplankton in the Alaskan arctic exhibits two noticeable peculiarities: (a) an extremely low proportion of blue-green algae, which may reflect low nutrient levels (Prescott, 1963), and (b) domination by small unicellular flagellates. Early plankton counts were gross underestimates because flagellates were not captured by standard-mesh plankton nets (Hobbie, 1973). Flagellates may be favored ecologically by their small size and motility, since they can select the depth of most favorable light intensity, and fare better under low nutrient conditions because of a high surface-to-volume ratio (Kalff, 1970).

To quote Hobbie (1973) concerning species composition:

> The dominant group of algae is usually the Chrysophyceae, although the Cryptophyceae, especially Cryptomonas and Rhodomonas minuta, are always present and may be dominant at certain times of the year. Diatoms may be important in deeper lakes, but are rare in tundra ponds and shallow lakes. Dinoflagellates reached sizable populations only in the deeper waters beneath an ice cover. . . All of the lakes studied have so far had different algal succession patterns.

Large numbers of phytoplankton can survive the winter encysted in ice. Those that remain in water depend on a combination of low-level photosynthesis, respiration of stored cell material, and heterotrophy (both phagotrophy and uptake of dissolved organic matter). Very low respiration rates probably occur as well (Kalff, 1970: Hobbie, 1973).

The species composition of benthic algae may contrast that of phytoplankton, being cyanophytes and diatoms, with some chlorophytes as well. The importance of benthic algae to aquatic communities is demonstrated by a biomass comparison for a pond at Barrow, where benthic algae were found to have a biomass of up to 3000 times that of the phytoplankton. In some arctic lakes, mosses may replace algae as the chief benthic producers (Hobbie, 1973).

Vascular aquatic plant species decrease in number from the sub-arctic to the high arctic. Emergent species, such as Carex aquatilis (a sedge), Arctophila fulva (a grass), and Hippuris vulgaris (mare's tail) are the dominant species. The vascular plant communities are of great importance to pond and shallow lake ecosystems, and may account for half of the primary production in ponds. The plants are not generally grazed directly, but are cycled through the sediments. The IBP study at Barrow concluded that most of the biomass of the vascular plants is in the roots and rhizomes (up to 90 percent for Carex), and that much of the standing crop is dead material. Along with other organic detritus (dead matter) from the pond community and from terrestrial matter introduced by run-off, this material dominates the sediments. Bacterial decomposition of this detrital reservoir is an important pathway by which the energy of primary production enters the ecosystem. In addition, decomposition rates largely determine nutrient supply rates to the pond community. Therefore, considering the benthic algae, benthic animals, and bacteria (subsections 2A.6.1.4.2 Consumption, and 2A.6.1.4.3 Decomposition), most biological activity apparently occurs in the sediments of tundra ponds (Hobbie, et al., 1972).

Table 2A.6-5 compares the productivity of a number of arctic waters to some typical temperate waters. A range in productivity of one hundred-fold is apparent within the arctic. Broad variation, which seems to characterize arctic waters, is found among neighboring lakes and ponds, and also within any lake or pond on both a daily and an annual basis. It has been previously mentioned that in no two cases have similar algal succession patterns been found. This variation is further reflected in faunal populations (Hobbie, 1973; Kalff, 1970; Kinney, et al., 1972). Such variations weaken generalizations about water bodies that have not been thoroughly investigated.

2A.6.1.4.2 Consumption

The simplicity of food webs in aquatic ecosystems of the Arctic Drainage Division is apparent at many taxonomic levels. Sponges, larger arthropods, reptiles, and amphibians are absent. The number of genera, and the numbers of species within genera, is less than those found in temperate waters. Fishes are absent from ponds, and from the least productive lakes, but are abundant in many rivers. Some lakes harbor only a single species of herbivore (a microscopic crustacean), and occasionally even this species is absent. There may be only one species of primary consumer. Given this low diversity, and the relatively short life of many lakes and ponds, the tenuous nature of life in the arctic becomes apparent. Subsections 2A.6.1.4.4 (Systems Dynamics) and 2A.6.1.5 (Regional Systems Interactions) elaborate upon this concept.

2A.6.1.4.2.1 Zooplankton

The number of zooplankton types existing in a lake is a direct reflection of the productivity of the lake, and a classification scheme is presented by Hobbie (1973). The order of complexity is as follows:

(1) Rotifers,
(2) Calanoid copepods,
(3) Cyclopoid copepods, and
(4) Cladocera

TABLE 2A.6-5

PRIMARY PRODUCTIVITY OF SOME ARTIC ALASKAN AND TEMPERATE WATERS

Type of Communtiy	Productivity (g C/m²/yr)	Reference
Tundra Pond		
Benthic algae	14	Hobbie, et al., 1972
Macrophytes	15	Hobbie, et al., 1972
Phytoplankton	1	Hobbie, et al., 1972
Phytoplankton	0.4-.8	Kalff, 1967a
Phytoplankton	0.3-.7	Alexander, et al., 1972
Tundra Lake		
Phytoplankton	8.5 1/	Kalff, 1967b
Phytoplankton	9.6 1/ 2/	Howard & Prescott, 1971
Phytoplankton	8 2/ 3/	Howard & Prescott, 1971
Phytoplankton	30 2/ 4/	Howard & Prescott, 1971
Arctic Mountain Lake		
Phytoplankton	0.9 5/	Hobbie, 1966
Phytoplankton	7.5 6/	Hobbie, 1966
Marion Lake (B.C., Canada)		
Benthic algae	40	Hargrave, 1969
Phytoplankton	8	Efford, 1967
Macrophytes	18	Davies, 1968
Lawrence Lake (Michigan)		
Phytoplankton	51	Allen, 1971
Macrophytes	88	Allen, 1971
Borax Lake (California)		
Phytoplankton	91	Wetzel, 1964
Macrophytes	28	Wetzel, 1964

1/ Imikpuk Lake
2/ Estimated from data provided by referenced author
3/ Ikroavik Lake
4/ Malikpuk Lake
5/ Lake Peters
6/ Lake Schrader

After Hobbie, et al., 1972

Each addition represents an increase in productivity.

The biomass of zooplankton in summer tends to be far greater than that of phytoplankton, but turnover (ratio of productivity to biomass) is much slower. The standing crop is, however, much less than in temperate waters, though it may be comparable to an oligotrophic temperate lake in winter (Kalff, 1970; Hobbie, 1973). As with other characters, great variations in zooplankton biomass exist in the Arctic.

Zooplankton are the major herbivores of arctic aquatic ecosystems. It is possible that phytoplankton are not the chief source of food, and that dissolved and particulate organic matter and detritus are more significant in the diet. This observation is supported by the high zooplankton-to-phytoplankton biomass ratio usually found. Even considering all sources, zooplankton populations may well be found limited in these waters (Hobbie, 1973).

For many species of zooplankton, temperature and length of growing season largely determine the number of generations of offspring produced annually. Most arctic species are monocyclic, though tetracyclism has been observed, and favorable summers may allow normally monocyclic species to become dicyclic (Stress & Kangas, 1969; Tash & Armitage, 1967).

In deep lakes, most forms are able to live through the winter (overwinter) as adults. Shallow lakes and ponds freeze to the bottom, or at least exhibit strong concentration of salts by freezing, and in these there is a tendency for overwintering in the egg stage. Flooding and scouring during spring melt may be important in the distribution of eggs across the tundra. After melt, numbers of zooplankton may be high in relation to biomass as eggs hatch. Differential timing of life cycles helps maintain summer population levels. In Barrow ponds, copepods dominate early in the summer, and the Clodoceran *Daphnia*, later (Hobbie, *et al.*, 1972).

Species associations have been studied in the Cape Thompson area. Closely allied species occupy different aquatic habitats, but when species belonging to the same genus co-occurred, there were differences in size and life cycles. The maximum number of zooplankton was correlated with maximum primary production (Tash & Armitage, 1967).

2A.6.1.4.2.2 Benthic Fauna

The biomass of benthic microfauna varies greatly with water depth and substrate. These organisms are an important part of aquatic ecosystems, and frequently exhibit densities greater than 10,000 per m^2, and occasionally near 100,000 per m^2, (cf McCart, *et al.*, 1973). These densities compare favorably with those found in more southerly latitudes, but productivity is nonetheless low. Insects (the dominant organisms numerically) and crustaceans appear to have extended life cycles and corresponding slow growth.

Chironomid (midge) larvae dominate the benthic microfauna in arctic and subarctic waters, and are most abundant in shallow ponds with organic sediments and in streams originating from springs. They frequently make up 50 to 90 percent of the fauna. Tundra ponds have about 10 species of chironomids, an order of magnitude less than temperate shallow lakes (Hobbie, 1973). Oligochaetes, plecoptera, and ephemeroptera are generally secondary in importance, and several other groups are found in smaller numbers.

Tributaries of the Sag River, including springs, beaded foothill streams, and mountain streams, have benthic fauna similar to the ponds. Species composition varies greatly between locations and seasons as insect species, the dominant group, change densities with life stage. Chironomid density may approach 100,000 per m^2, but on the other hand may be only 10 to 100 per m^2 and a small percentage of the total organisms present. At present, only preliminary information is available on macrofaunal densities and biomass, and little is available concerning life histories and population dynamics.

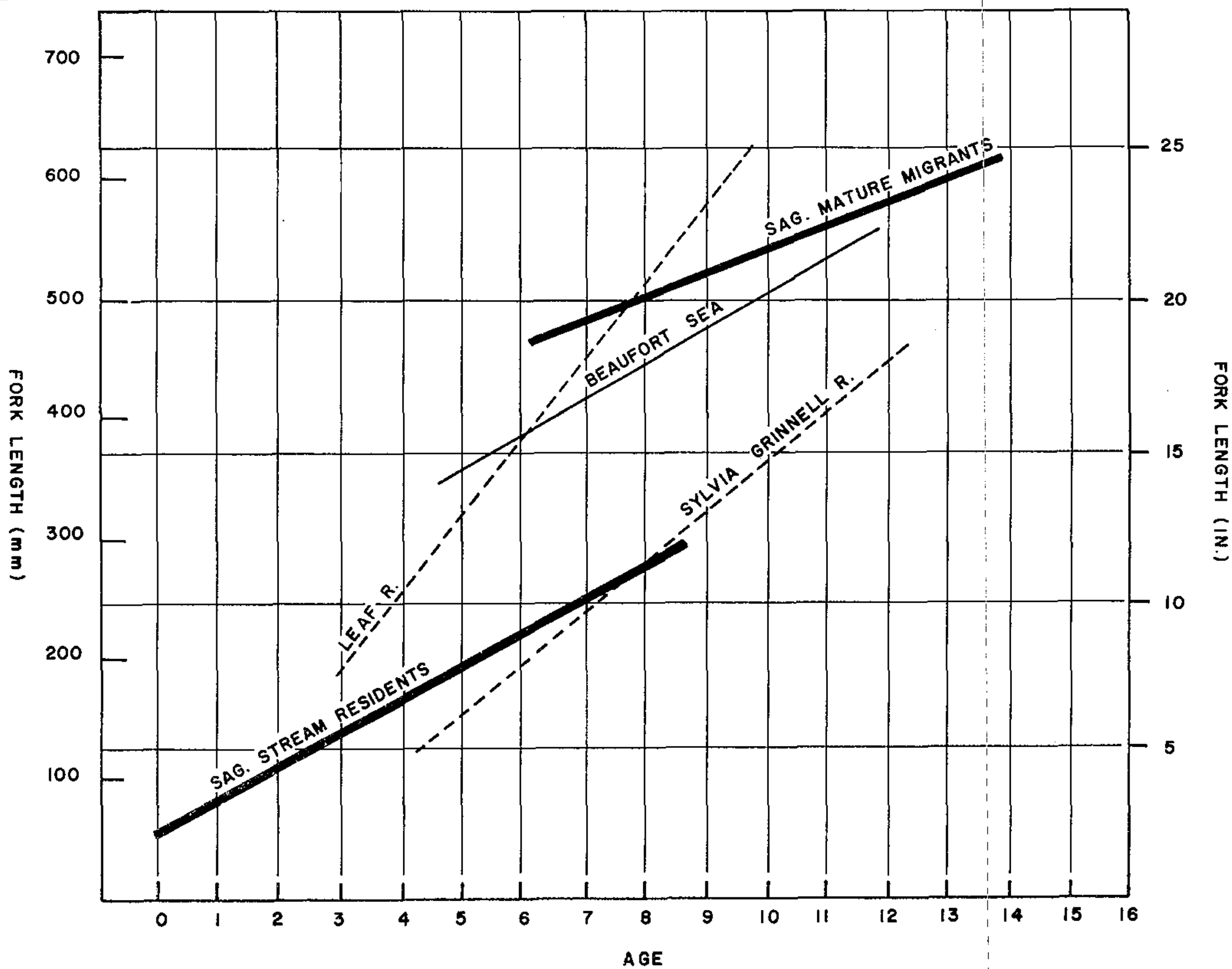
Macrofauna occupy an important ecological position. They are the primary herbivores in flowing waters, feeding on benthic algae, bacteria, and decaying plant material. Through their physical activity they cause suspension of algae, bacteria, and detritus which can be eaten by zooplankton in lakes and ponds. Macrofauna are the most important food for fish and shorebirds and so are particularly important in rivers where most fish production occurs. An important phenomenon in connection with fish feeding is "invertebrate drift" in streams, or the tendency for organisms to become dislodged from the substrate and drift downstream with the current, often tens of meters in distance. This occurs: (a) as a behavioral characteristic, (b) randomly through accidental causes, and (c) under catastrophic circumstances such as flooding or human disturbance. Insects normally are the only forms found in the drift. Its importance to insect distribution is shown by the number of organisms involved, up to a few hundred thousand per day, or about 4 per m^3 of flow (McCart, et al., 1973).

Benthic microfauna may be important in the cycling of nutrients, though their biomass is small, three orders of magnitude less than that of chironomids in a Barrow pond (Hobbie, et al., 1972). Organisms found in the pond were ciliates, flagellates, amoebae, nematodes, and rotifers.

2A.6.1.4.2.3 Fishes

Slow growth and development, and long life spans characterize fishes in arctic fresh waters. Low productivity of the waters and the short growing season are probably the conditions responsible. Examples of these characteristics are shown in length-to-age comparisons in Figures 2A.6-8, 9, 10 and 11. As indicated in Figure 2A.6-12, rapid growth may occur under some circumstances. Despite slow growth, arctic fishes may reach large sizes, and life spans may occasionally approach 40 years.

A preliminary survey of fishes along sections of the Sag River and tributaries to be crossed by the Alyeska haul road is available from the Alaska Department of Fish & Game (Yoshihara, 1973b). The arctic char is the most important species present. Its large size and high density in the fall make it a potentially important game fish. Grayling, another important game fish, are widely distributed. At



ALL AGES ESTIMATED FROM OTOLITHS

REF: McCART et al, 1973

TRANS-ALASKA GAS PROJECT

LENGTH–AGE RELATIONSHIP OF SELECTED ANADROMOUS ARCTIC CHAR POPULATIONS

FIGURE 2A.6–8

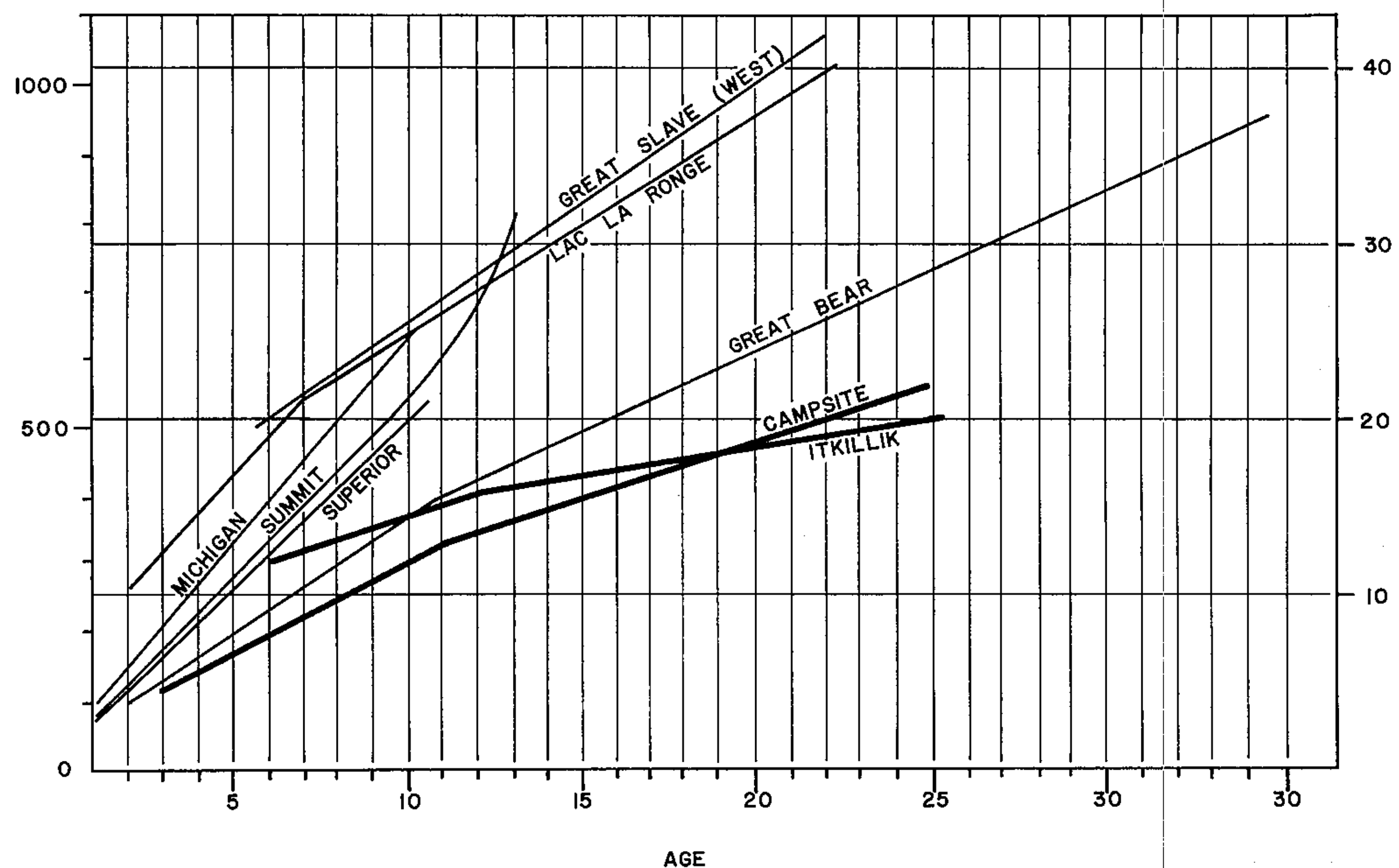
TRANS-ALASKA GAS PROJECT

LENGTH-AGE RELATIONSHIP OF LAKE TROUT FROM CAMPSITE AND ITKILLIK LAKES COMPARED TO OTHER POPULATIONS

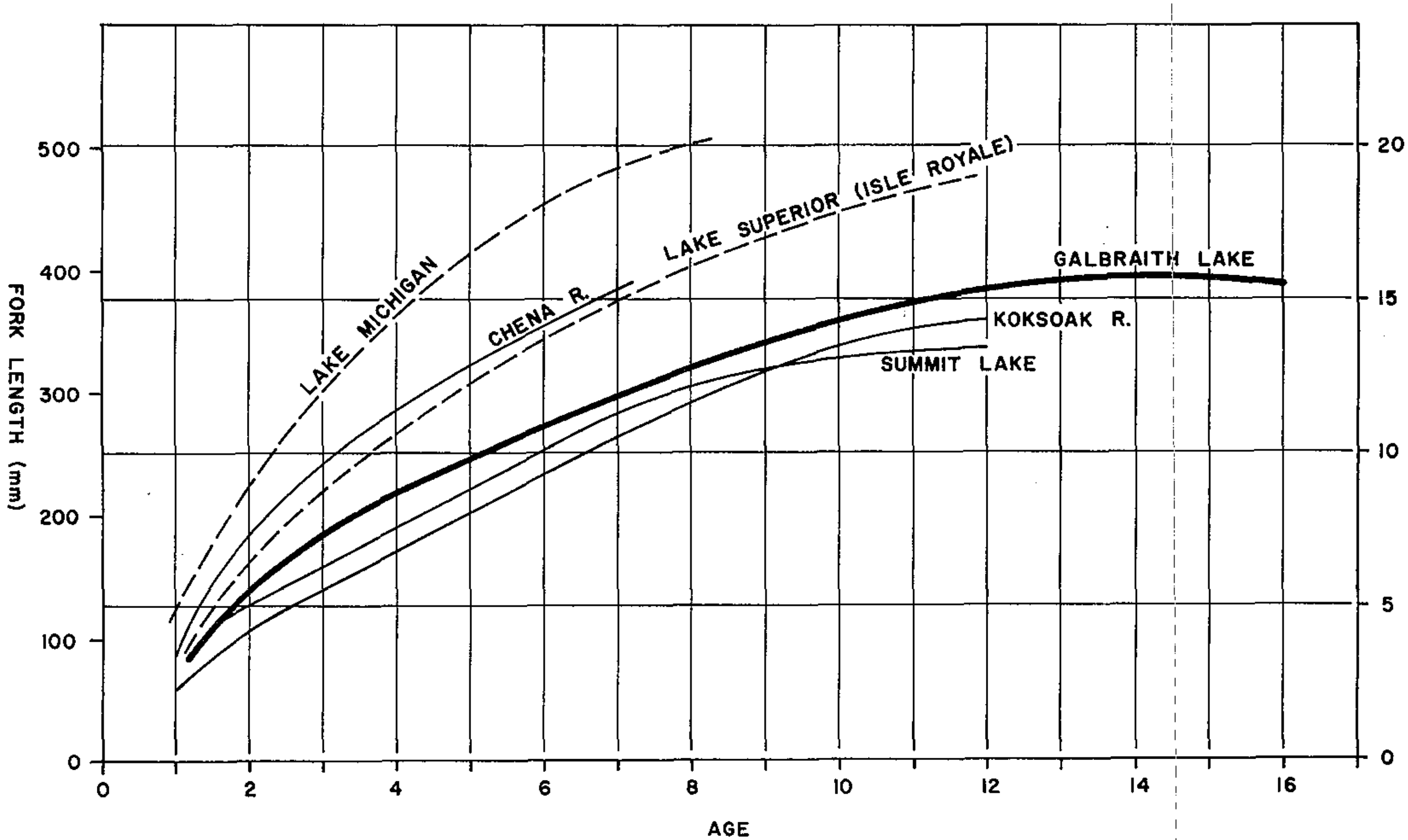
FIGURE 2A.6-9

CAMPSITE AND ITKILLIK AGES DETERMINED FROM OTOLITHS. OTHERS DETERMINED FROM SCALES.

