Hydrocarbon Development In The Beaufort Sea - Mackenzie Delta Region

VOLUME 3C MACKENZIE VALLEY SETTING

ENVIRONMENTAL IMPACT STATEMENT

1982

ENVIRONMENTAL IMPACT STATEMENT

FOR

HYDROCARBON DEVELOPMENT

IN THE

BEAUFORT SEA - MACKENZIE DELTA REGION

VOLUME 3C
MACKENZIE VALLEY SETTING

1982

BEAUFORT SEA-MACKENZIE DELTA ENVIRONMENTAL IMPACT STATEMENT

The Beaufort Sea Production Environmental Impact Statement was prepared by Dome Petroleum Limited, Esso Resources Canada Limited and Gulf Canada Resources Inc. on behalf of all land-holders in the Beaufort Sea-Mackenzie Delta region.

Information pertaining to the Environmental Impact Statement and its Support Documents can be obtained from:

Frontier Drilling and Production Division,
Dome Petroleum Limited,
P.O. Box 200, Calgary T2P 2H8
or
Pallister Resource Management,
Bay 105, 4116 - 64th Ave. S.E.
Calgary T2P 1P4
Telephone: (403) 236-2344

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ENVIRONMENTAL IMPACT STATEMENT

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INTRODUCTION

Volume 3C of the Environmental Impact Statement provides the environmental setting for the Mackenzie River Valley pipeline corridor. The 'Mackenzie Valley corridor' extends from the Mackenzie Delta to the Northwest Territories-Alberta border. It includes the Mackenzie River and lands on the adjacent east bank generally 30 to 100 km wide (Figure 1). The 'Mackenzie River Valley' is generally used to describe lands drained by the Mackenzie River. Emphasis has been placed on those subjects deemed most relevant for the purposes of assessing possible impacts of pipelining operations on the environment (Volume 4) and for addressing associated socio-economic issues (Volume 5). The information has also been used to evaluate the potential impacts of hypothetical major oil spills originating from pipelines (Volume 6) and to identify future research and monitoring proposals (Volume 7).

In accordance with the EARP guidelines, the information presented has been summarized as much as practical, while recognizing the importance of providing sufficient detail to permit completion of a satisfactory evaluation. Since the pipeline corridor extends into the coastal area of the Beaufort Sea-Mackenzie Delta region (Volume 3A), there is a necessary duplication of some of the information presented in these two volumes. The environmental setting of the Northwest Passage region is provided in Volume 3B.

For additional information, the reader is referred to various supporting documents to the Environmental Impact Statement as well as the literature cited in the text.

Volume 3C was prepared by the proponents with the assistance of several environmental consulting firms. Major external contributors included:

R.M. Hardy and Associates Ltd. -
Atmospheric Environment
Geology
Soils
Hydrology
Vegetation

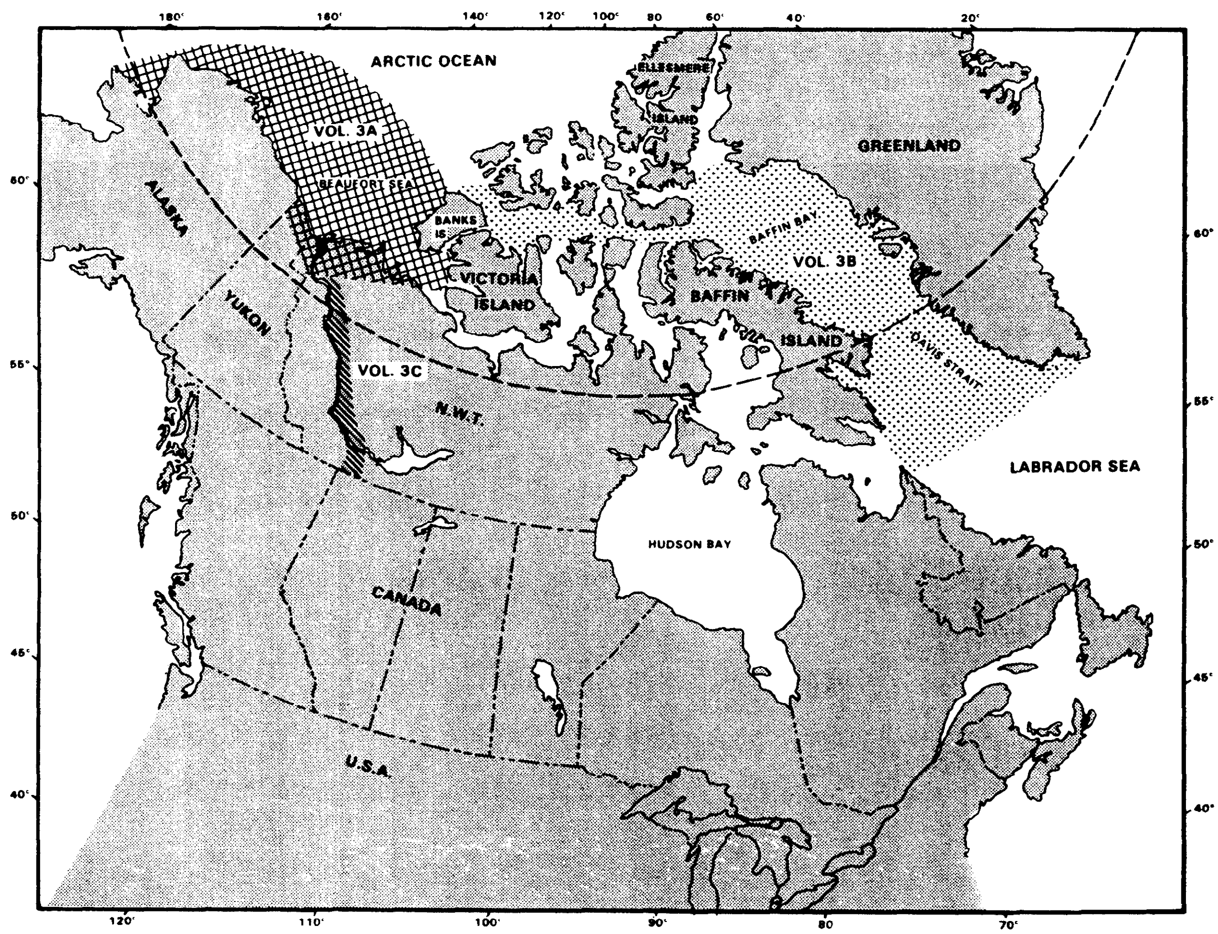


FIGURE 1 *Approximate boundaries of the three geographic regions designated in the Environmental Setting, Volumes 3A, 3B and 3C.*

