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Special Report 78-13

September 1978

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ECOLOGICAL BASELINE INVESTIGATIONS ALONG THE YUKON RIVER — PRUDHOE BAY HAUL ROAD, ALASKA

Jerry Brown, Editor

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Results of the first full year's field research on five projects along the Yukon River-Prudhoe Bay Haul Road are reported. Several projects are extensions of investigations begun in 1976 and are being conducted in cooperation with a Federal Highway Administration sponsored environmental engineering study. The extent and success of weeds and weedy species along the road and in material sites has been followed for summer 1976 and 1977. In order to document the vegetation along the complex elevational and latitudinal gradient CONT.

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and its potential for impact and recovery, 17 vegetation maps have now been completed, and vegetation described and plots established at 120 locations along the 600-kilometer-long road. Collections of vascular plants, bryophytes and lichens were made and catalogued for an additional 9 sites. Sampling for soil invertebrates to determine their sensitivity to impact was undertaken at approximately 25 sites. A detailed study of the impact of road dust upon the vegetation was initiated at one tundra site and four sites were established to monitor the amount of dust transported onto the tundra across 1000-meter-long transects. The clay mineralogy and chemistry of the dust and road material were investigated.

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PREFACE

This progress report covers the first 8 months of our Department of Energy (DOE) project. It was prepared prior to requesting second-year continuation funding of $100,000. The projects supported under the DOE funding are part of a larger coordinated effort which is being supported by the FHWA and CRREL with in-kind support of the Alaska Department of Highways. In addition, the Army Research Office (ARO) is funding two separate grants for complementary studies along the Haul Road which are cooperating with CRREL research. The results of a complementary study of tundra response to past petroleum exploration in the National Petroleum Reserve - Alaska (NPRA) is also coordinated with these investigations.

In July 1977, a first annual report to FHWA was prepared and distributed to those currently receiving this report. Follow-up quarterly reports have also been distributed. Therefore, we will not present the information contained in those reports, particularly since much of that material pertains to the environmental engineering studies. However, it is our intention both at the conclusion of the three-year FHWA program and the DOE studies to prepare final reports which integrate all aspects of these joint investigations.

The following summarizes the distribution of DOE and other funds which have been obligated for these ecological baseline studies.

	DOE project	DOE (ERDA)	Other*
Project 1	Weeds and weedy vegetation, San Diego State University	$ 5,000	$10,000
Project 2	Vegetation mapping and response, University of Colorado	20,000	29,000
Project 3	Botanical reconnaissance, University of Alaska	5,000	5,000
Project 4	Soil invertebrates, University of Alaska	12,500	12,000
Project 5	Distribution and properties of dust		
	Ohio State University	20,000	--
	Dartmouth	--	3,000
	CRREL	21,000	--
Logistics north of Yukon River and administrative costs		16,500	7,500
	TOTAL	$100,000	$66,500

*Other funding includes FHWA Haul Road, USGS-NPRA and CRREL projects. The CRREL project is funded under *Cold Regions Environmental Factors* (DA Project 4A161102AT24, Task A2, Work Unit 002).

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Although several of these projects were initiated in 1976 using FHWA and CRREL funds, the intention is to support the follow-up work largely with DOE and CRREL funding.

The projects and investigators involved in the DOE/CRREL-sponsored investigations are participating in the US-USSR Agreement on Cooperation in the Field of Environmental Protection under Project 02.05-21, "Protection of Northern Ecosystems." One of these subprojects, "Biological indicators of environmental change caused by natural and anthropogenic impacts," is directly related to much of the research reported in the following pages.

A set of maps containing locations of all CRREL research sites and some cooperative projects is contained in the appendix.

The cooperation of the Alyeska Pipeline Service Company in allowing access to the road and study sites and use of its camps and other support facilities as available on a reimbursable basis is appreciated. These investigations are conducted in conjunction with the CRREL Alaska Pipeline Program.

Appreciation is expressed to Stephen Bowen and Donna Murphy, CRREL, for assistance in editing and compiling this report. This report does not constitute an open-literature reference. The reader is urged to obtain the author's approval prior to citing results in the open literature.

JERRY BROWN
Research Soil Scientist
CRREL

CONTENTS

	Page
Preface	iii
The road and its environment	1
Project 1. Investigations of weeds and weedy vegetation along the Yukon River-Prudhoe Bay Haul Road (*A.W. Johnson and S.A. Kubanis*)	5
Summary	5
Background	5
Objectives	7
Methods	7
Discussion	12
Future plans	24
Literature cited	24
Project 2. Vegetation mapping and response to disturbance along the Yukon River-Prudhoe Bay Haul Road (*P.J. Webber, V. Komárková, D.A. Walker and E. Werbe*)	25
Summary	25
Subproject 1	25
Objective	25
Progress	26
Immediate activities	26
Subproject 2	26
Objective	26
Progress	40
Subproject 3	40
Objective	40
Progress	40
Explanation of map codes	40
Description of the vegetation at the Ray River site	44
Description of the vegetation at the Finger Mountain site	48
Description of the vegetation at the Sukakpak Mountain site	52
Description of the vegetation at the Toolik upland road effects study site	56
Description of the vegetation at the Franklin Bluffs oil spill site	62
Description of the Prudhoe Bay coastal site	63
Immediate future objectives	66
Subproject 4	66
Subproject 4A	66
Objective	66
Progress	67
Subproject 4B	67
Objective	67
Progress	67
Subproject 5	67
Objective	67
Progress	67

Page

Subproject 6. 69
Objective. 69
Progress 69
The study area 71
Methods. 71
Site uniformity. 73
Effects of the Haul Road on primary production . . . 80
Summary and conclusions. 83
Literature cited 85
Project 3. Botanical reconnaissance of the Yukon River-Prudhoe Bay Haul Road, 1977 (*D.F. Murray and B.M. Murray*). 88
Project 4. Soil invertebrates as indicators of environmental integrity along the Yukon River-Prudhoe Bay transportation corridor (*S.F. MacLean, Jr. and R.H. Thomas*) 92
Introduction. 92
Results 93
Discussion. 96
Literature cited. 97
Project 5. Distribution and properties of road dust and its potential impact on tundra along the northern portion of the Yukon River-Prudhoe Bay Haul Road. 98
Dust collection and distribution (*K.R. Everett*) 98
Analyses and results 101
Conclusions. 103
Clay mineralogy (*R.C. Reynolds and H.G. van Oss*). 105
Laboratory analysis. 105
Results. 107
Interpretations and conclusions. 109
Chemical composition of dust and vegetation (*I.K. Iskandar, S. Quarry and J. Brown*) 110
Appendix 1: Provisional CRREL maps and legend of Yukon River to Prudhoe Bay Haul Road. 113
Appendix 2: Distribution for CRREL-FHWA and DOE Haul Road Reports 127

THE ROAD AND ITS ENVIRONMENT*

Construction of the Trans-Alaska oil pipeline necessitated construction of an adjacent road over more than one-half of its length for access to workpads and for logistics. The road was constructed to Alaska secondary highway standards in two sections. The first section, approximately 90 km in length, was constructed between August 1969 and July 1970 and ran from Livengood to the Yukon River. It is referred to as the TAPS Road and the Alaska Department of Highways has now designated it the Yukon Highway. The 577-km-long "Haul Road" between the Yukon River and Prudhoe Bay was built during the period 29 April to 29 September 1974. Included in it are 20 permanent bridges, over 1000 culverts and 135 material sites. The road is unique in that it is closely associated with the 1.2-m-diameter hot oil pipeline and 0.2- to 0.25-m gas-feeder line. There are 15 oil line crossings of the road of which 9 are for the buried oil line and 6 are for the aboveground pipe. The road right-of-way incorporates the buried oil pipeline for about 19 km and the aboveground pipeline for about 25 km. The gas-feeder line, which will carry gas at below freezing temperatures from Prudhoe Bay to Pump Stations 2, 3 and 4 north of the Brooks Range, crosses the road seven times and is buried within 5 m of the toe of the road for about 180 km of its 229-km length.

The road traverses three main physiographic provinces in Alaska (Fig. 1). Proceeding northward from near Livengood, the road crosses a series of valleys and rounded ridges between 600 and 1200 m in elevation. It then enters the glaciated Brooks Range along the terraces and flood plains of the Koyukuk and Dietrich Rivers. The road crosses the Continental Divide at Atigun Pass at 1447 m elevation and gradually descends through the Brooks Range and northern foothills onto the flat outer coastal plain. Figure 2 presents a summary of the major terrain types traversed by the Haul Road. The route crosses both the discontinuous permafrost zone in the southern portion and the colder continuous permafrost zone to the north. Many of the upland and valley slopes south and north of the Continental Divide contain massive ice bodies.

The road traverses two major climatic regions broadly defined as the arctic climate of the North Slope and the continental climate of the interior. The Brooks Range is the transition zone between the two types.

The road passes through approximately 600 km of forest and tundra vegetation before it reaches Prudhoe Bay. Apart from concentrated studies around Prudhoe Bay, most of this area had previously received little more than superficial botanical exploration.

From the Yukon River to the southern foothills of the Brooks Range the vegetation consists of mixed deciduous-coniferous forests composed of *Picea mariana* (black spruce), *P. glauca* (white spruce), *Betula papyrifera*

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*Extracted from *Environmental engineering investigations along the Yukon River-Prudhoe Bay Haul Road*, by J. Brown and R. Berg. FHWA Annual Progress Report, CRREL, Hanover, N.H., July 1977.

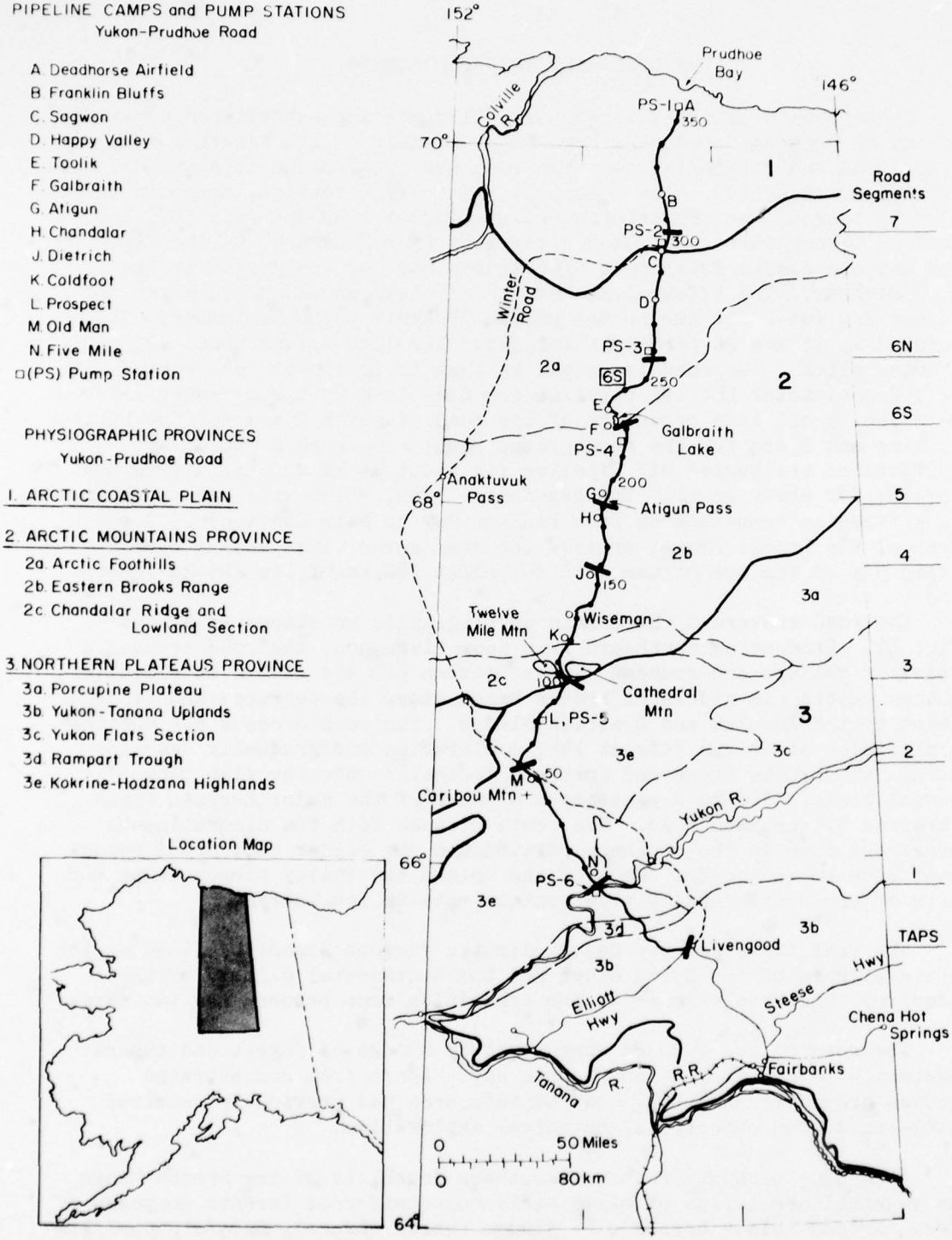
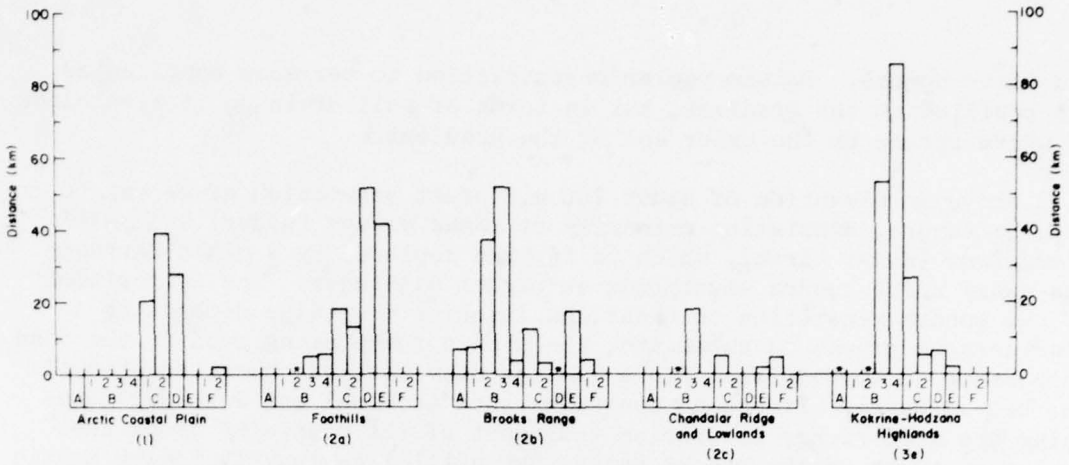


Figure 1. Haul Road and pipeline route and physiographic units traversed.



A. Bedrock

B. Gravity-Transported Deposits
1. Rapid, dry transport (avalanche, talus)
2. Rapid, wet transport (mudflow, alluvial fan, granular alluvial fan)
3. Slow, viscous transport (solifluction)
4. Slow, wet transport (colluvium)

C. Water-Borne Deposits
1. Active streams and rivers
2. Inactive streams and rivers

D. Wind-Blown Deposits

E. Glacial Deposits

F. Lake-Bed Deposits and Organics
1. Lacustrine silts and organics
2. Thaw lake materials

*< 1 km

Figure 2. Major terrain types encountered by the Haul Road. Numbers in parentheses correspond to the physiographic units in Figure 1. (Terrain classification modified from Kreig, R.A. and R.D. Reger (1976) Preconstruction terrain evaluation for the trans-Alaska pipeline project. In Geomorphology and Engineering *(D.R. Coates, Ed.). Stroudsburg, Pa.: Dowden, Hutchinson and Ross, Inc., p. 65-76.)*

(paper birch), *Populus tremuloides* (aspen), and *P. balsamifera* (balsam poplar). In the southern part of this area, *Larix laricina* (tamarack) is an occasional component on wetter sites in the forest. Nowhere north of the Yukon River, however, is it especially abundant along the Haul Road.

By far the largest forest type in terms of area covered is a low forest dominated by black spruce. This rather depauperate vegetation type occurs on most level and gently rolling surfaces below 700 m north to the point where it drops out of the vegetation. White spruce, which replaces black spruce on all sites somewhat north of Wiseman, tends to occupy steeper slopes and well-drained ridges where the two species occur together, and it is the major coniferous species growing on river terraces throughout the area. Depending on fire history, aspen and paper birch are mixed with spruce in all conceivable proportions up to pure or mixed stands of both of these deciduous successional species. Balsam poplar is found almost exclusively on river terraces where it usually forms mixtures with white spruce.

On a moisture gradient from wet to dry in the forested portions of this area black spruce lies at the wet end followed by paper birch, aspen

and white spruce. Balsam poplar's restriction to terraces complicates its position on the gradient, but in terms of soil drainage it lies close to white spruce on the drier end of the gradient.

Above an elevation of about 700 m, forest vegetation gives way to shrubby tundra, consisting primarily of *Alnus crispa* (alder) and *Betula glandulosa* (dwarf birch), which is in turn replaced by a mixed herbaceous-dwarf shrub tundra vegetation at higher altitudes. The composition of the tundra vegetation on these low interior mountains depends to a considerable extent on substrate, the acidic rocks along much of the road supporting an impoverished flora lacking many species characteristic of the Brooks Range. Limestone mountains such as Wiehl and Sukakpak Mountains are much richer in species than most of the mountains along the Haul Road south of the Brooks Range, but still lack many typically arctic and alpine tundra species.

Brooks Range vegetation is tundra, the complexity of which depends particularly on substrate and soil moisture and to a lesser extent on exposure and slope. Distinctive assemblages of species can be found on ridges. As one leaves the complications of the upland areas of the Brooks Range, the tundra vegetation of the Arctic Slope is subdivided into a foothills sedge tussock type and a coastal plain sedge meadow type. Riparian situations, late-lying snow-beds, rock outcrops and ponds add diversity to what is otherwise a monotonous vegetation.

PROJECT 1. INVESTIGATIONS OF WEEDS AND WEEDY VEGETATION ALONG THE YUKON RIVER-PRUDHOE BAY HAUL ROAD

Albert W. Johnson and Susan A. Kubanis
San Diego State University

Summary

With the introduction of weeds and the creation of an avenue of migration for these weeds extending from the Yukon River to Prudhoe Bay, a unique opportunity to study many important questions dealing with weeds, succession, and genetic adaptations was created. This opportunity is of particular importance because it permits investigation of these problems as they relate to the Arctic.

During July 1976, initial observations were made along the Haul Road by A.W. Johnson. The occurrence, abundance, and development of weed species along the road were documented. Dense colonies of *Chenopodium album*, *Corydalis sempervirens*, and *Senecio congestus* were observed. Other species were scattered widely along the road. Many of the weeds were in flower or fruit by the end of July 1976 and with a few weeks of growing season left, it is probable that many of them matured and dispersed seeds. At No Name Creek (Murray site 1), bales of straw which were used as mulch supported hundreds of seedlings of *Avena sativa*, *Hordeum vulgare*, and *Chenopodium album*. Evidently, thousands of weed seeds were introduced with a single bale of straw.

During July and August of 1977, investigations of the weeds and weedy species occurring along the Yukon River-Prudhoe Bay Haul Road were conducted by A.W. Johnson and S.A. Kubanis. The occurrence, abundance, and development of these species were documented. This report summarizes the progress made to date and future plans.

Background

Many weed species have been observed in subarctic regions, but few live in the Arctic. For example, nearly 200 species of introduced flowering plants were reported from the Alaskan subarctic by Hultén (1968), but only one species was observed north of the Brooks Range.

There are two primary reasons for the lack of weed species in the Arctic. First, few exotic weed species were introduced into the area. Little farming or grazing occurs in the Arctic, and it is through farming or grazing that many weeds are introduced into new areas. Subarctic areas of Alaska have been farmed or grazed, and consequently they are

saturated with exotic weed species. Weed species were also introduced into the subarctic areas of Alaska by means of the continuous road system from Canada into Alaska, but in the Arctic, until recently there were no such roads. Prior to this time, introduction of exotic weeds in the Arctic resulted from infrequent air or water transport.

The second major reason for the lack of weed species in the Arctic is that the characteristic physiology and growth habits of the weeds prevent their establishment. Weeds are often annuals and they "survive" the winter as seeds. Thus the success of an annual weed depends upon whether the environmental conditions are sufficient for the weed to mature and disperse its seeds during the short growing season. Although annuals can usually accomplish this in the boreal areas of Alaska, often they cannot in the Arctic where the length of the growing season is 60 days or less. Most native species are perennials and do not depend on annual seed set for survival. Few native annual species found in the Arctic have the ability to set seeds annually.

The construction of the Yukon River-Prudhoe Bay Haul Road provided opportunities for the introduction of exotic weed species. This road provides a route along which weed species can be introduced by trucks and man from the Alaskan interior. In addition, the weeds have the opportunity to differentiate variants and may become adapted to the more severe conditions and short growing season of the Arctic. These variants could survive and migrate north along the road. Thus, an extension of weed species could occur north along the Haul Road as adaptation occurs.

With the construction and use of the Haul Road, two main sources of weeds were initiated. The road cut and material sites were revegetated with grass seed which contained contaminants. Also, straw containing many weed seeds was used as a mulch in many areas. Thousands of seeds could be present in a single bale. The straw was obtained from the Big Delta area (Larry Johnson, CRREL in litt.) and any weeds occurring there may be introduced as well as the straw species *Avena sativa* and *Hordeum vulgare*.

A true weed is an opportunistic plant which is introduced into an area. It can take advantage of temporary resources, especially space. Weedy species, on the other hand, are native species which act like true weeds to some extent by pioneering on disturbed sites. These weedy species are usually generalists, and may be members of fairly different vegetation types.

Weeds often have certain characteristics or qualities related to their ability to colonize disturbed areas. They have become fairly dependent upon man for their spread and perpetuation. Usually, they are relatively light-demanding, xerophytic, frost resistant, deep rooting and unexacting as to soil (Daubenmire 1968). Weeds have the ability to build large populations quickly, and often evolve mechanisms to ensure dispersal. Through these characteristics and qualities, these opportunistic plants are adapted for invasion of any open space as long as its environment is within the physiological tolerances of the plant. Introduced weeds generally last only as long as the disturbed habitat exists.

They are intolerant of the conditions that develop with the establishment of dense plant cover (Daubenmire 1968). The high reproductive capacities of weeds enable them to survive by taking advantage of newly created bare areas. Weeds usually begin to produce seeds at a young age. In addition, they often produce great numbers of seeds.

On most disturbed sites in subarctic areas, a mixture of weeds and weedy species occurs. Twenty to thirty native invading species are to be expected on disturbed sites. The number of introduced weeds depends upon proximity to farming, transportation, grazing, and other activities related to man. Native invading species may remain as minor components of the vegetation even after the establishment of species belonging to more mature communities. Introduced weeds usually disappear as the native vegetation establishes and the disturbed site characteristics are eliminated. Weeds are intolerant of crowded conditions and do not fare well in competition with native species.

Objectives

The objectives of this study are summarized below. Investigations of these areas were undertaken by S.A. Kubanis during the summer of 1977 along the Yukon River-Prudhoe Bay Haul Road. Progress was made in all areas and is anticipated to continue over the next two years. Objectives:

1. To document the persistence of seeded grasses on roadsides and in material sites.

2. To document evidence of invasion of cleared and seeded areas by native plant species and study plant succession.

3. To investigate the extent and success of the introduced weeds by:
   a. preparing a full species list
   b. establishing the areas occupied by weeds and where they are located
   c. determining the larger areas which have not yet been invaded by weeds
   d. establishing the weeds' reproductive status
   e. recording the movement of weeds along the Haul Road
   f. assessing competition between weeds and native species, and attempting to evaluate how long they will persist
   g. exploring the question of whether or not selection for temperature and light variants has occurred.

4. To follow and document the extension of range, if any, of native plant species along the road.

Methods

Permanent transects and plots were established at 98 sites along the Haul Road (locations are indicated on appended maps). Most were established perpendicular to the road. These transects included the disturbed

areas on either side of the road and extended into the area of natural vegetation. Wooden stakes were driven into the ground at two or more points along the transect on either side of the road. The stakes were marked with the site number and tagged with lengths of surveyor's tape to facilitate relocating them in future growing seasons. The distance from the transect to the nearest road culvert was measured to the nearest tenth of a meter and recorded along with the culvert identification number. The distances to the nearest camp and access road or bench mark were also measured using the truck odometer. Other transects across reseeded material sites were established using similar techniques. Table 1 lists the sites, culverts, distances to camps, and other information relevant to the site locations.

Transects were established in differing areas representative of several situations: 1) bare areas, 2) areas of seeded grasses only, 3) areas of grasses and weeds, 4) areas of grasses and invading natives, and 5) areas of grasses, weeds and native invaders. These situations were selected to monitor different occurrences which included the appearance of weeds in areas free of them, disappearances from or persistence of weeds in areas where they now exist, succession into both bare and reseeded areas by native species, competition between natives and weeds, and persistence of grasses in seeded areas. Square meter plots were established along the transects by using a wooden quadrat frame. The number of plots varied with the length of the transect which was determined by the size of the disturbed area.

For each square meter plot, all species of plants were recorded and the percent cover for each species, grasses (collectively), and bare ground were estimated. The scale used was:

Less than 1% cover	= +
1-19% cover	= 0
20-39% cover	= 1
40-59% cover	= 2
60-79% cover	= 3
80-99% cover	= 4
100% cover	= 5

The area 50 m north and south of the transect was also examined for the types of weed species present. Site differences, the presence of pollinators, straw or netting, last year's growth, and other information were also recorded. Photographs were taken to document observations.

Phenological data for weed species were collected over the growing season. Vegetative growth, height, buds, flowers, fruits, dispersal, and senescence were recorded. Plants were revisited as often as the availability of transportation would allow. Phenological events were also documented with photographs.

Where single species stands, or stands of two or three species of weeds or native invaders, were found, permanent population observations were established using transects, plots, and locating techniques as described earlier. Again, a square meter quadrat was used and the number

Table 1. Site locations.

Site	Camp	Distance from camp to site, miles (km)	Nearest culvert station	Distance from culvert to site, meters	Side of road	Distance (N) from Yukon River to site, miles (km)	Other location information
K-1	Chandalar	2.1 S (3.4)	894+73	150.0 S	E	183.1 (294.6)	
K-2	Chandalar	5.2 S (8.4)	720+88	80.0 N	E	180.1 (289.8)	
K-3	Chandalar	10.1 S (16.3)	--	--	E	175.2 (281.9)	north of creek
K-4	Chandalar	13.4 S (21.6)	296+19	6.2 N	E	171.9 (276.6)	
K-5	Coldfoot	9.4 S (15.1)	1361+86	55.8 N	E+W	128.4 (206.6)	
K-6	Coldfoot	1.7 N (2.7)	--	--	E+W	120.7 (194.2)	
K-7	Coldfoot	10.4 N (16.7)	1417+69	96.0 N	E	129.4 (208.2)	
K-8	Coldfoot	15.0 N (24.1)	--	--	W	134.0 (215.6)	
K-9	Coldfoot	12.3 N (19.8)	--	--	E	131.3 (211.3)	across from 100 APL-2A
K-10	Coldfoot	10.6 N (17.1)	1426+24	125.0 N	W	129.6 (208.5)	
K-11	Coldfoot	11.8 N (19.0)	--	--	W	130.8 (210.5)	in parking area
K-12	Coldfoot	4.8 S (7.7)	--	--	W	114.2 (183.7)	
K-13	Coldfoot	4.9 S (7.9)	--	--	B	114.1 (183.6)	
K-14	Coldfoot	6.6 S (10.6)	528+26	108.7 N	W	112.4 (180.9)	along side road
K-15	Coldfoot	5.0 S (8.0)	--	--	E	114.0 (183.4)	across from 97 APL AMS 3
K-16	Coldfoot	4.5 S (7.2)	--	--	W	114.5 (184.2)	
K-17	Coldfoot	6.7 S (10.8)	528+26	62 S	E+W	112.3 (180.7)	
K-18	Coldfoot	6.7 S (10.8)	521+74	53.8 N	E+W	112.3 (180.7)	
K-19	Pump Sta. 5	1.8 N (2.9)	1315+16	53.0 N	E	83.0 (133.5)	
K-20	Pump Sta. 5	3.9 N (6.3)	--	--	W	85.1 (136.9)	Jim River 2, south side
K-21	Pump Sta. 5	3.9 N (6.3)	--	--	W	85.1 (136.9)	Jim River 2, south side
K-22	Pump Sta. 5	3.9 N (6.3)	--	--	W	85.1 (136.9)	Jim River 2, south side
K-23	Coldfoot	10.7 S (17.2)	326+94	136.0 N	E+W	108.3 (179.3)	in natural vegetation
K-24	Coldfoot	14.3 (23.0)	134+23	176.5 N	E+W	104.7 (168.5)	in natural vegetation
K-25	Coldfoot	21.5 S (34.6)	2098+18	11.5 S	E+W	97.5 (156.9)	
K-26	Pump Sta. 5	4.1 S (6.6)	1001+00	11.7 N	E+W	77.1 (124.1)	
K-27	Pump Sta. 5	4.3 S (6.9)	984+50	31.3 N	E+W	76.9 (123.7)	
K-28	Pump Sta. 5	6.4 S (10.3)	873+00	99.5 N	E+W	74.8 (120.4)	
K-29	Pump Sta. 5	20.5 S (33.0)	160+64	47.3 N	E+W	60.7 (97.7)	
K-30	Pump Sta. 5	28.6 S (46.0)	2924+22	260.1 N	E+W	52.6 (84.6)	
K-31	Pump Sta. 5	34.2 S (55.0)	2678+07	12.7 N	E+W	47.0 (75.6)	
K-32	Pump Sta. 5	2.4 S (3.9)	--	--	E	78.8 (126.8)	in 91.1 APL, at end of road
K-33	Old Man	21.5 S (34.6)	1740+44	30.4 S	E+W	29.3 (47.1)	
K-34	Old Man	29.1 S (46.8)	1306+60	4.1 N	E	21.7 (35.0)	
K-35	Old Man	23.7 S (38.1)	1600+84	15.4 N	W	27.1 (43.6)	
K-36	Five Mile	26.2 N (42.2)	1711+98	1.0 S	E	30.7 (49.4)	

Table 1. Site locations (cont'd).

Site	Camp	Distance from camp to site, miles (km)	Nearest culvert station	Distance from culvert to site, meters	Side of road	Distance (N) from Yukon River to site, miles (km)	Other location information
K-37	Five Mile	23.7 N (38.1)	1062+00	17.1 N	E+W	18.1 (29.1)	
K-38	Five Mile	27.7 N (44.6)	812+60	31.1 S	E+W	14.1 (22.7)	
K-39	Five Mile	2.3 S (3.7)	215+20	93.2 N	E+W	2.2 (3.5)	
K-40	Five Mile	0.1 N (0.2)	--	--	W	4.6 (7.4)	west of north bridgepost
K-41	Five Mile	3.0 N (4.8)	501+00	106.5 S	E+W	7.5 (12.0)	
K-42	Dietrich	6.4 S (10.3)	2396+65	82.4 S	E	147.3 (237.0)	
K-43	Dietrich	.09S (0.1)	666	124.8 N	E+W	153 (246.2)	
K-44	Dietrich	1.9 N (3.6)	2809+90	5.1 S	E	155.8 (250.7)	at creek north of DS 104
K-45	Dietrich	1.8 N (2.9)	2809+90	--	E	155.7 (250.1)	in DS 104
K-46	Galbraith	19.5 S (31.4)	552.40	37.8 N	W	200.9 (323.2)	just south of MS 112.0
K-47	Atigun	3.0 N (4.8)	--	--	E	198.4 (319.2)	back in off road on S 111.2
K-48	Atigun	3.8 N (6.1)	--	--	E	199.2 (320.5)	back in off road MS 111.2
K-49	Happy Valley	8.8 S (14.1)	2820+94	S	E	271.1 (436.2)	50 m north of slow grade sign
K-50	Happy Valley	8.9 S (14.3)	2820+94	S	W	271.0 (436.0)	5 m south of slow grade sign
K-51	Galbraith	5.7 N (9.2)	529+50	64.0 S	W	226.1 (363.8)	opposite APL 115.4
K-52	Toolik	5.1 N (8.2)	--	--	W	235.1 (378.3)	at 117 APL DA, north bridge
K-53	Chandalar	5.6 S (9.0)	--	--	E	179.7 (289.1)	
K-54	Chandalar	6.6 S (10.6)	--	--	E	178.7 (288.6)	
K-55	Prospect	7.1 S (11.4)	--	--	W	72.7 (117.0)	
K-56	Prospect	10.6 S (17.1)	--	--	E	69.2 (111.3)	at bridge North Fork Bonanza
K-57	Old Man	3.7 S (6.0)	--	--	E	47.1 (75.8)	
K-58	Old Man	6.6 S (10.6)	2503+64	N	E	44.2 (71.1)	where work pad crosses road
K-59	Old Man	16.7 S (26.9)	--	--	W	34.1 (54.9)	
K-60	Five Mile	0.9 N (1.5)	--	--	E	5.4 (8.7)	25 m south of north airport gate
K-61	Pump Sta. 3	25 N (40.2)	2133+30	12.1 N	W	255.4 (410.9)	north of 121 APL AMS 1
K-62	Pump Sta. 3	10.0 S (16.1)	--	--	E	242.9 (390.8)	.3 mi (0.5km) north of 119 AMS 1
K-63	Galbraith	0.0 (0.0)	--	--	W	220.4 (354.6)	just north of Galbraith entrance
K-64	Pump Sta. 5	17.6 N (28.3)	2139+83	155.5 N	E	98.8 (159.6)	
K-65	Five Mile	3.3 N (5.3)	518+30	79.7 S	E+W	7.8 (12.6)	
K-66	Five Mile	7.1 N (11.4)	--	--	E	11.6 (18.7)	by hill sign
K-67	Five Mile	10.4 N (16.7)	876+10	56.5 S	E	14.9 (24.0)	
K-68	Franklin Bluffs	1.3 S (2.1)	1216+10	.9 N	E	321.6 (517.5)	
K-69	Franklin Bluffs	2.1 S (3.4)	1216+10	.1 N	E	320.8 (516.2)	
K-70	Franklin Bluffs	3.1 S (5.0)	--	--	E	319.8 (514.6)	entrance to 130 APL AMS 5
K-71	Franklin Bluffs	11.5 S (18.5)	--	--	W	311.4 (501.0)	1.1 mi (1.8km) south of 130 APL AMS 2
K-72	Franklin Bluffs	16.2 S (26.1)	687+47	50.2 S	W	306.7 (493.5)	

Table 1 (cont'd).

Site	Camp	Distance from camp to site, miles (km)	Nearest culvert station	Distance from culvert to site, meters	Side of road	Distance (N) from Yukon River to site, miles (km)	Other location information
K-73	Franklin Bluffs	17.7 S (28.5)	--	--	E	305.2 (491.1)	
K-74	Happy Valley	14.1 N (22.7)	3991+00	55.1 N	W	294.0 (473.0)	
K-75	Happy Valley	20.0 N (32.2)	4300+50	99.7 N	W	299.9 (482.5)	
K-76	Chandalar	13.0 S (20.9)	--	--	W	172.3 (277.2)	
K-77	Dietrich	3.5 S (5.6)	2522+00	13.9 N	E+W	150.4 (242.0)	base of Sukapak Mtn.
K-78	Dietrich	19.6 S (31.5)	--	--	E+W	132.3 (212.9)	0.1 (0.2km) south of Hammond River Bridge
K-79	Coldfoot	9.6 S (15.4)	--	--	E+W	109.4 (126.0)	just north of 96 APL AMS 3A
K-80	Pump Sta. 5	2.2 N (3.5)	326+11	51.4 N	W	83.4 (134.2)	
K-81	Prospect	0.1 S (0.2)	--	--	E	79.7 (128.2)	opposite Prospect entrance
K-82	Prospect	3.4 S (5.5)	--	--	W	76.4 (122.9)	
K-83	Five Mile	2.1 N (3.4)	440+00	29.8 N	E	6.6 (10.6)	
K-84	Five Mile	5.5 N (8.8)	625+50	5.9 S	E+W	10.0 (16.1)	
K-85	Five Mile	6.2 N (10.0)	661+20	28.4 N	E+W	10.7 (17.2)	
K-86	Five Mile	7.1 N (11.4)	--	--	E+W	11.5 (18.5)	100 m south of MS 80-1 sign
K-87	Five Mile	2.6 N (4.2)	--	--	E	7.1 (11.4)	
K-88	Five Mile	17.6 N (28.3)	--	--	W	22.1 (35.6)	
K-89	Five Mile	29.4 N (47.3)	--	--	E	33.9 (54.5)	
K-90	Old Man	0.2 N (0.3)	--	--	E	51.0 (82.1)	200 m north of Old Man entrance
K-91	Old Man	1.2 N (1.9)	--	--	E	52.1 (83.8)	where pipeline crosses road
K-92	Old Man	1.9 N (3.1)	2944+22	80.4 N	W	52.7 (84.8)	
K-93	Happy Valley	1.6 S (2.6)	--	--	W	278.3 (447.8)	opposite MS 124-1
K-94	Happy Valley	2.8 S (4.5)	--	--	E	277.1 (445.9)	
K-95	Happy Valley	0.0 (0.0)	--	--	W	279.9 (450.4)	at sewage pool
K-96	Galbraith	2.3 S (3.7)	1451+48	50.2 S	W	218.6 (351.7)	
K-97	Galbraith	3.8 S (6.1)	--	--	W	216.6 (348.5)	
K-98	Five Mile	0.0 (0.0)	--	--	W	4.5 (7.2)	behind K trailer

of individuals of each species per quadrat was determined. Population plots were established for each of the 12 species at as many sites as possible along the Haul Road. Dispersal and the presence of straw were also recorded when observed in these plots. Also recorded was whether the plot was of a single species or mixed species. Photographs were also taken.

Whenever possible, mature seeds were collected from all weeds and weedy species for use in germination experiments to determine whether or not there are temperature and light variants over the altitudinal gradient. The location and date of seed collections were recorded on each voucher.

Table 2. Collected species and locations.*

Species	Collection sites	Species	Collection sites
Achillea borealis	K-2, K-4, K-44	Hordeum vulgare	K-22, K-56
Achillea sibirica	K-55	Matricaria inodora	K-58
Avena sativa	K-56	Plagiobothrys cognatus	K-14, K-72
Brassica juncea	K-20, K-39, K-56	Plagiobothrys hirtus	K-2, K-14
Camelina sativa	K-12	Polygonum aviculare	K-56, K-72
Capsella bursa-pastoris	K-7, K-14	Polygonum convolvulus	K-22
Chenopodium album	K-5, K-20	Potentilla norvegica	K-56
Corydalis sempervirens	K-6	Rorippa spp.	K-3, K-22, K-32
Descurainia sophioides	K-5, K-7	Rumex sp.	K-60
Epilobium palustre	K-61	Sisymbrium altissimum	K-5, K-39
Erigeron acris	K-32	Taraxacum spp.	K-56
Hordeum jubatum	K-25	Trifolium hybridum	K-65

* Table 2 represents the one-third of the collected specimens that were not lost in a bear raid on 18 August 1977.

In addition to the establishment of precise, permanent plots, frequent stops were made along the road to record what was present for future comparisons. Some areas along the road (ranging from approximately 0.8 to 16 km in length) which had no evidence of any exotic weeds as yet being established were found. These areas were traversed, examined, and marked off with surveyor's tape. The distance from each end of the area was measured to the nearest camp (using the truck odometer), so that these areas could be relocated and monitored over the next two years for the appearance of weeds which may migrate along the road. As would be expected, these areas were those where little or no roadside revegetation had been done (i.e. narrow road cuts) and where no straw had been used as mulch.

Collections of weed species and some native invaders were made along the road. Plants were tagged and pressed in the field. Table 2 lists the species and the sites at which they were collected. Collections were also made to document the extension of range of several native species.

Eleven sites that were investigated by A.W. Johnson in 1976 (Brown and Berg 1977) were revisited in 1977 for comparison. Weed species and native invaders present were recorded in these areas.

Discussion

Some observations and provisional conclusions can be reported at this time, but much data remain to be analyzed. Because emphasis is on the changes that occur over time, much of what was done during the summer of 1977 was for the purpose of establishing a data base from which to monitor future changes.

Table 3. Weed species from Alyeska Haul Road (summer 1977).

Avena sativa	Plagiobothrys cognatus
Brassica juncea	Plagiobothrys hirtus
Camelina sativa	Polygonum aviculare
Capsella bursa-pastoris	Polygonum convolvulus
Chenopodium album	Sisymbrium altissimum
Hordeum vulgare	Thlaspi arvense
Matricaria inodora	Trifolium hybridum
Matricaria matricarioides	

Table 4. Native invader species along Alyeska Haul Road (summer 1977).

Achillea borealis	Hordeum jubatum
Achillea sibirica	Ledum palustre
Arctagrostis latifolia	Luzula parviflora
Astragalus alpinus	Petasites frigidus
Betula glandulosa	Picea mariana
Betula nana	Polygonum alaskanum
Betula occidentalis	Polygonum bistorta
Betula papyrifera	Populus tremuloides
Calamagrostis canadensis	Rorippa hispida
Carex bigelowii	Rorippa islandica
Carex scirpoidea	Rosa acicularis
Chenopodium capitatum	Rumex acetosa
Cornus canadensis	Salix spp.
Corydalis sempervirens	Senecio congestus
Descurainia sophioides	Senecio pauperculus
Dryas octopetala	Spirea beauverdiana
Empetrum nigrum	Stellaria sp.
Epilobium angustifolium	Vaccinium uliginosum
Epilobium latifolium	Vaccinium vitis-idaea
Epilobium palustre	Wilhelmsia physodes
Equisetum arvense	mosses
Erigeron acris	liverworts
Hieracium triste	

Species lists of the weeds and native invaders were compiled to summarize the species established in disturbed areas along the Yukon River-Prudhoe Bay Haul Road by 1977. The 15 weed species observed are listed in Table 3. Native invaders are listed in Table 4. Some of the native species observed are common in Alaska, including *Vaccinium* spp., *Carex* spp., *Equisetum* spp., and *Polygonum* spp. Of the weed species, some have spread rapidly and extensively throughout other areas in Alaska to which they were introduced. These include *Matricaria matricarioides*, *Chenopodium album*, *Capsella bursa-pastoris*, *Polygonum aviculare*, and

Table 5. Weed species, annual weedy species and locations along Alyeska Haul Road (summer 1977).

| Species | Miles and kilometers north of Yukon River | | |

Trifolium hybridum. Some of these appear to have spread north to the Yukon River (a natural barrier), but had not been introduced north of the river until the construction and opening of the Haul Road and the initiation of the revegetation program. At the other extreme, some of these weeds have quite small areas of known occurrence (*Hordeum vulgare* and *Matricaria inodora*). *Camelina sativa* and *Plagiobothrys hirtus* each show only one site of occurrence in southeastern Alaska according to Hultén (1968). The establishment of these species north of the Yukon River illustrates dramatically how the activities of man may introduce exotic weed species.

All weed species identified in this study occur south of the Brooks Range, but north of the Brooks Range only 6 of the 15 weed species were observed. The numbers of species generally decrease from south to north along the 577 km of road between the Yukon River and Prudhoe Bay. This decrease is probably due to several factors. Climatic conditions north of the Brooks Range are more limiting, particularly to annual weeds which depend upon annual seed set and dispersal for survival. The growing season is shorter, temperatures are lower, and snow persists longer north of the Brooks Range. It was observed that germination of weed species north of the Brooks Range was considerably later than it was south of the Brooks Range. By 18 July, 13 weed species had been found in areas south of the Brooks Range. By 26 July, no true weeds had germinated north of the Brooks Range. The only annual native invader observed during this period was *Achillea borealis*, and it was seen in only a few areas. North of the Brooks Range ten days later, six weed species and several annual native species had germinated. Weeds north of the Brooks Range have a shorter growing season. It was observed near the end of the season that many species apparently would not set seed in time to reproduce successfully.

In addition to fewer species north of the Brooks Range, there were also less frequent occurrences of weeds and annual native invaders. Proceeding north of the Brooks Range, *Hordeum jubatum* was observed scattered fairly frequently along the road, but other species were found far less frequently. Aside from *Hordeum jubatum*, weeds and annual weedy species occur in approximately 15 sites north of the Brooks Range.

Table 5 shows which weeds and annual native invaders were observed in each of 36 16-km increments of the road from the Yukon River to Prudhoe Bay. A relatively smaller number of locations and species are found north of the Brooks Range.

Among these species, considerable variation exists in the number of increments in which each species was present. This number of increments is totalled in the right-hand column in Table 5. Some species occur in many of the 36 increments, including *Hordeum jubatum*, *Chenopodium album*, and *Corydalis sempervirens* found in 23, 20 and 13 of them respectively. Others are found more rarely -- *Avena sativa*, *Chenopodium capitatum*, *Erigeron acris*, and *Camelina sativa* are found in 3, 2, 1, and 1 (of the 36 increments) respectively. *Hordeum vulgare* and *Avena sativa*, the straw species, were not observed often.

Table 6. Percent cover of weeds and annual weedy species along Alyeska Haul Road (summer 1977).

Miles and kilometers north of Yukon River

Species	Mi	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320+
	Km	0	17	32	48	64	80	97	113	129	145	161	177	193	209	225	241	257	274	290	306	332	338	354	370	386	402	418	435	451	467	483	499	515
Achillea borealis		1									+				+	+	+,0		+	+,0	+,0				+		0		+,0		+,0	+		
Achillea sibirica		+,0					+	0	0		+																				+			
Avena sativa		+						+																										
Brassica juncea		+						+		+																								
Camelina sativa													+																					
Capsella bursa-pastoris			+	+		+		+					+,0	+						+														
Chenopodium album		[+,0 1,2]*	+,0				+	+,0,1 2,3		+,0,1			+				+,0,1		+,0					+			+,0		0		+,0	+		+
Chenopodium capitatum		0																									0							
Corydalis sempervirens		0	+				+,0	+,0	+	+		+,0,1		+																				
Descurainia sophioides		+						+						+			+		+												+			
Erigeron acris									0																									
Hordeum jubatum		+			+	+,0	+,0	+,0 1,3			+,0						0,+		+								+,0		+		+			+
Hordeum vulgare		+						+		+														+,0										
Matricaria inodora		+				+		+		+			+				+																	
Matricaria matricarioides			+					+																										
Plagiobothrys cognatus													+																			+		
Plagiobothrys hirtus						+		+					+							+			+											
Polygonum alaskanum				0																														
Polygonum aviculare																																+		
Polygonum convolvulus								+											+															
Rorippa spp.								+	0										+								0							
Senecio congestus		+																											+,3,4					
Sisymbrium altissimum		+						+					+	+																				
Thlaspi arvense						+							+																		+			
Trifolium hybridum		+			+																													
grasses only			0,1		+,0		+,0		+,0 1,3	0		0	0,+	0,1	0,1		+,0 1,2		+,0	0,1,2 3,4		0,1,2	3,4								+,0,2	+	+,0	0,2

+ = <1%
0 = 1-19%
1 = 20-39%
2 = 40-59%
3 = 60-79%
4 = 80-99%
5 = 100%

*Multiple values within an increment represent the range of percent cover found in the plots within the transects located in the increment.

