THE UNIVERSITY OF ALBERTA

SURFICIAL DISTURBANCE

AND

NATURAL PLANT RECOLONIZATION

IN THE

TUKTOYAKTUK PENINSULA REGION, N.W.T.

by

(C) HELIOS HERNANDEZ

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF BOTANY

EDMONTON, ALBERTA

FALL, 1972

ABSTRACT

Seismic lines and winter roads, surficial disturbances related to oil exploration, were sampled where they passed through three plant communities in the Mackenzie Delta and the major tundra plant communities in the Tuktoyaktuk Peninsula region, N.W.T. Winter disturbances have been less detrimental than summer disturbances for all communities examined. Winter roads through upland areas remove most of the vegetation but the peat layer usually remains intact. Wetland sedge meadows are most susceptible to summer activity and least affected by winter operations. Winter disturbed Delta communities recover much faster initially than similarly disturbed upland dwarf shrub-heath communities.

If exposure of mineral soil, as with 1965 summer seismic lines, results in wet conditions, the grass *Arctophila fulva* and the sedge *Carex aquatilis* are the most successful colonizers. If dry conditions are created, the grasses *Arctagrostis latifolia*, *Calamagrostis canadensis* and *Poa lanata* and the rush *Luzula confusa* are the most successful pioneers. Six years after exposure of mineral soil, plant cover was usually 30 to 50%. Once established, the above listed species slowly expand rhizomatously. *Eriophorum vaginatum* and *Carex bigelowii* appear to be stimulated by disturbances which are not severe enough to eliminate them. *Eriophorum* often flowers much more abundantly on a disturbed area than in the native tundra.

Thaw is increased 80 to 100% if mineral soil is exposed;

30 to 50% if the peat remains intact, and 1 to 10% if plant cover is virtually unchanged. Subsurface ice has occasionally been exposed resulting in thermokarst subsidence. However, water erosion has not occurred to any great extent, probably because of the low precipitation in the region.

ACKNOWLEDGEMENTS

My thanks go to the many people who helped throughout this study.

Mr. Glen Davis of Inuvik provided able field assistance during the summer of 1971.

Messrs. Maurice Dow, Ian Corns and Brian Pinchbeck were patient and helpful in explaining the computer programming for the data analyses.

Miss Kathie Kuchar was invaluable in typing and collating the final copy of the manuscript.

Drs. James M. Mayo and John A. Westgate provided valuable suggestions and criticisms for the 1971 field season and in the preparation of the manuscript.

Special thanks are due Drs. Lawrence C. Bliss and Ross W. Wein for their constant and invaluable guidance and assistance throughout all stages of the study, both in the field and during the preparation of the manuscript. Their concern was greatly appreciated.

Imperial Oil Limited provided maps of seismic lines. These proved invaluable in locating and ageing study sites. This company also provided generous transportation and accommodation throughout much of the study region during both field seasons.

Additional logistic and financial support was provided by the Inuvik Research Laboratory, the Arctic Land Use Research Programme of the Department of Indian Affairs and Northern Development and the Arctic Petroleum Operator's Association.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

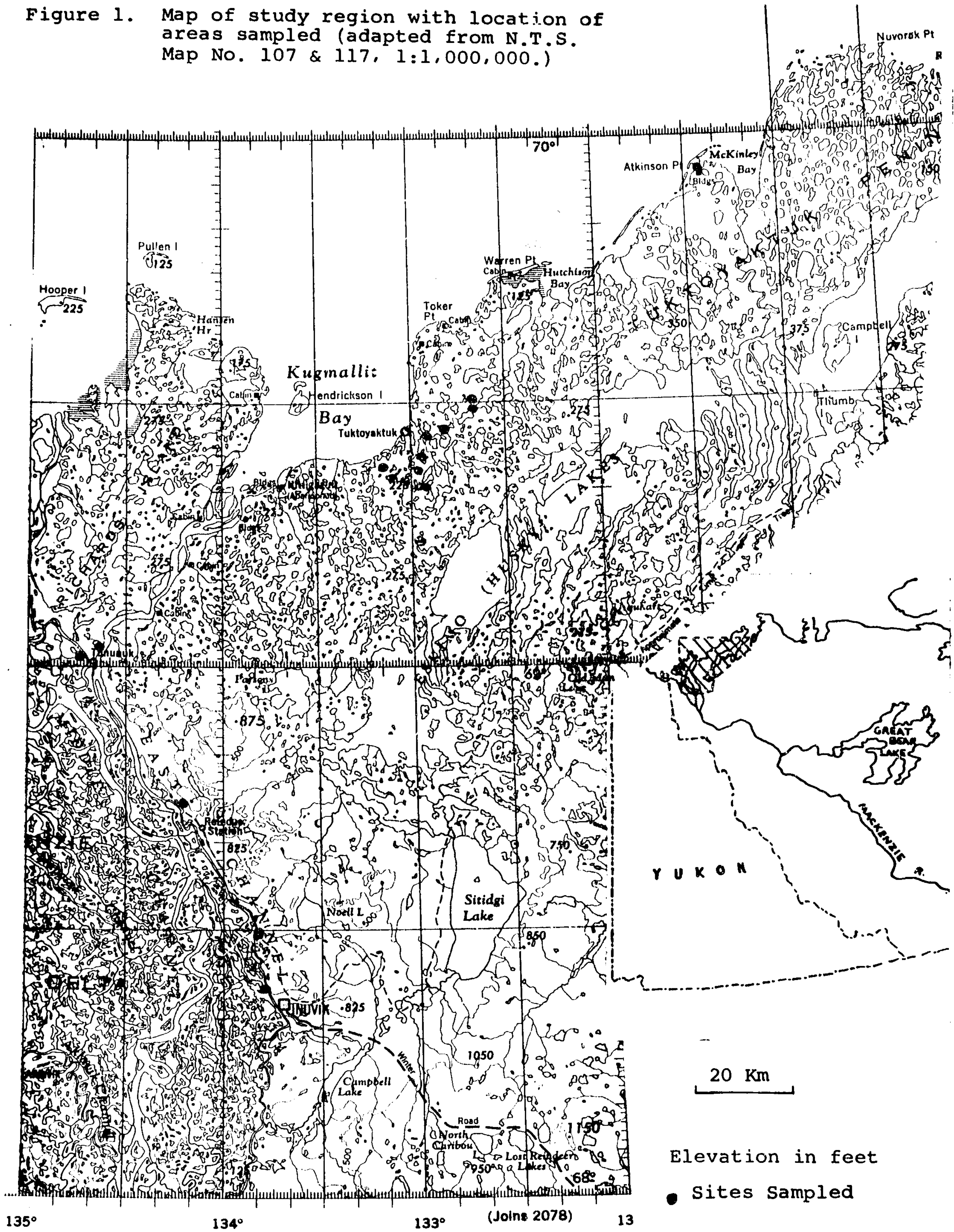
LIST OF FIGURES (Continued)

INTRODUCTION

One of the most important physical characteristics which differentiates arctic regions from temperate is the presence of permafrost. In summer, usually less than the top 50 cm thaws, drainage is impeded and the soil remains cold. Vegetation and accumulated peat are greatly affected by permafrost and they provide an insulating cover which reduces thaw depth. Surficial disturbance which disrupts this protective layer can lead to increased thaw as well as exposure and melting of subsurface ice. Removal of the thawed layer exposes underlying peat or mineral soil and creates conditions leading to secondary plant succession.

With the discovery of oil and gas at Prudhoe Bay, Alaska in 1968, exploration was further stimulated in the geologically related sedimentary basins of the Canadian Arctic. One of the regions of intense activity has been the Tuktoyaktuk Peninsula-eastern Mackenzie Delta region, N.W.T. As in other regions, surficial disturbance has occurred. Because of the lack of quantitative information of the effects of such disturbances, a study was conducted in 1970 and 1971 in the vicinity of 5 major locales in the Tuktoyaktuk Peninsula region (Fig. 1). The major aims were to assess quantitatively the impact of surficial soil and plant disturbances on plant cover and depth of thaw as well as to evaluate the natural plant recolonization of exposed soil.

Figure 1. Map of study region with location of areas sampled (adapted from N.T.S. Map No. 107 & 117, 1:1,000,000.)



20 Km

Elevation in feet

● Sites Sampled

DESCRIPTION OF STUDY AREA

Geology and Physiography

Surficial geology consists of Pleistocene fluvial, lacustrine and marine sediments, except for the much older Inuvik and Caribou Hills areas where Tertiary gravels occur in the north and shales in the south (Rampton 1971, 1972). The deposits and landforms result from at least two glaciations (Fyles, 1966). The most recent Wisconsin advance did not cover the arctic coastal half of the Tuktoyaktuk Peninsula (Fyles, 1967; Prest, 1969). Rampton's (1971) divisions of the region into 13 areas of characteristic surficial deposits and near surface unconsolidated sediments agrees closely with the physiographic regions of Mackay (1963).

Elevation in the Tuktoyaktuk Peninsula is usually less than 50 m above mean sea level, with local relief rarely more than 20 m except for the occasional pingo. This rolling terrain gradually flattens into the Arctic Coastal Plain. Lakes, predominantly of thermokarst origin or modified by thermokarst processes, cover 30 to 50% of the surface (Mackay, 1963). With the exception of deep lakes, continuous permafrost underlies the entire region.

Climate

The entire study area lies well above the Arctic Circle and, as such, receives continuous insolation in summer and none in winter for varying lengths of time, depending on the latitude. There is always a low sun angle. Hare (1970) presents data that net radiation in the Arctic is positive. But Thompson (1967) states that more heat is lost to space than comes in over one year, the deficit being replaced by upper atmosphere circulation.

A high pressure area usually sits over the Mackenzie basin from December to April with the prevailing wind from the northwest (Thompson, 1967). By mid June the ice has melted in most lakes and broken up in the Mackenzie Delta. Tuktoyaktuk Harbour is usually ice free in the latter third of June (Mackay, 1963). The summer airmass of July and August is warmer and more unstable. September to November are the stormiest as low pressure areas move through before the reestablishment of winter high pressure conditions (Thompson, 1967).

The limited climatic data of four locations in the study region are summarized in Table 1. The seven winter months of somewhat continental climate when the ocean is frozen are ameliorated by the large mass of relatively warm water below the ice (Thompson, 1967). This effect is least at Inuvik, the furthest from the coast, where the coldest month, January, is colder than that elsewhere. The maritime influence is greatest in summer along the coast where temperatures are lowered by the colder ocean and offshore ice. Coastal fogs are common. Inuvik, again, is least affected.

The low absolute humidity of the cold winter air results

Table 1. Annual precipitation and temperature data[a] for four locales in the eastern Mackenzie Delta - Tuktoyaktuk Peninsula region, N.W.T.

	Locations			
	Atkinson Point 69° 56'N 131° 24'W	Tuktoyaktuk 69° 27'N 133° 00'W	Tununuk Point 69° 01'N 134° 41'W	Inuvik 68° 18'N 133° 29'W
Mean Total Precipitation (cm)	15.2	15.6	16.9	27.6
Rainfall (cm)	9.2	10.2	10.2	11.0
Snowfall (cm)	60.7	54.1	67.1	172.7
Mean Daily Temperature (°C)	-11.9	-11.3	-10.1	-9.6
Mean Daily Maximum (°C)	-8.5	-7.6	-6.5	-4.6
Mean Daily Minimum (°C)	-15.3	-14.9	-13.7	-14.7
Maximum Recorded Temperature (°C)	27.8	27.8	27.8	31.7
Minimum Recorded Temperature (°C)	-46.7	-45.0	-48.3	-50.5

a Data adapted from Canada Department of Transport, Meteorological Branch, 1967.

in low snowfall, except for Inuvik. Rainfall throughout the area is 9 to 11 cm annually. Most falls during the two warmest months, July and August, when plant growth is the most active.

Soils

Soils have generally developed on surficial grey sands and till or till-like material (Rampton, 1970). Under the Canadian system of classification, the soils of the region are generally as follows: (a) wet sedge meadow soils are Organic; (b) depending on the moisture, those under dwarf shrub-heath communities are Gleyscls, Gleyed Brunisols or Brunisols (the half-bog, tundra and arctic brown soils respectively of Tedrow et al., 1958); and (c) those in the Delta proper are Regosols (Janz, 1972). Haag (1972) gives a detailed description of a typical Orthic Gleysol developed under a dwarf shrub-heath community near Tuktoyaktuk.

Vegetation

The study region contains three major vegetation types: the northern extension of the boreal forest of the Mackenzie Delta; the tall willows of the Delta and other watercourses; and the tundra communities of the Caribou Hills, Richards Island uplands and the Tuktoyaktuk Peninsula. Most previous studies have been taxonomic or phytogeographic (e.g. Porsild, 1964; Cody, 1965, 1971; Porsild and Cody, 1968; Hultén, 1968). Phytosociological investigations for comparable regions in Alaska are those of Hanson (1953), Churchill

(1955), Bliss and Cantlon (1957) and Johnson et al. (1966). Gill (1971) classified the successional relations of the plant communities on the alluvial materials of the Mackenzie Delta. Corns (1972) is currently classifying the various upland tundra communities of the study region.

Permafrost Characteristics

A characteristic of the region and one of the major sources for concern about the effects of disturbance, is the presence of massive subsurface ice bodies (ice lenses). Their ice content (weight of ice to dry soil) is generally 100 to 1000%, usually in the upper range (Mackay 1966, 1971). Shumskii (1964) believes most massive ice to originate from water injected under pressure into the freezing plane in areas where resistance is weak. Mackay (1966, 1971), however, feels that water is expelled from the freezing of sands by high pore water pressures below an aggrading impermeable permafrost layer. This water is then "drawn-up" to the freezing plane. Massive ice is most common in fine grained material (Tsytovich et al., 1964; Mackay, 1966).

Although much less massive, the other common type of soil ice is wedge or vein ice. Its origin and annual growth is described by Shumskii (1964). Found in patterned polygonal ground, it, too, predominates in fine grained sediments (Ferrians et al., 1969).

Once the insulating vegetative cover is disturbed, thaw is deeper (Brown et al., 1969; Mackay, 1970; and many others).

Subsurface ice may melt and thermokarst subsidence occur where ice contents are high. Tyrtikov (1964) summarizes the well known general interactions of permafrost and vegetation. Pruitt (1970) mentions these and other permafrost-tundra biotic community interrelationships.

Rampton and Mackay (1971) and Bouchard and Rampton (1972) provide detailed information on the surficial geology, distribution of massive ice and ice content of soils in the Tuktoyaktuk region.

METHODS

Preliminary aerial and ground surveys in mid-June 1970 allowed identification of the principal plant communities present and the visual impact of various disturbances in the study region. Since the disturbances are long, straight, relatively narrow paths (7 to 10 m) through the forest and tundra, stands were selected for their homogeneous appearance and sufficient length to contain at least one pair of 30 m transects. The data were obtained by laying out two parallel transects, one a control in the undisturbed area several metres removed from the disturbance and the other down the centre of the disturbance. In more extensive homogeneous areas, 2 or 3 such pairs, several tens of metres apart, were sampled.

Sampling trials to determine the efficiency of quadrat size and shape combined with the time required for sampling were inconclusive. Thus, at first, the largest quadrat which could most easily be sampled was chosen: 0.5 m^2 in low, flat sedge meadows; 1 m^2 in shrub tundra and 2 m x 2 m in the forest. This was modified in 1971 to a 1 m x 1 m quadrat for all tundra communities.

In 1970, quadrats spaced every 3 m (11 in total) were used for cover estimates of each vascular species, mosses, lichens, litter and bare ground. At every metre, depth of thaw was determined to the nearest centimetre. The sampling method was modified in 1971 to 16 restricted randomly located quadrats per transect for the cover estimates. Two thaw depth measurements were made in each quadrat.

Notes were made of the type, appearance and size of the disturbance. The amount of any slumping or erosion present was estimated. Slope and exposure were determined with a compass-clinometer. Hand texturing gave an estimate of drainage characteristics and, in a few stands, shallow soil profiles were examined. In wooded stands, the average height of each tree species was estimated, DBH determined and sample trees either sectioned for age (*Salix* spp., *Alnus crispa* subsp. *crispa*) or an increment bore taken (*Picea glauca*). Voucher specimens are deposited in the Herbarium of the University of Alberta and of the University of Toronto. Nomenclature follows Hultén (1968) unless otherwise stated.

In the initial data analysis, cover was compared on an individual species basis for control and disturbed transects with a t-test. An F-test compared the homogeneity of control and disturbed variances. If they differed, the degrees of freedom for the t-test were halved (Snedecor, 1956).

A total of 41 stands (91 paired transects) were sampled, 5 of these being examined in both years. Data were gathered in one general site before sampling another to minimize the effect that changes in plant phenology could have on cover estimates. Comparison of stands within a site by composition and species abundance is thus more reliable than between site comparisons.

Community comparisons were based on calculating Presence

Value (P.V. = mean cover $x\sqrt{\%\ \text{frequency}}$) for each vascular species to determine the dissimilarity between all transects. Dissimilarity (1 - similarity) was based on a modified Sørensen (1948) similarity coefficient which considers the quantitative co-occurrence and abundance of the species in the areas being compared. Carmichael and Sneath's (1969) clustering subroutine of their Taxmap programme was used to cluster:

a) the vascular P.V. data for the control (undisturbed) vegetation,

b) the vascular P.V. data for the vegetation growing on the disturbed sites,

c) all of the data.

An association table was constructed from this information and the natural communities were classified.

RESULTS AND DISCUSSION

Introduction and Literature Review

Palmer and Rouse (1945) simulated the effects of reindeer grazing in several Alaskan tundra communities similar to those sampled during the present study. Their treatments included spading, hand picking of lichens, removal of plant cover and different intensities of clipping of single plots. Recovery usually involved changes in relative species abundance rather than changes in species composition. This is the usual pattern of secondary succession in arctic regions (Muller, 1952; Churchill and Hanson, 1958). Pegau (1970) reconfirmed this when he revisited two of Palmer and Rouses's sites. Stimulation of the 'browse' species (*Ledum*, *Salix*, *Empetrum*, *Betula*, *Vaccinium*) by clipping reduced lichen recovery up to 38 years after the initial treatment.

Recovery studies of alpine tundra with a floristic similarity to arctic tundra are being conducted in Scotland (Watson *et al*., 1970). Permafrost is absent but comparable conditions of a thawed surface layer over a rigid frozen mass often occur. Natural recolonization is generally slow with moister hollows recovering faster than dry sites.

Published reports of the effects and extent of vehicular disturbance in the Arctic have largely been photographic and occasionally descriptive. Klein (1970) presents a photoessay on the impact of recent oil exploration on Alaska's North Slope and of the effects of the winter haul road used in

1968-69 along the northern half of the proposed Trans Alaska Pipeline route.

Hok (1969) documented various vehicle trails with photographs and some description of their history and effects through several areas in or near the Naval Petroleum Reserve No. 4 in Alaska. Summer trails tended to be more damaging than winter trails. At one summer drill site, trails were quite prominent but they were absent from a winter drill site. Wet areas were most affected in summer. Several 16 to 25 year old trails through sedge meadows consisted solely of wet peat. Moist bladed areas had partial to complete sedge meadow cover. Dry areas were usually well vegetated. A 7 to 10 year old portion of a trail which traversed an ice rich slope was still actively eroding in 1969. The prominent colonizer of the silty mud outwashes at the base of eroding slopes, *Senecio congestus*, was absent from the adjacent tundra. Several pictures of old bladed lines clearly show abundant clumps of grass. These, however, were not mentioned in the text. At one site, tussocks, presumably *Eriophorum vaginatum*, were described as more "youthful" than those of adjacent undisturbed areas.

Babb (1972) investigated the effects of several types of disturbance including those related to oil exploration activity in the Canadian Arctic Archipelago. Melting of subsurface ice is not a major factor and plant cover is sparse in many areas. Lush sedge meadows, apparently a major food base for large herbivores, are very susceptible to damage by summer vehicle traffic. Their recovery is very slow.

Bellamy *et al*. (1971) conducted tests with various tracked vehicles over several plant communities near Tununuk Point and Tuktoyaktuk, N.W.T. during the summer of 1970. Dry upland communities were least affected and wet lowland types most disturbed. Some rhizomatous regeneration had occurred in the vehicle ruts by the end of the summer.

Bliss and Wein (1972) presented some of the early data from current studies (including this one) of various types of disturbance in arctic regions. They, along with Rempel (1970), review the history and evolution of seismic oil exploration and technology from the initial summer operations to the current winter seismic surveys.

Various disturbed sites were located, aged and sampled with the aid of maps of seismic lines provided by Imperial Oil Ltd. Calculations showed that 0.56% of the land area of an intensively surveyed 2100 km^2 of the Tuktoyaktuk Peninsula has been disturbed by seismic operations from July 1965 to April 1970. Summer operations that were discontinued in 1965 covered 1.8 km^2.

Site Locations

Details of the geographic location, and other characteristics of each site presented in the text are given according to region and table number in which each appears in Appendix A. All sites are indicated on maps. For those that have been permanently marked with stakes, sketches of the transect locations are given.

Plant Community Classification

Corns (1972) is classifying the major tundra plant communities of the study region. Since his system is detailed and did not include some of the communities sampled during the present study, it was modified to arrive at the following classification (also see Appendix B). Three major types and several subtypes were recognized:

a) the *Picea glauca*-*Alnus crispa* subsp. *crispa*-*Salix arbusculoides* forest type of the Delta

b) the *Salix* spp.-*Alnus crispa* subsp. *crispa* tall shrub type of the watercourses, with two subtypes depending on the willow species, *Salix arbusculoides* or *S. alaxensis* subsp. *alaxensis*,

c) various tundra subtypes including:

i) the complex of various dwarf shrub-heath subtypes,

ii) the cottongrass (*Eriophorum vaginatum*) tussock tundra subtype,

iii) the various sedge meadow subtypes,

iv) the lake edge graminoid subtypes.

The most common tundra plant communities in the study area comprise the complex of dwarf shrub-heath subtypes. These cover 75% of the land surface. Tussock tundra covers 14%; sedge meadows 6% and lake edge communities 3% (adapted from Corns, 1972).

Inuvik Region

The Picea glauca-Alnus crispa subsp. crispa-Salix arbusculoides forest 3.5 km north of Inuvik was disturbed by a 1969-70 winter seismic line. It was sampled during both summers of the study, 1970 and 1971 (Table 2).