Northwest Hydraulics Consultants Ltd. -
Hydrology

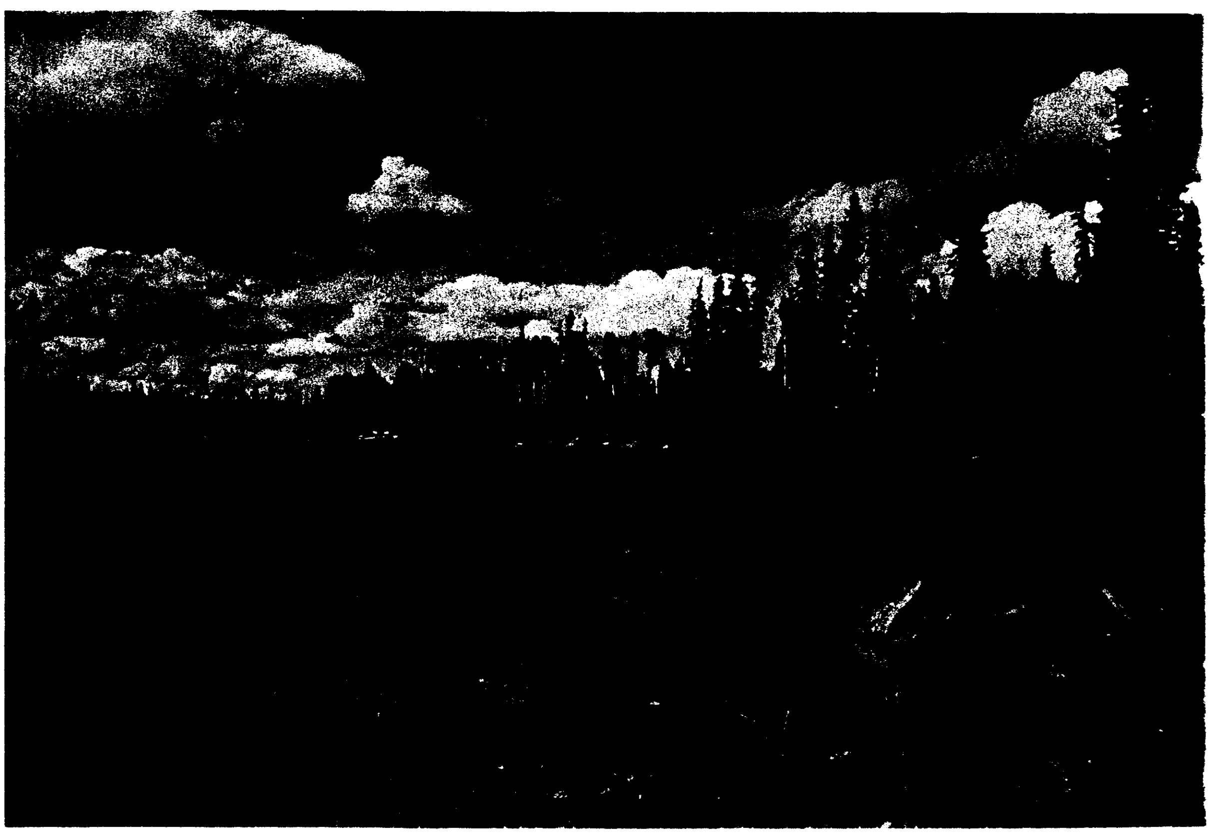
McCourt Management Ltd. -
Mammals
Resource Use (mammals)
Special Areas

Aquatic Environments Limited -
Aquatic Resources
Resource Use (aquatic)

LGL Limited -
Birds

ESL Environmental Sciences Limited -
Atmospheric Environment
General Editing

In-house expertise and project co-ordination was provided by scientists and specialists from Esso Resources Canada Limited, Dome Petroleum Limited and Gulf Canada Resources Inc.



CHAPTER 1
PHYSICAL ENVIRONMENT

The following sections summarize existing information on the physical environment of the Mackenzie Valley corridor, extending from the Mackenzie Delta to the Northwest Territories-Alberta border (Figure 1-1). The information presented here and in Chapter 2 forms part of the background for assessing the potential impacts of pipelining and associated activities in the region (Volume 4).

Separate sections review the climate and weather, geology, soil characteristics and hydrology of the region. Since the pipeline corridor extends into the coastal zone described in Volume 3A, there is necessarily some duplication of the information presented. Additional information is available in various supporting documents to the Environmental Impact Statement as well as the literature cited in the text.

1.1 ATMOSPHERIC ENVIRONMENT

The climate of the Mackenzie Valley is extensively reviewed by Burns (1973, 1974). Information on weather is available from the five active and three abandoned meteorological stations in the region, and is published in Ministry of Transport and Envir-