+ No species beyond 320 miles north

Weed species and annual native species also vary in the percent cover they exhibit in disturbed areas. Grasses show from 0 to 90% cover. Bare ground covers from 10 to 100% of the area. Table 6 shows the range of percent cover for each species by location. The column at the far right summarizes the range of percent cover for each species over the entire length of the road. *Avena sativa, Descurainia sophioides, Matricaria matricarioides, Matricaria inodora, Plagiobothrys hirtus, Polygonum convolvulus, Sisymbrium altissimum* and *Thlaspi arvense* are found only as less than 1% cover. *Achillea sibirica, Capsella bursa-pastoris, Corydalis sempervirens, Hordeum vulgare* and *Rorippa* species show up to 19% cover. A few species show cover greater than 19%: *Achillea borealis* ranges from 1 to 39% cover, *Chenopodium album* and *Hordeum jubatum* range from 1 to 79% cover, and *Senecio congestus* ranges from 1 to 99% cover.

Population data are summarized in Table 7. Table 7 shows the number of individuals per m^2 for 12 weeds and native invaders and also indicates where straw was observed and where dispersal was occurring. Population plots were established wherever a single species stand or a mixed species stand of only 2 to 3 species was found. The overall range of number of individuals per m^2 is from 1 to 645. One species, *C. album*, is particularly interesting in that it shows very dense populations in these m^2 plots. This species was observed sprouting directly on bales of straw and growing frequently in areas which had evidence of straw mulch. Apparently thousands of its seeds could be introduced in a single bale of straw. *C. album* had m^2 plots with dense populations of 124, 235, 460, 612 and 645 individuals. All of these dense populations were in areas where straw was present. A plenitude of seeds and favorable weather may produce dense populations of colonizers and for some time the crowded conditions may provide a microclimate favorable to supporting the seedings. However, eventually some necessary resource becomes too sparse and the situation degenerates. If the soil is fertile, genetic differences among the plants will rapidly be expressed, with the more hardy individuals gaining at the expense of the weaker individuals, and the total density will decrease fairly rapidly (Daubenmire 1968). On poorer soils such as in the disturbed, often scraped areas along the Haul Road, the individuals will be uniformly stunted despite potential differences in growth rates and survival ability (due to heterozygosity), and the dense populations may persist in these stunted forms. Eventually thinning will occur, but slowly because it results only from accidents like trampling, windthrow, etc. which can reduce the local density. Evidently this is the case with the observed dense populations of *C. album*. In the dense plots reported above, the height of the plant was stunted, ranging from only 2 to 25 cm near the end of the growing season. In other areas of less dense populations, the height of *C. album* ranged from 30 to 95 cm depending on the time of the season and individual site differences. Even north of the Brooks Range, where germination occurred much later than south of the Brooks Range (where the dense populations were seen), *C. album* was observed at heights of up to 75 cm. The dense population plots were examined several times from 14 July 77 until 24 August 77, and it was observed that little growth (less than 5 cm) took place over that period of time, and no thinning out of individuals occurred. Apparently genetic differences, if present, were not being expressed. Despite the stunted growth and density of the populations, *C. album* was setting seed in these areas.

Table 7. Population data for weeds and weedy species along Alyeska Haul Road (summer 1977).

Species	Number of individuals per m^2																						
Achillea borealis	3 SS	3 SS	1 SS	4 SS	12 SS	4 SS	13 SS	10 SS															
Achillea sibirica	3 SS	8 SS	19 SS	12 SS	8 SS																		
Chenopodium album	460 SS S	645 SS S	54 MS S	31 SS S	51 SS S	124 MS S	612 SS S	235 SS S	21 SS S	4 MS S	19 MS S	9 MS S											
Corydalis sempervirens	11 MS D	10 MS D	14 SS	26 SS	21 SS D	14 SS D	19 SS D																
Epilobium angustifolium	45 MS	54 MS																					
Hordeum jubatum	43 MS D S	21 MS D S	1 MS D S	12 MS D S	12 MS D S																		
Matricaria matricarioides	2 MS S																						
Polygonum alaskanum	7 SS	21 SS																					
Polygonum aviculare	3 MS	4 MS	5 MS	7 MS	9 MS	2 MS	22 MS	13 MS	2 MS	30 MS	3 MS	2 MS											
Polygonum convolvulus	10 MS S	1 MS S																					
Rorippa hispida	7 SS D	7 SS D	6 SS D	9 SS D	7 SS D	13 SS D	4 SS D	15 SS D	7 SS D	4 SS D	15 SS D	7 SS D	4 SS D	8 SS D	1 MS D S	1 MS							
Senecio congestus	9 SS D	7 SS D	6 MS D	7 SS D	32 SS D	26 SS D	9 SS D	27 SS D	27 MS D	12 MS D	14 SS D	5 MS D	9 MS D	10 MS D	10 MS D	5 MS D	7 MS D	11 MS D	8 MS D	2 MS D	6 MS D		

SS = single species stand
MS = mixed species stand
D = dispersal observed
S = straw present

The populations of *S. congestus* having 26-32 individuals/m^2 were also fairly dense. Because of the size of these plants, the cover of these populations ranged from 80-99%.

Seed collections are summarized in Table 8. Fewer seeds were available for collection north of the Brooks Range than south of it because of the less frequent occurrences, lower densities, and later germination and subsequent later seed maturation or failure to set seed. Two species in particular, *Chenopodium album* and *Achillea borealis*, were slow in setting seed, and collections of these species are sparse. Seeds of *Achillea borealis* were collected when not fully matured and may not be viable. Seed collections for *Capsella bursa-pastoris*, *Hordeum jubatum*, *Hordeum vulgare*, *Rorippa* species, and *Senecio congestus* were made over long distances along the road both north and south of

Table 8. Seed collections of weeds and weedy species along Alyeska Haul Road (summer 1977).

Species	Miles and kilometers north of Yukon River																														
	Mi	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300*
	Km	0	17	32	48	64	80	97	113	129	145	161	177	193	209	225	241	257	274	290	306	332	338	354	370	386	402	418	435	451	467	483
Achillea borealis																			i						i		i					
Achillea sibirica		i																														
Capsella bursa-pastoris			x										x						x												x	
Chenopodium album		x																	x								i					
Chenopodium capitatum		x																									x					
Corydalis sempervirens		x							x	x		x		x	x																	
Descurainia sophioides								x		x				x			x															
Hordeum jubatum		x	x			x					x		x			x			x								x		x			
Hordeum vulgare		x																	x					x								
Polygonum alaskanum				x			x		x																							
Rorippa hispida		x							x		x								x													
Senecio congestus		x		x	x				x	x																			x			x
Sisymbrium altissimum			x																													

x = mature seeds collected

i = immature seeds collected

* No species observed beyond 300 miles north.

the Brooks Range and, hopefully, these will be useful for germination tests.

The extension of range of several native species was observed. Several other species are also being examined for possible range extensions. *Achillea sibirica*, which had been recorded only as far north as the Brooks Range, was observed at site K-75 (in MS 127-2) which is 482.6 km north of the Yukon River or roughly 160 km north of the Brooks Range. This material site was reseeded and observed growth of grasses in 1977 covered 19% of the area. *Achillea sibirica* was healthy and flowering there. Its occurrence at the site appears to be directly related to haul road activities because it was present only in the seeded area of this material site.

Chenopodium capitatum was previously recorded about as far north as the Yukon River. It was observed in summer 1977 at several sites north of the Yukon: at site K-98 located at 5-mile Camp, about 7.2 km north of the Yukon, and in MS 79-2, about 13.5 km north of the Yukon. *Chenopodium capitatum* was also fruiting and dispersing at K-61, which is 411 km north of the Yukon River. This site is a small revegetation area on the west side of the road a few meters north of 121 APL AMSL. The cover estimated for *Chenopodium capitatum* at this site was 1-19%.

Corydalis sempervirens was recorded in central Alaska south and just north of the Yukon River. This species was observed repeatedly in disturbed areas along the road up to 240 km north of the Yukon River and was present in 10 of the permanent transects. It appears to be successful in these disturbed areas, presumably occurring for the second year at some sites because it shows both the rosette and flowering forms typical of its biennial growth habit. *C. sempervirens* was also observed and photographed at site K-10 (208.5 km north of the Yukon) where it was growing and dispersing approximately 10 m beyond the revegetation area in natural vegetation. It was also observed in disturbed areas where no apparent revegetation had been undertaken, such as at site K-6 which is 194.2 km north of the Yukon. Apparently this species has already begun migrating along the road.

Hordeum jubatum, which occurs throughout much of Alaska south of the Brooks Range, extended its range north along the Haul Road as far as site K-68, 517.5 km north of the Yukon River. Site K-68 is a small revegetation area with straw mulch present. *H. jubatum* is seen fairly consistently from this site to the Yukon. This species is probably migrating along the Haul Road by means of its wind-dispersed, mobile seeds.

These range extensions over impressive distances show how weedy species may be spread through the activities of man to new locations where they may invade and reproduce.

Observations comparing the 11 sites where second year observations were made in 1977 are summarized in Table 9. *Chenopodium album*, *Achillea borealis* and *Hordeum jubatum* reappeared in 1977 in nearly every site where they were observed in 1976. They appear to be reproducing successfully. It will be interesting to see whether they persist, and if so,

Table 9. Two-year comparison of species in selected sites along Haul Road.

Site I. Location: culvert 503+72, 1.4 miles (2.3 km) north of Benchmark Y155. Large revegetation area, no straw.

1976	1977
grasses	grasses
no weeds	no weeds

Site II. Location: near Benchmark M148. Roadside ridge, seeded, covered with straw.

1976	1977
Chenopodium album	*Chenopodium album*
Achillea sp. (one leaf)	—
Plagiobothrys sp.	—

Site III. Location: winter trail crossing the road near the pipeline crossing just south of Old Man (Larry Johnson site 2).

1976	1977
grasses	grasses
Plagiobothrys hirtus	*Plagiobothrys hirtus*
Plagiobothrys cognatus	*Plagiobothrys cognatus*
--	*Matricaria inodora*
--	*Thlaspi arvense*

Site IV. Location: No Name Creek. Straw present in 1976.

1976	1977
Chenopodium album	*Chenopodium album*
Hordeum jubatum	*Hordeum jubatum*
Avena sativa	—

Site V. Location: just north of MS 194-1. Straw present in 1976.

1976	1977
Hordeum jubatum	*Hordeum jubatum*
Chenopodium album	*Chenopodium album*
Achillea sp.	*Achillea borealis*
Rumex sp. (?)	*Rumex acetosa*
Barbarea sp.	—
	Matricaria inodora

Table 9 (cont'd). Two-year comparison of species in selected sites along Haul Road.

Site VI. Location: culvert 3058 + 25. Seeded in 1975.

1976	1977
grasses	grasses
Achillea sp.	Achillea borealis
Hieracium sp. ?	—

Site VII. Location: culvert 2809 + 90. At DS 104. Straw present in 1976.

1976	1977
Hordeum jubatum	Hordeum jubatum
Chenopodium album	Chenopodium album
Descurainia sophioides	Descurainia sophioides
Avena sativa	—
Amsinckia sp.	—
Barbarea sp.	—
Rorippa sp. ?	—
Polygonum convolvulus	—
--	Hieracium sp.
	Achillea borealis

Site VIII. Location: Benchmark S156. Small reveg. site east of road.

1976	1977
Chenopodium album	Chenopodium album
Polygonum convolvulus	--

Site IX. Location: Benchmark S155. Near culvert 781 + 56. Straw present in 1976, seeded in 1975.

1976	1977
Descurainia sophioides	—
Capsella bursa-pastoris	--
Crucifer	--
Achillea sp.	--
Rorippa sp. ?	—
Polygonum convolvulus	--
Plagiobothrys sp.	--
Chenopodium album	Chenopodium album

Table 9 (cont'd)

Site X. Location: culvert 543 + 00. Three bales of straw present in 1976, weeds were growing out of bales. Straw present in 1977.

1976	1977
Avena sativa	Avena sativa
Hordeum sp.	Hordeum vulgare
Chenopodium album	Chenopodium album
	Hordeum jubatum

Site XI. Location: Benchmark T154, near CRREL site 122-1A.

1976	1977
Thlaspi arvense	—
Plagiobothrys sp.	Plagiobothrys hirtus

for how long, at these sites. Other species also reappeared in some sites last summer, including *Plagiobothrys cognatus, P. hirtus, Descurainia sophioides* and *Avena sativa* but with less consistent success. Other species were not present in 1977 at the same sites as in 1976 because of their failure to reproduce successfully. These species include *Barbarea* sp., *Amsinckia* sp., *Polygonum convolvulus, Capsella bursa-pastoris,* and *Thlaspi arvense.* It was observed that at site XI as well as at other sites along the road, stalks from last year's growth of *Thlaspi arvense* remained standing with their silicles still intact. Their seeds were not dispersed. These seeds were collected at a few sites to run germination tests to determine if any of the seeds are still viable. More will be known about the reproductive success of the weeds and weedy species after the field season of 1978.

Much of the phenological data remain to be analyzed. Table 10 lists the species which were dispersing seeds during 1977 by 24 August. These species may have the potential to germinate in 1978, depending upon the viability of their seeds and other factors. North of the Brooks Range, dispersal was observed for *Chenopodium capitatum, Hordeum jubatum, Hordeum vulgare,* and *Senecio congestus.* A few other species, including *Achillea borealis, Avena sativa, Capsella bursa-pastoris, Descurainia sophioides* and *Rorippa hispida,* had nearly matured fruits, and may have dispersed viable seeds before being killed off by frost in late August or September.

Table 10. Species observed dispersing seeds in 1977 along Haul Road.

Avena sativa	Camelina sativa
Capsella bursa-pastoris	Hordeum vulgare
Chenopodium capitatum	Rorippa spp.
Corydalis sempervirens	Senecio congestus
Descurainia sophioides	Sisymbrium altissimum
Hordeum jubatum	Thlaspi arvense

Obviously, some of the species of weeds and annual native species are capable of setting seeds despite the short growing season. Thus, it may be possible that some will be perpetuated from year to year for a few years. Some species may also be perpetuated by means of vegetative reproduction.

The successional data collected in 1977 have not yet been analyzed. All the native species in Table 4 were observed invading plots in the seeded disturbed areas and in some bare areas. Approximately 65 of the permanent sites had natives invading the disturbed area plots. The continued invasion of native species over the next two years will be followed in these plots to learn more about succession of native species in both seeded and bare disturbed areas.

Literature Cited

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PROJECT 2. VEGETATION MAPPING AND RESPONSE TO DISTURBANCE ALONG THE YUKON RIVER-PRUDHOE BAY HAUL ROAD

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Summary

The vegetation research along the complex elevational and latitudinal gradient between the Yukon River and Prudhoe Bay in 1977 has been in part a continuation of the work accomplished in 1976. Several new subprojects were initiated in 1977; these include a "mile-by-mile" vegetation survey, a study of recovery rates following disturbance, a dust impact study, and an oil spill study.

The 1977 field achievements can be summarized as follows: 120 stops for the "mile-by-mile" survey were made and these sites analyzed for vegetation and environmental variables; seven new vegetation maps were prepared at a scale of 1:6000; 354 10- by 10-m plots were established and documented; 70 sites were analyzed for the disturbance study as well as the same number of undisturbed vegetation stands; 58 additional sites at significant points along the Haul Road were also sampled for vegetation and environment. An extensive collection of material for the Haul Road effects study was made. A recent oil spill was visited and the response of vegetation to the disturbance examined.

Only some of the data collected are included in this report. A small part of the data for the "mile-by-mile" survey was plotted in order to assess the value of the collected data. It is possible to conclude, on the basis of the data examined thus far, that the information gathered in 1977 is valuable and that it will contribute effectively to the achievement of the overall objectives of the project.

Our primary 1978 summer objectives will be: continuation of the "mile-by-mile" survey on a more detailed level, further vegetation mapping and revisiting of established and documented sites, location of additional permanent study sites, and further development of the data base for the study of vegetation recovery rates.

Subproject 1

"Mile-by-mile" description of landforms and vegetation between the Yukon River and Prudhoe Bay.

Objective

Describe major forest and tundra types on this transect.

Progress

The field work for the first stage of this subproject was completed during the past summer. A total of 120 stops were made along the Haul Road at 5-km intervals because it was impossible to make a literal "mile-by-mile" survey due to time and logistic constraints. At each stop, vegetation and environmental variables, including soils, were described and photographs of each stop were obtained. The vegetation sampling method was that of the Braun-Blanquet school of vegetation analysis (Westhoff and van der Maarel 1973). The vegetation sample, or relevé, consists of a cover estimate for each plant taxon present in a subjectively selected, uniform vegetation stand. The locations of the stops for the "mile-by-mile" survey are found on the appended CRREL Haul Road maps. Table 1 gives some of the values for selected factors which were estimated at each stop.

An elevational and latitudinal profile of the Haul Road is shown in Figure 1a for correlation with the distribution of selected factors (Fig. 1b, 1c, 2, 3 and 4), and with the climatic factors of Haugen, 1975 (Fig. 1d).

Preliminary analysis of results indicates that distinct patterns exist between the distribution of both plants and other variables and that these patterns can be related to the elevational and latitudinal complex environmental gradients. It is possible to conclude that the collected data set is appropriate and sufficient for the achievement of the first stage of this subproject: description of the vegetation along the Haul Road transect at definite intervals. Data from additional sites, sampled along the Haul Road at significant points (Table 2), and data provided by subprojects 3 and 4 will be utilized during the second stage. This second stage includes the description of major forest and tundra types along the Haul Road transect. A list of vascular plants from the survey is available separately.

Immediate activities

1) Complete plant identification, 2) develop a list of plants which have been determined (in conjunction with subproject 4), 3) conduct partial soil analysis of the collected samples, 4) plot the distribution of significant plants and other variables, and 5) compare our results with environmental and other studies along the Haul Road.

Subproject 2

Revisiting the ten 1976 map and permanent quadrat sites along the Haul Road.

Objective

Revisit plots to observe any obvious changes that have occurred in the past year.

Table 1. Selected estimated variables for each station of the Haul Road transect.

Stop number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
km from Yukon River	0	5	7.6	14.5	20	25	30	35.2	40	45	50	56.3	60	66	70.2	75	80.4	83.0	90	95	100	105	110	115	120	125
Relevé number	134	327	326	325	324	323	322	126	321	320	159	319	318	94	317	316	314	313	312	311	310	309	108	308	307	305
Elevation, m s.m.	100	150	200	183	233	183	217	183	283	400	583	533	576	666	466	450	416	650	333	433	533	366	283	333	533	366
Slope aspect	S	.	W	.	S	SW	.	.	.	.	.	N	S	SE	SE	E	E	NE	E	NNW	NW	W	.	W	W	N
Slope inclination, °	3	0	2	0	7	3	0	0	0	0	0	2	2	3	3	2	2	4	2	4	4	2	0	2	2	2
Scale - moisture site (1-10)	6	6.5	5	6	4	5	5	4	5	5	3.5	4	6	5	5	3.5	3.5	4	5.5	5.5	6	6	4	3.5	3.5	6.5
- moisture soil (1-10)	6	6	5	6	4	4	5	4	4	4	3.5	3.5	5.5	7	6	3.5	3.5	4	5.5	6	6	5.5	5	4	4	6.5
- temperature (1-10)	5	4	5	4	6.5	5	5	5	5	5	6.5	5	6	6	5	6	6	4	5	4	4	5	4	4	4	4
- snow (1-10)	6	5	5	5	5	5	5	5	5	5	4	5	5	4	5	5	4	6	5	6	6	5	6	5	6	5
- wind (1-10)	6-7	5	5	5	5	5	5	4	5	5	7	4	4	7	6	5	6	6	6	6	6.5	6	4	6	6.5	6
- surface age (1-10)	3	7	6	7	8	7	8	5	8	8	8	8	7	8.5	8	7.5	9	8	8	8.5	9	7	4	9	8	7
- stability (1-10)	2	9	7.5	8.5	8.5	8	8	6	9	8	8	8.5	8.5	8	9	3.5	7	8	8	8.5	8.5	8	7	8	8	7
- cryoturbation (1-10)	0	4	1	8	3	1	2	8	3.5	4.5	0.5	7	6	6	7.5	3	3	3	7	8	8	7	1	1	1	7
Cover - vegetation, %	60	98	100	100	98	90	97	95	97	98	100	97	97	95	95	85	95	100	100	100	100	100	95	97	100	100
- trees, %	35	40	95	80	35	80	80	3	70	60	5	40	40	0	0	35	8	2	0	0	0	7	60	40	2	1
- shrubs, %	10	30	18	5	15	6	5	25	6	10	75	50	45	18	10	10	55	65	30	30	35	35	15	4	35	5
- herbs, %	30	30	12	60	30	15	18	85	45	30	30	30	30	50	60	65	40	60	90	85	70	85	65	20	65	90
- cryptogams, %	15	80	15	60	30	65	75	8	45	70	70	70	65	65	65	18	80	40	25	35	75	35	80	85	60	30
- litter, %	12	15	80	8	40	22	6	5	12	10	15	25	13	8	8	12	12	10	20	12	12	11	10	20	8	7
- rock, %	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	4	0	0	0	0	0	0	0	0	0	0
- bare soil, %	35	1	2	0	2	2	2	3	2	0	0	3	2	3	2	7	2	0	0	3	3	1	0	2	1	2
- water, %	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Height - trees, m	13	7	15	6.5	21	20	10	0.7	3.2	7	4	10	12	0	0	6	6	2.3	0	0	0	1.2	22	9.5	5	1
- shrubs, m	2.5	2.3	0.5	0.5	4	6	2	0.5	0.7	2	1.3	2	2	0.3	0.8	2.3	1.4	1.0	0.25	2	1.2	2	0.45	5	1.1	1
- herbs, cm	35	30	15	25	18	12	32	18	20	35	18	20	17	14	13	28	16	15	18	25	20	30	38	25	22	18
- cryptogams, cm	1	3	2	4	2	2	3	3	4	4	3	4	4.5	3	3	1.2	2	2	2	3	3	3	2	3	3	3
Depth of thaw, cm	150	75	125	34	80	105	103	30	75	45	65	75	70	23	50	55	78	125	60	45	37	138	100	50	105	35
Surface horizon - depth, cm	60	20	1.5	33	5	5	5	30	10	20	7	2	12	16	40	2	2	13	45	30	35	7	2	2	11	30
Biomass scale - overall (1-10)	4	6.5	8	7.5	9	8.5	7.5	4.5	7.5	7.5	4.5	7.5	7.5	3	4.5	6.5	6	5.5	5	5.5	5	5.5	9	6	3.5	4
- trees (1-10)	3.5	4.5	8.5	7.5	9.5	8.5	7.5	1	6.5	6.5	1	5.5	5.5	0	0	4	1	0.5	0	0	0	1	8	5	0.5	0.5
- shrubs (1-10)	2	4	1.5	0.5	2	0.5	0.5	2	0.5	1.5	7	6	5.5	2	1	2	6	7	2.5	4	4	4	2	0.5	3.5	0.5
- herbs (1-10)	4	4	1.5	7	3.5	2.5	2.5	8	5.5	4	4	4	4	4	6.5	7	4.5	7	9.5	9	7.5	3	6	3	7.5	9
- cryptogams (1-10)	1	9	1.5	7.5	3.5	7	8.5	2	5.5	8	8	8	7.5	7	7.5	2	8.5	4.5	3	4	8	4	7.5	8.5	7.5	3.5
Age of vegetation (estimate, years)	.	30	15	45	60	60	40	.	30	.	35	60	60	.	.	60	40	.	.	20	15	18	80	50	30	.
Vertebrate scale - caribou (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- moose (0-3)	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
- lemming (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- ptarmigan (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- squirrel (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- bear (0-3)	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Insect scale (1-10)	2.5	0	3	0	0	0	0	1	0	0	1.5	0	3	1	0	0	0	0	0	2	1	0	5	0	0	0

Table 1 (cont'd). Selected estimated variables for each station of the Haul Road transect.

Stop number	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
km from Yukon River	131.8	135	141.5	145	150	155	160	164.5	168.5	175	181.5	185	191.5	195	199.5	205	210	215	220	225	230	234	240	245
Relevé number	304	303	302	301	300	299	298	297	295	294	293	292	291	290	288	58	287	286	285	284	283	282	280	279
Elevation, m s.m.	316	316	366	366	383	400	466	500	366	350	316	350	333	350	350	366	366	383	383	400	400	400	433	466
Slope aspect	.	.	.	.	.	N	SW	W	.	.	W	.	.	.	.	W	.	.	.	.	.	W	.	.
Slope inclination, °	0	0	0	0	0	1	18	2	0	0	4	0	0	0	0	3	0	0	0	0	0	4	0	0
Scale - moisture site (1-10)	6	6	6	6	6.5	6	4	6	6	6	5	6.5	4	6.5	5.5	5	4	6	4.5	5	6	6	5.5	6
- moisture soil (1-10)	6	6	6	6	6.5	6.5	4	6	6	6	6	5.5	4	5.5	6	5	4	5.5	4.5	5	6.5	6	5.5	6
- temperature (1-10)	4	3.5	4	4	4	5	6	5	5	5	5	5	6	5	5	5	6	5	5	5	5	5	4	5
- snow (1-10)	5	6.5	6	6	6	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	5
- wind (1-10)	6	5	5	4	6	6	5	5	6	6	6	6	5	5	5	5	5	5	5	5	5	5	5	5
- surface age (1-10)	7	2	8	7	4	6.5	3	7	8	7.5	7	7	5	7	7	8	8	6	6	6	7	7	2	5.5
- stability (1-10)	8	3	8	7	7	7	4	7	8	7.5	7.5	7	6	8	8	9	8	7	7.5	6	7	7	3	7
- cryoturbation (1-10)	7.5	3	8	8	7.5	8	1	7.5	6.5	8	7	3	2	7	7	3	1	2	2	7	2	8	0	7
Cover - vegetation, %	100	100	100	100	100	100	95	95	95	95	98	98	90	100	100	100	95	95	85	95	95	100	75	95
- trees, %	35	0	60	40	3	0	5	20	3	0	10	4	35	18	35	60	35	30	55	0	18	0	0	20
- shrubs, %	2	85	5	5	30	6	90	30	5	18	25	85	6	12	10	2	6	10	18	80	5	55	60	15
- herbs, %	90	40	75	70	75	95	35	75	75	90	80	40	35	90	69	60	25	60	30	18	55	75	18	85
- cryptogams, %	30	15	50	80	40	12	25	30	40	15	60	40	65	25	75	95	85	30	30	60	45	35	18	30
- litter, %	3	40	25	5	15	25	80	12	10	15	10	12	65	8	10	8	10	7	30	12	18	10	15	10
- rock, %	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- bare soil, %	2	0	2	0	2	3	3	2	2	5	0	0	10	0	0	0	3	5	5	5	3	3	50	10
- water, %	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Height - trees, m	1.8	0	4.3	4.5	0.8	0	8	4	1.8	0	4	4	16	4.2	8	6	6.5	6	8	0	7	0	0	3.5
- shrubs, m	0.4	1.5	0.3	0.5	0.9	0.2	7.5	0.9	0.3	0.3	0.6	1.5	2	0.5	0.75	0.75	1	0.7	0.75	0.9	0.4	0.9	1	1
- herbs, cm	15	25	19	30	15	15	35	15	12	13	15	25	18	18	9	12	8	22	17	20	16	15	25	15
- cryptogams, cm	3	2	3	4	3	2	1	2	2.5	2	3	3	1.5	3	3	4	2	1.5	1	2	2	2	1	2
Depth of thaw, cm	54	70	55	45	28	45	60	38	55	42	33	100	90	45	69	65	60	75	65	31	80	26	100	135
Surface horizon - depth, cm	12	3	24	30	28	20	3	17	40	40	30	6	2	35	8	3	2	5	4	30	2.5	13	9	9
Biomass scale - overall (1-10)	5.5	5.5	7	7	5	4	8	6.5	4	3.5	6.5	6.5	6.5	6.5	6.5	7	6.5	6.5	7.5	5	6	5	3.5	6.5
- trees (1-10)	3	0	5.5	4	0.5	0	1.5	4	0.5	.	1.5	0.5	3.5	2.5	4	6	4	3.5	6	0	2	0	0	2
- shrubs (1-10)	0.5	8	0.5	0.5	3	0.5	9.5	3.5	0.5	1.5	2.5	8.5	1	1	1	1	1	1.5	1.5	7	0.5	5	5	1.5
- herbs (1-10)	8.5	5	8	8	8	9	4	8	8	9	8	5	4	9	7	5	3	7	3	2	6	7	2	8
- cryptogams (1-10)	4	1.5	6	9	5	1.5	2	3.5	5.5	2	7	5	7	3.5	8	9	8	3.5	3	6.5	5	4	1.5	3.5
Age of vegetation (estimate, years)	20	10	35	30	.	.	25	30	.	.	30	.	.	.	40	.	.	30	30	20	50	.	11	45
Vertebrate scale - caribou (0-3)	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	2	1	2	1	0	0	0	0
- moose (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	2	0
- lemming (0-3)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
- ptarmigan (0-3)	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
- squirrel (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- bear (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Insect scale (1-10)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	2

Table 1 (cont'd).

Stop number	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73
km from Yukon River	249.7	255	260	265	270	275	280	284.6	290	296	300	305	310	314.5	320.5	324.5	330	335	340	345	349	354	360	365
Releve number	278	277	276	275	274	273	272	271	269	268	267	265	263	262	260	258	257	256	255	254	253	251	250	249
Elevation, m s.m.	500	566	600	616	666	700	733	866	850	1100	1133	1466	1333	1166	1033	1000	1000	916	933	900	933	1000	1000	933
Slope aspect	.	W	W	W	.	.	NW	W	NW	E	E	S	W	E	W	.	W	W	W	.	SW	SW	SW	W
Slope inclination, °	0	2	8	4	0	0	4	17	4	4	2	29	3	3	2	0	3	2	2	0			3	1
Scale - moisture site (1-10)	6	5.5	4.5	5	5.5	7	5.5	6	5	6	7	3.5	5	5.5	4	6.5	5	6.5	5	5		4.	5	4
- moisture soil (1-10)	6	5	4.5	5	5	7	5.5	6.5	5.5	6	6	4	5	5.5	4	6.5	5	6.5	4.5	5.5	4	5	5.5	4
- temperature (1-10)	4	5	5	5	4	4	4	4	4	4	4	3	3.5	4	4	4	4	4	4	4	4	5	4	4
- snow (1-10)	5	5	5	5	6	6	6	5	6	6	6	7	6	6	5	6	5	6	6.5	5	5	5	5	5
- wind (1-10)	6	6	6	5	5	6	6	6	6	6	6	6	6	6	6.5	6	6	6	6	5	6	5	6	6
- surface age (1-10)	5	6	7	6	2	3	4	5	5	5	3	4	5	6	7	4	5	5	4	5	6	7	8	9
- stability (1-10)	6.5	7	7	7	2	4	6	3.5	6.5	6	2	3.5	6	7	8	4	6	6	5	6	7	7	7	8
- cryoturbation (1-10)	8.5	7	6	7	0	1	6	6	6	7	1	2	2	7	1	6	4	5	5	7	6	7	7.5	6
Cover - vegetation, %	100	98	95	90	60	95	95	97	95	95	75	60	100	93	95	95	90	90	95	95	95	97	95	90
- trees, %	0	20	30	18	0	5	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- shrubs, %	30	6	8	10	55	35	15	45	25	40	60	0	0	18	25	40	2	45	1	3	18	50	50	0
- herbs, %	90	85	65	75	10	60	55	60	65	65	30	45	85	88	55	65	85	65	90	85	80	50	55	80
- cryptogams, %	25	25	45	30	5	65	85	45	50	80	40	35	45	30	65	80	20	75	18	25	30	15	40	35
- litter, %	15	8	6	12	40	15	15	20	8	5	45	2	18	0	5	25	12	18	20	10	15	30	25	15
- rock, %	0	0	0	0	0	0	0	0	0	0	0	40	0	0	8	0	0	0	0	0	0	0	0	0
- bare soil, %	0	4	5	3	60	7	5	8	5	5	15	5	0	0	5	5	8	8	5	10	8	12	7	5
- water, %	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Height - trees, m	0	5	7	5	0	1.5	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- shrubs, m	0.7	0.5	1.5	0.5	4	0.8	1	1	0.3	0.5	1.1	0	0	0.2	0.08	0.2	0.2	0.2	0.04	0.2	0.2	0.45	0.2	0
- herbs, cm	18	20	15	8	20	22	18	18	8	13	18	4	8	8	17	16	8	15	10	10	10	13	9	6
- cryptogams, cm	2	2	2	2	0.5	2	3	3	2	3	2	1.5	2	2	1	3	2	3	2	2	2	2	3	2
Depth of thaw, cm	28	28	45	35	120	95	80	90	55	36	80	70	60	70	60	34	55	32	58	60	63	52	32	65
Surface horizon - depth, cm	28	17	10	11	0	0.5	10	13	12	15	2	1	1.5	22	1	7	1.5	12	1	12	15	20	30	8
Biomass scale - overall (1-10)	5	6.5	6.5	6	4	6	6.5	6	5	6	6	2.5	5	5	3.5	6	4.5	6	4.5	5	5	5.5	5.5	4
- trees (1-10)	0	2	3.5	2	0	0.5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- shrubs (1-10)	2.5	1	1	1	6	4	1.5	4.5	2.5	3.5	6.5	0	0	1.5	1.5	3	0.5	3	0	0.5	1.5	4	4	0
- herbs (1-10)	8.5	8	7	7.5	0.5	6.5	5	6.5	6.5	6.5	2.5	3.5	7	7	4.5	6.5	7.5	6	8	7.5	7	4	4.5	7.5
- cryptogams (1-10)	3	3	5	3.5	0.5	7	9	5.5	5.5	8.5	4.5	3.5	5	4	5.5	8.5	2.5	8	2	3	4	2	5	4
Age of vegetation (estimate, years)	.	.	30	50	.	7	60	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Vertebrate scale - caribou (0-3)	0	0	0	0	0	0	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
- moose (0-3)	0	0	0	0	3	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
- lemming (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- ptarmigan (0-3)	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
- squirrel (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- bear (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Insect scale (1-10)	2	0	0	2	3.5	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 1 (cont'd). Selected estimated variables for each station of the Haul Road transect.

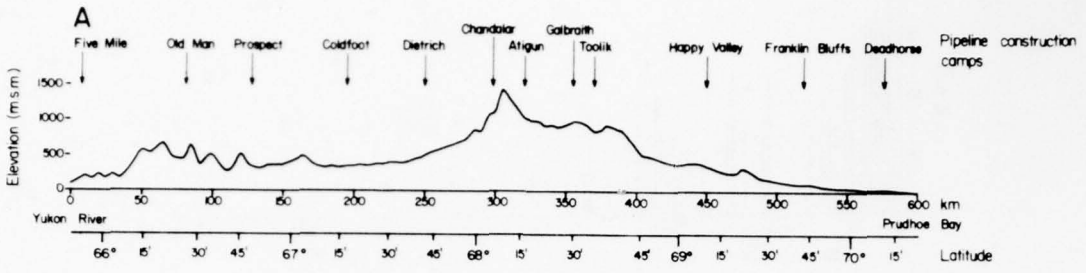
Stop number	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97
km from Yukon River	369.7	374.2	378.6	385	390	395	400	405	410	413.2	420	425	430	435	440	445	450	455	460	465	470	474.5	480	486.5
Relevé number	248	247	246	164	244	243	242	241	240	239	238	237	236	235	234	233	232	230	229	228	227	225	224	222
Elevation, m s.m.	833	866	933	900	866	733	616	500	500	450	433	400	386	366	400	400	350	333	283	250	266	333	300	233
Slope aspect	.	.	SW	.	S	E	E	.	.	.	.	N	.	S	N	S	.	NW	.	.	E	S	SW	.
Slope [illegible]lination, °	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	4	0	2	2	2	0	2	0	0	8	3	2	0
Scale - moisture site (1-10)	[illegible]	[illegible]	[illegible]	[illegible]	4.5	4.5	[illegible]	[illegible]	[illegible]	[illegible]	4.5	4.5	7.5	4.5	4.5	4.5	5	4.5	5	5.5	4.5	4.5	7.5	5
- moisture soil (1-10)	4	6.5	4.5	4.5	4.5	5	4	4.5	4.5	6.5	4	4.5	8	5	4.5	4.5	5	4.5	5	5	4.5	4.5	7.5	5
- temperature (1-10)	4	4	4	4.5	5	5	5	4	4	4	4	4	4	4	4	5	4	4	4	5	5	4	3.5	4
- snow (1-10)	5	5.5	5	6	5	5	5	5	5	5	5	6	5	5	5	5	5	5	5	6	5	6	7	5
- wind (1-10)	7	6	6	7	6	6	6	6	6	6	6.5	6	6	6	6.5	6	6	6	6	6	6	6	4	6
- surface age (1-10)	8	7	7	8	8	7	8	7	6	4	7	4	3	7	7	7	2	8	7	4	7	8	4	6
- stability (1-10)	8	7	7	8	8	7	8	7	7	5	7	6	4	7	7	7	2.5	7	7	5	7	7	4	7
- cryoturbation (1-10)	7	7	7	7	7	8	4	7	6	4	6	7	3	7	7	7	0	7	5	6	6.5	7.5	5	7.5
Cover - vegetation, %	95	85	98	95	97	85	90	97	96	95	95	96	85	95	97	98	75	95	95	85	95	98	96	100
- trees, %	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- shrubs, %	6	3	25	7	25	15	0	5	25	5	18	12	4	8	15	18	45	25	15	70	2	18	80	20
- herbs, %	90	80	80	85	70	80	80	95	88	75	90	85	75	90	90	90	40	90	75	50	80	85	70	80
- cryptogams, %	30	10	35	30	45	20	25	7	18	65	25	30	30	18	20	30	2	25	40	25	40	35	45	35
- litter, %	15	40	15	18	25	30	25	25	18	20	12	15	50	10	18	25	4	12	15	25	20	6	10	12
- rock, %	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0
- bare soil, %	8	10	0	5	0	10	10	5	5	2	5	10	10	10	4	4	10	5	5	10	5	3	0	3
- water, %	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	4	0
Height - trees, m	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- shrubs, m	0.2	0.15	0.2	0.08	0.2	0.2	0	0.2	0.3	0.4	0.2	0.5	0.5	0.2	0.25	30	2	0.2	0.5	0.8	0.2	0.2	1.2	0.35
- herbs, cm	9	18	8	10	10	10	8	10	10	18	6	10	45	8	9	12	30	10	10	10	10	8	35	10
- cryptogams, cm	2	2	3	3	3	2	1	2	3	3	2	2.3	3	2	2	2	1	2	2	2	3	4	4	3
Depth of thaw, cm	32	32	22	30	45	55	85	38	28	54	20	60	48	32	32	33	85	42	58	55	50	35	42	28
Surface horizon - depth, cm	8	30	18	6	8	25	12	12	25	30	20	6	40	15	15	15	0	7	9	15	3	15	30	18
Biomass scale - overall (1-10)	4.5	4.5	5	4	5	5	4	4	5	5	4.5	5	4.5	4.5	4.5	5	5.5	5	5	5.5	4.5	5	5.5	5
- trees (1-10)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- shrubs (1-10)	0.5	0.5	2	0.5	2	1.5	0	0.5	2.5	0.5	1.5	1.5	0.5	0.5	1	1.5	5.5	2	1.5	6.5	0.5	1.2	6.5	2
- herbs (1-10)	7.5	7	7	7.5	6.5	7	7.5	8	7.5	[illegible]	8	8	8	8.5	8	8	4.5	8	7	4.5	7.5	8	7	7.5
- cryptogams (1-10)	3	1.5	4.5	2.5	5.5	2.5	2	0.5	2	7.5	2.5	3.5	4	2	2	3	0.5	2.5	4	2.5	5	4.5	5	4
Age of vegetation (estimate, years)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Vertebrate scale - caribou (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- moose (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- lemming (0-3)	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
- Ptarmigan (0-3)	0	0	1	0	0	0	0	0	1	[illegible]	0	0	0	0	1	1	0	2	1	1	1	1	0	1
- squirrel (0-3)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
- bear (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Insect scale (1-10)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0

Table 1 (cont'd).

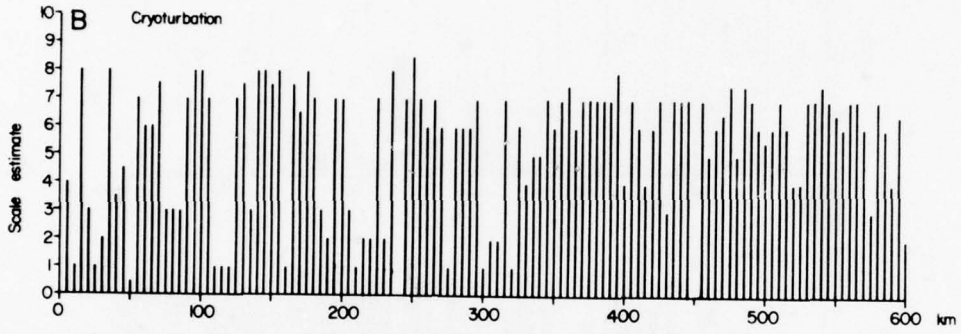
Stop number	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
km from Yukon River	488.2	495	500	505	510	515	520	525	530	535	540	545	550	555	560	565	570	575	580	585	590	595	600.8
Relevé number	221	220	219	218	217	216	214	213	212	209	208	207	206	204	203	202	201	200	194	199	198	186	195
Elevation, m s.m.	183	166	150	140	126	116	116	106	93	83	76	66	66	50	40	33	26	20	16	13	10	4	2
Slope aspect	.	.	.	E	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Slope inclination, °	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scale - moisture site (1-10)	5	5	4.5	4.5	5	4.5	5.5	6	4	4.5	5	5.5	4.5	5	5	6	5.5	4.5	4	6	4.5	7	4.5
- moisture soil (1-10)	5.5	5	4.5	4.5	5	4.5	5	6.5	4	5	5.5	5.5	4.5	4.5	5	6	5.5	4.5	4	6	5	6.5	4.5
- temperature (1-10)	4	4	4	4	4	4	4	4	5	4	4	4	4	4	4	4	5	4	5	3.5	4	3	3
- snow (1-10)	5	5	5.5	6	5	5	6	5	5	5	5	5	5	5	5	6	5	6	6	6	5	5	7
- wind (1-10)	6	6	6	6	6	6	6	6	6	6	6	6	6.5	6.5	7	7	7	7	7	7	7	8	8
- surface age (1-10)	6	6	6	6	6	6	7	6	6	6	6	6	6	6	6	6	6	4	7	4	4	7	1
- stability (1-10)	7	6.5	7	7	7	7	7	5	7	7	7	7	7	7	6	7	7	7	6.5	6	6	8	2
- cryoturbation (1-10)	7	6	5.5	6	7	6	4	4	7	7	7.5	7	6.5	6	7	7	6	3	7	6	4	6.5	2
Cover - vegetation, %	95	85	95	95	95	95	95	90	95	90	90	90	90	85	90	95	90	95	85	95	95	85	35
- trees, %	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- shrubs, %	3	2	4	4	5	4	18	1	2	7	8	5	7	5	3	7	5	2	2	0	1	0	0
- herbs, %	90	75	90	90	90	90	80	35	90	80	80	85	85	80	85	90	85	90	75	90	90	70	35
- cryptogams, %	15	20	15	12	15	18	25	80	18	25	30	16	15	10	10	15	18	50	35	20	18	25	0
- litter, %	18	25	15	12	25	18	15	10	10	15	8	10	10	12	20	15	15	25	15	20	20	9	8
- rock, %	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- bare soil, %	6	15	5	5	5	3	5	12	8	10	5	10	10	15	5	5	5	3	15	5	5	5	62
- water, %	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Height - trees, m	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- shrubs, m	0.2	0.2	0.25	0.25	0.25	0.25	0.3	0.15	0.15	0.2	0.3	0.2	0.2	0.25	0.2	0.18	0.2	0.1	0.05	0	0.05	0	0
- herbs, cm	12	13	8	8	13	11	4	17	9	10	9	11	10	10	13	17	18	15	11	16	12	7	3.5
- cryptogams, cm	2	1.5	2	2	2	2	2	3	2	2	2	2	1	1	1	1	2	1	1	1	1	1	0
Depth of thaw, cm	49	57	98	78	48	58	50	52	58	36	48	45	51	53	62	48	32	51	29	32	32	27	58
Surface horizon - depth, cm	25	18	20	2	25	1	1	25	1	4	25	25	25	1	25	25	5	0	20	25	25	20	5
Biomass scale - overall (1-10)	4.5	4	4.5	4.5	4.5	4.5	4.7	4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4	3.5	4	4	4	1
- trees (1-10)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- shrubs (1-10)	0.5	0.2	0.5	0.5	0.5	0.5	2	0.5	0.5	1	1	1	1	0.5	0.5	1	0.5	0.5	0.5	0	0.3	0	0
- herbs (1-10)	8	7	8	8	8	8	7	3.5	8.5	7.5	7.5	8	8	7.5	8	8.5	8	8.5	6.5	8.5	8.5	8	2.5
- cryptogams (1-10)	2	2	1	1	2	2	2	8	2	3	3	1.5	1.5		1	1.5	2	5	4	1.5	2	2	0
Age of vegetation (estimate, years)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Vertebrate scale - caribou (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1
- moose (0-3)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- lemming (0-3)	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
- ptarmigan (0-3)	1	0	0	0	0	0	1	0	0	1	1	1	0	0	1	1	0	1	0	0	0	0	0
- squirrel (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
- bear (0-3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Insect scale (1-10)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2. List of additional and significant points along the Haul Road at which vegetation and environment were analyzed.