REF: McCART et al, 1973



REF: McCART et al, 1973

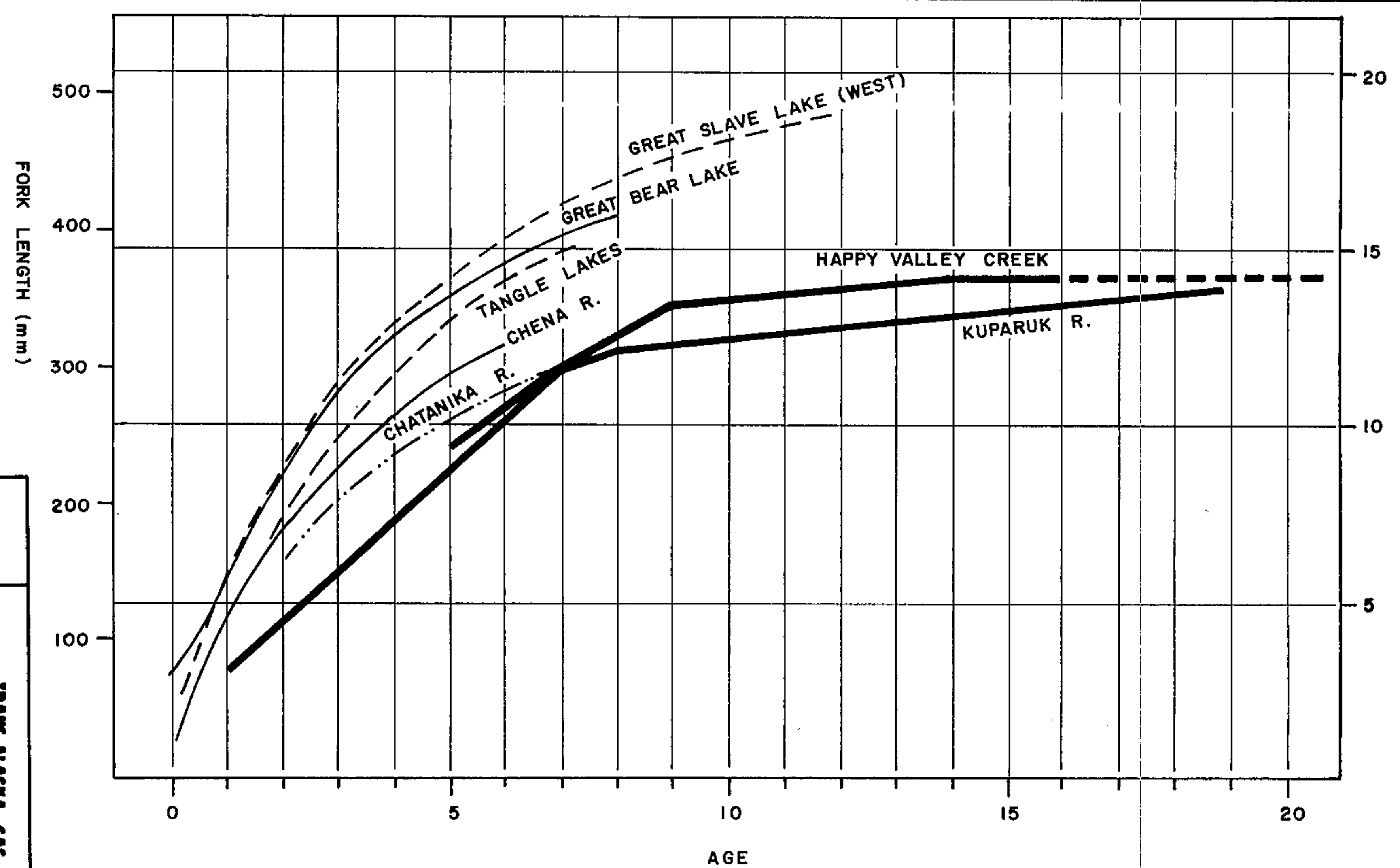


NOTE:
ALL AGES ESTIMATED FROM SCALES

TRANS-ALASKA GAS PROJECT

LENGTH–AGE RELATIONSHIPS OF GALBRAITH LAKE ROUND WHITEFISH AND OTHER NORTH AMERICAN POPULATIONS

FIGURE 2A.6-10



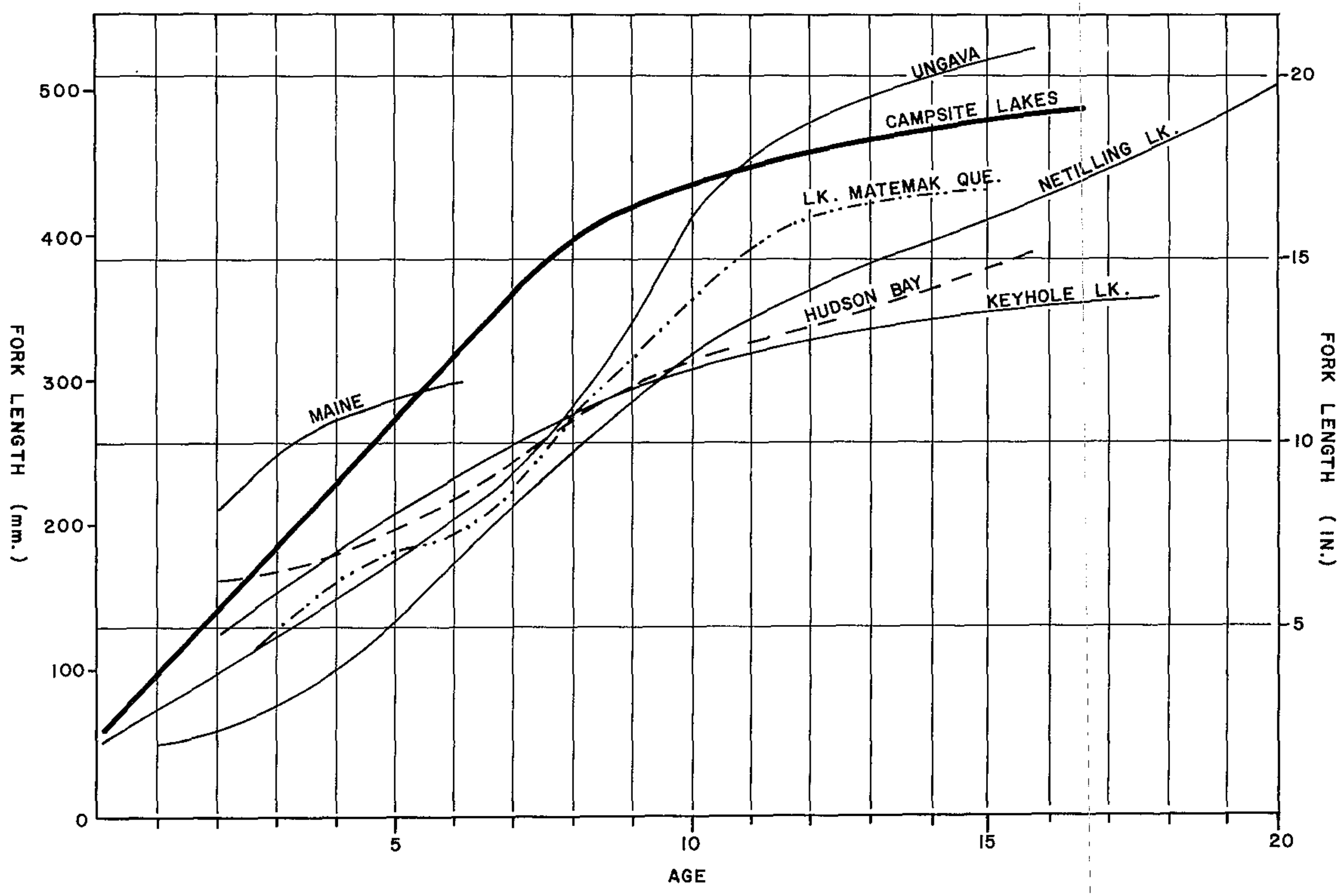
REF: McCART et al, 1973

TRANS-ALASKA GAS PROJECT

HAPPY VALLEY CREEK AND KUPARUK RIVER GRAYLING GROWTH RATES COMPARED TO OTHER POPULATIONS

FIGURE 2A.6-11

REF: McCART et al, 1973



TRANS-ALASKA GAS PROJECT

LENGTH-AGE RELATIONSHIP OF CAMPSITE ARCTIC CHAR COMPARED TO OTHER NORTH AMERICAN LAKE POPULATIONS

FIGURE 2A.6-12

least 11 other species of fish are also found (Appendix A). Commercial and subsistence fisheries are absent in the Sag drainage (Yoshihara, 1972).

Knowledge of the life histories and population dynamics of fishes in this area is extremely limited. The results of work in progress by the Alaska Department of Fish & Game are essential to an understanding of the requirements of these fishes (Yoshihara, 1972; 1973a). An important related study is available from the Alyeska Pipeline Service Company (McCart, et al., 1973). Both of those studies concentrate on the arctic char.

Both resident and anadromous populations of char exist in the Sag River drainage. Most char are anadromous and migrate upstream each year in August. Spawning takes place in September and October. Most char are nonconsecutive spawners, and the migrant population in any year contains immature fish and mature fish that will not spawn in that year. Fish densities change rapidly during migration, and 20,000 have been observed in the Ivishak River--a tributary of the Sag--in late August (Yoshihara, 1972). The spawning grounds are a series of freshwater springs in the Arctic Foothills, which are thus very critical habitat to the char.

Where the char overwinter is yet unknown, but possible sites are extremely limited. The average depth of the Sag River is less than six feet, and winter ice depth is commonly six to eight feet. Only deeper pools provide water year-round, and these pools also constitute critical habitat. Other critical aspects are water quality, stream velocity, and substrate. Soon after breakup, the adult char again migrate to the sea. Some fish may spawn several times in a lifetime, which may be 12 to 14 years for migrants, and 25 years for lake residents. One specimen has been tentatively aged at 38 years.

The diet of char varies with location and population. The migrants tend to do little feeding while in fresh water (as judged by the proportion of empty stomachs). For the migrants, small char and char eggs are important food items. Plant material and insects (Diptera, Trichoptera, Plecoptera, Ephemeroptera) afford the rest of the common diet. In the coastal area, mysids are the preferred prey, but isopods, amphipods, miscellaneous crustacea, and other fish are also important. Migrants feed much more heavily in salt water. Stream residents rely greatly on chironomids, as well as on other insects and fresh eggs. Their feeding is far heavier than the overwintering migrants. Both migrants and residents overwintering in streams presumably feed little after ice traps them in pools. Lake resident char most frequently feed on snails.

The grayling is also a migratory fish, both for feeding and spawning purposes. Spawning apparently takes place in the beaded streams of the Foothills in early June. Overwintering is apparently done in lakes and in some of the pools shared by char. Summer feeding grounds tend to be considerably removed from the above areas, implying regular seasonal movements. Only preliminary information is available on specific sites for any of these activities.

The diet of the grayling also varies with location. Plant material, snails, and insects (Trichoptera, Coleoptera, Chironomidae, Culicidae, and Tipulidae) are the most important food items. Several other groups are taken, but appear to be less important. Grayling grow very slowly, and life span in this area is about twice that of fish in some areas of interior Alaska (Figure 2A.6-11).

Other species of fish may also have particular spawning requirements, and may share the same overwintering areas. Their diets may be similar, since limited types and amounts of food are available. Lake trout consume snails, fish, and insects. Round whitefish consume snails, clams, crustaceans, and insects. During spawning, species other than the one spawning may congregate and consume large numbers of eggs. The extent to which this occurs in the Sag drainage is unknown, but it may be important in relation to egg mortality as well as to food for dependent species.

2A.6.1.4.3 Decomposition

As with the terrestrial ecosystems, decomposition in arctic aquatic systems is a limiting process, especially in shallow lakes and ponds with heavily organic sediments. The rate of decomposition largely determines the rate of supply of nutrients to the aquatic community. In this region, however, very little specific information exists on types, biomass, or functioning of organisms important to the process.

In a Barrow pond, the biomass of bacteria in the water was found to be twice that of the phytoplankton, while the biomass of sediment bacteria was 1000 times that of the water on an areal basis (Hobbie, et al., 1973). High rates of uptake of dissolved organic carbon and low turnover times for the pool of organic compounds indicate a moderately high level of activity for these bacteria.

Decomposition is assisted by benthic macrofauna, such as the chironomid larvae. These organisms are detritovores, and they serve to mix and break up sediment material. Microfauna may also figure in the decomposition process. Fungi are generally important in decomposition, but apparently have not been investigated in Alaskan arctic waters.

2A.6.1.4.4 Systems Dynamics

Many of the same limitations on biotic processes apply to terrestrial and aquatic ecosystems in the Arctic Drainage Division. The discussion of the stability of tundra largely applies to aquatic ecosystems as well. These systems are adapted to wide oscillation in seasonal physical phenomena. Low species diversity and simplified food webs appear to be a part of this adaptation.

Aside from low light levels and low temperatures, low productivity is a result of the inadequate supply of nutrients, particularly phosphate. The nutrient composition of water is ultimately a reflection of the parent bedrock in the drainage basin, and the low levels of available phosphate in arctic soils means similarly low levels in waters. In lakes and ponds, nutrients are locked up in sediment detritus, and rate of supply to the aquatic community is determined by rate of decomposition. Thus, the rate of turnover is as critical as the absolute supply of a nutrient.

Limited primary production is a direct constraint upon higher trophic levels. The complexity of the food web varies according to productivity. Consumers are absent in the least productive waters, but some lakes support a large number of zooplankton and benthic species, and several fishes. Even in the richer systems, growth and development of fauna are very slow. Zooplankton are largely monocyclic, and chironomids have a two-year life cycle. Fishes mature late, and may spawn with reduced frequency.

Fishes are the most conspicuous fauna, and are the only organisms with recreational potential or subsistence value. The dependence of fish on a limited food supply should be emphasized, as should their dependence on the physiographical nature of the river systems. Spawning grounds, overwintering areas, and food organisms must be protected. The advantage of mobility is offset by narrow environmental constraints upon life cycles.

The biological variation found in arctic waters has been stressed in preceding sections. A strong capacity for flexibility is indicated for arctic aquatic ecosystems. Most of the time, these systems exist under marginally favorable conditions, and their capacities to absorb unusual stresses is unknown.

2A.6.1.5 Regional Systems Interactions

Biotic transfers between the major environments (terrestrial, aquatic, marine) in the Arctic Drainage Division are not well defined, but are undoubtedly important. Examples of such transfers illustrate the importance of the processes to local or regional dynamics:

(1) Marine birds nesting on shore may deposit substantial nutrients on land, thereby increasing terrestrial primary and secondary productivity locally (cf Swartz, 1966).

(2) Run-off commonly releases pulses of nutrients from terrestrial environments into streams and ponds, particularly in the flat Coastal Plain (Bilgin & Douglas, 1972). The underlying "pan" of permafrost facilitates this lateral transfer process. Pulse amplitude may be profoundly influenced by phase relations of primary producer biomass, herbivore biomass, and the volume of litter or herbivore feces (cf Pitelka, 1972).

(3) Consumer species, such as ducks and phalaropes, spend much of the biologically active season dependent on aquatic productivity and nutrients, releasing these on land.

(4) Human settlements are foci of importation to terrestrial environments of energy and nutrients from the Beaufort Sea (as well as from outside the system) largely in the form of marine mammal products.

(5) The seasonal mobility of consumers probably results in a small net impoverishment of arctic terrestrial systems, since secondary production (reproduction and growth of young) is largely supported by tundra productivity for many bird and mammal species. Widespread winter emigration from the Arctic Drainage Division exports the secondary production, and to the extent that winter mortality occurs in these populations, the output of the tundra system enters biological systems elsewhere (cf West & DeWolfe, 1974).

Although the balance sheet for such nutrient and energy transfer processes is not clear, an underlying biogeochemical progression may be imagined: terrestrial - aquatic - marine. This progression is a "downhill" movement. Superimposed on this general flow downward from a "leaky system" are the eddies or reversals generated by ducks, ses-cliff birds, phalaropes, and man. Further superimposed are the import and export processes from the Arctic Drainage Divison. The effects of such biotic transfers are unevenly distributed, and it may be expected that interfaces such as stream and pond margins, estuaries, and seashore, are most heavily influenced.

2A.6.2 Interior Basin Division

This region extends from the Continental Divide in the Brooks Range to Thompson Pass, the drainage divide of the Chugach Mountains in south central Alaska (Figure 2A.6-1). Whereas the Arctic Drainage Division lies totally within the tundra biome, most of the Interior Basin Division lies within the coniferous forest biome (cf Viereck & Little, 1972). The entire region is a reasonably cohesive unit, both climatically and biologically. Cold winters, warm summers, minimum season lag, and low rainfall determine the continental character of the climate. Overall, the flora and fauna are more diverse than in the Arctic Division.

Ecological interest in the Interior has been less explosive than in the Arctic, but a steady volume of information continues to appear, generated by universities, by federal and state agencies, and by industrial interests.

2A.6.2.1 Species and Communities

The Interior Basin is characterized by taiga, the wooded vegetation of subarctic latitudes and subalpine elevations which occupies the bioclimatic zone adjacent to the treeless tundra. Taiga is dominated by cold-hardy conifers of the genera Picea and Larix and the hardwood genera Betula and Populus (La Roi, 1967). The continuity of closed forests is broken by tundra uplands, muskegs, and shrub-dominated communities.

Two thermally-correlated physiognomic subzones are discernible within the taiga of Alaska. From north to south or from high to low elevation these are:

(1) Subarctic forest-tundra, where groves of widely spaced conifers are restricted to optimal local environments, and

(2) Subarctic woodlands, where tundra is confined to exposed, unstable sites. Closed-crown forests with feather moss-herb underlayers are located in optimal environments, and open, lichen-heath woodlands and muskegs predominate elsewhere (La Roi, 1967).

Within major zones a complex mosaic of communities exists, influenced by exposure, drainage, angle of slope, elevation, position on slope, occurrence of permafrost, and disturbance.

Where fire or other serious disturbance is long absent from reasonably productive habitats, forest ecosystems that are dominated by white or black spruce develop (Viereck, 1970; 1973a; 1973b). Within these forests, five strata are recognizable:

(1) Tree strata containing plants with a diameter at breast height (DBH) greater than 7.5 cm,

(2) Tall shrub-transgressive, containing plants up to 135 cm tall and up to 2.5 cm DBH,

(3) Low-tree sapling with DBH between 2.5 cm and 7.5 cm,

(4) Medium-low shrub-transgressive, with shrubs ranging in height from 30 to 135 cm tall, and

(5) A herb-dwarf-shrub-seedling stratum containing herbaceous and woody plants less than 30 cm tall.

The following is taken from the Final Environmental Impact Statement for the Proposed Trans-Alaska {Oil} Pipeline (USDI, 1972).

> From the south slope of the Brooks Range to the north slope of the Chugach Mountains the vegetation is a mosaic of grasses, shrubs, broad-leaved deciduous trees, mixed deciduous and spruce trees and pure spruce stands (Scott, 1962, p 5880589). This heterogeneity reflects a long history of fire, of differences in exposure, surficial deposits, topography, and depth to permafrost (Pewe, 1965, p 12). Below 3000 feet in the north, 3200 feet at Isabel Pass in the Alaska Range, and 2000 feet in the Chugach Mountains, trees grow on all sites except poorly drained and physically unstable ones unless they have been temporarily removed by fire or man. . . . a general relation exists between the distribution of trees and physical character of the environment. . . .
>
> Vegetation in Brooks Range
>
> The bottomland vegetation along the Dietrich and Middle Fork Koyukuk Rivers, south to Cathedral Mountain increases in density of stand and size of the trees partly as a function of local differences in the physical environment. White spruce and balsam poplar are the predominant trees, whereas alders and tall willows are the prominent shrubs. The active flood plains are generally bare of any plants because of the continuous migration of the braided channel. Annual spring floods over gravel and sand point bars effectively prevent the growth of plants on them. On islands and higher point bars, willows are kept low and balsam poplar trees grow in a shrubby form because of frequent browsing by moose.
>
> Flooding in streams modifies the shape and location of channels most strikingly by cutting off meanders. The cut-off bends tend to be preserved as oxbow ponds with the help of beavers who build dams at the ends, thus stopping flow through them. In this quiet water grow herbaceous aquatic plants, pondweeds (Potomogeton sp), sedges (Carex sp) and grass (Arctophila fulva).
>
> Gently sloping colluvial deposits and terraces are back from the river, where poorly drained and generally treeless, vegetation consists of heath shrubs, dwarf birch, grasses,

sedges, and cottongrass tussocks. Locally on these surfaces bare areas are present because intense frost action prevents germination and growth of plants. Active soil slides and talus deposits are generally bare of vegetation. Alluvial fans at the mouths of most streams support stands of white spruce, white birch and aspen.

Vegetation between Cathedral Mountain and the Yukon River

Vegetation in lowlands and gently rolling hills south of Cathedral Mountain to the Yukon River, is a mosaic of types. Most of the area is covered with scattered, widely spaced, small black spruce in a ground mass of dwarf shrubs, sedges and cottongrass. White spruce forests are largely confined to banks of streams and scattered sites generally underlain by well-drained gravel. The stands are either pure spruce or the spruce mixed with aspen and white birch. Willows and heath shrubs are common under the trees, and in stands more than 50 years old, mosses are abundant. Some trees of saw-log size grow on terrace gravels especially along Prospect Creek, Jim River, and Middle Fork Koyukuk. Sparsely distributed black spruce grows with heath shrubs, dwarf birch, cottongrass, and herbaceous plants in places where the drainage is poor and the permafrost is close to the surface. . . . Mosses are abundant in older stands and completely cover the ground surface. As the mosses grow upward, the lower parts die. These dead parts create layers of peat that generally are as much as a foot thick.

Treeless areas are common in the lowlands where water stands at or just below the surface. . . . On such sites, sedges and cottongrass tussocks are abundant. With the sedges, grow dwarf birch and heaths. Locally in these poorly drained areas, mosses are abundant, but in the wettest places they are rare or absent.

Vegetation between Yukon River and Fairbanks

The country from the upper Ray River north of the Fort Hamlin Hills south to Fairbanks across the Yukon-Tanana Uplands is generally forested. Most of the rolling uplands are one of the areas that support white spruce trees of saw-log size (Zasada & Gregory, 1969, p 1).

The upland forests on well-drained sites consist of white spruce, white birch, aspen, and balsam poplar singly or in all combinations. Many upland areas support black spruce forests, especially where drainage is poor. A single species or a combination of two or more may cover small areas of a few acres or large ones of a few thousand acres. Boundaries between types are sharp, representing edges of early fires. Shrubs and ground cover are different within the stands and are related to the interval since the area was last burned.

The lower slopes and broad valley flats generally are forested with black spruce and associated heath and dwarf birch shrubs. Moss and peat layers are characteristic of floors of mature forests that have not been burned severely in perhaps the last 50-200 years.

On flood plains, close to the larger streams, are willows and alder shrubs, aspen, and balsam poplar. In places, these are small and scrubby in form, again reflecting young age resulting from recent establishment following severe flooding.

Along the proposed pipeline route, only Wickersham Dome is above timberline. Here, the vegetation is composed of matted, woody plants, small heath and willow shrubs, sedges, and herbaceous plants. In small hollows and in the lee of bedrock outcrops, the woody plants reach three to four feet in height.

Vegetation between Fairbanks and Thompson Pass

Forest vegetation is generally continuous along the pipeline route south of Fairbanks to the vicinity of Donnelly Dome. In flat, poorly drained areas, black spruce and larch are small and scattered, and the character of the vegetation is the result of predominance of heath, dwarf birch, and willow shrubs. Sedges and scattered herbaceous plants are prominent. The poorly drained Shaw Creek Flats are more heavily forested with black spruce and larch. The better drained uplands underlain by loess are forested with white spruce, white birch, aspen, and locally black spruce singly or in combination. The size and form of the trees is highly variable and most trees are small with trunks ranging from two to eight inches in diameter. Their small size is the result of age, again reflecting a long history of fire.

White spruce trees are absent at Phelan Creek north of Isabel Pass southward to Gulkana River just north of Paxson. In the vicinity of Isabel Pass and Summit Lake, the vegetation consists of willow and heath shrubs, grasses and sedges. This has been called shrub tundra (Sigafoos, 1958, p 179, map) and high brush (Spetzman, 1963).

From Paxson Lake southward, white spruce and other tree species are more abundant. Trees, in general, are larger and more closely spaced with decrease in elevation toward the Chugach Mountains. In the Copper River Valley, Hutchison (1967, p 21, map) shows areas of commercial white spruce forest.

Throughout the route south to about the headwaters of Little Tonsina River, vegetation has a patchwork appearance again because of frequent fires and variations in soil drainage. Stands of white and black spruce trees, either growing singly or in combination, alternate with pure stands of aspen, white birch, and balsam poplar or mixtures of two or more. Stands of small aspen and birch are prevalent in areas of recent fires. Small white or black spruce or both locally grow with the small deciduous trees. On poorly drained sites heath, dwarf birch, and willow shrubs along with cottongrass and thick layers of moss are characteristic. The surface of shallow bodies of water is broken by hummocks of moss, cottongrass, and low heath shrubs.

In the Chugach Mountains, from the divide between the Little Tonsina and Tiekel Rivers, south to Thompson Pass, white and black spruce are sparser and smaller. The vegetation generally consists of patchy spruce and aspen trees that are three to ten inches in diameter, and dense willow and alder thickets. On gentle slopes larger white spruce trees and heath shrubs are locally present. On the flood plain and lower tertaces of the Tiekel and Tonsina Rivers, balsam poplar to 18 inches in diameter and small white spruce are common. In addition to fire and poorly drained soil, frequent snow avalanches severely damage or destroy large areas of forest in the valleys. In the spring of 1971, snow avalanches largely destroyed the bottomland and lower slope forests as well as highway structures in a five-mile swath in the Tonsina River Valley.