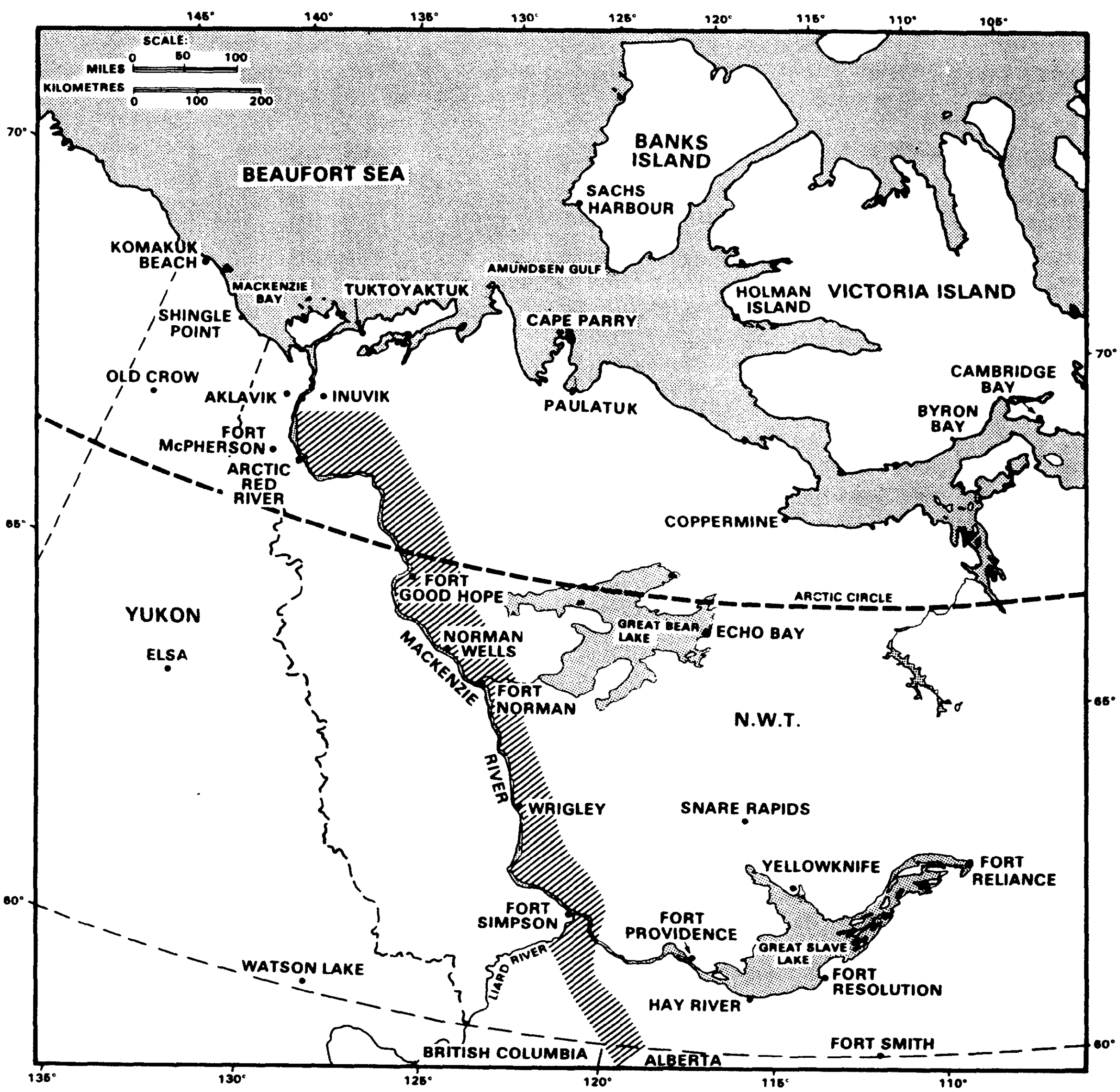


FIGURE 1-1 *Approximate boundary of the Mackenzie Valley Corridor described in Volume 3C.*

TABLE 1.1-1

METEOROLOGICAL STATIONS IN THE MACKENZIE VALLEY REGION

Station (Lat./Long./Elev.)	Period of Record: Temperature	Precipitation	Wind	Synoptic	Hourly	Sunshine	Radiation
Fort Good Hope (66°16′ 128°38′ 53 m)	1944-1981	1944-1981	1945-1981	1944-1950*			
Fort Good Hope 2 (66°15′ 128°38′ 42 m)	1908-1966*	1897-1966*		1908-1955*			
Norman Wells A** (65°17′ 126°48′ 63 m)	1943-1981	1943-1981	1949-1981	1943-1981	1955-1981	1959-1981	1967-1981
Fort Norman (64°57′ 125°00′ 81 m)	1908-1961*	1903-1961*		1908-1951*			
Wrigley A** (63°12′ 123°42′ 156 m)	1943-1981	1943-1970*	1957-1981	1943-1950*			
Fort Simpson (61°52′ 121°21′ 129 m)	1927-1963*	1927-1963*	1952-1963*	1927-1963*	1955-1963	1952-1981	1954-1964*
Fort Simpson A** (61°45′ 121°14′ 176 m)	1963-1981	1963-1981			1963-1981		
Fort Smith A** (60°01′ 111°58′ 201 m)	1943-1981	1943-1981	1943-1981	1943-1981	1943-1981	1943-1981	

* No longer in operation
** Airport

onment Canada reports. The location, climatic data measured, and period of record at each of these stations are presented in Table 1.1-1. Examples of annual variations in weather conditions throughout the Mackenzie Valley are also described in this section.

1.1.1 SYNOPTIC CLIMATOLOGY

The synoptic climatology of the Mackenzie Valley is related to the large-scale circulation patterns of the Northern Hemisphere. The major features of the upper-level circulation are a semi-permanent cold circumpolar vortex situated over the Queen Elizabeth Islands, and a semi-permanent ridge which lies over Alaska in winter and shifts eastward over the Yukon in summer. The shifting of this ridge produces a dominant anticyclonic circulation pattern (high pressure system) at the surface in winter, and a trough (low pressure system) along the Mackenzie Valley in summer.

Cyclonic activity in the region is caused by shortwave troughs which originate from upper-level lows over the Gulf of Alaska. These may produce surface low pressure centres which develop outside the region and follow trajectories across it, or they may result in local cyclogenesis (*in situ* generation of low pressure centres) in the lee of mountain barriers. The two areas of dominant local cyclogenesis are Fort Nelson, British Columbia during the spring and fall, and Norman Wells, Northwest Territories during the summer.

The normal upper-level air flow over the region is from the west in summer and from the northwest in winter. Severe weather often occurs when there are abnormal departures from this pattern caused by major shifts in the circulation of the upper atmosphere. For example, such shifts may result in a southerly flow of air aloft which introduces warm moist air into the region and produces record high temperatures and increased instability. On the other hand, persistent blocking circulation patterns may prevent surface lows from entering the region, resulting in long periods of drought and, in winter, stagnation of cold Arctic air and accompanying record low temperatures.

1.1.1.1 Winter

In winter a semi-permanent upper air ridge over Alaska results in a relatively strong mean northwesterly flow of air aloft over the Mackenzie Valley. At the surface the Northwest Territories and the Polar Basin constitute a single region of continuous snow and ice cover. As a result, Arctic air predominates in the area throughout the winter months of December through March and causes a high pressure system to develop at the surface.

The cold dome of continental Arctic air over the region acts as an effective block against penetration by maritime air masses. Migrating frontal lows are forced to follow trajectories around the periphery of the continental Arctic air mass well to the north and south of the region. For example, low pressure centres which originate in the Aleutians migrate across the Beaufort Sea between 73°N and 75°N latitude. These centres produce blizzards along the coast and in the lower Mackenzie Valley primarily in January and March. On the other hand, major snowfalls are caused by infrequent penetrations of maritime Arctic air accompanying migrating frontal lows, or are the result of local cyclogenesis. Frontal lows may enter the Mackenzie Valley region when upper- level ridges over the eastern Pacific and Alaska block the normal paths of storm trajectories, thereby forcing storms on a more northerly course from the Gulf of Alaska. These storms are most likely to occur during the spring and autumn months of March, April, October and November, but may also occur throughout the winter. Occasionally short-wave troughs (which emanate from over the Aleutians) result in cyclogenesis in the Mackenzie Valley - Great Slave Lake region. There is often sufficient moisture associated with these systems to cause major snowstorms along the Valley.

The high pressure systems which dominate the region from November through March originate over the polar ice pack in the Beaufort Sea or in northern Alaska. Their primary trajectory is southeastward along the Mackenzie Valley. In February these systems tend to stagnate over the Valley, resulting in prolonged cold spells.

1.1.1.2 Spring

Spring in the Mackenzie Valley begins with the gradual shift eastward of the dominant high pressure system from over the Valley to the region lying between approximately 107°W and 103°W longitude. High pressure systems still originate in the north and follow southeastward trajectories. However, whereas in February these systems would tend to stagnate over the Mackenzie Valley, by March they begin to assume a trajectory to the east of the Valley through the Great Bear and the Great Slave lakes region.

The eastward displacement of high pressure centres allows more frequent penetrations by frontal lows. This brings maritime Arctic and maritime Polar air masses into the region and results in generally increased instability. The continental Arctic air mass begins to retreat northward during the spring, while increased solar heating and lower albedoes begin to modify the southern portions of the Arctic air mass.