In July 1970 (Fig. 2, top), plant cover was 1.4% and consisted predominantly of patches of Arctostaphylos rubra. By the second summer (Fig. 2, bottom), cover had increased to 21%. Willow had a mean cover of 1.4% and alder 0.6%. Most willow cover was made up of regeneration from rootstocks rather than seedlings. One live spruce twig was seen. Most of the plant cover was mosses (6.4%) and Arctostaphylos rubra (7.8%). Also present were some Vaccinium uliginosum and Ledum groenlandicum Oeder. A few isolated grass culms of Arctagrostis latifolia and Calamagrostis canadensis were present on the line. Since these were not seen in the forest, grew singly and did not have extensive root systems, it appeared that they established from seed.

The silty soils thawed 60% deeper in the disturbed area than in the control during both years. Localized areas of subsidence, 3 to 4 m^2 in area and depressed 40 cm, were commonly scattered at 7 to 10 m intervals in the second year. These wetter areas had some Potentilla palustris.

The undisturbed 2.5 to 4.0 m tall willows and the 3.0 to 4.5 m alders ranged in age from 20 to 35 years. The 13 to 16 m tall spruce were 225 to 305 years of age. Gill (1971), in studying the hydrarch successional sequence in

Table 2. Changes in cover and thaw depth in a *Picea glauca-Alnus crispa* subsp. *crispa-Salix arbusculoides* community in the Mackenzie Delta north of Inuvik N.W.T. resulting from a 1969-70 winter seismic line. Data are given as means ± standard error.

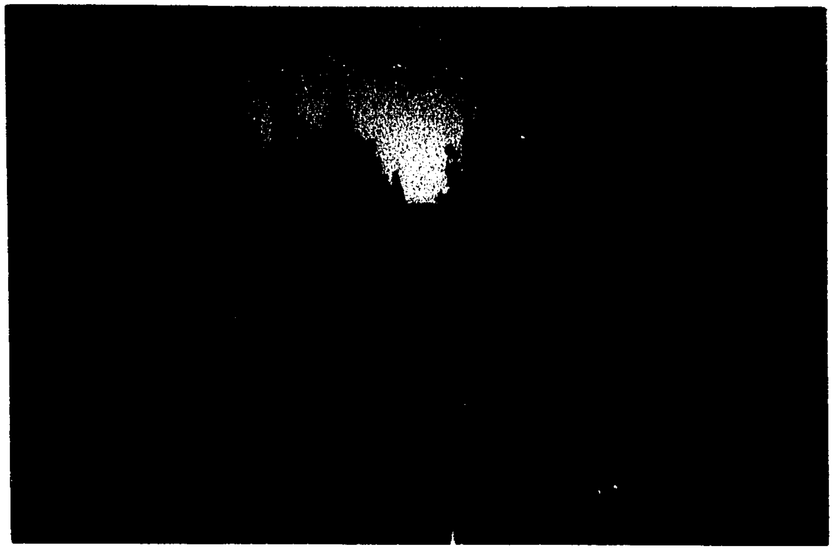
Species	July 4, 1970 Control	July 4, 1970 Disturbed	July 2, 1971 Control	July 2, 1971 Disturbed
	Cover (%) and Thaw Depth (cm)			
Picea glauca	16.0±3.6	0	13.7±3.0	+[a]
Alnus crispa crispa	41.1±6.3	0	35.9±4.6	0.6±0.2
Salix arbusculoides	10.3±3.7	0.1±0.1	11.3±2.5	1.4±0.3
Carex vaginata	1.2±0.2	0	0.9±0.2	0.7±0.3
Arctagrostis latifolia	--- [b]	---	0	0.1±0.1
Platanthera obtusata	0.2±0.1	0	0.1±0.1	0.1±0.1
Rosa acicularis	0.4±0.3	0	0.7±0.3	0
Potentilla fruticosa	0.2±0.2	0	0.2±0.1	0
Potentilla palustris	---	---	0	0.1±0.1
Rubus acaulis	---	---	0	0.2±0.2
Vaccinium uliginosum	4.1±0.7	0.1±0.1	2.4±0.8	0.7±0.4
Arctostaphylos rubra	18.3±2.0	0.9±0.6	19.8±2.0	7.8±1.2
Ledum groenlandicum Oeder	4.5±0.9	0	2.5±0.7	0.6±0.3
Pyrola grandiflora	5.8±0.9	0	5.2±0.9	0.4±0.2
Boschniakia rossica	0.2±0.1	0	0.4±0.2	0
Equisetum scirpoides	1.0±0.3	0	1.0±0.3	0.4±0.2
Equisetum arvense	1.0±0.3	0	0.1±0.1	0.9±0.6
Moss	23.3±2.0	0.1±0.1	26.9±2.5	6.4±1.3
Litter	42.0±3.0	0	44.7±3.6	0
Total Plant Cover	170.3±4.1	1.4±0.4	163.7±6.0	21.3±2.0
Bare Silt	0	98.1±0.3	0	77.6±2.1
Thaw Depth	16.1±0.3	26.5±0.8	20.4±0.5	31.4±0.7

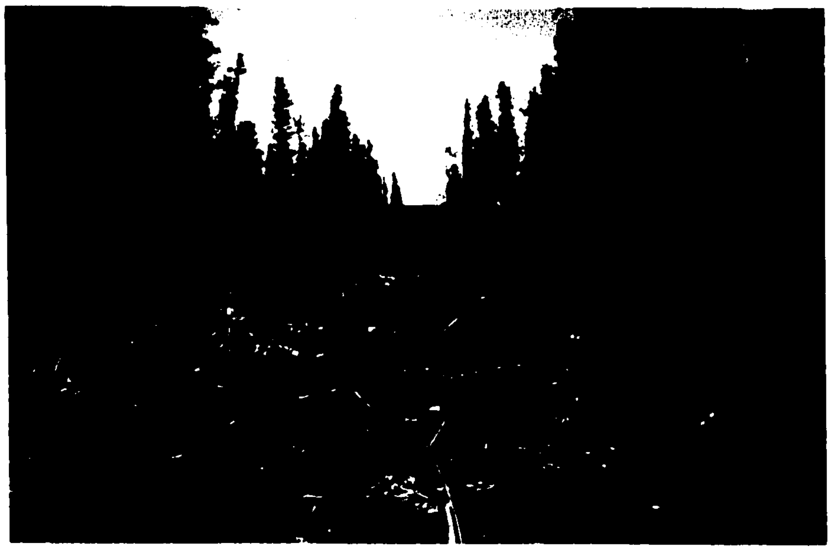
a Mean Cover less than 0.05%

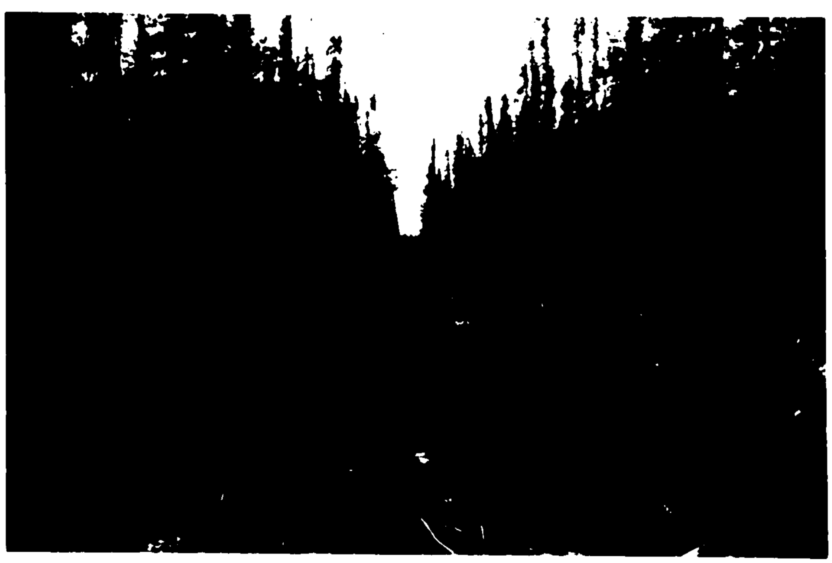
b Not present in any transect

Figure 2. A 1969-70 winter seismic line in the two summers immediately following its being surveyed through the *Picea glauca*-*Alnus crispa* subsp. *crispa*-*Salix arbusculoides* forest near Inuvik, N.W.T. Note increase in plant cover, most obviously from regenerating *Salix* rootstocks but also from *Arctostaphylos rubra* by the second year (bottom).

Top - July 4, 1970 Bottom - July 2, 1971







the Delta, gives 20 to 50 years as being required for the *Salix*-*Equisetum* stage, 50 to 200 years for the *Salix*-*Alnus* stage and greater than 200 years for the *Picea* stage. In view of the regenerating rootstocks of willow and alder, recovery to the *Salix*-*Alnus* stage appears relatively rapid. Recovery of the spruce forest to its former state, while it will take a long time, should not take as long as the implied 400 years. The initial wet stages of the hydrarch succession will not have to occur to provide a suitable habitat for the establishment of spruce. This is now available, or soon will be, with the re-establishment of the *Salix*-*Alnus* community on the seismic line.

The other common Delta community sampled was a *Salix alaxensis* subsp. *alaxensis*-*Alnus crispa* subsp. *crispa* tall shrub community. A trail had been created through it, probably in the winter of 1969-70 (Table 3). Earlier sampling in 1971 gave lower control cover values. Ground cover of the mosses increased on the trail since much of the litter of the natural community was removed. The composition of the disturbed area was similar in both years, the major difference being the increase in cover of the tall shrub species. *Hedysarum alpinum*, a common species in natural clearings, increased in the disturbed area. Patches of bare soil were quite small and infrequent. No signs of thermokarst were seen in either year. Since much of the vegetation remained *in situ* and alive after the disturbance, recovery to the mature 20 to 30 year old willow-alder thicket

Table 3. Changes in cover and thaw depth in a *Salix alaxensis* - *Alnus crispa* community in the Mackenzie Delta north of Inuvik, N.W.T., resulting from a vehicle trail in the winter of 1969-70. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm)			
	July 27, 1970		July 3, 1971	
	Control	Disturbed	Control	Disturbed
Picea glauca	0.4±0.3	0	0.5±0.4	0
Alnus crispa	22.5±4.9	0.6±0.4	16.4±3.6	3.1±1.0
Salix alaxensis	25.1±4.1	1.9±0.9	21.4±3.7	4.0±1.1
Hedysarum alpinum	2.9±0.4	3.3±0.5	3.4±0.7	5.5±1.1
Arctostaphylos rubra	36.6±3.9	31.6±2.7	21.1±1.5	22.6±1.7
Pyrola grandiflora	2.7±0.3	2.1±0.6	7.7±0.9	2.8±0.3
Moss (Live and Dead)	11.3±1.4	50.9±3.0	16.5±1.5	51.1±4.0
Litter	32.9±2.3	10.1±1.0	30.2±2.9	10.2±0.6
Total Plant Cover	134.4±6.2	100.5±1.0	117.2±4.2	99.3±1.1
Bare Soil	0	0.8±0.6	0	0.5±0.3
Thaw Depth	44.0±0.8	63.3±0.6	34.7±0.7	56.9±1.0

should occur rapidly.

Tununuk Point Region

Near Tununuk Point, a Salix arbusculoides-Alnus crispa subsp. crispa tall shrub thicket, was sampled during both summers. Data from a 1969-70 winter seismic line are given in Table 4. The line was 4 m wide and depressed 15 to 20 cm on the central portion. There were 1.5 m wide shoulders with some plant cover.

Arctostaphylos rubra comprised a greater cover on the shoulder than on the control. Pyrola grandiflora, however, was almost eliminated. This differing response to disturbance is not unexpected. Pyrola has weakly developed rhizomes while Arctostaphylos rubra has a more extensive root and rhizome system. Part remains intact in the soil and can thus regenerate.

Alnus crispa subsp. crispa showed little recovery even by the second year. Some 20 willow seedlings per transect were seen on the centre of the disturbed area but most of the Salix cover throughout the disturbance resulted from rootstocks.

Salix and Arctostaphylos, with their intact roots or rhizomes, quickly revegetate the relatively lightly disturbed Delta communities. This is in marked contrast to a nearby bare silt airstrip, also in a Delta willow community, that was used for one year and abandoned in late 1969. The only cover was a few 5 to 10 cm tall willow seedlings (22 per 10 m^2). Salix shoots were sprouting from rootstocks at the

Table 4. Changes in cover and thaw depth in a _Salix arbusculoides_ - _Alnus crispa_ community near Tununuk Point in the Mackenzie Delta, N.W.T., resulting from a winter 1969-70 seismic line. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) June 22, 1970 Control	Edge of Line	Centre of Line	July 6, 1971 Control	Edge of Line	Centre of Line
Alnus crispa	13.3±3.8	0.3±0.1	0	16.9±2.9	0.3±0.2	0
Salix arbusculoides	28.1±5.3	9.0±0.9	0.2±0.2	32.4±3.0	19.0±3.8	3.9±1.5
Arctagrostis latifolia	-[a]	-	-	0	0	0.4±0.2
Rubus acaulis	-	-	-	0	0	1.0±1.0
Hedysarum alpinum	0.2±0.1	0.3±0.1	0.1±0.1	1.4±0.3	2.4±0.8	0.4±0.3
Arctostaphylos rubra	12.0±1.6	20.0±2.6	0.3±0.1	11.1±1.9	18.1±2.2	0.9±0.7
Pyrola grandiflora	4.5±0.7	0.7±0.2	0	1.5±0.2	0.2±0.1	0
Equisetum scirpoides	-	-	-	0	0	0.5±0.4
Moss	16.0±1.3	10.7±1.1	1.6±0.3	13.4±1.6	12.3±2.0	11.6±1.8
Litter	30.5±2.9	0	0	28.1±2.1	0	0
Total Plant Cover	104.6±2.1	41.0±2.3	2.2±0.3	104.8±2.6	52.3±4.6	18.7±2.4
Bare Soil	0	58.1±3.0	97.9±0.3	0	46.9±5.0	82.1±3.6
Thaw Depth	11.7±0.3	13.7±0.3	28.9±0.7	28.5±1.1	34.6±1.1	54.9±0.8

a Not present in any transect

edge of the river channel where Hedysarum alpinum and Aster sibiricus were also present.

The remainder of the stands sampled at Tununuk Point, as well as at the remaining areas, were of exclusively tundra communities.

A cottongrass-sedge-heath tussock tundra community located 3.1 km north of Tununuk Point on Richards Island had a 1962 summer seismic line passing through it (Table 5). The thawed layer appeared not to have been bulldozed aside. Betula nana subsp. exilis has shown almost no recovery. Five Alnus crispa subsp. crispa seedlings, although not on the transects themselves, were seen at the edge of the line. Vaccinium uliginosum was the only heath to have an appreciable cover on the line (2.4 vs 11.7% on control). In the moister disturbed area, lichens had not recovered and mosses were half of their natural abundance.

The most striking difference between control and disturbed areas was the three-fold increase in Eriophorum vaginatum on the line. The tussocks were green, vigorous and flowering abundantly as compared to the controls (Fig. 3). They produced some 50 times more flowering heads ($61.7 \pm 5.7^*/m^2$ vs $1.07 \pm 0.07^*/m^2$). This same phenomenon was seen in a similar community near Tuktoyaktuk through which passed a vehicle trail of unknown age. Eriophorum cover increased

---

* Data are given as mean ± standard error

Table 5. Changes in cover and thaw depth in a cottongrass-sedge-heath community near Tununuk Point, N.W.T., resulting from a 1962 summer seismic line. Data given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) July 10, 1970 Control	Disturbed
Alnus crispa	0.8±0.6	0
Betula nana	5.0±1.0	0.4±0.2
Eriophorum vaginatum	9.0±1.0	32.6±3.0
Carex bigelowii	5.6±1.2	12.2±2.0
Empetrum nigrum	1.1±0.4	0
Vaccinium uliginosum	11.7±0.6	2.6±0.3
Vaccinium vitis-idaea	4.1±0.6	+[a]
Arctostaphylos rubra	6.4±0.9	0.4±0.3
Ledum palustre decumbens	3.8±0.7	0
Pyrola grandiflora	0.5±0.3	0
Mosses (Live and Dead)	47.7±2.1	22.9±1.3
Lichens	9.6±0.8	0
Total Plant Cover	105.5±3.0	70.9±3.4
Bare Soil	0	30.9±2.7
Thaw Depth	12.6±0.3	34.4±0.3

a Cover less than 0.05%

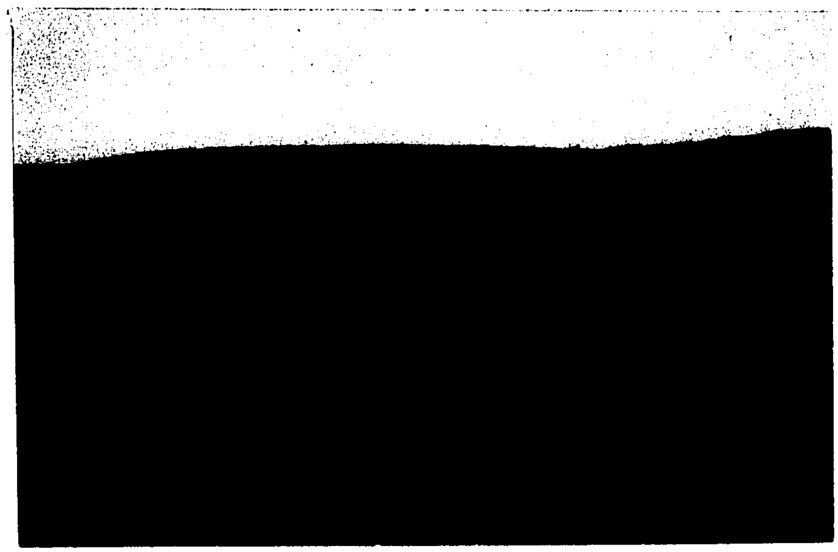


Figure 3. A 1962 summer seismic line through an *Eriophorum vaginatum*-heath tussock tundra community near Tununuk Point, N.W.T., July 10, 1970. Note greatly increased flowering on the seismic line.

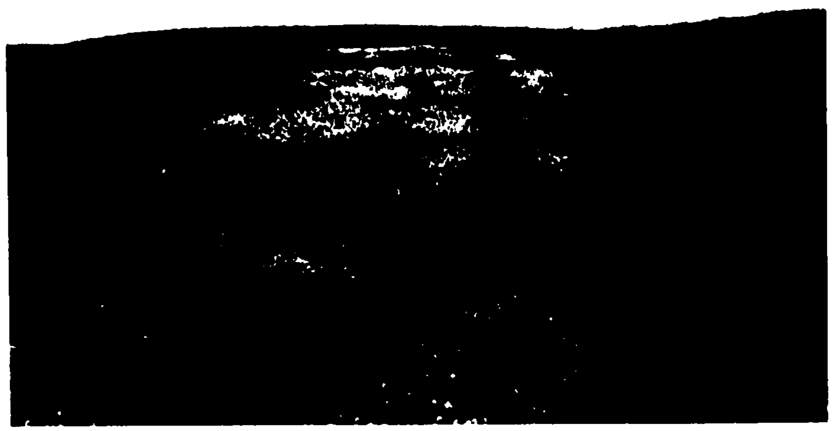


Figure 3. A 1962 summer seismic line through an <u>Eriophorum vaginatum</u>-heath tussock tundra community near Tununuk Point, N.W.T., July 10, 1970. Note greatly increased flowering on the seismic line.

from 14 to 52% and the number of flowering heads from 7.40 $\pm$ 0.17/m^2 to 98.0 $\pm$ 14.1/m^2. Wein and Bliss (1972) acknowledge that competition may have been reduced as a result of the disturbance. However, they give evidence that this effect may be predominantly due to increased mineral nutrition resulting from greater thaw depth and thus nutrient availability.

A dwarf shrub-heath community was also subjected to the same 1962 summer seismic line (Table 6). *Salix glauca* had the same cover on control and disturbed areas but *Betula nana* was greatly reduced. *Vaccinium uliginosum* and *Arctostaphylos rubra* are the only heaths with appreciable cover, approximately one-third of control. The major difference between control and disturbed areas is the presence of the grasses *Arctagrostis latifolia* and *Poa lanata* and the forbs *Stellaria monantha* and *Cardamine pratensis* on the line. These species are rarely seen in undisturbed communities. Bare soil was common but signs of thermokarst were minimal with two 50x70x15 cm depressions being the largest recorded.

Atkinson Point Region

A wet sedge meadow consisting of *Carex aquatilis* subsp. *stans* and *C. rariflora* through which passed a 1969-70 winter seismic line was sampled near Atkinson Point, in August 1970 (Table 7). The effects of the line were most readily noticed on very low ridges flanking the meadow. The depth of thaw was only slightly increased and, on the average, 5% of the

Table 6. Changes in cover and thaw depth in a dwarf shrub - heath community near Tununuk Point N.W.T., resulting from a 1962 summer seismic line. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) July 7, 1971 Control	Disturbed
Salix glauca	3.8±1.2	3.9±1.2
Betula nana	5.9±1.3	0.9±0.4
Arctagrostis latifolia	0.1±0.1	6.2±0.9
Poa lanata	0	5.6±1.5
Carex bigelowii	8.2±1.0	11.7±1.6
Carex capillaris	0	0.9±0.4
Luzula confusa	0	0.7±0.2
Stellaria monantha	+[a]	5.3±0.6
Cardamine pratensis	+[a]	1.9±0.3
Dryas integrifolia	6.1±0.7	5.2±1.0
Lupinus arcticus	2.2±0.8	1.2±0.3
Empetrum nigrum	3.8±0.6	0.1±0.1
Vaccinium uliginosum	14.2±0.9	4.1±0.8
Vaccinium vitis-idaea	2.0±0.7	0.2±0.2
Arctostaphylos rubra	5.9±1.0	1.8±0.9
Ledum palustre decumbens	1.3±0.7	0.2±0.2
Rhododendron lapponicum	0.5±0.3	0
Pyrola grandiflora	4.3±0.4	0.6±0.3
Pedicularis capitata	0.6±0.2	0.2±0.1
Pedicularis kanei	0.7±0.1	0.1±0.1
Saussurea angustifolia	0.8±0.2	1.8±0.3
Petasites frigidus	0.3±0.1	1.1±0.4
Moss	28.9±1.2	18.2±1.4
Lichens	10.0±0.9	0
Total Plant Cover	99.6±2.0	71.9±3.0
Bare Soil	0	27.1±3.0
Thaw Depth	19.6±0.5	44.5±1.5

a Cover less than 0.05%

cover was bare peat. The combination of flat topography and winter exploration when the ground was frozen has minimized plant community damage.