Thompson Pass is above timberline and the vegetation consists of matted woody plants less than three inches high, sedges, and low heath plants. South and west of the Pass above about 1100 feet elevation, the vegetation consists primarily of dense alder thickets growing to heights of six to ten feet [Vol 2, pp 125-134].

The following vegetation types are based on the classification of Viereck and Little (1972). They include forests, muskegs, alpine tundra, shrub tundra, and shrub-dominated successional communities. Forests, which typify the Interior Basin Division, are usually mixtures of two or more tree species, but are commonly dominated by one species. (See Appendix B hereto).

2A.6.2.1.1 <u>Closed Spruce-Hardwood (White Spruce Type)</u>

The best commercial stands of white spruce (Picea glauca) typify this type. They are found on warm, dry, south-facing hillsides and adjacent to rivers where drainage is good and permafrost absent. These stands are rather open under the canopy, but may contain shrubs of rose, alder, or willow. The forest floor is usually carpeted with a thick moss mat. On better sites white spruce may reach 100 to 200 years in age with diameters of 10 to 24 inches. Subdominant trees are paper birch (Bethula papyrifera) and balsam poplar (Populas balsamifer).

White spruce is the "climax vegetation" of well-drained forested sites in the region. Because of the frequency of wildfire in any moderately large area, there is a mosaic of several seral types leading to the white spruce type. The successional sequence is:

(1) Recent burn,

(2) Willow-shrub stage,

(3) Quaking aspen or paperbirch type, depending on slope, and

(4) White spruce or low-growing spruce forest, depending on drainage.

2A.6.2.1.2 Willow-shrub

Succession following fire is varied. The exact pattern depends on previous vegetation type, topography, drainage, and seed source. In general, however, fires are followed by a shrubby stage consisting of light-seeded willows. This stage is also associated with the presence of fireweed (*Epilobium* spp).

2A.6.2.1.3 Quaking Aspen Type

On xeric south slopes, fast-growing aspen stands, dominated by quaking aspen (*Populus tremuloides*), replace willow thickets. The aspen mature in 60 to 80 years and are eventually replaced by white spruce, except in excessively dry sites where they may persist. Occasionally, aspen stands also follow fire on well-drained lowland river terraces and are replaced by white or black spruce as succession progresses.

2A.6.2.1.4 Paper Birch Type

Paper birch (*Betula papyrifera*) is the common invading tree after fire on east- and west-facing slopes, and occasionally on north slopes and flat areas. This species occurs in pure stands, but more often is mixed with white spruce, aspen, or black spruce. The birch trees may be 60 to 80 feet tall and have diameters up to 18 inches, but a diameter of eight to nine inches is more common.

2A.6.2.1.5 Balsam Poplar Type

While not associated with fire succession, balsam poplar (*Populus balsamifera*) follow willow-shrub and precede white spruce in riparian succession. Invading sand and gravel bars, they grow rapidly to heights of 80 to 100 feet and diameters of 24 inches before being replaced by white spruce. Commercial stands occur in all major river valleys of interior Alaska.

2A.6.2.1.6 Open Low-Growing Spruce Forests

On north-facing slopes and poorly drained lowlands, forest succession leads to open black spruce (*Picea mariana*), and bogs, usually underlain by permafrost. Black spruce are slow growing and seldom exceed eight inches in diameter, though they are usually much smaller, reaching a diameter of two inches at breast height in 100 years.

Black spruce come in abundantly after fire because of their sclerotinous cones, which, after heating, open to spread seed over burned areas.

A thick moss mat, often of sphagnum mosses, sedges, grasses, and heath shrubs, usually makes up the subordinate vegetation. In wet bottomlands, tamarack (Larix laricina), becomes a dominant component of the vegetation. Often treeless muskegs and ponds occur within this type.

2A.6.2.1.7 Flood Plain Thickets

Flood plain thickets are found on newly exposed alluvial deposits that are periodically flooded. They develop quickly and may reach heights of 15 to 20 feet in south and central Alaska. The dominant shrubs are willows and occasionally alders, with a number of lower shrubs under the canopy.

2A.6.2.1.8 Birch-Alder-Willow Thickets

Birch, alder, and several willow species form thickets 3 to 10 feet tall. They occur just above tree line and may be extremely dense or open and interspersed with reindeer lichens, low heath shrubs, or patches of alpine tundra. Older thickets tend to occupy wetter sites. Tundra patches generally occupy drier or wind-exposed areas.

2A.6.2.1.9 Alpine Tundra

Much of this is Dryas fell-fields (see subsection 2A.6.1.1), which may cover entire ridges and slopes along with cushion plants such as Silene acaulis, several grasses, and sedges. In association with fellfields are extensive areas of Eriophorum tussock on wet sites, and shrub tundra on sites with better drainage. Shrub tundra is characterized by dwarf birch (Betula nana), resin birch (Betula glandulosa), and Labrador tea (Ledum decumbens). The understory is characterized by grasses, sedges, mosses, and lichens.

2A.6.2.2 Abiotic Characteristics

The Interior Basin Division includes several physiographically distinct provinces (see subsection 2A.2.1) which profoundly affect the occurrence, diversity, and interactions of biological systems. These provinces cover the spectrum from lowlands and flats of the two principal drainages (Yukon River and Copper River) through adjacent uplands, foothills, and mountains of three ranges (Brooks, Alaska, and Chugach). The nature of the vegetation, soils, and associated biotic communities reflects the local physiography, as well as climatic variables and past history of disturbance.

2A.6.2.2.1 Meteorology

The climate of the Interior Basin Division is continental, with pronounced daily and seasonal variation in ambient air temperatures, and minimum seasonal lag (Johnson & Hartman, 1969). Annual precipitation in this region varies from less than 8 inches to approximately 20 inches. Low relative humidity throughout much of the year, combined with long periods of daylight in summer, promotes drying in aboveground biotic systems, and is related to the importance of wildfires in this region. This drying tendency, however, does not generally extend to below ground or aquatic environments, for widespread permafrost, low mean annual temperatures, low soil temperatures, and the shortness of summer all act against water loss. As a result, native biotic systems are not limited by water availability in any conventional sense. The casual observer of interior Alaskan forests would not make the mistake of classifying the region as arid or semi-arid, as some climatologists have on the basis of annual precipitation (Johnson & Hartman, 1969).

High-pressure systems may remain fairly stationary over some or all of the Interior Basin, especially in winter. Cold and calm dominate the lowlands under these conditions, and surface temperature inversions frequently develop.

Through much of this region, snowfall makes up a large part of annual precipitation (Arkin, 1972). Biotically important conditions derive from the nature of snow (cf Formozov, 1946). Snow cover in interior Alaska is generally of low density, 0.2 to 0.24 g/cc (Johnson & Hartman, 1969), except where wind-drifted in mountains. In contrast, therefore, to wind-drifted snow cover of the Arctic Drainage Division, and to the wet snow cover of the maritime South Coastal Division, interior Alaskan snow cover tends to be excellent insulation, and provides extensive subnivean habitats to small mammals.

The minimal seasonal temperature lag of the Interior Basin, coupled with moderate snow cover, promotes early snow melt and prompt commencement of annual primary production at lower elevations. Native plant species leaf out about May 15, at Fairbanks, and non-native annuals may be planted on about June 1, with minimal danger of frost kill. The growing season thus begins three to five weeks before summer solstice, in contrast to the severely restricted period of primary production in the Arctic Drainage Division.

Because mean annual air temperatures of the Interior Basin Division are below freezing (Johnson & Hartman, 1969), widespread permafrost is not surprising. South-facing, well-drained slopes, and disturbed areas such as recently deposited alluvium (Viereck, 1970a), are the only areas reliably free of ice-rich permafrost between the crest of the Brooks Range and Thompson Pass. Particularly where the mean annual temperature is within a few degrees of freezing, permafrost is subject to degradation and buildup in consequence of natural disturbances, such as wildfire, flooding, and river meandering. As bare soil is revegetated during natural succession, the insulation of a developing organic layer precipitates the buildup of permafrost, and consequently, a shallower active layer (Viereck, 1970a).

2A.6.2.2.2 Soils

The following discussion is from Viereck (1973b):

The soils of the taiga of Alaska are described in a general way by Kellogg and Nygard (1951) and Lutz (1956). Specific areas in the taiga are mapped and the soils described in detail by Rieger (1963) and Rieger *et al.*, (1963). Forest soil types of the Tanana and Yukon Valleys are classified and described by Wilde and Krause (1960). In general, the forest soils are shallow and profiles only poorly developed. Bedrock is primarily micaceous schist; and most is overlain by Pleistocene loess, sand, outwash, or moraine formed by organic deposits formed in bogs or combined with redeposited loess, or by newly formed river alluvium. Distinct Podzols have developed in the wetter areas south of the Alaska Range, and Subarctic brown forest soil is predominant north of the Alaska Range to the latitudinal tree line. Bog soils or half bog soils (Wilde and Krause, 1960) predominate on wet sites over most of the lowland, and a highmoor peat is common on upland north-facing slopes.

Loess is widespread in a broad band north of the Alaska Range (Pewe, 1968) and, consequently, soils are highly erodible when stripped of protective cover. Much of the loess has been transported to lower elevations and mixed with organic material and frozen (Pewe, 1957).

Permafrost, or permanently frozen ground, is a unique feature of the soils of much of the taiga of Alaska. In the southern sections of the taiga, permafrost is sporadic, found only in the coldest sites and usually only in bogs or on north slopes under thick organic layers. North of the Alaska Range, permafrost is discontinuous, occurring in most of the sites, but lacking on south-facing slopes and in freshly deposited alluvium. In much of the frozen layer, water has been incorporated as wedges or lenses of the pure ice. In some soils, this may amount to as much as 50% of the substrate by volume. In other areas, usually in the coarser soils, permafrost contains little or no ice. . . .

Aspect and slope are of special importance in the distribution of vegetation and soils in interior Alaska. Krause *et al.*, (1959) compare the vegetation and soil on two adjacent stands on north- and south-facing slopes near Fairbanks. They found that with similar parent material a subarctic brown soil developed on the south-facing slope, whereas on the north-facing slope a half bog soil underlain by permafrost occurs. On the south-facing slope was a well-developed white spruce stand (diameter of 25-35 cm) with a moss layer of *Hylocomium splendens*. On the north-facing slope was an open black spruce stand with trees 8 cm in diameter and a moss layer of predominantly *Sphagnum* spp. Both stands were 115-130 years old and were probably established after the same fire. Sharp contrasts in vegetation and soils such as this, related to topography rather than fire history, are common in the taiga of Alaska.

2A.6.2.3 Terrestrial Environment

2A.6.2.3.1 Primary Production

Primary production in the Interior Basin Division, as elsewhere, varies with vegetation type. The least productive communities in the region are black spruce muskegs and tundra communities. Shrub types and balsam poplar communities are the most productive, while birch, aspen, and white spruce communities are intermediate.

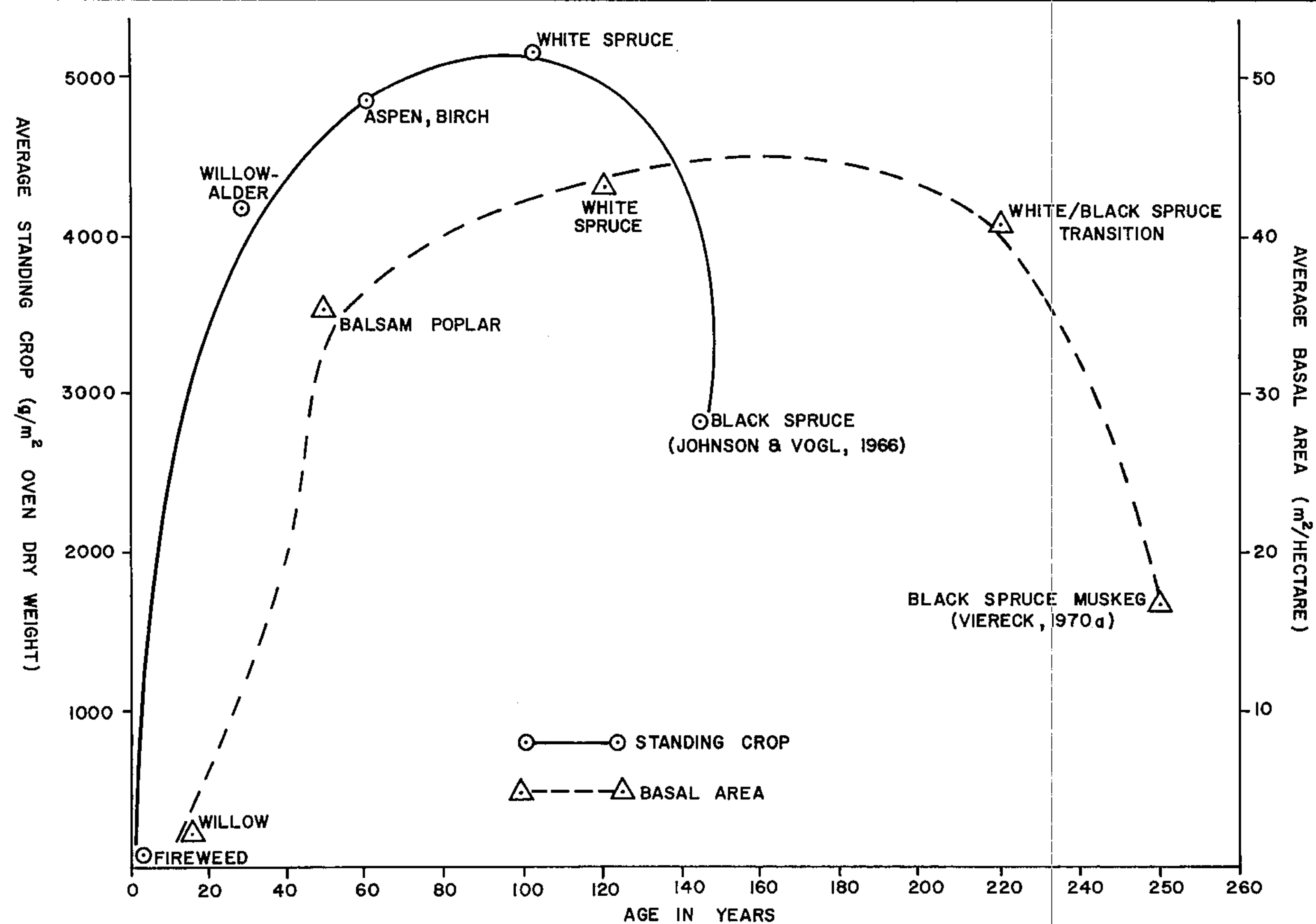
Production of high altitude tundras is similar to that of phytosociologically similar high latitude tundras. Thus, information on productivity and standing crop in these communities may be found in subsection 2A.6.1.3.1. The remaining shrub, forest, and muskeg types will be covered in this section. Further, since shrub, forest, and muskeg types represent different seral stages, it is useful to consider primary production of these types with respect to a time scale.

Theoretical considerations have led Louchs (1970) to predict that, at a geographic point in a forest ecosystem, primary production may be represented by a time-dependent function. The characteristics of this function are: (a) a period of rapid productivity following disturbance of the system (rejuvenation phase), followed by (b) a period of senescence or decreased production. Over long periods of time these "wave packets" are induced by random disturbances (i.e., fire, flood, or man-made). This prediction is supported by data for the Interior Basin Division.

The rejuvenation phase is characterized, in the Interior Basin Division, by shrub thickets dominated by willow and alder, followed in time by balsam poplar, aspen, or birch, depending on the site and the nature of disturbance.

Shrub thickets that usually appear first after a disturbance are highly productive (Figure 2A.6-13). Van Cleve, et al., (1971) have shown that annual production in alder-dominated shrub thickets near Fairbanks ranges from 407 $g/m^2/yr$ to 616 $g/m^2/yr$ for both above- and below ground components, depending on the age of the system. With respect to the aboveground component only, annual production ranges from 289 to 425 $g/m^2/yr$. From the energetic point of view, these systems are also highly productive (Van Cleve, 1973). Data of Johnson and Vogl (1966) imply similar rates of production in the Yukon flats area.

Balsam poplar communities that follow shrub types in succession along rivers in interior Alaska (Viereck, 1970a) are also highly productive (Figure 2A.6-13). Thus, the early portion of the rejuvenation phase is much more productive than tundra systems and, as will be shown below, more productive than subsequent phases.



TRANS-ALASKA GAS PROJECT

PRIMARY PRODUCTION OF INTERIOR BASIN PLANT COMMUNITIES

FIGURE 2A.6-13

Aspen and birch types, while having higher standing crops than shrub types, have lower rates of annual production (slope of standing crop curve) than shrub thickets. They also have a lower annual production than balsam poplar types, as well as lower standing crops (Figure 2A.6-13). Data of Johnson and Vogl (1966) indicate annual production on the order of 120 $g/m^2/yr$, but because of the nature of the data, these figures should probably be increased slightly (Van Cleve, personal communication).

Annual production of white spruce forests is less than that of the above types, and represents the transition between the rejuvenation phase and the senescent phase, which is characterized by open, low growing spruce forests and muskegs (see Subsection 2A.6.1.3.1). The senescent phase again has a low rate of production with respect to the rejuvenation phase and also with respect to the white spruce type. This final phase may be similar in productivity to tundra types (Van Cleve, personal communication).

The mechanism responsible for the type of production wave postulated by Loucks (1970) is related to the nutrient cycling dynamics, particularly nitrogen cycling--in forest systems (Van Cleve, personal communication). It is known that early stages of succession characterized by alder ecosystems are periods of rapid nitrogen buildup in the soil, which is due to the nitrogen-fixing capabilities of alder (Van Cleve, et al., 1971). This rapid accumulation of nitrogen decreases as succession proceeds, and probably reaches a maximum during the late rejuvenation phase, followed by a net loss from the soil during the senescent phase. The nitrogen lost from the soil is probably tied up in the standing crop, and is thus unavailable to support further rapid production--hence, the low rates of production found in the senescent phase (Van Cleve, personal communication).

In addition, the buildup of feather moss during succession lowers growing season soil temperatures and decreases the active layer (Viereck, 1970b). This lowering of soil temperature is probably also associated with decreasing productivity (Van Cleve, personal communication).

The effect of disturbance to such systems is two-fold: (a) nutrients are released, and (b) soil temperature is raised. Thus, the mechanism generating the production wave is probably a gradual tying-up of nutrients and lowering of soil temperature, coupled with random disturbance effects.

The following is quoted from the Fianl Environmental Impact Statement for the Alyeska oil pipeline (USDI, 1972).

Reproduction of Trees

> Unlike tundra species reproduction of trees is mostly from seed, although birch trees produce sprouts from stumps and cottonwood and aspen from roots as well. Much is known about seeding characteristics and seed bed requirements of trees primarily because of the commercial value of lumber.

Reproduction of non-tree species within the forested region is similar to that in the tundra region. Within the forested region, in contrast to the tundra, numerous annual grasses and herbaceous plants are present. Along roads and in cities and towns introduced species are common, including weeds.

The species are treated individually even though several grow together and start simultaneously in bare areas. Although only trees are discussed it is assumed that associated shrub and herbaceous species require the same environmental conditions to reproduce.

White Spruce

The dispersal of white spruce seed is in September with germination occurring in the following June and July. Soil moisture content of the seedbed is most critical in determining seedling survival of white spruce (Div. of Timber Man. Res., 1965, p 321). Humus, moss, and litter that dries out in the upper two to three inches results in the death of seedlings. Light is also critical, for shaded seedlings generally die by midsummer. Reproduction, then is favored by open areas of bar soil that remain moist (Lutz, 1956, p 20; Zasada & Gregory, 1969, p 10-12). Favorable sites are created by fires, floods and other natural physical disturbances, and by man's activity. Seeds are produced every year but heavy crops only every five to six years. At the Bonanza Creek Experimental Forest near Fairbanks, a 170- to 180-year old stand produced 86,000, 10,733,000, and 27,000 sound seeds per acre during three consecutive years (Zasada & Gregory, 1969, p 4). Seeds travel on the average about 300 feet from parent trees, but high winds blow seeds as far as 1000 feet (Nienstaedt, 1957, p 8-9). . .

Black Spruce

A moist seedbed is required for germination of black spruce seed and survival of seedlings. For this reason young seedlings are readily established in sphagnum moss but rarely in other mosses which dry out quickly (Div. Timber Man. Research, 1965, p 292; Johnston, 1971, p 2). Seedlings also are prevalent in mineral soil. Heavy seed crops occur about once in four years, but cones remain on the branches for several years; and seeds remain viable for as long as 15 years (Div. Timber Man. Research, 1965, p 292), thus a large seed source is nearly always present. Fires do not always destroy seeds in charred cones (G. W. Zamber, oral communication, Jan. 10, 1972). Because the seeds are fairly light they travel as far as 1000 feet from the parent tree (Div. Timber Man. Research, 1965, p 292).

Seedling survival requires an open area with abundant light, thus reproduction is poor in areas of heavy slash left from cutting. Black spruce trees may also reproduce vegetatively by rooting of lower branches after sphagnum moss has grown over them (Johnston, 1971, p 4). Because black spruce seeds germinate in sphagnum moss, the species is dominant in wet, poorly drained areas within the forested region . . .

Larch

Larch grows from central Alaska north to the Mackenzie River eastward to Newfoundland, and south to Pennsylvania; thus it is found in widely-varied sites (Roe, 1957, p 1-3). In central Alaska larch is a small tree restricted to poorly drained areas in pure stands or with black spruce (Heinselman, 1957, p 9).

Most studies of reproduction and growth of larch have been made within its commercial range in the Lake States and southeastern Canada. No data are available from Alaska (Roe, 1957, p 7). The behavior of seedlings and growth to maturity in Alaska cannot, with validity, be extrapolated from data available. It is quite likely that the isolated Alaska larch population differs genetically from that in the eastern part of its range. Alaska larch has been described as a separate variety (Hulten, 1968, p 60). Because larch grows either with black spruce or alone in wet areas in Alaska, it is assumed that its reproduction and growth are similar to those of black spruce. Sphagnum moss is abundant in these wet sites and because it is a favorable seedbed for black spruce it probably is also favorable for larch. . . .

Aspen

Aspen seeds are disseminated early in summer, and germination occurs within one to two days if a suitable seedbed is available; most reproduction, however, is vegetative. Aspen reproduces vigorously by growth of root suckers especially following fires that have killed mature aspen trees. Lutz (1956, p 34) counted small aspen suckers and seedlings in a series of milacre plots three years after a fire had killed an aspen tree 13 inches in trunk diameter. Root suckers had a density of 36,230 per acre. The suckers grow from buds on roots that are close to the surface. Most of the buds from which the suckers grow are produced annually. High soil temperatures and light intensities appear to be critical in the rapid growth of suckers as growth is inhibited in mature aspen stands (Div. Timber Man. Res., 1965, p 527). Aspen also produces sprouts from cut or broken stumps.

Reproduction by seedling growth is also high under favorable conditions; in the same study Lutz (1956, p 34) found that seedlings had a density of 23,120 per acre. If a moist seedbed is reached by the seed, high percentages of seed germinate. The seedbed must remain moist for most of the first summer as the root grows only 8-10 inches during the first year. . . .

Balsam Poplar and Black Cottonwood

Although two separate species, they are discussed as one because their reproduction, growth, and utilization are similar. Balsam poplar is restricted to Interior Alaska and black cottonwood to southeastern Alaska, along the Lowe River, and near Valdez along the proposed pipeline route.

Like aspen, both species reproduce by means of root suckers which appear in summer and grow rapidly (Div. Timber Man. Res., 1965, p 499).

Seeds are dispersed early in the summer and germinate immediately on a suitable seedbed. Mineral soil recently deposited by streams provides an ideal seedbed, but it must remain moist for a few weeks (Div. Timber Man. Res., 1965, p 499; Lutz, 1956, p 54; Roe, E. I., 1958, p 8; Roe, A. L. 1958, p 8; McKnight, 1971, p 4).