During March and April the region around Fort Nelson, British Columbia becomes a dominant area of cyclogenesis which brings more frequent storms to the upper Mackenzie Valley. As the season progresses cyclonic activity in the region increases. By May frontal lows from northern Alaska begin to follow trajectories through the northern Yukon and down the Mackenzie Valley bringing precipitation to the area from the Mackenzie Delta to Great Slave Lake.

1.1.1.3 Summer

The semi-permanent upper-level ridge which lies over Alaska in winter is shifted eastward to a position over the Yukon during the summer. In addition, strong winter winds from the northwest are weakened and become more westerly over the Mackenzie Valley. This results in the estabishment of a surface trough in the lee of the mountains along the entire length of the Mackenzie Valley.

With the break-up of landfast ice along the coast of the Beaufort Sea, the climate of the Beaufort Sea coast becomes more maritime. The Arctic air mass is reduced to the area covered by the permanent polar ice pack, and outbreaks of Arctic air change as they pass over the open water between the polar pack and the coast. Low cloudiness and a stable lapse rate within the boundary layer become the dominant features of the coastal climate. As the maritime air penetrates into the Mackenzie Valley it is further modified by surface heating and rapidly becomes more unstable. This results in more frequent precipitation in the lower Mackenzie Valley and Delta areas.

From May to July the Beaufort Sea coast and lower Mackenzie Valley are affected by frontal lows which follow a trajectory from northern Alaska through the northern Yukon, and southeastward along the Mackenzie Valley. These storms bring precipitation to all regions along the river valley. In addition, the upper Mackenzie Valley is affected by frontal lows which penetrate eastward from the Gulf of Alaska and travel through the southern Yukon.

Cyclonic activity in the region reaches a peak in July and August. Cyclogenesis is frequent in the area around Norman Wells. Low pressure systems penetrate the region from the central Yukon and follow trajectories along the Mackenzie Valley. In August and September the Beaufort Sea coast and lower Mackenzie Delta area receive precipitation from storms which develop north of Alaska and travel along the coast between 70°N and 72°N latitude.

1.1.1.4 Autumn

The autumn season (from late September to December) is the reverse of the spring season. The summertime upper-level ridge over the Yukon gradually begins to shift westward back to its winter position over Alaska, while air flow aloft changes from relatively weak flows from the west to strong flows from the northwest.

At the surface outbreaks of cold Arctic air become progressively more frequent and colder, penetrating further south along the Mackenzie Valley. As freeze-up begins, evaporation from relatively warm waterbodies introduces moisture into the atmosphere, causing overcast skies and frequent snow flurries.

During autumn, cyclonic activity begins to decline from its July peak. Major snowfalls along the coast and within the Delta accompany the passage of low pressure systems which travel eastward between 70°N and 72°N latitude in September. These become less frequent after October when the storm trajectories shift to higher latitudes between 73°N and 75°N. Upper-level blocking circulation patterns over the eastern Pacific and Alaska occasionally force low pressure centres from the Gulf of Alaska to pass eastward through the southern Yukon between 59°N and 62°N latitude. As in the spring, the area around Fort Nelson becomes a dominant region of cyclogenesis.

Beginning in November high pressure systems originating in either northern Alaska or over the Beaufort Sea travel southeastward along the Mackenzie Valley. By December the dominant high pressure system is re-established as Arctic air once again dominates the entire region.

1.1.2 ATMOSPHERIC INVERSIONS

Atmospheric inversions are important in affecting the dispersion of air pollutants. Cold Arctic air masses are characterized by a distinctive warm temperature inversion (an increase in temperature with height) which generally occurs less than 1,000 m above the surface. The inversion is caused by radiation cooling over the snow and ice surfaces which exist at high latitudes throughout most of the year. Low sun angle, high albedoes and short days combine to limit daytime heating at the surface, while the subsidence of cool air and warm air advection aloft help to maintain and intensify the depth of the inversion layer.

Table 1.1-2 shows the frequency of surface-based inversions found at two locations within the Mackenzie Valley. Low-level inversions, in which temperature initially decreases with height for the first few hundred metres and is capped by a shallow inversion layer, are common in the afternoon in this region. Although there are no statistics on their frequency of occurrence, it may be assumed that a fair number of nighttime (1100 GMT) surface-based inversions are transformed into low-level inversions by afternoon heating. These are not reflected in the statistics for 2300 GMT provided in Table 1.1-2. Therefore, how often afternoon surface-based inversions occur is not necessarily a measure of the air pollution potential associated with temperature inversions.

TABLE 1.1-2

SEASONAL DIFFERENCES IN THE FREQUENCY OF SURFACE-BASED TEMPERATURE INVERSIONS (%) OBSERVED AT NORMAN WELLS AND FORT SMITH (Source: Burns, 1973)

Months	Time of Day (GMT)	Frequency of Inversions (%) Norman Wells A	Fort Smith A
Dec-Feb	2300	49	28
	1100	59	47
Mar-May	2300	13	4
	1100	65	58
June-Aug	2300	5	3
	1100	69	71
Sept-Nov	2300	22	10
	1100	49	50

The mixing height concept has been developed as a means of determining pollution potential. The mixing heights presented in Table 1.1-3 are a measure of the maximum depth of vertical mixing which occurs at the earth's surface as a result of daytime heating. The concept, as defined by Holzworth (1967), is based on the principle that heat generated through solar radiation at the surface results in convection, vigorous vertical mixing and the establishment of a dry adiabatic lapse rate (a decrease in temperature with height at a rate of 0.98°C/100 m). The maximum (afternoon) mixing height is determined on a graph of temperature versus height by extending the maximum surface temperature at the dry adiabatic lapse rate from the surface to the point at which it intersects the vertical temperature profile observed in the early morning (Portelli, 1977).

The mean mixing-layer wind speed shown in Table 1.1-3 is simply the vertically-averaged wind speed between the surface and the top of the mixing layer (defined by the mixing height), while the mean maximum ventilation co-efficient (Table 1.1-3) is the product of the maximum mixing height and the mean wind speed through this mixed layer. Although expressed in units of m^2/s, the latter coefficient is in reality a volumetric flushing rate per unit distance normal to the wind direction (that is m^3/s-m) at which air within the mixed layer is transported (Holzworth, 1974). As a measure of the ability of the atmosphere to disperse pollutants, the ventilation coefficient is more dependent upon the mixing height than upon wind speed. Consequently, the pollution potential may be considered to be inversely proportional to the maximum afternoon mixing height, while the frequency of pollution episodes is directly proportional to the frequency of occurrence of surface-based and low-level inversions.