Table 7. Changes in cover and thaw depth in a sedge meadow at Atkinson Point, N.W.T. resulting from a 1969-70 winter seismic line. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) August 8, 1970 Control	Disturbed
Carex spp.[a]	65.6±3.1	56.7±1.8
Moss	35.2±3.0	38.4±1.4
Total Plant Cover	100.8±1.1	93.1±1.7
Bare Peat	0	5.0±1.2
Thaw Depth	34.7±1.1	35.1±0.7

a Carex aquatilis subsp. stans and C. rariflora

An area of raised centre polygons with a dwarf shrub-heath community was intersected by two 1969-70 winter seismic lines (Table 8). The passage of the seismic vehicles exposed mineral soil by shearing off the tops of many of the 1 to 2 m tall 8x5 m polygons. This was the sole mesic tundra community sampled in which grasses (mostly Arctagrostis latifolia but also Poa lanata) were an appreciable part of the natural plant cover (6%). Of the dwarf shrubs, Betula nana subsp.

Table 8. Changes in cover and thaw depth in a dwarf shrub - heath raised centre polygon community at Atkinson Point, N.W.T., resulting from a winter 1969-70 seismic line. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) August 8, 1970 Control	Disturbed
Salix glauca	7.5±1.4	4.5±1.0
Betula nana	14.9±2.3	2.4±0.8
Arctagrostis latifolia	5.8±1.0	2.5±0.6
Carex bigelowii	5.9±0.9	4.2±0.8
Luzula confusa	1.1±0.3	0.7±0.4
Stellaria monantha	2.4±0.4	1.1±0.4
Dryas integrifolia	1.6±0.4	1.4±0.7
Empetrum nigrum	2.3±1.0	0.1±0.1
Vaccinium vitis-idaea	5.8±1.6	2.1±0.8
Ledum palustre decumbens	3.8±1.0	1.1±0.6
Cassiope tetragona	0.6±0.3	0.6±0.4
Saussurea angustifolia	0.2±0.2	0.1±0.1
Lichens	6.2±1.2	1.8±0.6
Litter[a]	45.8±2.1	43.0±3.1
Total Plant Cover	103.9±0.8	65.6±6.5
Bare Soil	0	36.7±8.0
Thaw Depth	34.8±0.6	35.7±0.7

a Consists predominantly of dead moss. Could almost be considered bare peat.

exilis was proportionately more reduced since it grew most commonly near the tops of the polygons. No thermokarst was seen and thaw depths were not significantly different.

A large expanse of sedge meadows occurs at Atkinson Point. An airstrip was constructed through it in the mid 1950's by depositing 1 to 2 m of sand, the parent material of the region, onto the vegetation. The species growing in the sedge meadow and on the sides of the runway are markedly different (Table 9).

Table 9. Changes in cover and thaw depth in a sedge meadow at Atkinson Point N.W.T. resulting from construction of a sand airstrip in the mid 1950's and maintained since then. Data are given as mean ± standard error.

Species	Cover (%) and Thaw Depth (cm) August 9, 1970 Control	Disturbed
Salix pseudopolaris	3.3±1.3	0
Carex aquatilis stans	76.0±2.7	1.0±0.7
Eriophorum angustifolium	4.0±1.0	0
Elymus arenarius	0	19.7±3.7
Poa arctica	0	6.0±1.9
Cochlearia officinalis	0	1.0±0.5
Tripleurospermum phaecocephalum	0	0.7±0.4
Moss	17.4±1.6	0
Total Plant Cover	100.7±0.4	28.4±5.0
Bare Sand	0	72.2±5.0
Thaw Depth	38.3±0.5	82.2±1.3

Carex aquatilis subsp. *stans* was 76% of the natural plant community cover but the grasses *Elymus arenarius* and *Poa arctica* contributed most of the sparse cover on the edge of the airstrip. This community growing at the edge of the runway was similar to that on the sandy ocean beach. Thaw depth in the coarse exposed dry sand of the airstrip was much greater than in the moist peat and vegetation covered sand of the sedge meadow.

Reindeer Station Region

Three kilometres north of Reindeer Station the slope of the 150 to 200 m high Caribou Hills is predominantly covered by *Eriophorum vaginatum*-*Betula nana* subsp. *exilis*-heath tussock tundra communities. The plateau is dominated by dwarf shrub-heath communities. Data for a 1969-70 winter seismic line through the latter are given in Table 10. Only 11% was bare mineral soil, usually the sheared off tops of hummocks, but most species were reduced 30 to 50% in cover. Signs of thermokarst were not seen.

The tussock tundra communities of the slope were greatly affected by the passage of the vehicle train containing the seismic crew in the winter of 1969-70. Ordinarily, it follows the path of the seismic line during winter operations but here it meandered up the slope near the seismic line. This area was one of the few to show definite signs of erosion. A trickle of water was present in various portions of the rutted trail and small areas of sediment deposition were

Table 10. Changes in cover and thaw depth in a dwarf shrub-heath community at the top of the Caribou Hills north of Reindeer Station N.W.T. resulting from a winter 1969-70 seismic line. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) July 31, 1970 Control	Disturbed
Betula nana	5.6±1.3	2.4±0.8
Salix glauca	4.7±1.7	3.5±1.1
Salix arctica	0.2±0.2	0.1±0.1
Carex bigelowii	3.4±0.7	1.6±0.5
Lupinus arcticus	1.6±0.6	0.4±0.3
Empetrum nigrum	8.5±1.5	3.0±0.8
Vaccinium uliginosum	8.2±1.6	4.6±1.0
Vaccinium vitis-idaea	4.8±1.2	1.7±0.7
Arctostaphylos rubra	6.2±1.2	5.4±1.2
Ledum palustre decumbens	5.2±1.7	1.3±0.4
Pyrola grandiflora	0.7±0.5	0.1±0.1
Petasites frigidus	0.9±0.6	0.3±0.2
Saussurea angustifolia	0.2±0.2	0.1±0.1
Mosses (Live and Dead)	38.3±1.9	56.5±2.0
Lichens	10.4±1.5	6.4±1.5
Other Species[a]	0.2±0.1	0.1±0.1
Total Plant Cover	99.1±1.0	87.4±2.0
Bare Soil	0	11.4±1.0
Thaw Depth	47.8±1.0	58.9±1.2

a Castilleja raupii and Pedicularis kanei were both present in Control and Disturbed found near the bottom of the hill. Two massive slumps, 30x3x0.8 m, occurred near the top.

Three combinations of the vehicle trail and seismic line disturbances were sampled. Data for both near the top of the hill are in Table 11. The plant cover was similar in both disturbances. Carex bigelowii increased in cover but Eriophorum vaginatum was almost eliminated. Eriophorum flowering in the control was 10.8 $\pm$ 2.7/m^2; on the line 0.06 $\pm$ 0.06/m^2 and on the trail 0.2 $\pm$ 0.2/m^2. Lichens, mosses and Alnus crispa subsp. crispa were absent. The greater amount of bare soil on the trail was compensated for by the presence of litter and dead tussock material on the seismic line. One of the slumps was in the portion of the trail sampled and thaw was much deeper in it than in the seismic line. Both disturbances thawed more than the control.

A part of the trail consisted of two 20 cm deep tracks with some standing water. One track and the 1.5 m wide vegetated portion between them were sampled (Table 12). The track consisted of 3.9% Carex bigelowii, 4.7% mosses, 44.1% bare peat and 46.8% standing water. Masses of filamentous green algae were scattered throughout the water. Cover in the region between the tracks was markedly reduced. Ledum palustre subsp. decumbens and lichens were absent. None of the other species was significantly increased in cover but several (Empetrum nigrum, Vaccinium vitis-idaea, the dwarf shrubs and mosses) were markedly reduced. Flowering of Eriophorum vaginatum was almost non-existent in both control (0.83 $\pm$ 0.53/m^2) and disturbed (0.38 $\pm$ 0.25/m^2) sites.

Table 11. Changes in cover and thaw depth in an *Eriophorum vaginatum* - heath tussock tundra community on the slope of the Caribou Hills north of Reindeer Station N.W.T., resulting from both a seismic line and associated vehicle trail in the winter of 1969-70. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) July 5, 1971 Control	Disturbed Seismic Line	Disturbed Vehicle Trail
Alnus crispa	2.3±0.9	0	0
Betula nana	12.4±2.1	3.0±0.7	2.9±1.1
Eriophorum vaginatum	19.5±4.0	0.5±0.4	0.3±0.3
Carex bigelowii	0.6±0.2	4.3±1.3	7.1±1.1
Empetrum nigrum	3.8±0.7	0.2±0.1	0.1±0.1
Vaccinium uliginosum	3.1±0.9	5.3±1.1	3.4±0.9
Vaccinium vitis-idaea	12.9±1.3	0.1±0.1	0.2±0.2
Arctostaphylos rubra	6.4±1.7	1.2±0.4	0.9±0.2
Ledum palustre decumbens	16.1±1.5	1.4±0.4	1.0±0.3
Andromeda polifolia	0.7±0.3	1.0±0.7	0
Moss	9.8±1.6	0	0.6±0.2
Lichens	31.1±3.6	0	0
Litter[a]	0	16.3±2.6	0
Total Plant Cover	118.7±4.0	33.3±3.7	16.5±1.9
Bare Soil	0	69.6±3.4	83.8±4.2
Thaw Depth	28.1±1.0	49.2±1.8	62.7±1.4

a Predominantly dead tussock material

Table 12. Changes in cover and thaw depth in an Eriophorum vaginatum-heath tussock tundra community on the slope of the Caribou Hills north of Reindeer Station, N.W.T. resulting from a vehicle trail in the winter of 1969-70. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) July 5, 1971 Control	Vehicle Trail Between Tracks	Within Track
Picea glauca	0.3±0.2	0	0
Alnus crispa	2.3±0.8	0.3±0.3	0
Betula nana	3.1±1.3	0.5±0.5	0
Eriophorum vaginatum	6.8±1.7	8.5±2.0	0
Carex bigelowii	0.5±0.5	0.9±0.5	3.9±1.0
Rubus chamaemorus	19.5±1.3	13.1±1.9	0
Empetrum nigrum	11.7±1.2	1.4±0.5	0
Vaccinium uliginosum	3.5±1.0	6.4±1.3	0
Vaccinium vitis-idaea	12.7±1.6	3.3±0.7	0
Arctostaphylos rubra	4.5±1.0	4.6±1.5	0
Ledum palustre decumbens	11.4±1.4	0	0
Andromeda polifolia	1.0±0.3	5.0±2.1	0
Moss	43.6±3.5	6.1±2.3	4.7±2.6
Lichens	3.3±1.4	0	0
Total Plant Cover	124.2±3.6	50.1±7.6	8.6±3.3
Bare Peat	0	51.8±6.3	44.1±4.1
Standing Water[a]	0	0	46.8±4.8
Thaw Depth	21.7±0.4	43.6±0.4	47.4±0.8

a Had collected in track created by vehicle tread. Contained masses of filamentous green algae scattered throughout.

In the third stand of tussock tundra sampled in the Caribou Hills (Table 13) vehicle tread marks were visible but the peat layer remained intact.

Table 13. Changes in cover and thaw depth in an Eriophorum vaginatum - heath tussock tundra community on the side of the Caribou Hills north of Reindeer Station N.W.T., resulting from a vehicle trail in the winter of 1969-70. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) July 5, 1971 Control	Disturbed
Alnus crispa	5.0±1.8	+
Betula nana	6.1±0.9	1.7±0.3
Eriophorum vaginatum	32.7±2.7	17.2±1.7
Carex bigelowii	1.6±0.8	1.7±1.2
Rubus chamaemorus	5.9±0.7	8.1±0.9
Empetrum nigrum	5.3±1.5	0.6±0.2
Vaccinium uliginosum	7.0±1.1	3.8±0.4
Vaccinium vitis-idaea	13.6±0.9	4.2±0.7
Arctostaphylos rubra	2.0±0.6	0.2±0.2
Ledum palustre decumbens	11.2±0.9	3.0±0.8
Andromeda polifolia	0.1±0.1	0
Moss	7.5±1.8	8.8±2.5
Lichens	6.6±1.5	+[a]
Total Plant Cover	104.6±1.3	49.3±2.7
Bare Peat	0	50.8±3.5
Thaw Depth	22.3±0.7	54.4±0.8

a Cover less than 0.05%

Alder and lichens were all but absent. Rubus chamaemorus increased in cover but Carex bigelowii and mosses were unchanged. All other species were significantly reduced. Eriophorum vaginatum flowered much less than on the undisturbed site ($2.3 \pm 0.5/m^2$ vs $9.7 \pm 1.7/m^2$).

The differing severity of the disturbances described above may be explained as a function of steepness of slope. Vehicles are more likely to churn up vegetation and frozen ground while climbing a slope than when on level ground. The first area described was at the steepest part of the slope (12° to 15°). Subsurface ice appears to have been present and exposed. Ice thaw as well as any spring runoff which occurred probably drained along the depression caused by the vehicle tracks. The absence of further or massive erosion is most likely a result of the low rainfall prevalent throughout the study region (see Table 1). The lower slopes are less steep (at most 4° to 5°) and thus less subject to severe damage.

Tuktoyaktuk Region

Most of this study was conducted in the general vicinity of Tuktoyaktuk, N.W.T. (see Fig. 1). Various communities, ranging from lake edge graminoid subtypes through sedge meadows, tussock tundra and the complex of dwarf shrub-heath, were sampled. The effects of two major classes of disturbance, winter roads and seismic lines, were examined in as many communities as possible.

Winter Road

A compacted snow and ice road passing over both lake edge and upland dwarf shrub-heath communities is used to supply and move drilling rigs northeast of Tuktoyaktuk. Much of the same path has been used during the winters of 1969-70 and 1970-71. A raised centre polygon community and a dwarf shrub-heath community through which the winter road passed were sampled (Tables 14 and 15 respectively). The effects of the road on both were very noticeable. The 4 to 5 m wide centre portion of the road was 96 to 100% bare peat because of heavy traffic. The less travelled 2 to 3 m wide edges had 14 to 20% plant cover. This pattern was typical of the winter road through dry upland areas.

The composition of the two natural communities differs but the response of the species common to both is usually similar. Winter breakage of above ground plant parts is likely, not only because of continually being passed over by vehicles but also because of the brittleness of the vegetation due to low temperatures. Vaccinium vitis-idaea subsp. minus and Empetrum nigrum subsp. hermaphroditum, with their evergreen leaves and single rooted stems, are greatly reduced in cover. But Carex bigelowii, with its thin leaves which die back every year and many underground interconnected rhizomes, is not as susceptible to being eliminated if the leaves are broken off. The dwarf shrubs with their shallow and protruding rootstocks appear to be susceptible to being uprooted by continual vehicular passage over them.

Table 14. Changes in cover and thaw depth in a raised centre polygon community near Tuktoyaktuk N.W.T. resulting from a winter road used in 1969-70. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) July 20, 1970 Control	Disturbed Edge of Road	Centre of Road
Betula nana	25.2±3.5	0.8±0.6	0
Salix glauca	0.5±0.3	0.1±0.1	0
Carex bigelowii	0.7±0.5	1.5±1.0	0.2±0.2
Rubus chamaemorus	3.9±1.0	4.1±1.2	0
Empetrum nigrum	7.8±2.3	0.4±0.3	0
Vaccinium uliginosum	0.5±0.5	1.2±0.8	0
Vaccinium vitis-idaea	10.8±1.2	1.4±0.9	0
Arctostaphylos rubra	0.5±0.5	1.1±0.7	0
Ledum palustre decumbens	7.7±1.2	0.5±0.3	0
Moss (Live and Dead)	32.6±2.7	0	0
Lichens	9.7±1.7	3.1±1.0	0
Total Plant Cover	99.9±1.0	14.2±2.3	0.2±0.2
Bare Peat	0	85.5±2.5	99.9±0.2
Thaw Depth	26.7±0.5	28.0±0.5	33.8±1.0

Table 15. Changes in cover and thaw depth in a dwarf shrub-heath community near Tuktoyaktuk, N.W.T., resulting from a winter road used in 1969-70 and 1970-71. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) August 5, 1971		
	Control	Disturbed	
		Edge of Road	Centre of Road
Betula nana	11.9±1.2	2.9±0.5	0.1±0.1
Salix glauca	12.0±1.2	4.6±0.8	1.0±0.3
Arctagrostis latifolia	0.1±0.1	0.7±0.4	0.5±0.3
Calamagrostis canadensis	1.0±0.5	2.5±0.4	0.1±0.1
Poa lanata	+[a]	0	0
Carex bigelowii	3.4±1.0	3.2±0.4	1.7±0.5
Dryas integrifolia	2.1±1.2	0.2±0.2	+[a]
Empetrum nigrum	8.0±1.1	1.0±0.6	0
Vaccinium uliginosum	2.3±0.8	2.0±0.6	0.2±0.2
Vaccinium vitis-idaea	12.7±1.0	1.3±0.5	0.2±0.2
Arctostaphylos rubra	1.4±0.7	0	0
Ledum palustre decumbens	3.7±0.9	0.4±0.3	0
Pyrola grandiflora	1.4±0.8	0	0
Mosses	19.2±1.0	0	0
Lichens	19.5±1.0	0	0
Total Plant Cover	100.8±1.5	18.9±1.9	4.3±0.6
Bare Peat	0	80.4±2.0	96.0±1.0
Thaw Depth	44.4±0.7	53.4±1.0	64.0±1.5

a Mean Cover less than 0.05%

Mineral soil was rarely exposed although vegetation was almost totally removed. Subsidence was in very small areas, 0.5 to 1.0 m^2. In the centre of the road, the depth of thaw was increased 28% for the polygon community and 44% for the dwarf shrub-heath community. This was not as great as would be expected had the peat been removed and mineral soil exposed. Drying of the top few centimetres of the peat appears to provide adequate insulation. Massive slumping was only observed once on a winter road that had been used for three successive winters, 1 km south of the Imperial Oil base camp near Tuktoyaktuk. Constant passage over the crest of a ridge wore down the 15 to 20 cm peat layer to the point that a subsurface ice wedge was exposed and began to melt in June 1971. This formed a depression 1.5 to 2.0 m deep by August.

A common lake edge and meadow community of the region is composed primarily of <u>Carex aquatilis</u>. Part of the winter road passing through such a community and across a small bay of a lake was sampled (Table 16). Much bare peat (>90%) occurred on the road near the lake. But farther from it, the road was not noticeable when looking across the meadow. Close examination revealed 26% bare peat. There was no significant change in thaw depth. The pattern observed may be explained by the fact that, in winter, the rhizome-containing peat layer at the edge of the lake would be slightly raised and probably unsaturated. Thus, it could be easily disturbed because of the lack of ice cement. On the meadow, however,

Table 16. Changes in cover and thaw depth in a *Carex aquatilis* lake edge community northeast of Tuktoyaktuk, N.W.T. resulting from a winter road used in 1969-70 and 1970-71. Data are given as means ± standard error.

Species	Transect[a]	Cover (%) and Thaw Depth (cm) July 30, 1971 Control	Disturbed
Carex aquatilis	1	53.0±2.4	20.4±2.1
	2	52.3±3.6	13.7±0.6
	3	62.2±2.2	8.6±0.9
	4	58.4±1.5	8.2±0.9
	5	58.4±2.0	1.8±0.5
Other Species[b]	1	20.7±1.2	8.5±0.6
	2	22.6±1.0	2.8±0.3
	3	8.3±1.7	0
	4	0	0
	5	0	0
Moss	1	30.9±2.2	34.1±3.0
	2	28.4±2.0	34.1±1.8
	3	30.0±2.9	7.1±1.3
	4[c]	0	0
	5[c]	0	0
Total Plant Cover	1	104.6±1.5	74.6±4.8
	2	103.7±1.4	59.3±2.5
	3	100.5±0.5	15.9±1.8
	4[c]	58.4±1.5	8.2±0.9
	5[c]	58.4±2.0	1.8±0.8
Bare Peat	1	0	26.7±4.1
	2	0	40.3±2.2
	3	0	83.4±1.6
	4[c]	41.6±1.5	91.8±0.9
	5[c]	41.6±2.0	97.8±0.4
Thaw Depth	1	39.6±0.4	41.6±0.3
	2	40.4±0.4	39.2±0.3
	3	41.4±0.4	44.0±0.2
	4	42.6±0.2	43.0±0.2
	5	42.6±0.2	43.4±0.2

a Transects are in order of increasing proximity to the lake: 1 is several hundred metres removed from it and 5 ends at the water's edge.

b Other Species were: *Salix pseudopolaris*, *Eriophorum russeolum*, *Potentilla palustre*, *Caltha palustris* and *Pedicularis sudetica*.

c Control vegetation of transects 4 and 5 was solely *Carex aquatilis*. Live moss was absent. Peat and standing water comprised the ground layer.

the water table was probably high enough that a layer of ice protected both peat and rhizomes.

A second lake edge community, dominated by *Arctophila fulva* was sampled along the winter road, east of Tuktoyaktuk (Table 17). Bare peat covered by standing water occurred on several stretches of the road while other parts of the road appeared undisturbed. The range of variation is reflected in the three separate transects of Table 17. *Ranunculus gmelini* was much more abundant on the open sections of the road.

It appears that, in winter, wet graminoid communities with their roots and rhizomes protected by the peat, are much less susceptible to damage than upland communities. This is the reverse of the situation in summer when wet areas are very sensitive to even one pass of a vehicle as shown by Bellamy *et al*. (1971).

Seismic Lines

The most intensively sampled types of surficial disturbance in the Tuktoyaktuk region were seismic lines. All types of tundra communities except lake edge were disturbed by lines ranging in age from the summer of 1965 to the winter of 1970-71.

Two different *Eriophorum vaginatum* tussock tundra communities, both subjected to 1968-69 winter seismic lines, were sampled, one in 1970, the other in 1971 (Table 18). The former was visibly the drier of the two and this is

Table 17. Changes in cover and thaw depth in an *Arctophila fulva* lake edge community east of Tuktoyaktuk, N.W.T. resulting from a winter road used in 1969-70 and 1970-71. Data are given as means ± standard error.