Both species grow rapidly and balsam poplar reaches heights of 75 feet and 3 feet in trunk diameter (Lutz, 1956, p 54-55; Roe, E. I., 1958, p 9). Black cottonwood on the Lowe River flood plain are 10-18 inches in diameter. . . .

White Birch

Light, exposed mineral soil, and soil moisture are essential for the germination of white birch seed. The seedling root will not grow through leaf litter and if shaded by leaves the seedling will die (Div. Timber Man. Res., 1965, p 95). White birch is a prolific seed-producing species; Lutz (1956, p 34) reported as many as 131,000 seedlings per acre.

Vegetative reproduction is significant, as well, occurring as sprouts from stumps following cutting and fire (Div. Timber Man. Res., 1955, p 95). In places, pure stands of white birch are composed solely of clumps of sprouts. . . . [Vol 2, pp 135-142].

2A.6.2.3.2 Consumption

Because of more favorable climate, greater structural diversity in the environment, and greater input by primary production, more species of consumers occur in the Interior Basin Division than do in the Arctic Drainage Division (see Appendix B hereto). The herbivore-based food chains are substantially better developed in this region than on the North Slope, although as yet little is known about invertebrate herbivores in general. Saprovore-based food chains are not as conspicuous as in the Arctic Drainage Division, but doubtless are of more importance.

Some destructive phytophagous (plant-eating) insects are well known because of their actual or potential economic threat to timber resources. Chief among these are approximately 17 species of Scolytidae (spruce bark beetles) that can erupt from their normal resource base of fallen timber to attack and kill living trees, under certain circumstances (Hard, 1967; Beckwith, 1972a; 1972b; personal communication). Destructive eruptions of these beetles commonly occur after a substantial source of fallen timber has been provided, allowing the beetle populations to grow rapidly. Such fallen timber may result from strong wind, spring breakup, or floods. Once this slash resource is exhausted, mature or overaged nearby spruce are vulnerable to attack, particularly if many of the living trees are senescent or under some other stress (such as drought). Unnatural disturbances, particularly logging, clearing, and slash accumulation, have been blamed for recent outbreaks on the Kenai Peninsula and around the Village of Tyonek (R. C. Beckwith, personal communication).

Of less economic importance, but nonetheless dramatic, are outbreaks of large aspen tortrix caterpillar, which periodically completely defoliate stands of aspen over large areas, both in Canada and interior Alaska (Beckwith, 1968; 1970). Although the infestation typically lasts 1 to 3 years in a given area, the larvae soon outrun the resource, and aspens are not killed unless otherwise unhealthy or stressed.

In contrast to bark beetle, tortrix outbreaks do not seem to be abetted in any way by human influence, except that the present distribution of aspen was enhanced by past clearcut logging and wildfires in interior Alaska (cf Lutz, 1956).

The abundance of vertebrate consumers in these subarctic latitudes may fluctuate widely. A classic example is the herbivorous snowshoe hare and its obligate predator, the lynx. The periodic peaks in hare abundance have a profound effect on brown-sable plants. Girdling of small willows and birches in particular results in dieback of all aboveground portions of these species. When preferred species are no longer available, hares frequently begin to consume small white spruce, during the latter stages of a period of abundance. Although the effects of hare outbreaks on plant communities have not been rigorously measured, it is logical to assert that plant species assemblages are significantly influenced by past history of hare browsing. Among the species least subject to browse are several alders (Alnus, spp) that are important in building up nitrogen in the soil during early successional stages (Van Cleve, et al., 1971; see also subsection 2A.6.2.3.1).

The following discussions of vertebrate consumers in the Interior Basin Division is taken from the Final Environment Impact Statement, Proposed Trans-Alaska {Oil} Pipeline (USDI, 1972).

Small Mammals

The dusky, masked Arctic, and pygmy shrews are all found in some locality in this area. The pygmy shrew is by weight probably the smallest animal in the world (Burt and Grossenheider, 1970), and its habitat preferences are similar to those described for the North Slope.

Pikas are common in the talus slopes and rubble of the Alaska Range. They are dependent on a large supply of grasses and forbs for "hay" because they are apparently active all winter (Howell, 1924).

The hoary marmot in the Brooks Range and Alaska Range is found above 2000 feet elevation (Rausch, 1953). They prefer stable rocky slopes which have large rocks for use as lookouts (Buckley and Libby, 1957).

The principal habitat requirement of the Arctic ground squirrel is the same along this section of the route as on the North Slope: well-drained soil free of permafrost.

The snowshoe hare, a species subject to violent population fluctuation, is found all along this section of the proposed route wherever food and cover are adequate. The size of the hare population determines the size of the lynx population (Buckly and Libby, 1957) because the lynx is the prime hare predator.

The range of the red squirrel within this area is the same as that of the white spruce, the seeds of which are its principal food. The northern flying squirrels can occur anywhere in the area where there are tall spruce or spruce mixed with other tall trees. Their main food is probably spruce seeds (Buckley and Libby, 1957).

The beaver is present along this whole section of the proposed pipeline, wherever there is suitable habitat. The preferred foods of the beaver are aspen and cottonwood followed by willow, birch, and alder. They will occur wherever these foods can be found in conjunction with standing or slow-moving water which does not freeze to the bottom (Buckley and Libby, 1957).

The small game and furbearers in the Rampart Dam impoundment area [Table 2A.6-6] were studied by Koontz (1968). He found that the mean number of beaver lodges for the 10,500 square mile area was 1995. He estimated the population at 31,500. The average harvest there for the years 1958-62 was 890 animals with an average annual total value of $20,025. He also estimated an average population density of 3 animals per square mile.

Several species of small rodents are known to occur along this section of the proposed route. These include the: northern bog lemming, brown lemming, collared lemming, northern red-backed vole, meadow vole, long-tailed vole, yellow-cheeked vole, tundra vole, Alaska (Singing) vole, and the meadow jumping mouse. The bog lemming prefers low swampy areas where grasses, sedges, and mosses are major components of the vegetation (Buckley and Libby, 1957). The meadow vole prefers meadows with dense grass. The long-tailed vole occurs along the route from the Salcha River to the Alaska Range and it

TABLE 2A.6-6

ESTIMATED SIZE OF FURBEARER POPULATIONS IN THE RAMPART DAM IMPOUNDMENT (10,500 sq. mi.)

Species	Estimated Density	Estimated Population
Beaver	3/1 sq mi	31,500
Mink	2.2/1 sq mi	23,100
Marten	1/5 sq mi	2,100
Otter	1/150 sq mi	3,360,000(*sic*)*
Short-tailed weasel	1/1/ sq mi	10,500
Lynx	1/5 sq mi	2,100
Red Fox	1/2 sq mi	5,250
Wolf	1/50 sq mi	210
Wolverine	1/80 sq mi	131
Snowshoe hare	140/1 sq mi	1,470,000
Red squirrel	12/1 sq mi	126,000

*Should read 70

Muskrat omitted:	320/1 sq mi	3,360,000

Source, USDI, 1972.

apparently prefers meadows of somewhat drier type than those of the meadow vole. The yellow-cheeked vole has been collected most often in areas of wet black spruce muskeg with a ground cover predominantly of moss and a shrub layer of alder (Buckley and Libby, 1957). The meadow jumping mouse ranges from the Yukon River south along the route, preferring grassy meadows and open woodland. The other small rodents show preference for habitat types similar to those they occur in north of the Brooks Range.

Muskrats are found along the proposed route from the Brooks Range south wherever there is suitable habitat, which is essentially the same as that for beaver. They feed on all parts of herbaceous aquatic vegetation, including the roots and tubers.

The average annual harvest of muskrat in the Rampart Dam impoundment area from 1925-1962 was 41,040 animals with a value of $50,479.20 and for the period from 1958-1962 the average annual harvest was 15,169 with an average annual value (Seattle) of $11,983.51 (Koontz, 1968).

The bark and twigs of aspen, white birch, and other trees are the food of the porcupine and they occur almost everywhere that they can obtain this food. Buckley and Libby (1957) indicate that porcupines might be absent from areas frequented by wolverine, since they are easy prey for this animal.

Koontz (1968) in a study of the Rampart Dam impoundment area notes the average annual income from all trapping in the area between 1925-1962 was $143,000. Dean and Klein (1962) estimated that the potential value of the furbearer resource in that area for the next 100 years was 300 million dollars. These figures are significant in relation to the average annual per capita income for the area which Koontz estimates was $124.38 from 1958-1962.

Birds

At least 161 species of birds have been reported from interior Alaska (Kessel, 1964), and perhaps three-fourths of these might be regularly encountered along the proposed pipeline route within this particular region. Some of the more common birds of the interior have been listed by major habitat types by Kessel et al., (1967) and Buckley and Libby (1957). Population estimates for most non-game species within this region are almost nonexistent.

Weeden and Ellison (1968) described the valuable game birds of Alaska and noted that periodically good numbers of Willow Ptarmigan, Rock Ptarmigan, Spruce Grouse, Ruffed Grouse and lesser numbers of Sharp-tailed Grouse can be encountered in parts of the interior. With the advent of fire protection, habitat is tending to be maintained in late successional stages to the benefit of Spruce Grouse, but to the detriment of Sharp-tailed Grouse which favors an early successional stage that is often maintained by fire.

The fall numbers of ducks migrating from principal waterfowl habitats within the Koyukuk River Drainage, Yukon Flats and in the Tanana-Kukokwim lowlands, portions of which are either adjacent to or downstream from the proposed pipeline route, are given in Table [2A.6-7]. Other species of ducks are found in fewer numbers. No confident estimates are available for White-fronted Geese and Lesser Canada Geese, both of which nest in most large tracts of waterfowl habitat in the northern half of the interior lowlands and probably number in the tens of thousands.

The proposed pipeline route would cross good waterfowl habitat in the Kanuti Flats, the Ray River, the flood plains of the Tolovana and Chatanika Rivers, the oxbows and ponds along the Chena and Salcha Rivers and morainal ponds near Donnelly Dome and several other areas of lesser importance (Bartonek, 1969b). It would also traverse several drainages entering Minto Flats which is important both as a waterfowl hunting area for sportsmen from the Fairbanks area and as a waterfowl production area (Hooper, 1952).

King (1968b) estimated from extrapolation of 13 years of waterfowl inventory data that somewhat fewer than 315 Trumpeter Swans, a formerly endangered but still rare species, were present in the lower Koyukuk Valley in spring. He also reported 340 adult and immature, and 138 young Trumpeter Swans counted during a late-summer survey in 1968 in the Fairbanks area which included Minto Flats and portions of the Tanana Valley, Wood River and Kantishna River. Drainages of some of these afore-mentioned areas are traversed by the proposed pipeline route.

Recoveries of waterfowl banded on the Yukon Flats indicate the continental value of the resource (Table 2A.6-8) and suggest certain affinities to migration routes and wintering areas by waterfowl breeding along the proposed pipeline route within the interior. White-fronted Geese probably follow the mid-continent route described by Miller et al., (1968) and winter in Texas.

Haugh (1970) reported seven Peregrine eyries along the Tanana River in 1970. At least three pairs of Peregrines were known to have formerly nested each year along the bluffs between Fairbanks and Nenana, but none nested there in 1970. Disturbance by heavy traffic of boats and aircraft along the river was suspected by Haugh to be the cause for their absence.

Sandhill Cranes are common migrants through the State and some nest in the interior. Cranes sometimes cause

TABLE 2A.6-7

ESTIMATES OF MIGRATING DUCK POPULATIONS FROM HABITAT IN THE YUKON RIVER DRAINAGE ADJACENT TO OR DOWNSTREAM FROM THE PROPOSED PIPELINE ROUTE

	Koyukuk Drainage	Yukon Flats	Tanana-Kuskokwim
Mallard	92,000	130,000	80,000
Pintail	181,000	256,000	158,000
Green-winged teal	124,000	176,000	109,000
Am. widgeon	136,000	192,000	119,000
Shoveler	46,000	65,000	40,000
Canvasback	11,000	16,000	10,000
Scaups	159,000	225,000	139,000
Goldeneyes	40,000	57,000	35,000
Bufflehead	19,000	27,000	16,000
Scoters	41,000	58,000	36,000
Oldsquaw	11,000	2,000	1,000
TOTAL	850,000	1,161,000	743,000

Source, USDI, 1972.

TABLE 2A.6-8

LOCATION OF RECOVERIES FROM ALL WATERFOWL BANDED ON THE YUKON FLATS PRIOR TO SEPTEMBER 1961 (FROM U.S. DEPT. INTERIOR, FISH AND WILDLIFE SERVICE 1964), WHICH SUGGESTS CERTAIN AFFINITIES OF WATERFOWL FROM ALONG THE PROPOSED PIPELINE ROUTE WITHIN THE INTERIOR TO MIGRATION ROUTES AND WINTERING AREAS

Species	Number Banded	Number Returns	Location of Recovery						
			Alaska	Canada	Pacific Flyway	Central Flyway	Mississippi Flyway	Atlantic Flyway	Mexico & Caribbean
Mallard	152	19	4	9	6				
Wigeon	3,455	276	13	41	201	6	11	1	3
Pintail	799	35		14	16	3	1	1	
Green-winged Teal	99	4			2	1	1		
Shoveler	334	39		1	37	1			
Canvasback	664	18		6	11			1	
Scaup	8,383	156	5	13	23	31	65	14	5
Barrow's Goldeneye	2,737	25	24	1					
Bufflehead	1,234	2	1	1					
White-winged Scoter	464	2	1				1		
Canada Goose	5	2	—	—	2	—	—	—	—
TOTALS	18,326	578	48	86	297	42	79	17	8
Percent of Recoveries			8.3	14.0	51.4	7.3	13.7	2.9	1.4

depredation problems on the limited amount of farmland in this area, but they also provide hunting and aesthetic values here and along their migration route.

Copper River System

Birds

The Copper River Drainage contains many species of birds that are common to either the Yukon River Drainage or the Gulf of Alaska coast, but it also lacks many species from these same areas. About 119 birds could expectedly be encountered within this region. Kessel *et al.*, (1967) described the birds and habitat found along the Richardson Highway, from Delta Junction to Valdez, which roughly parallels the proposed pipeline route.

The fall numbers of ducks migrating from principal waterfowl habitats within the Copper River-Nelchina River Basin, portions of which are either adjacent to or downstream from the proposed pipeline route, are given in Table [2A.6-9].

Local areas of good duck habitat are found along the Gulkana River between and including Summit and Paxson Lakes, thaw lakes between Hogan Hill and Glennallen, Willow and Pippin Lakes, and ponds adjacent to the Tonsina and Little Tonsina Rivers (Bartonek, 1969b). The Copper River delta is an outstanding goose, duck, and swan production area and is frequented during season by hunters from Cordova.

Geese are uncommon breeders in the Copper River Basin. The Dusky Canada Goose, however, which numbers about 25,000 birds (Chapman *et al.*, 1969), breeds only along the Gulf of Alaska coast from the Bering Glacier to Cook Inlet but mainly on the Copper River delta and winters in northwestern Oregon (Hansen, 1962). This race is presently sustaining maximum harvests (State of Alaska, 1971).

King (1968b) reported 400 adult and immature and 190 young Trumpeter Swans being counted during late-summer surveys in 1968 in the Copper River-Nelchina River Basin and 114 adult and immature and 44 young Trumpeters in the Copper River Canyon. . . . A pair of swans and a single swan occupied ponds adjacent to the proposed pipeline route in August of 1969 (Bartonek, 1969b). King (1968b) feels that even though Trumpeters were widely scattered within their range and many water areas were unoccupied, that the suitable habitat was nearly saturated. He observed that with 3500 or more Trumpeters summering in Alaska it seemed remarkable that their wintering area remained unknown [Vol 2, pp 186-198].

TABLE 2A.6-9

ESTIMATES OF MIGRATING DUCK POPULATIONS FROM HABITAT IN THE COPPER RIVER DRAINAGE ADJACENT TO OR DOWNSTREAM FROM THE PROPOSED PIPELINE ROUTE

Mallard	38,000
Pintail	75,000
Green-winged Teal	52,000
Am. Wigeon	57,000
Shoveler	19,000
Canvasback	5,000
Scaups	66,000
Goldeneyes	17,000
Bufflehead	8,000
Scoters	17,000
Oldsquaw	1,000
TOTAL	355,000

Source, USDI, 1972.

Large Mammals

The Yukon River watershed supports a broad diversity of wildlife habitat. Except for the larger tributary river valleys and the mountainous areas along the Brooks and Alaska Ranges, the terrain is rolling and vegetated primarily by spruce-birch interior forests. Along the river valleys the interior forest becomes more diversified and includes more deciduous species. The mountainous areas of the Alaska Range are similar to those of the Brooks Range.

Moose, bison, caribou, sheep, wolves, and black and grizzly bears are common, at least locally, along the Yukon drainage portion of the proposed pipeline route. Fur bearers include the wolverine, lynx, red fox, coyote, mink, marten, otter, weasel, beaver, and muskrat. Moose, wolves, and bears are common in the Dietrich River Drainage, and sheep are found in the adjacent mountains. Aerial counts of sheep within 15 miles of the pipeline route in mid-July 1970 indicated 1375 sheep from the divide south to Wiseman (T. Smith, written communication, 1971). The count was not completed because of adverse weather and a fatal airplane crash. Important winter ranges for caribou of the Arctic herd are in Fort Hamlin Hills and south into the Ray Mountains and a large portion of that herd wintered there in 1970-71 (Klein, personal observations). In excess of 100,000 animals may be in these areas in winter (Lent, 1960). Skoog (1963) reported a late winter-early spring movement in 1961 of large numbers of caribou up the Dietrich River and the adjacent north fork of the Koyukuk River and down the Itkillik in a westerly trending direction. There is good moose range locally in these hills along the creeks and rivers. Black and grizzly bears and wolves are also common in this area. Over 200 wolves have been bountied from the Koyukuk River Drainage alone in a single year (Alaska Dept. of Fish and Game, 1968). Black bear densities were estimated at one per 20 square miles in the Yukon Flats, through which the proposed pipeline would pass (USDI, 1964). Although black bears are more common in the forested lowlands, grizzlies predominate in the adjacent hills, with large areas of alpine habitat. Hatler (1967) has estimated black bear densities in the Tanana Hills and Fairbanks area at one per 10 square miles and he reports black bears move into alpine areas in search of berries in late July to early August. Moose and wolves are common along the proposed route from the Yukon River to Fairbanks, and moose are locally abundant in the meandering valleys of the Tolovana and Chatanika Rivers. Population estimates of moose in the Yukon Valley in the impoundment area of the proposed Rampart Dam, through which the proposed pipeline would pass, were made in 1962 on the basis of systematic aerial surveys (Evans et al., 1966). These indicated a mean density of 0.45 moose per square mile with variation from a mean of 1.77 moose in the high density quadrats to 0.30 in the low density quadrats. The proposed pipeline route traverses the fall range of the Big Delta bison herd, recently estimated at more than 200 animals. Dall sheep are common in the mountains adjacent to the proposed pipeline route through the Alaska Range.

The most favorable habitat is on the north face of the Range where winter snow accumulation is minimal. Alaska Department of Fish and Game (T. Smith, personal communication) aerial counts indicate a minimum of 650 sheep in the mountains extending 10-15 miles on both sides of Isabel Pass from Donnelly to Rainbow Mountain (a distance of about 25 miles). Hunters harvested approximately 25 legal rams from area in 1970, while in previous years the harvest has been slightly less than this. From the Tanana River crossing to the Delta River crossing, moose, bear, and wolf habitats appear to be good. Aerial surveys in 1962 of moose in 150 square miles of the Tanana Flats, which includes this area, indicated a minimum population of 8 per square mile (Alaska Dept. of Fish and Game, 1963) [Vol 2, pp 184-186].

Copper River System

Large Mammals

[One] section of proposed pipeline extends through the Copper River drainage from Isabel Pass in the Alaska Range to Thompson Pass in the Chugach Mountains. Mammals present are similar to those found in the Yukon River drainage. The proposed pipeline route north of Glennallen transects the range of the Nelchina caribou herd (estimated at 61,000 animals in 1967), (Alaska Dept. of Fish and Game, 1968). During the past decade these animals have made early winter and spring crossings of the Richardson and Glenn Highways (Skoog, 1968). The proposed pipeline route passes through two major winter-use areas of this herd and either of these areas may contain 10,000 to 20,000 or more caribou during the winter months (December through March). The relative numbers in each area and their boundaries are highly variable, however. Moderately high moose populations are found throughout most of this section (20-25,000 in the upper Copper and upper Susitna River drainages), (Alaska Dept. of Fish and Game, 1968).

The Gakona and Gulkana drainages support densities of moose that are among the highest in the entire area. Bishop (1969) reports average densities of 0.50 to 0.87 moose per square mile in these areas. Black and grizzly bears and wolverines are common throughout the area. Grizzlies are estimated to number 1000 and black bears 3500 in the Copper River drainage (U. S. Federal Field Comm., 1968). Wolves are very numerous throughout the Nelchina caribou range (Wildlife Management Unit 13 and the Mt. Sanford and Mt. Drum portions of Unit 11) and a minimum estimate for the area is 300 (Alaska Dept. of Fish and Game, 1968). Average pack sizes are large in comparison to those in other Alaskan wolf habitats, a characteristic of high wolf density and abundance of prey. Dall sheep are abundant in the adjacent Wrangell and Chugach Mountains, and mountain goats are found in the mountains from Tonsina southward. A small herd of approximately 120 bison normally winter adjacent to this section of the proposed pipeline route along the Copper River from the Gulkana to the Tonsina River (R. Hinman, personal communication). It yields an annual harvest to hunters of about 15 animals [Vol 2, pp 193-195]

Recent surveys indicate a drastic decline of the Nelchina herd from the 61,000 animals cited above to 8,100 in early 1973 (R. Le Resche, personal communication). Possible causes for the decline are overhunting, poor calf survival, and emigration of animals to join other herds.

Caribou, Dall sheep, and presumably mountain goats are game species for which mobility and unhindered access to special resources are vital. Special needs include calving and lambing areas, and--primarily to Dall sheep--spring use of mineral licks (Linderman, 1972; W. Heimer, personal communication).

Subsequent to the writing of the Impact Statement for the oil pipeline, a number of population estimates and measurement of secondary productivity have appeared on nongame species. These estimates indicate that small consumers, such as forest birds and small mammals, may achieve population levels approaching those of temperate latitude animals, either seasonally or during peak abundances every few years (Norton, personal observation). These populations of small consumers are not maintained at high densities, however, and on the average exist well below the levels of southern localities. The suspected explanation of this generalization is that primary productivity in interior Alaska is low, and this, in turn, limits consumers and their productivity. Smith (1967) documented the dependence of red squirrels (<u>Tamiasciurus hundsonicus</u>) on a fluctuating principal resource, spruce cones. During cone crop failure, squirrel populations dropped to 33 percent of their initial densities, strongly indicating the importance of primary production to this species.

If, as assumed, primary productivity limits the secondary productivity of this region (and others), the implication for Alaskan populations of large consumers is clear; <u>i.e</u>, their productivity and the rate at which they can replace losses from their populations are limited at least as stringently as is the case with large consumers at lower latitudes.

Patterns of human dependence on biotic resources in the Interior Basin Division over the past 100 years indicate extensive involvement with ecological systems. Native peoples in the Koyukuk-Lower Yukon, Porcupine-Upper Yukon, Tanana, and Copper River Regions (as defined by the Federal Field Committee, 1968) traditionally depended on the broad spectrum of fish, birds, mammals, and vegetable products for food. As with the Eskimos, a substantial proportion of the wild food harvest was needed to sustain dogs. Various upheavals, notably the Russian-inspired fur harvest and the "gold rush" era, caused major shifts in the resource availabilities and livelihood patterns among Interior natives. Incursions on big game populations by professional meat hunters for large gold camps, coupled with the availability of wage positions, forced native hunter-trappers to rely more strictly on fish and small game for subsistence (Federal Field Committee, 1968). With the decline in gold mining, natives fell back to various degrees on their more traditional subsistence patterns.