TABLE 1.1-3

MEAN MAXIMUM AFTERNOON MIXING HEIGHTS (m), MEAN MIXING LAYER WIND SPEEDS (km/h) AND MEAN MAXIMUM VENTILATION COEFFICENTS ((m²/s)/10) DETERMINED FOR NORMAN WELLS (NW) AND FORT SMITH (FS)
(Source: Portelli, 1977)

Month	Mean Maximum Afternoon Mixing Height (m)		Mean Mixing Layer Wind Speed (km/h)		Mean Maximum Ventilation Coefficient ((m²/s)/10)	
	NW	FS	NW	FS	NW	FS
Jan	155	208	11.5	13.0	88	82
Feb	247	324	12.2	14.8	96	146
Mar	474	547	18.7	17.3	261	269
Apr	812	1025	19.1	19.1	403	534
May	1327	1499	19.4	21.2	685	872
June	1555	1779	18.7	19.1	750	919
July	1448	1610	19.1	19.8	730	873
Aug	1117	1537	19.1	22.0	550	906
Sept	758	1009	17.3	21.2	397	622
Oct	355	578	16.9	21.2	194	347
Nov	180	283	10.4	16.2	77	150
Dec	135	231	11.9	14.8	69	114
Annual	753	930	16.6	18.4	378	512

For Norman Wells, Table 1.1-2 shows that nighttime (1100 GMT) surface-based inversions occur frequently throughout the year, ranging from a low of 49% during the months of September through November, to a high of 69% during June to August. However, these data also show that, whereas afternoon (2300 GMT) surface heating is able to eliminate most surface inversions which occur from March through August, only 17% of all nighttime inversions during December through February are eliminated by afternoon heating.

A similar trend is evident for afternoon mixing heights (Table 1.1-3). Afternoon mixing improves markedly in March and remains good throughout the summer until September. By November mean maximum afternoon mixing heights are less than 200 m above the surface and remain low until February. Therefore, although surface-based and, by extension, low-level inversions occur frequently throughout the year, their significance to pollution potential is minimized by higher mixing heights and wind speeds during the months of March through September. On the other hand, November through February is the period with the highest potential for pollution-producing episodes at Norman Wells. The same may be stated for Fort Smith, although higher mixing-layer wind speeds at Fort Smith result in a lower pollution potential.

1.1.3 DAYLIGHT

The duration of daylight varies with latitude and season, and the more northerly the location, the more variable is the duration of daylight. In the extreme northerly portions of the lower Mackenzie Valley daylight varies from zero hours during December and January to 24 hours in June and July. In the southern parts of the upper Mackenzie Valley, daylight ranges from five to six hours during December and January and up to 19 hours in the latter half of June. The seasonal relationship between duration of daylight and latitude is presented in Figure 1.1-1 (Burns, 1973).

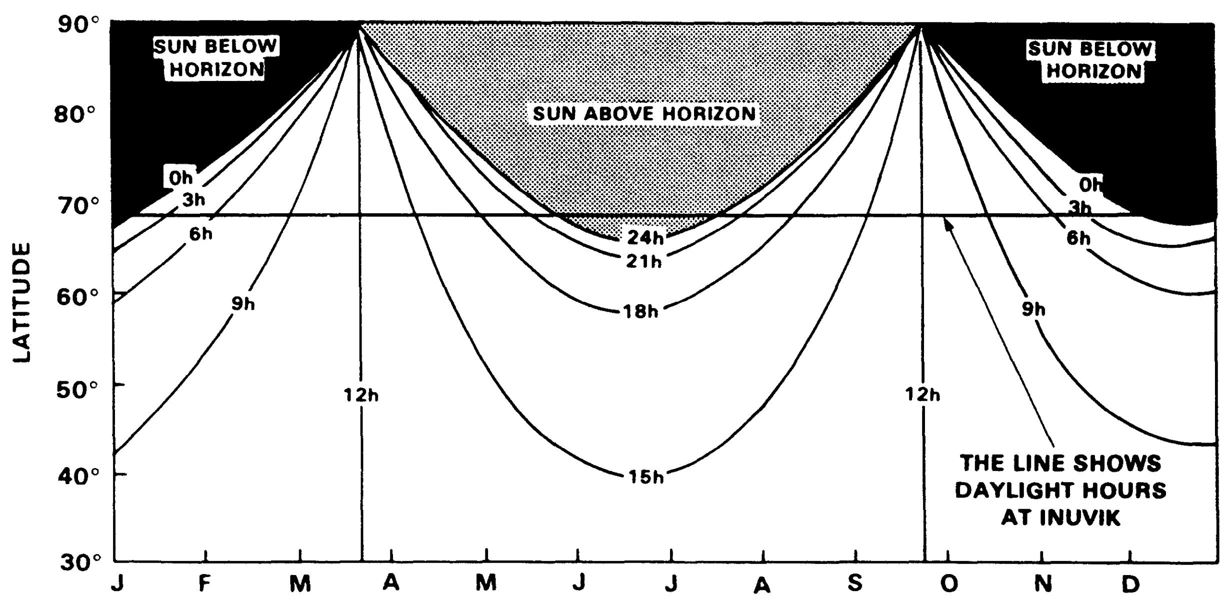


FIGURE 1.1-1 *Duration of daylight hours as a function of latitude and season. (Source: Burns, 1973). In the extreme northerly portions of the lower Mackenzie Valley, daylight varies from zero hours during December and January to 24 hours in June and July. In the southern parts of the upper Mackenzie Valley, daylight ranges from five to six hours during December and January and up to 19 hours in the latter half of June.*

1.1.4 AIR QUALITY

At the present time there is no published information on air quality in the Mackenzie Valley. The Environmental Protection Service of Environment Canada operates air quality monitoring stations at Whitehorse and Yellowknife, but does not monitor the Mackenzie Valley.

According to Eley (1974) and Benson (1969), certain conditions may lead to deterioration of air quality. Low-lying areas may be more susceptible to ice fog and air pollution episodes due to cold air drainage and temperature inversions. On the other hand, slopes and wind-swept hilltops are less likely to experience these conditions.

The Atmospheric Environment Service of Environment Canada has systematically collected samples of precipitation for chemical analysis at various locations in Canada since June 1977. Fort Simpson was chosen as one of the initial CANSAP (Canadian Network for Sampling Precipitation) stations, becoming operational in January 1978. However, the station was abandoned after July of the same year. The Fort Simpson station has not provided sufficient data to establish 'norms' for ion concentrations or pH levels (Table 1.1-4). Furthermore, analyses of individual precipitation samples has shown that ion concentrations vary greatly depending upon prior atmospheric conditions, airflow trajectories, and precipitation amounts and intensities. Therefore, the analysis of bulk precipitation samples on a monthly basis may not be appropriate for northern locations, and no conclusions may be drawn from the existing CANSAP data.