		Cover (%) and Thaw Depth (cm) July 21, 1971	
Species	Transect[a]	Control	Disturbed
Arctophila fulva	1	89.0±2.6	22.6±3.0
	2	77.9±3.8	28.4±3.1
	3	77.3±4.7	48.4±4.5
Caltha palustris	1		
	2	3.6±1.1	1.2±0.6
	3	3.7±1.6	1.6±0.5
Ranunculus gmelini	1	0.9±0.4	0
	2	8.6±1.0	12.3±1.4
	3	8.9±1.9	27.3±3.3
Hippuris vulgaris	1	2.5±0.6	2.6±0.7
	2	0.9±0.3	1.8±0.7
	3	0.6±0.4	0.4±0.2
Senecio congestus	1	0.1±0.1	0
	2	2.9±0.5	0.4±0.2
	3	0.7±0.3	0.8±0.3
Total Plant Cover	1	92.5±2.5	25.2±3.1
	2	93.9±2.0	44.1±4.2
	3	91.2±2.2	78.5±2.1
Bare Peat[b]	1	8.4±2.5	74.4±3.1
	2	8.8±2.0	56.3±4.2
	3	8.4±2.2	20.6±2.1
Thaw Depth	1	73.3±0.9	96.9±0.4
	2	65.2±0.4	88.4±0.5
	3	65.8±0.4	85.6±0.9

a Data are for three separate transects parallel to the lake.

b In both Control and Disturbed this is covered by a few centimetres of water.

Table 18. Changes in cover and thaw depth in two separate *Eriophorum vaginatum* tussock tundra communities near Tuktoyaktuk N.W.T. resulting from different 1968-69 winter seismic lines. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) (a) July 17, 1970 Control	(a) July 17, 1970 Disturbed	(b) July 18, 1971 Control	(b) July 18, 1971 Disturbed
Betula nana	7.2±1.1	2.5±0.7	5.2±0.8	0.4±0.2
Salix glauca	3.6±0.8	2.2±0.9		
Calamagrostis canadensis	0.6±0.2	1.1±0.3	+[a]	0.4±0.2
Eriophorum vaginatum	30.1±4.1	10.2±3.2	30.9±2.2	20.9±1.5
Carex bigelowii	14.9±1.5	9.4±2.1	3.2±0.5	8.2±0.7
Carex rariflora			2.2±1.0	0
Rubus chamaemorus	2.1±0.5	1.0±0.4	5.7±0.8	+[a]
Empetrum nigrum	7.5±0.7	1.7±0.8	5.8±0.5	+[a]
Vaccinium uliginosum	1.6±0.9	1.3±0.8		
Vaccinium vitis-idaea	6.4±0.6	1.9±0.5	4.5±0.5	+[a]
Arctostaphylos rubra	2.3±1.1	1.3±0.8		
Ledum palustre decumbens	6.2±0.7	1.8±0.7	7.2±0.5	0.1±0.1
Pyrola grandiflora	2.0±0.3	0.4±0.2		
Petasites frigidus	1.5±0.4	0.7±0.3		
Moss	11.8±0.8	5.5±1.1	35.2±1.8	16.4±1.4
Lichens	3.4±0.4	0.9±0.4		
Other Species[b]	1.5±0.4	1.2±0.3	0.8±0.4	0
Total Plant Cover	102.7±2.7	43.1±6.0	100.7±1.1	46.6±2.5
Bare Soil	0	52.5±5.1	0	47.7±3.2
Thaw Depth	22.3±0.4	38.3±1.0	23.9±0.5	41.7±0.7

a Cover less than 0.05%

b Other Species were: 1970 sampled line Control and Disturbed - *Lupinus arcticus*, *Cardamine pratensis* and *Saussurea angustifolia*; 1971 sampled line Control - *Salix arctica* reflected by the differences in composition and abundance of the species.

Many tussocks of the 1970 sampled line were overturned and Eriophorum vaginatum cover was one-third that of the undisturbed area. Live tussocks were not markedly different in vigour or flowering from that of the controls. This line was revisited in 1971 but not resampled. It appeared the same with some 45 to 50% plant cover, little Eriophorum cover and few flowering heads.

On the 1971 sampled community, Eriophorum cover was reduced to two-thirds of the controls but the tussocks were green and vigorous. Flowering was not significantly greater on the line than the adjacent undisturbed area ($25.9 \pm 3.8/m^2$ vs $20.2 \pm 3.2/m^2$). The number of seed heads on the control, however, except for one other site, was much more abundant than that found in all control communities sampled at Reindeer Station or Tununuk Point or presented by Wein and Bliss (1972). The other exception is presented later (page 55).

The most common plant community in the Tuktoyaktuk Peninsula, the dwarf shrub-heath complex, was subjected to a variety of seismic surveys which differed not only in time of year but also in method. An examination of several different lines thus allows a comparison of the magnitude and effects of these disturbances on the same type of plant community. Data from four different seismic lines through comparable examples of the same community are given in Table 19. They were: (a) a 1965 summer line in which the

Table 19. Changes in cover and thaw depth in dwarf shrub-heath communities in the Tuktoyaktuk Peninsula, N.W.T. resulting from a 1965 summer seismic line and 1967-68, 1968-69 and 1970-71 winter seismic lines. Data are given as means ± standard error.

Species	(a) 1965 Line July 16, 1971 Control	(a) 1965 Line July 16, 1971 Disturbed	(b) 1967-68 Line July 18, 1970 Control	(b) 1967-68 Line July 18, 1970 Disturbed	(c) 1968-69 Line July 16, 1970 Control	(c) 1968-69 Line July 16, 1970 Disturbed	(d) 1970-71 Line July 27, 1971 Control	(d) 1970-71 Line July 27, 1971 Disturbed
	Cover (%) and Thaw Depth (cm)							
Betula nana	13.2±1.2	0.5±0.4	10.7±1.5	5.7±1.4	15.0±1.8	7.0±1.5	9.4±1.0	5.7±0.6
Salix glauca	10.8±1.1	1.0±0.7	21.2±3.7	11.9±2.8	12.6±2.1	8.3±1.0	8.2±0.6	4.5±0.4
Arctagrostis latifolia	+a	5.6±1.6	0	1.6±0.4	0.5±0.2	0.8±0.2	0.3±0.2	0.3±0.2
Calamagrostis canadensis	0	9.5±2.1					+a	0
Poa lanata	0	6.2±1.8	0	0.3±0.2				
Carex bigelowii	2.8±0.6	6.6±1.2	5.0±0.7	5.6±0.9	2.3±0.5	2.5±0.5	3.5±0.3	2.2±0.2
Lupinus arcticus	3.1±0.6	0.1±0.1	0.5±0.3	0.1±0.1	5.5±1.8	1.6±0.3	3.5±0.7	1.0±0.3
Empetrum nigrum	13.1±0.9	0	17.6±2.0	5.1±1.1	10.1±1.2	3.2±0.8	9.3±0.4	3.1±0.3
Vaccinium vitis-idaea	11.0±0.8	+a	4.5±0.7	3.5±0.5	4.6±0.6	1.2±0.3	8.1±0.4	3.9±0.5
Arctostaphylos rubra	0.6±0.4	0	1.5±0.8	0.7±0.5	4.5±1.8	1.2±0.6	0.9±0.4	0.3±0.2
Ledum palustre decumbens	5.6±0.5	0	1.8±0.8	2.1±1.1	4.7±0.8	1.9±0.3	6.4±0.6	2.7±0.5
Pyrola grandiflora	6.0±0.6	0	2.5±0.2	1.6±0.4	4.0±0.4	1.0±0.2	4.6±0.4	0.2±0.2
Petasites frigidus	1.9±0.9	2.5±0.9	2.1±0.3	2.9±0.7	1.0±0.4	0.8±0.4	3.0±0.4	2.0±0.5
Moss (Live and Dead)	21.7±0.6	2.0±1.3	35.3±3.5	35.0±2.0	35.5±1.3	35.0±3.0	39.3±1.2	31.4±1.3
Lichens	8.8±1.0	0.1±0.1	11.1±3.1	4.0±1.2	3.5±0.5	1.0±0.4	10.7±0.6	5.5±0.4
Other Species[b]	1.4±0.4	8.0±2.0	1.1±0.4	2.0±0.6	6.1±1.7	2.6±0.4	0.9±0.2	0.2±0.1
Total Plant Cover	102.4±1.0	43.7±3.6	115.0±4.6	82.1±4.7	109.4±1.8	63.9±3.5	108.3±2.1	64.0±3.7
Bare Soil	0	56.1±3.7	0	25.4±4.1	0	43.6±3.8	0	32.3±3.0
Thaw Depth	28.7±0.4	58.0±1.2	19.1±0.6	26.9±1.3	22.0±0.5	38.2±0.9	30.0±0.7	34.2±0.7

a Mean Cover less than 0.05%

b Other Species were (mean cover given if greater than 0.05%): 1965 Control - *Stellaria monantha*, *Cardamine pratensis*, *Rubus chamaemorus*, *Pedicularis kanei* (0.05) and *P. capitata* (0.05); 1965 Disturbed - *Carex capillaris* (0.05), *Luzula confusa* (1.7), *Stellaria monantha* (1.0), *Epilobium angustifolium* (1.0), *Senecio congestus*, *Rumex arcticus* (2.9); 1967-68 Control and Disturbed - *Saussurea angustifolia* (1.1 and 2.0 respectively), *Pedicularis capitata*; 1968-69 Control - *Castilleja raupii*, *Vaccinium uliginosum* (4.6); 1968-69 Disturbed - *V. uliginosum* (1.1); 1970-71 Control and Disturbed - *Pedicularis capitata* and *P. kanei*.

thawed layer was bulldozed aside for geophone placement, (b) 1967-68 winter and (c) 1968-69 winter lines in which the bulldozer blade was used to level the surface, resulting in sheared off hummock tops and (d) a 1970-71 winter line in which the bulldozer was equipped with "mushroom shoes" to maintain the blade above the hummocks.

The 1965 summer line was the most affected because of the bulldozing aside of the vegetated layer. Mackay (1970) and Rempel (1970) describe the appearance of such lines in the four years following their formation. Figure 4 is of one such line in July 1971.

Total plant cover was only 43% after six years. The species growing on the control and disturbed areas were very different. The grasses *Arctagrostis latifolia*, *Calamagrostis canadensis* and *Poa lanata* were scattered in clumps throughout the line. The clumps were 40 to 80 cm in diameter, 100 to 130 cm tall for the first two species and approximately one-third to one-half of this for *Poa*. In the natural tundra, however, these species usually occur as single culms and are less than 1% of the plant cover (e.g. Appendix B, Table 19). The dwarf shrubs *Betula nana* subsp. *exilis* and *Salix glauca*, as well as the heaths *Vaccinium vitis-idaea* subsp. *minus*, *Arctostaphylos rubra*, *Ledum palustre* subsp. *decumbens*, *Pyrola grandiflora*, *Empetrum nigrum* subsp. *hermaphroditum*, although abundant in the natural community, were rarely found on the line. Lichens were virtually absent. Cover of mosses was greatly reduced and they usually grew in moist depressed areas.

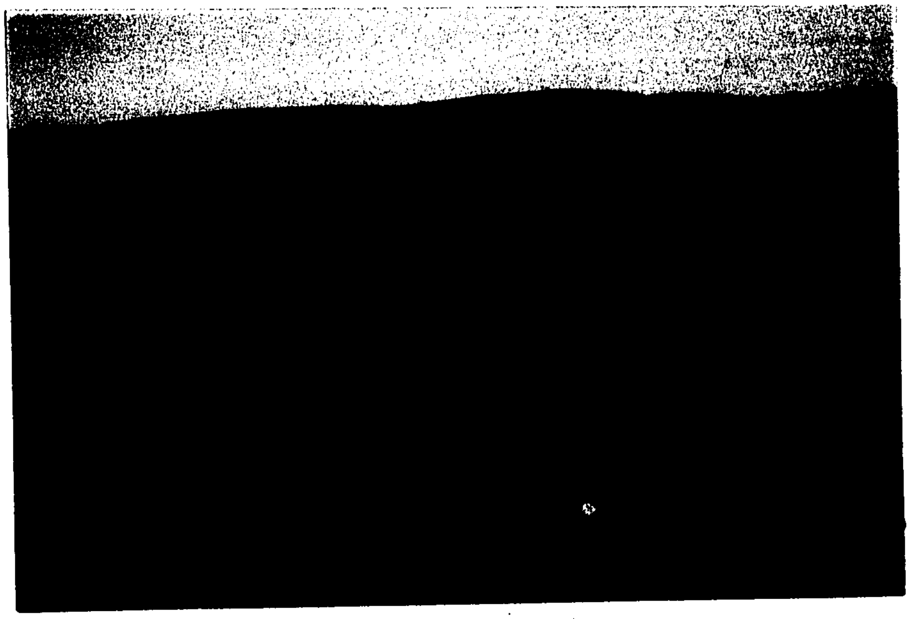


Figure 4. A 1965 summer seismic line (left) and associated vehicle trail (right) through an upland dwarf shrub-heath community in the Tuktoyaktuk Peninsula, N.W.T., July 17, 1971.
Note: Red erect plant in middle ground is Rumex arcticus. Straw colour in mid and background is last year's dead culms of Arctagrostis latifolia and Calamagrostis canadensis. White dots in foreground of trail are flower heads of Eriophorum vaginatum. Reddish green area in mid-ground of line is Arctophila fulva.

Figure 4. A 1965 summer seismic line (left) and associated vehicle trail (right) through an upland dwarf shrub-heath community in the Tuktoyaktuk Peninsula, N.W.T., July 17, 1971.
Note: Red erect plant in middle ground is Rumex arcticus. Straw colour in mid and background is last year's dead culms of Arctagrostis latifolia and Calamagrostis canadensis. White dots in foreground of trail are flower heads of Eriophorum vaginatum. Reddish green area in mid-ground of line is Arctophila fulva.

Thaw was 102% deeper on the line. Slumped areas, approximately 2.5x1.0x0.5 m, were occasionally seen. Measurements of the amount of material pushed aside and of the volume of the line revealed that some 2.0 m^3 of material per metre of length of the line were missing. At other sites along this and other 1965 summer lines, values ranged from 1.5 to 3.0 m^3 per metre of line. The missing volume, as suggested by Mackay (1970), was due to thermokarst subsidence and general subsurface melting of supersaturated soils and loss of water by evaporation since no signs of erosion or gullying were seen. One exposed ice wedge was seen on a 1965 summer seismic line. An 8 m long pool of water was present in front of the actively melting wedge.

Disturbance was much less on the winter seismic lines (Table 19). Plant cover on all three lines was from the species present and abundant in the native community. The difference in total cover between the control and disturbed areas was due to a reduction in the abundance of most species. Dwarf shrubs were shorter on the lines than on the controls, 25 to 45 cm vs 50 to 65 cm. Although the total cover was greatest on the 1968-69 line, the visual impact was the least on the 1970-71 line (Fig. 5). This is a result of the change in survey methods.

Thaw, while deeper than in adjacent undisturbed sites, did not result in the massive thermokarst subsidence of the summer line. This is a result of the difference between

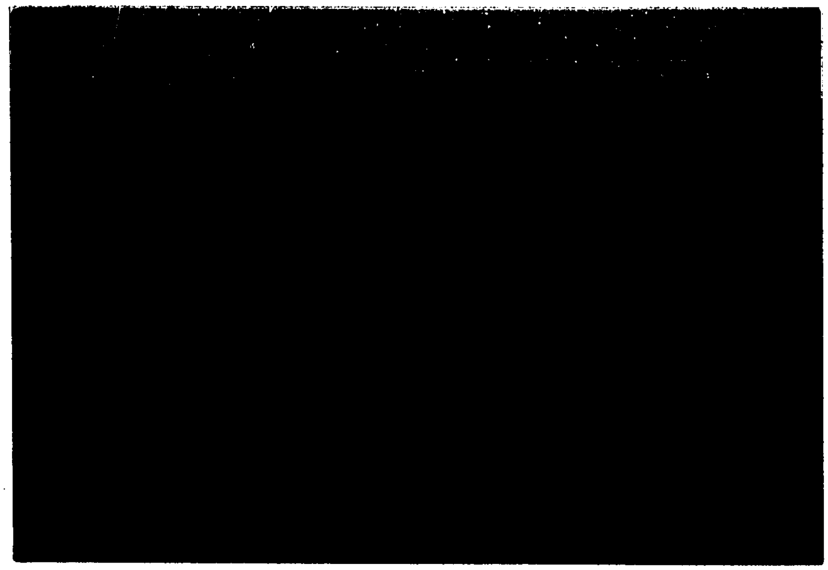


Figure 5. A 1970-71 winter seismic line in the Tuktoyaktuk Peninsula, N.W.T., July 27,1971. Note minimal damage to the existing vegetation, in contrast to Figure 4.

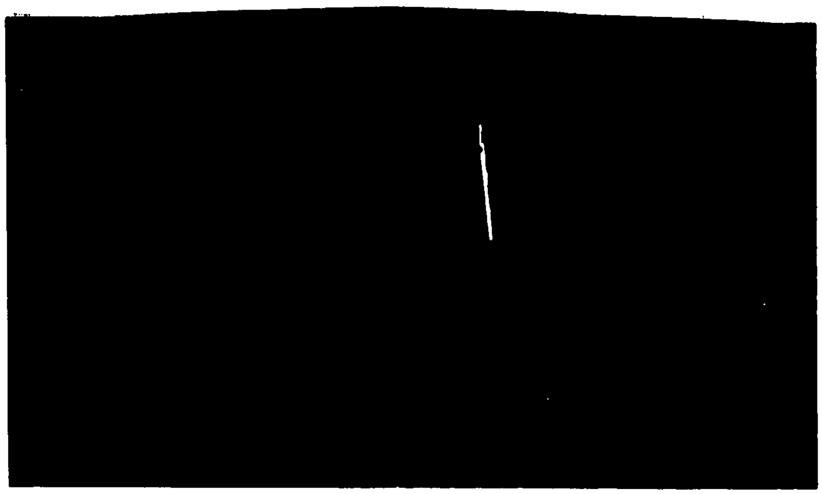


Figure 5. A 1970-71 winter seismic line in the Tuktoyaktuk Peninsula, N.W.T., July 27,1971. Note minimal damage to the existing vegetation, in contrast to Figure 4.

summer and winter exploration. Summer activity exposed the clayey, till-like parent material of most of the Tuktoyaktuk Peninsula for the entire extent of these lines. Winter operations only exposed bare mineral soil on the tops of the hummocks. This was commonly 5 to 20% of the total cover, usually in the lower end of the range. Thus the amount of soil exposed and the resultant increase in depth of thaw was not as great as on summer surveyed lines.

Recolonization of 1965 Summer Seismic Lines

The 1965 summer seismic lines provide an excellent opportunity to study the initial stages of succession on newly exposed mineral soil in a Low Arctic region. Several different plant communities throughout the Tuktoyaktuk Peninsula were traversed during that summer's operations.

Two sedge meadows, one east and one south of Tuktoyaktuk, were sampled (Table 20). They were similar in composition and responded in a similar manner. The major part of the 26% plant cover on both lines consisted of mosses, *Carex aquatilis* and *C. membranacea* which occurred in the natural community, and *Arctophila fulva* which was not present in the natural community. Other species found solely on the lines were typical of wet communities. They included *Ranunculus gmelini*, *Hippuris vulgaris* and *Senecio congestus*. The lines were approximately 75% bare peat. Thaw was approximately 35% deeper instead of 80 to 100%, as in the 1965 summer seismic lines where mineral soil was exposed.

Table 20. Changes in cover and thaw depth in two separate sedge meadow communities east and south of Tuktoyaktuk N.W.T. resulting from different 1965 summer seismic lines. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) (a) July 31, 1971 Control	(a) July 31, 1971 Disturbed	(b) July 28, 1971 Control	(b) July 28, 1971 Disturbed
Salix pseudopolaris	1.1±0.5	0		
Arctophila fulva	0	8.4±1.6	0	13.1±3.1
Eriophorum russeolum	1.4±0.3	0.5±0.5	1.3±0.5	0.5±0.5
Carex spp.[a]	63.7±1.5	3.8±1.5	81.0±4.5	7.6±2.1
Caltha palustris			0	0.1±0.1
Ranunculus gmelini	0	3.4±1.4	0	0.8±0.4
Hippuris vulgaris	0	0.4±0.3	0	0.1±0.1
Senecio congestus	0	0.4±0.2		
Moss (Live and Dead)	34.1±1.3	9.2±1.5	19.0±4.2	5.0±2.7
Total Plant Cover	100.3±0.3	26.1±2.7	101.4±1.0	26.7±4.5
Bare Peat	0	73.9±2.8	0	73.5±4.1
Thaw Depth	36.2±0.5	48.2±0.8	39.0±0.5	53.2±2.7

a In both meadows *Carex membranacea* and *C. aquatilis* were present. Since few plants were flowering they were difficult to distinguish vegetatively. However, *C. aquatilis* appeared to be the major component of both meadows.

An Eriophorum vaginatum tussock tundra community south of Tuktoyaktuk was sampled where both the 1965 seismic line and the accompanying vehicle trail passed through it (Table 21). The natural community and vehicle trail were moist but the seismic line had standing water.

Arctophila fulva was the most abundant species on the line. Also present were Carex aquatilis and Eriophorum angustifolium. These three species are typical of many wet sites in the tundra. Heaths were totally absent from the line as were the birch and willow dwarf shrubs, Carex bigelowii, Rubus chamaemorus and lichens. Some Eriophorum vaginatum tussocks were present in the drier portion of the line where Arctagrostis latifolia occurred. Wet clayey mineral soil covered almost 50% of the line and thaw was 73% deeper.

The vehicle trail, although floristically intermediate to the natural community and the line, was closer to the former. Heaths, mosses and dwarf shrubs were reduced in cover and lichens eliminated. Carex bigelowii and Eriophorum vaginatum increased in cover with the latter doubling its production of seed heads ($50.1 \pm 6.9/m^2$ in the trail vs $24.4 \pm 3.4/m^2$ in the control). The increase was not as dramatic as at Tununuk Point (page 24) because of the much greater production of seed heads in the control than in those sites (see also page 47). Thaw was 41% deeper and 21% bare soil was exposed on the trail.