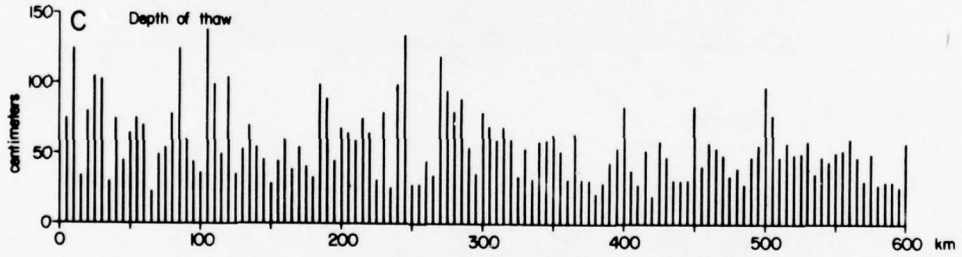
km	Relevé number	Site	km	Relevé number	Site
~10.0	326	Five Mile camp runway & crossing	320.0	260	Pipe crossing
14.5	325	CRREL 79-1	322.5	259	CRREL 111-1, Everett's map
20.0	324	Pipe crossing	324.5	258	CRREL 112-1A, Walker-Webber map 8
35.2	126	CRREL 82-1, Walker-Webber map 1A	345.0	254	Pipe crossing at Pump Station 4
40.0	321	CRREL 82-2	349.0	253	CRREL 114-1A, Walker-Webber map 9
56.5	319	CRREL 84-1	353.8	352	North end of Galbraith runway
70.2	317	Pipe crossing	354.0	251	Galbraith entrance
79.0	315	Old Man runway	~370.0	166	Toolik camp runway
80.4	314	Entrance Old Man	374.2	247	CRREL 117-1, Walker-Webber map 10
83.0	313	Pipe crossing	378.6	246	Pipe crossing
121.5	306	Gobbler's Knob, near shelter	380.0	245	CRREL 117-2, Everett's map
125.0	305	CRREL 90-1	385.0	164	Everett's dust site, Everett's map
131.8	304	Pump Station 5, near pit 91-3.1	405.0	241	CRREL 119A-1
141.5	302	Pipe crossing	413.2	239	Pump Station 3
164.5	297	Pipe crossing	425.0	237	CRREL 121-1
168.0	296	CRREL 96-2	435.0	235	CRREL 122-1A, pipe crossing
168.5	295	CRREL 96-1, Walker-Webber map 4	449.8	232	Happy Valley entrance
181.5	293	CRREL 97-1	452.0	231	CRREL 124-1A
191.5	291	Coldfoot entrance	473.5	226	CRREL 127-1, Walker-Webber map 12, Everett's map
198.0	289	CRREL 99-1			
205.0	58	Walker-Webber map 5A	474.5	225	Everett's dust site
234.0	282	CRREL 103-1, Walker-Webber map 6	482.3	223	CRREL 127-2
239.0	281	CRREL 103-3	486.5	222	CRREL 127-3
249.7	278	CRREL 104-1	488.2	221	Pump Station 2
275.0	273	CRREL 107-1	510.0	217	Everett's dust site
288.5	270	Treeline weather station, CRREL 108-1	519.0	215	Franklin entrance
290.0	269	CRREL 108-2, Walker-Webber map 7	532.0	211	CRREL 132-1, Walker-Webber map 13
296.0	268	CRREL 109-1	534.0	210	CRREL 132-2
314.5	262	Atigun entrance	552.0	205	Pipe crossing
			~580.0	194	Everett's dust site



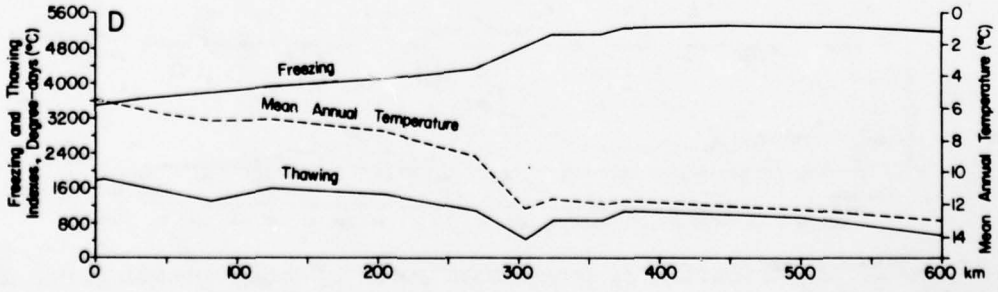
a. Elevation and latitude.



b. Cryoturbation.



c. Depth of thaw.



d. Freezing and thawing degree days and mean annual temperature (from Haugen 1975).

Figure 1. Distribution of various abiotic attributes along the Haul Road transect.

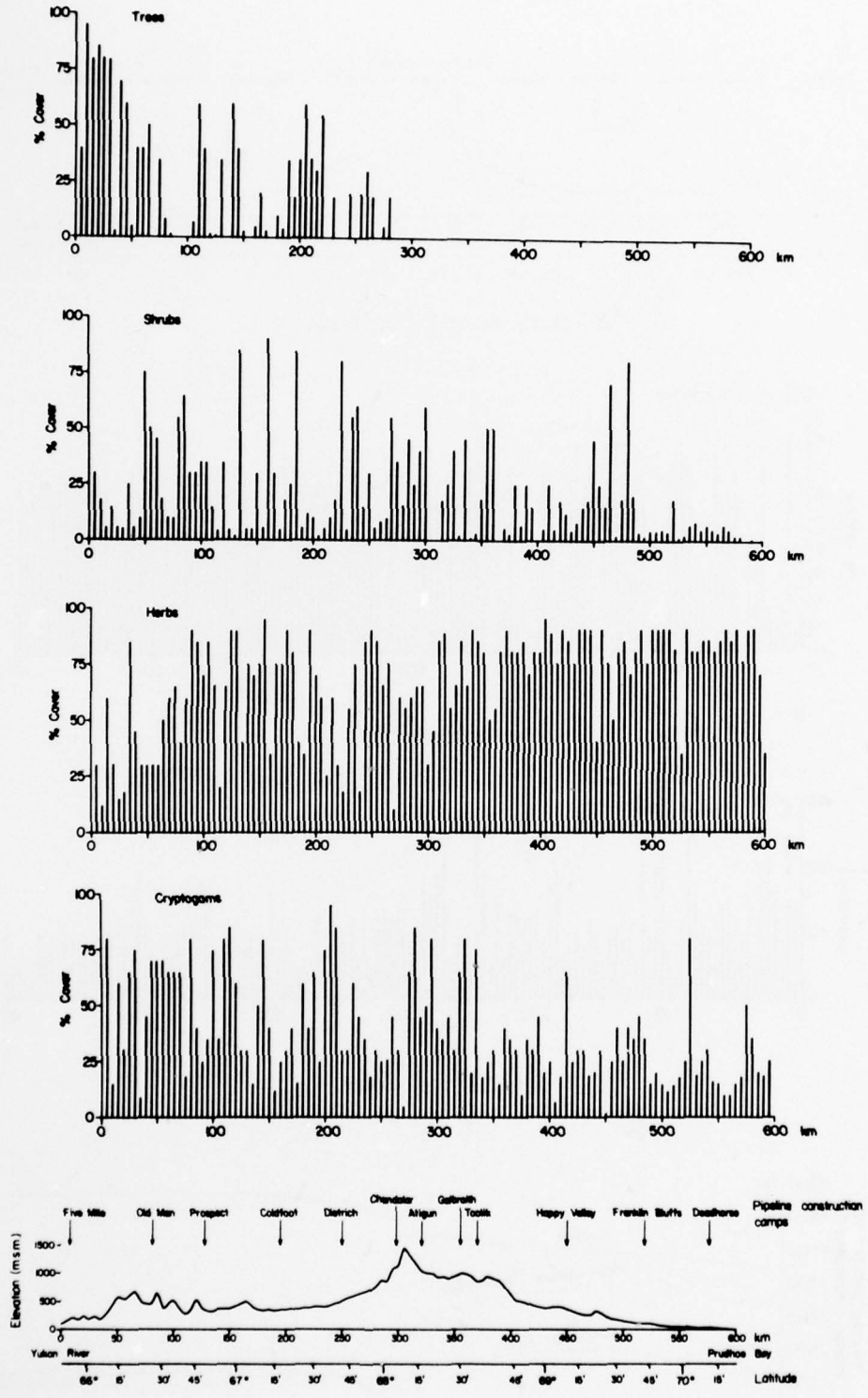


Figure 2. Distribution by percentage cover of major growth forms along the Haul Road transect. Trees are limited to the forested region in the southern part of the transect. Shrubs do not reach high cover north of the Brooks Range unlike herbs which do not reach high cover in many cases in the forest and shrub communities. The cover of herbs appears to be inversely related to the cover of cryptogams.

Figure 3. Distribution by percentage cover of selected plant taxa along the Haul Road transect.

The taxa are arranged according to their major growth form (tree, shrub, herb, cryptogam) and according to their distribution along the transect. The taxa restricted to the southern part of the transect near the Yukon River appear first, while taxa with an optimum in the coastal region near Prudhoe Bay appear last within their major growth form categories. Several types of taxa distribution can be recognized among the taxa plotted for this report.

Taxa with an optimum within the forested part of the transect which do not occur north of the treeline on the south slope of the Brooks Range. This group includes all trees (Picea mariana, Betula papyrifera, Populus balsamifera, Populus tremuloides, Picea glauca) and two other taxa (Rosa acicularis, Ledum palustre ssp. groenlandicum).

Wide-ranging taxa with an optimum in the forested region and a secondary optimum in the northern foothills of the Brooks Range, and with a gap in the Brooks Range (Alnus crispa, Rubus chamaemorus, Vaccinium vitis-idaea, Ledum palustre ssp. decumbens, Cetraria cucullata in part).

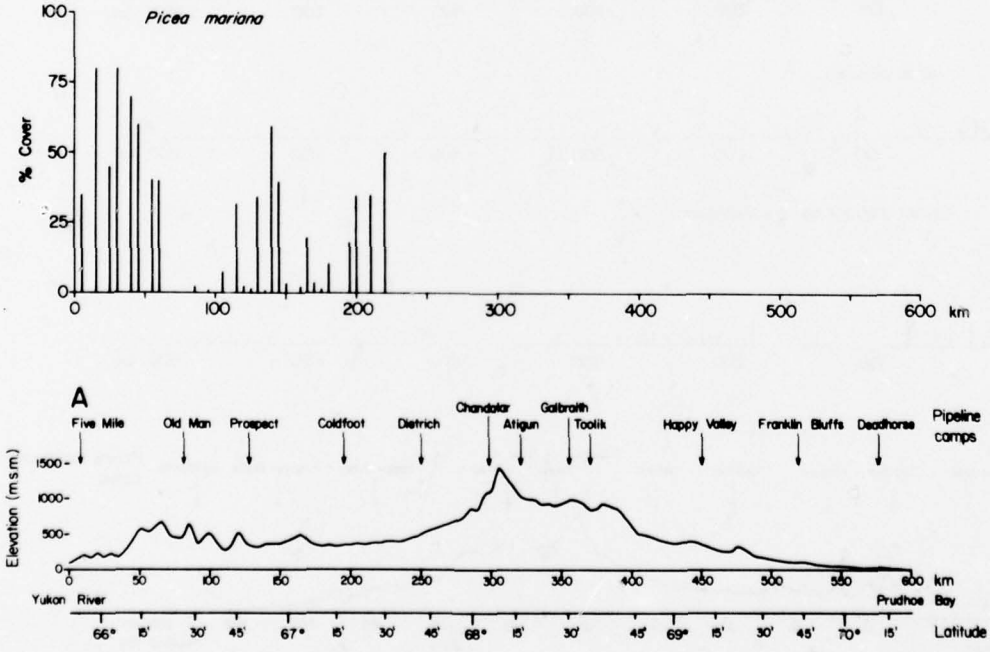
Wide-ranging taxa with an optimum north of the Brooks Range, a secondary optimum south of the Brooks Range, and a gap in the Brooks Range (Eriophorum vaginatum, Rhododendron lapponicum).

Taxa limited to the Brooks Range (Dryas octopetala).

Taxa with an optimum in the Brooks Range and on the coastal plain (Salix reticulata, Dryas integrifolia).

Taxa with an optimum in the Brooks Range and in its northern foothills (Dactylina arctica).

Taxa with an optimum on the coastal plain (Eriophorum angustifolium).



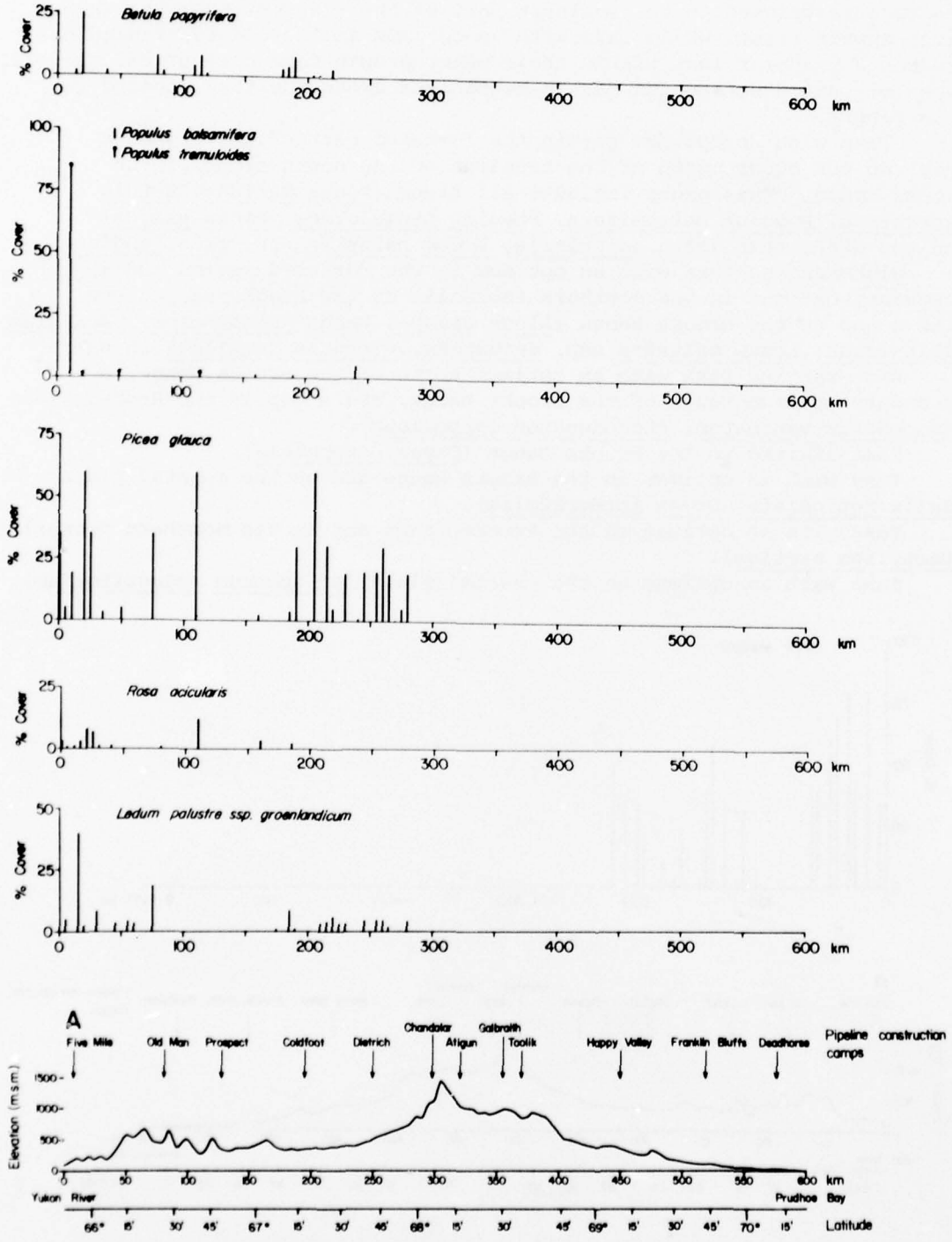


Figure 3 (cont'd).

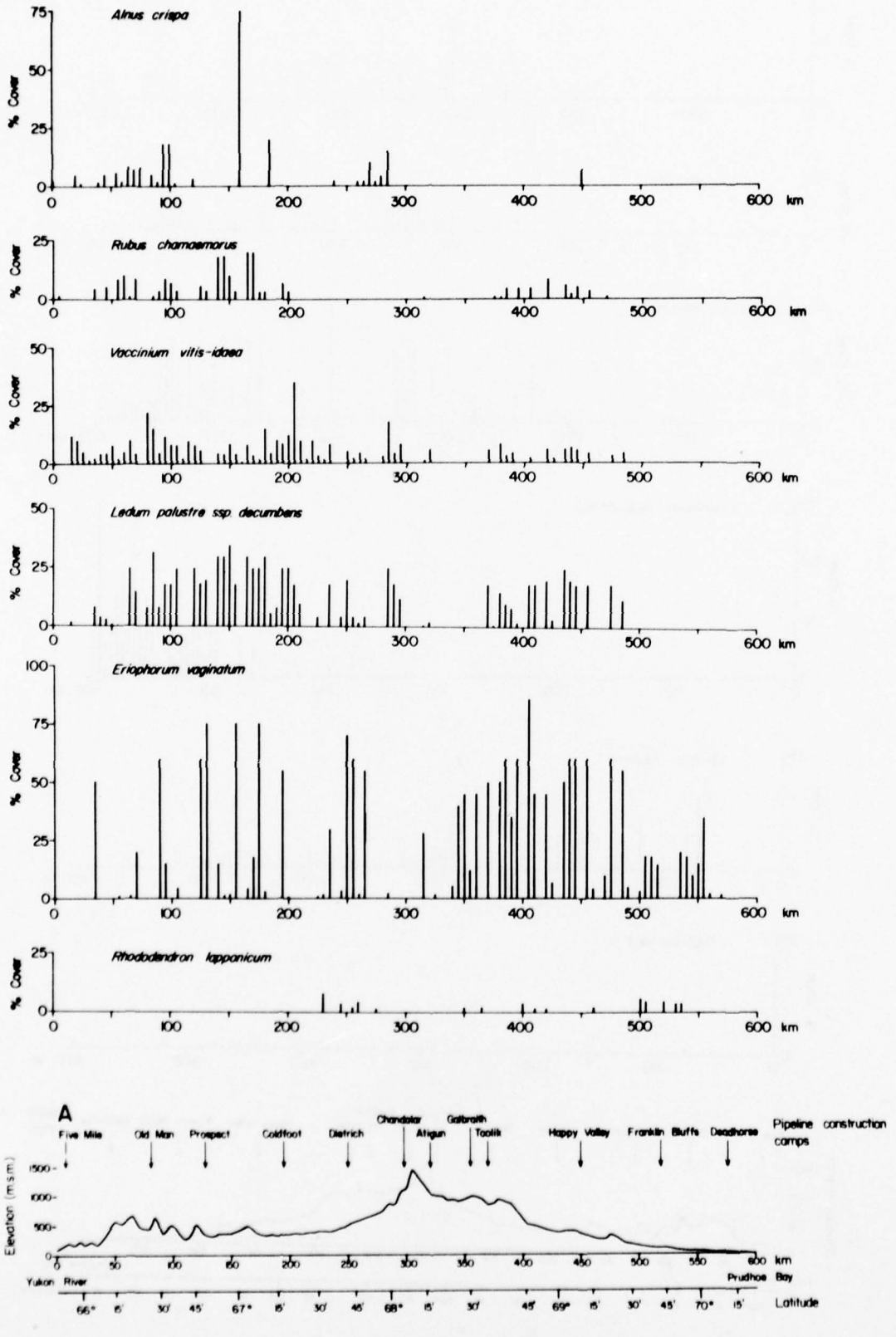


Figure 3 (cont'd).

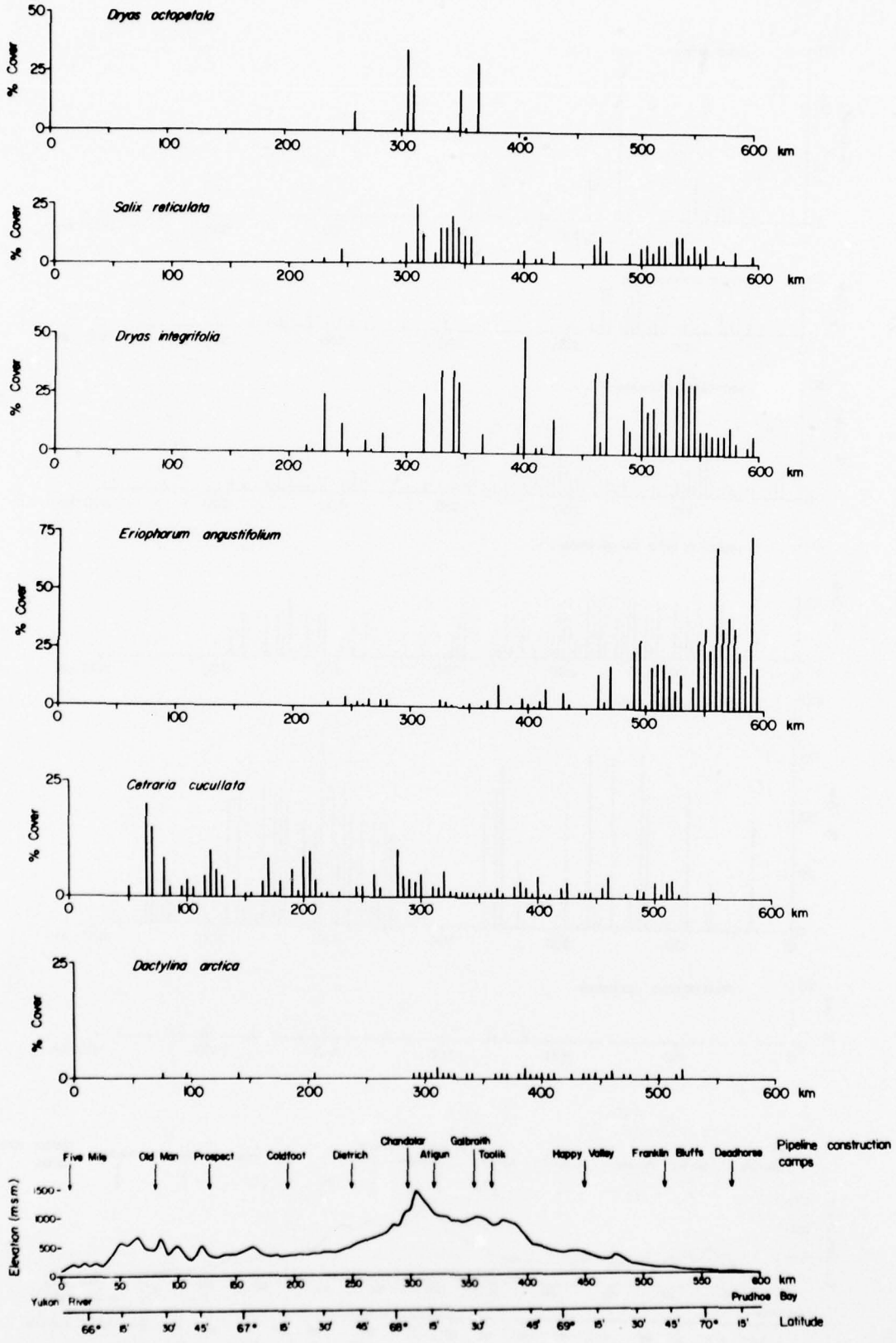


Figure 3 (cont'd).

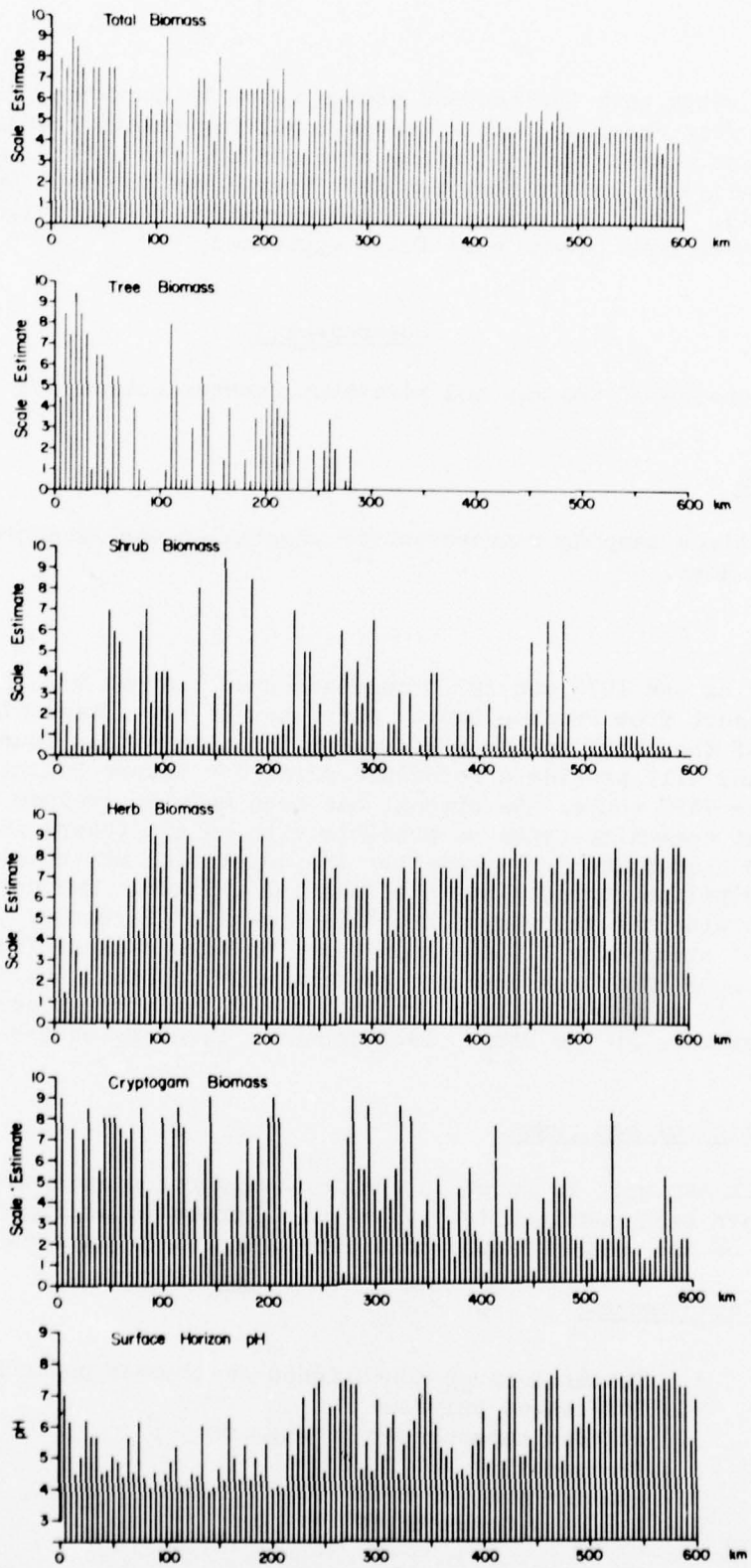


Figure 4. Distribution of biomass estimates and pH along Haul Road transects.

Progress

The sites were visited and photos taken to document visual changes. However, most changes, such as those involving relative abundance of lichens and mosses due to dusting or flooding, are subtle and it will be several years before they manifest themselves and thus become fully documented. We will revisit all the vegetation transect lines when the disturbances have become more fully expressed.

Subproject 3

Expansion of the map and permanent quadrat coverage by ten more sites.

Objective

Continue mapping representative vegetation and landforms along the Haul Road.

Progress

During the 1976 and 1977 field seasons 17 areas were mapped along the transect from Prudhoe Bay to the Yukon River. These sites are a sample of the total spectrum of vegetation communities found in the region and will provide a reference point for future botanical studies along the TAPS route. An attempt has been made to include as many different community types as possible with an aim toward an eventual detailed classification scheme for the vegetation of the entire region of the pipeline corridor north of the Yukon River. The maps, in conjunction with the relevés of the "mile-by-mile" inventory and the successional studies, will be a good base for such a classification. Table 3 summarizes the communities from all 17 sites thus far mapped. Each map is accompanied by a vegetation key and a brief description of the vegetation at the site. Each location is shown on the appended set of maps.

Explanation of map codes

Each map unit is based on the following coded information. These codes have been combined into units as illustrated in Figures 5-10. Details of the mapping approach are reported in Everett et al. (1978).

Relief feature

1. Featureless or non-aligned sedge-moss hummocks
2. Low-center polygons
3. Aligned hummocks or strangmoor
4. Frost boils
5. Small ridge, or hill
6. River or creek bluff

Table 3. Summary of vegetation communities appearing on the 17 vegetation maps along the Haul Road north of the Yukon River.

Site Name	Vegetation Communities
A. Prudhoe Bay-Coastal Site	1. DRY Cochleariopsis groenlandica ssp. arctica-Puccinellia phryganodes SPARSELY VEGETATED BEACH 2. DRY Salix rotundifolia-Ochrolechia frigida PROSTRATE WILLOW HEATH 3. MOIST Carex bigelowii-Ochrolechia frigida FROST ACTIVE TUNDRA COMPLEX 4. MOIST Dupontia fisheri-Cochleariopsis groenlandica ssp. arctica SALINE GRASS-FORB MEADOW 5. MOIST Carex aquatilis-Salix planifolia ssp. pulchra SEDGE MEADOW 6. MOIST Carex aquatilis-Salix planifolia ssp. pulchra; WET Carex aquatilis-Eriophorum angustifolium MEADOW COMPLEX 7. WET Carex subspathacea-Puccinellia phryganodes SALINE SEDGE MEADOW 8. VERY WET Arctophila fulva SHALLOW MARSH
B. Prudhoe Bay-Sand Dunes Site	1. DRY Leymus mollis ssp. villosissimus SPARSELY VEGETATED ACTIVE SAND DUNE COMPLEX 2. DRY Salix ovalifolia-Artemisia borealis SPARSELY VEGETATED SANDY FLATS 3. DRY Dryas integrifolia-Artemisia borealis DRYAS HEATH 4. WET Carex aquatilis-Dupontia fisheri SEDGE MEADOW 5. WET Carex aquatilis-Dupontia fisheri; DRY Carex aquatilis-Dryas integrifolia LOW-CENTER POLYGON COMPLEX 6. VERY WET Dupontia fisheri-Carex aquatilis SHALLOW MARSH 7. VERY WET Arctophila fulva DEEP MARSH
C. Franklin Bluffs-North	1. DRY Dryas integrifolia-Arctous alpina ssp. rubra PROSTRATE SHRUB HEATH 2. DRY Hedysarum alpinum ssp. americanum-Artemisia arctica SPARSELY VEGETATED GRAVEL BARS 3. DRY Salix alaxensis-Arctous alpina ssp. rubra DWARF SHRUB RIVER TERRACES 4. MOIST Carex bigelowii-Dryas integrifolia TUSSOCK MEADOW 5. MOIST Salix lanata ssp. richardsonii-Dryas integrifolia DWARF SHRUB SNOWBANK 6. WET Carex aquatilis-Drepanocladus brevifolius SEDGE MEADOW 7. WET Carex aquatilis-Drepanocladus brevifolius; DRY Dryas integrifolia-Arctous alpina ssp. rubra LOW-CENTER POLYGON COMPLEX 8. WET Carex aquatilis-Drepanocladus brevifolius; MOIST Carex bigelowii-Dryas integrifolia COMPLEX (Low-center polygons and aligned hummocks) 9. VERY WET Carex aquatilis-Scorpidium scorpioides; MOIST Carex bigelowii-Dryas integrifolia LOW-CENTER POLYGON COMPLEX
D. Franklin Bluffs-Oil Spill Site	1. DRY Dryas integrifolia-Arctous alpina ssp. rubra PROSTRATE SHRUB HEATH 2. DRY Salix alaxensis-Astragalus alpinus ssp. alpinus SPARSELY VEGETATED GRAVEL BARS 3. DRY Salix glauca-Arctous alpina ssp. rubra DWARF SHRUB RIVER TERRACES 4. MOIST Eriophorum angustifolium-Dryas integrifolia SEDGE DWARF SHRUB MEADOW 5. MOIST Salix lanata ssp. richardsonii-Carex aquatilis DWARF SHRUB RIVER TERRACES 6. WET Eriophorum angustifolium-Drepanocladus brevifolius; MOIST Eriophorum angustifolium-Dryas integrifolia COMPLEX (Low-center polygons, strangmoor, etc.) 7. VERY WET Carex aquatilis-Eriophorum angustifolium SHALLOW MARSH 8. VERY WET Arctophila fulva-Scorpidium scorpioides DEEP MARSH
E. Sagwon Upland	1. MOIST Eriophorum vaginatum-Betula nana ssp. exilis TUSSOCK DWARF SHRUB UPLAND MEADOW 2. MOIST Betula nana ssp. exilis-Vaccinium uliginosum DWARF SHRUB HIGH CENTER POLYGONS 3. VERY WET Carex aquatilis-Comarum palustre; WET Salix planifolia ssp. pulchra-Sphagnum sp. MEADOW COMPLEX 4. VERY WET Menyanthes trifoliata-Coptidium pallasii DEEP MARSH
F. Toolik Upland-Road Effects Study Site	1. DRY Cassiope tetragona ssp. tetragona-Rubus chamaemorus DWARF SHRUB SNOWBANK 2. DRY Betula nana ssp. exilis-Vaccinium uliginosum; WET Eriophorum scheuchzeri-Carex aquatilis HIGH-CENTER POLYGON COMPLEX 3. MOIST Eriophorum vaginatum-Betula nana ssp. exilis TUSSOCK DWARF SHRUB UPLAND MEADOW 4. MOIST Eriophorum vaginatum-Betula nana ssp. exilis; WET Eriophorum scheuchzeri-Carex aquatilis HIGH-CENTER POLYGON COMPLEX 5. MOIST Salix planifolia ssp. pulchra-Nardosmia frigida DWARF SHRUBLAND 6. MOIST Betula nana ssp. exilis-Salix planifolia ssp. pulchra; DRY Betula nana ssp. exilis-Vaccinium uliginosum; WET Eriophorum scheuchzeri-Carex aquatilis DWARF SHRUB BOG COMPLEX 7. MOIST Eriophorum angustifolium-Nardosmia frigida SEDGE-FORB MEADOW 8. WET Eriophorum scheuchzeri-Carex aquatilis SEDGE MEADOW (Flat areas and shallow drainage channels) 9. WET Eriophorum scheuchzeri-Carex aquatilis; WET Betula nana ssp. exilis-Sphagnum sp. BOG COMPLEX (Aligned and non-aligned hummocks)
G. Toolik Upland-South	1. DRY Arctous alpina ssp. alpina-Dryas octopetala PROSTRATE SHRUB HEATH 2. DRY Cassiope tetragona ssp. tetragona-Vaccinium vitis-idaea ssp. minus DWARF SHRUB SNOWBED 3. DRY Arctous alpina ssp. alpina-Dryas octopetala; MOIST Carex bigelowii-Betula nana ssp. exilis MEADOW COMPLEX 4. DRY Umbilicaria sp.-Rhizocarpon sp. LICHEN COVERED ROCKS 5. MOIST Betula nana ssp. exilis-Festuca altaica SHORT SHRUB CREEK BANKS 6. MOIST Carex bigelowii-Betula nana ssp. exilis TUSSOCK DWARF SHRUB MEADOW 7. MOIST Betula nana ssp. exilis-Festuca altaica; DRY Umbilicaria sp.-Rhizocarpon sp. MEADOW ROCK COMPLEX

Table 3 (cont'd). Summary of vegetation communities appearing on the 17 vegetation maps along the Haul Road north of the Yukon River.

Site Name	Vegetation Communities
	8. WET Betula nana ssp. exilis-Sphagnum sp. DWARF SHRUB BOG
	9. WET Betula nana ssp. exilis-Sphagnum sp.; WET Eriophorum angustifolium-Carex chordorrhiza COMPLEX (Hummocky hillsides)
	10. WET Eriophorum angustifolium-Carex chordorrhiza SEDGE MEADOW
H. Atigun River-Sand Dunes	1. DRY Salix glauca-Arctous alpina ssp. rubra; DRY Equisetum arvense-Chamerion latifolium ACTIVE SAND DUNE COMPLEX
	2. DRY Chamerion latifolium SPARSELY VEGETATED RIVER BLUFFS
	3. DRY Dryas octopetala-Arctous alpina ssp. rubra; Tomenthypnum nitens-Carex bigelowii STABILIZED SAND DUNE COMPLEX
	4. MOIST Carex bigelowii-Dryas octopetala TUSSOCK MEADOW
	5. MOIST Tomenthypnum nitens-Carex bigelowii; MOIST Carex bigelowii-Dryas octopetala ALIGNED HUMMOCK COMPLEX
	6. MOIST Salix lanata ssp. richardsonii-Equisetum arvense SHORT SHRUB RIVER BANK
	7. WET Carex aquatilis-Drepanocladus revolvens; MOIST Carex bigelowii-Dryas octopetala LOW-CENTER POLYGON COMPLEX
	8. WET Carex aquatilis-Eriophorum angustifolium SEDGE MEADOW
I. Atigun River-Alluvial Fans	1. DRY Dryas octopetala-Carex microchaeta ssp. microchaeta DRYAS SEDGE MEADOW
	2. DRY Cassiope tetragona ssp. tetragona-Cetraria richardsonii DWARF SHRUB LICHEN SNOWBED
	3. DRY Salix glauca-Dryas octopetala DWARF SHRUBLAND
	4. DRY Salix glauca-Empetrum eamesii ssp. hermaphroditum MEDIUM HEIGHT SHRUB TALUS SLOPE
	5. DRY Salix glauca-Rhytidium rugosum MEDIUM HEIGHT SHRUB FLOOD PLAIN
	6. DRY Umbilicaria sp.-Rhizocarpon sp. LICHEN COVERED TALUS SLOPE
	7. MOIST Betula nana ssp. exilis-Nardosmia frigida DWARF SHRUBLAND
	8. MOIST Salix planifolia ssp. pulchra-Equisetum arvense DWARF SHRUB ALLUVIAL FANS
	9. MOIST Carex bigelowii-Tomenthypnum nitens TUSSOCK MEADOW
	10. MOIST Salix alaxensis-Equisetum arvense MEDIUM HEIGHT SHRUB ALLUVIAL FANS
	11. WET Carex aquatilis-Campylium stellatum SEDGE-FORB MEADOW
	12. VERY WET Carex aquatilis-Scorpidium scorpioides; MOIST Carex bigelowii-Tomenthypnum nitens ALIGNED HUMMOCK COMPLEX
J. Dietrich River-Treeline	1. DRY Saxifraga tricuspidata-Artemisia arctica SPARSELY VEGETATED SCREE SLOPES
	2. DRY Betula nana ssp. exilis-Cladonia rangiferina MEDIUM HEIGHT SHRUBLAND
	3. DRY Cassiope tetragona ssp. tetragona-Cetraria cucullata DWARF SHRUB LICHEN SNOWBEDS
	4. DRY Populus balsamifera ssp. balsamifera-Shepherdia canadensis SHRUB DECIDUOUS FOREST GRAVEL BARS
	5. DRY Picea glauca-Betula nana ssp. exilis SHRUB LICHEN WOODLAND
	6. MOIST Carex bigelowii-Vaccinium uliginosum TUSSOCK DWARF SHRUB MEADOW
	7. MOIST Equisetum arvense-Calamagrostis canadensis SPARSELY VEGETATED MUD FLOW
	8. MOIST Betula glandulosa-Salix planifolia ssp. pulchra DWARF SHRUBLAND
	9. MOIST Carex bigelowii-Vaccinium uliginosum; MOIST Alnus viridis ssp. crispa-Carex bigelowii; WET Eriophorum angustifolium-Carex aquatilis TALL SHRUB MEADOW COMPLEX
	10. MOIST Alnus viridis ssp. crispa TALL SHRUB THICKETS
	11. MOIST Picea glauca-Empetrum eamesii ssp. hermaphroditum DWARF SHRUB LICHEN CONIFEROUS FOREST
	12. MOIST Picea glauca-Salix lanata ssp. richardsonii
K. Sukakpak Mountain-Ice-cored mound site	1. DRY Salix alaxensis-Shepherdia canadensis SPARSELY VEGETATED GRAVEL OUTWASH
	2. DRY Picea glauca-Dryas integrifolia; MOIST Picea glauca-Betula glandulosa CONIFEROUS FOREST COMPLEX
	3. MOIST Picea glauca-Betula glandulosa SHRUB WOODLAND (Small ice-cored mounds)
	4. MOIST Picea glauca-Eriophorum vaginatum TUSSOCK WOODLAND
	5. MOIST Eriophorum vaginatum-Betula glandulosa TUSSOCK DWARF SHRUB MEADOW
	6. MOIST Picea glauca-Betula glandulosa; WET Baeothryon caespitosum-Triglochin palustre COMPLEX (Meadows and ice-cored mounds)
	7. WET Baeothryon caespitosum-Triglochin palustre; MOIST Kobresia simpliciuscula-Dryas integrifolia COMPLEX (Non-aligned hummocks and small ice-cored mounds)
	8. MOIST Salix lanata ssp. richardsonii-Carex aquatilis; WET Carex rotundata-Carex aquatilis STREAMSIDE COMPLEX
	9. VERY WET Carex aquatilis-Menyanthes trifoliata SHALLOW MARSH
	10. WET Baeothryon caespitosum-Triglochin palustre; VERY WET Carex aquatilis-Menyanthes trifoliata MEADOW MARSH COMPLEX
	11. VERY WET Hippuris vulgaris-Potamogeton gramineus DEEP MARSH
L. Sukakpak Mountain-South	1. DRY Salix alaxensis-Hedysarum alpinum ssp. americanum MEDIUM HEIGHT SHRUB GRAVEL BARS
	2. DRY Picea glauca-Betula glandulosa DWARF SHRUB WOODLAND
	3. DRY Picea glauca-Dryas integrifolia DWARF SHRUB WOODLAND
	4. MOIST Picea glauca-Eriophorum vaginatum TUSSOCK DWARF SHRUB WOODLAND
	5. MOIST Picea glauca-Alnus viridis ssp. crispa CONIFEROUS FOREST
	6. WET Betula glandulosa-Carex saxatilis ssp. laxa SHALLOW MARSH

Table 3 (cont'd).

Site Name	Vegetation Communities
M. Wiseman Vicinity	1. DRY Picea mariana-Betula papyrifera-Cladonia arbuscula; MOIST Picea mariana-Betula papyrifera-Vaccinium uliginosum COMPLEX
	2. MOIST Picea mariana-Vaccinium uliginosum; MOIST Betula papyrifera-Rosa acicularis COMPLEX (Steep river bluff)
	3. MOIST Picea mariana-Alnus viridis ssp. crispa TALL SHRUB CONIFEROUS FOREST
	4. WET Eriophorum vaginatum-Betula glandulosa TUSSOCK SHRUB BOG
	5. WET Picea mariana-Eriophorum vaginatum TREED TUSSOCK BOG
N. South of Coldfoot	1. DRY Betula papyrifera-Arctostaphylos uva-ursi LICHEN DWARF SHRUB CONIFEROUS WOODLAND
	2. MOIST Picea mariana-Betula papyrifera-Vaccinium uliginosum DWARF SHRUB MIXED CONIFEROUS-DECIDUOUS FOREST
	3. MOIST Picea mariana-Vaccinium uliginosum DWARF SHRUB CONIFEROUS FOREST
	4. MOIST Picea mariana-Eriophorum vaginatum TREED TUSSOCK BOG
	5. MOIST Picea mariana-Sphagnum sp. TREED SPHAGNUM BOG
	6. WET Betula nana ssp. exilis-Eriophorum vaginatum TUSSOCK SHRUBLAND
	7. VERY WET Carex limosa-Drepanocladus brevifolius SHALLOW MARSH
	8. VERY WET Carex aquatilis-Comarum palustre SHALLOW MARSH
O. Finger Mountain	1. DRY Umbilicaria sp.-Parmelia sp. LICHEN-COVERED TORS AND BOULDER FIELDS
	2. DRY Cladonia alpestris-Arctous alpina-ssp. rubra LICHEN HEATH
	3. DRY Picea spp.-Betula papyrifera-Betula glandulosa SHRUB LICHEN MIXED CONIFEROUS-DECIDUOUS FOREST
	4. DRY Betula papyrifera-Cladonia alpestris LICHEN DECIDUOUS WOODLAND
	5. DRY Betula papyrifera-Betula glandulosa SHRUB LICHEN DECIDUOUS WOODLAND
	6. MOIST Alnus viridis ssp. crispa-Carex bigelowii; DRY Cladonia rangiferina-Rubus chamaemorous FROST BOIL COMPLEX
	7. MOIST Picea spp.-Betula papyrifera MIXED CONIFEROUS-DECIDUOUS FOREST
	8. MOIST Betula glandulosa-Salix planifolia ssp. pulchra MEDIUM HEIGHT SHRUBLAND
	9. MOIST Picea mariana-Carex bigelowii SEDGE SHRUB SUBALPINE WOODLAND
	10. WET Salix planifolia ssp. pulchra-Sphagnum TALL SHRUBLAND (Drainages)
P. No Name Creek	1. DRY Picea glauca-Betula papyrifera-Empetrum eamesii ssp. hermaphroditum DWARF SHRUB MIXED CONIFEROUS-DECIDUOUS WOODLAND
	2. MOIST Picea glauca-Equisetum pratense DWARF SHRUB CONIFEROUS FOREST
	3. MOIST Picea spp.-Lupinus arcticus DWARF SHRUB CONIFEROUS FOREST
	4. MOIST Picea mariana-Cladonia rangiferina LICHEN WOODLAND
	5. MOIST Picea mariana-Vaccinium vitis-idaea ssp. minus DWARF SHRUB CONIFEROUS FOREST
	6. MOIST Picea mariana-Betula nana ssp. exilis DWARF SHRUB TREED BOG
	7. MOIST Salix planifolia ssp. pulchra-Tomenthypnum nitens TALL SHRUBLAND (Drainages)
	8. WET Picea mariana-Sphagnum sp. TREED BOG
	9. WET Eriophorum vaginatum-Chamaedaphne calyculata TUSSOCK DWARF SHRUB BOG
	10. WET Picea mariana-Eriophorum vaginatum TREED BOG
	11. VERY WET Carex rostrata-Comarum palustre SHALLOW MARSH
	12. VERY WET Nuphar polysepalum DEEP MARSH
Q. Ray River	1. DRY Chamerion latifolium-Castilleja caudata SPARSELY VEGETATED GRAVEL BARS
	2. DRY Populus balsamifera ssp. balsamifera-Shepherdia canadensis SHRUB DECIDUOUS FOREST
	3. DRY Populus tremula ssp. tremuloides-Arctostaphylos uva-ursi DWARF SHRUB DECIDUOUS FOREST
	4. DRY Picea mariana-Betula papyrifera-Cladonia arbuscula LICHEN MIXED CONIFEROUS-DECIDUOUS FOREST
	5. MOIST Picea glauca-Betula papyrifera-Vaccinium vitis-idaea ssp. minus DWARF SHRUB MIXED CONIFEROUS-DECIDUOUS FOREST
	6. MOIST Picea glauca-Vaccinium vitis-idaea ssp. minus DWARF SHRUB CONIFEROUS FOREST
	7. MOIST Picea glauca-Rosa acicularis DWARF SHRUB CONIFEROUS FOREST
	8. WET Picea mariana-Sphagnum sp. TREED SPHAGNUM BOG

7. Sand dunes
8. Closely spaced large rocks
9. Scattered large rocks
10. High-center polygons
11. Irregular microrelief
12. Solifluction lobes
13. Thermokarsted polygon troughs
14. Mixed polygons
15. Beach sand sometimes mixed with peat blocks
16. Scattered peat blocks
17. Flat or weakly defined polygons (includes the reticulate pattern of Everett et al. 1978)
18. Discontinuous polygon rims
19. Pingo
20. Tor, large granitic rock outcrop
21. Stream bottom with boulders
22. Ice-cored mounds (especially as at Sukakpak Mountain)
W1. Lake

Height of microrelief feature

1. Less than 25 cm
2. 25 to 50 cm
3. Greater than 50 cm

Estimated slope class

0. $< 2^{o}$
1. $2\text{-}5^{o}$
2. $5\text{-}30^{o}$ also shown by ΔΔΔ in areas
3. $> 30^{o}$ too narrow to map

Other codes

Location of vegetation description
Location of 10x10-m vegetation plot

Description of the vegetation at the Ray River site

This site (Fig. 5) is located 15 km north of Five-Mile Camp along a stretch of road which overlooks the meandering Ray River. The region is characterized by steep hills with mixed spruce and deciduous forests. Some areas have extensive aspen stands. The pipeline is located just east of the eastern boundary of the map and is supported on VSM's through most of this section.