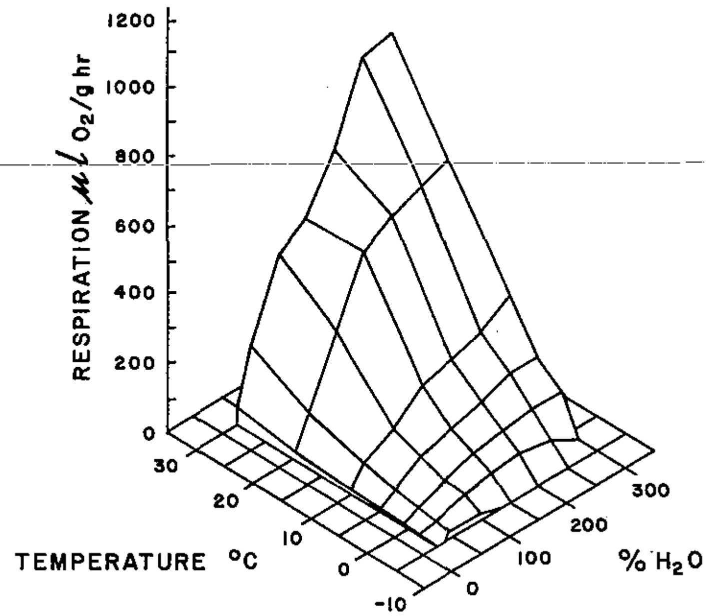
The advent and permanence of white settlers in Interior population centers (such as Fairbanks) introduced a variable degree of non-native trapping, a consistently increasing degree of sport hunting and fishing, and non-consumptive recreational uses into the Interior. Too rigid a distinction between sport and subsistence harvest is misleading, however, because meat and fish harvested by non-native residents is usually used in the form of supplemental subsistence. Interior non-native fishermen and hunters cherish the opportunity to stock their freezers with meat and fish, despite the fact that many do so at net economic loss, when their investments in boat, airplane, or snow machine are computed against the savings effected.

Human dependence on biotic resources in the Interior Basin Division thus ranges from recreational nonconsumptive to subsistence, with a large measure of intermediate use that is more than recreational, but not strictly subsistence. This spectrum of involvements in the productivity of regional biotic systems characterizes a way of life which native and non-native residents both seek to preserve in the face of anticipated pressures. As with human consumers in the Arctic Drainage Division, the patterns of subsistence consumption for the Interior are expected to continue, particularly in consequence of ANSCA, which will afford natives substantial control over the stewardship of natural resources.

2A.6.2.3.3 Decomposition

Decomposers in interior Alaska are limited in diversity and effectiveness by the same factors as pertain to the Arctic Drainage Division. The limitation upon decomposition rates in the Interior results in a significant net accumulation of both below ground and aboveground dead organic matter through primary production. The impressive ecological consequence of slow decomposition in the tundra was the development of saprovore-based food chains, but the correspondingly impressive consequence in the Interior is the prevalence of wildfire. Soils of interior Alaska tend to be dominated by microfungi and yeasts. Scarborough and Flanagan (1973) recorded 150 species of microfungi in undisturbed forest soils at College, Alaska. These organisms are credited with contributing to the widely observed acidity of taiga soils, as their metabolic products include secretions of organic acids. This acid environment is inimical to bacterial decomposers, which are correspondingly scarce in typical taiga soils (Lindholm & Norrel, 1973).

Critical dependence of soil respiration and, hence, decomposer activity upon soil moisture and soil temperature is shown in Figure 2A.6-14 for the three different layers of forest soils in an



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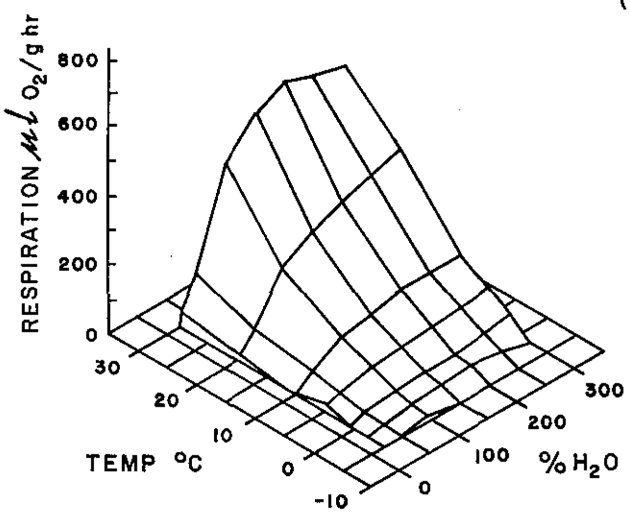
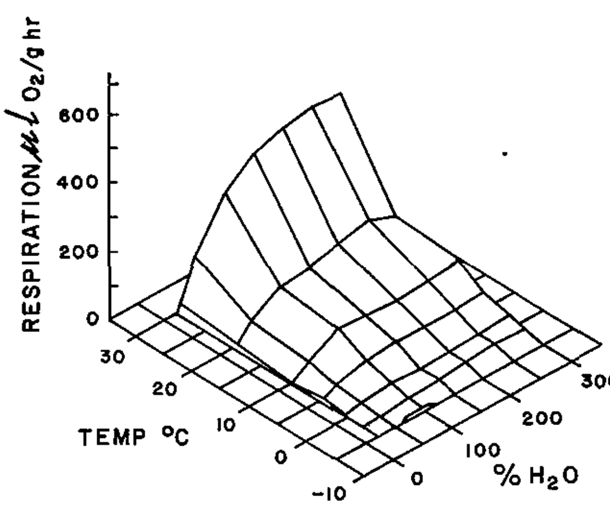


F LAYER
(FERMENTATION)



H LAYER
(HUMUS)

LABORATORY DATA

REF: VAN CLEVE, 1972

TRANS-ALASKA GAS PROJECT

MOISTURE–TEMPERATURE RESPONSE SURFACE FOR RESPIRATION RATE

FIGURE 2A.6–14

aspen stand. These limiting factors are important, because most tree species in this region are shallow-rooted, and the availability of nutrients at the interface between humus and mineral soil layers depends on microbial activity and nutrient release immediately above this interface. Rates of tree growth depend on microbial nutrient release, hence upon the physical factors of temperature and moisture (Van Cleve, 1972).

A complex interrelationship between the organic mat thickness, insulation, temperature and moisture, and nutrient release by microflora characterizes the major lowland communities. These factors distinguish various successional community types, and influence the balance of micrometeorological processes affecting buildup or degradation of permafrost under the plant cover (Viereck, 1970a) in this region of discontinuous permafrost (Figure 2A.6-15). A turning point in these relationships seems to be commonly achieved when a moss (Hyloconium sp, Rhytidiadelphus sp, and Sphagnum sp) layer develops. This surface mat retains moisture effectively, and acts as a wick that remains cold as a result of evaporation, and blocks incoming radiation from warming the soils underneath it.

2A.6.2.3.4 Wildfire

More wildfires occur in the Interior than anywhere else in the State. Wildfires in the taiga and tundra of interior Alaska are, and probably always have been, integral dynamic processes of ecosystem functioning. Fire ecology in this region has been reviewed by Lutz (1956), Hardy and Franks (1963), Barney (1971), Slaughter, et al., (1971), and Viereck (1973a; 1973b). The natural ecological role of fires is:

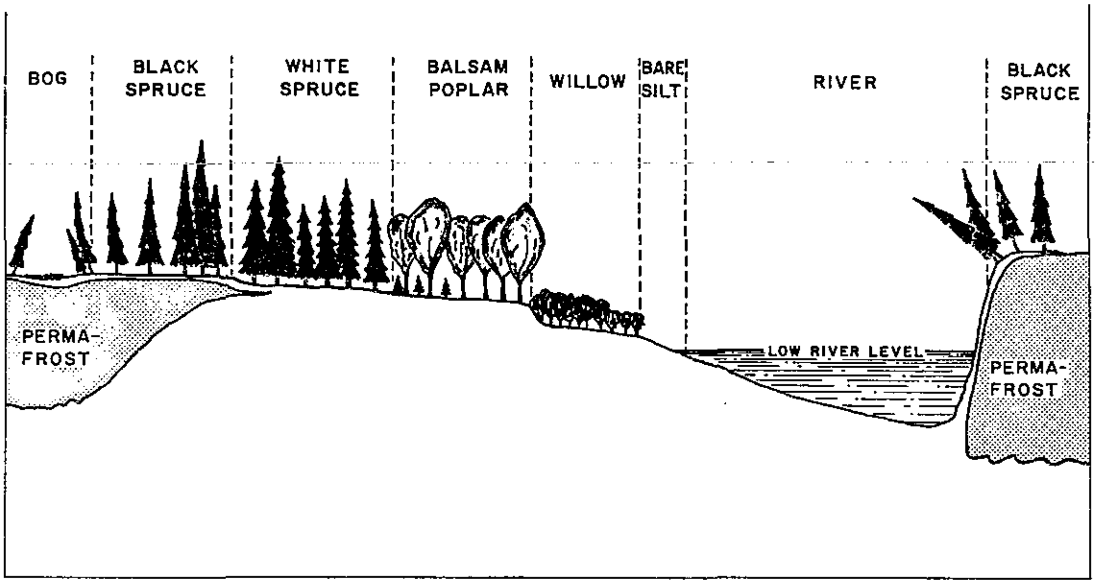
(1) A by-pass of the decomposition process, which is limited in the Interior by dry and cool conditions that inhibit microbial activity,

(2) An important agent for recycling essential nutrients that otherwise become tied up in dead organic materials, such as litter, standing dead plants, and peat accumulations, and

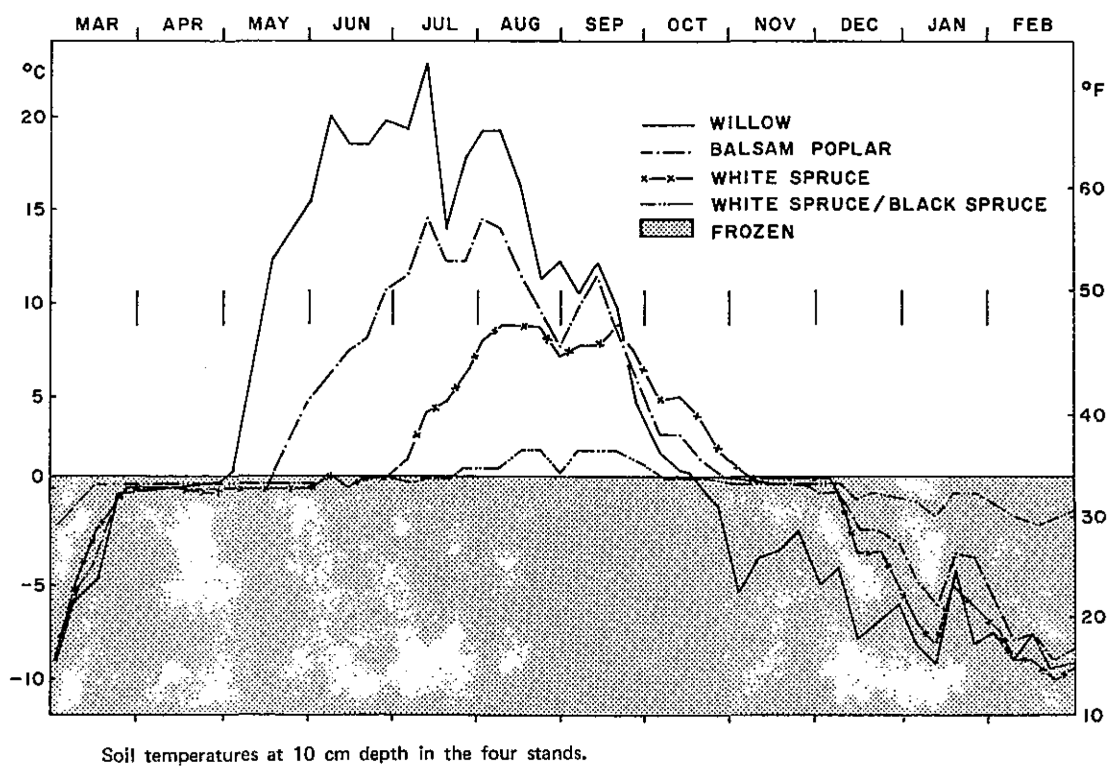
(3) A natural disruptive force that prevents succession of vegetative communities to a climax type, with its impoverished diversity in structure and species numbers.

Thus, fire is essential to ecotone, or "edge habitat," development, which enhances both primary and secondary (i.e., wildlife) productivity.

This modern appreciation of wildfire ecology is necessary, but not sufficient, to form an understanding of the dynamics of fire in interior Alaska. Agents of ignition, fuel type, fuel load, climate, weather, and past fire history all influence the probability of wildfire and the intensity of a burn.



Diagrammatic cross-section of typical distribution of vegetation and permafrost across a meander of a river in interior Alaska.



Soil temperatures at 10 cm depth in the four stands.

REF: VIERECK, 1970b

TRANS-ALASKA GAS PROJECT

DISTRIBUTION OF VEGETATION AND PERMAFROST AND SOIL TEMPERATURES AT 10 cm DEPTH IN THE FOUR STANDS

FIGURE 2A.6–15

Twentieth century man has altered the aboriginal balance between accumulation and burning of combustible materials in interior Alaska, as elsewhere. This alteration stems from: (a) human activities as agents of ignition (i.e., in addition to lightning), (b) consequent lengthening of the fire season, and (c) human activities in suppression of active fires. Since the initiation of standard record-keeping in this region in 1940, a reasonably constant 400,000 hectares, or 1 million acres, have burned per year. This consistent total masks two divergent underlying trends:

(1) The number of ignitions per area surveyed has steadily increased, and

(2) The area burned per fire has steadily decreased (Barney, 1971; Viereck, 1973b).

Fire ecology is strongly influenced by the dilemma facing such environmental management agencies as the Bureau of Land Management, national Park Service, and U. S. Forest Service. Although ecologists can show that wildfire is necessary and not (as once thought) universally destructive, they cannot let all ignitions go undetected or unsuppressed. On the other hand, suppression is costly, both finanacially and in terms of environmental disturbance (cf Lotspeich, et al., 1970).

The present mosaic of plant and animal communities dominating interior Alaska is largely a result of fire history. The successional forest patterns in the wake of single and repeated burns are shown in Figure 2A.6-16. This flow diagram emphasizes the relationship between fires and community diversity.

2A.6.2.3.5 Systems Dynamics

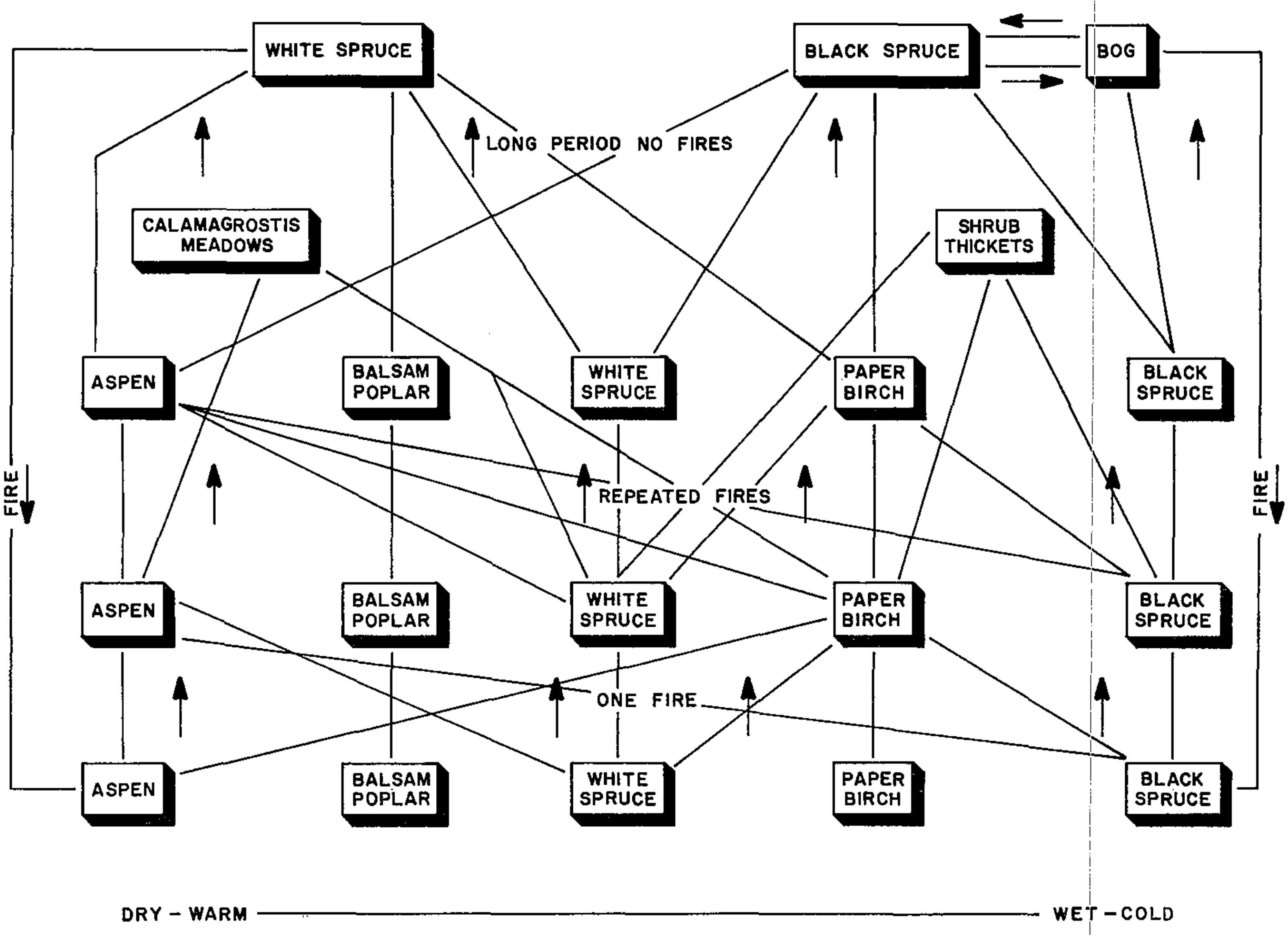
The structure and function of regional terrestrial ecosystems are not thoroughly understood, but sensitive biological processes, and recovery processes following natural cyclic disturbances may be pointed out.

Biotic and abiotic variables interact continuously, changing the freeze/thaw balance in soils over much of the Interior Basin Division.

Wildfires, meandering rivers, floods, and to a lesser extent the activities of herbivores, have been identified as agents which set communities back to earlier successional stages in this region. These agents also positively affect development of ecotones, diversity, and productivity of primary producer organisms.

Decomposition, as far as is now known, is a delicate, and limiting process in this region, as it generally fails to keep pace with primary production. The excess production becomes litter aboveground precipitating the development of the wildfire process. Unconsumed litter eventually becomes peat below ground.

As in the Arctic Drainage Division, moderate natural pertur-



REF: VIERECK, 1973b (MODIFIED FROM LUTZ, 1956)

TRANS-ALASKA GAS PROJECT

PATTERNS OF FOREST SUCCESSION FOLLOWING FIRE IN ALASKA

FIGURE 2A.6-16

bations are part of the biotic systems of the Interior Basin Division, and these systems are adapted, or composed, so that they are relatively resilient, given sufficient time to recover. Unusually severe or extensive perturbations, such as glaciation, require substantially longer times for floral and faunal recovery of significant productivity. Viereck (1966) determined, for example, that glacial outwash in the Alaska Range required 25 to 30 years to revegetate to a pioneer community over bare gravel, and 200 to 300 years to a "late shrub stage" dominated by shrub birch (Betula glandulosa). True tundra climax, or equilibrium stage, bordering Viereck's (1966) study area, is thought to be between 5000 and 9000 years old.

Natural revegetation and succession in this climatically severe alpine region of the Alaska Range, and in more sheltered sites, depend on nitrogen input during the pioneer stage by plants associated with nitrogen-fixing organisms. Such species include Dryas drummondii, legumes such as Astragalus nutzotinensis (Viereck, 1966), and alders (Alnus, spp) at lower elevations (Van Cleve, et al., 1971).

The rates of primary and secondary production may briefly reach astonishing peak levels in this region, but both rates are strictly limited on an annual basis. Limited productivity puts a ceiling on the capacity of the biota to sustain consumptive use or abuse. The rates of sustained yield human harvest of biotic resources--timber, fish, waterfowl, and mammals-- are expected to be much lower in this region than those at lower latitudes. In the absence of close regulation of harvest rates, biotic resources of the Interior Basin Division could be severely depleted or extirpated as greater pressures from increased human population develop. Harvest rates exceeding natural replacement rates in caribou populations of interior Alaska have already been blamed for an alarming decline in herd size.

2A.6.2.4 Aquatic Environment

In the Interior Basin of Alaska, which includes the Yukon and Copper River Drainages, nearly all available information on aquatic biology deals with fishes (see Appendix B hereto). Commercial, subsistence, and sport fisheries are very important recreationally and economically in this region. Primary production and secondary production (other than fishes) are unknown for most of the region, and information on fishes is limited to a few well-studied localities. For the major species, spawning times, migratory patterns, and feeding behavior are generally known.

Species diversity is somewhat increased over that of the Arctic Drainage Division. Sponges and amphibians are found in the Interior. The list of vascular aquatic plants is much longer. Phytoplankton and zooplankton populations have not been adequately assessed. Primary productivity is low, but somewhat greater than in the Arctic Drainage Division.

2A.6.2.4.1 Primary Production

Many of the same constraints upon primary production discussed in subsection 2A.6.1.4.1 apply to the Interior as well. Winter conditions are much the same in both areas. Summer temperatures are warmer in the Interior, and the growing season is correspondingly longer. Nutrient levels are poorly known. Little can be inferred about primary production from existing information other than that it remains low, but is comparable in some cases to oligotrophic temperate waters. Comprehensive species lists are unavailable for phytoplankton, epiphytes, or benthic algae. There is some indication, however, that blue-green algae dominate some lakes in later summer, and that diatoms may be numerous in rivers (Alexander & Barsdate, 1971; Frey, *et al.*, 1970). Vascular plants are greatly diversified compared to those in the Arctic Drainage Division, with some 20 species identified. Plant communities are well developed in many lakes and ponds (Likens & Johnson, 1968).

2A.6.2.4.2 Consumption

2A.6.2.4.2.1 Zooplankton

A single general survey of lake zooplankton has been published for interior Alaska, recording about a dozen species of copepods and cladocerans, ostracods, and insects, including a diving beetle (*Dysticus* sp), and a giant water bug (*Belostoma* sp) (Likens & Johnson, 1968).

Information of life histories and population dynamics for zooplankton of the Interior does not exist in print.

2A.6.2.4.2.2 Benthic Fauna

The conspicuous benthic fauna have been described in a few lakes and one river (the Chena). As in the Arctic, the chironomids dominate benthic fauna. Other insect groups, amphipods, annelids, snails, and pea clams are also present (Alexander & Barsdate, 1971; Frey, *et al.*, 1970). Life histories and population dynamics are unknown for the Interior.

2A.6.2.4.2.3 Fishes

Interior fishes are relatively well known in areas of heaviest exploitation. Several continuing studies by the Alaska Department of Fish and Game are investigating life histories and population dynamics of important species. Studies include population structure, distribution, migratory patterns, spawning habits, productivity, and feeding behavior. Considerable information from these studies is available as a basis for regulation of pipeline construction and operation with regard to fisheries.

The Environmental Impact Statement for the Proposed Trans-Alaska Pipeline provides a summary of fish usage for the Interior Basin (USDI, 1972).

Yukon River System

The Yukon River dwarfs all others in Alaska with a drainage area of 330,000 square miles, one-third of which is in Canada (Hickok, 1968). The streams along and near the proposed pipeline route in this river system are as variable as the terrain within the drainage basin. The species of fish that inhabit these waters are equally variable.

The Yukon has long been noted for producing catches of salmon which migrate as far as 2000 miles to the headwaters to spawn (U. S. Dept. of Interior, 1964). These salmon, with their capacity for extremely long migrations, represent unique and irreplaceable races of their species and are much esteemed for their exceptional quality. While the main economic value of these salmon is commercial and subsistence fishing, they also provide considerable sport fishing.