Table 21. Changes in cover and thaw depth in an *Eriophorum vaginatum*-dwarf birch-heath community south of Tuktoyaktuk N.W.T. resulting from a 1965 summer seismic line and associated vehicle trail. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) July 17, 1971 Control	Disturbed Trail	Disturbed Line
Betula nana	9.3±1.0	1.2±0.5	0
Salix glauca	0.3±0.3	0.8±0.6	0
Arctagrostis latifolia	0.2±0.1	1.3±1.0	1.5±1.2
Arctophila fulva	0	0.3±0.3	32.5±3.6
Eriophorum vaginatum	17.3±1.3	40.7±4.5	5.4±1.9
Eriophorum angustifolium	0	0	0.9±0.9
Carex bigelowii	3.7±0.9	7.9±2.5	0
Carex aquatilis	0	0	1.8±0.8
Luzula confusa	0	0.2±0.2	0
Rubus chamaemorus	8.0±0.9	3.1±1.1	0
Empetrum nigrum	2.6±0.6	0.5±0.3	0
Vaccinium vitis-idaea	9.6±0.9	5.0±0.8	0
Arctostaphylos rubra	0.9±0.5	0	0
Ledum palustre decumbens	8.6±0.7	2.1±0.4	0
Rumex arcticus	0	1.6±1.1	0.6±0.6
Petasites frigidus	0	0.3±0.3	0
Moss	30.0±1.6	12.6±1.3	6.4±1.5
Lichens	7.3±1.6	0	0
Total Plant Cover	97.8±1.1	77.6±2.8	50.3±4.7
Bare Soil	0	21.4±1.8	49.7±4.7
Thaw Depth	27.3±0.5	38.6±0.8	47.0±1.3

A depressed centre polygon community east of Tuktoyaktuk was sampled in both 1970 and 1971 (Table 22). The vegetation growing on the line was different from the natural community. Rubus chamaemorus, Betula nana subsp. exilis, lichens and the heaths were abundant on the controls but absent from the line. Arctophila fulva was the most abundant vascular species on the line in both years. Ranunculus gmelini and the mosses increased their cover in 1971. Carex aquatilis and C. membranacea, although present in 1970 were not in the quadrats, nor were they as abundant. Bare moist peat was most of the cover of the line in both years.

Most upland dwarf shrub-heath communities which have been disturbed by a 1965 summer seismic line typically have the grasses Arctagrostis latifolia, Calamagrostis canadensis and Poa lanata in various combinations as their major vegetative cover. On one occasion this was not the case. Wet conditions had been created. Table 23 compares this site to a more typical one. Arctophila fulva was the major component of the plant cover on the wet site while the dry site was dominated by Carex bigelowii and the aforementioned grasses. Heath species were absent from both sites. Clayey mineral soil was exposed in both lines. Both thawed some 85% deeper than their respective controls.

A dwarf shrub-heath community south of Tuktoyaktuk, subjected to both a 1965 summer seismic line and the associated vehicle trail, was sampled (Table 24).

Table 22. Changes in cover and thaw depth in a dry birch-heath low centre polygon community east of Tuktoyaktuk, N.W.T. resulting from a 1965 summer seismic line. Sampled in 1970 and 1971. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) July 19, 1970 Control	July 19, 1970 Disturbed	July 31, 1971 Control	July 31, 1971 Disturbed
Betula nana	7.5±1.9	0	12.6±1.5	0
Salix pseudopolaris			1.0±0.4	0
Arctophila fulva	0	7.0±1.0	0	8.4±1.6
Eriophorum angustifolium	0	0.2±0.2	0	0.5±0.5
Carex membranacea	0	+a	0	1.4±0.4
Carex aquatilis	0	+a	0	2.4±1.6
Carex rariflora	4.5±2.3	0	3.6±0.7	0
Ranunculus gmelini	0	1.2±1.0	0	3.4±1.4
Rubus chamaemorus	19.1±1.3	0	11.1±0.5	0
Empetrum nigrum	3.3±1.2	0	4.0±0.9	0
Vaccinium uliginosum			0.2±0.2	0
Vaccinium vitis-idaea	5.4±1.4	0	8.1±1.1	0
Ledum palustre decumbens	6.9±1.8	0	8.4±1.2	0
Hippuris vulgaris			0	0.4±0.3
Senecio congestus			0	0.4±0.2
Moss	28.2±1.7	1.0±0.4	24.1±3.3	9.2±1.5
Lichens	22.4±2.7	0	26.9±3.0	0
Total Plant Cover	97.3±2.7	9.4±1.3	100.0±1.0	26.1±3.0
Bare Peat	0	90.5±1.5	0	73.9±2.8
Thaw Depth	25.9±0.7	33.6±1.0	30.1±0.7	48.2±0.8

a Present on the seismic line but not in the quadrats. They were not abundant.

Table 23. Changes in cover and thaw depth in two separate dwarf shrub-heath communities in the vicinity of Tuktoyaktuk, N.W.T. resulting from different 1965 summer seismic lines. One line remained dry (a), the other wet (b). Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) Dry (a) July 27, 1971 Control	Dry (a) July 27, 1971 Disturbed	Wet (b) July 19, 1970 Control	Wet (b) July 19, 1970 Disturbed
Betula nana	6.3±0.8	0	15.6±1.7	0
Salix glauca	2.1±1.2	0.7±0.4	11.4±2.3	0.6±0.3
Arctagrostis latifolia	0	5.7±1.6	0.2±0.2	0.8±0.5
Calamagrostis canadensis	0.2±0.1	6.6±1.2		
Poa lanata	0.2±0.2	0.7±0.3	0.1±0.1	0
Arctophila fulva		13.0±1.7	0	51.6±7.2
Carex bigelowii	3.5±1.2	1.0±0.7	3.5±0.6	0
Luzula confusa	0.7±0.4	2.1±1.3		
Stellaria monantha	0.3±0.2	0		
Dryas integrifolia	5.7±1.2	+[a]		
Lupinus arcticus	1.5±1.0	2.0±1.5	1.6±0.6	0
Epilobium angustifolium	0	0		
Empetrum nigrum	1.7±0.4	+[a]	9.4±1.4	0
Vaccinium vitis-idaea	9.0±0.7	0	6.9±0.8	0
Arctostaphylos rubra	2.1±1.0	0	1.1±0.5	0
Ledum palustre decumbens	10.9±0.5	0	6.5±1.1	0
Pyrola grandiflora	0.2±0.2		3.0±0.7	0
Petasites frigidus	5.6±0.5	0.4±0.4	4.5±0.9	0.5±0.4
Senecio congestus	0	6.9±1.0	0.1±0.1	0.7±0.3
Mosses (Live and Dead	27.9±1.5	1.8±1.2	26.2±2.1	2.6±1.0
Lichens	24.0±1.0	0	17.8±1.8	0
Other Species	0.8±0.2[b]	1.6±0.6[c]	1.6±0.3[d]	0.5±0.3[e]
Total Plant Cover	102.7±1.8	42.5±4.2	109.5±1.5	57.4±7.0
Bare Soil	0	56.7±3.8	0	44.5±7.1
Thaw Depth	24.6±0.5	45.1±1.5	22.6±0.4	42.0±1.0

a Mean cover less than 0.05% b *Pedicularis kanei*, *Cardamine pratensis*, *Hierochloe alpina*
c *Festuca brachyphylla* (1.1%), *Cardamine pratensis* d *Cardamine pratensis*, *Pedicularis capitata*, *Vaccinium uliginosum* e *Ranunculus gmelini*

Table 24. Changes in cover and thaw depth in a dwarf shrub-heath community south of Tuktoyaktuk, N.W.T. resulting from a 1965 summer seismic line and associated vehicle trail. Data are given as means ± standard error.

Species	Cover (%) and Thaw Depth (cm) August 6, 1971 Control	Disturbed Trail	Line
Betula nana	9.4±1.7	4.4±0.8	1.3±0.7
Salix glauca	8.9±3.9	7.8±0.7	3.9±1.3
Arctagrostis latifolia	0	8.9±1.6	14.6±3.0
Calamagrostis canadensis	0.1±0.1	8.1±2.0	7.6±2.6
Poa lanata	0	1.6±0.6	2.0±0.6
Hierochloe alpina	0.9±0.2	1.4±0.6	0
Carex bigelowii	0.1±0.1	0	1.7±0.6
Luzula confusa	0.1±0.1	2.0±0.5	2.6±0.7
Stellaria monantha	0	0.8±0.3	0.6±0.4
Cardamine pratensis	0	1.4±0.4	0
Lupinus arcticus	2.7±0.9	0.8±0.4	0.2±0.1
Epilobium angustifolium	0	0	0.4±0.4
Empetrum nigrum	13.3±1.0	0.8±0.4	0
Vaccinium uliginosum	1.3±0.7	0	0
Vaccinium vitis-idaea	3.2±0.7	3.4±0.6	0
Arctostaphylos rubra	0.2±0.2	0.6±0.6	0
Ledum palustre decumbens	5.8±0.9	1.0±0.3	0
Pyrola grandiflora	9.0±1.0	0.6±0.3	0.3±0.3
Pedicularis kanei	1.4±0.3	0	0
Petasites frigidus	0	5.6±1.7	1.0±0.8
Saussurea angustifolia	0.2±0.2	0	0
Moss	20.3±1.0	8.9±1.8	1.9±0.7
Lichens	19.1±1.6	0	0
Total Plant Cover	96.0±2.5	58.1±2.8	38.3±4.6
Bare Soil	0	38.8±2.4	62.2±4.5
Thaw Depth	35.0±0.6	55.5±1.0	67.3±2.2

The vehicle trail appeared intermediate floristically and in species abundance to the seismic line and the natural community. The grass complex of typical dry 1965 summer lines was present in reduced abundance on the vehicle trail. And the heaths, absent on the seismic line, were present but less abundant than in the natural community. Bare soil and thaw depth were greater on the line than on the trail.

A general picture of the recolonization and initial stages of succession in various tundra communities can be obtained from their response to exposure of mineral soil by removal of the vegetation. Both Bliss (1971) and Savile (1972) review several aspects of arctic plant adaptations including germination, seedling establishment and dispersal mechanisms.

The major pioneer species (Table 25) of either wet or dry areas are predominantly grasses or sedges: Arctophila fulva and Carex aquatilis in wet areas; Arctagrostis latifolia, Calamagrostis canadensis, Poa lanata, Carex bigelowii, the less abundant but typically present rush Luzula confusa, and occasionally Carex capillaris in dry areas. Other pioneer vascular species include Epilobium angustifolium, Senecio congestus, Stellaria monantha and Cardamine pratensis in more moist microsites of the dry lines.

The heath species which form such an abundant and conspicuous portion of all but the wettest natural communities appear totally incapable of becoming established on mineral

Table 25. Species which have shown an ability to pioneer on various substrates in disturbed areas in the eastern Mackenzie Delta - Tuktoyaktuk Peninsula region, N.W.T.

Species	Habitat Moisture	Type of Substrate[a]	Inuvik	Tununuk Point	Tuktoyaktuk Peninsula
Eriophorum angustifolium	wet	w	X	X	X
Arctophila fulva	wet-moist	w & p & m			X
Carex aquatilis	wet-moist	w & p & m			X
Ranunculus gmelini	wet-moist	p & m			X
Senecio congestus	wet-moist	p & m	X	X	X
Eriophorum vaginatum	moist	m	X	X	X
Equisetum scirpoides	moist	m	X	X	X
Rumex arcticus	moist-dry	m & p			X
Epilobium angustifolium	moist-dry	m & p	X	X	X
Stellaria monantha	dry	m & p	X	X	X
Cardamine pratensis	dry	m & p	X	X	X
Calamagrostis canadensis	dry	m & p	X	X	X
Arctagrostis latifolia	dry	m	X	X	X
Poa lanata	dry	m	X	X	X
Luzula confusa	dry	m	X	X	X
Carex capillaris	dry	m		X	X

a w = open water, p = exposed peat, m = exposed mineral soil

soil. Bliss (1957) found that only Ledum palustre subsp. decumbens of the common heaths showed any germination in his studies of northern Alaskan species.

The autecology of successfully established species on 1965 summer lines near Tuktoyaktuk is presently being studied (W.E. Younkin, personal communication). He found that Arctagrostis latifolia and Calamagrostis canadensis produce much viable seed. Late ripening (mid-August) ensures that they will not germinate until the following spring when conditions are most suitable for successful seedling establishment.

Rhizomatous connections between plants growing on the dry disturbed areas and the adjacent natural community were confined to the pushed up edges of the line. Such species included Petasites frigidus and the dwarf shrubs. The grasses of the dry sites, however, do have rhizomatous root systems and can grow in clumps once they are established.

Thus, in view of the method of disturbance and since most species growing on the lines, although rare or absent in the adjacent natural community, do have a very viable seed, it is most likely that their successful establishment has been from seed. Once a few seeds are established, the gradual expansion of the clone can cover a relatively extensive area.

SUMMARY AND CONCLUSIONS

A comparison of summer and winter disturbed communities throughout the study area reveals that summer disturbance is much more detrimental to all plant communities sampled. Sparsely vegetated gravelly areas such as eskers and moraines which cover a minor portion of the study area are possibly the only exceptions.

Summer seismic lines originally bladed to permafrost, resulted in exposure of mineral soil for their entire length. Recolonization of such areas has been slow, especially for dry upland sites. The grasses Arctagrostis latifolia, Calamagrostis canadensis and Poa lanata and the rush Luzula confusa, species uncommon in adjacent undisturbed communities, are the most common and typical pioneers of the drier sites. The grass Arctophila fulva and the sedge Carex aquatilis are the most common pioneers of wet areas. Once all these species are established, growth is by gradual rhizomatous expansion.

Winter seismic lines result in limited exposure of mineral soil. Usually at least 50% of the natural community is undisturbed. Thus the composition of the plant community on winter lines is similar to the natural community. The abundance of the individual species is usually reduced. Roots and rhizomes often remain intact in the peat layer.

Forested and tall shrub Delta communities suffer much greater initial damage from winter seismic lines than do tundra communities. But recovery of the vegetation is more rapid in the Delta.

Wet communities in the tundra are less damaged by winter seismic lines and winter roads than dry upland communities. This is the reverse of conditions in summer when wet communities are very sensitive to even one pass of a vehicle.

Unless the peat is removed, winter disturbed wetland and dry upland communities regenerate predominantly from undisturbed roots and rhizomes.

Eriophorum vaginatum appears to be stimulated both vegetatively and in production of seed heads by disturbance which does not eliminate it. This appears to be due to an ameliorated nutrient regime. Carex bigelowii was also observed to increase significantly in cover on several seismic lines.

Almost all disturbances result in a deeper thaw. Exposure of mineral soil usually results in increases of 80 to 100%. If the peat layer remains intact, the increase is usually 30 to 50%. And if the plant cover is little modified, thaw depth usually increases only 1 to 10%.

Few signs of erosion were seen during this study. This is probably due to the low precipitation in the region.

LITERATURE CITED

Babb, T.A. 1972. The effects of surface disturbance on vegetation in the Northern Canadian Arctic Archipelago. M. Sc. Thesis, Department of Botany, Univ. of Alberta. 71 p.

Bellamy, D., J. Radforth and N.W. Radforth. 1971. Terrain, traffic and tundra. Nature 231:429-432.

Bliss, L.C. 1958. Seed germination in arctic and alpine species. Arctic 11:180-188.

Bliss, L.C. 1971. Arctic and alpine life cycles. Ann. Rev. of Ecol. and Syst. 2:405-438.

Bliss, L.C. and J.E. Cantlon. 1957. Succession on river alluvium in northern Alaska. Am. Midl. Nat. 58:452-469.

Bliss, L.C. and R.W. Wein. 1972. Plant community responses to disturbances in the Western Canadian Arctic. Can. J. Bot. 50:1097-1109.

Bouchard, M. and V.N. Rampton. 1972. Environmental geology, Tuktoyaktuk, District of Mackenzie (107C). Geol. Surv. Can. Paper 72-1A:141-143.

Brown, J., W. Rickard and D. Vietor. 1969. The effect of disturbance on permafrost terrain. CRREL, U.S. Army Special Rep. 138:1-9.

Canada Department of Transport, Meteorological Branch. 1967. Temperature and precipitation tables for the North - Y.T. and N.W.T. 21 p.

Carmichael, J.W. and P.H.A. Sneath. 1969. Taxometric maps. Syst. Zool. 18:402-415.

Churchill, E.D. 1955. Phytosociological and environmental characteristics of some plant communities in the Umiat region of Alaska. Ecology 36:606-627.

Churchill, E.D. and H.C. Hanson. 1958. The concept of climax in arctic and alpine vegetation. Bot. Rev. 24:127-191.

Cody, W.J. 1965. Plants of the Mackenzie River Delta and Reindeer Grazing Preserve. Can. Dept. Agr., Plant Res. Instit., Ottawa. 56 p.

Cody, W.J. 1971. A phytogeographic study of the floras of the Continental Northwest Territories and Yukon. Nat. Can. 98:145-158.

Corns, I.G.W. 1972. Plant communities in the Mackenzie Delta region. p. 4-46 In Bliss, L.C. and R.W. Wein (eds.) Botanical studies of natural and man modified habitats in the eastern Mackenzie Delta Region and the Arctic Islands. Rep. to ALUR of Dept. of Indian Affairs and Northern Development, Ottawa. 288 p.

Ferrians, O.J., R. Kachadoorian and G.W. Greene. 1969. Permafrost and related engineering problems in Alaska. U.S. Geol. Surv. Prof. Paper 678. 37 p.

Fyles, J.G. 1966. Quaternary stratigraphy, Mackenzie Delta and Arctic Coastal Plain. Geol. Surv. Can. Paper 66-1:30-31.

Fyles, J.G. 1967. Mackenzie Delta and Arctic Coastal Plain. Geol. Surv. Can. Paper 67-1A:34-35.

Gill, D. 1971. Vegetation and environment in the Mackenzie River Delta, Northwest Territories - A study in subarctic ecology. Ph. D. Dissertation, Department of Geography, Univ. of British Columbia. 694 p.

Haag, R.W. 1972. Mineral nutrition and primary production in native tundra communities of the Mackenzie Delta region, N.W.T. M. Sc. Thesis, Department of Botany, University of Alberta. 89 p.

Hanson, H.C. 1953. Vegetation types in northwestern Alaska and comparisons with communities in other arctic regions. Ecology 34:111-140.

Hare, F.K. 1970. The tundra climate. p. 32-38 In Hare, F.K. (ed.) The Tundra Environment. Trans. Royal Soc. Can., Fourth Series Vol. 7. U. of Toronto Press, Toronto. 50 p.

Hok, J.R. 1969. A reconnaissance of tractor trails and related phenomena on the North Slope of Alaska. U.S. Dept. of Interior, Bureau of Land Management. 66 p.

Hultén, E. 1968. Flora of Alaska and Neighbouring Territories. Stanford Univ. Press. 1008 p.

Janz, A. 1972. Soil survey in the Mackenzie Delta region. p. 47-68 (See Ref. Corns).

Johnson, A.W., L.A. Viereck, R.E. Johnson and H. Melchior. 1966. Vegetation and flora. p. 277-354 In Willinosky, N.J. (ed.) Environment of the Cape Thompson Region, Alaska. U.S. Atomic Energy Comm., Washington, D.C.

Klein, D.R. 1970. The impact of oil development in Alaska, (A photoessay). p. 209-242 In Fuller, W.A. and P.G. Kevan (eds.) Productivity and Conservation in Northern Circumpolar Lands. IUCN and Natural Resources, Morges, Switzerland. 344 p.

Mackay, J.R. 1963. The Mackenzie Delta Area, N.W.T. Mem. 8, Geog. Branch, Dept. Mines and Tech. Surveys. Ottawa. 202 p.

Mackay, J.R. 1966. Segregated epigenetic ice and slumps in permafrost, Mackenzie Delta area, N.W.T. Geograph. Bull. Can. 8:59-80.

Mackay, J.R. 1970. Disturbances to the tundra and forest tundra environment of the Western Arctic. Can. Geotech. J. 7:420-432.

Mackay, J.R. 1971. The origin of massive icy beds in permafrost, Western Arctic Coast, Canada. Can. J. Earth Sci. 8:397-422.

Muller, C.H. 1952. Plant succession in arctic heath and tundra in northern Scandinavia. Bull. Torr. Bot. Club 79:296-309.

Palmer, L.J. and C.H. Rouse. 1945. Study of the Alaska tundra with reference to its reaction to reindeer and other grazing. U.S. Dept. of Interior, Fish and Wildlife Serv. Res. Rep. 10. 48 p.

Pegau, R.E. 1970. Succession in two exclosures near Unalakleet, Alaska. Can. Field Nat. 84:175-177.

Porsild, A.E. and W.J. Cody. 1968. Checklist of vascular plants of Continental Northwest Territories, Canada. Can. Dept. Agr., Plant Res. Instit., Ottawa. 102 p.

Prest, V.K. 1969. Retreat of Wisconsin and recent ice in North America (map). Geol. Surv. Can. Map 1257-A.

Pruitt, W.O. 1970. Some aspects of the interrelationships of permafrost and tundra biotic communities. p. 33-41 (See Ref. Klein).

Rampton, V.N. 1970. Quaternary geology, Mackenzie Delta and Arctic Coastal Plain, District of Mackenzie (Parts of 107B, 117A,C,D). Geol. Surv. Can. Paper 70-1A:181-182.

Rampton, V.N. 1971. Quaternary geology, Mackenzie Delta and Arctic Coastal Plain, District of Mackenzie. Geol. Surv. Can. Paper 71-1A:173-177.

Rampton, V.N. 1972. Quaternary geology, Arctic Coastal Plain, District of Mackenzie and Herschel Island, Yukon Territory. Geol. Surv. Can. Paper 72-1A: 171-175.

Rampton, V.N. and J.R. Mackay. 1971. Massive ice and icy sediments throughout the Tuktoyaktuk Peninsula, Richards Island and nearby areas, District of Mackenzie. Geol. Surv. Can. Paper 71-21. 16 p.

Rempel, G. 1970. Arctic terrain and oil field development p. 243-250 (See Ref. Klein).

Savile, D.B.O. 1972. Arctic adaptations in plants. Monog. No. 6, Can. Dept. Agr., Ottawa. 81 p.

Shumskii, P.A. 1964. Ground (subsurface) ice. Translated by C. de Leuchtenberg. Nat. Res. Council Can. Tech. Transl. 1130. 118 p.

Snedecor, G.W. 1956. Statistical Methods. Iowa State Coll. Press. 534 p.

Sørensen, T. 1948. A method for establishing groups of equal amplitude in plant sociology based on similarity of species content. Acta Kong. Danske Vidensk. Selsk. Biol. Skr. J. 5:1-34.

Tedrow, J.C.F., J.V. Drew, D.E. Hill and L.A. Douglas. 1958. Major genetic soils of the Arctic Slope of Alaska. J. Soil Sci. 9:33-45.

Thompson, A.H. 1967. The climate of the Canadian Arctic p. 55-74 In The Canada Yearbook. Dominion Bureau of Statistics, Ottawa. 1287 p.

Tsytovich, N.A. et al. 1964. Physical phenomena and processes in freezing, frozen and thawing soils. Translated by G. Belkov. Nat. Res. Council Can. Tech. Transl. 1164. 109 p.