The southwest portion of the mapped area consists of a steep slope which drops to the terraces of the Ray River. Vegetation on this slope consists of dense *Picea glauca* with scattered *Betula papyrifera*. The understory is dominated by *Vaccinium vitis-idaea, Geocaulon lividum, Ledum groenlandicum, Mertensia paniculata,* and *Hylocomium alaskanum.* Among the highest terraces of the river there are large *Picea glauca.*

Legend for Ray River Site



DRY Chamerion latifolium-Castilleja caudata SPARSELY VEGETATED GRAVEL BARS.

Chamerion latifolium, Castilleja caudata, Galium boreale ssp. septentrionale, Aster sibiricus ssp. subintegerrimus, Hedysarum mackenzei, Hedwigia ciliata.



DRY Populus balsamifera ssp. balsamifera-Shepherdia canadensis SHRUB DECIDUOUS FOREST (Gravel river terraces).

Medium-dense to dense medium-sized (5-15 cm dbh) Populus balsamifera.
Understory: Shepherdia canadensis, Picea glauca, Geocaulon lividum, Galium boreale ssp. septentrionale, Aster sibiricus ssp. subintegerrimus, Castilleja caudata, Hedysarum mackenzei, Chamerion latifolium, Saxifraga tricuspidata, Hedwigia ciliata, Drepanocladus uncinatus.



DRY Populus tremula ssp. tremuloides-Arctostaphylos uva-ursi DWARF SHRUB DECIDUOUS FOREST.

Medium-dense to dense medium-sized (5-15 cm dbh) Populus tremula ssp. tremuloides.
Understory: Arctostaphylos uva-ursi, Geocaulon lividum, Galium boreale ssp. septentrionale, Anticlea elegans, Picea glauca, Vaccinium vitis-idaea ssp. minus, Chamerion platyphyllum, Antennaria sp., Viburnum edule, Rosa acicularis, Aster sibiricus ssp. subintegerrimus, Cladonia pyxidata, Peltigera canina.

DRY Picea mariana-Betula papyrifera-Cladonia arbuscula LICHEN MIXED CONIFEROUS-DECIDUOUS FOREST.

Picea mariana dominant with Betula papyrifera and/or Populus tremula ssp. tremuloides.



Medium-dense to dense small (less than 5 cm dbh) trees.



Medium-dense to dense medium-sized (5-15 cm dbh) trees.

Understory: Cladonia arbuscula, C. rangiferina, Vaccinium vitis-idaea ssp. minus, Ledum palustre spp. decumbens, Geocaulon lividum, Vaccinium uliginosum, Hylocomium splendens, Peltigera spp., Cladonia gracilis.



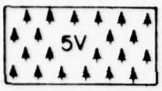
MOIST Picea glauca-Betula papyrifera-Vaccinium vitis-idaea ssp. minus DWARF SHRUB MIXED CONIFEROUS-DECIDUOUS FOREST.

Scattered to medium-dense large (greater than 15 cm dbh) Picea glauca dominant with scattered medium sized Betula papyrifera.
Understory: Vaccinium vitis-idaea ssp. minus, Mertensia paniculata, Rosa acicularis, Geocaulon lividum, Ledum groenlandicum, Hylocomium splendens, Cladonia spp., Peltigera aphthosa.

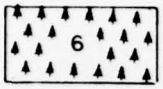


MOIST Picea mariana-Populus tremula ssp. tremuloides MIXED CONIFEROUS-DECIDUOUS FOREST.

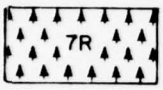
Picea mariana dominant with scattered Populus tremula ssp. tremuloides.
Scattered to medium-dense large (greater than 15 cm dbh) trees.
Understory: Mixed or unspecified.



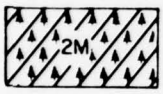
MOIST Picea glauca-Vaccinium vitis-idaea ssp. minus DWARF SHRUB CONIFEROUS FOREST.
Dense medium-sized (5-15 cm dbh) Picea glauca.
Understory: Vaccinium vitis-idaea ssp. minus, Mertensia paniculata, Rosa acicularis, Ledum groenlandicum, Hylocomium splendens, Drepanocladus uncinatus, Cladonia spp., Peltigera aphthosa.



MOIST Picea glauca FOREST.
Scattered to medium-dense large (greater than 15 cm dbh) Picea glauca.
Understory: Mixed or unspecified.



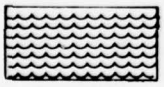
MOIST Picea glauca-Rosa acicularis DWARF SHRUB CONIFEROUS FOREST.
Dense large (greater than 15 cm dbh) Picea glauca.
Understory: Rosa acicularis, Viburnum edule, Alnus viridis ssp. crispa, Equisetum arvense, Linnaea borealis, Mertensia paniculata, Moneses uniflora, Pyrola asarifolia, Boschniakia rossica, Hylocomium splendens, Dicranum sp., Ptilidium ciliare, Cladonia deformis.



WET Picea mariana-Sphagnum sp. TREED BOG.
Scattered to medium-dense small (less than 5 cm dbh) Picea mariana.
Understory: Sphagnum spp., Vaccinium vitis-idaea ssp. minus, Ledum palustre ssp. decumbens, Rubus chamaemorus, Alnus viridis ssp. crispa, Equisetum arvense, Eriophorum vaginatum, Carex bigelowii ssp. bigelowii, Arctagrostis latifolia, Salix planifolia ssp. pulchra, Vaccinium uliginosum, Chamaedaphne calyculata, Oxycoccus microcarpus, Nardosmia frigida, Hylocomium alaskanum.



WET Salix spp. THICKETS.
Dense tall (greater than 3 m) Salix spp.
Understory: Mixed.



WATER



DISTURBED

INTERMITTENT STREAM

CLEARED TRAIL



ROAD

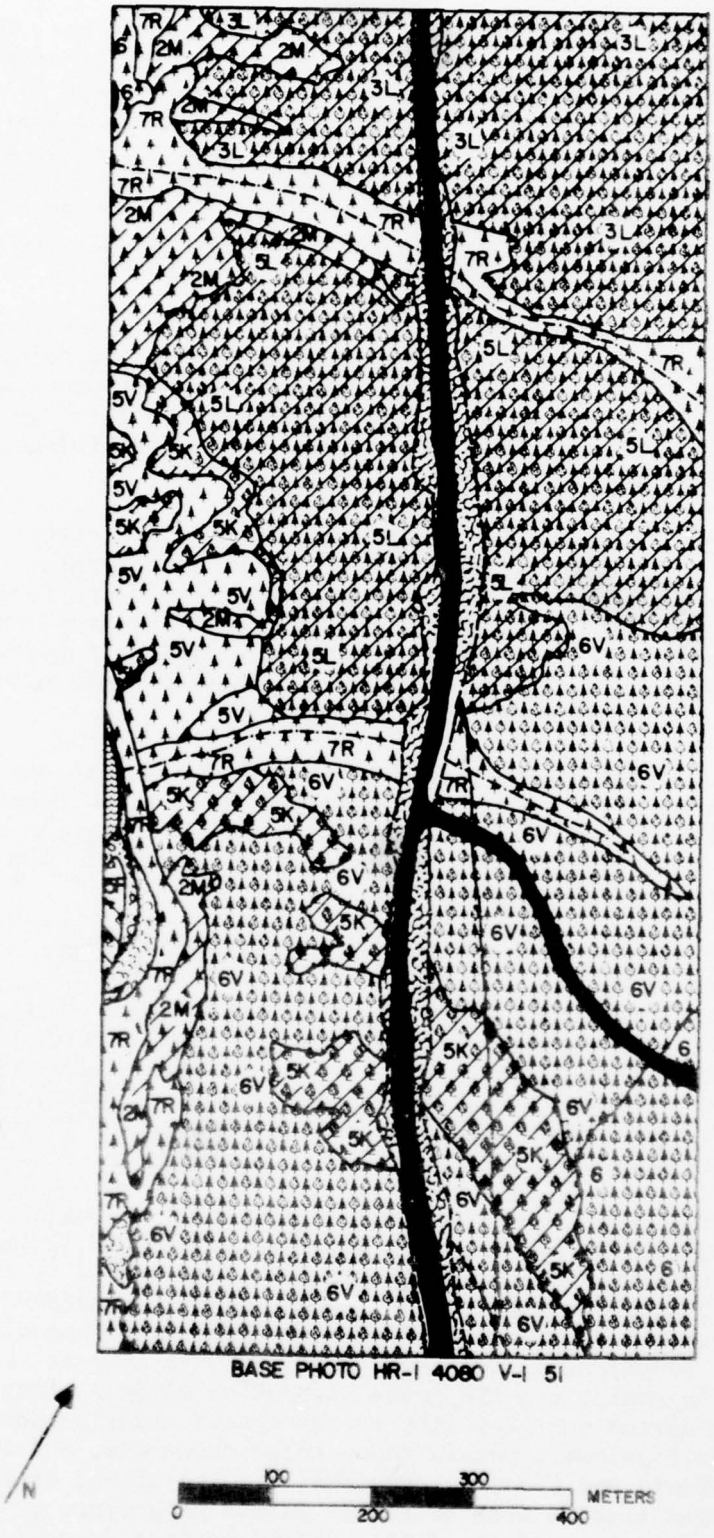


Figure 5. Ray River site.

Some trees have diameters at breast height exceeding 60 cm. The understory in this area consists mainly of *Rosa acicularis, Linnaea borealis, Ribes triste, Equisetum arvense, Mertensia paniculata,* and *Hylocomium alaskanum.* This type of forest also extends up two small drainages which run from east to west across the mapped area. Also on the lowest terrace there is a boggy area with small *Picea mariana, Sphagnum* spp., *Chamaedaphne calyculata, Rubus chamaemorus, Oxycoccus microcarpus,* and *Carex bigelowii.* This same association with *Chamaedaphne* absent is also found on some hillsides in areas which have apparently been burned.

Lower terraces of the river have dense willow thickets and the vegetation on a small gravel bar is dominated by *Populus balsamifera.* A large area of aspen trees is located on a steep southwest-facing slope in the southern half of the map. The understory for this forest type consists mainly of *Arctostaphylos uva-ursi, Geocaulon lividum, Galium boreale,* and *Zygadenus elegans.*

Fire has played a large role in the region. The central portion of the map is located on a broad hilltop which has been burned. Medium-sized (5-10 cm dbh) *Picea mariana* and *Populus tremuloides* forest with a rich lichen understory covers most of this area. The area north of a small drainage (culvert no. 873+28) has a very similar forest, but *Betula papyrifera* occurs instead of aspen. Another similar forest occurs in the southeast corner of the map.

The main disturbance in this area is associated with the extensive fills and cuts necessary for construction of the road. These areas have been revegetated and are becoming well-stabilized. There is also a cleared trail which parallels the road about 50 m east of the road in the southern half of the map.

Description of the vegetation at the Finger Mountain site

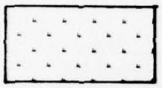
This site is located 11.7 km south of Old Man Camp (Fig. 6). The area is located approximately at treeline and contains forested areas, a subalpine band of tree islands and a dry upland with widely spaced alder shrubs. There are also three large granitic rock outcrops, which are typical of the many tors which occur on the broad hills of the region. The pipeline is buried in this area.

The tor features are richly covered with lichens, with the dominant genera being *Umbilicaria, Parmelia, Physcia, Lecidea,* and *Cladonia.* The lower parts of the tors are beautifully landscaped with lichen-covered rocks, scattered small birch trees (*Betula papyrifera*), and an understory consisting primarily of lichens (*Cladonia arbuscula, C. alpestris, C. rangiferina, Stereocaulon* sp.), dwarf shrubs (*Ledum decumbens, Betula nana*), and the grass *Hierochloë alpina.* Most of the map is covered by upland surfaces with evenly spaced alder shrubs (*Alnus crispa*), *Carex bigelowii, Betula nana, Ledum decumbens,* and the lichens *Cetraria cucullata* and *Cladonia rangiferina.* The upland areas have very widely scattered tree islands of either *Betula papyrifera* or *Picea mariana.* The downslope edges of this upland surface grade into subalpine meadows dominated by *Carex bigelowii, Betula nana,* and *Sphagnum* spp.

Legend for the Finger Mountain Site



DRY Umbilicaria sp.-Parmelia sp. LICHEN-COVERED TORS AND BOULDER-FIELDS.
Umbilicaria spp., Parmelia spp., Rhizocarpon geographicum, Physcia spp., Hypogymnia sp., Cornicularia divergens, Xanthoria elegans, and many other lichens.



DRY Cladonia alpestris-Arctous alpina ssp. rubra LICHEN HEATH.
Cladonia alpestris, C. rangiferina, C. arbuscula, Cetraria cucullata, Stereocaulon tomentosum, Arctous alpina ssp. rubra, Ledum palustre ssp. decumbens, Betula nana ssp. exilis, Vaccinium vitis-idaea ssp. minus, Empetrum eamesii ssp. hermaphroditum, Loiseleuria procumbens, Hierochloë alpina.

DRY Picea spp.-Betula papyrifera-Betula glandulosa SHRUB-LICHEN MIXED CONIFEROUS-DECIDUOUS WOODLAND.
Picea mariana and P. glauca dominant mixed with Betula papyrifera.



Scattered to medium-dense medium-sized (5-15 cm dbh) trees.



Scattered tree islands or krummholz.

Understory: Betula glandulosa, B. nana ssp. exilis, Ledum palustre ssp. decumbens, Vaccinium vitis-idaea ssp. minus, Empetrum eamesii ssp. hermaphroditum, Lycopodium annotinum, Vaccinium uliginosum, Polytrichum juniperinum, Cladonia rangiferina, C. alpestris, Cladonia ssp., Stereocaulon tomentosum.



DRY Betula papyrifera-Cladonia alpestris LICHEN DECIDUOUS WOODLAND.
Scattered to medium-dense medium-sized (5-15 cm dbh) Betula papyrifera.
Understory: Cladonia alpestris, C. rangiferina, C. arbuscula, Cetraria cucullata, Stereocaulon tomentosum, Arctous alpina ssp. rubra, Ledum palustre ssp. decumbens, Betula nana ssp. exilis, Vaccinium vitis-idaea ssp. minus, Empetrum eamesii ssp. hermaphroditum, Loiseleuria procumbens, Hierochloë alpina.



DRY Betula papyrifera-Betula glandulosa SHRUB-LICHEN DECIDUOUS WOODLAND.
Scattered to medium-dense medium-sized (5-15 cm dbh) Betula papyrifera.
Understory: Betula glandulosa, B. nana ssp. exilis, Ledum palustre ssp. decumbens, Vaccinium vitis-idaea ssp. minus, Empetrum eamesii, Lycopodium annotinum, Polytrichum juniperinum, Cladonia rangiferina, C. alpestris, Cladonia ssp., Stereocaulon tomentosum.



MOIST Alnus viridis ssp. crispa-Carex bigelowii ssp. bigelowii; DRY Cladonia rangiferina-Rubus chamaemorus OPEN-SHRUB MEADOW/FROST-BOIL COMPLEX.

Open medium-height (1-3 m tall) Alnus viridis ssp. crispa. The understory is a frost-boil complex.

Tops of frost-boils: Cladonia rangiferina, Cetraria cucullata, C. tilesii, Cladonia alpestris, Carex bigelowii ssp. bigelowii, Rubus chamaemorus, Vaccinium vitis-idaea ssp. minus, Ledum palustre ssp. decumbens, Polytrichum juniperinum, Dicranum sp., Rhacomitrium lanuginosum, Aulacomnium turgidum.

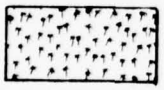
Inter-frost-boil areas: Carex bigelowii ssp. bigelowii, Betula nana ssp. exilis, B. glandulosa, Vaccinium uliginosum, V. vitis-idaea ssp. minus, Ledum palustre ssp. decumbens, Rubus chamaemorus, Bistorta plumosa, Eriophorum vaginatum, Andromeda polifolia ssp. polifolia, Pedicularis labradorica, Sphagnum spp., Hylocomium splendens, Dicranum sp., Peltigera canina.



MOIST Picea spp.-Betula papyrifera MIXED CONIFEROUS-DECIDUOUS FOREST.

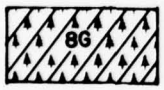
Scattered to medium-dense medium-sized (5-15 cm dbh) Picea mariana, Picea glauca, and Betula papyrifera.

Understory: Mixed or unspecified.



MOIST Betula glandulosa-Salix planifolia ssp. pulchra MEDIUM HEIGHT SHRUBLAND.

Dense medium-height (1-3 m) Betula glandulosa and Salix planifolia ssp. pulchra with Ribes triste, Calamagrostis canadensis, Spiraea beauverdiana, Vaccinium uliginosum, Ledum groenlandicum, Equisetum silvaticum, Vaccinium vitis-idaea ssp. minus, Sphagnum spp.



MOIST Picea mariana-Carex bigelowii ssp. bigelowii SEDGE-SHRUB SUBALPINE WOODLAND.

Scattered small tree islands with Picea mariana, Betula glandulosa, and Alnus viridis ssp. crispa.

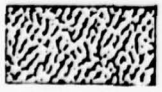
Surrounding meadows: Scattered medium-height (1-3 m) Alnus viridis ssp. crispa with Carex bigelowii ssp. bigelowii, Betula nana ssp. exilis, B. glandulosa, Ledum palustre ssp. decumbens, Vaccinium vitis-idaea ssp. minus, V. uliginosum, Andromeda polifolia ssp. polifolia, Bistorta plumosa, Eriophorum vaginatum, Rubus chamaemorus, Pedicularis labradorica, Oxycoccus microcarpus, Sphagnum spp., Aulacomnium palustre, A. turgidum.



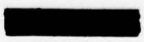
WET Salix planifolia ssp. pulchra-Sphagnum sp. TALL SHRUBLAND.

Dense tall (greater than 3 m) Salix planifolia ssp. pulchra.

Understory: Sphagnum sp., Comarum palustre, Calamagrostis canadensis, Mnium sp., Calliergon sarmentosum.



DISTURBED



ROAD

STREAM



REVEGETATED WORKPAD AND BURIED PIPELINE

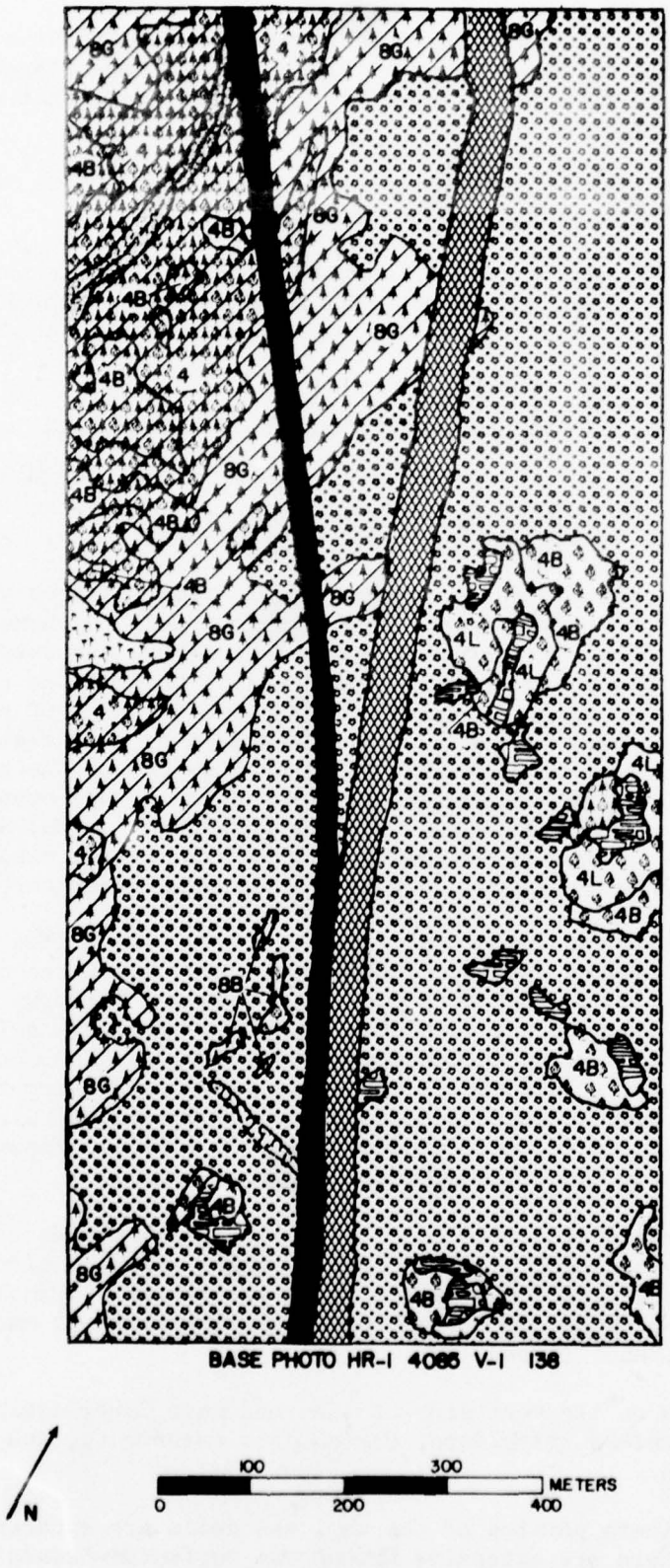


Figure 6. Finger Mountain site.

These meadows also have uniformly spaced alder shrubs and tree islands consisting of *Picea mariana*. Many of these islands have flagged trees and krummholz which have been shaped by the strong winds that are predominantly from the east.

The forested areas consist mainly of medium-sized (5 to 15 cm dbh) *Picea mariana* with scattered *Betula papyrifera*.

A small stream cuts across the northeast corner of the map. The vegetation in the stream bottom consists of dense willow thickets with a uniform understory consisting of *Sphagnum* sp., *Mnium* sp., and *Potentilla palustris*.

Description of the vegetation at the Sukakpak Mountain site

This area (Fig. 7) is located at the foot of Sukakpak Mountain, 10.1 km south of the turnoff to Dietrich Camp. The pipeline is elevated in this region and is located just west of the mapped area.

The site is unique because of many small mound features which have formed on both sides of the road. These small mounds reach maximum heights of about 3 m. The cause of these features is suspected to be subsurface ice. The mounds on the uphill (east) side of the road are much more disturbed, with large cracks and other evidence of recent surface upheaval. Many of the mounds are covered by medium-sized white spruce which have become tilted in all directions due to the growth of the mounds. Vegetation on the larger, more stable mounds usually consists of *Picea glauca* and shrubs (*Betula glandulosa, Salix lanata, Potentilla fruticosa, Ledum groenlandicum, Dryas integrifolia*). The smaller mounds are often without trees but usually have *Betula* and other shrubs.

The area which receives runoff from the limestone cliffs on Sukakpak Mountain is very calcareous. Much of the area below the cliffs consists of moist to wet calcareous meadows with *Trichophorum caespitosum, Triglochin palustre, T. maritimum, Kobresia simpliciuscula, Juncus triglumis, Carex atrofusca, Drepanocladus brevifolius,* and *Catascopium nigritum*. More mesic calcareous microsites have *Dryas integrifolia, Andromeda polifolia, Kobresia simpliciuscula, Potentilla fruticosa, Anemone parviflora, Salix reticulata, Tofieldia pusilla, Tomenthypnum nitens,* and *Drepanocladus brevifolius*.

In the forested areas the understory is often somewhat dry and consists of *Dryas integrifolia, Carex scirpoidea, Festuca altaica, Potentilla fruticosa, Arctostaphylos rubra, Vaccinium uliginosum, Salix reticulata,* and many species of lichens including *Cetraria cucullata, C. richardsonii,* and *Cladonia* spp.

Wet meadows on the west side of the road have *Carex aquatilis, C. rotundata, Menyanthes trifoliata, Utricularia intermedia,* and *Scorpidium scorpioides*.

In the southern portion of the map, the soils are apparently much more acidic. There are extensive *Eriophorum vaginatum-Betula glandulosa*

Legend for Sukakpak Mountain Ice-Core Mound Site



DRY Salix alaxensis-Shepherdia canadensis SPARSELY VEGETATED GRAVEL OUTWASH.

Salix alaxensis, S. lanata ssp. richardsonii, Shepherdia canadensis, Pentaphylloides floribunda, Betula glandulosa, Equisetum arvense, Salix arctica, Kobresia simpliciuscula, Carex scirpoidea, Chamerion platyphyllum.



DRY Picea glauca-Dryas integrifolia; MOIST Picea glauca-Betula glandulosa CONIFEROUS FOREST COMPLEX.

Scattered to medium-dense medium-sized (5-15 cm dbh) Picea glauca.
Understory: Drier microsites--Dryas integrifolia, Carex scirpoidea, Festuca altaica, Pentaphylloides floribunda, Salix reticulata, Arctous alpina ssp. rubra, Vaccinium uliginosum, Hedysarum alpinum ssp. americanum, Bistorta vivipara, Rhododendron lapponicum, Rhytidium rugosum, Rhacomitrium lanuginosum, Cetraria cucullata, C. richardsonii, Cladonia arbuscula, C. pyxidata.
Moister microsites--Betula glandulosa, Pentaphylloides floribunda, Ledum groenlandicum, Dryas integrifolia, Arctous alpina ssp. rubra, Rhododendron lapponicum, Vaccinium uliginosum, V. vitis-idaea ssp. minus, Carex scirpoidea, Salix lanata ssp. richardsonii, Equisetum arvense, Eriophorum vaginatum, Andromeda polifolia ssp. polifolia, Tomenthypnum nitens, Distichium capillaceum, Cladonia pyxidata.





• spot symbol for ice-core mound

MOIST Picea glauca-Betula glandulosa SHRUB WOODLAND (Small ice-core mounds).

Scattered to medium-dense medium-sized (5-15 cm dbh) Picea glauca.
Understory: Betula glandulosa, Pentaphylloides floribunda, Ledum groenlandicum, Dryas integrifolia, Arctous alpina ssp. rubra, Rhododendron lapponicum, Vaccinium uliginosum, V. vitis-idaea ssp. minus, Carex scirpoidea, Salix lanata ssp. richardsonii, Equisetum arvense, Eriophorum vaginatum, Andromeda polifolia ssp. polifolia, Tomenthypnum nitens, Rhytidium rugosum, Distichium capillaceum, Cladonia pyxidata.

MOIST Picea glauca-Eriophorum vaginatum TUSSOCK WOODLAND.



Scattered to medium-dense small (less than 5 cm dbh) Picea glauca.



Scattered to medium-dense medium-sized (5-15 cm dbh) Picea glauca.

Understory: Eriophorum vaginatum, Betula glandulosa, Salix lanata ssp. richardsonii, Ledum palustre ssp. decumbens, Vaccinium uliginosum, Empetrum eamesii ssp. hermaphroditum, Vaccinium vitis-idaea ssp. minus, Hylocomium splendens, Pleurozium schreberi, Dicranum sp., Cladonia spp., Cetraria cucullata.



MOIST Eriophorum vaginatum-Betula glandulosa TUSSOCK DWARF SHRUB MEADOW.
Eriophorum vaginatum, Betula glandulosa, Salix lanata ssp. richardsonii, Ledum palustre ssp. decumbens, Vaccinium uliginosum, Empetrum eamesii ssp. hermaphroditum, Vaccinium vitis-idaea ssp. minus, Hylocomium splendens, Pleuvozium shreberi, Dicranum sp., Cladonia spp., Cetraria cucullata.



MOIST Picea glauca-Betula glandulosa; WET Baeothryon caespitosum-Triglochin palustre COMPLEX (Meadows and small ice-cored mounds).
Higher microsites (ice-core mounds and hummocks): Picea glauca, Betula glandulosa, Pentaphylloides floribunda, Ledum groenlandicum, Dryas integrifolia, Arctous alpina ssp. rubra, Rhododendron lapponicum, Vaccinium uliginosum, V. vitis-idaea ssp. minus, Carex scirpoidea, Salix lanata ssp. richardsonii, Equisetum arvense, Eriophorum vaginatum, Andromeda polifolia ssp. polifolia, Tomenthypnum nitens, Distichium capillaceum, Cladonia pyxidata.
Lower microsites (wet meadows): Baeothryon caespitosum, Triglochin palustre, T. maritimum, Juncus triglumis, Andromeda polifolia ssp. polifolia, Carex atrofusca, Pedicularis sudetica, Equisetum palustre, Carex aquatilis, Eriophorum angustifolium, Drepanocladus brevifolius, Catascopium nigritum, Scorpidium scorpioides.



WET Baeothryon caespitosum-Triglochin palustre; MOIST Kobresia simpliciuscula-Dryas integrifolia COMPLEX (Non-aligned hummocks and small ice-core mounds).
Higher microsites: Kobresia simpliciuscula, Dryas integrifolia, Salix lanata ssp. richardsonii, S. reticulata, S. arctica, Andromeda polifolia ssp. polifolia, Pentaphylloides floribunda, Equisetum variegatum, Betula glandulosa, Rhododendron lapponicum, Bistorta vivipara, Tofieldia pusilla, Carex scirpoidea, Arctous alpina ssp. rubra, Anemone parviflora, Tomenthypnum nitens, Drepanocladus brevifolius.
Lower microsites: Baeothryon caespitosum, Triglochin palustre, Triglochin maritimum, Juncus triglumis, Andromeda polifolia, Carex atrofusca, Pedicularis sudetica, Equisetum palustre, Carex aquatilis, Eriophorum angustifolium, Drepanocladus brevifolius, Catascopium nigritum, Scorpidium scorpioides.



MOIST Salix lanata ssp. richardsonii-Carex aquatilis MEDIUM HEIGHT SHRUBLAND.
Salix lanata ssp. richardsonii, Betula glandulosa, Carex aquatilis, Juncus castaneus, Equisetum pratense, Carex rotundata, Campylium stellatum, Drepanocladus brevifolius.



MOIST Salix lanata ssp. richardsonii-Carex aquatilis; WET Carex rotundata-Carex aquatilis STREAMSIDE COMPLEX.
Scattered medium-sized dead Picea sp.
Moist microsites: Salix lanata ssp. richardsonii, Betula glandulosa, Carex aquatilis, Juncus castaneus, Equisetum pratense, Carex rotundata, Campylium stellatum, Drepanocladus brevifolius.
Wetter microsites: Carex rotundata, C. aquatilis, Hippochaete variegata ssp. variegata, Cinclidium sp., Campylium stellatum, Drepanocladus brevifolius.



VERY WET Carex aquatilis-Menyanthes trifoliata SHALLOW MARSH.
Carex aquatilis, C. rotundata, Menyanthes trifoliata, Utricularia intermedia, Carex laxa, Scorpidium scorpioides.



WET Baeothryon caespitosum-Triglochin palustre; VERY WET Carex aquatilis-Menyanthes trifoliata MEADOW MARSH COMPLEX.
Wet microsites: Baeothryon caespitosum, Triglochin palustre, Triglochin maritimum, Juncus triglumis, Andromeda polifolia, Carex atrofusca, Pedicularis sudetica, Equisetum palustre, Carex aquatilis, Eriophorum angustifolium, Drepanocladus brevifolius, Catascopium nigritum, Scorpidium scorpioides.
Very wet microsites: Carex aquatilis, Menyanthes trifoliata, Carex rotundata, Utricularia intermedia, Carex laxa, Scorpidium scorpioides.

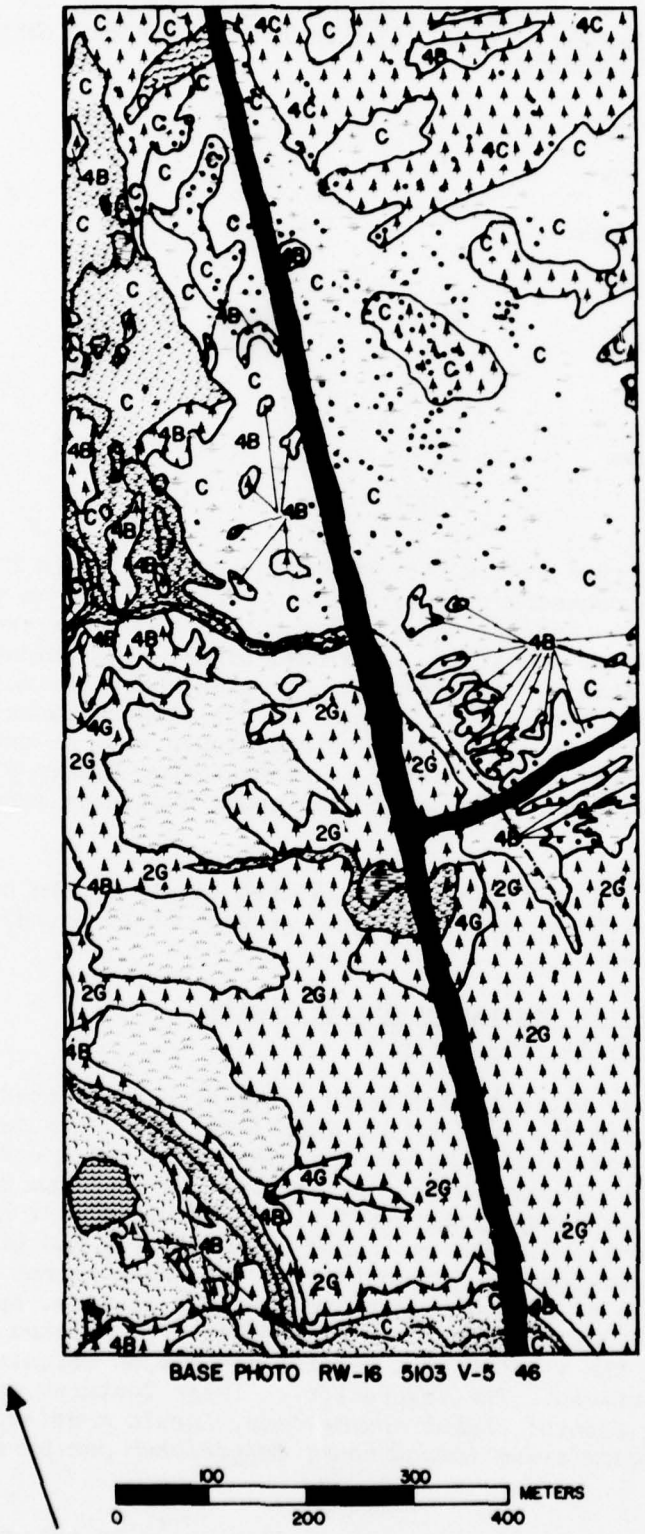
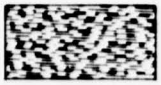
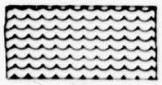


Figure 7. Sukakpak Mountain site.



VERY WET Hippuris vulgaris-Potamogeton gramineus DEEP MARSH. Hippuris vulgaris, Potamogeton gramineus, Carex aquatilis, Scorpidium scorpioides.



WATER



DISTURBED



ROAD

CREEK

meadows. This type is also the principal understory in *Picea glauca* forests in the southern part of the map. A small stream crosses the map area near the southern boundary. Vegetation along the creek consists primarily of *Carex aquatilis, C. rotundata* and *Salix lanata*. Extensive shrub meadows also lie adjacent to the creek where the main species are *Salix lanata* and *Betula glandulosa*. On the sloping banks adjacent to the creek bottom are medium-sized *Picea glauca* with an understory consisting of *Vaccinium uliginosum, V. vitis-idaea, Betula glandulosa, Potentilla fruticosa, Hylocomium alaskanum, Rhytidium rugosum,* and *Cladonia* spp.

Disturbances in the area are limited mainly to the drainage changes which are apparently contributing to growth of the mounds on the uphill side of the road.

Description of the vegetation at the Toolik upland road effects study site

The Toolik upland road effects study site is located 16.6 km north of the turnoff to the Toolik Lake Camp (Fig. 8). This is an area of broad rolling hills with the type of vegetation which covers much of the foothills of the Brooks Range. Cottongrass (*Eriophorum vaginatum*) dominates the landscape with dwarf birch (*Betula nana*), Labrador tea (*Ledum decumbens*), Cloudberry (*Rubus chamaemorus*), and Lingonberry (*Vaccinium vitis-idaea*). *Sphagnum* spp. are the dominant mosses and several species of *Cladonia* occur regularly. In some, apparently drier areas, *Carex bigelowii* and *Salix planifolia* ssp. *pulchra* are important components of the vegetation. Frost boils are an ubiquitous feature on the upland surfaces. The vegetation on these features usually includes the following plants: *Rubus chamaemorus, Luzula arctica, Cassiope tetragona, Rhacomitrium lanuginosum, Polytrichum juniperinum, Cladonia* spp.

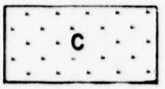
There are many slightly wetter sites, usually associated with shallow drainage channels. Vegetation in these sites is dominated by

Legend for Toolik Upland-Road Effects Study Site



DRY Cassiope tetragona ssp. tetragona-Rubus chamaemorus DWARF SHRUB SNOWBANK.

Cassiope tetragona ssp. tetragona, Rubus chamaemorus, Carex bigelowii ssp. bigelowii, Betula nana ssp. exilis, Vaccinium uliginosum, Loiseleuria procumbens, Polytrichum juniperinum, Dicranum sp., Aulacomnium turgidum, Cetraria nivalis, C. richardsonii, C. delisei, Cladonia richardsonii, Cladonia spp.



DRY Betula nana ssp. exilis-Vaccinium uliginosum; WET Eriophorum scheuchzeri-Carex aquatilis HIGH-CENTER POLYGON COMPLEX.

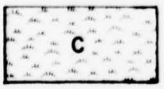
Tops of polygons: Betula nana ssp. exilis, Vaccinium uliginosum, V. viti-idaea ssp. minus, Ledum palustre ssp. decumbens, Rubus chamaemorus, Rhacomitrium lanuginosum, Dicranum sp., Rhytidium rugosum, Aulacomnium turgidum, Cladonia rangiferina, C. gracilis, Dactylina arctica, Cetraria spp.

Polygon troughs: Eriophorum scheuchzeri, Carex aquatilis, C. rotundata, Salix ovalifolia, Sphagnum spp., Drepanocladus sp., Polytrichum juniperinum.



MOIST Eriophorum vaginatum-Betula nana ssp. exilis TUSSOCK DWARF SHRUB UPLAND MEADOW.

Eriophorum vaginatum, Betula nana ssp. exilis, Ledum palustre ssp. decumbens, Vaccinium vitis-idaea, Rubus chamaemorus, Salix planifolia ssp. pulchra, Carex bigelowii ssp. bigelowii, Andromeda polifolia ssp. polifolia, Pedicularis labradorica, Sphagnum spp., Aulacomnium palustre, A. turgidum, Cladonia arbuscula, C. rangiferina, Cetraria cucullata, Cetraria spp.



MOIST Eriophorum vaginatum-Betula nana ssp. exilis; WET Eriophorum scheuchzeri-Carex aquatilis HIGH-CENTER POLYGON COMPLEX.

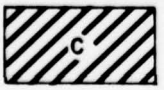
Tops of polygons: Eriophorum vaginatum, Betula nana ssp. exilis, Ledum palustre ssp. decumbens, Vaccinium vitis-idaea ssp. minus, Rubus chamaemorus, Salix planifolia ssp. pulchra, Carex bigelowii ssp. bigelowii, Sphagnum ssp., Aulacomnium palustre, A. turgidum, Cladonia arbuscula, C. rangiferina, Cetraria cucullata, Cetraria spp.

Polygon troughs: Eriophorum scheuchzeri, Carex aquatilis, C. rotundata, Salix ovalifolia, Sphagnum spp., Drepanocladus sp., Polytrichum juniperinum.



MOIST Salix planifolia ssp. pulchra-Nardosmia frigida DWARF SHRUBLAND.

Salix planifolia ssp. pulchra, Nardosmia frigida, Carex bigelowii ssp. bigelowii, Equisetum arvense, Aulacomnium palustre, A. turgidum, Hylocomium splendens, Peltigera canina.



MOIST Betula nana ssp. exilis-Salix planifolia ssp. pulchra; DRY Betula nana ssp. exilis-Vaccinium uliginosum; WET Eriophorum scheuchzeri-Carex aquatilis DWARF SHRUB BOG COMPLEX (Irregular polygons and hummocks in natural thermokarst area).

Higher microsites: Betula nana ssp. exilis, Salix planifolia ssp. pulchra, S. fuscescens, Ledum palustre ssp. decumbens, Pedicularis labradorica, Dicranum sp., Polytrichum juniperinum, Aulacomnium turgidum, Ptilidium ciliare, Cetraria cucullata, Cladonia spp. Dactylina arctica.

or

Betula nana ssp. exilis, Vaccinium uliginosum, V. vitis-idaea ssp. minus, Ledum palustre ssp. decumbens, Rubus chamaemorus, Rhacomitrium lanuginosum, Dicranum sp., Rhytidium rugosum, Aulacomnium turgidum, Cladonia rangiferina, C. gracilis, Dactylina arctica, Cetraria spp.

Lower microsites: Eriophorum scheuchzeri, Carex aquatilis, C. rotundata, Salix ovalifolia, Sphagnum spp., Drepanocladus sp., Polytrichum juniperinum.

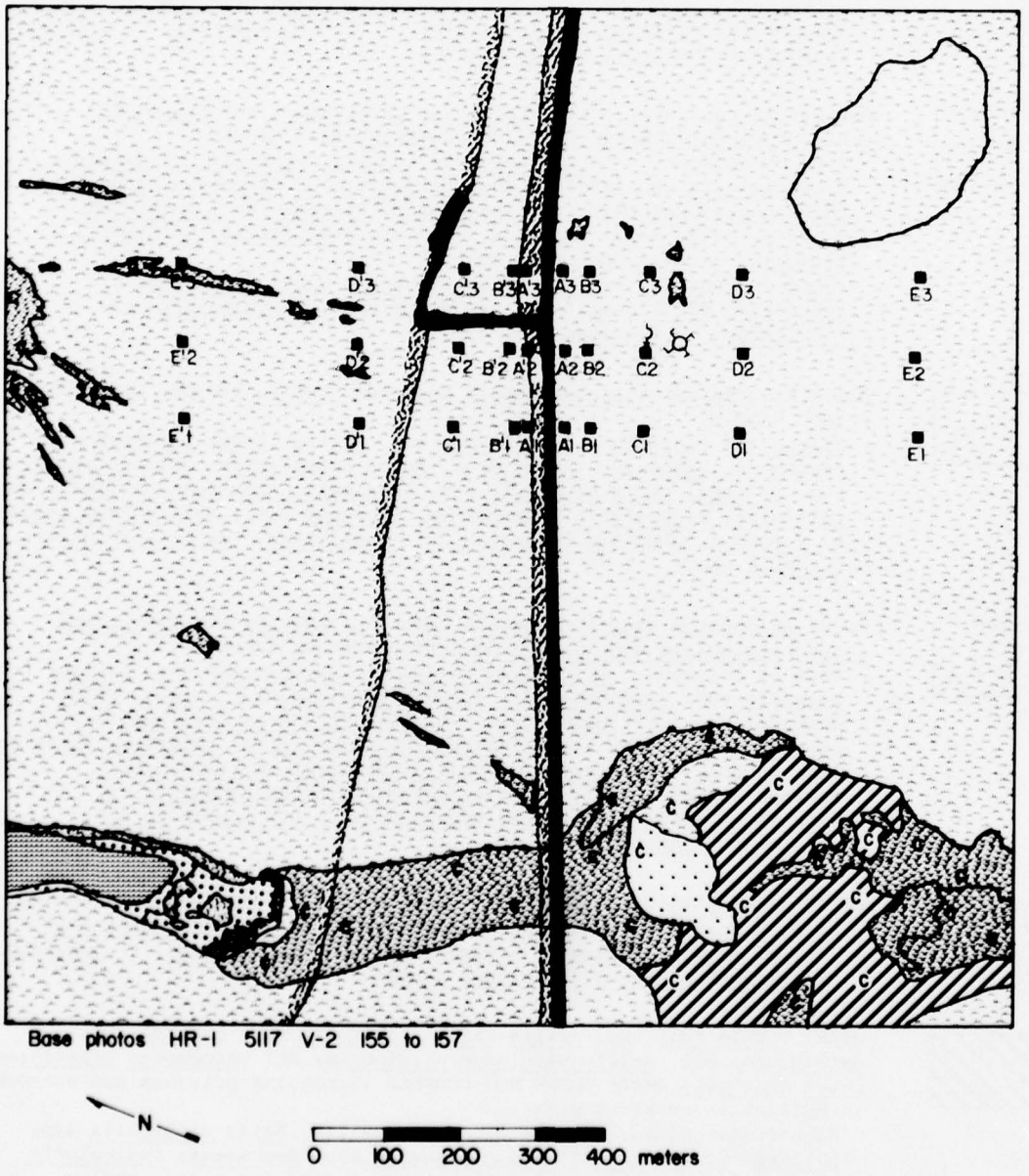
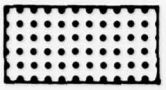
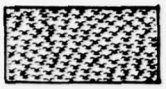


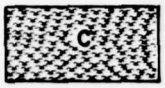
Figure 8. Toolik upland road effects study site.



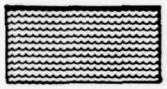
MOIST Eriophorum angustifolium-Nardosmia frigida SEDGE-FORB MEADOW.
Eriophorum angustifolium, Carex aquatilis, Nardosmia frigida, Salix ovalifolia, Salix fuscescens ssp. poronaica, Saxifraga cernua, S. punctata, Drepanocladus sp., Brachythecium sp., Dicranum sp.



WET Eriophorum scheuchzeri-Carex aquatilis SEDGE MEADOW (flat areas and shallow drainage channels).
Eriophorum scheuchzeri, Carex aquatilis, C. rotundata, Salix ovalifolia, Sphagnum spp., Drepanocladus sp., Polytrichum juniperinum.



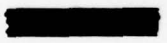
WET Eriophorum scheuchzeri-Carex aquatilis; WET Betula nana ssp. exilis-Sphagnum sp. BOG COMPLEX (Aligned and non-aligned hummocks).
Lower microsites: Eriophorum scheuchzeri, Carex aquatilis, C. rotundata, Salix ovalifolia, Sphagnum spp., Drepanocladus sp., Polytrichum juniperinum.
Higher microsites: Betula nana ssp. exilis, Rubus chamaemorus, Salix ovalifolia, Pedicularis labradorica, Andromeda polifolia ssp. polifolia, Sphagnum spp.



WATER



DISTURBED



ROAD



DUST COLLECTION BOXES AND VEGETATION PLOTS



HIGH VOLUME DUST SAMPLER



ANEMOMETER

Eriophorum scheuchzeri and *Sphagnum* spp. Hummocks in these areas usually have *Salix ovalifolia, Betula nana,* and *Sphagnum* spp. The west end of the dust transect and also a large area in the southeast corner of the map have poor drainage with complex landform and vegetation patterns. Some local areas have aligned hummocks with vegetation similar to that found in moist drainages mentioned above. Some areas have high-center polygons which have communities dominated by dwarf shrubs (*Rubus chamaemorus, Betula nana, Vaccinium vitis-idaea, Salix ovalifolia,* and *Sphagnum* spp.). More well-developed high-center polygons have drier centers with *Rhacomitrium lanuginosum, Dicranum* spp. and several fruticose lichen species.