The tributaries to the Yukon River that flow directly out of the Brooks Range are the Dietrich, South and Middle Forks of the Koyukuk, and the Jim Rivers. All are relatively clear streams with gravel to cobble size beds. The most common fish species are grayling, sculpins, suckers, and whitefish (N.F. Netsch, unpublished survey data), although chum and a few chinook salmon migrate up the Koyukuk at least as far as Coldfoot (Ron Regnart, personal communication; N. F. Netsch, unpublished survey data). Lake trout are found in the deeper lakes. Dolly Varden have been found in some of the mountain streams and northern pike are found in many lakes from the Brooks Range south (U. S. Dept. of Interior, 1970: and N. F. Netsch, unpublished survey data).

Most of the streams that enter the Yukon in the general area of the proposed pipeline route contain grayling and whitefish, but many also contain northern pike, burbot, inconnu and suckers. Further to the south, the Tanana River and many of its tributaries contain grayling, whitefish, burbot, inconnu, northern pike and suckers; some of the streams support runs of chinooks, chum and coho salmon (U. S. Dept. of Interior, 1970). Many excellent streams in the Fairbanks area are readily accessible to the sport fisherman and the Chena River alone supports about 25,000 fisherman hours of angling annually (Van Wyhe, 1969), primarily for grayling. These streams are typically stained about the color of weak tea, have a relatively low gradient, many nice pools and a sand or gravel stream bed. The Delta River, although turbid and highly braided, contains grayling, burbot and whitefish. Although the headwaters of the Delta are clear and produce excellent grayling fishing, many tributaries that would be crossed by the proposed pipeline further downstream are fed directly by glaciers, have a steep gradient and contain few fish.

Copper River System

This system includes some of the most valuable fish producing waters that would be crossed by the proposed pipeline route. As with the Yukon system, there is considerable variation in the characteristics of streams that would be crossed by the proposed pipeline within the Copper River system, which extends from Isabel Pass in the Alaska Range to Thompson Pass in the Chugach Mountains. This system, particularly along the proposed pipeline route, is unique in one important respect--it is readily accessible to fishermen by road. This, coupled with the high fishing quality of many streams, has resulted in an intensive sport fishery in many areas.

The Gulkana River, a beautiful clear stream which is accessible by road almost throughout its length, is the most important fishery stream in the Copper River system. Some 100,000 sockeye and 20,000 chinook salmon and some steelhead migrate up this stream annually to traditional spawning areas (Ken Roberson, personal communications). These salmon, along with abundant populations of rainbow trout and grayling, provide a large amount of sport fishing annually. Fish Creek, a tributary to the Bulkana, alone provides access for a spawning run of sockeye salmon to Fish Lakes estimated at 20,000 fish in 1969 (Ken Roberson, personal communication).

Paxson and Summit Lakes are located in the alpine country in the Alaska Range and are large, clear and deep. Both support considerable sport fishing for grayling and lake trout, with some whitefish, burbot and rainbow trout, and are important rearing areas for sockeye salmon hatched in the upper Gulkana and Fish Lakes (Fred Williams, personal communication).

Other major tributaries of the Copper River include the Tazlina, Klutina and Tonsina Rivers. These sizeable streams characteristically have a "milky" color due to glacial runoff, yet support sizeable runs of sockeye, chinook, and coho salmon and some steelhead trout (Myron, 1969). Resident fishes include Dolly Varden, burbot and lake trout. The Tiekel River has a resident population of Dolly Varden throughout and supports some sockeye and coho salmon below the proposed pipeline crossing. The Little Tonsina River, an exceptionally high quality clear angling stream, supports a resident population of Dolly Varden and grayling and runs of chinooks and coho salmon [Vol 2, pp 155-158].

2A.6.2.4.2.4 Aquatic Mammals

Beaver, mink, muskrat, and otter are fur bearers of considerable economic importance in the Interior. They are treated briefly in subsection 2A.6.2.3.2 Consumption (Terrestrial Biology).

2A.6.2.4.3 Decomposition

Specific information on the process of decomposition in aquatic ecosystems in the Interior Basin is fragmentary. Decomposers are a vital link in any ecosystem, and become especially vital in the coldest climates. Their activity cannot be taken for granted. The discussion of decomposition for the Arctic Drainage Division may generally apply to the Interior Basin.

2A.6.2.4.4 Systems Dynamics

The dynamics of aquatic ecosystems in the interior of Alaska cannot be adequately described from existing information. These ecosystems are somewhat more complex (diversified) than arctic ecosystems, but maintain the same general features as phytoplankton and benthic fauna, which in turn support insects (e.g., diving beetles) and frogs. Birds and fishes may have complex diets depending on species and environment. Aquatic furbearers are also integral parts of these ecosystems. ecosystems.

These systems are adapted to wide oscillation in seasonal physical phenomena. Existing logging, mining, construction, and agricultural activities in this extensive area can affect hydrology and animal distributions directly and indirectly. Thus, the Interior Basin Division, like any ecosystem, is in a state of dynamic flux. In any unknown system of this magnitude, stresses that can be absorbed without degradation of the system (in aesthetic or economic terms) are difficult to predict.

2A.6.2.5 Regional Systems Interactions

Biotic transfers between the major environments in the Interior Basin Division take place chiefly at the interfaces of terrestrial and aquatic environments, and are not well understood. As in the Arctic Drainage Division, organisms that must contribute conspicuously to such transfers are identifiable. These include waterfowl, moose, beavers, man, anadromous and nonmigratory fish, and undoubtedly a large but poorly known invertebrate fauna.

Even an unquantified awareness of these transfer processes is useful in understanding the dependence of biota upon more than one system or environment for required energy and nutrients or protection.Beavers, for example, depend on terrestrial systems that supply sufficient quantities of fast-growing deciduous trees, such as willows and balsam poplars for food and structural materials. These they largely consume or deploy in an aquatic environment that offers protection and stability. Degradation of either the terrestrial or the aquatic environment would clearly threaten beavers, and in the case of a beaver population sustaining a trapping industry, such degradation would ultimately affect trappers.

Another example of the interrelationships of different environments is that of anadromous salmon and species dependent on them, such as bears, bald eagles, and man. Migrating and spawning salmon bring marine-originated nutrients and energy far inland by way of major drainages such as the Yukon and Copper River systems. A significant proportion of this marine resource is tapped by inland fisherman and bears, or enters the terrestrial environment via carrion-eating bald eagles and several species of gulls. Because these transfer steps are vital to the maintenance of obviously impressive species populations (salmon, bears, eagles) as well as populations that currently happen to command less public sentiment, any threatened link in the process is cause for alarm.

As in the Arctic Drainage Division, human population aggregations are foci of important energy and nutrients. The non-native settlements, in particular, are not subsisting on local productivity, so that large quantities of food must be imported from outside the region. The nutrients and energy of degraded human food generally leave the system and go to the sea, or are tied up through deposition out of reach of biological recycling agents. This potential net accumulation of nutrients (as for agriculture) has not been exploited, but may be in the future.

In contrast to the human importation process, other consumers in interior Alaska probably account collectively for a small net export of nutrients, as is the case in the Arctic Drainage Division

The vigor and diversity of interior Alaskan biotic systems are clearly related to ecotonal conditions, such as the mosaic of different aged forests and forest-bog borders, and to interfaces between aquatic and terrestrial environments, such as occur in the Yukon Flats area.

2A.6.3 South Coastal Division

This region, extending from Thompson Pass to Hinchinbrook Entrance (Figure 2A.6-1), is the most biologically productive and diverse of the three geographic divisions transected by the proposed Alaskan Gas Pipeline. However, the terrestrial and aquatic environments of this region are the least known of the three divisions--in part because the proposed gas pipeline departs from Alyeska's oil pipeline and fewer investigations of terrestrial and aquatic biology have been performed in this region than in the other two regions. Federal, state, and private agencies are the sources of information reported in this section.

It is necessary to consider the regional terrestrial, aquatic, and marine biotic systems of Prince William Sound and the Chugach Mountains, because of the extent of ecological interactions between sea, land, and fresh water. The human population of Prince William Sound depends heavily upon commercial and sport fisheries, sport and subsistence hunting, and minor amounts of trapping and timber harvest.

2A.6.3.1 Species and Communities

Between the crest of the Chugach Mountains at Thompson Pass and the exit of Prince William Sound at Hinchinbrook Entrance, the proposed project will encounter a wide array of biological conditions. The Sound and surrounding mountains are geologically young, heavily glaciated, folded, and faulted. The Sound is a submerged fiord system. Level terrain is limited, so biotic communities are likewise limited in area (*e.g.*, coastal forest grades quickly into brush and subalpine tundra). Likewise, the intertidal zone is severely limited by the usually steep bottom profiles. A major exception to the above generalizations is the Copper River Delta area, beginning 17 miles southeast of the Gravina Site, just east of Cordova and Eyak Lake. The Delta is on a par with the Yukon Flats, Yukon-Kuskokwin Delta, and Izembek Lagoon in the sense of being an unusually productive wildlife habitat in Alaska.

At present, insufficiently detailed information on terrestrial, aquatic, and marine biotic communities is available from the Federal-State Land Use Planning Commission, in the form of draft maps. Terrestrial vegetation types treated in these draft maps include coastal spruce-hemlock forest, high and low brush, and alpine tundra and barren. In order that understanding and mapping of community types be useful in baseline and impact analysis, these categories will have to be refined, and mapped on a finer scale than is currently available. Without floristic studies to document the species composition of such communities, it is premature to list or characterize communities in this region.

The occurrence of species in the Prince William Sound region ranges from poorly to well known. Plant species lists (see Appendix C) are tentative, and require further updating. Invertebrates in all but the marine environment are unknown. Fish and wildlife species known to occur in the region can be listed with fair accuracy, but in many cases, measures of abundance are either nonexistent or out-of-date. Recent work on birds indicates that more than 200 species occur in the region (Isleib, 1973).

Gravina is biologically important to Cordova residents for at least two reasons: (a) Sheep Bay supports some of the most concentrated tanner crab fishing in the region, and some of this fishing area is within proposed shipping (and terminalling) zones, and (b) the presence of Sitka black-tailed deer on Gravina, upon which some Cordova residents rely for meat.

2A.6.3.2 Abiotic Characteristics

Complex, rugged terrain dominates the physiography of the South Coastal Division. From sea level, the Chugach Mountains rise steeply to elevations of 3000 to 6000 feet. On such convoluted terrain, biotic communities are restricted in extent, or confined in altitudinal zones of varying widths. Lowlands are conspicuously limited to the Copper River Delta and smaller rivers draining into the eastern side of Prince William Sound, at the heads of Orca Bay, Port Gravina, and Port Fidalgo.

The climate of the region is marine-dominated, with annual precipitation of 120 inches, much of which occurs as snowfall (Johnson & Hartman, 1969). The marine influence accounts for the cool wet summers, the moderate winters in which mean January minimum temperatures remain above 0°F, and the common occurrence of thaw periods during the winter.

Pressure gradients between the Gulf of Alaska and interior Alaska commonly result in high winds through mountain passes, particularly down the Copper River Valley.

2A.6.3.3 Terrestrial Environment

2A.6.3.3.1 Primary Production

Primary production follows the same successional pattern characteristic of Interior Basin forests (subsection 2A.6.2.3.1). The gradual increase in standing crop following disturbance reaches a maximum at approximately 100 years, and is followed by a senescent phase leading to low rates of production (Reiners, et al., 1971).

The major difference between the Interior Basin forests and South Coastal forests with respect to primary production is, thus, one of degree rather than kind. In general, the amount of dry phytomass produced in South Coastal forests at any stage in succession is greater than that found under similar conditions in the Interior forests.

Limitation of production is again related to nutrient supply, particularly nitrogen. This element is available in larger quantities in the South Coastal Division, and accounts, to a large degree, for the increased primary productivity (Van Cleve, et al., 1971).

Since the dominant plants of the region are trees, plant reproductive strategies of importance are those of the dominant tree species--Sitka spruce, western hemlock, mountain hemlock, balsam poplar, and black cottonwood. The following discussion on the reproduction of Sitka spruce is extracted from the Final Environmental Impact Statement for the Trans-Alaska [Oil] Pipeline (USDI, 1972).

> Sitka spruce, the largest of the spruce, grows only in the vicinity of Valdez along the proposed pipeline route. Elsewhere it grows in southeastern Alaska and southward along the coast to northern California. Moisture is critical in the germination of Sitka spruce seed and the survival of young seedlings. Although germination rates are highest in moist mineral soil, germination and survival is also high in organic seedbeds. In Alaska, however, survival in moss is low because of drying when exposed to sunlight. Reproduction is common on rotten, fallen logs. Rapid growth of forest shrubs tends to inhibit seedling growth. Sitka spruce is a prolific seed producer and heavy crops are produced every 3-4 years with lighter crops in intervening years (Div. Timber Man. Res., 1965, p. 313). Seeds are disseminated in late fall followed by germination in the spring. [Vol 2, p 138]

2A.6.3.3.2 Consumption

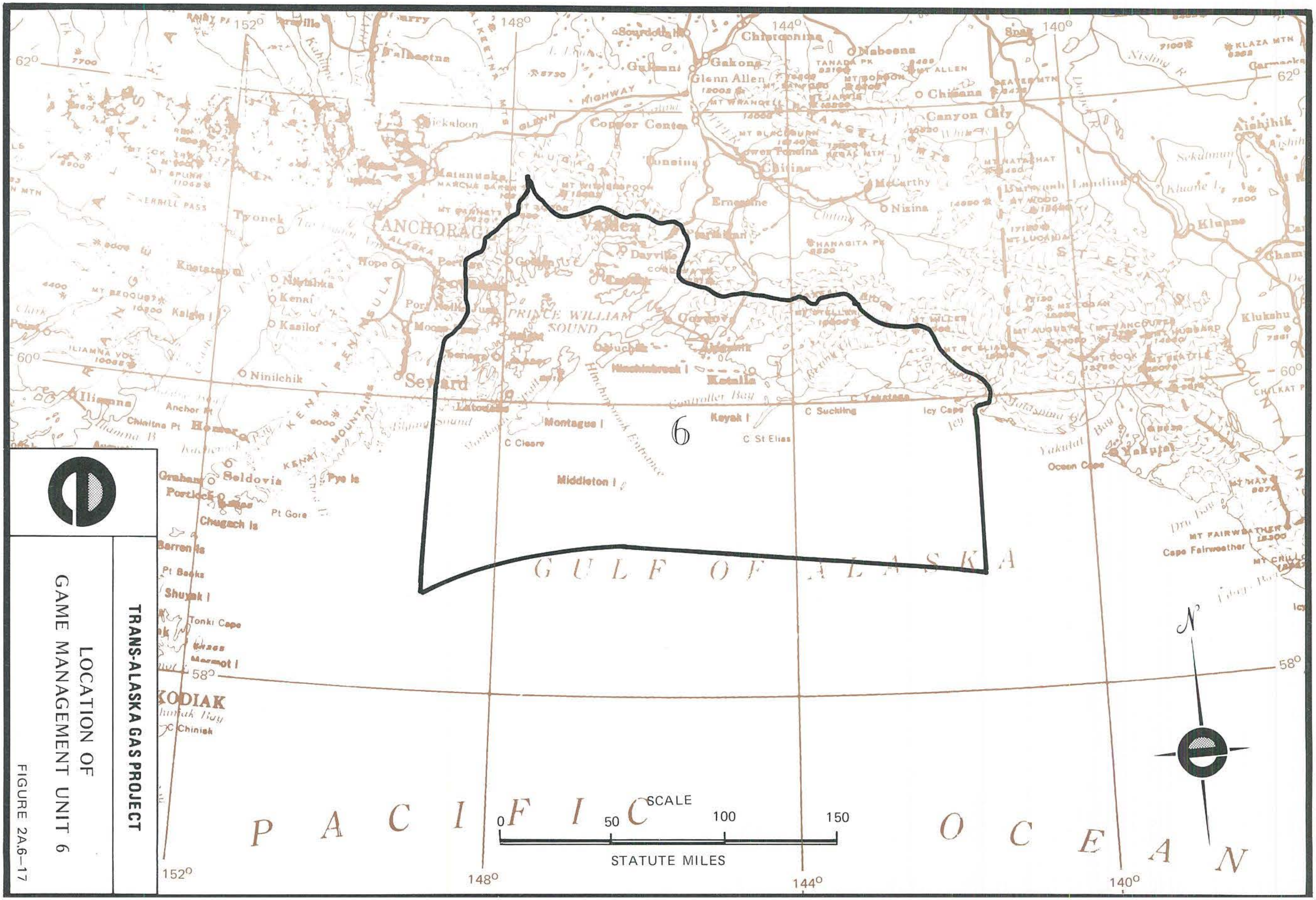
The ecological roles of consumers are less clear in the South Coastal Division than elsewhere in Alaska. Most available information deals with game or furbearing species of mammals. Birds are better known, chiefly through the efforts of individuals and through several on-going federal agency studies of waterfowl and seabird colonies; however, a substantial portion of this information will be unavailable until publication.

The following species accounts of mammals (see Appendix C) are largely based on Alaska Department of Fish & Game analyses, and inferences drawn from recent changes in hunting regulations for Game Management Unit 6 (Figure 2A.6-17). It should be noted that two species--caribou and Dall sheep--are virtually absent from this region, while two others--moose and Sitka black-tailed deer--are present only through past transplants of animals.

2A.6.3.3.2.1 Brown/Grizzly Bear *(Ursus arctos)*

Brown/grizzly bears are found on larger islands and on the mainland in this area.

The years 1961-1970 saw a marked increase in hunting pressure on this species. To protect it from suspected incursions on the quality of the population, the hunting seasons were shortened between 1966 and 1970 from 9 months of open season (January 1 to June 30; September 1 to



TRANS-ALASKA GAS PROJECT

LOCATION OF
GAME MANAGEMENT UNIT 6

FIGURE 2A.6-17

December 31) to less than 4 months (April 1 to May 31; October 10 to November 30). Because of winter dormancy, the real reduction in open season is less than the apparent reduction, however. In 1970, 27 brown/grizzly bears were harvested, 9 of which were taken by nonresidents. The proportion taken from Unit 6 annually by nonresidents ranged between 16 and 52 percent in the same decade. Of the 27 animals in 1970, only 12 were males, raising concern that heavy hunting in 1967 and 1968 had possibly reduced the proportion of males in the population. The mean age of male bears taken in 1970 was lower than in the previous two years (5.9 vs. 7.1 and 9.3 years). Other indications were more hopeful; mean male hide length and skull size in 1970 were both above the mean for the decade, and a healthy proportion of sows with cubs was observed during aerial survey and by incidental observations. (The foregoing paragraph after Reynolds, 1971; 1973a).

Brown/grizzly bear management poses a special problem in that the species historically has been unable to coexist with human populations (Erickson, 1965). Several of these powerful carnivores are usually shot each year in Unit 6 "in defense of life and property" (Reynolds, 1971: personal communication). Garbage access is most frequently cited as the origin of nuisance habits by bears. Statewide, however, about one unprovoked bear attack per year is reported (as well as about two provoked attacks--Erickson, 1965).

Other problems hamper effective brown/grizzly bear management. One is that individual bears are not thought to range very widely, but to stay generally within 30 miles of den sites (Erickson, 1965).

Dietary requirements of the species seem to fall chiefly into four categories: (a) grasses, (b) berries, (c) salmon, and (d) carrion. In coastal Alaska, concentrations of this species are found where subalpine grassland habitats, salmon streams, and tidewater exist in relative proximity. In these situations, bears seem to capitalize, by shifting habitats, on ripening blueberries (*Vaccinium*) and crowberries (*Empetrum*) in late summer, even when salmon are still running (Erickson, 1965).

2A.6.3.3.2.2 Black Bear (*Ursus americanus*)

In this area, black bears are found only on the mainland surrounding Prince William Sound.

Information on black bear harvest is fragmentary because until 1974 there was no requirement that hides be sealed, hence examined, by the Alaska Department of Fish & Game. Hunting patterns affecting Prince William Sound black bears were nevertheless part of a study by McIlroy (1970), which dealt with the significant increase in pressure by Valdez based hunters, both guided and unguided, during the 1960's. This increase was largely due to the opening of the Valdez Army Recreation Camp in 1962. In 1966, when the first study of Prince William Sound black bear hunting was initiated, 80 to 85 bears were harvested by hunters based out of Valdez, of which about 50 were attributed to military hunters. In that same year the bag limit per hunter was reduced from three to two bears, and the next year it was further reduced to one. Between 1966 and 1969, the proportion of black bears harvested by guided hunters (transported out of Valdez by boat) rose, the average distance from Valdez traveled by successful hunters increased, and the mean number of Hunter days per kill increased dramatically from 3.3 to 23.6. McIlroy's study (1970) strongly suggested that hunting pressure had changed the ~~absolute abundance, as well as the age distribution of the population.~~

In selected unhunted study areas, McIlroy (1970) observed black bear densities of 8, 14, and 10 per square mile of suitable habitat. Two heavily hunted areas near Valdez yielded values of 1.4 per square mile and 0.4 per square mile.

Suitable habitat in Prince William Sound was found to include forested slopes and drainages surrounding tidal marshes. Scat studies revealed that black bears in this region eat a wider variety of foods than do interior Alaskan animals (cf Hatler, 1967). Principal items found by McIlroy (1970) were grasses and sedges, ferns, horsetails, salmonberry, and blueberry. Salmon are apparently more digestible by these nominal carnivores, hence appeared only rarely as identifiable material in scat samples.

Although bears in this area emerge from dormancy in April, there is evidence to suggest that they lose weight, or at least do not fatten until salmon and berries become abundant in late July (McIlroy, 1970). The July-October period thus appears to be critical, in that it determines the physiological condition of bears entering dormancy. This is the period of the year in which bears of both species concentrate on particular salmon streams. Virtually every major stream between Port Fidalgo and Orca Narrows is known for such summer-fall concentrations (Alaska Department of Fish & Game, 1973).

2A.6.3.3.2.3 Mountain Goat (*Oreamnos americanus*)

Mountain goats are found on the mainland above timberline, particularly near glaciers. Between Valdez and Icy Bay, the south side of the Chugach Mountains supports a population of goats estimated by Klein (1953) at 3500 animals. At the present time, no regulations are in effect to allow documentation of the annual harvest in Unit 6. By means of a hunter questionnaire, Reynolds (1971; 1973a) estimated that some 42 goats were harvested by Cordova-based hunters in 1970, and 66 in 1971. In all, probably fewer than 100 goats are annually harvested by resident and nonresident hunters from the Prince William Sound area (Reynolds, 1973a).

Because of the expense, rigor, and difficult access involved, hunting is judged to have virtually no effect on the goat populations of the south side of the Chugach Mountains. In the absence of Dall sheep, goat populations seem to have the range to themselves, and to be in excellent demographic condition, with the possible exception of the Suckling Hills area southeast of the Copper River Delta (Reynolds, 1971). There is evidence to suggest that goats are slowly extending their range northward in Alaska (Klein, 1953; Alaska Dept. Fish & Game, 1973).

Habitat preferences of goats seem to involve steep, especially convoluted terrain that allows seasonal movements uphill and downhill. Storms and winter snows above timberline seem to bring on movements down to the upper fringe of timber, or around slopes to the lee side of prevailing winds. A desire for mineral salts results in movements to natural licks or to tidewater, especially during spring and early summer (Klein, 1953). Natural salt licks are known and mapped for some regions of Alaska, but none are recorded by the Alaska Department of Fish & Game (1973) in the Lowe River to Cordova area.

Studies of food habits indicate that Alaskan goats are primarily grazers, depending on grasses and sedges, ferns (Athyrium spp, Dryopteris spp) and smaller amounts of any other species of low-growing plants in the alpine and subalpine areas (Klein, 1953; Hjeljord, 1971).

Goat management, censusing, and life history studies (e.g., annual movement patterns) are especially difficult to conduct because the animals react strongly to aircraft (Reynolds, personal communication). The most successful population and behavior studies to date have been conducted on foot, and sufficient time or personnel have not been available within the Alaska Department of Fish & Game to conduct studies on goats in this region.

2A.6.3.3.2.4 Sitka Black-Tailed Deer (*Odocoileus Hemionus sitkensis*)

Deer occur abundantly on large islands in Prince William Sound, and more sparsely on the mainland. They were introduced from southeast Alaska as early as 1920 (Alaska Dept. Fish & Gam, 1973) and harvest was permitted after 1935. Local residents depend heavily on deer for meat, favoring hunting in October, November, and December, and enjoying best success on Hinchinbrook, Hawkins, and Montague Islands. Deer killed on the mainland in 1968, for example, accounted for an estimated 6 percent of the total harvest of 2120 animals in Prince William Sound (Merriam, 1971a). The shore of Sheep Bay at Garvina is one of the few mainland areas where hunters regularly succeed in harvesting deer.