TABLE 1.1-4

CANSAP PRECIPITATION DATA SUMMARY FOR HAY RIVER AND FORT SIMPSON
(Source: Atmospheric Environment Service, 1977-1980)

Station:	Hay River		Fort Simpson			
Year:	1980		1978			
Month:	Feb.	May	Jan.	Apr.	June	July
Sampling Period (Days)	18	31	31	30	31	32
Catch of Collector (mm)	1	11	2	3	7	39
Catch of Standard (mm)	2	21	10	14	64	77
pH	7.6	6.8	6.8	—	7.0	6.5
Conductance (u s/cm)	—	91.2	—	—	36.0	11.0
Acidity (u g/L)	—	—	—	—	—	—
Sulfate (SO_4^{*})(mg/L)	16.1	6.7	1.8	5.0	4.7	—
Nitrate (NO_3-)(mg/L)	—	1.86	BD	.09	.06	.02
Chloride (Cl-)(mg/L)	13.20	4.67	.53	1.90	1.00	.07
Ammonium (NH_4+)(mg/L)	—	1.44	.00	.01	.01	.01
Sodium (Na+)(mg/L)	—	2.6	—	1.8	.5	BD
Potassium (K+)(mg/L)	—	3.20	.04	1.23	.73	BD
Magnesium (Mg+3)(mg/L)	—	.97	.12	.10	.05	.21
Calcium (Ca++)(mg/L)	—	10.00	.70	1.40	—	1.75

*BD * Values that were below detectable limits.

1.1.5 WEATHER OF THE MACKENZIE RIVER VALLEY

1.1.5.1 Temperature

The analysis of the temperature regime for the Mackenzie River Valley is complicated by having all its meteorological stations situated adjacent to the river, making them unrepresentative of conditions within the more complex terrain of the Valley as a whole. Thus, environments within tributary valleys and at higher elevations are likely to have significantly different daily and seasonal temperatures.

In the Mackenzie Valley there is a mountainous region to the west and a broad uniform region of low-lying terrain to the east. The climate within the Valley may be considered as a transition between that experienced in these two regions since it exhibits a large degree of variability.

Temperatures within the Mackenzie Valley follow the expected north to south gradient of colder temperatures in the north and somewhat milder temperatures in the south. Examples of the yearly temperature cycle at two stations (Norman Wells A, Fort Simpson A) are given in Figure 1.1-2. However, considerably greater temperature gradients are found across the Valley from west to east. The mountainous western portion of the Valley is more likely to experience air mass subsidence or penetrations of warmer Gulf of Alaska air, while the eastern region is more likely to be influenced by relatively stable Arctic air under anticyclonic conditions, particularly during winter. The contrasting air masses produce a west to east temperature gradient west of the river, and a north to south gradient east of the river.

Local differences in temperature maxima and minima are superimposed on these regional patterns of thermal gradients. During the winter the highest temperatures occur over higher ground due to the characteristic Arctic inversion (Section 1.1.2). In summer, when lapse rates assume the more normal decrease of temperature with height, lower minimum temperatures are associated with higher terrain. Large bodies of water act as heat sinks in the summer and result in local temperature minima, while in the autumn and early winter net heat flux is upward from the water, resulting in thermal maxima. River valleys, lower terrain and plateaus are generally areas of local temperature minima due to ponding effects, cold air drainage, and thermal inversions in the winter. In summer, these same areas may become sites of local temperature maxima relative to higher terrain during warm windless days, although nocturnal radiation cooling often produces inversions. As a result of all of the above effects, thermal fields within this region are characterized by large meso-scale variability.

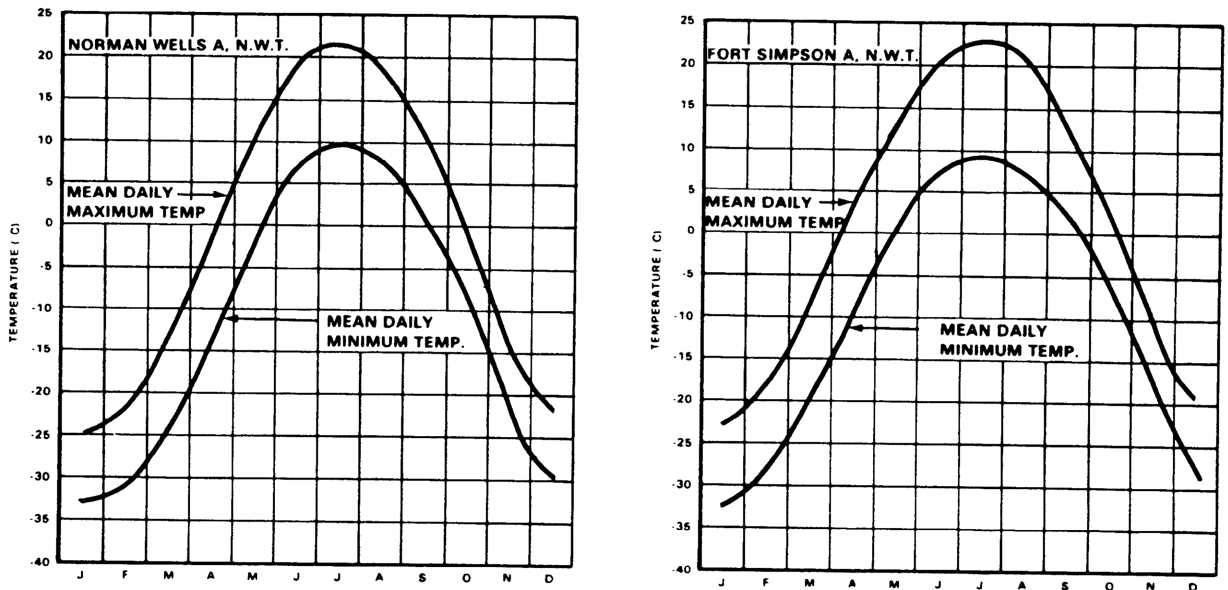


FIGURE 1.1-2 *Annual cycle of mean daily air temperatures at Norman Wells Airport and Fort Simpson Airport, N.W.T. (Source: Atmospheric Environment Service, 1975a). Although Norman Wells (65° 17'N) is well north of Fort Simpson (61° 52'N), mean daily temperatures are similar. Considerably greater temperature gradients are found across the Valley from west to east.*

July is usually the warmest month of the year within the Mackenzie Valley, while January is the coldest month. Mean daily temperatures in July exhibit little variation, ranging from approximately 13°C in the lower Mackenzie Valley to about 16°C in the southern portions of the upper Mackenzie Valley. Temperatures along the entire length of the Valley are also warmer than adjacent regions to either the west or east. In winter the lower Mackenzie Valley is colder than the upper regions, with mean daily temperatures of approximately -30°C in January. The upper Mackenzie Valley (south of Fort Norman) has more or less uniform temperatures during January, ranging from about -24°C to -29°C. In addition, a very strong thermal gradient exists at this time along the leeward slope of the mountains to the west.

The most pronounced seasonal temperature differences within the Mackenzie Valley occur in the spring and autumn. There is a gradual progression of spring from south to north as air masses are changed by an increase in solar radiation at the surface combined with reduced surface albedoes due to less snow and ice cover. This pattern is reversed in the autumn. During these seasons a true north to south thermal gradient exists along the length of the Mackenzie Valley, although it is somewhat altered by the persistent west to east temperature gradient. The north-south gradient is slightly stronger in spring than it is during autumn. Mean daily temperatures in April range from about -9°C in the north to -4°C in the south. In October the mean temperatures from north to south are -5°C to -1°C, respectively.