Tyrtikov, A.P. 1964. Perenially frozen ground and vegetation. Translated by R.J.E. Brown. Nat. Res. Council Can. Tech. Transl. 1163. 34 p.

Watson, A., N. Bayfield and S.M. Moyes. 1970. Research on human pressures on Scottish mountain tundra, soils and animals. p. 256-266 (See Ref. Klein).

Wein, R.W. and L.C. Bliss. 1972. Primary production of arctic cottongrass tussock tundra communities. (Unpublished manuscript).

Appendix A

Details on the location of each of the sites discussed in the text are presented in this appendix. The sites are referred to according to the region and the table number in the text in which the data are given. Latitude and longitude have been estimated to the nearest half minute and all sites located on maps. Sketches of transect locations for the permanently marked sites are also given.

Inuvik Region Sites (Fig. 6)

Table 2.

This site is a 1969-70 winter seismic line through a *Picea glauca*-*Alnus crispa* subsp. *crispa*-*Salix arbusculoides* (white spruce-alder-willow) forest community. It is 3.5 km northwest of Inuvik on the west bank of the East Channel of the Mackenzie River Delta at latitude 68° 23.0'N and longitude 133° 46.5'W (Fig. 6).

The E-W line is approximately perpendicular to the East Channel. The soil is a Regosol consisting of a 5 to 10 cm litter and organic matter horizon overlaying the silty parent material. This site was permanently marked (Fig. 7). The transects sampled were approximately 275 m in from the river.

Table 3.

This site is a vehicle trail created in the winter of 1969-70 through a *Salix alaxensis* subsp. *alaxensis*-*Alnus*

Figure 6. Location of Inuvik Region sites sampled on N.T.S. map 107 B/7 (1:50,000) with sites referred to by their table number in the text.

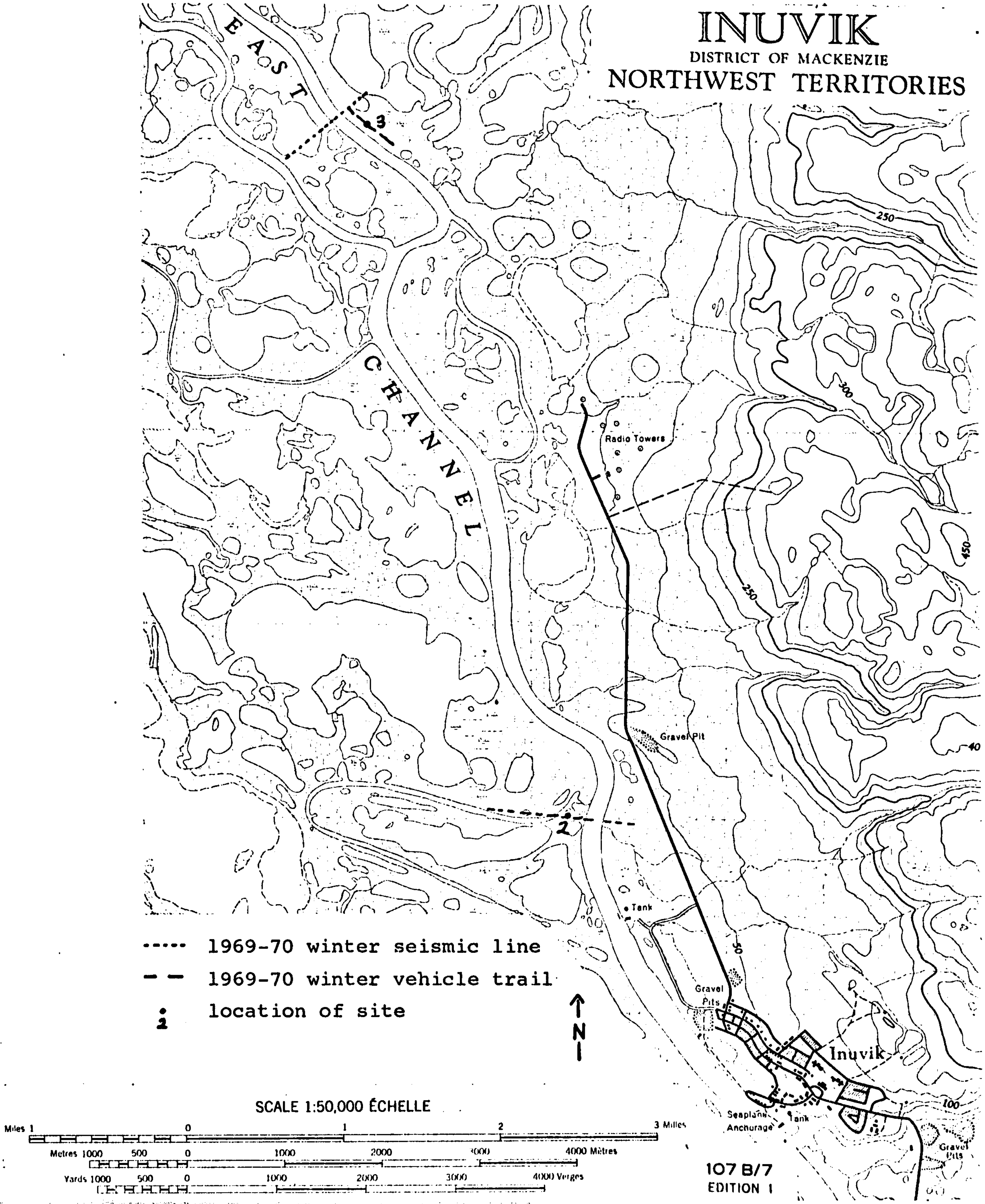
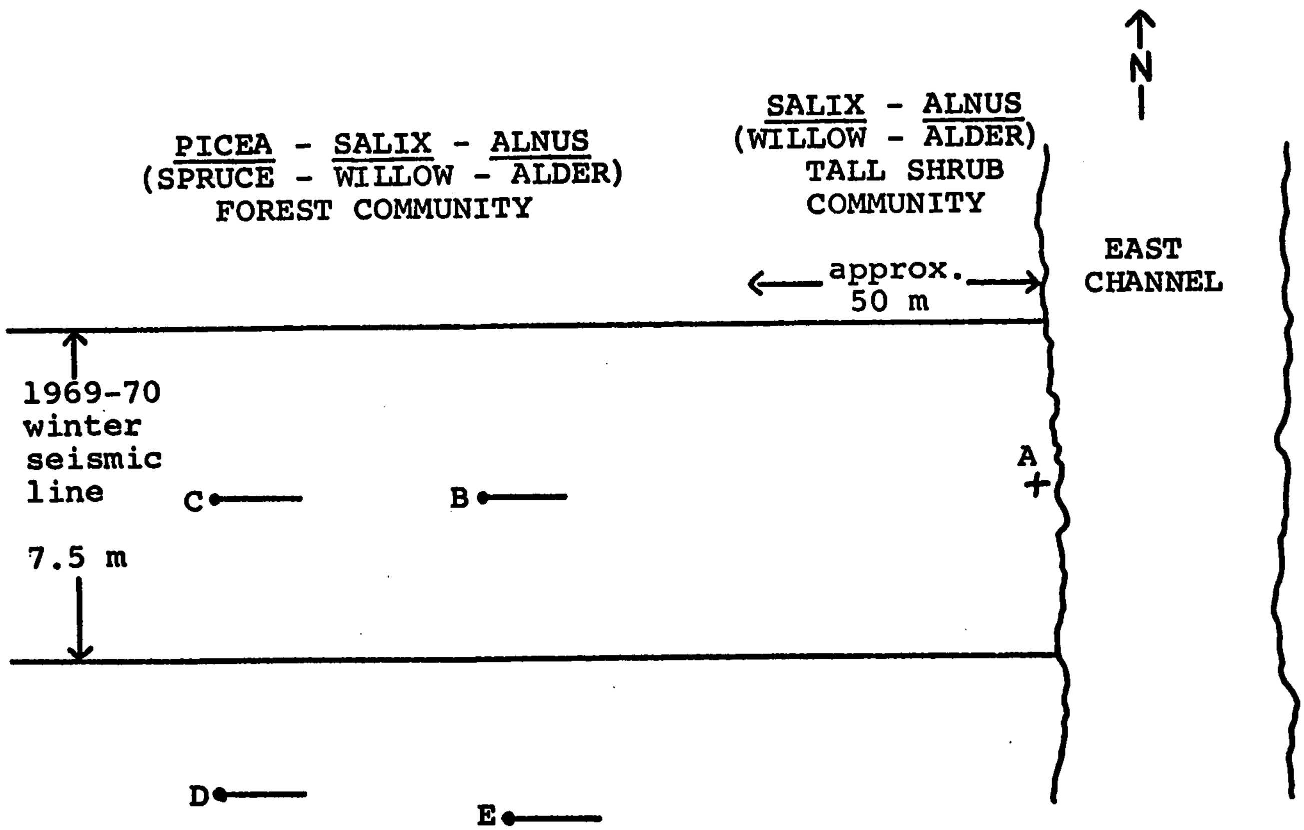


Figure 7. Location of the individual transects sampled for the Inuvik Region site presented in Table 2 in the text.



AB approx. 275 m
BE 12.8 m
DE=CB 53.0 m
CD 11.0 m

•—— transect (30 m long)

• start of transect - marked with flagging and stake (1" x 1")

+ sign and large stake (3" x 3")

crispa subsp. crispa (felt leaf willow-alder) tall shrub community. It is 11 km northwest of Inuvik on the east bank of the East Channel of the Mackenzie River Delta at latitude 68° 27.0'N and longitude 133° 49.0'W (Fig. 6). Running NW-SE parallel to the river, it is approximately perpendicular to a 1969-70 winter seismic line which crossed the river. This site has been permanently marked (Fig. 8). The soil is the typical Delta Regosol. The sites sampled were approximately 300 m from the seismic line.

Tununuk Point Region Sites (Fig. 9)

Table 4.

This site is a N-S 1969-70 winter seismic line through a Salix arbusculoides-Alnus crispa subsp. crispa (green leaf willow-alder) tall shrub community. It is 3.2 km northwest of Tununuk Point on the south bank of the first channel on the western side of the channel forming the west side of Richards Island at latitude 69° 01.5'N and longitude 134° 44.5'W (Fig. 9). The sites sampled were located some 400 m from the channel's edge.

Table 5.

A 1962 summer seismic line passed through a cottongrass (Eriophorum vaginatum) tussock tundra community, 3.1 km north of Tununuk Point on the east side of Richards Island at latitude 69° 01.5'N and longitude 134° 39.0'W (Fig. 9). The N-S line is at the base of a ridge in a relatively flat

Figure 8. Location of the individual transects sampled for the Inuvik Region site presented in Table 3 in the text.

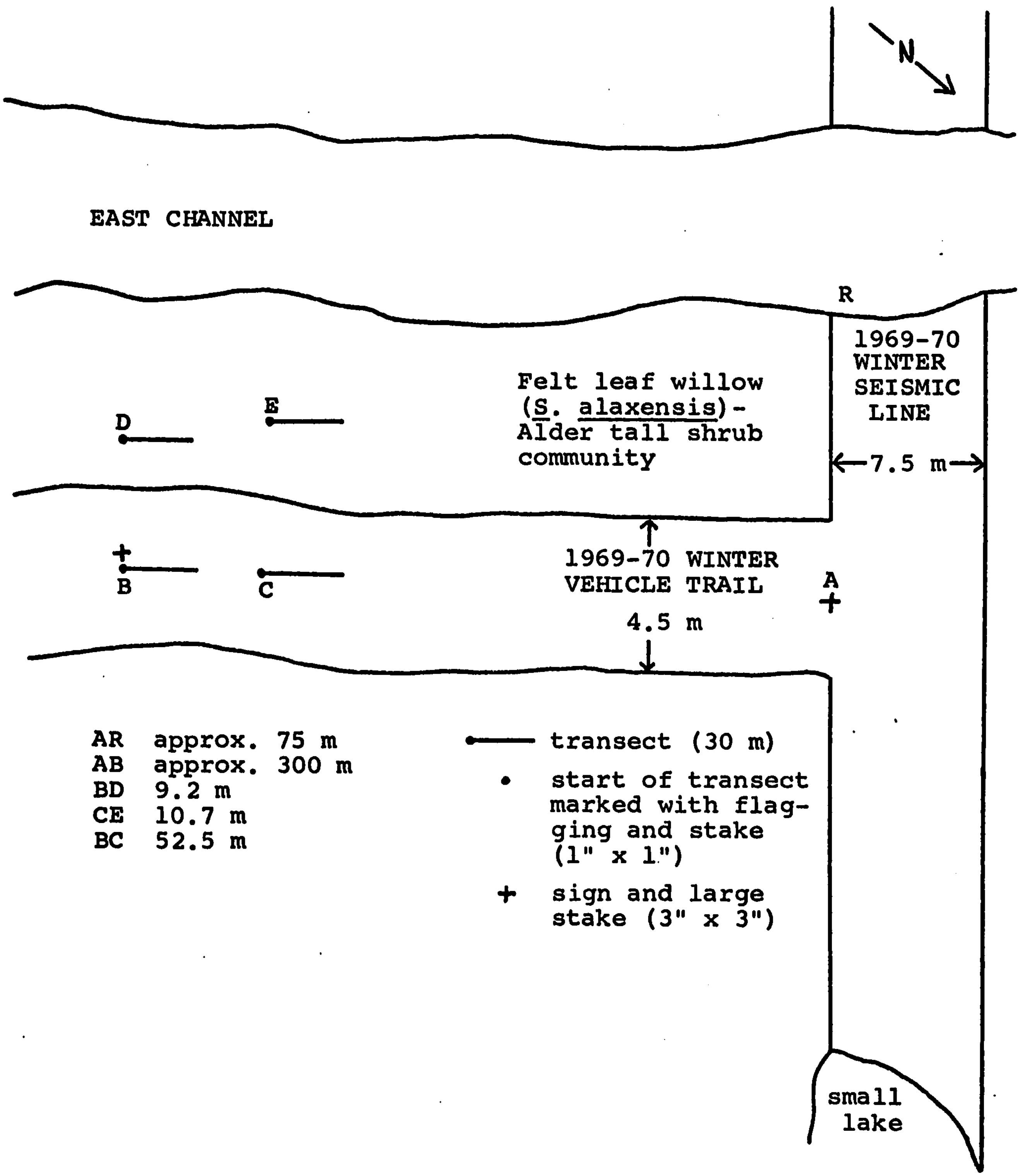
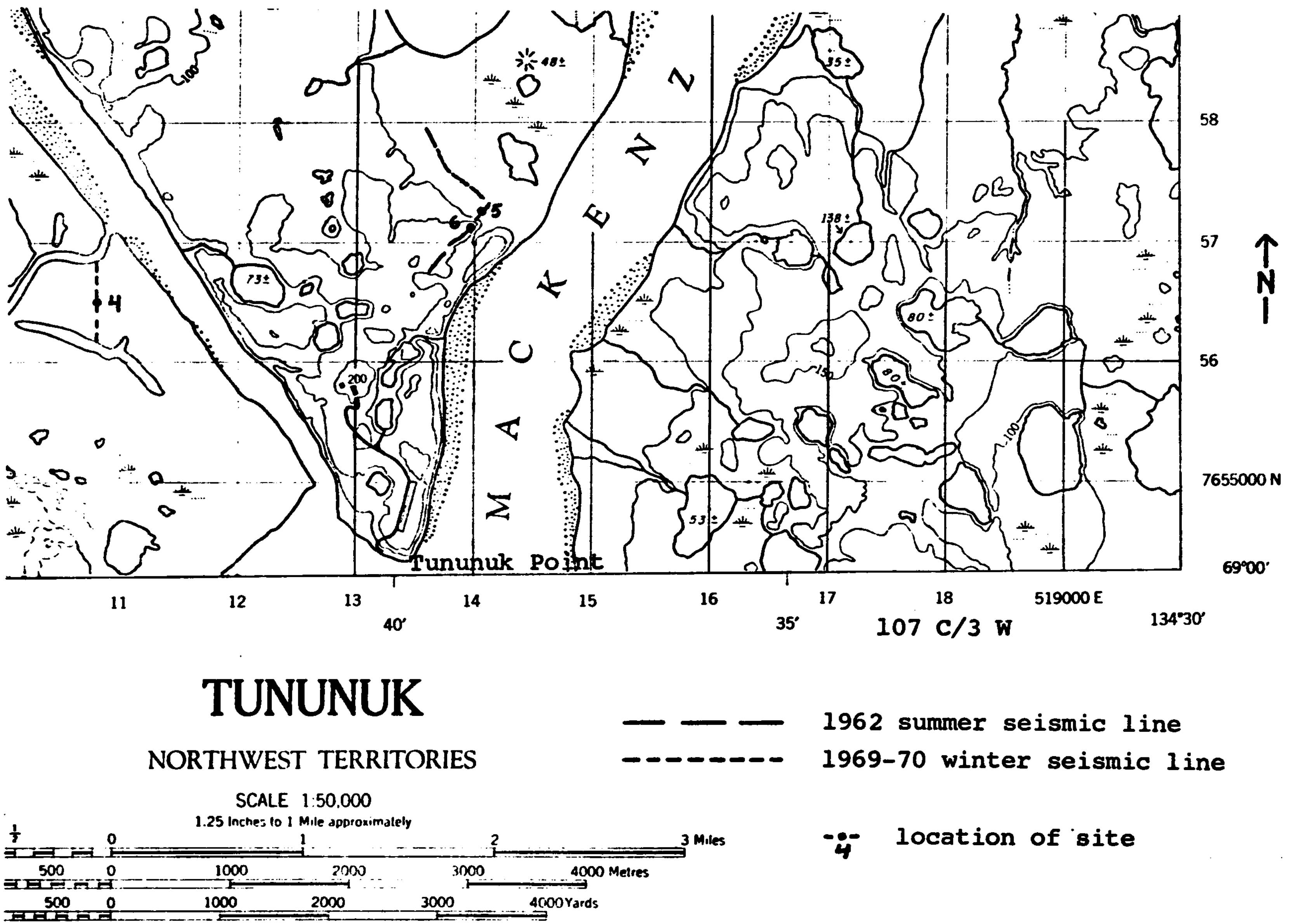


Figure 9. Location of Tununuk Point Region sites sampled on N.T.S. map 107 C/3 W (1:50,000) with sites referred to by their table number in the text.



moist tussocky area which gently slopes (<1%) to the river. The soil consists of a 15-20 cm litter and humus peat horizon overlaying a clayey parent material containing scattered gravel.

Table 6.

The same 1962 summer seismic line as in Table 5 also passed through a dwarf shrub-heath community. This site is 2.9 km north of Tununuk Point on the east side of Richards Island (latitude 69° 01.5'N, longitude 134° 39.0'W - Fig. 9). The NE-SW line is on a ridge (elevation approximately 100 ft) through a hummocky area. A thin 5 to 10 cm peat horizon overlies the clayey parent material containing scattered gravel.

Atkinson Point Region Sites (Fig. 10)

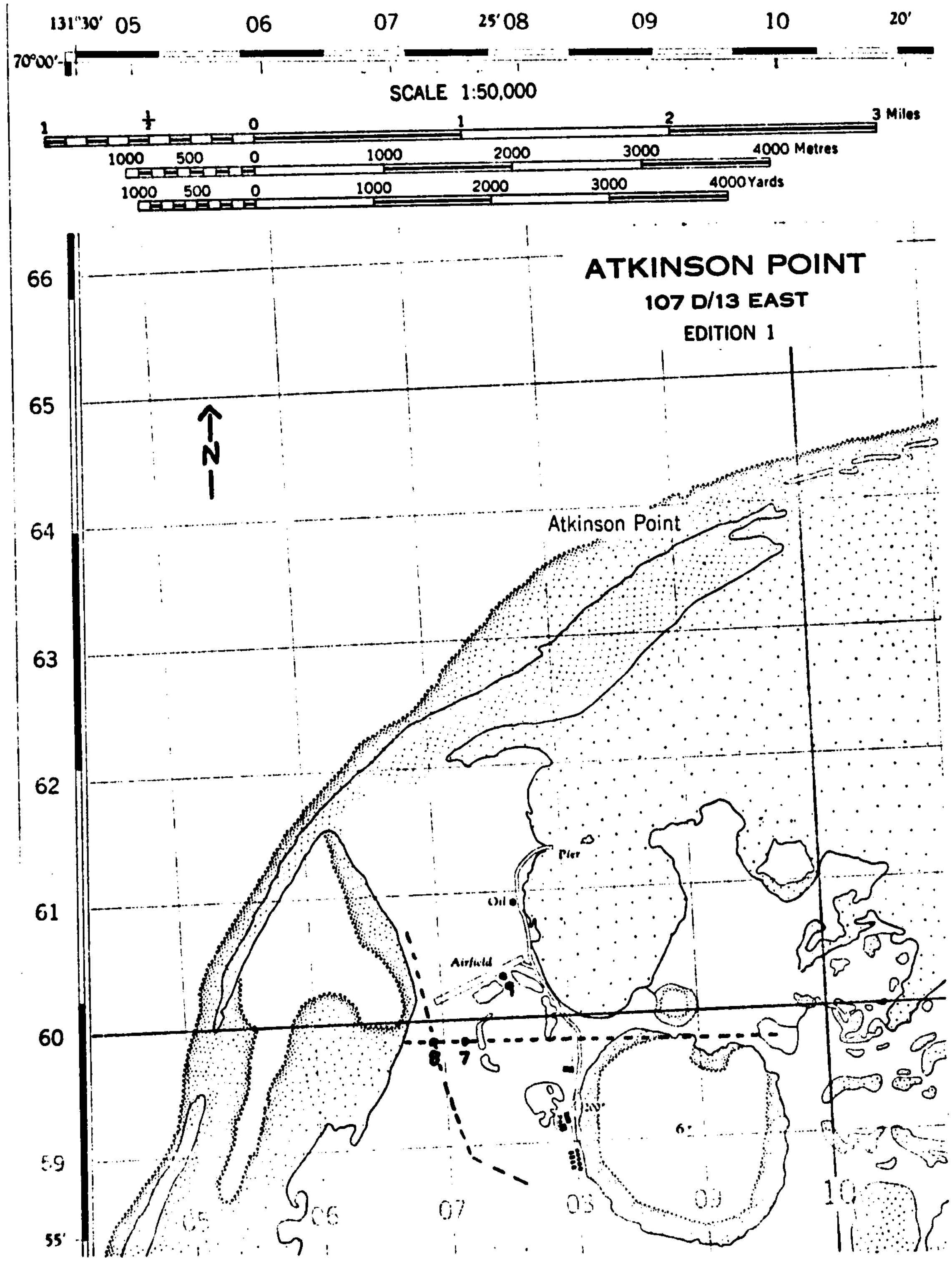
Table 7.