Seasonal movements are important to these deer. In summer, they range up into subalpine grasslands. The advent of heavy snows forces them downward into forested shorelines, even to tidewater. Snow depths greater than 18 inches apparently impede their foraging and mobility, and significant mortality occurs, chiefly in winter, and especially when snows are deeper than usual. Severe snow conditions are mitigated by intact timber, and deer commonly move into such cover where snow accumulations are only 33 to 50 percent as deep as on open areas. The most important browse item in the winter period is blueberry (Vaccinium ovalifolium). To release conifer reproduction, the U. S. Forest Service has applied the herbicide 2-4-D to some cut-over forest lands in concentrations of two pounds per acre. An unfortunate result of this program is that the blueberry was killed off in areas so treated. Moreover, V. ovalifolium is slow to colonize areas where it is not present. (Foregoing paragraph based on Merriam, 1971b).

2A.6.3.3.2.5 Moose *(Alces alces)*

Moose were introduced periodically into the Prince William Sound region between 1948 and 1958, and have built up populations substantial enough to allow limited annual hunting since 1960. In 1970 and 1971, 46 and 39 moose, respectively, were harvested by permittees west of the Copper River (Reynolds, 1973a).

Moose habitat requirements rest on the continued existence of suitable browse, chiefly willows (Salix spp), which locally are most abundant in transitional stages of vegetation on alluvial outwash areas below receding glaciers (Alaska Dept. Fish & Game, 1973).

In reference to the proposed gas piepline, few moose are expected to occur except in the Lowe River Valley (Alaska Dept. Fish & Game, 1973).

2A.6.3.3.2.6 Wolverine *(Gulo luscus)*

Harvest of this omnivore, largely by trapping, occurs at a very low level in Game Management Unit 6, averaging only 14 animals annually in the decade 1961-1971 (Reynolds, 1973b). Bounties were paid on them through the season of 1968-1969. Trapping and hunting continue, even without bounties, for the fur is highly prized in the manufacture of parka ruffs. Harvest statistics now derive from the regulation requiring sealing of hides. Populations in Prince William Sound are unknown, probably sparce but apparently stable, in view of continuing success by trappers.

2A.6.3.3.2.7 Beaver *(Castor canadensis)*

The State total fur harvest ranged from $600,000 to $1 million annually during the five year period 1966-1970 (Burris, 1973). Beavers constituted some 20 percent. During this period, the average contribution of Game Management Unit 6 was 1.2 percent of the total beaver harvest, as might be expected in an area not heavily trapped (an average of 9.8 trappers per year in Unit 6). Beavers are sufficiently abundant to reward trappers in this area with one of the higher per-trapper harvests in the State (0.8 percent of the statewide trappers secured 1.2 percent of the harvest during the five-year period, 1966-1970, Burris, 1973). The percentage of kit pelts sealed was generally about 15 percent, indicating little effect on populations by the trapping effort. Kit pelt occurrence greater than 20 percent is considered evidence of over-trapping.

Beaver habitats range from slow-to-fast-moving, generally clear streams, in which preferred foods, such as poplars, aspens, (Populus, spp), alders (Alnus, spp) and willows (Salix, spp), are available (Burt & Grossenheider, 1964).

2A.6.3.3.2.8 Other Furbearers

Muskrats (Ondatra zibethica), red quirrels (Tamiasciurus hudsonicus), mink (Mustela vison), marten (Martes americana), river otter (Lutra canadensis), lynx (Lynx canadensis), and weasels (Mustela, spp) can be expected in the area (Burt & Grossenheider, 1964), but no breakdown by species is available from trapping reports for Unit 6.

2A.6.3.3.2.9 Additional Mammal Species

Snowshoe hares (Lepus americanus) occur in the area, but apparently do not show the pronounced population cycles that they do elsewhere in Alaska and Canada (M. E. Isleib, personal communication).

The collared pika (Ochotona collaris) may not occur in the Chugach Mountains. These relatives of rabbits and hares inhabit talus slopes and rockslides above timberline. They forage diurnally, store grasses and herbs within the rockpiles, and remain active all winter. This species may not find enough suitable habitat in the Chugach Mountains to range there, whether because of excessive snowfall, lack of vegetation near rockslides, or a combination of these and other factors.

The hoary marmot (Marmota caligata), an inhabitant of untimbered rocky mountain slopes, is to be expected in the Chugach Mountains. Like pikas, marmots feed on nonwoody plants, but differ in that they hibernate between September and May.

The porcupine (Erithizon dorsatum) can be expected between the Lowe River and Hawkins Island, although no information on its local abundance is available. Porcupines are known for the damage they inflict on trees by barking them. They also can damage plastic-insulated communication and electric lines, and various other man-made structures and materials. They inhabit forested and brushy areas and can be expected at least into the subalpine meadows of the Chugach Mountains.

Small rodent fauna probably includes the tundra red-backed vole (Clethrionomys rutilus), meadow vole (Microtus pennsylvanicus), tundra vole (Microtus oeconomus), and Alaska vole (Microtus miurus), but information on local populations is not available.

The bird life in Prince William Sound is abundant and conspicuous. The diversity of available habitats is one reason for this abundance; another is the strategic location of the Copper River Delta, Prince William Sound, and north gulf coast on major migration routes for species breeding farther north.

Strictly speaking, there is no single rare and endangered species of bird to be expected along this segment of the pipeline route (USDI, 1973). But there are several critical habitats for some populations of species in the Prince William Sound area.

Of the more than two hundred recorded from the region (see Appendix C), some thirteen species of birds that are rare or otherwise in unique situations near the proposed natural gas pipeline route. A comprehensive avifaunal list for the area was published recently by Isleib (1973), and a fuller account of Alaskan north gulf coast birds (Isleib and Kessel, in preparation) will appear shortly.

2A.6.3.3.2.10 Great Blue Heron *(Ardea herodias)*

Hawkins Island is north of the usually accepted northern limit of breeding distribution of this species (Yakutat), but Isleib and Kessel (manuscript) cite strong circumstantial evidence that a few pairs breed in coniferous forests bordering sheltered lagoons and inlets in Prince William Sound, north of Cordova.

2A.6.3.3.2.11 Trumpeter Swan *(Olor buccinator)*

Trumpeters breed in widely dispersed locations, notably on the flats of the Copper River Delta. A few pairs, however, nest in Prince William Sound localities north of Hawkins Island. Once considered rare and endangered, this species has been found to be more abundant, especially in Alaska, than was previously thought. Nevertheless, this large and dramatic bird still draws public attention to its nesting success, which requires relatively undisturbed habitat around the lakes on which it breeds.

2A.6.3.3.2.12 Canada Goose *(Branta canadensis)*

The common subspecies nesting on the Copper River Delta is the small dusky canada goose (*B. c. occidentalis*). This is not the rare and endangered Aleutian (*B. c. leucopareia*) form, but the duskies are not numerous. Their suitable habitat on the Delta may be disappearing following changes in water regime in consequence of the 1964 earthquake, which uplifted the Delta area six to ten feet (Isleib and Kessel, manuscript).

2A.6.3.3.2.13 American Osprey *(Pandion haliaetus)*

Officially identified in *Threatened Wildlife of the United States* (USDI, 1973) as "status undetermined," Ospreys have suffered substantial decline in nesting success elsewhere. A few pairs almost certainly nest along bays and inlets of Prince William Sound (Isleib and Kessel, manuscript).

2A.6.3.3.2.14 Bald Eagle *(Haliaeetus leucocephalus)*

Bald eagles are abundant along the coasts of Prince William Sound, where they nest in coniferous forests. Isleib and Kessel (manuscript) estimate the breeding population of the north gulf coast at 1000 to 2000 birds, and the winter population at 3000 to 4000 birds. This ~~subspecies, H. l. alascanus, is not to be confused with the southern bald~~ eagle (H. l. leucocephalus) which is officially listed as threatened. Nevertheless, like trumpeter swans, bald eagles command public sentiment, and are strictly protected. They are most sensitive: (a) to destruction of traditional nest trees, and (b) at the time young are feeding on spawned-out salmon carcasses in autumn, before they have mastered the art of foraging for themselves.

2A.6.3.3.2.15 Golden Eagle *(Aquila chrysaetos)*

Golden eagles nest in mountains above timberline, are widely dispersed, and thought to be uncommon between Thompson Pass and Cordova, and leave the area in winter. Golden eagles may be found nesting in the high mountains between Lowe River and Simpson Creek.

2A.6.3.3.2.16 Peregrine Falcon *(Falco peregrinus)*

The falcon species is represented in the Prince William Sound area by the only American subspecies (F. p. peali), not considered in immediate danger of extinction (Cade & Fyfe, 1970). Its breeding habitats are generally near seabird or waterfowl colonies, usually on cliff ledges within sight of water. Isleib and Kessel (manuscript) estimate that only 10 to 12 pairs nest in Prince William Sound and the north gulf coast. Like bald eagles, golden eagles, and trumpeter swans, this species must be considered seriously, and its breeding scrupulously respected.

2A.6.3.3.2.17 Aleutian Tern *(Sterna aleutica)*

This species is a rarely observed local breeder between the Copper River Delta and the Bering River (Isleib, 1973). Historically, the species seems to have established North American (Alaskan) breeding colonies, then abandoned them again (Gabrielson & Lincoln, 1959). Isleib and Kessel (manuscript) estimate that several hundred birds breed in the north gulf coast area. These unpredictable birds seem to prefer level, well-vegetated (moss or grassy carpet) situations for nesting (Gabrielson & Lincoln, 1959), or what Isleib (1973) refers to as wetlands.

2A.6.3.3.2.18 Marbled Murrelet *(Brachyramphus marmoratus)*

Hardly a rare bird, Isleib and Kessel (manuscript) consider it the most abundant, in terms of avian biomass, of all species in the area. There is one unusual aspect to the biology of this and another species of small alcid; their local breeding sites are not known. These sea birds almost certainly leave the sea to nest above timberline in rocky or alpine tundra habitat. Thus, they must travel, daily, distances of perhaps 10 miles between the sea and their nests (cf Bailey, 1973). Breeding colonies in the uplands bordering Prince William Sound may soon be discovered. It is not known how the unfledged chicks get from the nest to the sea. Bailey (1973) surmised that Kittlitz's murrelet chicks accomplished a similar journey partly by swimming down fast mountains streams.

2A.6.3.3.2.19 Kittlitz's Murrelet *(Brachyramphus brevirostre)*

This species displays the same nesting habits as the marbled murrelet, but is locally less abundant (Isleib, 1973). Its Prince William Sound nesting colonies are suspected to be near glaciers, in moraine rocks.

2A.6.3.3.2.20 Dunlin *(Calidris alpina)* and Western Sandpiper *(Calidris mauri)*

These two species are extremely abundant in spring migration. Isleib estimated that about 10 million birds of these two species stopped in Orca Inlet (surrounding Hawkins Island) between April 28 and May 31, 1973. There they occupied tidal mud flats for a few hours before moving northward again. These numbers probably represent the majority of the world's breeding population of each species. Few ornithologists have witnessed and described the phenomenon, but with increasing public access to Cordova, one can expect that visitors will come specifically to see these birds in the future.

2A.6.3.3.2.21 Dipper *(Cinclus mexicanus)*

This is a stream-inhabiting species that resides through the winter along open, swift-moving water. Dippers are widespread but not abundant, and can be expected to breed on virtually every appropriate lake outlet or open inlet in the Prince William Sound area. Dippers spend much time in and under clear water.

Waterfowl in this region are most abundant in the Copper River Delta area, and their habits and movements reflect their important access to interior Alaska via the Copper River Valley (Table 2A.6-10).

Many species of birds in Prince William Sound exist and depend on resources from aquatic and marine environments, making it difficult to distinguish and separate their ecological roles as consumers into terrestrial biology or marine biology.

TABLE 2A.6-10

ESTIMATES OF MIGRATING DUCK POPULATIONS FROM HABITAT IN THE COPPER RIVER DRAINAGE ADJACENT TO OR DOWNSTREAM FROM THE PROPOSED PIPELINE ROUTE

Duck		Population
Mallard		38,000
Pintail		75,000
Green-winged teal		52,000
Am. wigeon		57,000
Shoveler		19,000
Canvasback		5,000
scaups		66,000
Goldeneyes		17,000
Bufflehead		8,000
Scoters		17,000
Oldsquaw		1,000
	TOTAL	355,000

from Bartonek, USDI, 1972, Vol 2

2A.6.3.3.3 Decomposition

Decomposition rates, decomposer organisms, and limitations on nutrient cycling by microbial life has not been quantified for this region although it can be implied that the milder climatic and positive conditions of the South Coastal Division creates an environment more suitable for these processes to occur than those discussed under the Interior Basin Divsion. Also implied by this reasoning is that these same processes are less suitable than in the more temperate climate, but well studied, areas to the south in British Columbia.

2A.6.3.3.4 Wildfire

Owing to high precipitation, forests in this region do not burn readily, and wildfire occurance is not a natural part of the ecosystem function (cf Noste, 1969).

2A.6.3.3.5 Systems Dynamics

Terrestrial biological systems in the Prince William Sound region appear to be rather open, in that they exchange energy and nutrients with aquatic and marine environments to a high degree. The heavy annual precipitation contributes to the flux of matter seaward. The prevalence of anadromous fish, the abundant marine bird, and marine mammal life which use the land in various ways, represent reverse trends.

It is expected that much of the terrestrial biota is influenced by the essentially pioneer stages of vegetative succession and soil formation.

The appearance of abundance and lushness of Prince William Sound terrestrial biota may be misleading, in that the ability of biotic systems to absorb impact depends more on productivity than on standing crop, or biomass, and terrestrial productivity seems to be low in the region. The marked susceptibility of certain species to over-harvesting is suggestive of low secondary productivity (cf McIlroy, 1970). The interval between successive timber harvest on a given site is 120 and 150 years, indicating the slow growth of western hemlock in the region (R. Groff, personal communication).

2A.6.3.4 Aquatic Environment

2A.6.3.4.1 Primary Production

The lack of published information concerning fresh water ecosystems of the South Coastal Division is due largely to the relatively small influence (as compared to the Marine waters) these systems have on the total primary production of the region. The small drainage basins, most with extremely steep gradients and few significant tributary systems, preclude an abundance of primary producers. An additional constraint to their abundance is the usual poor water quality associated with the high sediment loads of glacier fed streams.

2A.6.3.4.2 Consumption

2A.6.3.4.2.1 Fishes

Both commercial and sport fisheries exist in Prince William Sound for salmon. Several moderate-sized rivers support spawning runs of salmon. Dolly Varden are also present in these rivers. The Gravina and Lowe Rivers are the only large rivers on the pipeline route. Streams to be crossed by the Alyeska oil pipeline are discussed briefly in the Final Environmental Impact Statement for the Trans-Alaska (Oil) Pipeline (USDI, 1972).

> The Lowe River is typically turbid in the summer because of silt derived from melting glaciers; in the fall and winter it is typically clear. Resident populations of Dolly Varden occur in this system which also is an important production area for sockeye, pink and chum salmon (Van Wyhe, 1969). Much of the salmon spawning occurs in the small tributaries of the river (N. F. Netsch, personal observation).
>
> Other streams flowing directly into Prince William Sound that would be crossed by the proposed pipeline are typically smaller, but the lower reaches, which are frequently in the intertidal zone, are spawning areas for pink and chum salmon (U. S. Dept. of Interior, 1970). Many of these streams are precipitous a short distance inland, and upstream movements of fish from the Sound are limited. Several of the streams that do not have barriers support runs of coho salmon. . . . (USDI, 1972, vol 2, p 158)

2A.6.3.4.3 Decomposition

No specific information on decomposition in aquatic ecosystems in the South Central Division exists for the identical reasons none exist for primary production, as discussed in Section 2A.6.3.4.1. Although decomposers are vital to any ecosystem, the majority of the decomposition will occur in the intertidal marine areas below the steep terrain from which the decomposable matter originates.

2A.6.3.4.4 Systems Dynamics

The degree of diversity in the dynamics of aquatic ecosystems of the South Coastal Division appears to be unknown. The flora and fauna are known only in general terms. The fishes are the only important aspects of the aquatic biology with commercial or recreational value.

In particular, the gas pipeline route south of the Lowe River is completely unassessed. Some very rugged terrain is involved. The proposed pipeline would run adjacent to a sizable lake, which apparently has not been studied. This whole area is proximal to the ocean. Stresses that can be absorbed without degradation of the system (in aesthetic or economic terms) are difficult to predict.

2A.6.3.5 Marine Environment

Because of the marine setting of the proposed LNG Plant and Alaskan Marine Terminal, and because Prince William Sound contains approximately 3000 miles of shoreline (Bartonek & Sowl, 1972), the thrust of marine activity will be directed into the nearshore areas. The nearshore waters of Prince William Sound may be divided into two major zones or habitats; (a) an intertidal zone--those areas influenced by the rise and fall of tides--and (b) the subtidal, or sublittoral, zone. Each zone may then be further divided into habitats or microhabitats according to certain physical and geological features prevalent in each, recognizing however the interaction of physical processes in these nearshore waters, such as water movement and sediment transport (Inman & Brush, 1973).

2A.6.3.5.1 Primary Production

The initial energy that enters the marine community is in the form of solar radiant energy. In the sea, both free floating and attached plants utilize this energy, along with CO_2 and inorganic nutrients, to build organic material (primary production). The production of organic matter by vascular and nonvascular plants initiates a complex flow of energy that terminates at higher trophic levels occupied by the marine mammals and man. To understand trophic hierarchy and community metabolism, some measure must be made of either energy or chemical materials that are passed along in the system.

Primary production in the sea may be measured in the same general way as on land. Various techniques for such measurements in aquatic systems is discussed by Strickland and Parsons (1968). The radioactive carbon (C^{14}) method of Steeman Nielsen (1952) is one currently in use. The objective of primary productivity studies is to evaluate the capacity of the ecosystem to build up organic compounds of high energy potential for transformation to higher levels in the food chain (Goering, *et al.*, 1973).

One of the most important questions concerning primary production in any environment involves the factors controlling the rates of primary production. Light has been found to be an important factor limiting production in the ocean (Ryther, 1956). The producers are directly dependent upon the rate of incident solar radiation as a source of energy (Lindeman, 1942). Knowing the rate at which light decreases with depth (extinction coefficient), the amount of solar radiation, and the quantity of plant chlorophyll in the water column, permits calculation of the net production of the phytoplankton. In addition to these factors, nutrients, such as phosphate and nitrate, seem to limit primary production in coastal waters. In the Gulf of Alaska, Ryther and Yentsch (1957) estimated the rate of primary production at 1.50 g C/m^2/day. Seasonal background information on primary production is available from Prince William Sound, primarily in the vicinity of Port Valdez. Goering, et al., (1973) found that, in general, large blooms of phytoplankton occurred in the spring of the year and produced maximum amounts of chlorophyll and organic matter. The phytoplankton bloom at this time of year was composed mainly of diatoms. Following the spring peak, rates of production and standing corps of phytoplankton remained low. However, Horner, et al., (1973) reported a bloom of small flagellates in Galena Bay during October, 1971. Standing stocks varied with changes in location and the calendar month. Phytoplankton growth during winter months virtually ceased. The pattern of productivity in Prince William Sound seems to be typical of other marine systems in high latitudes (Ryther, 1963).

Productivity was low near the mouths of rivers, especially during summer and fall when silt-laden fresh water reduced water transparency. Sediment loading reduced light penetration in the Sound to such an extent that only the upper meter of water contained enough light for phytoplankton growth (Goering, et al., 1973).

Possibly another contributing source to the overall organic production in the Sound is the benthic diatoms. Mare (1942) reported this group to be important in shallow European waters, and no doubt they can be found on mud, rock surfaces, undersides of ice, and on seaweeds in Prince William Sound.

In addition to those groups, the macrophytes (attached algae and flowering plants) contribute to the overall primary production in the Sound. The sea grasses are represented by two genera, Zostera and Phyllospadix. Both plants are perennial and usually occur in different habitats (Scagel, 1967). Reported rates of production for sea grasses range between 10 and 20 g C/m^2/day. If the other algal components of a sea grass community are added to this figure, the beds or meadows must be one of the most productive systems on the earth (McRoy, 1973). Primary production in a sea grass bed or meadow involves at least six major groups of plants: (1) The sea grass, (2) Microepiphytic algae, (3) Macroepiphytic algae, (4) Benthic microalgae, (5) Benthic macroalgae, and (6) Phytoplankton (McRoy, 1973).

All of these groups must be considered when calculating primary production.

The majority of the work on Alaskan sea grass has been conducted on one species, Zostera marina (commonly known as eelgrass). McRoy (1970) investigated standing stocks of eelgrass in ten different locations along the coast of Alaska; three of his study areas were in Prince William Sound. However, standing stock measurements of eelgrass do not provide an estimate of productivity (Westlake, 1963). McRoy measured the productivity of eelgrass in Izembek Lagoon on the Alaska Peninsula and calculated net production at 8 g C/m^2 in a 15-hour day. Based on these data the turnover rate would be about two percent per day, with total turnover occuring in fifty days. In higher latitudes, however, productivity varies with season, location, and time of day; therefore, measurements should be taken at frequent intervals.

Another important contributing source of primary production in Prince William Sound is the seaweeds or attached macroalgae. The seaweeds are conspicuous even to the casual observer, for some Alaskan genera such as Nereocystis and Alaria support seasonal canopies that float along the sea surface. Some of the larger plants are attached to the sea floor and are commonly referred to as kelps. Others, such as the rockweed, Fucus, form dense mats or patches that cover a great deal of the solid substratum in the intertidal regions of Prince William Sound. The commercially important kelp species of western Alaska were surveyed in 1913 as a potential source of potash fertilizer (Rigg, 1915). During this expedition, Rigg estimated the amount of kelp growing on the sea surface in the areas surveyed at 3,567,000 tons. Portions of Prince William Sound were mapped and the background data that were gathered provide some information on kelp bed distribution.

To date, no information on the productivity of seaweeds is available from Prince William Sound. However, the information that is available from other comparable regions in North America suggests high rates of production. The intertidal rockweed Fucus has rates comparable to the kelps. For example, in Nova Scotia the rockweed had an estimated production of 640 to 840 g C/m^2/yr (Westlake, 1963). The giant kelp community off Southern California, when compared to other natural ecosystems, is believed to have a productive capacity similar to a coral reef, freshwater springs, and marine grass flats (McFarland & Prescott, 1959). Clendenning (1971) calculated that the net annual production of a kelp bed off La Jolla, California was 400 to 800 C/m^2.

Seasonal production measurements are vital to any study investigating intertidal and subtidal plant communities. Some species of seaweeds are perennial while others are annual. The growth strategies, or patterns, of subtidal seaweeds have been shown to be different. For example, perennial plants such as Laminaria and Agarum grow rapidly throughout the winter (Mann, 1973), while other annual kelps such as Nereocystis appear to grow only during the spring and summer months (Scagel, 1947). The seaweeds of southern Alaska generally produce surface canopies during the summer months, followed by periods of tissue breakdown and senescence. Mann (1973) estimated the primary production in the seaweed zone off Nova Scotia averaged 1750 g C/m^2/yr. In addition, data by Westlake (1963) indicate that the annual production of seaweeds is about 10 times as great as planktonic algae, of the order of 1000 to 2000 g C/m^2/yr. These estimates are important in evaluating the contribution of the seaweeds to the production of carbon in Prince William Sound, a marine ecosystem dominated by its lengthy shoreline and extensive kelp zone.

2A.6.3.5.2 Consumption

In Prince William Sound the herbivore guild is believed to be composed of at least four major groups: (1) zooplankton, (2) intertidal and subtidal invertebrates, (3) fishes, and (4) water birds.