The mean annual number of frost-free days along the length of the Mackenzie Valley ranges from 70 to 90 days (Figure 1.1-3). Last frost usually occurs between May 30 and June 10 while first frost usually occurs between August 10 and August 30 (Figures 1.1-4, 1.1-5).

According to Burns (1973), the greatest extremes in temperature are most likely to occur in the continental areas along the upper reaches of the Mackenzie Valley. The record extreme minimum for Fort Simpson is -56°C, while the extreme maximum is 36°C. Table 1.1-5 provides estimates of return periods of annual extreme maximum and minimum temperatures. Differences between stations in the region are minor, especially for return periods of fewer than 20 years.

The percentage probability of occurrence of extremely cold temperatures is higher in northern sectors of the Valley than in the south (Burns, 1973). For example, at Fort Good Hope there is a 10 to 25% probability that mean daily temperatures of less than -40°C will occur between mid December and mid February. At Fort Simpson, the probability of such a temperature is reduced to between 3 and 8%, and at the same time, minimum daily temperatures below -40°C do not persist for longer than six consecutive days. At Fort Good Hope temperatures less than -40°C may persist from 7 to 12 days during December and January.

1.1.5.2 Wind

Within the Mackenzie Valley the predominant winds parallel the river valley. However, since the recording stations are all located adjacent to the river, significant differences in wind fields may be expected at other locations along the periphery of the Valley.

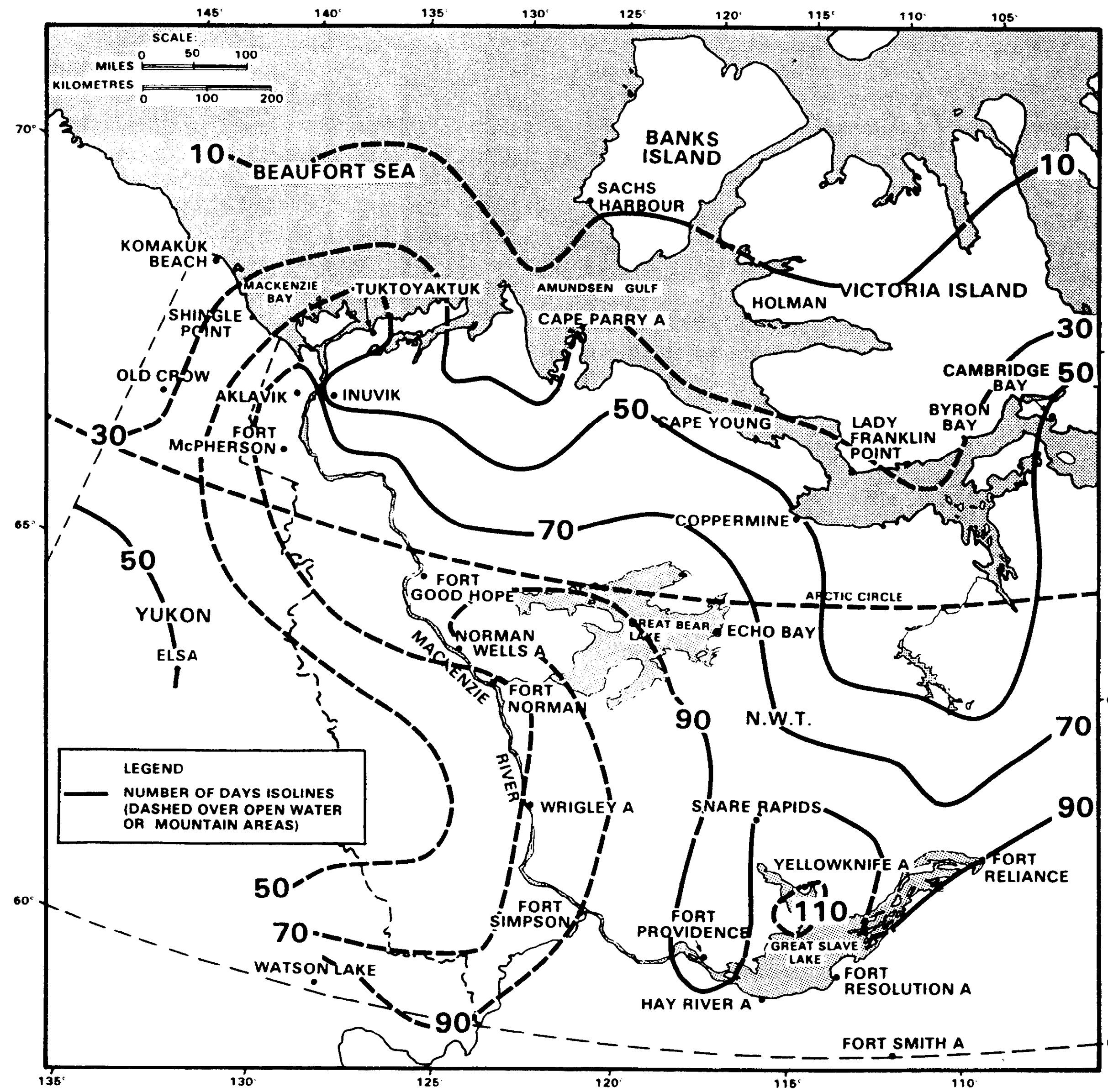


FIGURE 1.1-3 *Mean annual number of frost-free days (from Burns, 1973). The mean annual number of frost-free days along the length of the Mackenzie Valley ranges from 70 in the north to 90 in the south.*