An E-W 1969-70 winter seismic line passed through a wet sedge meadow approximately ½ km south of the airstrip at Atkinson Point (latitude 69° 56.0'N, longitude 131° 25.5'W - Fig. 10).

Table 8.

Two 1969-70 winter seismic lines intersect in an area of raised centre polygons at latitude 69° 56.0'N and longitude 131° 26.0'W, ½ km south of the airstrip at Atkinson Point (Fig. 10). One line runs NW-SE; the other E-W. The soil is poorly developed, the sandy parent material being

Figure 10. Location of Atkinson Point Region sites sampled on N.T.S. map 107 D/13 East (1:50,000) with sites referred to by their table number in the text.



------ 1969-70 winter seismic line

location of site

soft and crumbling easily.

Table 9.

This site was adjacent to the airstrip at Atkinson Point at latitude 69° 56.0'N and longitude 131° 25.0'W (Fig. 10). A wet sedge meadow and peat horizon covers the sand in the natural community.

Reindeer Station Region Sites (Fig. 11)

Table 10.

The Caribou Hills 3 km north of Reindeer Station are covered predominantly by dwarf shrub-heath communities. Microrelief is present due to 20 to 30 cm high hummocks but topography is flat or gently rolling. The site sampled was a NE-SW 1969-70 winter seismic line at latitude 68°44.0'N and longitude 134°10.0'W (Fig. 11). The parent material of the soil was clay with some sand.

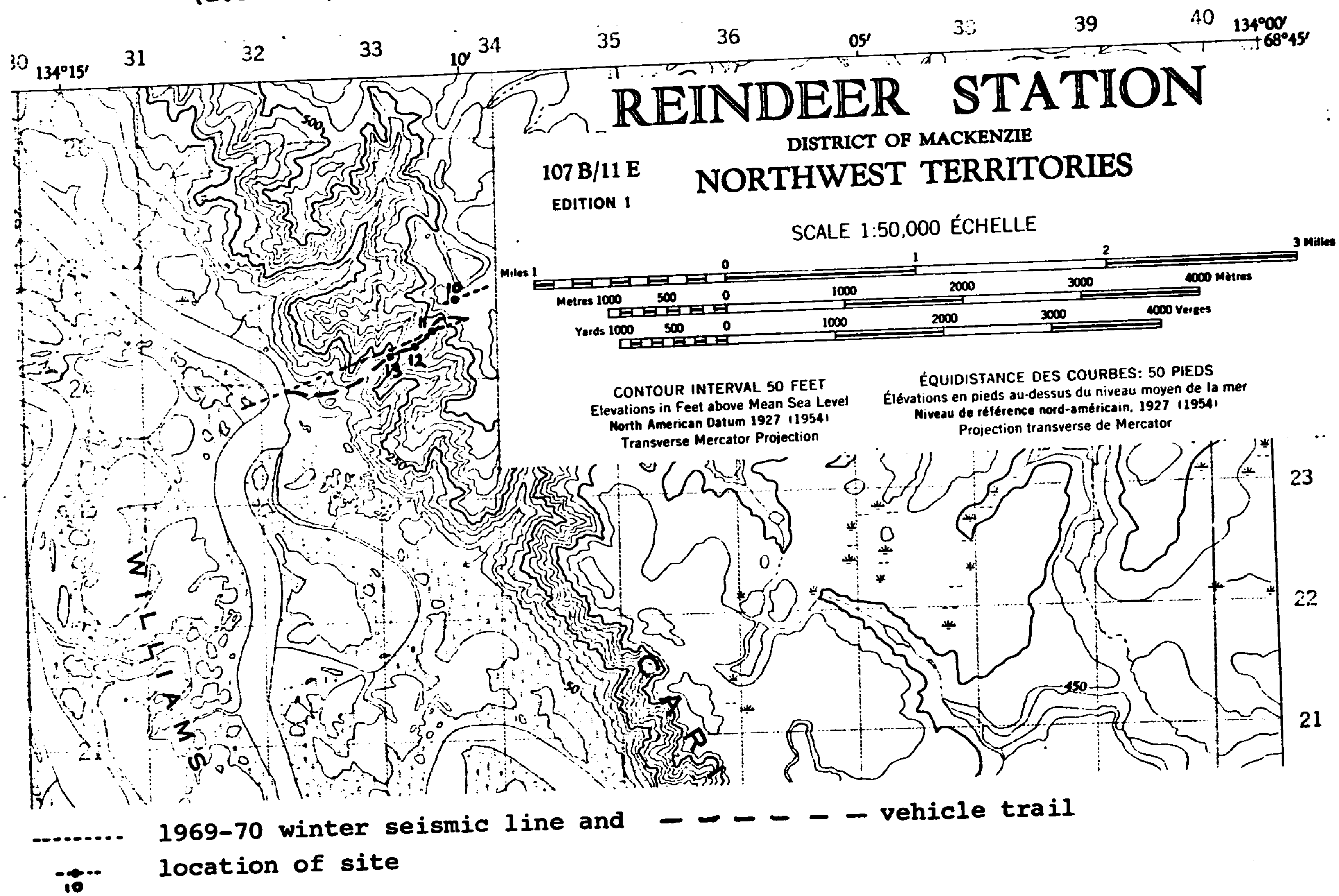
Table 11.

A 1969-70 winter seismic line and vehicle trail near the top of the Caribou Hills at latitude 68°44.0'N and longitude 134° 10.5'W (Fig. 11) lie NNE up the 15° slope through a cottongrass tussock tundra community.

Table 12.

This site is along the same vehicle trail as Table 11. It is approximately 3/4 of the way up the hill where the slope is 8°, (latitude 68° 44.0'N and longitude 134°11.0'W - Fig. 11).

Figure 11. Location of Reindeer Station Region sites sampled on N.T.S. map 107 B/11 E (1:50,000) with sites referred to by their table number in the text.



1969-70 winter seismic line and — — — — vehicle trail

location of site

Table 13.

This site is halfway up the hill along the same vehicle trail as the previous sites (11 and 12). The slope is 4° at latitude 68°43.5'N and longitude 134°11.0'W (Fig. 11).

Tuktoyaktuk Region Sites (Figs. 12, 13, 14 and 15)

Winter Road (Figs. 12 and 13)

Imperial Oil has a base camp ("Tuk Base") 4 km southeast of and across the harbour from Tuktoyaktuk. A winter road generally heading northeast from the base camp was sampled at several sites.

Table 14.

A site 1.5 km along the road at latitude 69° 26.0'N and longitude 132°54.5'W (Fig. 12) was sampled beside some raised centre polygons. A surficial peaty humus horizon was 25 to 30 cm thick on both disturbed and undisturbed areas.

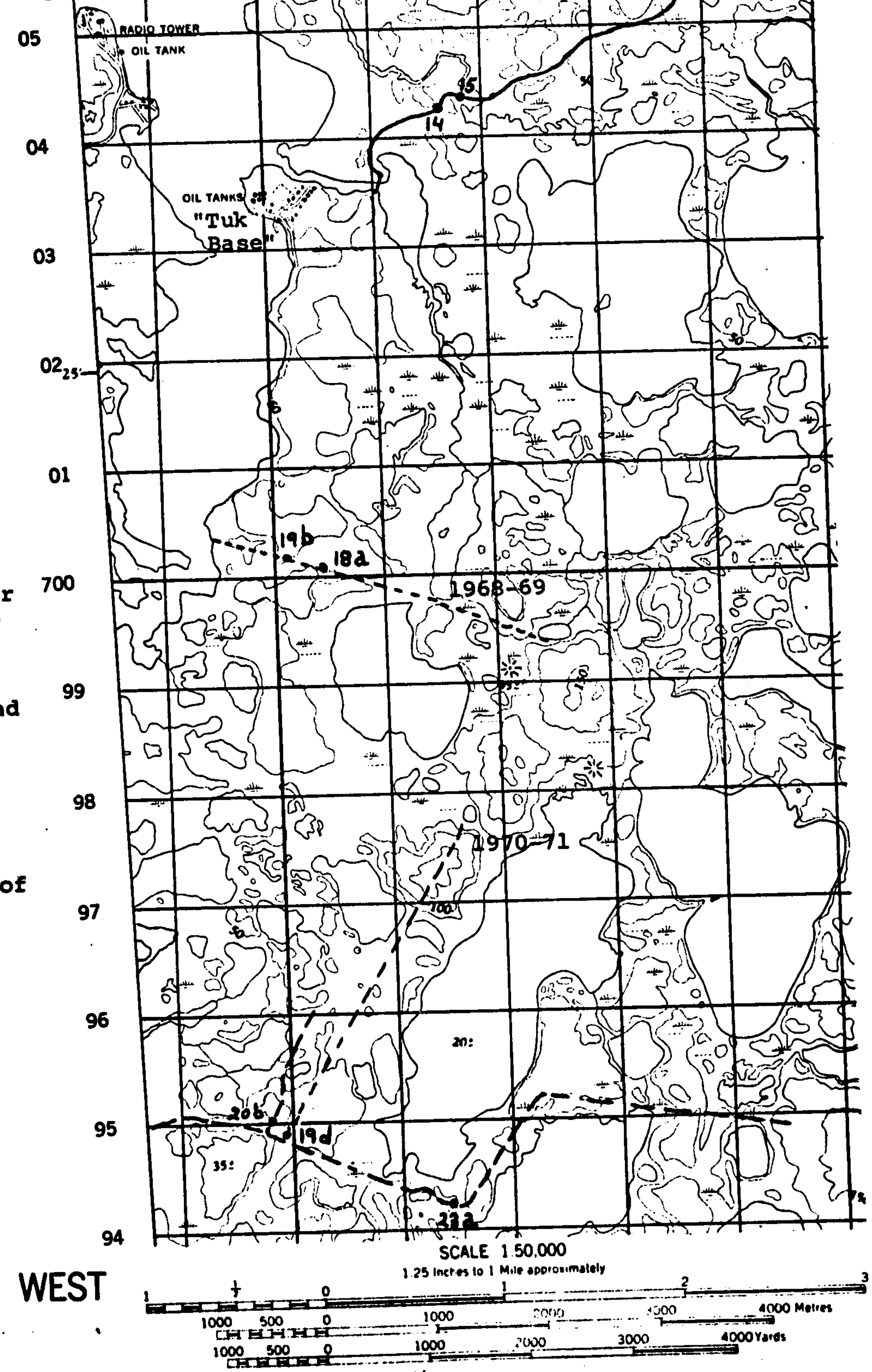
Table 15.

Two km northeast of "Tuk Base" the road descended from a raised area to cross a creek (latitude 69°26.5'N, longitude 132°55.0'W - Fig. 12). The upland area was sampled. The humus horizon under the vegetation was 10 to 15 cm thick and the parent material clayey.

Table 16.

Some 12 km northeast of "Tuk Base", the winter road crossed a large expanse of sedge meadow (*Carex aquatilis*)

Figure 12. Location of the Tuktoyaktuk Region sites sampled on the western portion of N.T.S. map 107 C/8 West (1:50,000) with sites referred to by their table number in the text.



N

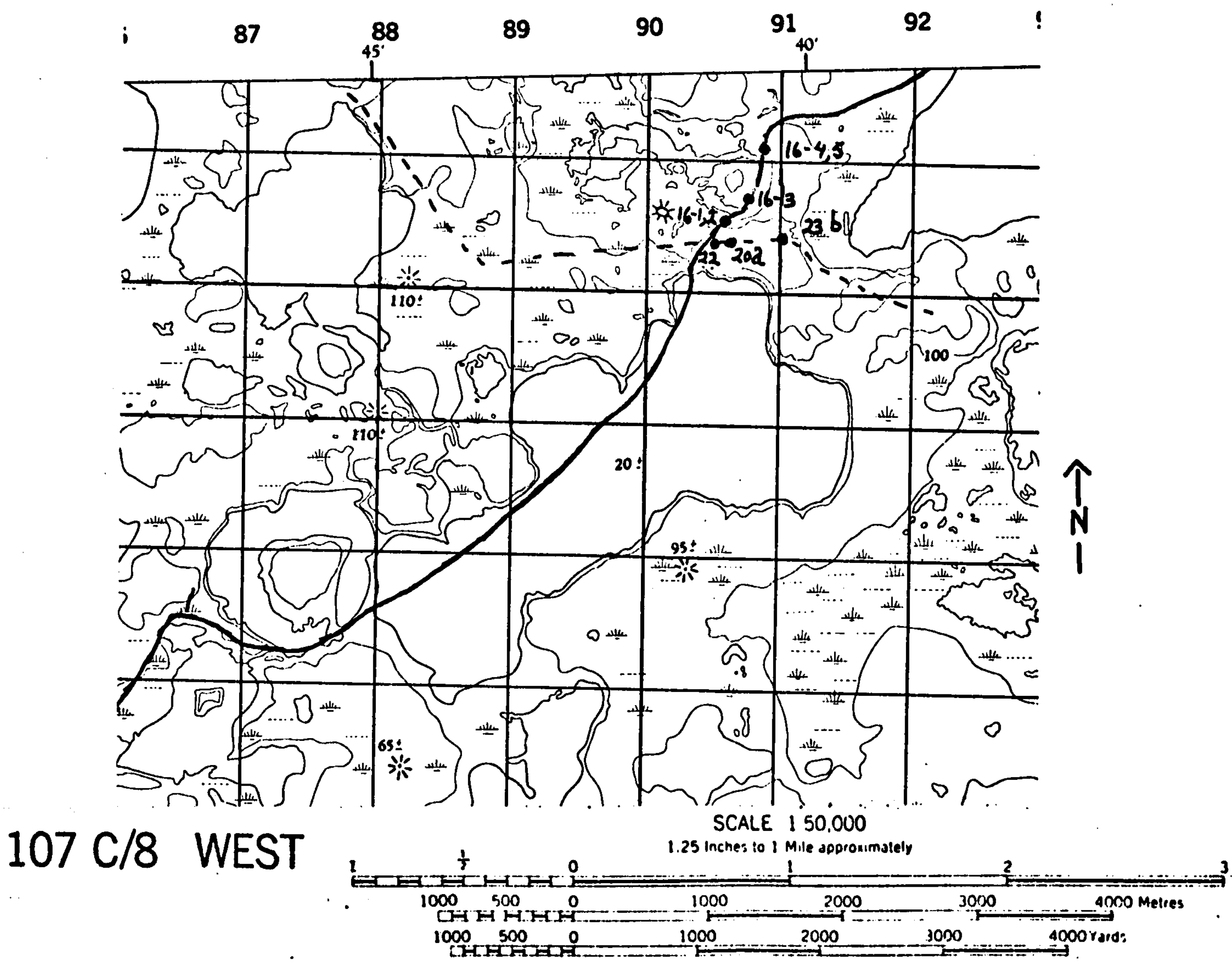
---- winter
and
—— 1965 summer
seismic lines

—— winter road

• location of
20b site

107 C/8 WEST

Figure 13. Location of the Tuktoyaktuk Region sites sampled on the northern portion of N.T.S. map 107 C/8 West (1:50,000) with sites referred to by their table number in the text.



------ 1965 summer seismic line

———— winter road

-•- location of site
16-1,2

Figure 14. Location of the Tuktoyaktuk Region sites sampled on N.T.S. map 107 C/7 East (1:50,000) with sites referred to by their table number in the text.

---- 1968-69 winter seismic line

------ 1965 summer seismic line

•• location of site
19a

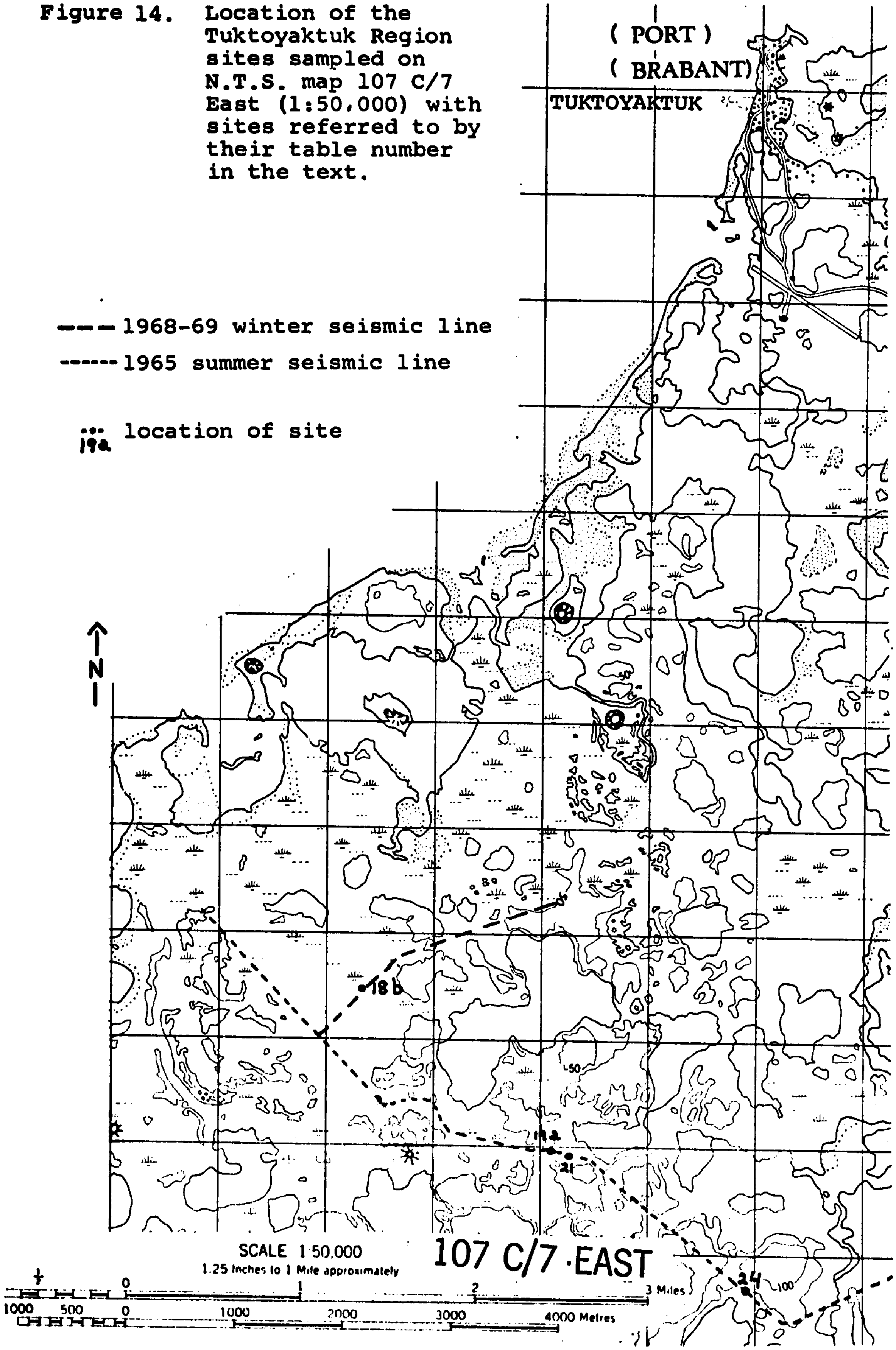
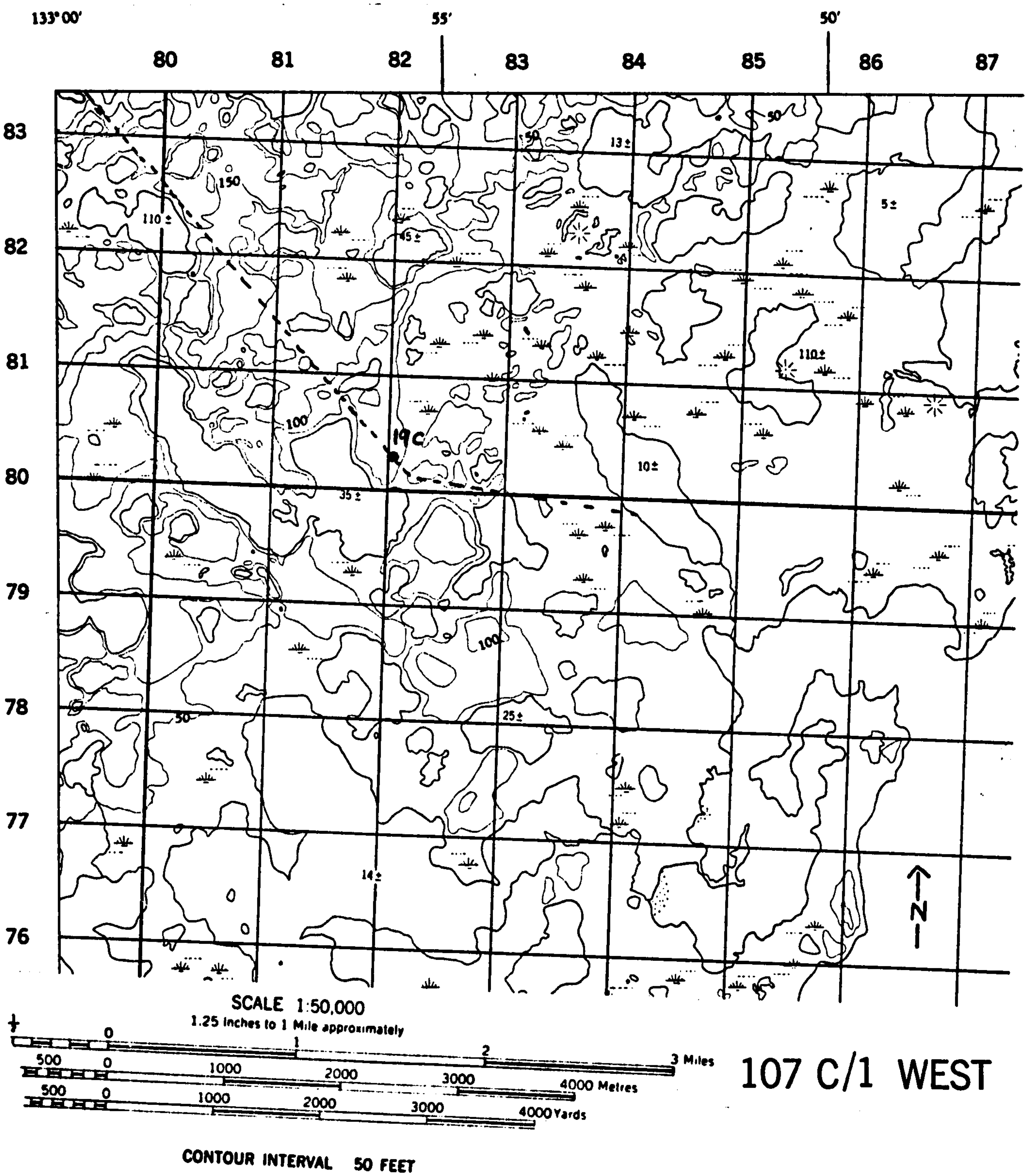


Figure 15. Location of the Tuktoyaktuk Region site sampled on N.T.S. map 107 C/1 West (1:50,000) with site referred to by its table number in the text.