The zooplankton is made up of a wide array of animals with differing life styles and morphology, but the one unifying feature of the group is dependence on water motion for large scale movements. Some zooplankton spend their entire existence in the water column, while for others the drifting stage is only transitory. The zooplankton of northeastern Prince William Sound were partially described by Cooney, et al., (1973). Forty categories of zooplankton, including 30 genera, were identified from plankton tons in the vicinity of Valdez arm. Of these, the calanoid copepods numerically dominated the samples for a period of one year (1971-1972). Most of the species reported in this study have also been found in the vicinity of Auke Bay, in southeast Alaska (Wing & Reid, 1972). The zooplankton probably represent the most important group of phytoplankton consumers in the oceanic system, and are believed to be responsible for controlling the size of the phytoplankton population in subarctic waters of the eastern Pacific (Larrance, 1971). Since most of the photosynthesis is restricted to depths shallower than 200 meters, a large fraction of herbivore biomass occurs near the sea surface (Cooney, 1972). It is not surprising that most of the planktonic herbivory is believed to take place in this portion of the water column.

Rates of phytoplankton grazing are difficult to determine. There is some suggestion that copepods and other herbivorous plankters will eat far more than their need if the phytoplankton is rich (Raymont, 1963). Copepods are probably the most important group of grazers on phytoplankton populations in the Sound, and this position has been summarized by Clarke (1939), when he stated that, "Copepods in fact regulate the floating plant populations." No doubt, other zooplankton such as euphausids, pteropods, cladocerans, and larval forms of both benthic and pelagic animals contribute to the planktonic herbivory in Prince William Sound. Of all the plankton herbivores, the copepods have perhaps been most studied, and diatoms are regarded as the most important source of food in the North Pacific (Beklemiskev, 1954).

The next group of herbivores to be considered in the overall grazing scheme is the intertidal and bottom dwelling invertebrates. Included are animals such as sea urchins, isopods, crabs, gastropods and polychaete worms that browse heavily upon attached macrophytes and benthic diatoms. In rocky intertidal and subtidal habitats, invertebrate herbivores are often responsible for suppressing algal growth. Herbivorous gastropods, such as limpets, graze on both algal spores and sporelings (Moore, 1938; Southward, 1953), and numerous investigators have demonstrated that limpet removal results in heavy algal growth along European shorelines (Jones, 1948; Southward, 1956), as well as on rocky substrata in the Pacific Northwest (Dayton, 1971). The intertidal surveys conducted by the National Research Council (1971) in 1964 described distribution and abundance patterns of some members of the herbivore guild. Periwinkles, chitons, and limpets appear to be the most important components of rock surface fauna in Prince William

Sound (Haven, 1971). These animals graze upon both attached macroalgae (Paine, 1969; Dayton, 1971) and benthic diatom populations (Castenholz, 1961). No studies have yet been conducted on the feeding behavior and factors that influence the distribution of gastropods in Prince William Sound.

Sea urchins are quite possibly the most important single group of invertebrate grazers in temperate and tropical seas. Foraging habits appear to influence patterns of plant distribution and abundance. Ogden (1973) demonstrated that in Carribean waters the sea urchin Diadema crops sea grasses to such an extent as to limit the plants' local distribution. No data exist on the interactions of sea urchins and seagrasses off Alaska; however, Hubbard (1971) reported that grazers were notably absent in the eelgrass beds of Olsen Bay, Prince William Sound. In addition, the eelgrass beds off Kodiak Island apparently lack surface dwelling macroinvertebrates (Nybakken, 1969), although this overall impression may have been derived from field observations made while the eelgrass beds were exposed at low tide. The activity periods of the herbivores may have not coincided with the timing of the investigations.

Sea urchins, particularly Strongylocentrotus spp, graze heavily upon attached algae and are known to overexploit algal resources in areas of high sea urchin density off California (North, 1971) and Washington (Paine & Vadas, 1969). The most ubiquitous sea urchin in southern Alaska is the green sea urchin, Strongylocentrotus droebachiensis. The green sea urchin inhabits Prince William Sound, but its distribution and relative abundance are unknown. Howard Feder, University of Alaska (personal communication), reported the green sea urchin was uncommon in the northern portions of the Sound, and Calkins (1972) noted that it was rare in the intertidal zone on the northern end of Montague Island. This species is capable of overgrazing seaweed beds off Nova Scotia (Mann, 1973); in southeast Alaska it was observed feeding upon attached kelps, algal litter and detritus (Rosenthal, unpublished data).

The leather star Dermasterias imbricata is another echinoderm that has been reported to feed upon eelgrass and detritus in Prince William Sound (Feder, personal communication); this same feeding behavior was noted by Mauzey, et al., (1968) in subtidal waters off British Columbia. Whether the leather star can digest plant material is still uncertain; however, some nutritional benefit must certainly be gained from this feeding behavior.

Another herbivore, the isopod Idothea spp, was studied under laboratory conditions by Jones (1971), who found that it preferred kelp blades and stipes, with limited grazing on Zostera and Phyllospadix. In addition, Naylor (1955) found Idothea feeding upon Laminaria and rockweed in European waters. Idothea resecata ranges from Alaska to California and Pentidothea spp, has been collected at Glacier Bay, Alaska (Mueller, 1973). Another plant-eating isopod is Limnoria spp, which is usually found associated with the holdfasts of various brown algae; Menzies (1957) found Limnoria algarum burrowing into the holdfasts of both Nereocystis and Laminaria. The grazing activities of the isopods inhabiting Prince William Sound are unknown.

There appears to be herbivory by some of the other crustaceans as well, for both brachyuran and anomuran crabs feed upon or ingest plant material. For example, diatoms and seaweeds were found in the stomachs of dungeness crab Cancer magister (McKay, 1942; butler, 1954), tanner crab Chionoecetes spp, (Yasuda, 1967), and the king crab Parlighodes spp, (McLaughlin & Hebard, 1959). However, possibly some of the plant material is ingested incidentally.

Herbivory is practiced by a number of fishes along the west coast of North America, but a good deal of this grazing is probably directed at the invertebrates found associated with these plants. Three of the species that inhabit Prince William Sound--the buffalo sculpin Enophrys bison, Pacific herring Clupea harengus pallasi, and the pink salmon Oncorhynchus gorbuscha-- are known to enter the food chain at this level. Larval herring have been found to feed upon diatoms (Hart, 1973) and buffalo sculpin were found with the sea lettuce Ulva in their stomachs off the coast of British Columbia. Bailey (unpublished) studied the stomach contents of Prince William Sound pink salmon and found that diatoms constituted the third most common food item in the stomachs of these specimens.

A variety of benthic forms capture phytoplankton from the river column and therefore can be considered as herbivores. Included in this group are filter feeders such as scallops, mussels, clams, and tunicates. Some species of clams ingest detritus that settles along the sea floor, while others feed upon plankton floating in the water column. Another filter-feeding bivalve, the bay mussel Mytilus edulis, is probably one of the most ubiquitous species in Prince William Sound. Fundamental research on the feeding behavior of bivalve mollusks is reviewed by Barnes (1968). Many of the bivalve mollusks are capable of ingesting a great deal of phytoplankton. For example, a pismo clam can strain about 5800 gallons of water a year (Fitch, 1953), illustrating the filtration capabilities of bivalve mollusks.

Many of the animals that inhabit Prince William Sound can be classified as herbivores during early stages of development, but as adults they become carnivorous. Alterations in feeding behavior seem to take place not only in space and time, but also as the animal undergoes changes in size and morphology.

However, since trophic information is lacking, a functional understanding of the zooplankton community in Prince William Sound can only be arrived at by extrapolation from other marine systems.

Carnivory among members of the marine community is practiced at various levels in the food chain, usually beginning with the zooplankton. However, knowledge of specific dietary requirements of the major groups of zooplankton is fragmentary. Many forms classified as herbivores are probably omnivorous. For example, copepods, which are generally thought of as herbivores, will also feed upon other copepods (Lebour, 1922). Some species of euphausids are carnivorous and feed upon drifting mollusks, amphipod, and copepods. In high latitudes, the taking of animal food by zooplankters may be more important during winter months when there is a purported scarcity of phytoplankton. Seasonality affects the feeding behavior of zooplankters, as do changes in size and morphology. The pioneering work of Lebour (1928) demonstrated that planktonic crab larvae fed on algae in early stages of development, but need animal food to complete a series of moults leading to a bottom dwelling existence. Some of the major groups, such as copepods, chaetognaths, amphipods, cnidarians, and larvacians are known to consume other zooplankton in waters of the North Pacific. Cnidarians, such as jellyfishes, will occasionally consume small fishes.

Nearshore fishes live along the sea floor as well as in the water column, and are know to attack a variety of prey organisms in Prince William Sound. Generally, there is a remarkable complexity of feeding patterns in fishes, with dietary changes taking place in both space and time. The major groups of commercially important fishes that practice carnivory in the nearshore waters of the Sound are: (1) salmon, (2) flounder, (3) rockfish, and (4) herring. Helle, et al., (1964) studied the life history and intertidal ecology of the pink salmon in the vicinity of Olsen Bay, approximately seven miles north of the proposed LNG Plant on Gravina. Pink salmon were found to ingest a variety of prey, with copepods, barnacle larvae, and tunicate larvae being the predominant food items. Some qualitative information on feeding relationships of nearshore fish communities in subarctic waters is presented by Isakson, et al., (1971). Additional clues to understanding the food habits of Alaskan fishes can be found in Hart (1973).

Bottom-dwelling invertebrates may also be carnivorous. Some of the major groups that inhabit the Sound are sea stars, brittle stars, crabs, shrimps, octopus, squids, sea anemones, polychaete worms, and snails. In addition to attacking live animals, most of these will scavenge dead or moribund (physiologically static) organisms encountered along the sea floor.

The sea stars are an active group of predators that prey upon a wide spectrum of bottom-dwelling organisms. Four conspicuous species that inhabit the intertidal and shallow subtidal regions in southeastern Prince William Sound are *Pycnopodia helianthoides*, *Evasterias trochellii*, *Pisaster ochraceus*, and *Dermasterias imbricata*. The feeding behaviors of these four species in the waters of Puget Sound have been partially quantified by Mauzey, et al., (1968). The sun star, *Pycnopodia*, preys heavily upon sea urchins in rocky subtidal waters of Washington (Mauzet, et al., 1968) and southeast Alaska (Rosenthal & Barilotti, 1974); yet, in more protected habitats in Prince William Sound the primary food items appear to be clams and mussels (Feder & Paul, unpublished data). *Dermasterias* was observed eating sea urchins off the coast of southern California (Rosenthal & Chess, 1972); in the subtidal water of Washington (Mauze, et al., 1968) and southeast Alaska (Rosenthal & Barilotti, 1974); yet, in more protected habitats in Prince William Sound the primary food items appear to be clams and mussels (Feder & Paul, unpublished data). *Dermasterias* was observed eating sea urchins off the coast of southern California (Rosenthal & Chess, 1972); in the subtidal waters of Washington (Mauzey, et al., 1968) and southeast Alaska Rosenthal, unpublished data) the diet is composed mainly of sedentary invertebrates, such as sea anemones, tunicates, bryozoans, and sponges.

These examples illustrate changes in diet of an opportunistic predator from one habitat to another. Pisaster and Evasterias are reported to feed upon clams, mussels, and barnacles off the coast of Washington (Mauzey, et al., 1968).

Brittle stars are members of this same phylum (Echinodermata); they are reported to be generalists in their food habits (Fell, 1966). In northern European waters Mortensen (1927) found the diets of two genera (Ophiothrix and Ophiocomina) consisted of worms, crustaceans, clams, dead fish, and kelps.

There are at least five species of Pandalid shrimps found in Prince William Sound (Myren, 1971), and a number of other species that are not harvested by man. Shrimps are opportunistic predators that feed upon a variety of organisms such as polychaetes, mollusks, shrimps, crab larvae, and fishes (Berkeley, 1929; L. Barr, personal communication). Generally they are active carnivores, but they will scavenge dead fishes and invertebrates.

Information on the food habits of the dungeness, king and tanner crab is derived from other areas in the North Pacific. All three genera appear to be omnivorous and utilize a variety of organisms for food. For example, McKay (1943) and Butler (1954) found clams, crabs, shrimps, barnacles, and seaweeds in the stomachs of dungeness crabs. Tanner crabs are known to eat brittle stars, crustaceans, clams, and snails (Yasuda, 1967). King crabs feed upon clams, polychaete worms, algae, crustaceans (McLaughlin & Hebard, 1959) and sea urchins (Powell, personal communication).

Octopuses and squids are free-living mollusks that are known to prey on snails, crabs, and small fishes (Lane, 1957; Kosloff, 1973). In some regions they are active predators; however, in Prince William Sound, their diets and relative abundances are unknown. Many of the snails are carnivorous and apparently feed upon both living and moribund organisms. In the intertidal regions of southern Prince William Sound, Hanna (1971) reported finding Searlesia, Thais, and Amphissa. All three genera are carnivorous and are known to eat littorines, barnacles, limpets, mussels, and sea urchins in the Pacific Northwest (Kosloff, 1973). Nudibranchs, or sea slugs, are more specific in their diets; sponges, hydroids, and sea anemones are known prey from the waters of California and Washington (Kosloff, 1973). The diets of nudibranchs that inhabit Prince William Sound still remain unreported; however, one, Melibe leonina, captures plankton drifting in the water column.

Additional members of the invertebrate group such as sea anemones and polychaete worms practice carnivory (Barnes, 1968); however, only qualitative feeding information is reported (Feder, et al., 1973).

The marine mammals represent one of the highest trophic levels in the overall food chain. In Prince William Sound, the sea mammals are represented by the whales, porpoises, seals, sea lions, and sea otters. Some species appear to be residents in the Sound on a year-round basis, whereas others inhabit the area on a transitory, or seasonal basis (Scheffer, 1973).

The sea otter is possibly the most conspicuous marine mammal in Prince William Sound. Nearly extinct around the turn of the 20th century, the herds have increased, and Pitcher and Vania (1973) estimated the population in the Sound at 5000 animals. Sea otters have been observed foraging in both the intertidal and subtidal regions of the Sound. The term "keystone" species, proposed by Paine (1969), probably describes the sea otter as well as any marine predator. In the North Pacific, its diet generally consists of botton-dwelling invertebrates and sedentary reef fishes (Kenyon, 1969). Sea otters are known to eat clams, crabs, octopuses, and sea stars in the vicinity of Montague Strait, southern Prince William Sound (Calkins, 1972). In subtidal waters off southeast Alaska, their diets consisted of sea urchins, clams, barnacles, abalones, and mussels (Rosenthal & Barilotti, 1974). However, feeding is not restricted to the subtidal zone, since sea otters have been seen eating clams and mussels along beaches and mud flats in the Sound (Feder, Paul, and Nickerson, personal communication).

Harbor seals range throughout Prince William Sound; they are known to eat fishes, crabs, mollusks, and shrimps in other regions of the North Pacific (Scheffer, 1944) but little is known about their food habits in Prince William Sound. Predation upon salmon and damage to commercial nets in the vicinity of Cordova and the Copper River Delta led to depredation hunts on harbor seals. Much of the salmon predation apparently takes place during the spawning season when the fishes are trapped in nets or entering spawning streams.

Steller sea lions live year-round in the Sound; the greatest concentrations are found on the offshore rocks and islands exposed to direct oceanic swells from the Gulf of Alaska (Pitcher & Vania, 1973). In Alaskan waters the following food items have been identified from the stomachs of steller sea lions: squid, octopuses, clams, crabs, mussels, rockfishes, greenling, and sand lance (Thorsteinson & Lensink, 1972; Mathisen, 1959). Occasionally, other marine mammals may enter into their diets; (Karl Schneider, personal communication) reports that Steller sea lions kill and occasionally eat fur seals in the Aleutians.

Dall and harbor porpoises are common residents of the Sound (Pitcher & Vania, 1973). Both species feed upon fishes and squid in more southerly waters of the Pacific (Norris & Prescott, 1961). Killer whales also inhabit these waters (Pitcher & Vania, 1973). Very little is known about their movements in this area, but movement and food habits are apparently closely aligned to the appearance of spawning salmon. Seals, sea lions, porpoises, whales, squid, and salmon are known constituents of the killer whales' diet (Slijper, 1962).

Some of the larger baleen whales, such as the minke and humpback, have been sighted in Prince William Sound. Generally, these larger whales rely heavily upon zooplankters such as shrimps, euphausids, and smaller fishes for most of their food requirements.

Man, along with the marine mammals, shares in key role in the nearshore food chain. The greatest use of the living marine resources is centered around commercial fishing and local consumption. Most of the exploitation to date has involved a limited number of species, notably salmon, herring, clams, and crabs. Not all of the fishing is directed for immediate human consumption; for example, razor clams are currently used as bait in dungeness crab pots. The importance of fishing is reflected in the present-day economy of Cordova, where it is the major industry.

The transfer or flow of energy from the primary source in plants through the herbivores to carnivores is referred to as the food chain. The description suggests a neat, orderly flow of food materials through the various trophic levels. In reality, few marine systems probably operate in such predictable and orderly fashion. Many of the animals in a system occupy a variety of feeding levels, and interactions or trophic relationships seem to change with changes in season and/or habitat (Krebs, 1972).

2A.6.3.5.3 Decomposition

Tissue breakdown by bacteria often leads to mineralization and the return to sea water of the chemical constituents of plant and animal tissue. In turn, the bacteria provide food for protozoans and deposit feeders. Provasoli (1958) has suggested that the high fertility found in nearshore waters may be associated with high vitamin content, much of which is derived from bacterial decomposition and run-off from land. Even with the work of Zobell (1957), understanding the importance of bacteria and their involvement in the organic cycles in the sea has only begun.

The bacteria probably play important roles as decomposers in Prince William Sound, especially since the receiving waters are influenced by an extensive shoreline, high amounts of precipitation and fresh-water run-off. The shoreline is fringed by terrestrial plants, subtidal and intertidal seaweeds, and occasional beds of eelgrass. In the vicinity of the shoreline, terrestrial drainage and run-off contributes detrital material to the overall system. Coastal streams that feed the Sound not only add plant material, but also contribute quantities of animal matter. For example, during the summer and fall spawning season, many creeks and streams are filled with dying salmon. The ultimate fate of much of this animal tissue is the shallow waters of the Sound.

Coastal shrubs and trees contribute detritus to the system, especially following leaf shedding and wind storms. The interaction of nearshore waters and terrestrial plants is apparent from the surface water stain that characterizes many of the smaller embayments in southern Alaska. Most of the discoloration in the receiving water has been traced to the leaching of plant material, especially tannins.

Seaweeds contribute to the detrital buildup on a year-round basis. Many species are annuals and undergo yearly tissue breakdown while other, perennial, algae periodically shed blades and tissue material during reproduction, perination, and growth. Most of the particulate matter from these plants and animals accumulates on the sea floor, and its ultimate breakdown is probably dependent on bacterial decomposition.

2A.6.3.5.4 Systems Dynamics

A study of the ecology of a marine system usually begins with a descriptive account of the species present, followed by a listing of the biotic groups and apparent assemblages. It is generally accepted that most plants and animals are organized into recurring assemblages or communities. Despite this assumption, few data are available to indicate how natural communities develop (Krebs, 1972). Assuming that community concept is valid, there should be some way to measure the interactions or relationships between the components of the system. A number of factors appear to influence the composition of marine communities in other areas, i.e., food space and light, and these factors no doubt contribute to community structure in Prince William Sound.

Until the past decade, ecological research in the waters of Prince William Sound had been almost totally neglected. Exploratory trawling and pot fishing in 1954 by the National Marine Fisheries Service produced some information on the location and relative abundance of bottomfish and shellfish. It is believed that the general lack of attention was primarily due to the remoteness of the area, in addition to the low human population density along the coast (Feder & Mueller, 1973).

Two incidents, one a natural phenomenon involving the Good Friday earthquake of 1964, and the other the location of the terminus of the crude oil line at Port Valdez, provided most of the stimuli for the recent research in Prince William Sound. Inventories of intertidal and bottom-dwelling plants and animals inhabiting the Sound, along with some estimates of their abundance and distribution were accumulated during both the Alyeska studies (Rosenburg, 1973; Hood, et al., 1973), and the post-earthquake biological survey (National Research Council, 1971). The majority of existing background information on benthic communities has been collected near Port Valdez.

A community, or an assemblage of organisms, because of its complexity, is much more difficult to deal with and to understand than a single-species population. Therefore, one approach is to study specific populations within a marine system, and after the data have been gathered the pieces can be fit together into an ecological puzzle. Only a few population studies, however, have been conducted in the Sound. Most of these studies have dealt with fisheries-oriented problems, with emphasis on commercially important species such as pink salmon (Helle, et al., 1964), littleneck clam (Paul & Feder, 1973), razor clam (Nickerson, unpublished manuscript), and mussel (Myren, unpublished data). The interaction of these species in multispecies assemblages is still poorly understood. Therefore, understanding of marine communities in Prince William Sound is derived from other studies outside of the Sound, i.e., Amchitka (Lebednik, et al., 1971), Kodiak (Nybakken, 1969), British Columbia

(Scagel, 1947), Washington (Dayton, 1971; Paine, 1969), and California (Fager, 1968; Connell, 1970).

The Good Friday earthquake of 1964 injects still another variable into the ecological picture of Prince William Sound. During and proceeding this catastrophic incident, the nearshore biota of the Sound experienced severe physical disturbance from changes in shoreline elevation (i.e., both uplift and subsidence). Since the area is believed to be still undergoing recovery, the post-earthquake investigations of the National Research Council (1971) will be heavily relied upon in order to identify ecological changes that have taken place as a result of this natural event.

Most of the ecological progress has been made from a descriptive point of view, and little or no functional information exists. In defense of the descriptive approach, Fager (1963) believes that one cannot study something until it can be objectively identified and described. In this context, the structural or descriptive aspects of the community are as important as the functional aspects. Both are necessary before any operative understanding of marine communities is possible.

The marine environment in the vicinity of Gravina can best be described as a mosaic. The intertidal shoreline, water column, and subtidal benthos all merge into one system. All three regions interact and a change or disturbance in one should ultimately affect the others.

2A.6.3.6 Regional Systems Interactions

Most of the biological research in the coastal waters of the North Pacific has been conducted along the intertidal beaches, primarily because of their accessibility and the continuity of the shoreline with the terrestrial environment. The nearshore waters of Prince William Sound typify the close interaction of the terrestrial and marine environments. However, unlike some regions of the world where the shoreline represents a meeting of the terrestrial and aquatic environments, the nearshore areas of Prince William Sound appear to merge into one maritime environment. For example, life history patterns, energy flow, and weather patterns are reflected in this dynamic coastal system. In many cases, it is difficult to tell where the terrestrial system ends and the marine environment begins.

Weather appears to be one of the first clues to this systems' interaction. The climate of eastern Prince William Sound is described as subarctic maritime, with high amounts of precipitation in the form of rain and snow. Tidal extremes, currents, and storm waves alter the physiognomy. Most of the alteration is gradual and occurs over a long period of time; however, occasionally forces such as tsunamis and earthquakes can drastically change the face of the shoreline in just a few hours.

Heavy rainfall and run-off results in brackish water conditions at heads of bays; it also lowers salinity levels near the sea surface. Freshwater transport from the land carries sediments and nutrients into the coastal system. Conversely, storms and winds moving along the sea surface drive waves onto the shoreline creating splash zones and pools of saline water.

Many life history patterns transcend the two environments. For example, anadromous fishes (such as salmon) spend portions of their lives in both habitats. Terrestrial predators and scavengers rely heavily upon this life history interaction. Bears, mink, land otter, and raptorial birds utilize the salmon as a source of energy during the summer and fall spawning seasons. In addition to the raptors, other water-related birds (such as ducks, geese and shorebirds) interact with both environments on an almost daily basis. Feeding, reproduction, and rest stops carry over into different habitats in Prince William Sound. Many of the water birds feed along the shoreline, or dive for marine plants and animals adjacent to the shores. A great deal of the living material is returned to marine and freshwater systems in the form of bird excrement.

Some terrestrial organisms feed directly in the marine environment; land otters frequently forage in the Sound, whereas marine mammals such as harbor seals forage in coastal streams and rivers. Even larger herbivores such as black-tailed deer utilize and interact with the marine environment. During winter months, when heavy snows force the deer out of high country, they seek out new sources of nourishment, and are frequently seen along the shorelines in Prince William Sound feeding on marine kelps and seaweeds.

The human inhabitants of Prince William Sound interact with the overall system on a daily basis. They use the waters of the Sound for highways, and harvest sea animals and plants for food and profit. Canneries that process sea products usually deposit the waste materials back into the nearshore waters, eventually to be decomposed and recycled in this dynamic maritime system.

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