A lake in the southwest corner of the map has several communities associated with it which are not found in other areas of the map. Included here are a *Cassiope tetragona* snowbed community, a meadow community dominated by *Eriophorum angustifolium, Carex aquatilis, Petasites frigidus,* and *Drepanocladus brevifolius,* and a shrub community dominated by *Salix planifolia* ssp. *pulchra.*

The main disturbances, other than the dust from the Haul Road, include the gas line area, which has been revegetated, and the area adjacent to and east of the pipeline where there was a snowpad used during construction of the pipeline.

This site is the location of a major study involving the impact of dust on upland tundra vegetation. The map shows the location of the vegetation transects involved in the study and an area for the study of impact caused by the winter construction snowpad. Eight permanent photo points were established in this section to monitor recovery of vegetation. Two thaw transects were also established, and notes were taken regarding miscellaneous aspects of the impact.

Description of the vegetation at the Franklin Bluffs oil spill site

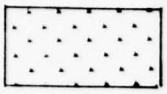
This area (Fig. 9) was mapped four days after an estimated 1500 bbl spill occurred on 19 July at the site following a rupture in a vent pipe. Most of the impacted area can be classified as moist or mesic calcareous tundra, types which are very common along the Sagavanirktok River. A small lake with submerged moss vegetation was also impacted. This lake received light spray from the oil spill and was later drained as a source of water during the clean-up operations. The map shows the vegetation as it existed in 1976. The moist tundra sites within the impacted area have the sedges *Eriophorum angustifolium* and *Carex aquatilis*; the horsetail *Equisetum variegatum*, the dicotyledon *Pedicularis sudetica*, and the mosses *Drepanocladus brevifolius*, *Cinclidium arcticum* and *Meesia triquetra*. The slightly drier sites have *Eriophorum angustifolium* and *Carex bigelowii*; with the shrubs (< 25 cm), *Salix lanata* and *Cassiope tetragona*; the prostrate shrubs *Dryas integrifolia*, *Salix reticulata*, *S. arctica* and *Arctostaphylos rubra*; and the mosses *Tomenthypnum nitens* and *Ditrichum flexicaule*.

There are other vegetation types within the map area which were not impacted by the oil. Most of these are associated with the river and its old channels. The dry river bluffs are dominated by *Dryas integrifolia*, *Arctostaphylos rubra*, *Salix reticulata*, *Astragalus alpinus*, *Oxytropis borealis*, *Carex scirpoidea*, *Kobresia myosuroides*, *Distichium capillaceum* and *Ditrichum flexicaule*. Lower terraces have shrub communities (< 50 cm) which are dominated by *Salix glauca* with *Arctostaphylos rubra*, *Hedysarum alpinum*, *Anemone parviflora*, *Oxytropis borealis*, *Tomenthypnum nitens*, and *Ditrichum flexicaule*. The gravel bars have scattered plants of *Astragalus alpinus*, *Salix alaxensis*, *Artemisia borealis*, *Epilobium latifolium*, *Salix glauca* and many others.

Prior to the spill, the main disturbances in the area were several vehicle trails which are noticeable because of increased flowering of *Eriophorum vaginatum* and a slightly moister microenvironment in the tracks. There was also a small flooded area adjacent to the work pad in the vicinity of the recent spill.

The map shows the approximate extent of areas which received light oil spray, heavy oil spray, and total saturation, respectively. Areas within the light spray zone will probably show nearly total recovery within one year. In the zone of heavy spray there will probably be good recovery by the sedges and willows which are the dominant plants. The fate of other plants such as the erect dicots, horsetails, mosses, and lichens is less certain. In the zone of total saturation, the area has been so disturbed that it is doubtful that any plants will show significant recovery within several years.

Legend for Franklin Bluffs Oil Spill Site



DRY Dryas integrifolia-Arctous alpina ssp. rubra PROSTRATE SHRUB HEATH.
Dryas integrifolia, Arctous alpina ssp. rubra, Salix reticulata, Astragalus alpinus ssp. alpinus, Oxytropis borealis, Carex scirpoidea, Kobresia myosuroides, Pedicularis capitata, Salix glauca, S. lanata ssp. richardsonii, Distichium capillaceum, Ditrichum flexicaule.



DRY Salix alaxensis-Astragalus alpinus ssp. alpinus SPARSELY VEGETATED GRAVEL BARS.
Salix alaxensis, Astragalus alpinus ssp. alpinus, Oxytropis gorodkovii, Salix glauca, Chamerion latifolium, Artemisia borealis ssp. purshii, Festuca rubra, Castilleja candata.



DRY Salix glauca-Arctous alpina ssp. rubra DWARF SHRUB RIVER TERRACES.
Salix glauca, Arctous rubra, Hedysarum alpinum ssp. americanum, Oxytropis borealis, Pedicularis capitata, Anemone parviflora, Ditrichum flexicaule, Tomenthypnum nitens.



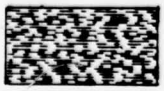
MOIST Eriophorum angustifolium-Dryas integrifolia SEDGE DWARF SHRUB MEADOW.
Eriophorum angustifolium, Dryas integrifolia, Salix lanata ssp. richardsonii, Salix reticulata, Carex bigelowii ssp. bigelowii, Cassiope tetragona ssp. tetragona, Arctous alpina ssp. rubra, Salix arctica, Hippochaete variegata ssp. variegata, Tomenthypnum nitens, Ditrichum flexicaule.



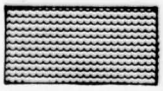
MOIST Salix lanata ssp. richardsonii-Carex aquatilis DWARF SHRUB RIVER TERRACES.
Salix lanata ssp. richardsonii, Carex aquatilis, Hippochaete variegata ssp. variegata, Arctous alpina ssp. rubra, Hedysarum alpinum ssp. americanum, Distichium capillaceum.



WET Eriophorum angustifolium-Drepanocladus brevifolius; MOIST Eriophorum angustifolium-Dryas integrifolia COMPLEX (Low-center polygons, strangmoor, irregular hummocks).
Lower microsites: Eriophorum angustifolium, Carex aquatilis, Carex saxatilis ssp. laxa, Pedicularis sudetica, Hippochaete variegata ssp. variegata, Drepanocladus brevifolius, D. revolvens, Meesia triquetra, Cinclidium arcticum, Calliergon richardsonii.
Higher microsites: Eriophorum angustifolium, Dryas integrifolia, Salix lanata ssp. richardsonii, S. reticulata, Carex bigelowii ssp. bigelowii, Cassiope tetragona ssp. tetragona, Arctous alpina ssp. rubra, Salix arctica, Hippochaete variegata ssp. variegata, Tomenthypnum nitens, Ditrichum flexicaule.



VERY WET Carex aquatilis-Eriophorum angustifolium SHALLOW MARSH.
Carex aquatilis, Eriophorum angustifolium, Carex saxatilis ssp. laxa, Drepanocladus brevifolius, D. revolvens, Scorpidium scorpioides.



WATER



DISTURBED



WORKPAD AND BURIED PIPELINE

VEHICLE TRAILS

STREAM

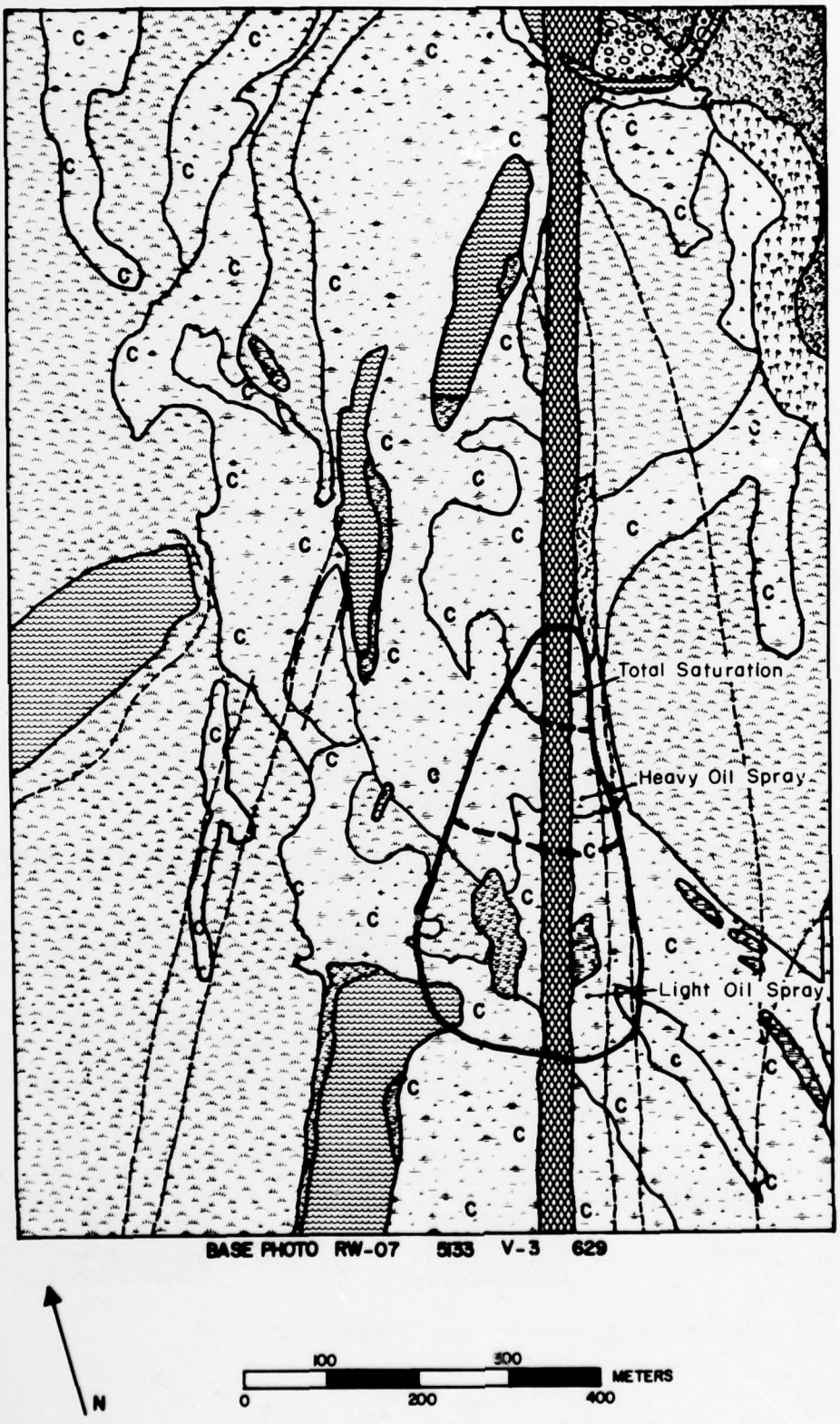


Figure 9. Franklin Bluffs oil spill site.

Description of the Prudhoe Bay Coastal Site

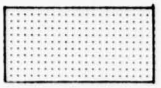
This area is located at the northernmost extension of the road network at Prudhoe Bay near the Arco West Dock. The road in this vicinity was completed in the summer of 1975 and has not seen much traffic to date. The mapped area is mainly north of the road and extends to the beaches of the Beaufort Sea.

Vegetation immediately adjacent to the coast is represented by three fairly distinct communities. Active areas of the beach and slumping coastal bluffs have little or no vegetation. Slightly more stable areas have scattered plants of *Cochlearia officinalis, Stellaria humifusa, Phippsia algida,* and *Puccinellia andersonii.* In quiet lagoon areas that are frequently flushed with salt water, *Carex subspathacea* and *Puccinellia phryganodes* form dense mats of vegetation. These areas are frequently utilized by waterfowl as indicated by the heavy concentrations of goose feces. Stable areas between the beach or lagoonal areas and the highest storm strand line often have communities with dense cover of *Dupontia fisheri.* These areas are often quite sandy and sometimes have large active frost boils with little or no vegetation.

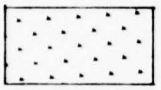
Inland from the beach areas, the landscape is flat with many lakes. Most of the larger lakes are elongated and oriented perpendicular to the dominant winds. Some of the lakes have *Arctophila fulva* communities in areas of shallow water. The terrain between the lakes is often quite rough due to the presence of aligned hummocks, rims, troughs, and high centers associated with ice-wedge polygons. The western half of the mapped area is considerably more broken up than the eastern half. Microrelief variations in map units in the western half sometimes exceed 50 cm while the relief in the eastern half rarely exceeds 25 cm. The vegetation also reflects this. The vegetation in the eastern half is generally meadow-like with large areas of mesic tundra dominated by sedges (mainly *Carex aquatilis* and *Eriophorum angustifolium*) and prostrate willows such as *Salix pulchra, S. ovalifolia,* and *S. arctica.* The willows appear to grow no higher than about 10 cm at this northern edge of the Arctic Coastal Plain. Wetter areas have sedges with few or no willows. At this date (30 July 1977), it is still very difficult to differentiate the species of sedges; *Carex aquatilis* and *Eriophorum angustifolium* are very abundant, but other species also undoubtedly occur.

In the western half of the map area there are many microsites with drier vegetation types. These sites occur on slightly raised areas such as the tops of high-center polygons, with frost active areas. Much of the soil is covered by lichens such as *Cladonia pyxidata, Thamnolia subuliformis, Ochrolechia frigida,* and *Fulgensia bracteata.* Dominant vascular plants include *Salix rotundifolia, Carex* cf. *rotundata* (Coll. no. 279), *Dryas integrifolia, Luzula arctica,* and *Carex misandra.* Mosses are not abundant, but *Dicranum* spp. and *Polytrichum juniperinum* and *Bryum* spp. are usually present. Areas with aligned hummocks have vegetation which is often dominated by the lichen *Ochrolechia frigida.*

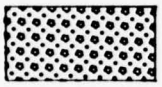
Legend for Prudhoe Bay Coastal Site



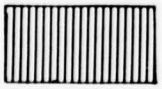
DRY Cochleariopsis groenlandica ssp. arctica-Puccinellia phryganodes SPARSELY VEGETATED BEACH.
Cochleariopsis groenlandica ssp. arctica, Puccinellia phryganodes, Stellaria humifusa, Puccinellia andersonii.



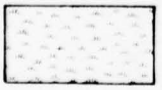
DRY Salix rotundifolia-Ochrolechia frigida PROSTRATE WILLOW HEATH.
Salix rotundifolia, Ochrolechia frigida, Salix planifolia ssp. pulchra, Stellaria laeta, Artemisia arctica, Poa arctica, Festuca baffinensis, Luzula arctica, Carex rupestris, Salix arctica, Dicranum sp., Polytrichum juniperinum, Oncophorus wahlenbergii, Lecanora epibryon, Cetraria islandica, Thamnolia subuliformis, Cladonia pyxidata.



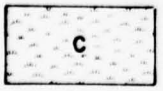
DRY Carex bigelowii-Ochrolechia frigida; MOIST Carex aquatilis-Salix planifolia ssp. pulchra FROST ACTIVE TUNDRA COMPLEX.
Higher microsites (e.g., polygon rims with considerable evidence of cryoturbation): Carex bigelowii, Ochrolechia frigida, Carex fuliginosa, Dryas integrifolia, Carex aquatilis, Draba pseudopilosa, Salix reticulata, Pedicularis lanata ssp. lanata, Dicranum sp., Polytrichum juniperinum, Thamnolia subuliformis, Cetraria islandica, Sphaerophorus globosus, Cladonia pyxidata.
Lower microsites (meadows, low polygon centers): Carex aquatilis, Salix planifolia ssp. pulchra, S. ovalifolia, Eriophorum angustifolium, Salix arctica, Nardosmia frigida, Dupontia fisheri, Campylium stellatum, Distichium capillaceum,
or
Carex aquatilis, Eriophorum angustifolium, Dupontia fisheri, Pedicularis sudetica, Drepanocladus brevifolius, Campylium stellatum.



MOIST Dupontia fisheri-Cochleariopsis groenlandica ssp. arctica SALINE GRASS FORB MEADOW.
Dupontia fisheri, Cochleariopsis groenlandica ssp. arctica, Puccinellia andersonii, Stellaria humifusa.



MOIST Carex aquatilis-Salix planifolia ssp. pulchra SEDGE MEADOW.
Carex aquatilis, Salix planifolia ssp. pulchra, S. ovalifolia, Eriophorum angustifolium, Salix arctica, Nardosmia frigida, Dupontia fisheri, Campylium stellatum, Distichium capillaceum.



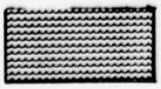
WET Carex aquatilis-Eriophorum angustifolium; MOIST Carex aquatilis-Salix planifolia ssp. pulchra MEADOW COMPLEX.
Higher microsites: Carex aquatilis, Salix planifolia ssp. pulchra, S. ovalifolia, S. arctica, Eriophorum angustifolium, Nardosmia frigida, Dupontia fisheri, Campylium stellatum, Distichium capillaceum.
Lower microsites: Carex aquatilis, Eriophorum angustifolium, Pedicularis sudetica, Drepanocladus brevifolius, Campylium stellatum.



WET Carex subspathacea-Puccinellia phryganodes SALINE SEDGE MEADOW.
Carex subspathacea, Puccinellia phryganodes, Stellaria humifusa, Carex ursina.



VERY WET Arctophila fulva SHALLOW MARSH



FRESH WATER LAKES

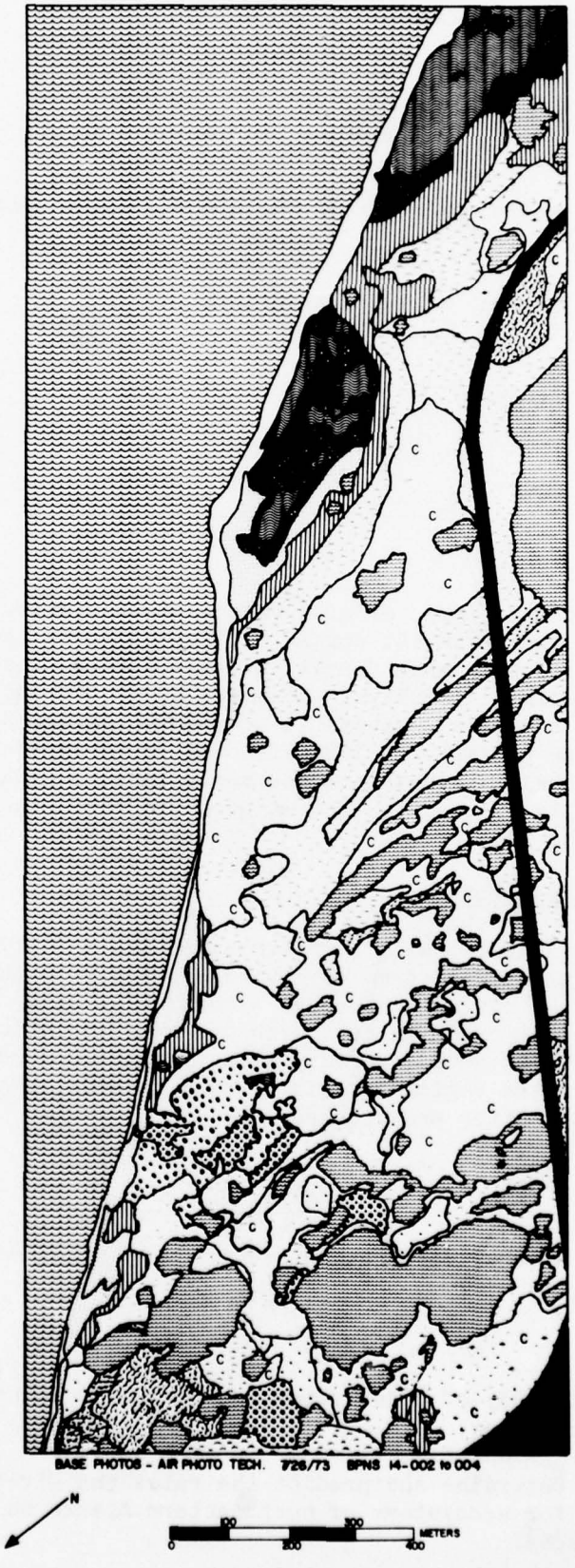
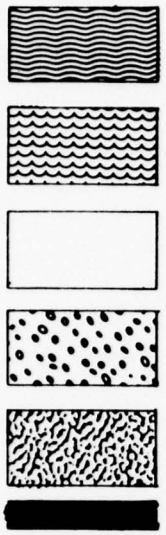


Figure 10. The Prudhoe Bay coastal site.



BRACKISH LAKE

OCEAN

BARREN BEACH SAND AND GRAVEL WITH SCATTERED PEAT BLOCKS

BARE MUD OR PEAT (DRAINED LAKE)

DISTURBED

ROAD

There are two main types of disturbance at this site. The oldest disturbance is in the northwest corner of the map where there is an abandoned drill site with much debris, scraped tundra, and scattered gravel in the immediate vicinity. There are weedy communities of mosses and liverworts in the area, especially around the sewage pond. The other type of disturbance consists of large flooded areas adjacent to the road. These areas are merely indicated on the map with no boundaries. This is because the photography used for the mapping was taken in 1973, before construction of the road.

Immediate future objectives

The system of mapping will be reevaluated and a unified mapping system developed which will draw on our experience from the entire Haul Road route and other sites in northern Alaska. The system thus developed will be aimed at creating maps with maximum vegetation information that will be useful to a wide variety of activities and requirements. Additional maps in the region of Atigun Pass, Chandalar Shelf, Grayling Lake, and the Yukon River are planned.

Subproject 4

Analysis of natural disturbance and recovery to assess highway-induced impacts.

Subproject 4A

Successional study of older sites recovering from natural or man-induced disturbances.

Objective. Determine and predict the rates and direction of natural recovery for ecosystems of northeastern Alaska on the basis of known time sequences.

Progress. A number of disturbed sites along the Haul Road undergoing natural revegetation have been located and sampled, as well as undisturbed neighboring sites, presumably representing the pre-disturbance vegetation status of the disturbed sites. The disturbance sampling was concentrated in the forested area south of the Brooks Range and only a few sites have been sampled on the North Slope. In general, it was difficult to find sites recovering from disturbances (both natural and man-caused) aged 20 years and older. Disturbances 8 years old and younger have been, on the other hand, numerous.

A summary of the sampled sites according to the type and age of disturbance, vegetation type, and site location is given in Table 4. A preliminary conclusion can be made that the natural revegetation of disturbed sites in which the vegetation cover has been removed almost completely takes about 3 to 6 years in the presence of adequate moisture.

Subproject 4B

Successional study of recent man- and road-induced disturbances.

Objective. Establish a basis for long-term monitoring of vegetational change on recently disturbed surfaces along the Haul Road.

Progress. New, permanent long-term monitoring sites have been established under subprojects 2 and 3. Other sites available for long-term monitoring have been noted during the past field season, and permanent long-term monitoring plots will be established next summer. This subproject will study surfaces which have not been revegetated because studies by other researchers on revegetation are underway. Most likely, the plots will be located in places where revegetation efforts did not succeed.

Subproject 5

Analysis of all phytosociological samples collected in above subprojects.

Objective

Summarize the data collected in the above activities into a working hypothesis concerning environmental controls upon vegetation composition, production, phenology, and development.

Progress

Some progress has been made on this subproject to date, but generally as an expansion of our data base. This expansion is represented by all the Haul Road data collected during the 1977 season. This project is a synthesis, and the activities during the 1977 summer were principally limited to field work. At present we are involved in work on a unified map legend system which will encompass all the various map

Table 4. Summary of the disturbed sites which were sampled. The type and estimated age of disturbance, vegetation type, and location are given for each site.

Table entries are relevé numbers; the numbers of disturbed site relevés are underlined. Age estimates are given in years and an asterisk shows that a tree section has been made.

Disturbance type: Bulldozed road

Distance (km)		
0.5	Picea mariana forest:	140(wet)-142 (age 3)
0.5	Picea mariana forest:	141(dry)-142 (age 3)
18.1	Picea mariana forest:	143(dry)-141 (age 4)
18.1	Picea mariana forest:	145(rockpile)-141 (age 4)
18.1	Picea mariana forest:	146(wet)-141 (age 4)
70.0	Alnus crispa-Ledum:	96(dry)-94 (age 4)
70.0	Alnus crispa-Rubus:	95(wet)-97 (age 4)
70.0	Alnus crispa-Rubus:	98(wet)-97 (age 4)
110.2	Picea-Equisetum forest:	109-108 (age 4-5)
187.4	Picea glauca forest:	29-30 (age 4-5)
187.4	Picea glauca-Ledum:	31-32 (age 4-5)
203.0	Picea glauca forest:	57(dry)-56 (age 4-5)
203.0	Picea glauca forest:	55(dry)-54 (age 4-5)
203.0	Alnus-Betula bog:	53(bog)-52 (age 4-5)
205.1	Picea glauca-Ledum:	33-35
205.1	Picea glauca-Ledum:	34-35
205.1	Grass community:	36-38
205.1	Grass community:	37-38
205.1	Betula forest:	40(wet)-39 (age 7)
205.1	Betula forest:	41(dry)-39 (age 7)

Disturbance type: Fire

0	Picea glauca forest:	136-135 (age 6?)
84.5	Picea glauca forest:	114-115*
84.5	Picea glauca forest:	112-115*
110.2	Betula papyrifera forest:	110-108*
110.2	Picea-lichen forest:	102-107*
133.2	Picea glauca forest:	63-64* (age 6)

Disturbance type: Logging

36.2	Populus tremuloides:	131-130*
203.7	Picea glauca forest:	48-49

Disturbance type: River oxbow

158.5	Picea glauca forest:	86-87*
158.5	Picea glauca forest:	85-87*

Disturbance type: Beaver pond

Distance (km)		
158.5	Salix alaxensis shrub:	83-84 (age 3-4)

Disturbance type: Riverbar

km		
0	Picea glauca forest:	133-135*; 134-135*
37.3	Picea glauca forest:	128-127*
110.2	Picea-Equisetum forest:	111-108 (age 35?)
133.2	Picea glauca forest:	60-61*; 59-61*
158.5	Picea glauca forest:	91-87 (age 2); 90-87*; 89-87*; 88-87 (age 50)
187.4	Picea glauca forest:	27-30*; 28-30*
272.6	Picea glauca forest:	15-16*; 14-16 (age 3); 13-16*; 12-16*
320.5	Dryas octopetala:	168-167*; 169-167*; 170-167; 260-167; 261-167

Disturbance type: Slumped slope

205.1	Picea glauca forest:	43-42 (age 7)
235.7	Chamerion latifolium:	23-24
243.3	Alnus crispa ravine:	5-4

Disturbance type: Excavation by man

347.1	Dryas octopetala:	162-163 (age 5)
600.8	Dryas integrifolia:	181-180 (age 25?); 182-180 (age 25?)

Disturbance type: Sand dune

347.1	Dryas octopetala:	160-163; 161-163
600.8	Dryas integrifolia:	187-191; 188-191; 189-191; 190-191

Disturbance type: Oil drilling - related disturbance

600.8	Dryas integrifolia:	173-171; 174-175 (age 7)
600.8	Eriophorum angustifolium:	178-177 (age 27)
600.8	Carex aquatilis:	183-186; 184-186; 185-186 (age 7)

legend systems that our group has been using in the past (Webber and Walker 1975, Walker and Webber 1976, Webber et al. 1976, Everett et al. 1978, Komárková and Webber 1978, Everett et al. in prep., Komárková and Webber in prep.). Data processing for the development of predictive models will continue.

Subproject 6

Documentation of dust fallout on vegetation along the highway (in cooperation with Project 5).

Objective. Assess the impact of road dust on the major ecosystems along the Haul Road.

Progress. Figure 11 summarizes our current view of the simplified combined Haul Road effects on the plant primary production. This word model lists the principal environmental factors, the way they are changed by the Haul Road, and the direction and manner of changes in primary production. For example, the road may impede the drainage, which may increase the plant production at first, but decrease it if

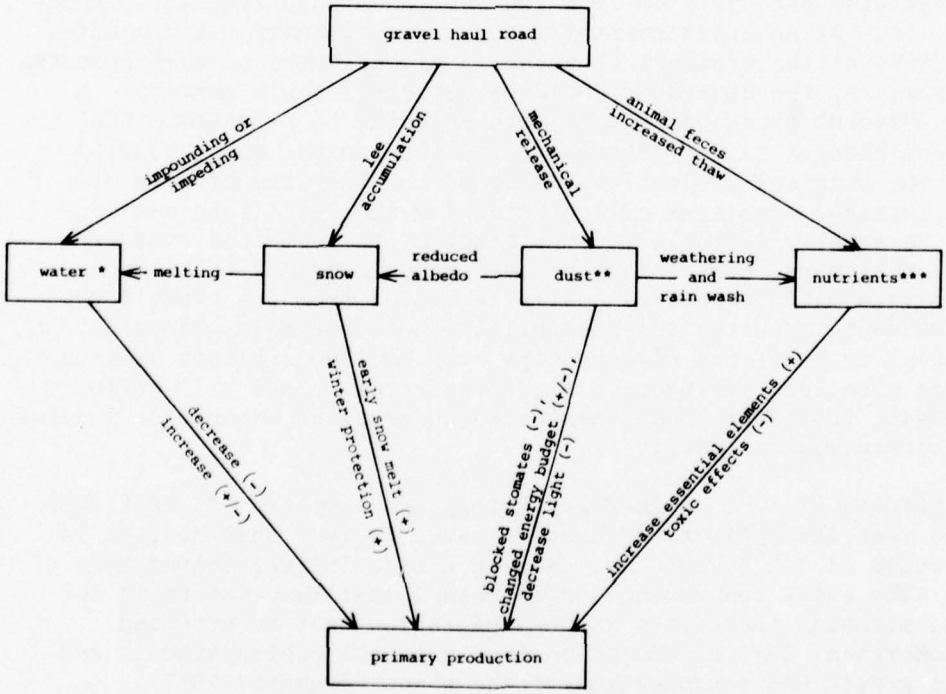


Figure 11. Word model of principal effects of the Haul Road on the primary production of adjacent tundra vegetation. In this model construction damage (e.g., vehicle tracks) and rehabilitation procedures (e.g., fertilizing) are assumed to have been minimal.

drainage is prevented to the point that ponding results. Similar complex effects on primary production can also be reasoned for the other principal factors. During the previous work on this project, we assumed that it would be possible to separate the effects of dust from the other effects of the road on vegetation readily. However, in the course of the analysis of the 1977 summer field data it became apparent that the dust effects are combined with other road effects in a complex way, and the project design and hypothesis were modified accordingly.

In order to recognize the effects of the road on vegetation from natural habitat and vegetation changes, it was necessary to establish that the environment and vegetation at the site are uniform. It was assumed that the time period after the construction of the Haul Road has not been long enough to affect the cover and composition of vascular plants in the upland tussock tundra community in places which were not affected by surface disturbance during the Haul Road construction, and that any detected differences in this composition would reflect the differences in natural habitat.

We also assumed that the effects of the road on vegetation will be recognizable in terms of plant production, for instance, in different growth rates of the dominant plants; the growth rates of these plants would change with the distance from the Haul Road on a transect perpendicular to it. At an environmentally and vegetationally uniform site, the end points of the transect (located in places where no environmental changes caused by the Haul Road could be detected) would serve as controls. Several plant parameters were selected to illustrate the road-induced changes on the material collected for the dust study. (Although the original project was designed to study the effects of dust, the data and specimens collected during the 1977 field season proved to be equally suitable for the study of the combined road effects.) Furthermore, even though we are emphasizing now that the dust effects on vegetation cannot be easily separated from the overall road effects, we want to pursue the possibility that evergreen plants have a physiological or energetic disadvantage over deciduous plants when dust accumulates upon leaf surfaces; i.e., an evergreen plant will suffer greater impact from dust loads than a deciduous plant because it retains its leaves from year to year.

The effects of dust on leaf physiology are complex. Eller (1977) postulated that absorptivity of dusted leaves is more than doubled in the wave range of 700 to 1350 mm, causing a rise in leaf temperature of 2 to 4 ^{o}C. The exact consequence of increased leaf temperature is not yet known, although there is a strong suggestion that by altering respiration rates, dust accumulation can lower net photosynthesis and thus limit growth and reproduction of the plant (Saunders 1971). Operating simultaneously in this wave range may be a reduced degree of reflectivity in dusted leaves, although Eller (1977) stated that dusty leaves tend to diffuse visible light more readily than undusted leaves (also Eveling 1967). Any rise in internal leaf temperature may be offset to some degree in arctic regions, however, where high winds may increase the effects of convective cooling at the leaf surface (Gates 1962).

On the other hand, plants collecting heavy dust loads may experience a longer growing season because dust promotes an earlier snow melt (Warren Wilson 1968, Kryuchkov 1976). Rather than inhibit growth, dust would then enhance growth by exposing plants to greater amounts of incident radiation at earlier dates in the late spring or early summer. Aerial photographs of the Prudhoe Bay spine road taken in late May support this; snow is virtually absent adjacent to the well-traveled road, but flanks a nearby untraveled road in large drifts (Benson et al. 1974). Bilgin (1975) showed that thaw depth (which is increased by road construction) influences nutrient fluctuations at Prudhoe Bay.

The study area

The site is the same as discussed under subproject 3 and is located approximately 16 km north of the Toolik Lake turnoff at APL 117-3.

The northwest side of the road is considerably more man-disturbed than the southeast side; the oil pipeline with a caribou crossing (175 m from the road), a revegetated gas feeder pipeline (5 m from the road), and a work pad over which the pipeline is elevated (35 m from the road) are all located there.

Methods

Three 1600-m-long transects were established in a direction perpendicular to the Haul Road at 100-m intervals (Fig. 8). The middle transect was surveyed for elevation (Fig. 12). The sampling sites (A, B, C, D, E, F on the southeast side of the road, and A', B', C', D', E', F' on the northwest side of the road) were located at 10-, 25-, 100-, 250-, 400-, and 800-m intervals parallel to the Everett dust collection boxes (Project 5). Vegetation was analyzed at each transect interval at 36 plots and 180 1-m^2 quadrats for plant cover and frequency (Bray and Curtis 1957). A soil sample and five values for depth of thaw were collected at each plot.

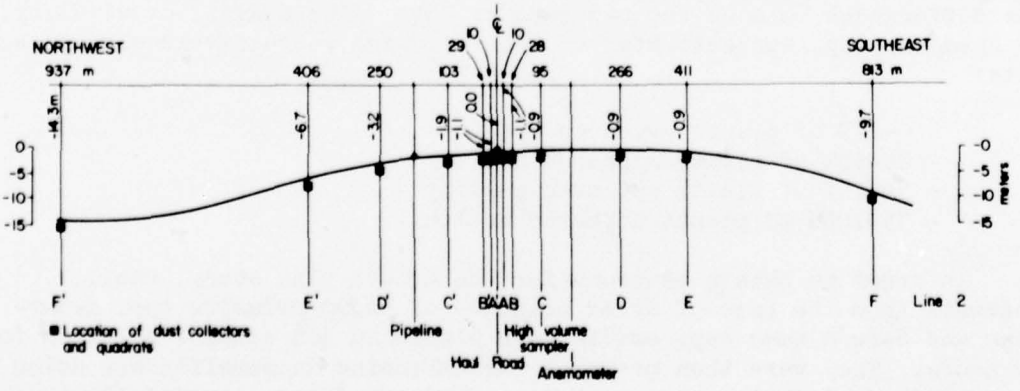


Figure 12. Topographical profile and the location of sample plots on the middle transect perpendicular to the Haul Road.

Twelve specimens each of *Ledum palustre* ssp. *decumbens* and *Betula nana* ssp. *exilis* were collected at each of the 36 plots. Twelve specimens each of *Rubus chamaemorus*, *Vaccinium vitis-idaea* ssp. *minus*, and *Salix planifolia* ssp. *pulchra* were collected at the three plots nearest and the three plots farthest away from the road (a total of 1080 specimens). The specimens were collected at the end of the vegetation season between 16 and 18 August 1977.

To establish the uniformity of the site, the agglomerative clustering average linkage method of Sokal and Sneath (1963), which produces polythetic, hierarchal dendrograms, was applied to the vegetation data. Between-stand similarity was also computed (cf. Bray and Curtis 1957). The distribution and importance of six selected species along the three transects in the study area are illustrated in diagrams in which six species index classes are represented by six circle sizes which are proportional to the ranges of each class (Figs. 17-22). Although these diagrams were used to investigate the uniformity of the site, they could also be examined for the effects of the Haul Road on the distribution and importance of individual species. However, only the differences that are apparent on both sides of the road on all transects can be considered as Haul Road-induced changes, and very few of those are apparent in the diagrams. It is also difficult to assess whether the actual cover of individual species may not be the same even in sites with different relative species index values. It appears necessary to investigate these relationships more, namely with respect to the distribution of actual percentage cover of individual species. Soil samples of surface soil horizons were analyzed according to methods standard in the Sedimentology Laboratory, Institute of Arctic and Alpine Research, University of Colorado, Boulder, Colorado.

Several methods were used to detect the effects of the Haul Road on plant production. Twenty leaves per specimen were measured for each of five specimens at A2, E2, and F2 sites on the more uniform southeast side of the road. One of these sites (A2) was used as an experimental site; the sites at the end of the transect (E2 and F2) were used as control points. (It was necessary to use F2 site as a control for *Rubus chamaemorus*, which did not occur at the E2 site in sufficient quantities.) Student's t-test was used to determine the significance of the differences between the two sets of data. The health, or vitality, of *Sphagnum* spp. was estimated on the following subjective scale at each site:

- 0-25% of plants appeared healthy
- 25-50% of plants appeared healthy
- 50-75% of plants appeared healthy
- 75-100% of plants appeared healthy.

In order to obtain sections for the growth ring study, small segments from the base of dried branches of *Ledum palustre* spp. *decumbens* and *Betula nana* ssp. *exilis* were placed in 30% ethanol solution for 24 hours. They were then prepared for embedding in paraffin wax using the standard alcohol series method. After embedding, several 10-micrometer transverse sections of the twigs were made with a rotary microtome.

The sections were double stained with saffranin and fast green. The sections were mounted on glass slides in Permount medium with cover glasses. Sections have been studied but measurements still have to be made.

Site uniformity

Table 5 shows the overall plant composition of the site on the basis of summarized data from 36 plots in terms of species index (Webber 1971) and relative frequency. One of the requirements for site selection was the analysis of vegetation and environmental uniformity in order to ensure that the changes caused by the Haul Road could be detected and measured. Apart from the considerable disturbance and the presence of high moisture sites on the northwest side of the road, the site appeared to be uniform when inspected in the field.

Subsequently, several tests were performed to establish the site uniformity quantitatively. Hierarchal dendrograms (Sokal and Sneath 1963) were used for the classification of vegetation stands along the transect. (Clusters of stands separated at low similarity levels indicate that the vegetation of the site is not uniform.) Three dendrograms were produced, one for the whole transect and one for each side of the road (Figs. 13-15).

The vegetation on the overall transect was found to be fairly uniform and clustered at the 75% level of similarity (Fig. 13). Moreover, the similarity among the majority of stands was around the 80 to 85% level; apparently, the overall similarity was lowered by the inclusion of three highly disturbed stands (A'1, A'2, A'3) and of three very moist stands (F'1, F'2, F'3). The high similarity of noda I, II and III is based on three species with the highest species index values which these noda have in common (*Sphagnum* spp., *Eriophorum vaginatum*, and *Dicranum* spp.). Nodum IV is set apart primarily by the reduced importance of *Dicranum* spp., which is replaced by *Betula nana* ssp. *exilis*.

The vegetation composition is less complex on the southeast side (Fig. 14) than on the disturbed northwest side (Fig. 15) of the road. On the southeast side, only two clusters of stands were produced above the 80% similarity level, while on the northwest side four noda were produced, and only two of them were linked at the 80% similarity. The third and fourth noda were linked to the first two noda at 75% and 70% similarity, respectively. The two noda on the southeast side and the two noda linked at the highest similarity level on the northwest side show the same three species with the highest species index values as the whole transect. On the northwest side, nodum III, which includes the sites at the end of the transect (F'1, F'2, F'3), is differentiated from the other noda by considerably greater abundance of *Sphagnum*. Since the non-uniformity of the F' sites with the rest of the transect in terms of site moisture was also observed in the field, they were dropped as control points. The depression of the terrain causing the differences in environment and vegetation at the northwest end of the transect can be observed in Figure 12. The sites A'1, A'2 and A'3, which form nodum IV

Table 5. Species importance in 36 plots.

	Mean species index	Relative frequency		Mean species index	Relative frequency
Sphagnum spp.	20.31	100.0	Cladonia coneocraea	0.27	11.1
Eriophorum vaginatum	16.33	100.0	Peltigera polydactyla	0.26	13.9
Dicranum spp.	10.34	100.0	Cladonia pyxidata	0.20	13.9
Betula nana ssp. exilis	3.68	94.4	Hylocomium splendens	0.18	13.9
Vaccinium vitis-idaea ssp. minus	3.48	100.0	Hypnum cupressiforme	0.15	16.7
Aulacomnium turgidum	3.45	100.0	Bistorta vivipara	0.14	5.6
Ledum palustre ssp. decumbens	3.39	100.0	Poa sp.	0.14	2.8
Rubus chamaemorus	3.12	94.4	Pogonatum dentatum	0.13	16.7
Polytrichum juniperinum	3.05	100.0	Peltigera aphthosa	0.12	19.4
Carex bigelowii ssp. bigelowii	3.02	100.0	Undet. moss (2)	0.12	8.3
Cetraria cucullata	2.67	97.2	Cetraria richardsonii	0.09	8.3
Liverworts	2.29	91.7	Cetraria sp.	0.09	8.3
Dactylina arctica	1.93	88.9	Eriophorum angustifolium	0.09	8.3
Cladonia rangiferina	1.89	91.7	Lolium sp.	0.09	5.5
Cassiope tetragona ssp. tetragona	1.74	75.0	Bistorta plumosa	0.08	8.3
Aulacomnium palustre	1.69	80.6	Undet. grass	0.08	8.3
Andromeda polifolia ssp. polifolia	1.63	80.6	Vaccinium uliginosum	0.07	8.3
Cladonia sp.	1.61	91.7	Pohlia sp.	0.07	5.6
Pedicularis labradorica	1.44	91.7	Salix phlebophylla	0.06	2.8
Thamnolia subuliformis	1.44	88.9	Salix planifolia ssp. pulchra	0.05	5.5
Cetraria ericetorum	1.39	83.3	Marchantia polymorpha	0.04	2.8
Cetraria islandica	1.10	47.2	Luzula arctica	0.03	2.8
Carex rotundata	1.04	38.9	Nephroma arcticum	0.03	2.8
Drepanocladus brevifolius	1.03	77.8	Alectoria ochroleuca	0.02	2.8
Cladonia gracilis	0.95	83.3	Brachythecium sp.	0.02	2.8
Cladonia arbuscula	0.76	55.6	Juncus biglumis	0.02	2.8
Peltigera canina	0.62	50.0	Peltigera malacea	0.02	2.8
Cladonia sp. (2)	0.44	63.9	Rhacomitrium lanuginosum	0.02	2.8
Cladonia sp. (3)	0.38	16.7	Calamagrostis purpurascens	0.01	2.8
Salix ovalifolia	0.37	30.6	Ochrolechia frigida	0.01	2.8
Undet. moss (1)	0.30	13.9	Poa arctica	0.01	2.8

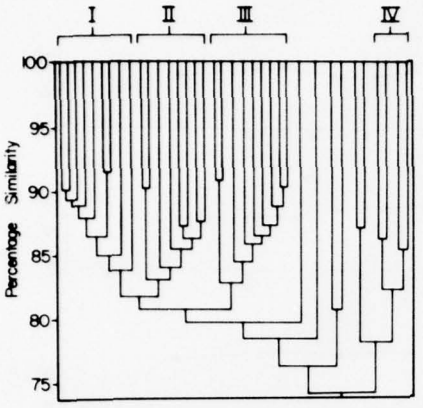


Figure 13. Hierarchal dendrogram of vegetation stands along the whole 1600-m-long transect, based on species composition and constructed according to average linkage method (Sokal and Sneath 1953). Clusters differentiating groups of stands are identified only above 75% similarity level.

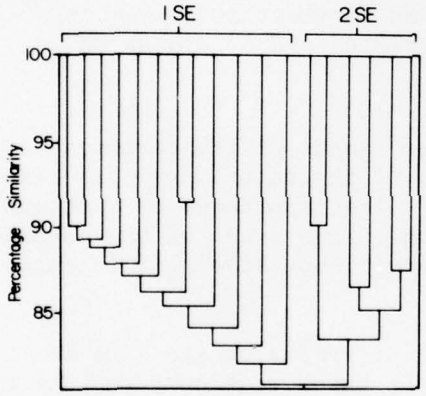


Figure 14. Dendrogram of vegetation stands on the southeast side of the Haul Road. Two noda are shown, linked at a high 80% similarity level which indicates that the vegetation on the southeast side is fairly uniform.

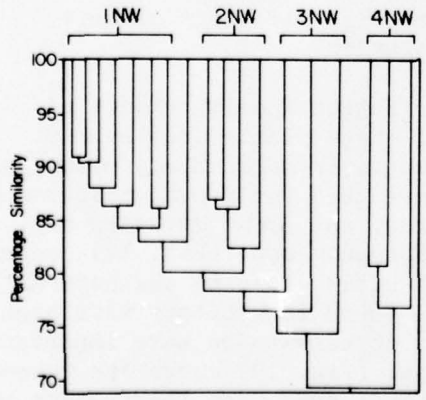


Figure 15. Dendrogram of vegetation stands on the northwest side of the Haul Road. Noda I and II, linked at 80% similarity level, are related to the vegetation on the southeast side of the road to a greater degree than noda III and IV, which represent vegetation of wet and disturbed habitats, respectively.

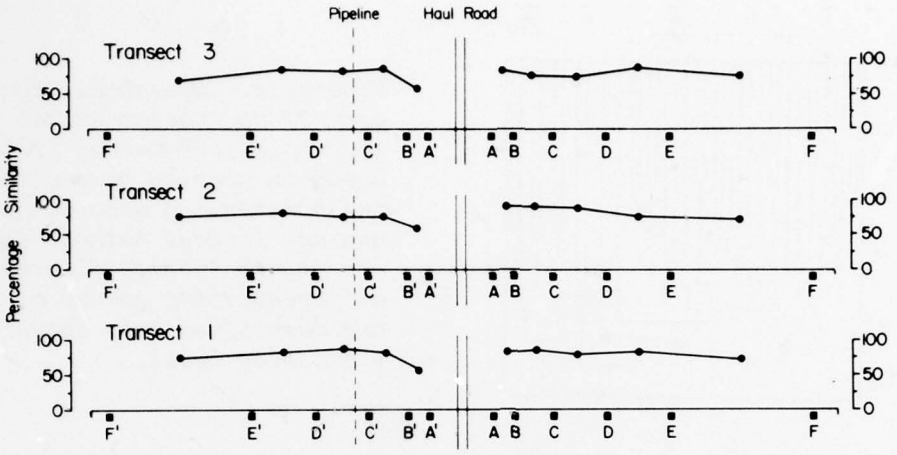


Figure 16. Between-stand similarity along the three transects. All transects exhibit a decrease in percentage similarity values between the two stands farthest away from the Haul Road, and low similarity between A' and B' stands on the northwest side of the road.

and show the least similarity to the other stands on the northwest side of the road, are located in the proximity of the natural gas pipeline (which is buried 5 m from the Haul Road). The importance of *Sphagnum* is lower in this disturbed site than in the other sites on the northwest side, while the importance of *Carex bigelowii* ssp. *bigelowii* is considerably higher.