---•--- 1967-68 winter seismic line with location of site
19c

as well as the small bay of a lake (latitude 69° 29.5'N, longitude 132° 40.5'W - Fig. 13). This site has been permanently marked (Fig. 16). Peat extended throughout the thawed layer (39 to 44 cm).

Table 17.

Five km northeast of "Tuk Base", the winter road skirted the edge of a relatively large lake (latitude 69° 27.0'N, longitude 132°50.0' to 132°51.0'W - Fig. 12). It passed through a flat grassy Arctophila fulva dominated community adjacent to the water. This site is probably on the former lake bottom. A gravelly beach ridge with much felt leaf willow (Salix alaxensis) occurs some 30 to 50 m from the present shoreline.

Seismic Lines (Figs. 12, 13, 14 and 15)

Table 18(a).

This site is an E-W 1968-69 winter seismic line through a moist cottongrass tussock tundra 3 km south of "Tuk Base" (latitude 69°24.0'N; longitude 132° 57.0'W - Fig. 12). It is situated in a low flat valley surrounded by 15 m high hills. The parent material is clayey and contains some sand.

Table 18(b).

This site is a NE-SW 1968-69 winter seismic line through a very moist cottongrass tussock tundra community, 9.5 km SW of Tuktoyaktuk at latitude 69° 23.0'N, and longitude 133° 08.0'W (Fig. 14).

Figure 16. Location of the individual transects sampled for the Tuktoyaktuk Region site presented in Table 16 in the text.

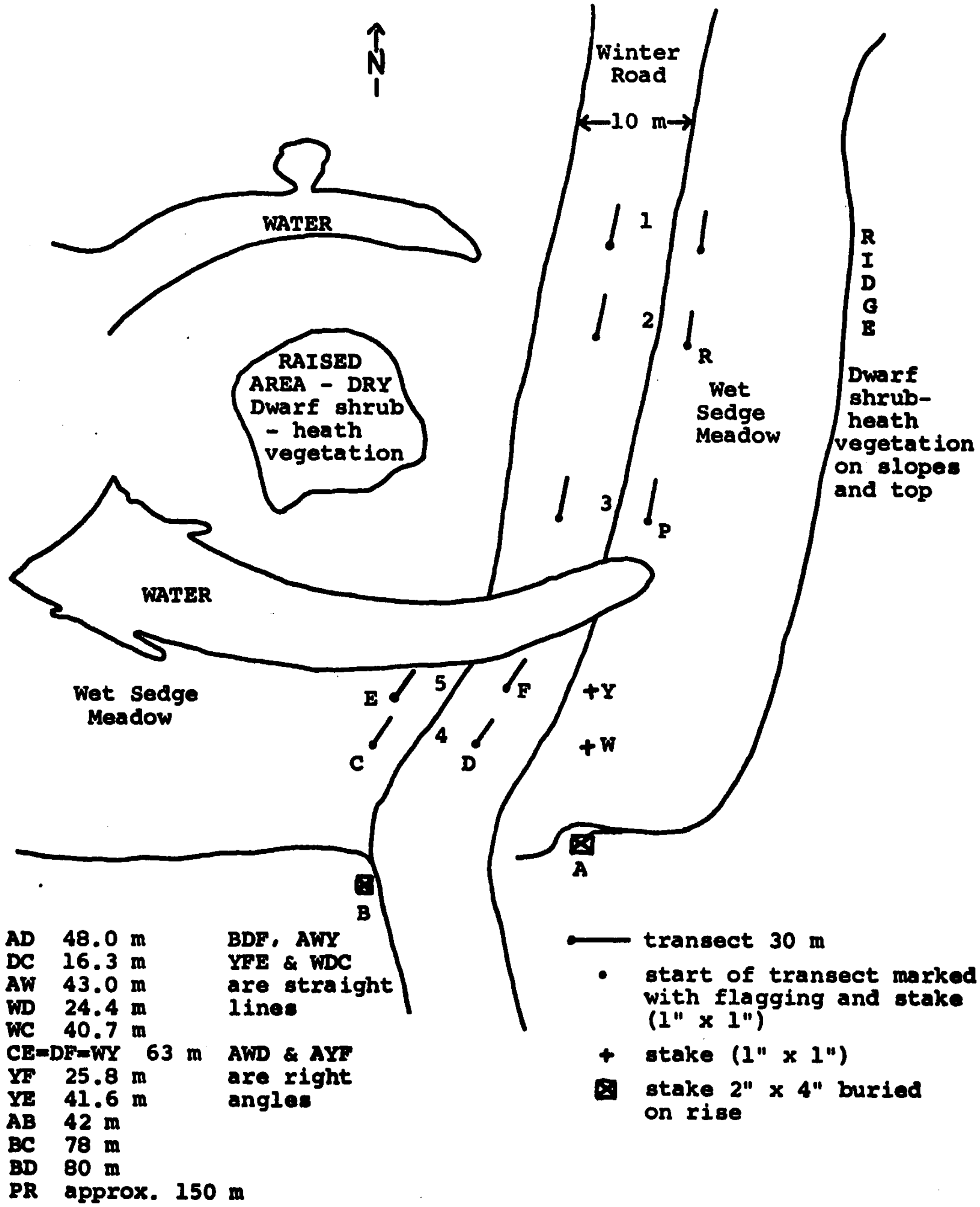


Table 19(a).

An E-W 1965 summer seismic line through dwarf shrub-heath communities was sampled 10.5 km south of Tuktoyaktuk (latitude 69°22.0'N, longitude 133°05.5'W - Fig. 14). Four separate transects in three different topographic situations were sampled (Fig. 17): south exposed slope (transects 1 & 2); top of ridge (3); bottom of slope (4).

Table 19(b).

This site is 3 km south of "Tuk Base" on the same E-W 1968-69 sinter seismic line but 100-200 m east of site 18(a) (latitude 69°24.0'N, longitude 132°56.5'W - Fig. 12). The line passed through a dwarf shrub-heath community developed on a raised area over the typical clayey till-like parent material of the region.

Table 19(c).

Four km northeast of the Eskimo lakes and 26 km south of Tuktoyaktuk is a NW-SE 1967-68 winter seismic line (latitude 69°13.0'N, longitude 132°55.5'W - Fig. 15). The site was at the top of a 20 m hill covered with a dwarf shrub-heath community. The predominantly clayey soil contained some gravel.

Table 19(d).

At latitude 69°21.5'N and longitude 132°58.0'W (Fig. 12) a NW-SE 1970-71 winter seismic line was sampled 8 km south of "Tuk Base". This site through a dwarf shrub-heath community was marked (Fig. 18).

Figure 17. Location of the individual transects sampled for the Tuktoyaktuk Region sites presented in Table 19(a) and 21 in the text.

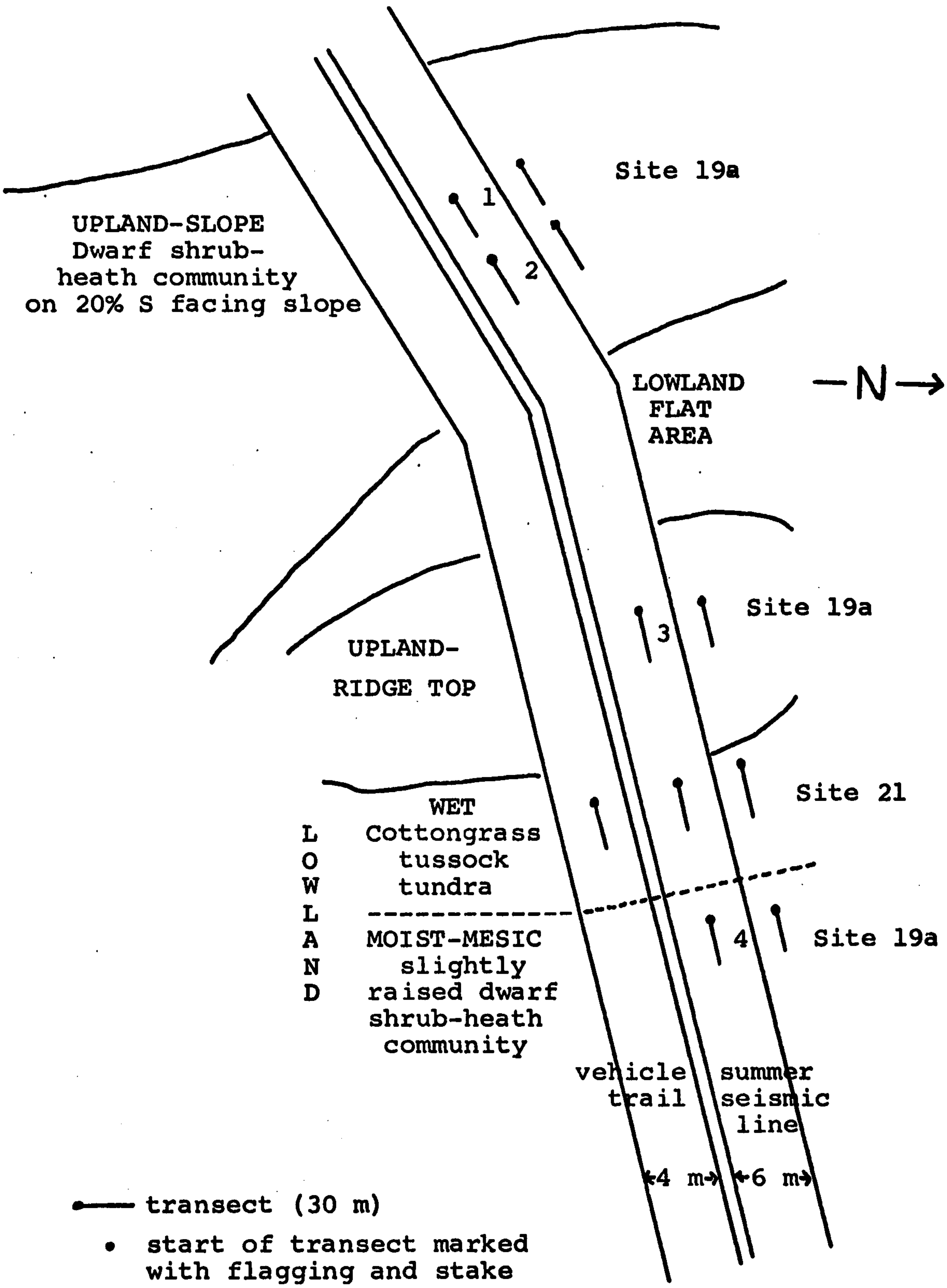
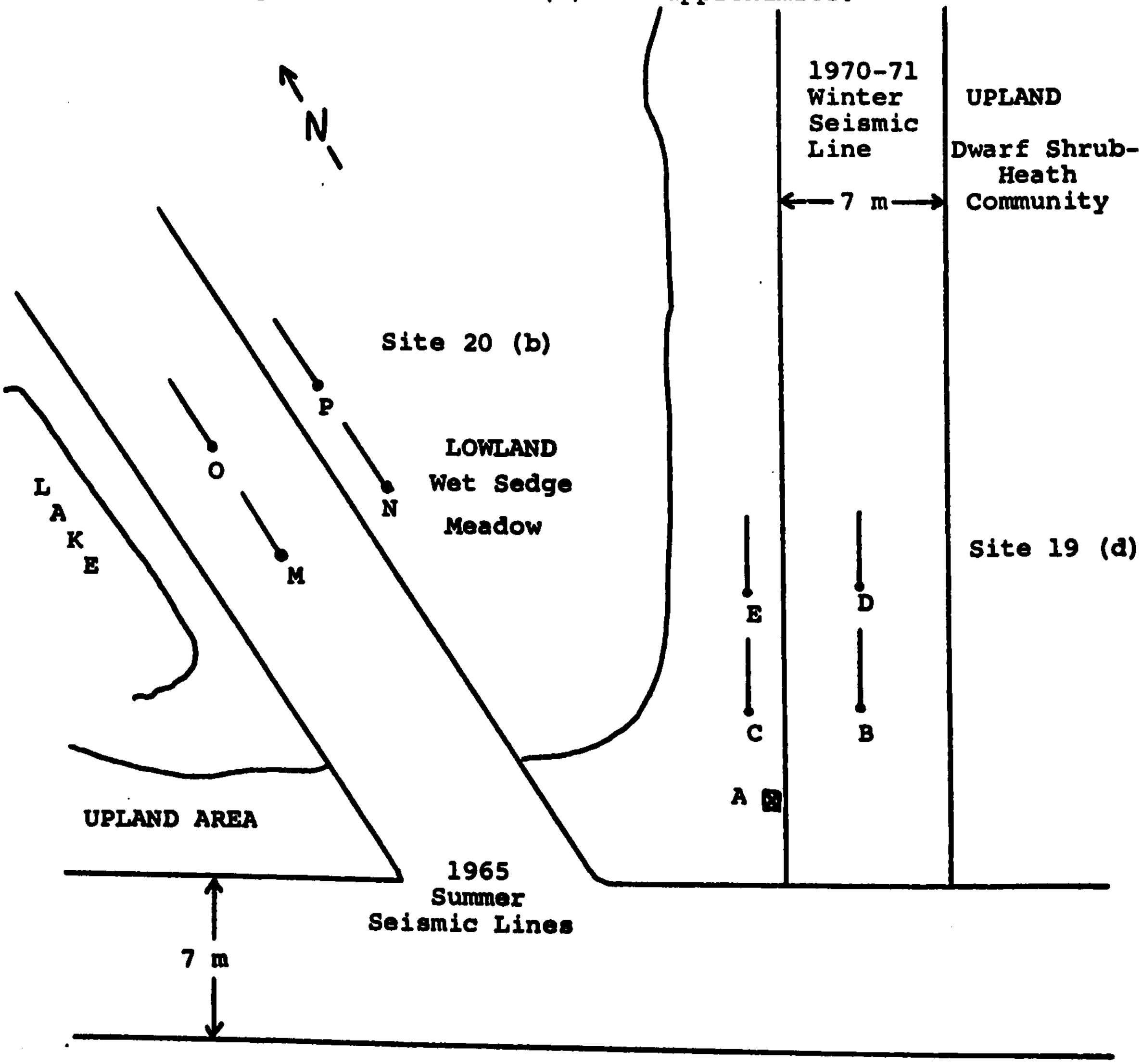


Figure 18. Location of the individual transects sampled for the Tuktoyaktuk Region sites presented in Table 19 (d) and 20 (b) in the text. The positions given for site 20 (b) are approximate.



AB 7.3 m
AC 12.7 m
CE=BD 45 m
ED=CB 14.0 m

MO & NP approx. 45 m
MN & OP approx. 15 m

—— transect (30 m)

• start of transect marked with flagging and stake (1" x 1")

■ stake 4" x 4"

Table 20(a).

An E-W 1965 summer seismic line descended from an upland, passed through an area of dry and wet depressed centre polygons and crossed the winter road in the vicinity of the site in Table 16 (12 km along the winter road; latitude 69°29.5'N, longitude 132°41.5'W - Fig. 13). The wet polygons contained sedge meadows of *Carex aquatilis* and *C. membranacea*. Peat was some 40 cm thick and gravel was present at depths greater than 50 cm.

Table 20(b).

This site is along a N-S 1965 summer seismic line and is near site 19(d): 8 km south of "Tuk Base" at latitude 69° 21.5'N and longitude 132°58.5'W (Fig. 12). The line descended from an upland and passed through a wet sedge meadow (*Carex aquatilis* and *C. membranacea*) beside a small lake (Fig. 18).

Table 21.

Site 21 is along the same E-W 1965 summer seismic line as site 19(a) between transects 3 and 4 (Fig. 17). It is 10.5 km south of Tuktoyaktuk at latitude 69°22.0'N and longitude 133°05'W (Fig. 14) in a low moist area of cotton-grass (*Eriophorum vaginatum*) tussock tundra.

Table 22.

The same E-W 1965 summer seismic line as in Table 20(a) passed through an area of slightly depressed centre to flat relatively dry polygons: 12 km northeast of "Tuk Base"; latitude 69°29.5'N, longitude 132°41.5'W (Fig. 13).

Table 23(a).

This site is along a NW-SE 1965 summer seismic line 9 km south of "Tuk Base" and 1.5 km east of site 19(d) at latitude 69°21.0'N and longitude 132°56.5'W (Fig. 12). The site is on an upland ridge top with a dwarf shrub-heath community.

Table 23(b).

An E-W 1965 summer seismic line passed through an upland dwarf shrub-heath community 12 km northeast of "Tuk Base" at latitude 69°29.5'N and longitude 132°40.5'W (Fig. 13). This site is approximately ½ km east of sites 22 and 20(a). When it was revisited in 1971, it was found to have been disturbed once again. The bulldozed-aside material had been pushed back into the line.

Table 24.

This site is 11 km south of Tuktoyaktuk and 2 km south-east of sites 19(a) and 21 (latitude 69°21.0'N, longitude 133°02.5'W - Fig. 14). It is along the same 1965 summer seismic line which lies NW-SE at this point. The dwarf shrub-heath community sampled was at the top of a 15 m high hill.

Appendix B. Association table for the natural communities sampled in the Tuktoyaktuk Peninsula-eastern Mackenzie Delta region with mean cover of all vascular species sampled.

Species	Community[a] and Mean Cover[b]																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Equisetaceae																				
Equisetum arvense	+	x																		
Equisetum scirpoides	1																			
Pinaceae																				
Picea glauca	15	+										+								
Graminae																				
Arctagrostis latifolia							x		6	x	x			x						
Calamagrostis canadensis						+	+													
Poa lanata						+	x		+					x						
Hierochloe alpina						x	x													
Arctophila fulva																				81
Cyperaceae																				
Eriophorum angustifolium																4				
Eriophorum russeolum																+	2	1	1	
Eriophorum vaginatum										x		7	9	25						
Carex vaginata	1																			
Carex bigelowii					1	4	3	5	6	8	3	+	6	6						
Carex rariflora				4										+	27					
Carex aquatilis															39	76	57	61	64	
Carex membranacea																	+	20		

Appendix B. Continued

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Community and Mean Cover																			
Juncaceae																				
Luzula confusa						1	x		1											
Orchidaceae																				
Platanthera obtusata	+	x																		
Salicaceae																				
Salix arbusculoides	11		30																	
Salix alaxensis		23																		
Salix glauca					+	2	12	21	8	4	5			2						
Salix arctica											+			+						
Salix pseudopolaris				+											1	3	3		1	
Betulaceae																				
Betula nana				10	25	6	14	11	15	6	6	3	5	7						
Alnus crispa	39	19	15									2	1	1						
Polygonaceae																				
Rumex arcticus							x													
Caryophyllaceae																				
Stellaria monantha						+	x		2	x										
Ranunculaceae																				
Caltha palustris														x			1			2
Ranunculus gmelini																				6

Appendix B. Continued.

Species	Community and Mean Cover 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cruciferae																				
Cardamine pratensis						x	x													
Rosaceae																				
Rubus chamaemorus				15	4	9	+	x				20	x	4						
Potentilla palustris																	4			
Potentilla fruticosa	x																			
Rosa acicularis	+																			
Dryas integrifolia						6	+		2	6			x							
Leguminosae																				
Lupinus arcticus						2	3	+		2	2			+						
Hedysarum alpinum		3	1																	
Haloraceae																				
Hippuris vulgaris																				1
Pyrolaceae																				
Pyrola grandiflora	6	5	3			+	4	3		4	1		+							
Empetraceae																				
Empetrum nigrum	1			4	8	2	11	18	2	4	9	12	1	6						

Appendix B. Continued.

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Community and Mean Cover																			
Ericaceae																				
Vaccinium uliginosum	3			x	+		2			14	8	4	12	2						
Vaccinium vitis-idaea	1			7	11	9	8	5	6	2	5	13	4	9						
Arctostaphylos rubra	19	29	12		+	2	2	2		6	6	5	6	2						
Ledum palustre decumbens				8	8	10	5	2	4	1	5	11	4	8						
Ledum groenlandicum Oeder	3																			
Cassiope tetragona							x		1											
Rhododendron lapponicum										+										
Andromeda polifolia												1		x						
Scrophulariaceae																				
Castilleja raupii							x				x									
Pedicularis capitata							x			1										
Pedicularis kanei						+	1			1	x			x						
Pedicularis labradorica							x							x						
Pedicularis sudetica																	1			
Orobanchaceae																				
Boschniakia rossica	x	+																		
Compositae																				
Petasites frigidus						6	1	2			1			1						
Saussurea angustifolia						1	x	1		1	x			+						
Senecio congestus							x		x	+										1

Appendix B. Continued.

	Community and Mean Cover																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Table Number[c] in text in which this community appears	2	3	4	22	14	23	19 24 15	19	8	6	10	12	5	18 21 13 11	7	9	16	20	20	17

a Community Classification: The communities were obtained from the cluster analysis.
1. _Picea glauca-Alnus crispa_ subsp. _crispa-Salix arbusculoides_ forest type
2. _Salix alaxensis-Alnus crispa_ subsp. _crispa_ tall shrub subtype
3. _Salix arbusculoides-Alnus crispa_ subsp. _crispa_ tall shrub subtype
4. Dwarf birch-_Rubus_-heath low centre polygon subtype) Complex of dwarf shrub-heath subtypes
5. Dwarf birch-heath raised centre polygon subtype)
6 to 11. Various dwarf shrub-heath subtypes)
12 to 14. Cottongrass tussock tundra subtypes
15 to 19. _Carex aquatilis_ dominated sedge meadow subtypes
20. _Arctophila fulva_ lake edge subtype

b Cover
+ Mean Cover less than 0.1%
x Mean Cover between 0.1 and 0.5%
1, 2, etc. Mean Cover rounded off to the nearest %

c For communities 7 and 14 several tables are listed. This was because several different stands were placed in the same cluster.