An illustration of the vegetational uniformity at the site is provided by between-stand similarity values which were computed for all three transects separately (Fig. 16). The effects of the two main sources of lower vegetation similarity, disturbance and higher site moisture, which were seen in the dendrograms, are identified on all transects. The similarity for all transects fluctuates within a low 30-percentage-points range (15 percentage points if the similarity values between A' and B' stands are disregarded).

A series of diagrams shows the distribution and importance of six species on the three transects. Three of these plants are the most common ones in the study area (*Sphagnum* spp., *Eriophorum vaginatum*, and *Dicranum* spp.); the other three plants were used for growth measurements (*Betula nana* ssp. *exilis*, *Rubus chamaemorus*, and *Ledum palustre* ssp. *decumbens*; see the following section). *Sphagnum* spp. (Fig. 17) occurred at all sites, except for the disturbed A' sites close to the natural gas pipeline. High species index values were found in habitats with high moisture. *Eriophorum vaginatum* (Fig. 18) appears to be more important near the road on both sides. *Dicranum* spp. (Fig. 19) shows the lowest and the highest species index values farthest away from the road on both sides. *Betula nana* ssp. *exilis* (Fig. 20) shows consistently low species index values throughout the study area, except for a slight increase in the wet habitats farthest away from the road on the northwest side.

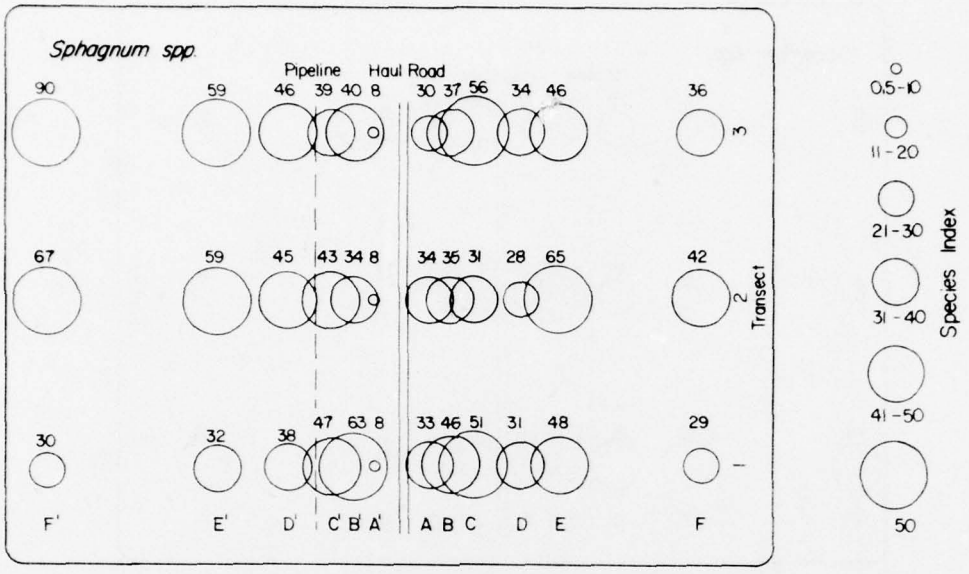


Figure 17. Distribution and importance of Sphagnum *ssp. along the three transects in the study area. The circle size is proportional to the indicated species index value at each site. The relative importance of* Sphagnum *is diminished in the disturbed sites (A').*

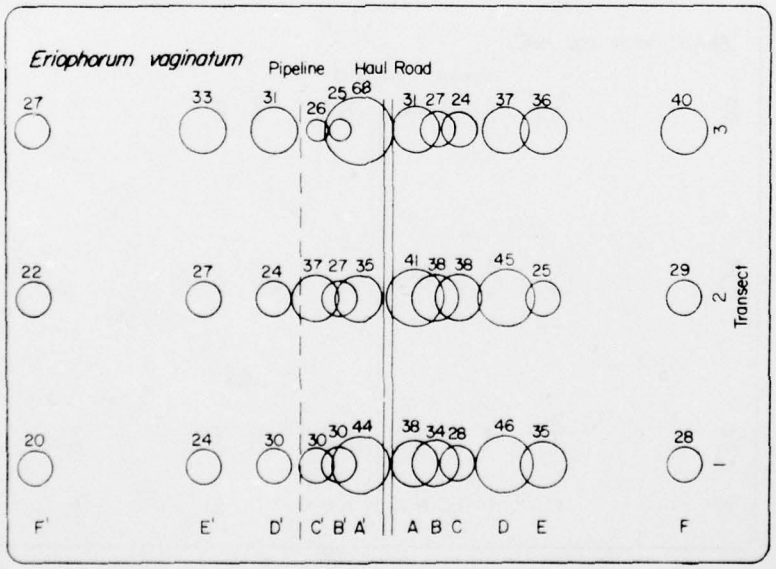


Figure 18. Distribution and importance of Eriophorum vaginatum *along the three transects in the study area. The circle size is proportional to the indicated species index value at each site. The species index values appear to be slightly higher near the road.*

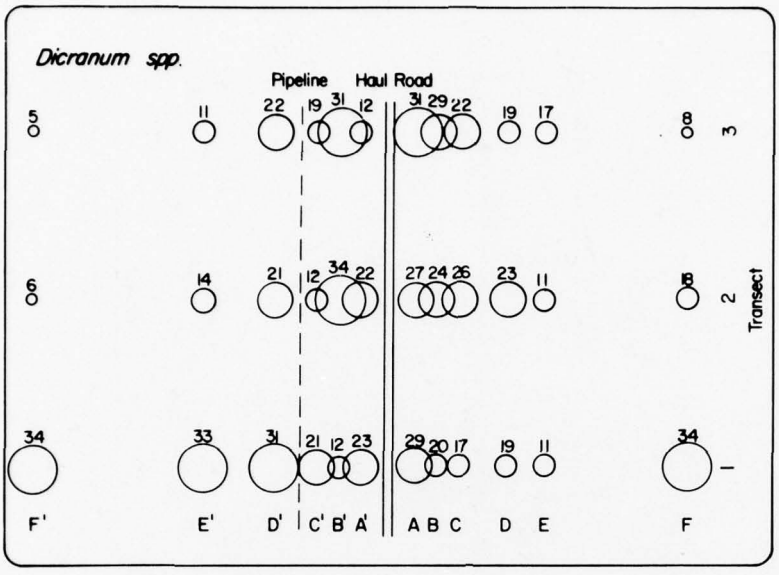


Figure 19. Distribution and importance of Dicranum *spp. along the three transects in the study area. The circle size is proportional to the indicated species index value at each site. No obvious trends are apparent.*

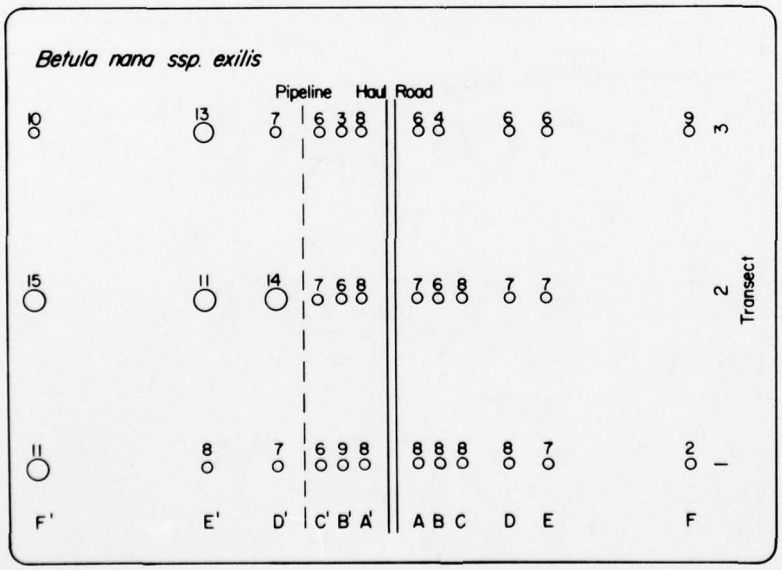


Figure 20. Distribution and importance of Betula nana *ssp.* exilis *along the three transects in the study area. The circle size is proportional to the indicated species index value at each site. The relative importance of this species appears to be higher in the wet habitats of F' sites on the northwest side of the road.*

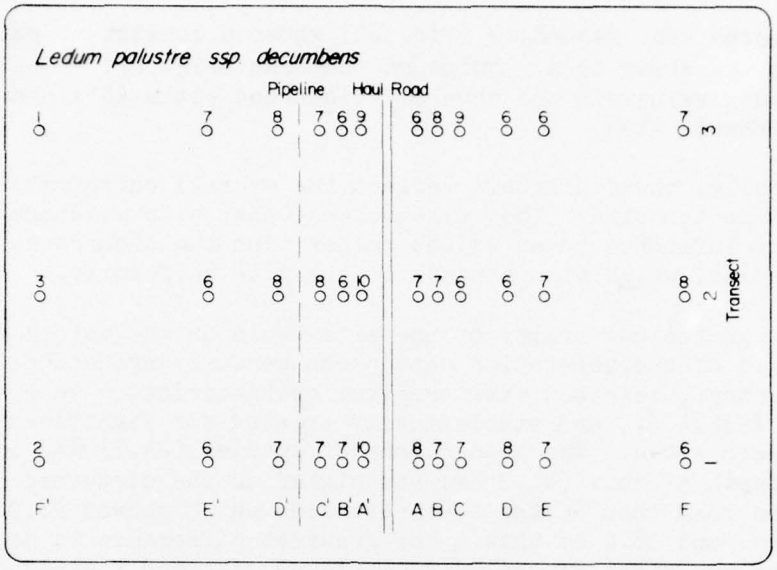


Figure 21. Distribution and importance of Ledum palustre *ssp.* decumbens *along the three transects in the study area. The circle size is proportional to the indicated species index value at each site. This species shows a very uniform pattern of importance and distribution throughout the study area.*

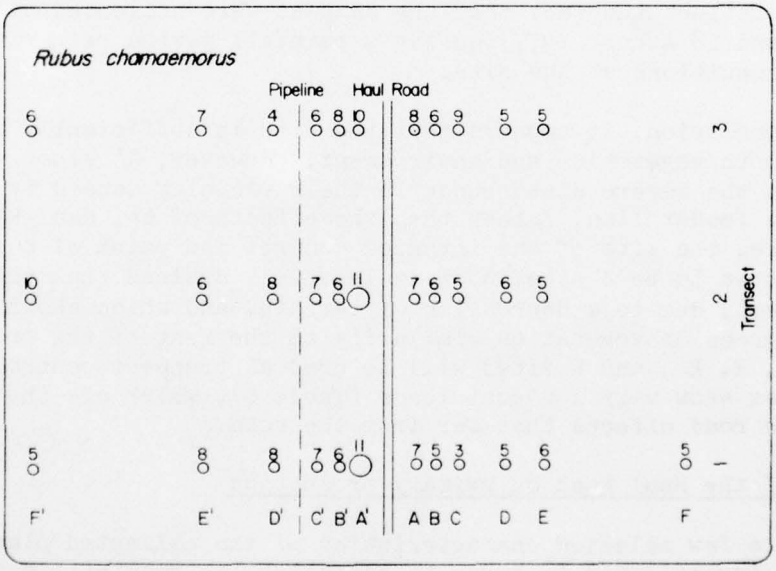


Figure 22. Distribution and importance of Rubus chamaemorus *along the three transects in the study area. The circle size is proportional to the indicated species index value at each site. The relative importance of this species is slightly increased in the disturbed sites on the northwest side of the road (A').*

Ledum palustre ssp. *decumbens* (Fig. 21) shows a consistent pattern throughout the study area. *Rubus chamaemorus* (Fig. 22) shows higher species index values in the severely disturbed sites (A') near the road on the northwest side.

Generally, these diagrams reflect the overall uniformity of the vegetation at the site. They also suggest that site moisture and severe disturbance influence cover values rather than the occurrence of individual species, which also attests to the site uniformity.

Although the uniformity of the site would be adequately determined on the basis of the vegetation data alone because vegetation integrates the environment, selected environmental characteristics were measured, tabulated (Table 6), and statistically treated for significant differences between sites. The mean number of species (24.7) was lower and the mean depth of thaw (41.2 cm) was higher on the disturbed northwest side of the road than on the southeast side which showed 28.0 species on the average, and 38.0 cm thaw. The greatest difference in depth of thaw between the two sides of the road was found at A and F sites (A' and F' sites showed also the vegetation with the least degree of similarity to the vegetation on the rest of the transect). The disturbed A' site had mean depth of thaw of 49.5 cm, while the wet F' site had mean depth of thaw of 31.7 cm. The mean pH values for both sides of the road were about 4.5; pH ranged between 3.9 and 5.1. The southeast side of the road showed a wider range of bulk density values, which indicate a high content of organic matter in all samples but two on the southeast side of the road and one on the northwest side. The soil moisture values appear to reflect the fact that the samples were collected on different days (16 and 18 August 1977) during a rainfall period rather than the moisture conditions at the site.

In conclusion, it appears that the site is sufficiently uniform in terms of both vegetation and environment. However, A' sites were found to reflect the severe disturbance in their vicinity caused by burial of the gas feeder line, rather than the effects of the Haul Road. Furthermore, the site of one intended control end point of the transect, F', was shown to be a site which is less well drained than the rest of the transect, due to a depression of terrain, and which shows one of the lowest degrees of vegetation similarity to the rest of the transect. Therefore, E, E', and F sites will be used as transect controls. All these sites show very low dust loads (Table 6), which are the only observable road effects that far from the road.

Effects of the Haul Road on primary production

Only a few selected characteristics of the collected plant specimens were investigated in order to establish the feasibility of detecting the effects of the Haul Road on plant production. It appears that these effects are recognizable in the material collected and that the methods used in the present study are suitable for this purpose. Additional methods will be used at a later date.

Table 6. Selected characteristics of vegetation and environment at investigated transect points.

Site number and designation	Plant with the highest importance value	Number of species	Distance from the road m	Depth of thaw cm	Soil moisture	Bulk density g cm^{-3}	Surface soil pH	Dust load * g m^{-2}
1 A1	Eriophorum vaginatum	28	10	49.6	1029.8	.10	5.1	
2 A2	Eriophorum vaginatum	24	10	41.8	661.1	.12	4.2	240
3 A3	Eriophorum vaginatum Dicranum spp.	28	10	40.4	410.0	.19	4.3	
4 B1	Sphagnum spp.	30	28	32.0	720.7	.11	4.6	
5 B2	Eriophorum vaginatum	27	28	43.0	25.3	1.51	4.2	30
6 B3	Sphagnum spp.	30	28	46.4	431.5	.17	4.1	
7 C1	Sphagnum spp.	30	95	31.0	526.3	.15	4.4	
8 C2	Eriophorum vaginatum	29	95	36.6	147.9	.43	4.3	8
9 C3	Sphagnum spp.	22	95	42.0	806.3	.10	4.4	
10 D1	Eriophorum vaginatum	25	266	36.0	458.5	.17	4.5	
11 D2	Eriophorum vaginatum	26	266	41.4	327.8	.23	4.3	1.6
12 D3	Eriophorum vaginatum	33	266	41.2	257.1	.26	4.4	
13 E1	Sphagnum spp.	27	411	36.8	286.9	.22	4.6	
14 E2	Sphagnum spp.	24	411	38.8	376.9	.18	4.8	1.05
15 E3	Sphagnum spp.	25	411	33.4	195.2	.36	4.6	
16 F1	Dicranum spp.	36	813	29.4	353.1	.17	4.8	
17 F2	Sphagnum spp.	29	813	33.6	151.9	.40	4.4	0.75
18 F3	Eriophorum vaginatum	32	813	32.0	66.9	.81	4.5	
19 A'1	Eriophorum vaginatum	21	10	47.0	45.5	.92	5.0	
20 A'2	Eriophorum vaginatum	16	10	55.6	466.8	.16	4.5	132
21 A'3	Eriophorum vaginatum	22	10	44.0	242.5	.30	4.2	
22 B'1	Sphagnum spp.	23	29	37.4	356.1	.21	4.6	
23 B'2	Sphagnum spp.	27	29	40.4	268.3	.26	4.3	53
24 B'3	Sphagnum spp.	25	29	44.6	460.3	.17	4.6	
25 C'1	Sphagnum spp.	29	103	39.0	422.5	.20	4.4	
26 C'2	Sphagnum spp.	24	103	38.6	329.8	.21	4.2	-
27 C'3	Sphagnum spp.	30	103	39.2	241.7	.29	4.5	
28 D'1	Sphagnum spp.	26	250	46.0	408.8	.18	4.6	
29 D'2	Sphagnum spp.	26	250	39.4	1071.7	.07	3.9	4.2
30 D'3	Sphagnum spp.	28	250	41.6	310.7	.22	4.3	
31 E'1	Dicranum spp.	27	406	40.8	416.0	.18	4.7	
32 E'2	Sphagnum spp.	29	406	36.6	512.1	.14	4.3	2.08
33 E'3	Sphagnum spp.	25	406	39.2	283.8	.26	4.2	
34 F'1	Dicranum spp.	31	937	44.2	232.4	.30	4.5	
35 F'2	Sphagnum spp.	22	937	31.0	448.9	.18	4.4	1.14
36 F'3	Sphagnum spp.	15	937	35.4	424.9	.17	4.9	

* Everett, 1978, personal communication

Table 7. Leaf dimensions (cm) of three species at two sites on the southeast side of the road.

	A2 Site (site close to road)		E2 Site (control site)		F2 Site (control site)		Significance	
Species	length	width	length	width	length	width	length	width
Rubus chamaemorus								
mean	2.68	3.90	-	-	1.94	2.77	p<0.001	p<0.001
standard deviation	0.45	0.61	-	-	0.43	0.64		
standard error	0.20	0.37	-	-	0.18	0.41		
Betula nana ssp. exilis								
mean	1.05	1.10	0.93	0.99	-	-	p<0.001	p<0.001
standard deviation	0.18	0.21	0.12	0.13	-	-		
standard error	0.03	0.04	0.01	0.02	-	-		
Ledum palustre ssp. decumbens								
mean	0.80	0.17	0.80	0.13	-	-	not	p<0.001
standard deviation	0.18	0.04	0.20	0.02	-	-	signifi-	
standard error	0.31	0.001	0.39	0.001	-	-	cant	

Leaf dimensions of three species were measured at two sites on the undisturbed southeast side of the road (Fig. 23). *Ledum palustre* ssp. *decumbens* was chosen as an evergreen dwarf shrub, *Betula nana* ssp. *exilis* as a deciduous shrub. *Rubus chamaemorus* was chosen for its large leaf size. The results (Table 7) indicate that the differences in leaf size between the two sites are significant at the <0.001 level for all three species measured. *Rubus chamaemorus* and *Betula nana* ssp. *exilis* showed both longer and wider leaves, and *Ledum palustre* ssp. *decumbens* showed wider leaves at the site close to the road than at the control site. The field observation that some shrubs and herbs have larger leaves in the vicinity of the Haul Road than farther away from it was thus documented; the yearly increments, for instance, were also observed to be greater but were not yet measured.

It was also observed during the field work that the vitality of mosses declined with decreasing distance from the Haul Road. A subjective scale was used to document this observation for *Sphagnum* spp. (Fig. 24). The results show that the decline in *Sphagnum* vitality occurs on both sides of the road and thus it is undoubtedly an effect of the road (most likely, it is an effect of dust). *Sphagnum* spp. could be used to monitor the road effects at other sites along the Haul Road.

A preliminary growth ring investigation of woody plants was carried out to find out whether it will be possible to compare the road (dust) effects on evergreen and deciduous plants as originally proposed. Excellent sections have been obtained (Fig. 25). These show clearly defined growth rings which are easy to measure. Although we have not yet analyzed the growth ring data we can make the following statements: 1) there is a distinct variation of growth increments from year to year; 2) *Ledum* (evergreen) has more uniform growth rings than *Betula* (deciduous); 3) in specific years increments are large in many specimens while

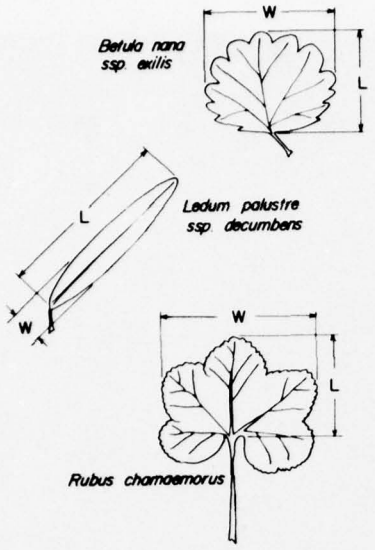


Figure 23. The leaf dimensions of plants which were compared for the study of Haul Road effects on leaf size.

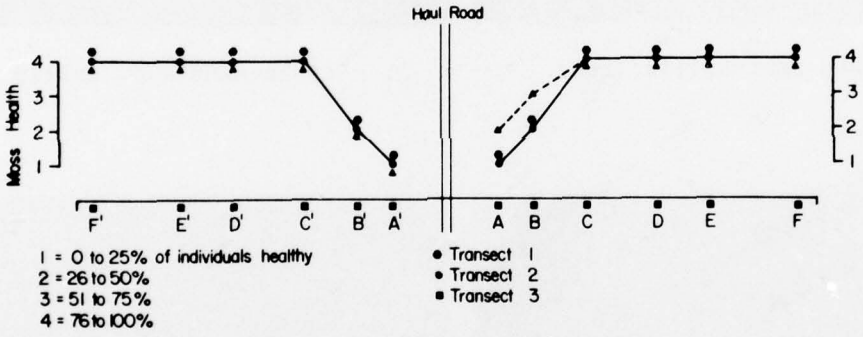
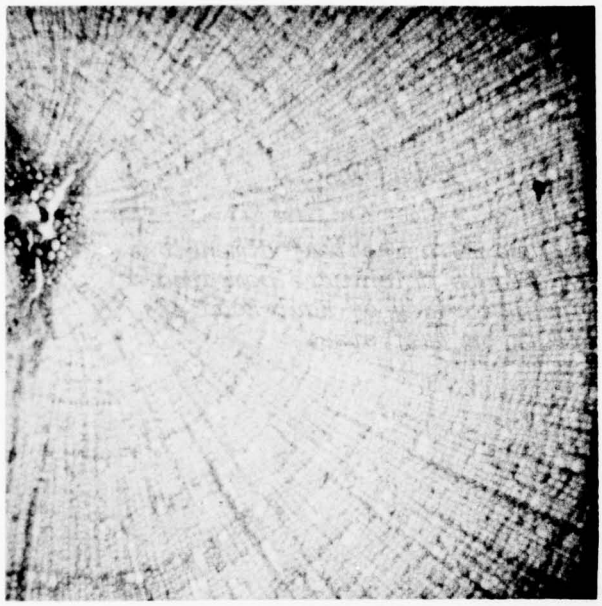


Figure 24. Health of Sphagnum *spp. was estimated at each site. On both sides of the road, the health of this plant decreases with decreasing distance from the Haul Road.*

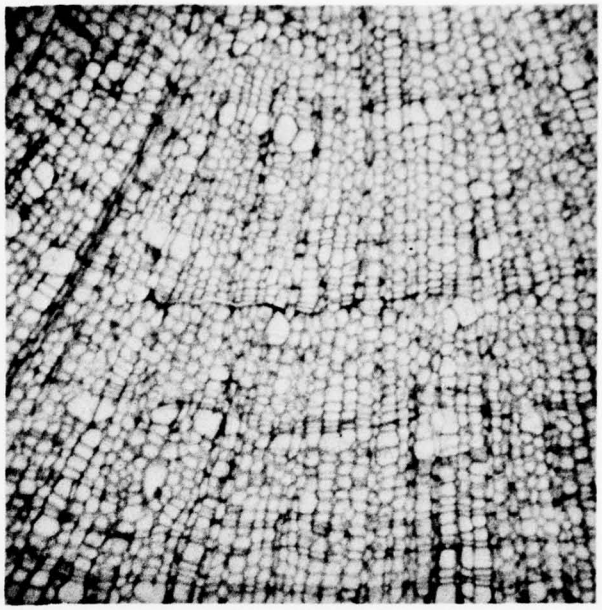
in other years increments are small in many specimens. Therefore, because of our success at obtaining measurable transverse sections and because the stems appear to be sensitive to extrinsic factors, we are optimistic that this method will give insights into the effects of the Haul Road on the stem incremental growth of dwarf shrubs.

Summary and conclusions

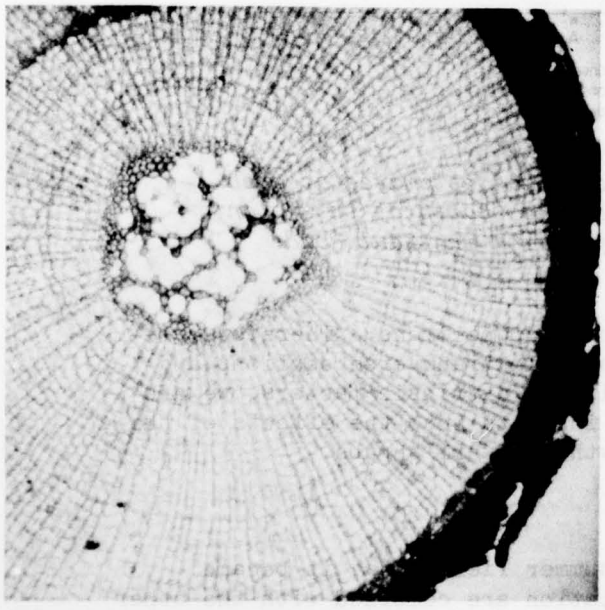
During the analysis of the 1977 summer field data, it became obvious that the dust effects on vegetation are combined with the other Haul Road effects in a complex way, and that it is very difficult to investigate the effects of dust separately. However, the collected plant material proved to be equally suitable for an investigation of the combined road effects and we proceeded with it without trying to separate the individual cause and effect relationships.



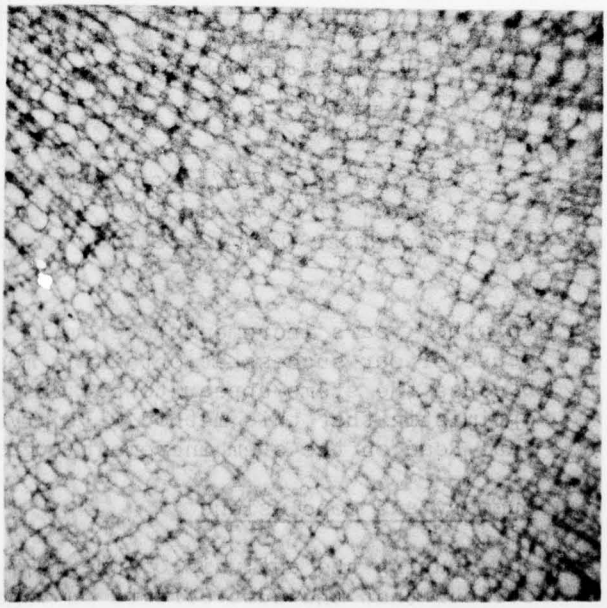
a. Betula nana *ssp.* exilis *(x60).*



b. Betula nana *ssp.* exilis *(x150).*



c. Ledum palustre *ssp.* decumbens *(x60).*



d. Ledum palustre *ssp.* decumbens *(x150).*

Figure 25. Thin (10-micron) transverse sections of dwarf shrub branches. Note the definable growth rings. These specimens are all from the control plots away from the road.

As a first step, it was necessary to establish that the environment and vegetation at the site are uniform, so that the effects of the road on vegetation would not be confused with the natural habitat and vegetation changes. It appears that the site is sufficiently uniform in terms of both vegetation and environment; this was determined by investigations of stand vegetation similarity, of distribution and importance of selected plants, and by comparison of several abiotic properties of the environment. The effects of surface disturbance close to the Haul Road and of the high site moisture at the end of the transect, both on the northwest side of the road, have to be taken into account later during the interpretation of the results of this study.

Several selected characteristics of the collected plant specimens were examined with respect to the effects of the Haul Road on plant production. The observations made during the field work suggested that leaf size and yearly increments of several woody plants and herbaceous dicotyledons are enhanced and that the vitality of mosses is lowered in the vicinity of the Haul Road. These observations were confirmed for both the leaf size, which was measured on some of the specimens, and for the moss vitality, which was estimated on a subjective scale in the field. It was also established that the evergreen and deciduous shrubs present at the site have growth rings which can be measured for the possible demonstration of the road (dust) effect differences between the evergreen and deciduous growth forms.

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PROJECT 3. BOTANICAL RECONNAISSANCE OF THE YUKON RIVER-PRUDHOE BAY HAUL ROAD, 1977

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and
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A second period of field work (15-24 July) was used to follow up on aspects of Haul Road botany noted during the 1976 season. New sites were selected to expand our coverage of landscape units and to increase the diversity of plant habitats and species observed. Approximately 700 lichen and bryophyte collections and 195 vascular plant collections were made that are now part of the permanent collection at the Herbarium of the University of Alaska Museum. Duplicate material will be distributed to herbaria at institutions engaged in studies of northern botany; the first duplicate set of vascular plants is going to the Komarov Botanical Institute, Leningrad. Not implemented this year for lack of funding was a computerized catalog of all Haul Road collections; however, we see this as a very worthwhile project, vital to keep pace with the need to permute an ever-increasing amount of information that is so basic to tundra ecology.

The following is an account of the locations visited with preliminary notes on our accomplishments. Some of the 1976 sites were revisited, and nine new areas were examined. These new sites are located and briefly described in Table 1. The maps appended to this report include the new sites.

16 July. Five-Mile Camp and vicinity, pipeline crossing area and revegetated borrow pits and roadsides for specimens of prominent native taxa and weeds. No Name Creek near M-1. Alder tundra (M-77-3) to examine age structure of the alders.

17 July. Alder tundra (M-77-1) near M-5/6 particularly for bryoflora of *Sphagnum*-dominated heath and for nearest-neighbor analysis of nearby stand of alders. Large sedge bog (M-77-2) adjacent to airstrip at Old Man Camp where we found a population of the shrub *Myrica gale* at its eastern and northern limit.

18 July. Visited Sukakpak mounds to study in greater detail the flora of the mounds and the intermound fens. Although at least some of the mounds are frozen below the surface and have the appearance of ice-cored features formed by up-thrusting, an attractive erosional theory for their formation was developed by A.W. Johnson. This erosional theory addresses some of the questions left unanswered by wholly

Table 1. New sites established in 1977.*

Site No.	Milepost	(km)	Quandrangle	Location	Description
1	41.5	(66.8)	Bettles	66°19'N, 150°24'W	Alder tundra - dwarf birch-birch-sphagnum heath and wet sedge meadow
2	50.5	(81.3)		66°26'N, 150°37'W	Sedge bog
3	56	(90)		66°30'N, 150°43'W	Alder tundra
4	197	(312)	Philip Smith	68°12'N, 149°24'W	Alluvial fan - prostrate shrub-subshrub meadow and sparsely vegetated alluvium
5	208	(335)		68°22'N, 149°24'W	Sedge meadow on lacustrine deposits and sand/silt of river banks
6	215	(346)		68°28'N, 149°18'W	Wet sedge meadow with active frost boils
7	220	(354)		68°30'N, 149°25'W	Tundra slopes and conglomerate outcrops
8	221	(356)		68°32'N, 149°27'W	West-facing tundra slope and summit - prostrate shrub-subshrub meadow and summit fellfield
9	271	(436)	Sagavanirktok	69°02'N, 148°46'W	Willow thickets and forb meadow

*See CRREL 1977 FHWA Annual Progress Report for documentation of 1977 sites.

frost-related hypotheses. Discussions with other field parties that had spent some time examining and analyzing both the alder tundra and Sukakpak mounds revealed how our approaches to these brief studies and our tentative conclusions reflected biases peculiar to our respective disciplines. Each group had a somewhat different and naturally incomplete picture of these phenomena, yet the whole story needs to be sought for such superb examples of naturally patterned landscapes. Time would be well spent developing a field plan and schedule for 1978 to permit an interdisciplinary investigation to refine the most important questions. It seems likely that each study would be an excellent topic for graduate research. A range extension for the sandwort *Minuartia stricta* was recorded at this site.

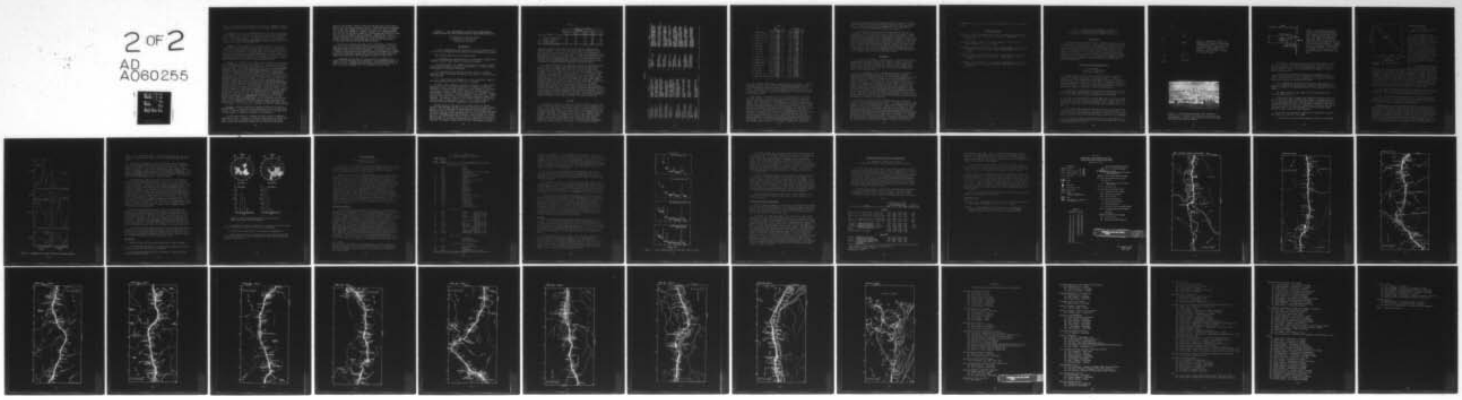
19 July. Alluvial fan on the west valley wall of the upper Atigun River (M-77-4) was selected to compare with M-37. Previously unrecognized variation (which deserves further study) was noted for *Erigeron purpuratus*. Wet meadow with numerous conspicuous, active frost boils (M-77-6) was examined briefly. *Dryas* slope and summit fellfield of a truncated ridge just east of Galbraith Camp (M-77-8) provided us with a taxonomic problem involving *Claytonia* and more information on the distribution of *Oxytropis scammaniana* which was previously unknown for this portion of the Arctic Slope.

20 July. Revisited site M-40 which we have dubbed Mt. Hultén in honor of the eminent Swedish botanist. It would be appropriate to formally honor a man who has done so much for Alaskan botany. This year we chose a different route of ascent and sought new habitats. More time was spent in a col and summit area with excellent alpine aspect - boulders, fellfield, snowbed, and snowflush. The rare moss *Oreas martiana* was

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ECOLOGICAL BASELINE INVESTIGATIONS ALONG THE YUKON RIVER-PRUDHO--ETC(U)
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found to be abundant and fruiting at one site here. *Barbula coreensis*, reported by Barbara Murray in 1976 as new to Alaska from M-24 was found here also.

21 July. Bluff of the Sagavanirktok River just north of the Happy Valley cut and at the pipeline crossing two boreal sedges (*Carex aurea* and *C. concinna*) were found at or near their northern limit and well north of their mapped ranges. Away from the bluff on a shrub-tussock upland we discovered *Oxycoccus macrocarpus* otherwise known on the Arctic Slope from the middle Colville River.

22 July. We made a traverse of mountain summits in the Galbraith system (M-77-7) of principally conglomerate bedrock to contrast the flora with a similar range of settings seen on the more highly calcareous limestone immediately to the south (M-40, Mt. Hultén). Most interesting was the discovery of *Stellaria umbellata*, which in Alaska has an unusually discontinuous distribution. Additional collections of a yet undescribed species of the lichen genus *Polyblastia* reported in 1976 by Barbara Murray from site M-40 were made here and at M-24.

23 July. To compare with the alpine sites visited in the Galbraith areas we examined a valley bottom transect from relatively well-drained ground, through extensive wet sedge meadows, to the sand and silts of the Atigun River. We revisited M-43 to re-collect the moss *Garysmithia bifurcata* (W.C. Steere, 1977, *Garysmithia bifurcata*, a new genus and species of Leskeaceae (Musci) from Alaska and Colorado, *Phytologia*, vol. 36, p. 165-170) which Barbara Murray reported in 1976 as an undescribed genus. We collected its associates and looked unsuccessfully for sporophytes which are as yet unknown. Site M-43 is one of three known Alaskan localities for the moss, which has also been found twice in Colorado. While there we also obtained seed from *Erigeron grandiflorus* with which Janice Bente of the University of Alaska was able to obtain a chromosome count, 2n = 36. This is the first count for the taxon from Alaska, and it is consistent with the number obtained elsewhere. To obtain this number for the Alaskan population is important in the light of another count Janice Bente made on *Erigeron muirii* from material taken at its type locality, 2n = 18. The two taxa have been distinguished primarily on the basis of leaf and stem pubescence, *E. muirii* being densely lanate whereas *E. grandiflorus* is hirsute-pilose. Hultén allied the two under *E. grandiflorus*, but our information now indicates there is a more fundamental difference between them; consequently the morphological differences are more reliable and legitimate than previously thought. Also at this site is another locality for *Carex albonigra*.

24 July. Revisited site M-54 to examine further the population of *Erigeron muirii*. Lichens and mosses were gathered here, well away from the dust of the Haul Road, as vouchers (and controls) for a CRREL study on the transport of materials adhering to dust particles.

Site M-56 was revisited to examine the hybrid swarm of *Oxytropis* discovered in 1976. Specimens collected by Susan Kubanis from this site later in the season provided us with viable seeds from which Janice Bente obtained the chromosome numbers 2n = 36, 40-42, 48, 50 and 56.

Based on the specimens obtained last year and this year, the putative parents are the blue-flowered and viscid *O. borealis* (reported elsewhere as 2n = 48) and a member of the yellow-flowered, non-viscid *O. campestris* complex (?*O. jordalii*). Numbers reported for *O. campestris* have been 2n = 32, 36, and 48, although 2n = 96 was reported on material from the Soviet Union named by them *O. jordalii*. Obviously more work is needed, especially with fresh material undergoing meiosis. This is an unusual opportunity to study hybridization in northern populations in which such interactions had not been suspected.

We have now recorded data from a total of 68 sites. Fourteen of these are in the valley of the Atigun River-Galbraith Lake. For this spectacular area we can construct a cross valley profile of the major vegetation types and floristic assemblages. We propose further studies to refine our data toward a descriptive botanical statement to integrate bedrock and topographic changes with common landforms and conspicuous vegetation types as well as a systematic treatment of the flora.

A landscape unit we have not studied well are snowbeds, and a number are well developed on the terraces of the Sagavanirktok River at Franklin Bluffs. Although these have been visited by John Koranda, we feel it would be profitable for us to carefully collect there.

PROJECT 4. SOIL INVERTEBRATES AS INDICATORS OF ENVIRONMENTAL INTEGRITY ALONG THE YUKON RIVER-PRUDHOE BAY TRANSPORTATION CORRIDOR

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Introduction

In 1977 a study assessed the feasibility of using community structure of soil invertebrates as an indicator of environmental disturbance.

The ultimate objectives of the research are:

1) to determine the sensitivity of soil invertebrate communities to stresses caused by human impact on northern ecosystems;

2) to select aspects of community structure (e.g. species composition, species richness, dominance, total abundance...) that best serve as indicators of ecosystem alteration;

3) to determine the consistency of these indices of community structure across latitudinal and habitat (e.g. moisture) gradients, and over time; and

4) to collect baseline information on soil invertebrate community structure, against which future data can be compared.

In August 1976 S. MacLean (University of Alaska), V. Behan (McGill University), and A. Fjellberg (University of Bergen) traveled from Fairbanks to Prudhoe Bay and returned to collect samples for the analysis of the soil fauna. Behan is an authority on the taxonomy and zoogeography of arctic mites (Acari), Fjellberg is a taxonomic specialist on arctic Collembola. Collecting began at the Yukon River. Between the Yukon River and treeline, collecting sites emphasized tundra-like habitats. The number of species of mites and collembola found at each collecting site is summarized in Table 1. This work provided the taxonomic and distributional background for the present study.

Between 18 and 26 June and 2 and 13 August 1977, R.H. Thomas traveled from Fairbanks and return to set up study plots, begin investigation of various environmental parameters, and collect samples for analysis of the soil fauna. In June, a series of 17 primary study plots of 10×10 m were set up, corresponding more or less to the 1976 collecting sites of MacLean, Behan and Fjellberg. Where possible, plots were set up in pairs at a given location, one of a "wet" habitat and one of a "dry" habitat, so as to allow between-habitat comparisons at the same latitude. Distinction between "wet" and "dry" was made on the basis of

Table 1.

Site	Number of species: Acarina: Prostigmata	Acarina: Mesostigmata	Acarina: Cryptostigmata	Acarina: Total mites	Collembola
I. Arctic Coastal Plain	24	18	38	80	80
II. Arctic Foothills	24	16	45	86	79
III. Brooks Range	23	14	48	86	62
IV. South-Slope Tundra	37	19	53	110	79

vegetation composition at the location and does not represent any absolute ranking. Lists of the main plant species on each plot were made at the time they were set up. Table 2 gives the locations and descriptions of each of the study plots. In August, an additional seven disturbance and control plots were set up, three along the Everett dust transect near Toolik Camp (at APL 117-3), two along the Everett dust transect near the abandoned Sagwon airfield, and two at the oil spill site north of Franklin Bluffs, between MS 133-2 and MS 133-3.

To obtain a measure of the temperature regime on the primary study plots, a set of 24 temperature integrator tubes (using the sucrose inversion method; Berthet 1960) were placed on each of the plots. Fourteen of the plots were set up in June and the remainder in August. In August, two of the eight replicate series on each of the plots were returned to Fairbanks where the temperature sum was determined. The remainder of the tubes will be retrieved in June 1978. Lignin decomposition potential will be measured by weight loss from wooden tongue depressors which were placed in August at three depths and horizontally in eight replicates (for a total of 24) at each plot. Cellulose decomposition potential will be measured by using loss of tensile strength from special cotton strips placed vertically into the ground (Latter and Howson 1977). Sixteen cotton strips were placed around each of the plots (to minimize trampling within the plot) in August. Half of the replicates of both the lignin and the cellulose will be retrieved in August 1978 and the other half in August 1979. In both June and August, replicate series of ten cores (5 cm diam) were taken on each plot.

Results

The number of species of mites and Collembola found at each of the sites sampled by MacLean, Behan and Vjellberg in 1976 is summarized in Table 1. The existence of latitudinal trends in species richness is one of the basic generalizations of biogeography: fewer species are found at higher latitudes. This trend does not occur in Collembola along the transect. The number of species found on the Arctic Coastal Plain, foothills, and south slope tundra is virtually identical, with fewer species found in the Brooks Range north of treeline. The species richness of mites, and particularly the dominant Oribatei (Cryptostigmata) does increase steadily from north to south along the transect.

Table 2.

Site and Location	Habitat
1) Prudhoe Bay (Wet) foot of West Dock, near climatic station 20.	Wet Meadow - Carex aquatilis, Eriophorum anqustifolium, Salix phlebophylla, S. reticulata
2) Prudhoe Bay (Dry) foot of West Dock, near climatic station 20.	Raised Polygon Center - Carex aquatilis, Eriophorum angustifolium, Salix pulchra, Saxifraga cernua
3) Franklin Bluffs (Dry) approx 1 km N of MS132-2S of W side of road, on bench	Dry Meadow - Carex bigelowii, Eriophorum angustifolium, Salix arctostaphylos, S. pulchra, Cassiope tetragona
4) Franklin Bluffs (Wet) approx. 1 km N of MS132-2S on W side of road, below	Mesic Meadow - Carex aquatilis, Eriophorum angustifolium, Salix pulchra, Dryas integrifolia
5) Sagwon (Dry) at what was MS127-2.1B (revegetation site)	Tussock Tundra - Eriophorum vaginatum, Cassiope tetragona, Salix pulchra, Betula glandulosa, Vaccinium vitis-idaea, Polygonum bistortoides, Carex bigelowii
6) Sagwon (Wet) at what was MS127-2.1B (revegetation site), in drainage at the foot of an old moraine	Salix Swale - Salix pulchra, Eriophorum angustifolium, Carex aquatilis, Betula nana, Equisetum sp., Vaccinium uliginosum
7) Toolik (Wet) on E side of the road in CRREL 117-1, about 4.5 km past Toolik Camp turnoff	Salix-Carex Swale - Salix pulchra, Carex sp., Betula nana, Eriophorum vaginatum
8) Toolik (Dry) on E side of the road about 4.5 km N of Toolik Camp turnoff, 1.5-2.0 km uphill	Tussock Heath - Eriophorum vaginatum, Salix pulchra, Betula nana, Carex sp.
9) Atigun (Wet) approx 80 m W of the pipe at APL112-1	Carex - Salix Swale - Salix sp., Carex sp., Rhododendron sp., Pedicularis suedetica
10) Atigun (Dry) on bench near the Atigun R at APL112-1	Mixed Heath - Eriophorum vaginatum, Carex bigelowii, Betula nana, Salix pulchra, S. reticulata, S. phlebophylla, Dryas integrifolia, Petasites frigidus, Poa arctica
11) Chandalar (Dry) E side of the road near Table Mtn SC, on alluvial fan	Shrub Tundra - Betula nana(?), Ledum palustre, Salix sp., Vaccinium vitis-idaea, Carex sp., Cladonia sp., Cetraria sp.
12) Chandalar (Wet) E side of the road near Table Mtn SC, N of 11	Salix sp., Betula nana, Ledum palustre, Carex sp., Eriophorum vaginatum, Vaccinium uliginosum, V vitis-idaea, Empetrum nigrum
13) Gcobler's Knob near summit, by climatic station 3	Dry Shrub Tundra - Betula nana, Cassiope tetragona, Carex sp., Cladonia sp., eitraria sp.
14) Hickel Highway on E side of the road, a few hundred meters N of 87-2B	Wet Tussock - Eriophorum veginatum, Betula nana, Salix sp., Vaccinium uliginosum, Ledum palustre, Rubus chamaemorus, Eriophorum scheuchzeri
15) Finger Mountain near summit of E side of road	Lichen Heath - Cetraria sp., Cladonia sp., Dactylina sp., Betula nana, Empetrum nigrum, Ledum palustre, Salix phlebophylla
16) Elliott Highway Burn approx mile 98 of Elliott Hwy, on CRREL 1968 fire disturbance	Tussock Heath - Eriophorum vaginatum, Ledum palustre, Rubus chamaemorus, Vaccinium vitis-idaea, V uliginosum
17) Elliott Highway Control approx 1 km farther up Elliott Hwy on the right	Tussock Heath - Eriophorum vaginatum, Ledum palustre, Betula glandulosa(?), Vaccinium uliginosum, V vitis-idaea, Salix pulchra

Table 3.

	Site	Acari ind/m^2	Acari 95% conf (up/low)	Acari % top 2.5cm	Collembola ind/m^2	Collembola 95% conf (up/low)	Collembola % top 2.5cm
1	Prudhoe Bay (Wet)	2,470	(5,300) (970)	94	23,600	(52,960) (8,910)	90
2	Prudhoe Bay (Dry)	14,870	(25,540) (8,080)	83	44,990	(66,940) (23,620)	91
3	Franklin Bl. (Dry)	27,450	(35,390) (20,990)	82	12,980	(20,930) (7,130)	76
4	Franklin Bl. (Wet)	5,920	(9,270) (3,610)	94	2,670	(8,530) (570)	90
5	Sagwon (Dry)	19,450	(35,200 (9,880)	88	6,910	(11,100) (4,080)	65
6	Sagwon (Wet)	16,390	(30,270) (8,100)	87	1,780	(6,160) (330)	62
7	Toolik (Wet)	5,860	(9,500) (3,420)	76	1,820	(3,090) (1,000)	79
8	Toolik (Dry)	10,190	(19,200) (4,900)	82	3,870	(7,640) (1,750)	75
9	Atigun (Wet)	8,170	(14,550) (4,240)	83	1,890	(5,910) (430)	74
10	Atigun (Dry)	85,420	(121,690) (58,290)	73	29,780	(66,270) (11,380)	64
11	Chandalar (Dry)	77,150	(101,420) (57,720)	68	29,480	(41,110) (20,670)	73
12	Chandalar (Wet)	68,600	(94,110) (48,880)	71	11,230	(15,900) (7,730)	70
13	Gobbler's Knob	42,320	(63,630) (27,090)	59	21,100	(28,770) (15,150)	56
14	Hickel Hwy	33,380	(56,880) (18,320)	85	10,320	(41,270) (1,450)	78
15	Finger Mtn.	40,990	(50,760) (32,770)	68	13,620	(19,310) (9,350)	67
16	Elliott Hwy Burn	16,130	(32,970) (6,950)	72	6,500	(12,630) (3,000)	75
17	Elliott Hwy Control	44,020	(51,970) (37,070)	74	15,720	(19,690) (12,410)	66

Thus, the two major microfaunal groups differ in this regard. It should be noted, however, that inclusion of forested habitats south of the Brooks Range would doubtless increase the species richness of both groups. Both groups have sufficient species richness in northern Alaska to provide a large pool of potential information to be used in disturbance-oriented studies.

Upon return to Fairbanks the soil cores taken in June and August 1977 were extracted for microarthropods and then percent accumulated organic matter was determined by weight loss on ignition of the dried sample. Over 1000 samples (2.5-cm segments of cores) were extracted and organic matter determinations were done on most of these. Table 3 gives mite and collembola abundances in individuals per m^2 for the June 1977 samples, representing some 20,000 animals counted. The high variance is the result of a clumped distribution of the organisms. Collembola showed no discernible latitudinal trend in abundance, whereas mites tend to increase in abundance from north to south, in parallel with the species richness determined in 1976. Both mites and Collembola have greater abundance in dry than wet habitats at any given latitude along the transect. On all plots except the Prudhoe Bay sites, mites were more abundant than Collembola. The range of variation in abundance of

mites and Collembola was certainly greater than the range of variation in productivity of the habitats sampled, implying that we are not yet able to predict with accuracy the abundance of soil invertebrates occurring in any particular habitat along the transect.

Table 3 also gives the proportion of the fauna in the top 5 cm occurring in the top 2.5 cm of the soil profile, as an index of depth distribution. As in 1976, the greatest surface concentration of the fauna occurred at the two arctic coastal plain locations. On the south side of the Brooks Range there is a tendency for a smaller proportion of the fauna to concentrate in the surface layer, especially on the drier sites. Mites tended toward greater surface concentration than Collembola, consistent with the 1976 work and data from Barrow (Douce and Crossley 1977). As with total abundance, the generalizations are not sufficiently strong to allow accurate prediction of depth distribution of soil fauna in an unknown area along the transect.

Discussion

As of yet, we are unable to offer a model to predict with accuracy the abundance and depth distribution of the soil fauna. The Soviet zoogeographic literature stresses the concept of zonal regularity in faunal and floral community structure. These results indicate that broad generalizations may be made, but any given habitat may deviate widely from the "zonal type."

Work is in progress on the counting and sorting of the August samples, and preliminary analysis of the June results continues. Identification of individual animals, to species where possible, will be done and biomass estimated by regression on size measurements (Douce 1976, Petersen 1975). These data will allow the distributions of particular species to be compared and used as indices of environmental change. For example, while abundance of major faunal groups is only weakly related to moisture, the species that compose the fauna show distinct differences in distribution along moisture gradients. Thus, the effect of surface runoff impoundment should be immediately apparent in the composition (but not necessarily total abundance) of the soil fauna. Community structure will be analyzed by means of various indices of dominance, diversity, and association, correlation with environmental parameters, and analysis of variance.

This study, as well as others, indicates that soil mites and Collembola are highly aggregated in nature. This fact explains the high variance in the June abundance data. Thus in some samples there are an average of five or more mites and Collembola per cm^3 whereas in others there is an average of considerably less than one individual per cm^3. Normalizing transformations of the existing abundance data allows the estimation of the sample sizes necessary to show significant differences between the mean densities of any given pair of habitats. For example, 64 samples would be necessary to show a significant difference (at the 5% level) between the mean densities of Collembola on the Prudhoe Bay wet and dry sites, whereas the ten samples in hand suffice to show

a significant difference between the mean densities of mites on the same sites.

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PROJECT 5. DISTRIBUTION AND PROPERTIES OF ROAD DUST AND ITS POTENTIAL IMPACT ON TUNDRA ALONG THE NORTHERN PORTION OF THE YUKON RIVER-PRUDHOE BAY HAUL ROAD

Introduction

Several individual studies are being conducted under this project to identify the chemical, physical, and mineralogical properties of the dust and chemical modifications to the vegetation. Responses of the vegetation and invertebrate fauna are being examined under Projects 2 and 4. For purposes of this progress report, 1977 results will be reported in three parts: collection and distribution of dust, clay mineralogy of the dust and related materials, and preliminary chemical investigations. Results of this project are being compared with another DOE report entitled *Effects of Road Construction on Nearby Lakes on Alaska's North Slope.*

Dust Collection and Distribution

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During the period 23 to 25 April 1977, four general areas were selected for summer measurement of road dust impact. In order to document winter dust accumulation, snow samples (from snow surface to ground surface) were collected at three sites (subsequently chosen for summer measurements) either side of the road at distances of 8, 30, 125, 312, 500 and 1000 m. Electrical conductivity measurements and trace element determinations were made on the incorporated dust.

Beginning on 23 June 1977, dust collection transects were set out near Toolik Lake, Sagwon Uplands, Franklin Bluffs and Prudhoe Bay (Fig. 1). At each site the following instrumentation was deployed:

a) Pairs of shielded dust collecting pans (Fig. 2) were positioned at intervals of 8, 30, 125, 312, 500 and 1000 m from either edge of the road at each site except Prudhoe Bay where a single transect was laid out north of the road. Each collection pan had a catchment area of 241 cm^2.

b) A Woelfle-type mechanical wind recorder was positioned at 188 m along each collection transect on one side of the road only (see Figure 1 for locations). These recorders provided a continuous record of wind direction and velocity for the period of record (24 June to 4 September).

c) A static non-directional dust recorder was placed 188 m along the dust measurement transect and 16 m from the wind recorder if it was on the same side of the road.

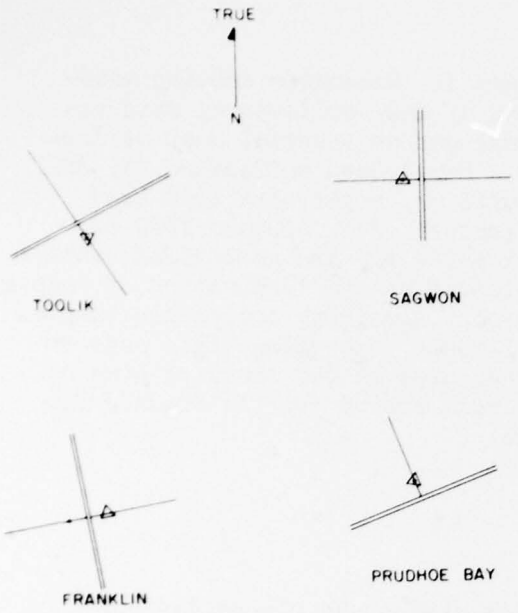


Figure 1. Relative positions of transects with respect to Haul Road orientation at each of the four dust collection sites. Transect line on each side of road equals 1000 m. Triangle: inertial dust collector. Dot: wind recorder.

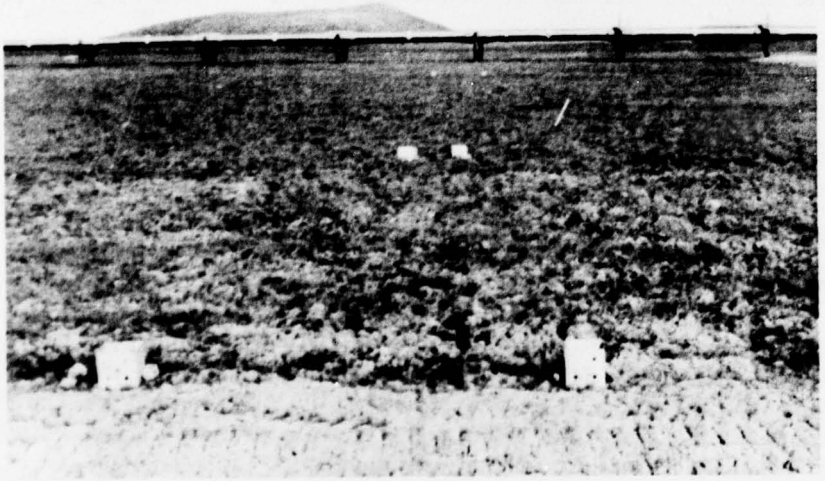


Figure 2. Shielded dust collectors, west transect at Toolik site. The 241-cm^2 collecting pans are inside the shielded boxes. Inertial dust collector and wind recorder are located on opposite transect.

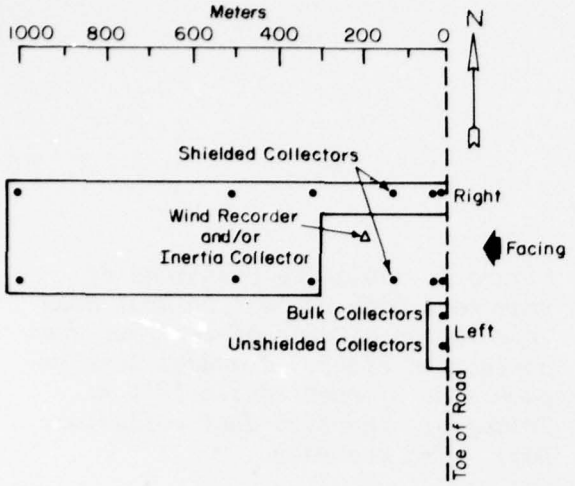


Figure 3. Schematic showing positions of dust collectors, wind recorder and/or inertial dust collector. Right-hand collectors (8, 30 and 125 m), right- and left-hand collectors (312, 500 and 1000 m), bulk collector and unshielded control collected at the termination of sample period. Remaining collectors sampled at 1-month intervals. This pattern is repeated on the opposite side of the road except for the Prudhoe Bay site.

d) On 23 July a supplemental collection device was placed 8 m off one or both sides of the road depending upon the site (Fig. 3). The collector consisted of a plastic bag stretched so that the collection area was 876 cm^2. These collectors provided bulk samples for clay mineral identification.

e) On 23 July an unshielded aluminum collecting pan (241 cm^2 surface area) was placed at 8 m on either side of the road at all four sites. This was done to provide a comparison of collection efficiency between the shielded and unshielded collectors.

f) Soil samples were collected at each of the four sites near the position of each pair of shielded dust collectors. The samples were taken at the base of the vegetation from 0 to 2.5 cm and 2.5 to 5 cm (84 samples).

Dust sample collection was begun on 17 June according to the following scheme (Fig. 3).

a) Facing the line of transect the shielded collectors on the left at 8, 30 and 125 m were collected every 30 days. The shielded collectors on the right side at 8, 30 and 125 m were collected at the end of the sampling period (87 days). The shielded collectors at 312, 500 and 1000 m (both right and left) were combined and collected at the end of the sample period. This was necessary to insure sufficient sample because of the low yield at these distances.

b) The bulk (clay analysis) sample and the unshielded collectors were taken up at the end of the summer.

c) The inertial collectors were removed at the end of the summer.

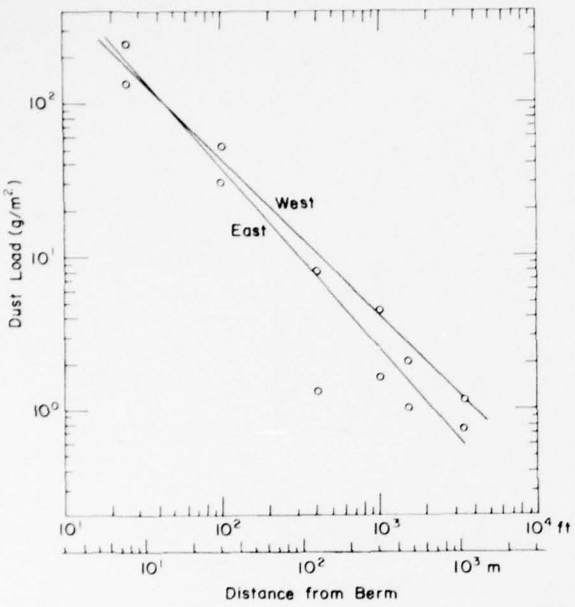


Figure 4. Dust load from Toolik transect.

Analyses and results

The following analyses are underway or completed.

a) The unshielded bulk samples were washed and filtered. The material retained on the ~20 μm filter was sent to Dartmouth (see Reynolds project) for analysis. The filtrate was retained for microparticle analysis. As an example, the filtrate from the collector at 8 m, east side at Franklin contained 133,250 particles ranging from 16.0 to 0.50 μm. Similar counts will be made on the remaining samples. SEM analysis is proposed for the particles retained on the Millipore filter.

b) All samples, representing the entire sample period (right side) and the 312-, 500- and 1000-m composite samples, have been washed, centrifuged and weighed. Each sample was then treated with 30% hydrogen peroxide to remove organic residues and reweighed. Organic inclusions (vegetation fragments and insects) accounted for a substantial part of the sample weight from the distant collectors at all sites. Preliminary total summer plots of these data show a surprisingly close correspondence in line slope for all sites (as well as between opposing transects at each site; Fig. 4 for Toolik). This suggests the rather uniform influence of some factor, probably wind direction and speed. More definite interpretations must await further analyses of the wind data.

c) The samples obtained monthly from the shielded collectors at 8, 30 and 125 m (left side) and the unshielded comparison collectors at 8 m (70 samples in all) are being processed in a manner similar to (b).

d) The soil samples have been dried, ground and passed through a 2-mm sieve. A 10-g (or less) alliquot has been leached with ammonium acetate (30 minutes). The leachate was analyzed for Ca, Mg, K and Na ions by means of atomic absorption spectrophotometry.

These data indicate the quantity and distribution of ions, some of which (Ca and Mg) might be expected to produce plant growth response. These data (those for Toolik are shown in Figure 5) are difficult to interpret for a number of reasons, primarily because of the wide range in elemental concentrations that can occur over short distances within a relatively homogeneous appearing soil-microrelief unit. Much of this variability results from subtle microsite differences which include point to point differences in composition of the exchange complex. Thus it is likely that any given value obtained from so few data points is

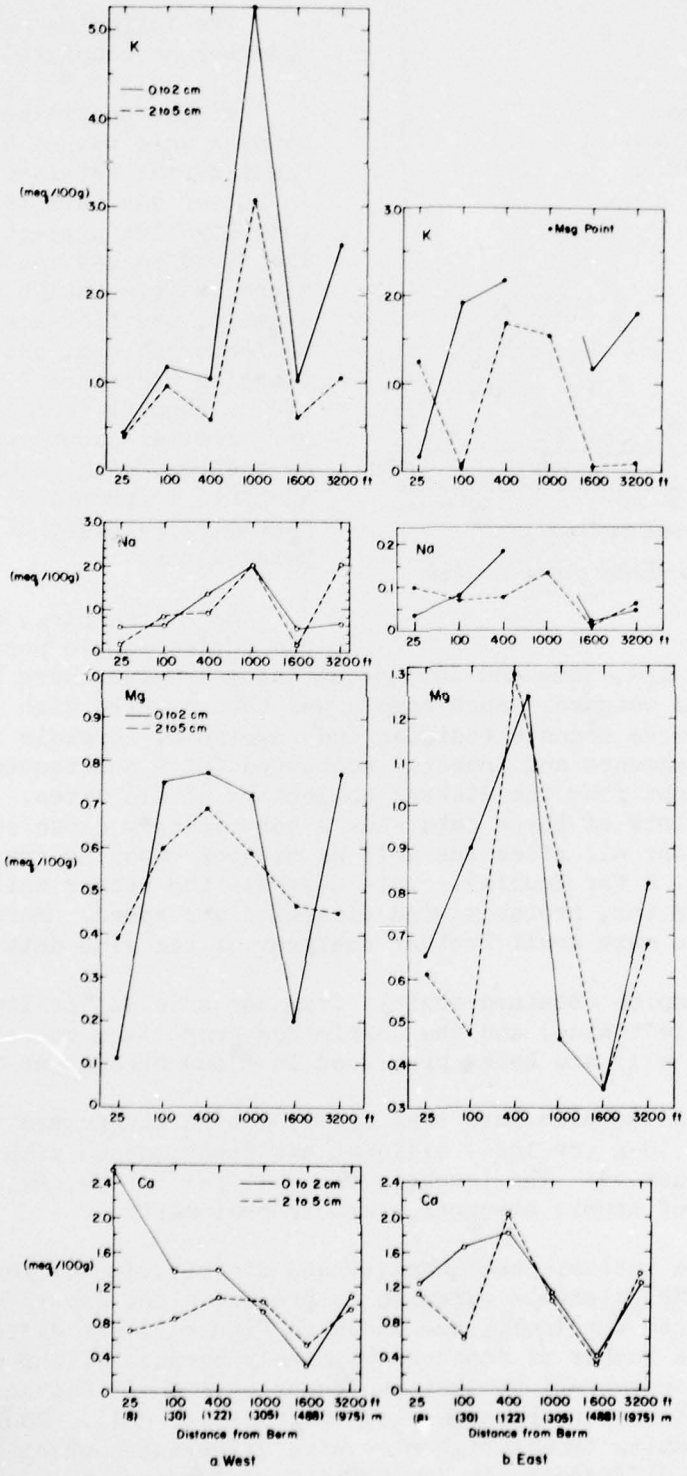


Figure 5. Exchangeable cations from Toolik surface samples.

likely to fall within the range of that variable within the soil unit in question. Trends in data thus become more significant than absolute values.

Simple visual inspection of the Toolik plots suggests a general peak in available element concentrations at 400 ft (122 m) and a major depression at 1600 ft (488 m) on either side of the road. If the pattern is real it is not related apparently to dust volume. However, it may be related to particle size and/or mineralogic composition. The Sagwon data generally show a peak at 100 ft (30 m) and a suggestion of a depression between 1000 ft (305 m) and 1600 ft (488 m). In contrast the Franklin and Prudhoe data show no definable trends.

In approximately 75% of the cases, the values for the exchangeable cations are significantly greater in the 0-2 cm soil depth than in the 2-5 cm depth. This is a common relationship in wet tundra soils in which leaching is insignificant and natural atmospheric infall (ombitrophic conditions) provides one of the principal mechanisms for soil nutrient enrichment. Ions may enter the soil directly in the form of soluble salts (Na, Ca, Mg). They may be released from primary minerals, especially those in the clay size range, through chemical weathering, or by replacement on the exchange complex of clay minerals. It is likely that all three methods of input are operative in the case of Haul Road dust although release from primary minerals is probably much too slow to be effective in the short term. The relatively high percentage of clay mineral species, as opposed to clay size silica, in the Haul Road samples (Reynolds and van Oss, this report) suggests that exchange complex replacement may be significant.

When the absolute ionic values for the Toolik and Sagwon dust transects are compared with the limited number of values obtained from similar soils at similar depths in the 1976 soil survey (ARO Contract DAA-G29-76-G-0293) it is seen that although the dust transect values fall within the range of the soil survey values they are greater, especially for the high end of the range, and this is particularly true for Sagwon. Inasmuch as the same analytical techniques were used (different technician) in both years the elevated values of the dust transects are regarded at this time to be related to road dust additions.

e) Wind direction and velocity charts have been reduced and data abstracted hourly, and daily means calculated. Figure 6 shows the wind rosette for two 12-hr periods for the summer at the Toolik site. There is a definite difference in direction and velocity for these two periods. This diurnal trend seems to hold for the other sites.

Conclusions

Experience with dust collection methods used in 1977 indicates:

a) The shielded collectors do not adequately sample the dust fall. Values less than the total fall are recorded.

b) Sample recovery methods must be modified to reduce field and laboratory transfer steps.

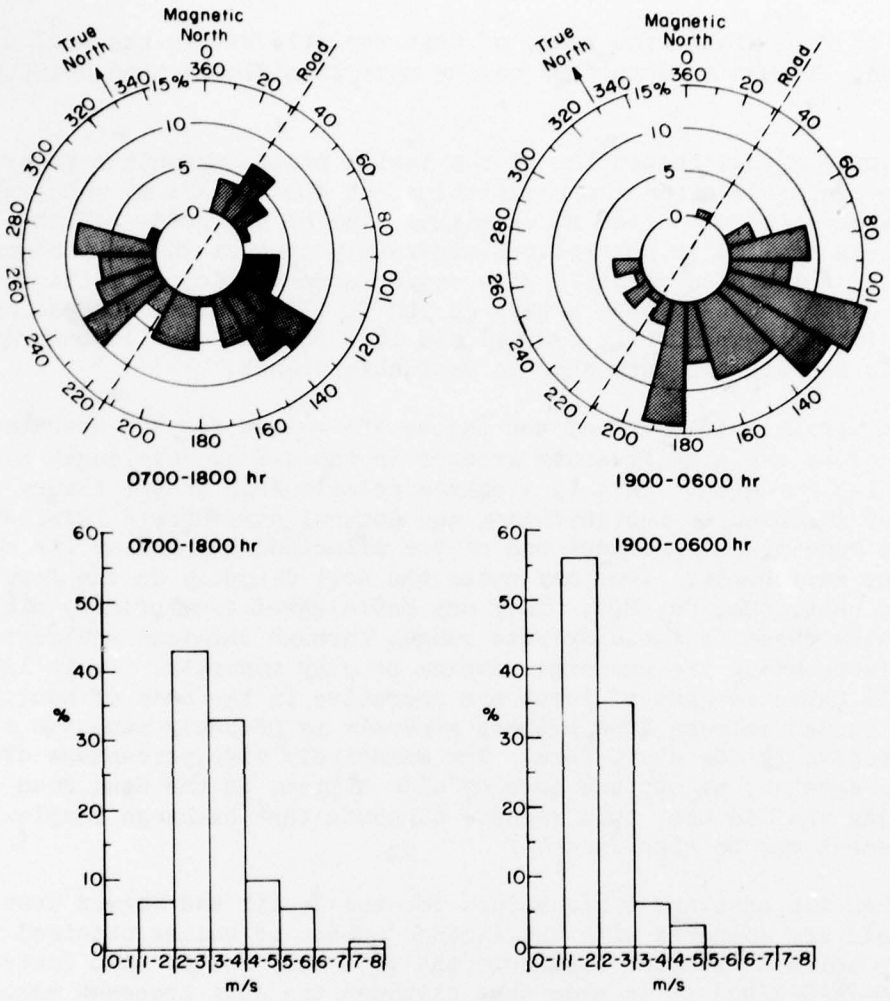


Figure 6. Wind rosettes and wind velocity for day and night conditions for Toolik transect.

c) Supplemental (event) air samples are desirable at several heights above the surface; a portable 10-m tower is recommended.

d) Traffic monitoring (event) is necessary to supplement (c).

e) The program should be continued and possibly several additional sites added during the course of proposed use of the Haul Road for gas pipeline construction.

Clay Mineralogy*

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The purpose of the present study was to determine the type of clay minerals added to the tundra from road dust. Samples were obtained from the road and adjacent material sites including bedrock exposures, adjacent tundra soils, and the dust itself.

Samples were collected by Richard Haugen (CRREL) in June 1977 and Hendrick van Oss in July 1977 during a round trip from Prudhoe Bay to the Brooks Range (Table 1). The road and material site samples were sieved in the field; materials coarser than 2 mm were discarded. The soil samples were collected at varying distances (between 100 and 300 m) on either side of the road. A few of the soil samples were taken from frost boil material; most, however, were taken from the gley horizon that existed 10-15 cm below the organic-rich surface layer. This mineral layer should be uncontaminated as it is overlain by tens of centimeters of dense organic matter. The gley samples are generally plastic, indicating a high clay content. They did, however, contain coarser clastic material in addition to the clay. The soil samples were sealed in plastic bags to maintain their moisture content. Three bedrock samples were also collected (No. 11b, 15, 27d), and four dust samples (No. 6b, 27e, 30d, 32c) were supplied by Dr. Kaye Everett of Ohio State University.

Laboratory analysis

The clay mineralogy determinations were made by X-ray diffraction analysis at the Department of Earth Sciences, Dartmouth College, Hanover, New Hampshire, by Hendrik van Oss. The analysis procedure was as follows. Between 10 and 30 g of material was agitated in water overnight to release clays into suspension. If the sample was consolidated, minor grinding was done preliminary to the agitation. The suspension was washed to remove soluble salts by centrifuging at 2000 rpm for ten minutes. This left most of the material settled at the bottom of the centrifuge cup. The remaining suspension was discarded. About 60 ml distilled water was added to the bottom material which was then brought again into suspension by a combination of stirring followed by ultrasonic agitation. A peptising agent ($Na_4P_2O_7 \cdot 10\ H_2O$) was then added to the suspension, which was then further ultrasonically agitated for about 20 seconds. This procedure causes the clay particle aggregates to deflocculate. The next step was to centrifuge the deflocculated suspension for ten minutes at 450 rpm. The procedure leaves the <2-μm clay

*This report is abstracted from a final report to CRREL by Dartmouth College in November 1977 entitled, "Clay mineralogy of road materials and soils along the northern section of the Yukon River-Prudhoe Bay Haul Road, Alaska."

Table 1. Sample sites.
(See appended maps for locations.)

Sample Locations

Field Number	CRREL Map Number	Location
		Road and Material Site Samples
1	R-1	MS 111-2
2	R-2*	MS 112-0
3	R-3	MS 112-3.1
4	R-4	stream sediments at Atigun River Bridge
5	R-5	CRREL 114-1ABC
6a	R-6	Toolik Lake material site
7	R-7*	Cross-section 117-1
8a	R-8	117 APL-3
10	R-10	MS 117-2
11a	R-11-1	Slope Mountain material site
12	R-12	MS 119-4N
13	R-13*	CRREL 119A-1
14	R-14	MS 121-1
16	R-16*	CRREL 122-1A
17	R-17	MS 124-1
18	R-18	CRREL 124-1
21	R-21	126 APL-AMS 1A
22	R-22*	MS 127-1.2
24	R-24*	CRREL 127-2
25a	R-25	MS 127-2.1B
26	R-26*	0.4 km north of CRREL 127-3
27a	R-27	CRREL 127-1
28	R-28	MS 130-5 (MS 130-3)
29	R-29*	MS 132-1
30a	R-30	Franklin Bluff
31	R-31*	MS 135-ABC-2
32a	R-32-1*	Gas Arctic Road
32b	R-32-2	Gas Arctic Road
33	R-33	Prudhoe Bay gravel site
		Tundra Soil Samples
8b	R-8W	117 APL-3 200 m west of road
8c	R-8E	117 APL-3 200 m east of road
9	R-9	117-1 100 m west of road
19	R-19	MS 124-4 100 m east of road
20a	R-20W	0.8 km north of MS 124-2 100 m west of road
20b	R-20E	0.8 km north of MS 124-4 100 m east of road
23a	R-23W	CRREL 127-2 100 m west of road
23b	R-23E	CRREL 127-2 100 m east of road
25b	R-25W	MS 127-2.1B 300 m west of road
27b	R-27E	CRREL 127-1 Sagwon Upland 200 m east of road
27c	R-27W	CRREL 127-1 Sagwon Upland
30a	R-30W	Franklin Bluff 200 m west of road
30b	R-30E	Franklin Bluff 200 m east of road
		Bedrock Samples
11a	R-11-2	Slope Mountain
15	R-15	Happy Valley Cut
27d	R-27B	Sagwon Upland sandstone
		Dust Samples (Supplied by Everett)
6b	DT-TL	Toolik Road (117APL-3)
27e	DT-SU	Sagwon West
30d	DT-FB	Franklin West
32c	DT-PB	Prudhoe Road (Gas Arctic Site)

*Collected by R. Haugen, USA CRREL, June, 1977.

fraction in suspension. This suspension was decanted. A clay mount was prepared of the sample by centrifuging the clay fraction suspension (10 minutes, 2000 rpm) onto a porous porcelain plate. This step was generally repeated once in order to achieve a reasonable clay thickness on the plate. The clay mount was then air-dried at room temperature and further dried for several hours at about 100°C. The clay mount was then X-rayed using Ni-filtered Cu K-alpha radiation; scans were made from 30° to 2°2θ at a speed of 2° 2θ per minute.

In order to allow determination of an expandable clay (such as montmorillonite) component, the clay mounts were then glycolated by exposing the clay mounts, upside down, to an atmosphere saturated with ethylene glycol vapor at 60°C for a minimum of 8 hours. The mounts were then X-rayed again.

To confirm the presence of chlorite, the clay mounts were placed in a 550°C oven for 1 hour. This treatment causes the 001 peak of well-crystallized chlorite to be enhanced and its other peaks to be decreased. It also converts any kaolinite to meta-kaolinite, thus removing kaolinite peaks from the diffractogram. If, however, the chlorite is poorly crystallized, all of its peaks will be destroyed by this heat treatment.

Because chlorite and kaolinite share many of the same peaks (especially the 7 Å and 3.5 Å peaks) on a diffractogram, it is very difficult to identify kaolinite with the above procedures. It is thus necessary to selectively remove the chlorite. This was accomplished by taking fresh material from 17 samples and heating them in 2N HCl at about 85°C for 4 hours. A clay mount was then made of each sample by the method described above, but it should be noted that since the HCl treatment adds salt to the suspension, it was necessary to wash the suspensions four times by centrifugation prior to introduction of the peptising agent. The HCl treatment removes all but the most Mg-rich chlorite, and leaves any kaolinite unaffected.

Results

The X-ray diffractogram peaks were assigned to clay minerals as follows: the 4.3 Å peak is quartz, the 5 and 10 Å peaks are illite, the 7 Å peak is chlorite and/or kaolinite. The 14 Å peak is assigned to chlorite, and, for the glycolated clay mounts, the 17 Å peak is assigned to montmorillonite. Certain peak asymmetries (especially for the roughly 3.35Å peak) and a peak "platform" after glycolation, in the range of 10 to 20 Å, are assigned to a mixed-layer clay with an expandable component.

The clay mineralogy of all samples (road material, tundra soil, dust, and bedrock) was virtually identical. The mineralogy was: chlorite, illite, a mixed-layer expandable clay, and minor quartz. All non-soil samples contained minor amounts of calcite. The low pH and high moisture content would preclude the presence of calcite in the tundra soils. Of the 17 samples treated with 2N HCl (these included samples from all categories), 16 showed kaolinite.

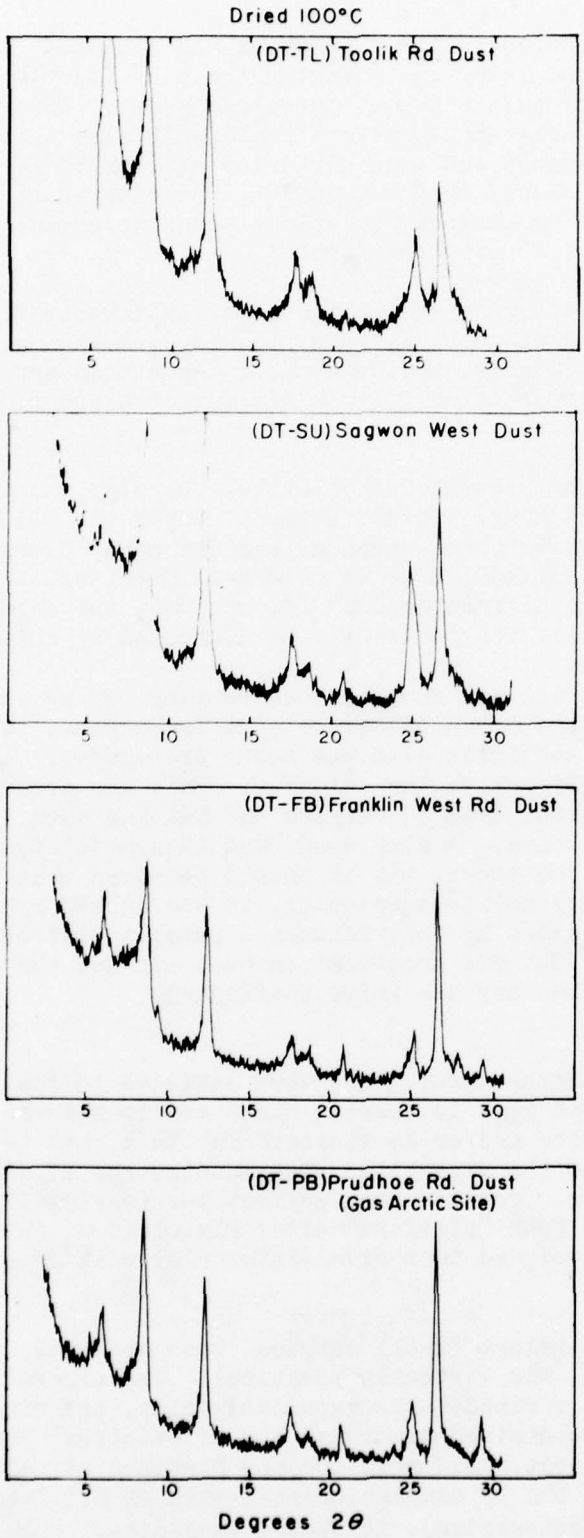


Figure 1. X-ray diffractograms of road dust dried at 100°C.

Only three samples (No. 30a, 32a, 32b) showed discrete montmorillonite. These are road material samples from locations at Prudhoe Bay. Four samples (No. 10, 29, 30b, 32b) had small peaks in the 8-9 Å range. These peaks are tentatively assigned to a zeolite mineral. A lack of other good peaks precludes a specific identification. Two samples (No. 18, 27d) had peaks at about 11.3 Å, probably indicating a mixed layer clay. Five samples (No. 3, 23a, 23b, 25a, 30c) had peaks at 6.3 Å; this probably represents lepidocrocite (FeO(OH)). These minor peaks were all destroyed during the 550°C treatment. Because the assigned materials all contain either H_2O or OH groups, this result is not surprising.

The 550°C treatment revealed the only apparent difference between the tundra soil and other samples. All but one of the tundra soil samples either failed to show a 14 Å peak after this treatment, or had their 14 Å peak reduced in intensity from that generated after simple air-drying. However, virtually all other samples showed the expected enhancement of the 14 Å peak. It is interesting to note that with many of the samples (of all categories), the 10 Å (illite) peak was reduced in intensity and the large peak at about 3.36 Å experienced a significant increase in intensity, following the 550°C heat treatment.

Diffractograms for the dust samples are shown in Figure 1. The complete set of diffractograms for all samples listed in Table 1 is on file at CRREL.

Interpretations and conclusions

The fact that the bedrock, road material, and material site samples all have the same clay mineralogy is not surprising. Most of the road material came from gravel deposits of the Sagavanirktok River which are derived from the Brooks Range. The alluvial fan material is derived directly from bedrock of the Brooks Range.

The tundra soil clay mineralogy is also the same as that of the other samples. Had these soils developed in place, one might expect a different mineralogy as, for example, more montmorillonite. The tundra soil diffractograms had good sharp peaks, indicating good crystallinity. However, the failure of the chlorite 001 (14 Å) peak to be enhanced after the 550°C heat treatment indicates that the soil chlorite is less well crystallized than chlorite in the other samples. This difference is interpreted as indicating that the soils are in fact derived from transported material of Brooks Range origin, the chlorite having degraded or weathered somewhat since deposition of the soil material. Of interest also is the restriction of discrete montmorillonite to three samples, all located in the vicinity of Prudhoe Bay. These were all road samples, and the presence of montmorillonite in them is interpreted as being the result of drilling mud contamination. Drilling mud is rich in bentonite (and thus montmorillonite) and the mud had been spread to control road dust.

Chemical Composition of Dust and Vegetation

I.K. Iskandar, S. Quarry and J. Brown
U.S. Army Cold Regions Research and Engineering Laboratory

Selective moss and lichen samples from the Toolik dust site were analyzed for major cations as a pilot study in preparation for neutron activation and soluble chemical analyses. Moss samples from B-1 (30 m from the road) and F-1 (830 m from the road) were vertically subdivided (see Project 2, Fig. 11). Several lichens were also selected from a site 25 m east of the road. The samples were weighed and oven-dried, and the total sample was digested in a mixture of 3:1 (v/v) of NHO_3 and $HClO_4$ acids. Cations were determined by a 303 Perkin Elmer atomic absorption spectrophotometer. Table 1 contains our preliminary results and comparisons with literature values.

The moss samples were collected after relatively heavy rain which resulted in dust being washed from the surface. The Na, Ca and Mg concentrations from the more distant moss samples (F1) show lower concentrations in the surface layer, suggesting that these cations had

Table 1.

Sample	Concentration (µg/g) (dry weight basis) Na	K	Ca	Mg	Moisture content (%)
Toolik*					
Moss - B1 - 3 m from road - plant tops	1274	4795	4124	4905	404
Moss - B1 - 3 m from road - plant mid	1311	2900	2066	2811	697
Moss - B1 - 3 m from road - plant bottom	1361	2686	4117	1512	777
Moss - F1 - 830 m from road - plant tops	1458	5667	2139	1270	532
Moss - F1 - 830 m from road - plant mid	1945	5223	4445	2334	686
Lichens - *Dactylina arctica* - tops	1491	3380	2355	1525	15
Lichens - *Dactylina arctica* - bottoms	2371	4139	2334	2232	14.8
Lichens - *Cetraria cucullata* - whole	1443	3556	6136	1421	14.3
Error	<4%	<3%	<3%	<2%	
Normal range in lichens†	<1000	<8500	<9000	<900	
Barrow**					
Mosses - *Campylium stellatum*	400	5500	10000	4200	
Mosses - *Polytrichum hyperboreum*	1100	6600	3000	1800	
Mosses - *Polytrichum commune* var. *jenensii*	1200	8800	1500	1300	

*See Project 2, Toolik map for locations (Fig. 8).
†Tuominen and Jaakkola (1973).
**Rastorfer (1974).

been leached by the rain. Also K is highest farther from the road, possibly reflecting higher clay content. The moss samples closest to the road show higher values of K, Ca and Mg on the surface, which suggests that they are less likely to be leached or are replenished more readily than the more distant samples.

The lichen samples show cation concentrations similar to the mosses. However, Na and Mg concentrations are much higher than normal values reported by several investigators and presented by Tuominen and Jaakkola (1973). It is possible that Ca and K are also higher.

The high content of cations is due to the presence of dust in the unwashed specimens. No efforts were made to separate the dust in this preliminary analysis. The neutron activation analyses will enable us to calculate the amounts of dust within the plant based on the concentration of Sc. It is known that Sc is present in very low concentrations in biological samples compared to mineral samples. Also, the plant parts will be washed and analyzed and both the vegetation and the solids analyzed separately for major and minor elements during the next reporting period.

These initial results warrant additional analyses of all collected samples both east and west of the road.

Literature cited

Rastorfer, J.R. (1974) Element contents of three Alaska-Arctic mosses. *Ohio Journal of Science*, vol. 74, no. 1, p. 55-59.

Tuominen, Y. and T. Kaakkola (1973) Absorption and accumulation of mineral elements and radioactive nuclides. In *The lichens* (Ahmadjian and Hale, Eds.). New York: Academic Press Inc.

APPENDIX 1

PROVISIONAL CRREL MAPS AND LEGEND OF YUKON RIVER-TO-PRUDHOE BAY HAUL ROAD

(Updated 15 March 1978)

Cultural Legend

- Haul Road
- Pipeline, aboveground
- Pipeline, underground
- Gas feeder line
- Trail
- Airfield
- Camp
- Pump Station
- Oil pipeline-road crossing
- AS# Alignment sheet
- 20 → Mileage
  Road: N from Yukon
  Pipeline: S from Prudhoe Bay
- Bridge
- Major drainage structure (culverts total over eight ft wide)

CRREL Observational and Sample Location

- CRREL climatic station (● snow gage)
- III-2 (2) CRREL cross-section;
  (2) - Subsurface temperature installation (number of profiles at each site)
- Walker and Webber vegetation map (WW#)
- 2-326 Komarkova-Webber transects and plots
- M-59 Murray site
- K1 Kubanis weed/succession transects and plots (A.W. Johnson)
- Everett soil map strip
- Dust transects and location (DT-PB)
- *79J1 Photo-vegetation point (L. Johnson)
- *118G1 Gas line transect (L. Johnson)
- *85T1 Trail site (L. Johnson)
- 116TC Chapin trail site (with Shaver)
- F Chapin fertilizer site (with Shaver)
- ML MacLean invertebrate site
- R van Oss road, dust and soil samples (R. Reynolds)
- Q-4 Staff gage - suspended sediment sampling point (L. Onesti)

Other Agencies

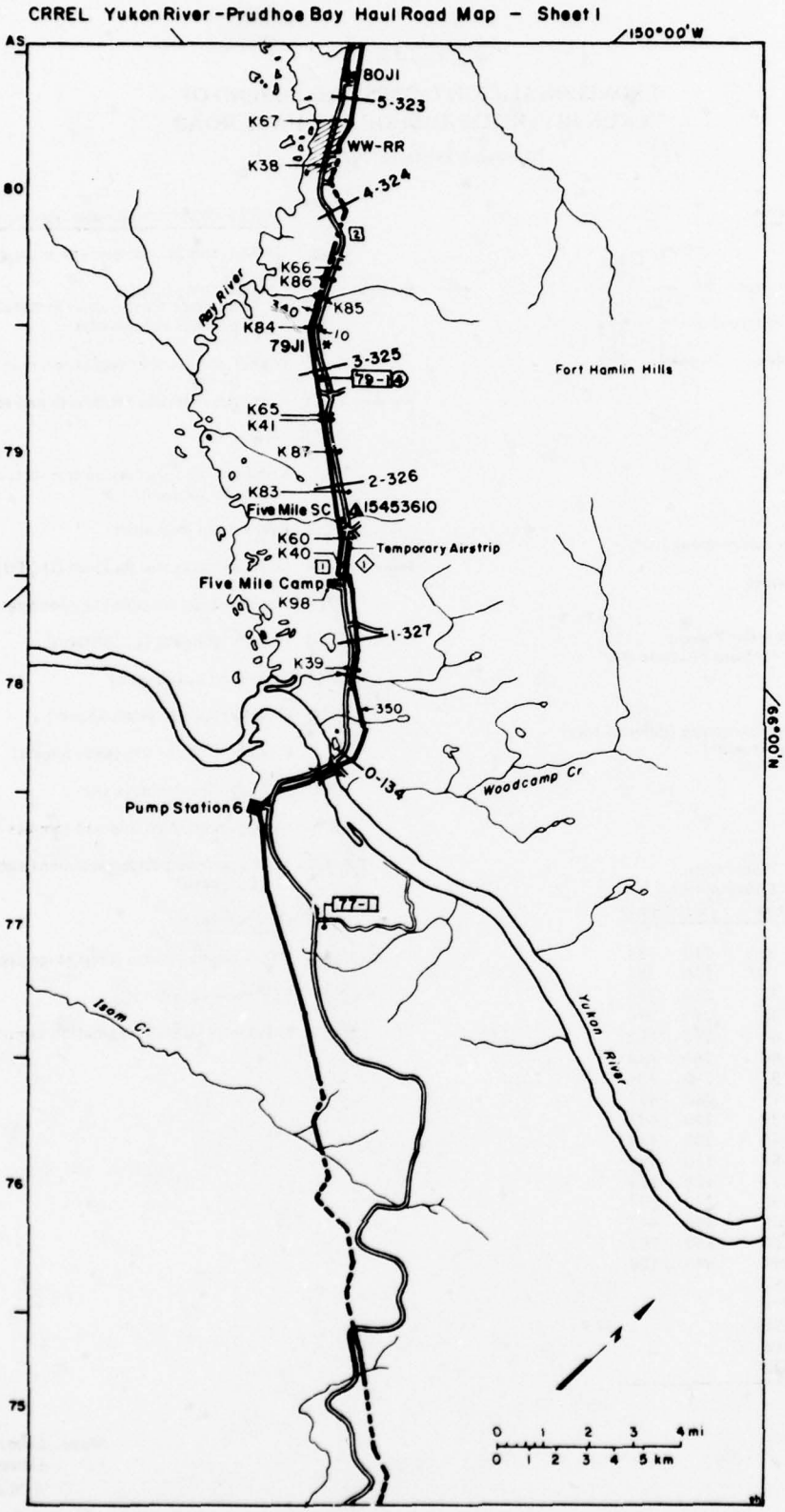
- △ (▲) USGS gaging station (crest-stage gage)
- SCS snow course (SC)
- ⊕ Shacklette (USGS) vegetation sample site

Conversion
(1.609× mi = km)

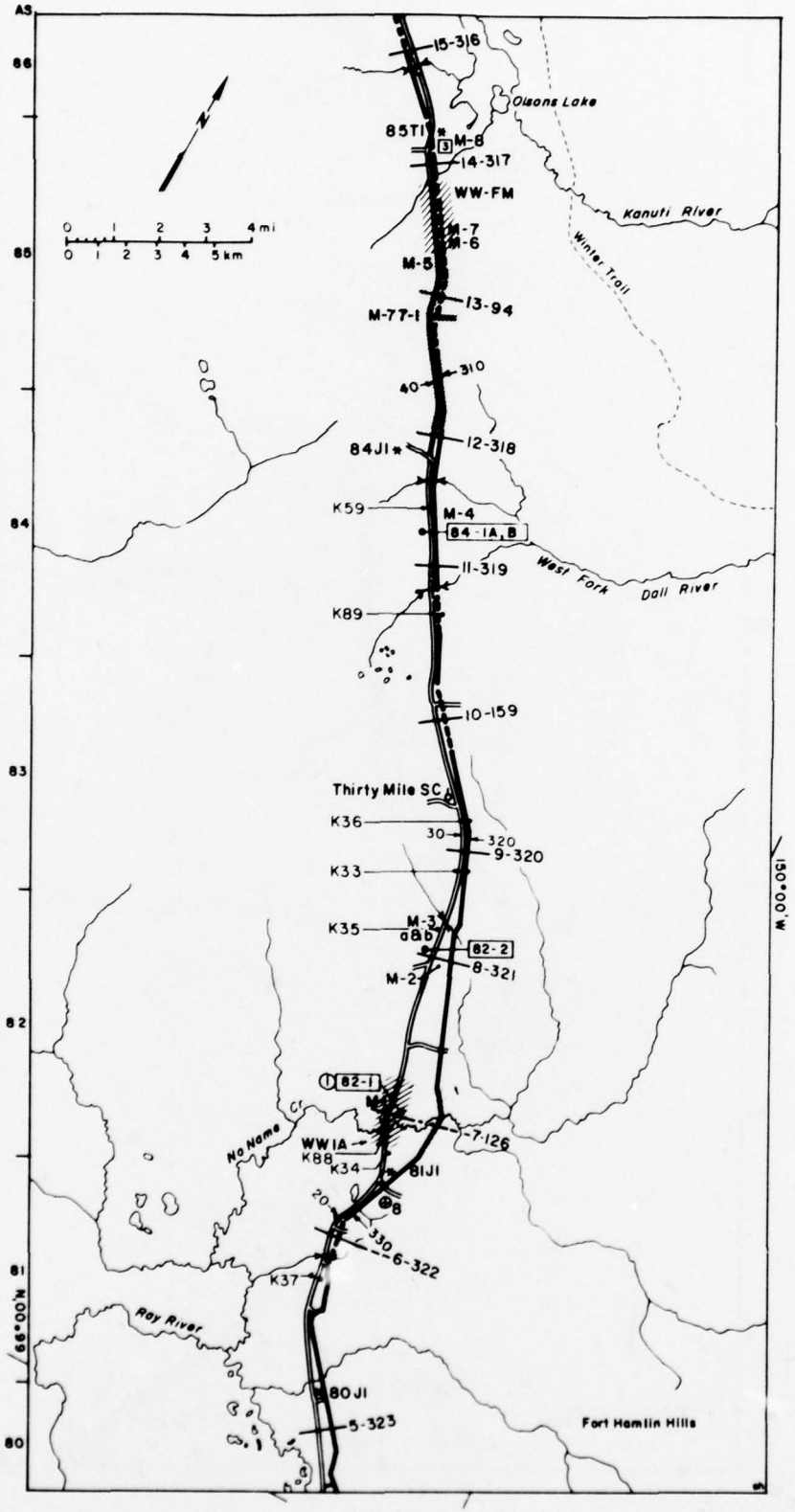
(mi)	(km)	(mi)	(km)
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10	16	220	354
20	32	230	370
30	48	240	386
40	64	250	402
50	80	260	418
60	97	270	435
70	113	280	451
80	129	290	467
90	145	300	483
100	161	310	499
110	177	320	515
120	193	330	531
130	209	340	547
140	225	350	563
150	241	360	579
160	257		
170	274		
180	290		
190	306		
200	322		

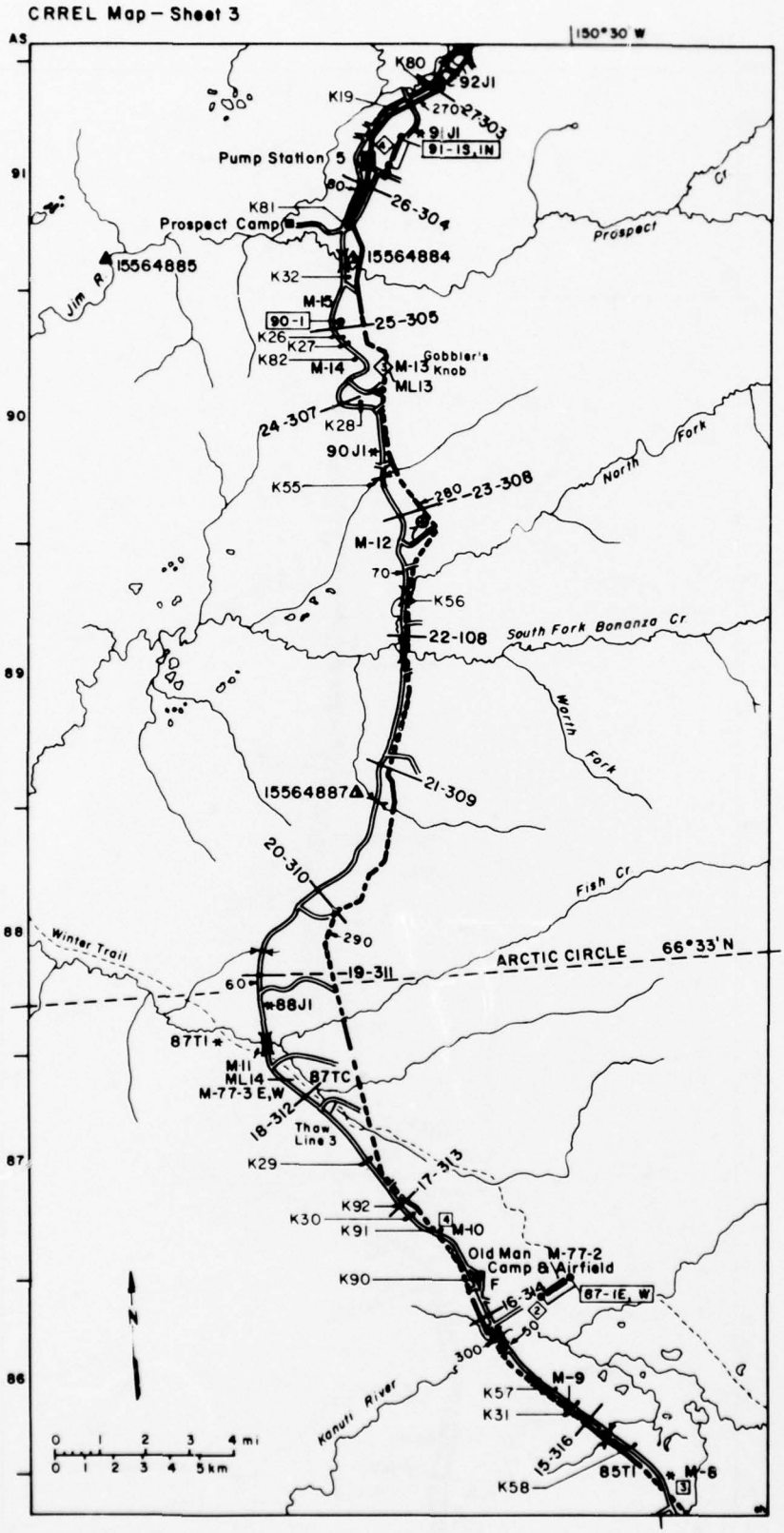
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Maps: Compiled by E. Huke
Edited by J. Brown
1 March 1978

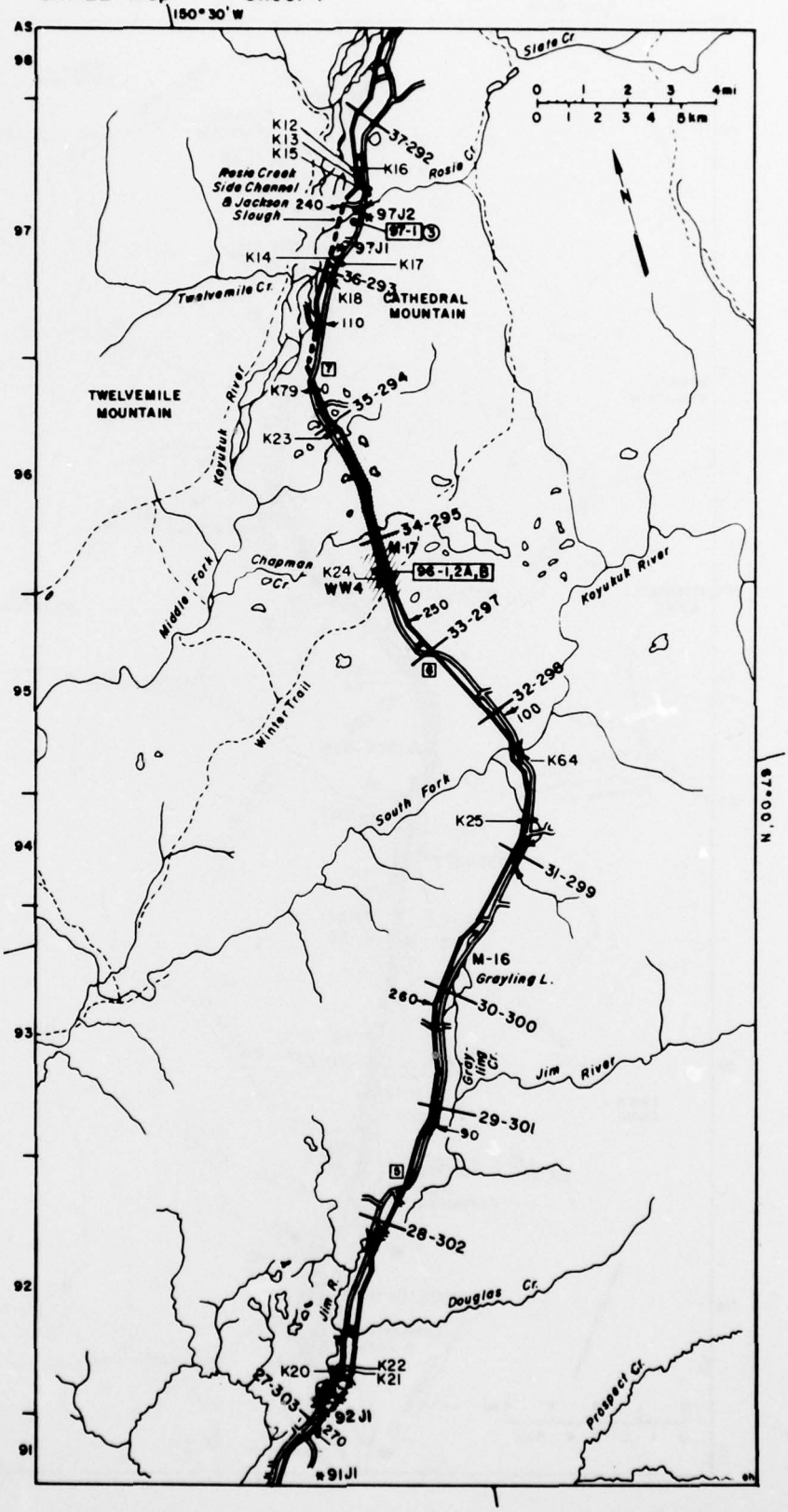

CRREL Yukon River - Prudhoe Bay Haul Road Map - Sheet 1
150°00'W
66°00'N
80JI
5-323
K67
WW-RR
K38
A-324
K66
K86
K85
K84
79JI
3-325
Fort Hamlin Hills
K65
K41
K87
2-326
K83
Five Mile SC
1545610
K60
K40
Temporary Airstrip
Five Mile Camp
K98
1-327
K39
350
O-134
Woodcamp Cr
Pump Station 6
77-1
Isom Cr
Yukon River
0 1 2 3 4 mi
0 1 2 3 4 5 km

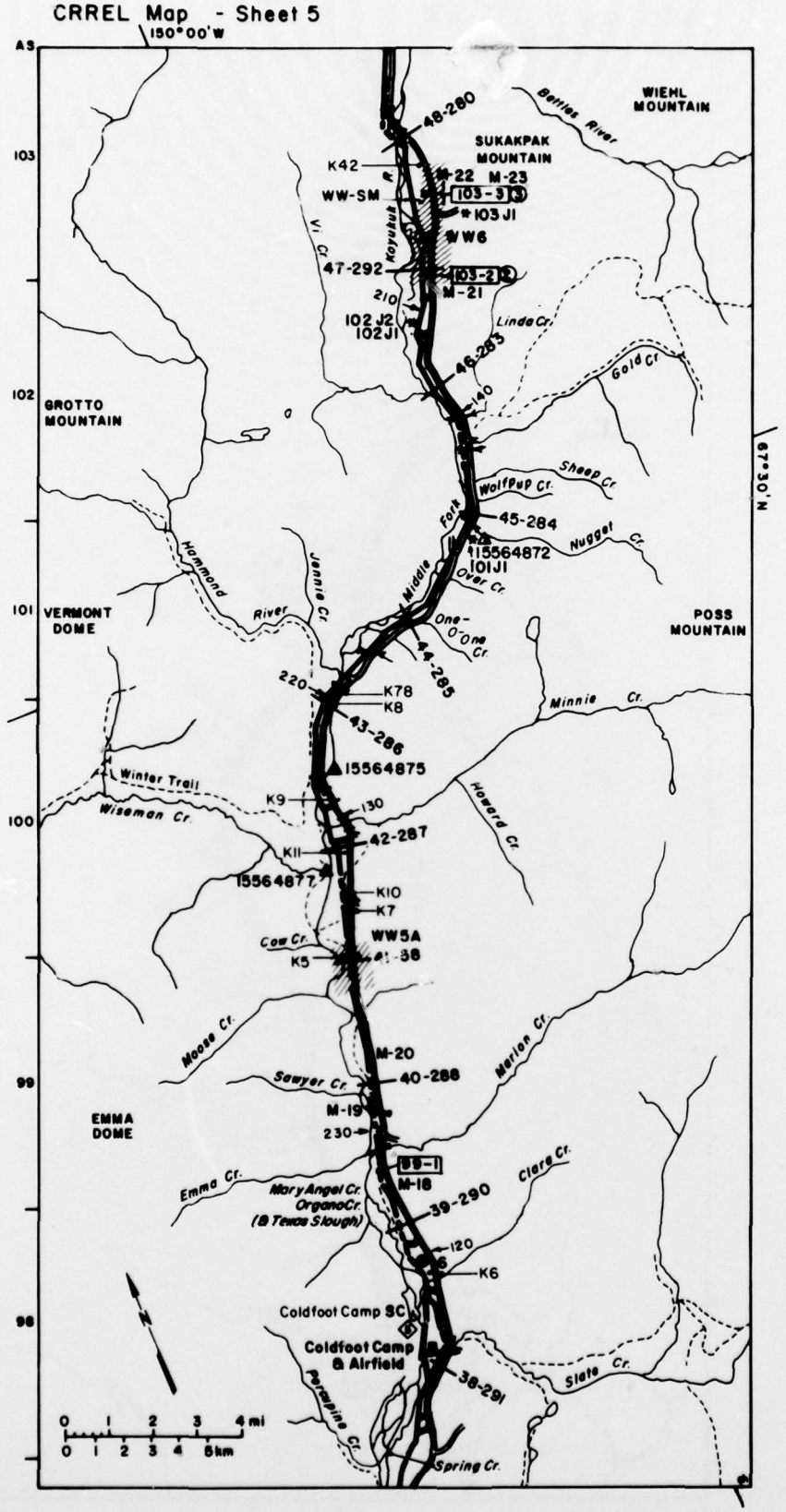
CRREL Map – Sheet 2

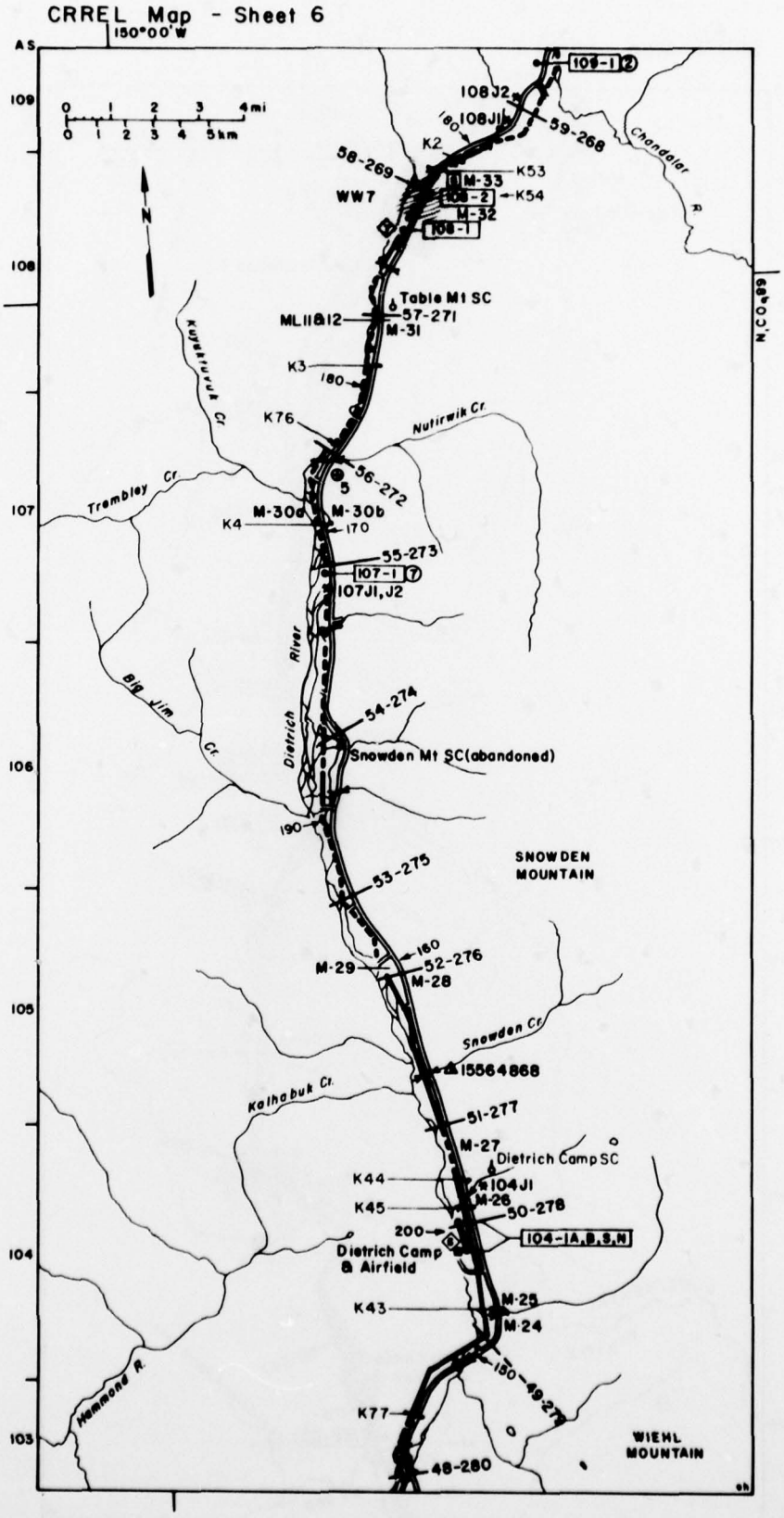



CRREL Map – Sheet 3
150°30 W
AS
91
90
89
88
87
86
K80
92JI
K19
270
27303
9JI
91-15, IN
Pump Station 5
80
26-304
K81
Prospect Camp
15564884
15564885
Jim R
K32
M-15
90-1
25-305
K26
K27
K82
M-14
M-13
Gobbler's Knob
ML13
24-307
K28
90JI
K55
280
23-308
North Fork
M-12
70
K56
22-108
South Fork Bonanza Cr
Worth Fork
15564887
21-309
20-310
Fish Cr
290
Winter Trail
ARCTIC CIRCLE
66°33'N
19-311
60
88JI
87TI
M11
ML14
M-77-3 E,W
87TC
18-312
Thaw Line 3
K29
17-313
K92
K30
K91
M-10
Old Man Camp & Airfield
M-77-2
87-1E, W
K90
F
16-314
50
300
M-9
K57
K31
Kanuti River
15-316
85TI
M-8
K58
N
0 1 2 3 4 mi
0 1 2 3 4 5 km

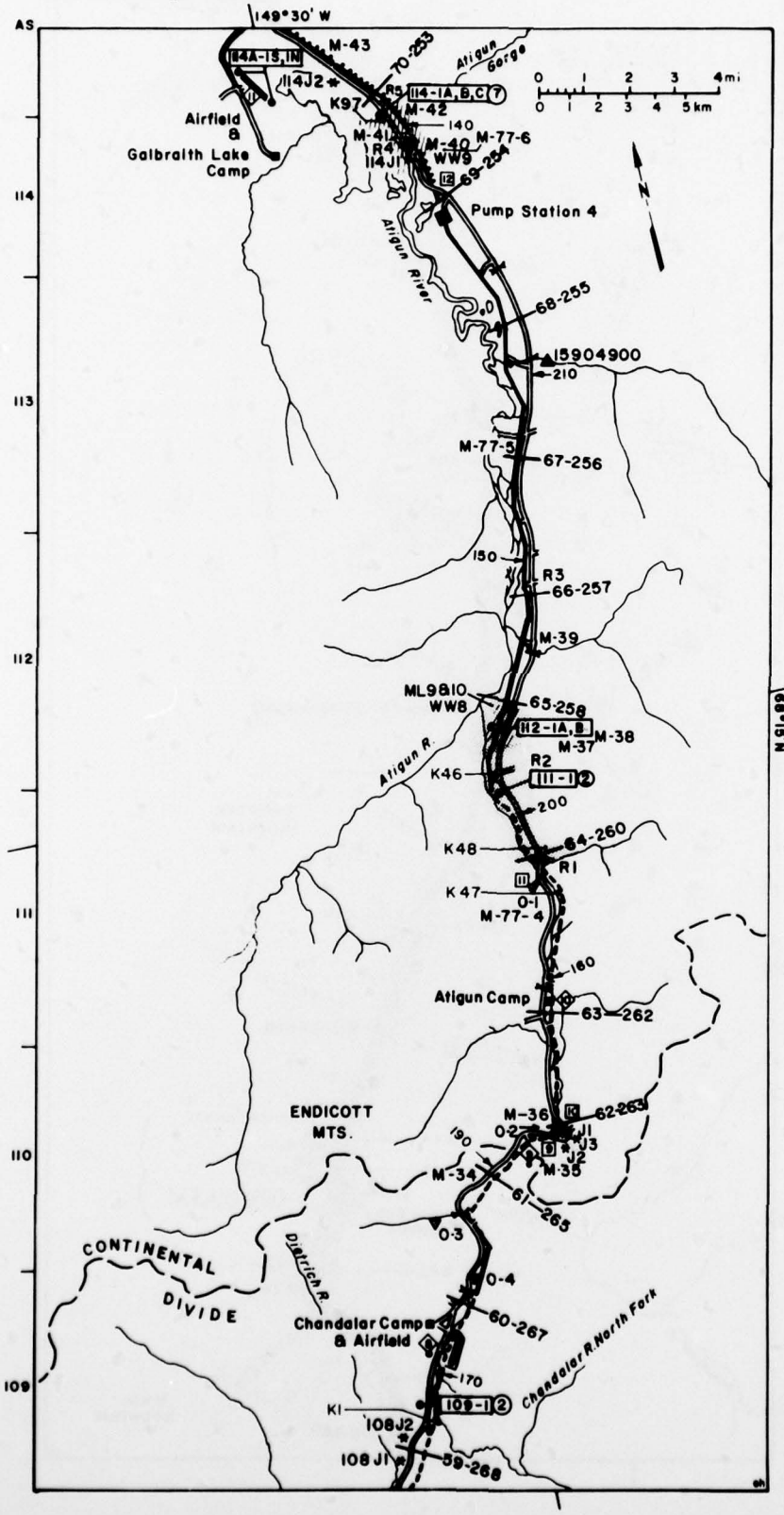
CRREL Map - Sheet 4

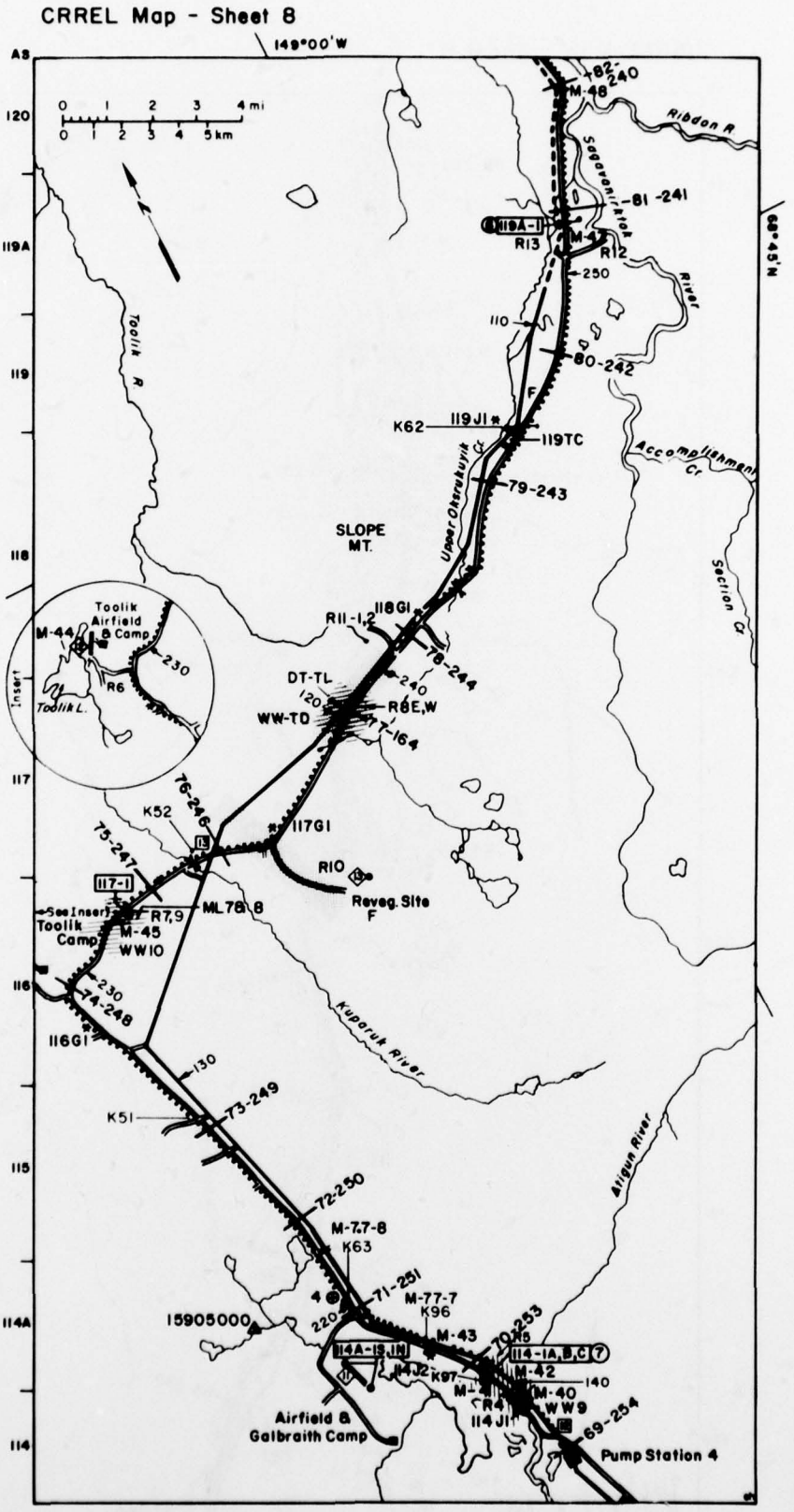



CRREL Map - Sheet 5
150°00'W
67°30'N
WIEHL MOUNTAIN
SUKAKPAK MOUNTAIN
GROTTO MOUNTAIN
VERMONT DOME
POSS MOUNTAIN
EMMA DOME
Battles River
Koyukuk R.
Vi Cr.
Linda Cr.
Gold Cr.
Sheep Cr.
Wolfpup Cr.
Fork
Nugget Cr.
Middle
Over Cr.
Jennie Cr.
Hammond River
One-O-One Cr.
Minnie Cr.
Howard Cr.
Winter Trail
Wiseman Cr.
Cow Cr.
Moose Cr.
Marion Cr.
Sawyer Cr.
Emma Cr.
Mary Angel Cr.
Organo Cr.
(& Texas Slough)
Clara Cr.
Coldfoot Camp SC
Coldfoot Camp & Airfield
Porcupine Cr.
Slate Cr.
Spring Cr.
48-280
K42
22
M-23
WW-SM
103-3
103 JI
WW6
47-292
103-2
M-21
210
102 J2
102 JI
46-283
140
45-284
15564872
101 JI
44-285
220
K78
K8
43-286
15564875
K9
130
42-287
K11
15564877
K10
K7
WW5A
K5
M-20
40-288
M-19
230
39-1
M-18
39-290
120
K6
38-291
0 1 2 3 4 mi
0 1 2 3 4 5km

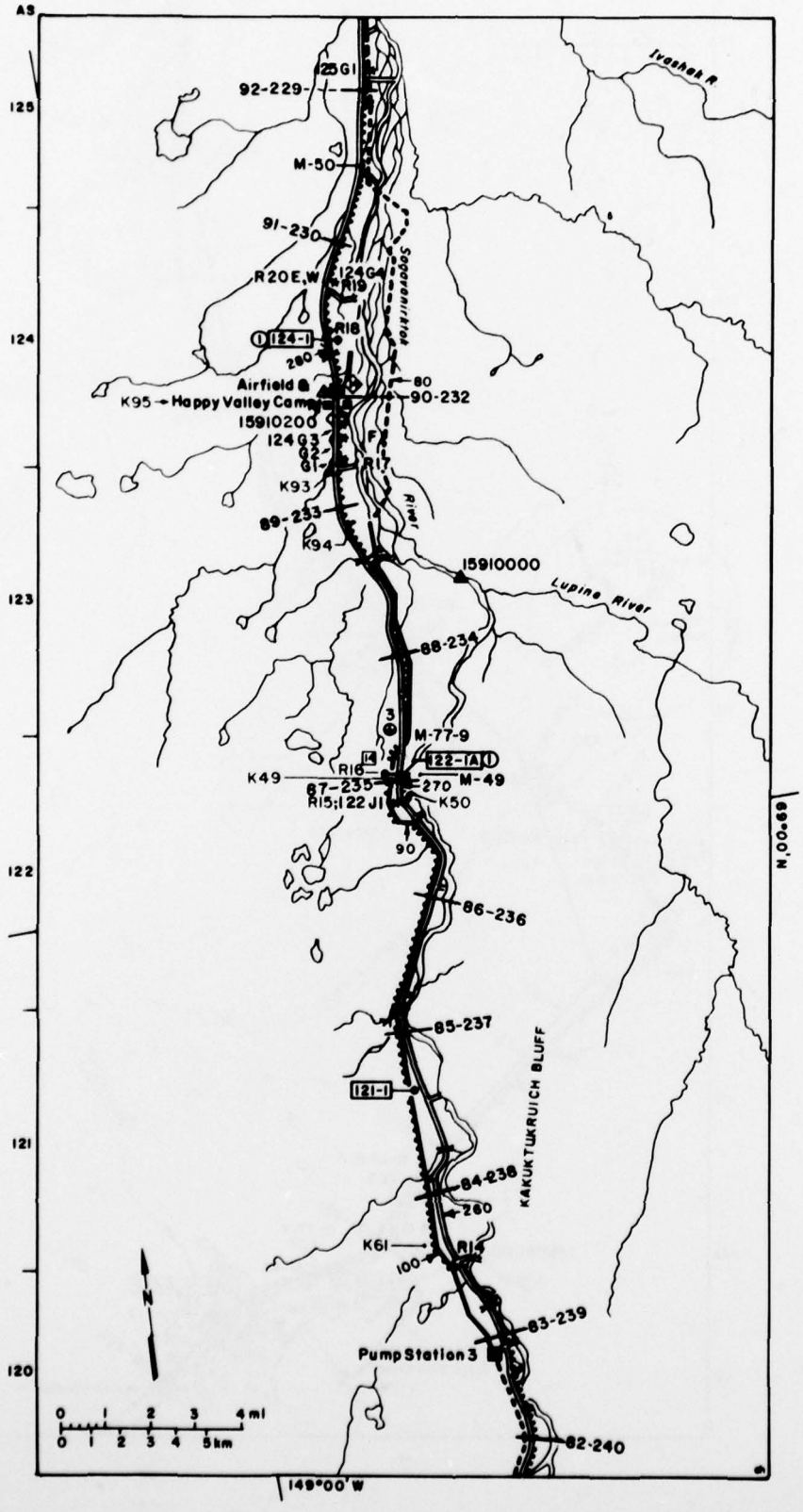

CRREL Map - Sheet 6
150°00'W
AS
109
108
107
106
105
104
103
68°00'N
0 1 2 3 4mi
0 1 2 3 4 5km
N
109-1
108J2
108J1
59-268
Chandalar R.
K2
58-269
M-33
K53
WW7
108-2
K54
M-32
108-1
Table Mt SC
ML11&12
57-271
M-31
K3
180
Kuyukturuk Cr.
K76
Nutirwik Cr.
56-272
Trembley Cr.
M-30a
M-30b
K4
170
55-273
107-1
107J1, J2
Big Jim Cr.
Dietrich River
54-274
Snowden Mt SC(abandoned)
190
SNOWDEN MOUNTAIN
53-275
160
M-29
52-276
M-28
Snowden Cr.
15564868
Kalhabuk Cr.
51-277
M-27
Dietrich Camp SC
K44
104J1
M-26
K45
50-278
200
104-1A,B,S,N
Dietrich Camp & Airfield
M-25
K43
M-24
150
49-279
Hammond R.
K77
WIEHL MOUNTAIN
48-280

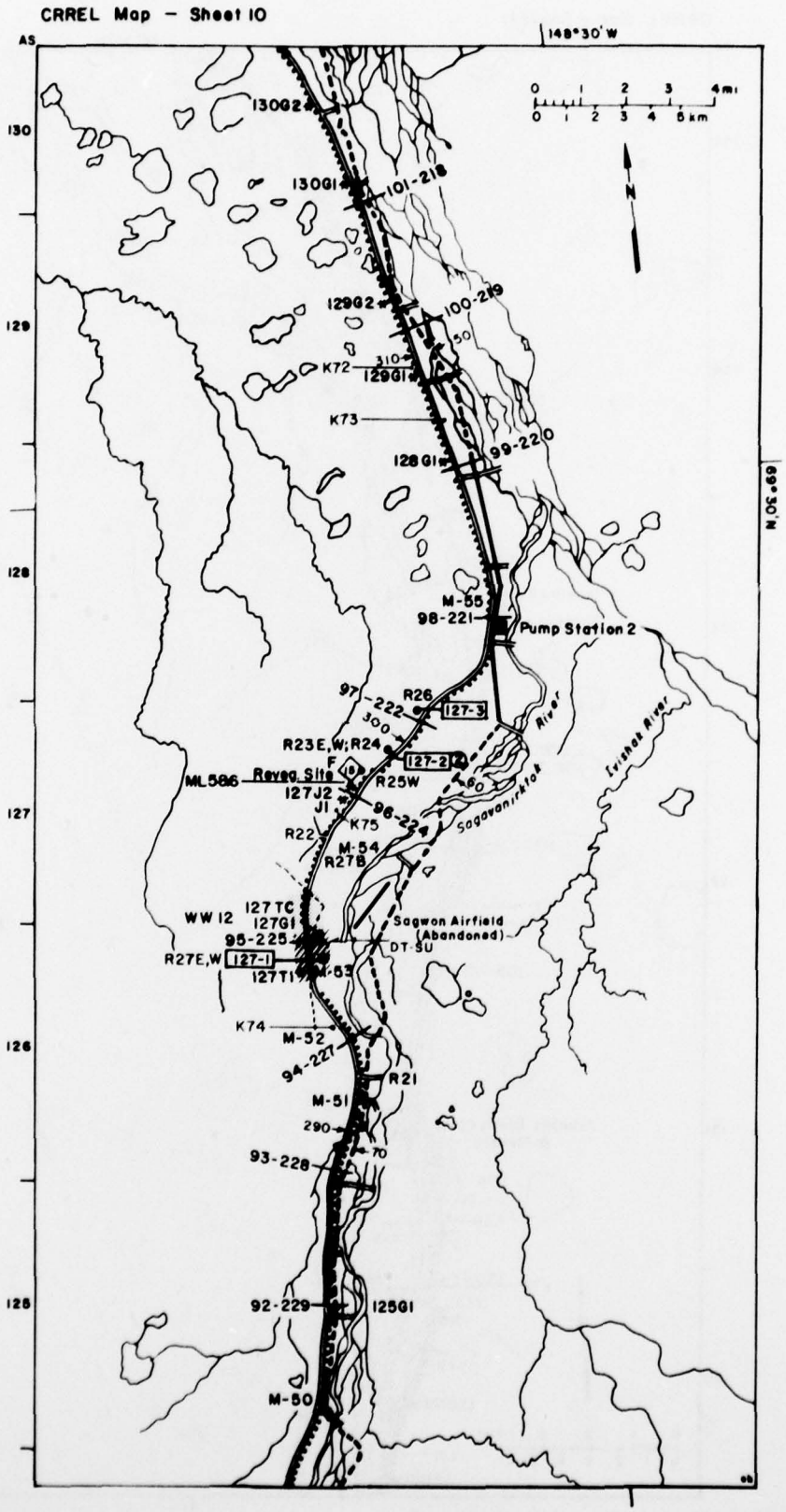
CRREL Map - Sheet 7

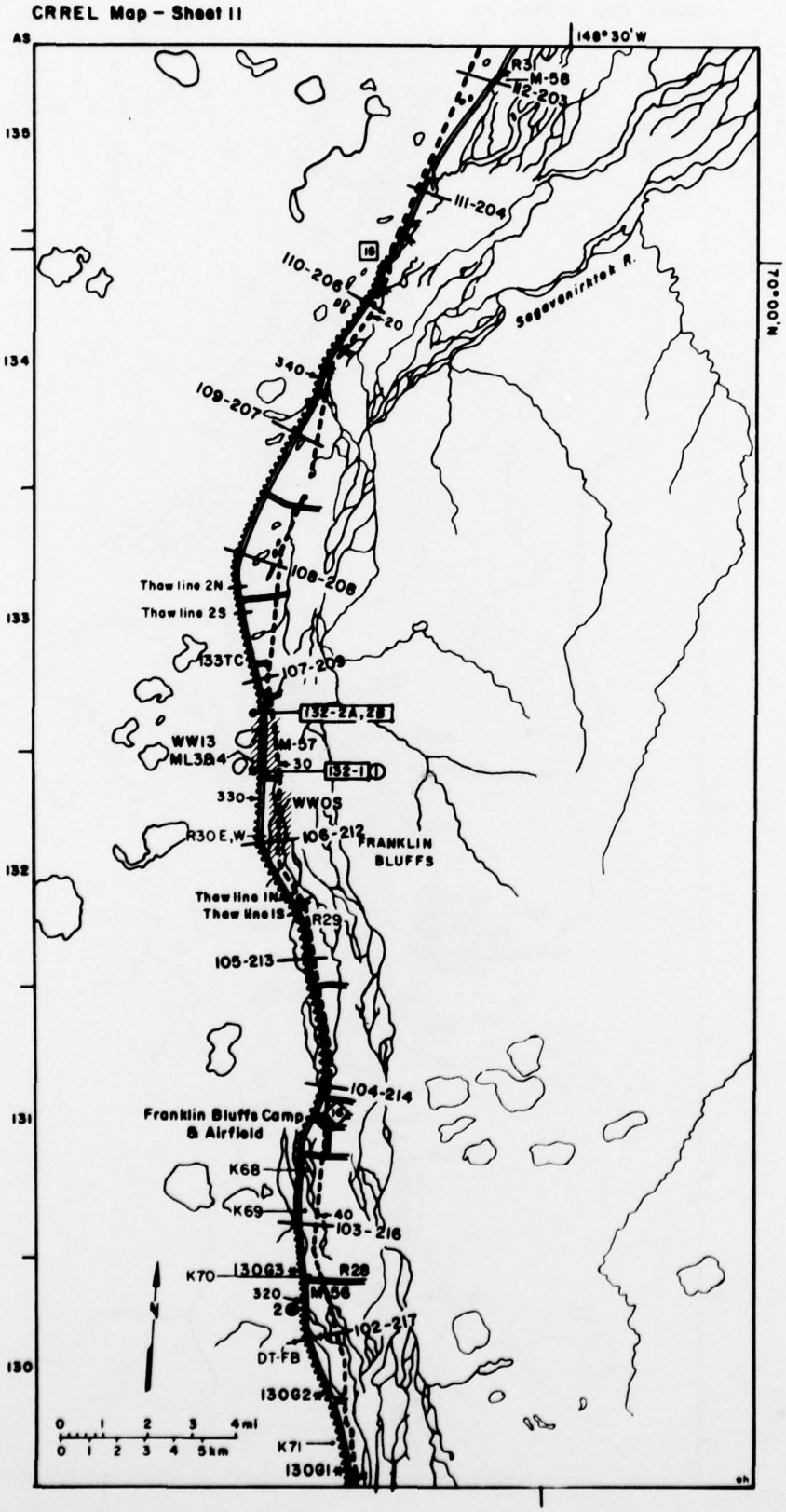



CRREL Map - Sheet 8
149°00'W
68°45'N
0 1 2 3 4 mi
0 1 2 3 4 5 km
A8
120
119A
119
118
117
116
115
114A
114
M-48
82-240
Ribdon R
Sagavanirktok River
81-241
119A-1
R13
M-41
R12
250
110
80-242
Toolik R
K62
119J1
119TC
Accomplishment Cr
79-243
SLOPE MT.
Upper Oksrukuyik Cr
Section Cr
118G1
R11-1,2
78-244
240
DT-TL
120
R8E,W
WW-TD
T-164
Toolik Airfield & Camp
M-44
230
R6
Toolik L.
Insert
76-246
K52
117G1
75-247
117-1
R10
Reveg. Site F
See Insert
R7,9
ML78-8
Toolik Camp
M-45
WW10
230
74-248
116G1
Kuparuk River
130
73-249
K51
72-250
M-77-8
K63
71-251
M-77-7
K96
15905000
220
M-43
70-253
114-1A,B,C
114A-1S,1N
M-42
140
M-40
WW9
114J1
R4
69-254
Airfield & Galbraith Camp
Pump Station 4
Aligun River

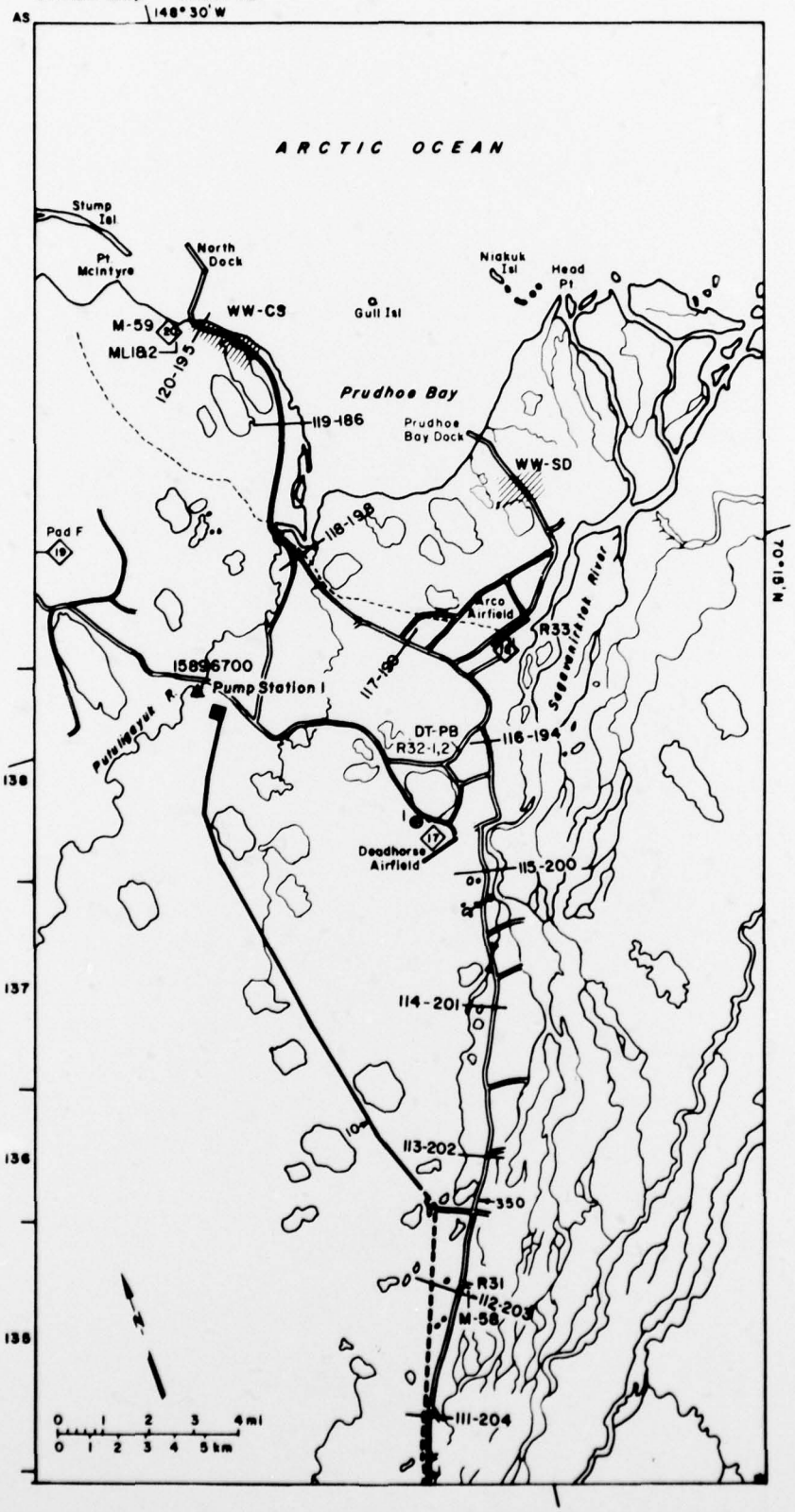
CRREL Map - Sheet 9




CRREL Map – Sheet 10
148°30'W
69°30'N
0 1 2 3 4mi
0 1 2 3 4 5km
N
130G2
130G1
101-218
129G2
100-219
K72
129G1
K73
128G1
99-220
M-55
98-221
Pump Station 2
R26
97-222
127-3
R23E,W;R24
127-2
R25W
ML586
Reveg. Site
127J2
J1
K75
96-22
R22
M-54
R27B
Sagavanirktok River
Ivishak River
127TC
127G1
WW 12
95-225
Sagwon Airfield (Abandoned)
DT-SU
R27E,W
127-1
127T1
M-53
K74
M-52
94-227
R21
M-51
290
93-228
70
92-229
125G1
M-50


CRREL Map – Sheet II
148°30'W
70°00'N
R31
M-58
12-203
111-204
110-206
20
Sagavanirktok R.
340
109-207
108-208
Thaw line 2N
Thaw line 2S
133TC
107-209
132-2A, 2B
WW13
ML3B4
M-57
30
132-1D
330
WW05
R30E,W
106-212
FRANKLIN BLUFFS
Thaw line 1N
Thaw line 1S
R29
105-213
104-214
Franklin Bluffs Camp & Airfield
K68
K69
40
103-216
K70
13003
R29
320
M-56
20
102-217
DT-FB
13002
0 1 2 3 4mi
0 1 2 3 4 5km
K71
13001
AS
138
134
133
132
131
130

CRREL Map — Sheet 12



APPENDIX 2

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