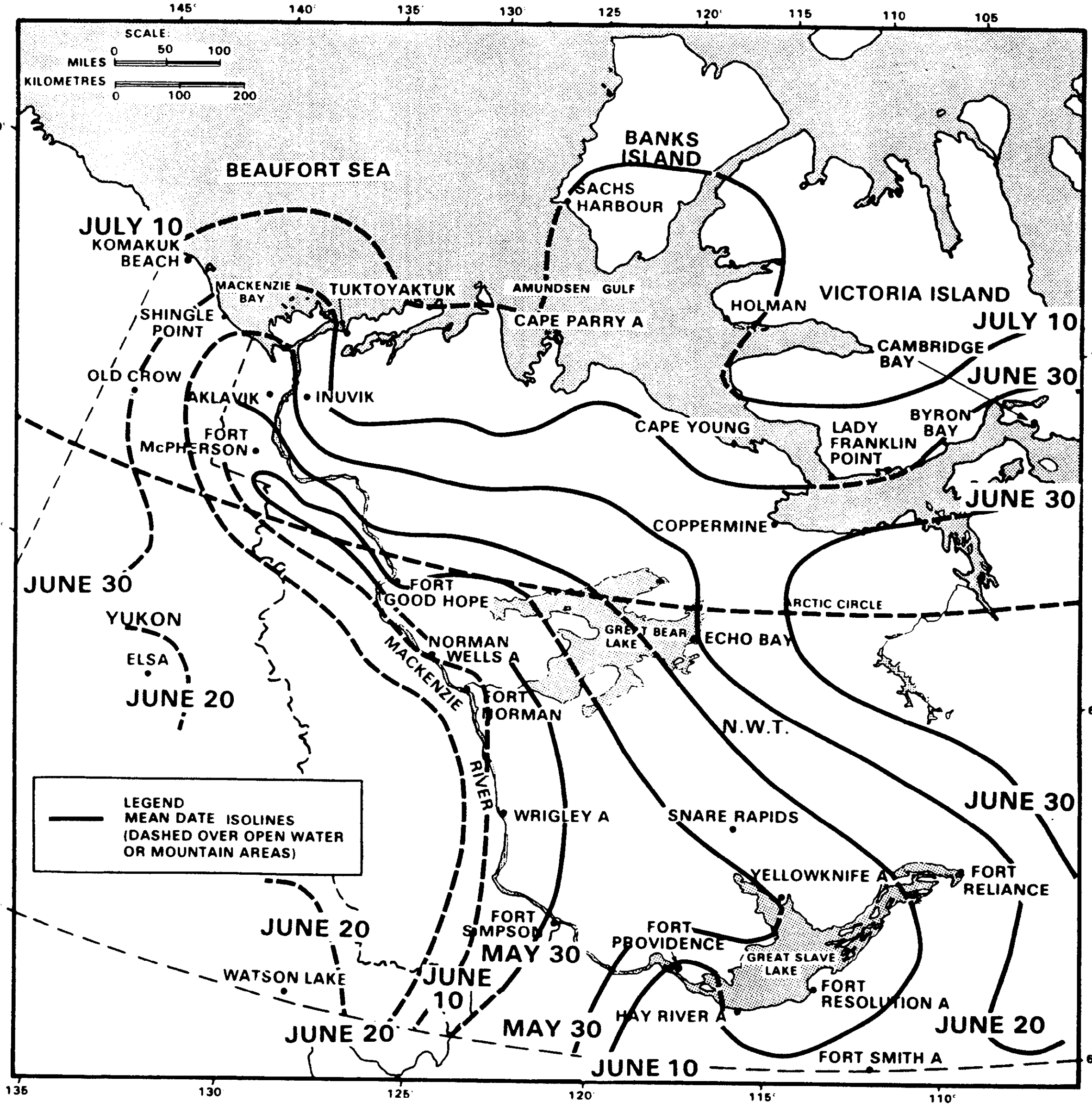


FIGURE 1.1-4 *Mean date of last (spring) frost in the Mackenzie Valley Region (from Burns, 1973). The last frost usually occurs in the northern part of the Valley near June 10 and in the south near May 30.*

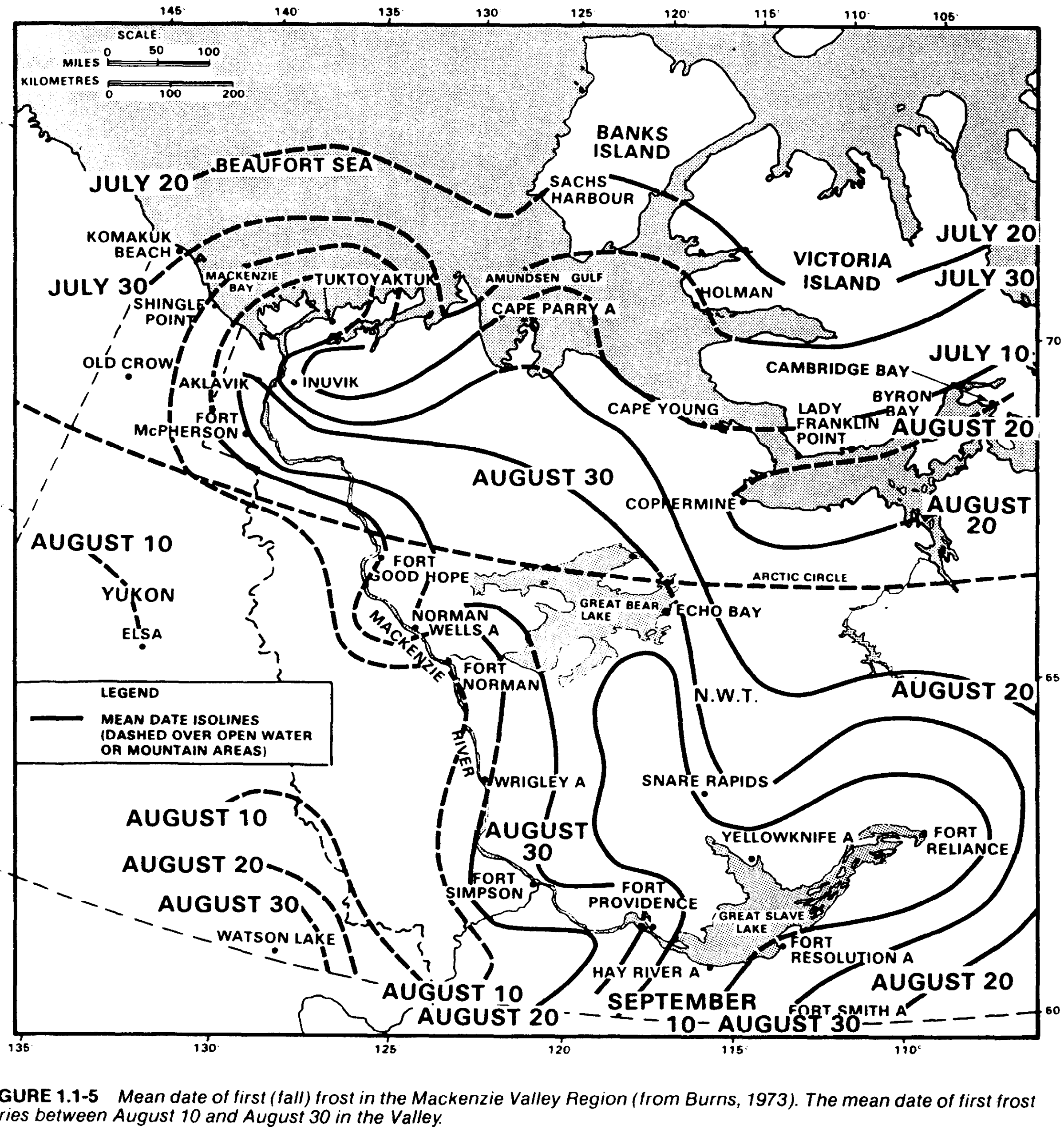


FIGURE 1.1-5 *Mean date of first (fall) frost in the Mackenzie Valley Region (from Burns, 1973). The mean date of first frost varies between August 10 and August 30 in the Valley.*

TABLE 1.1-5

ANNUAL EXTREME MAXIMUM AND MINIMUM TEMPERATURES (°C) AND ASSOCIATED RETURN PERIOD FOR METEOROLOGICAL STATIONS IN THE MACKENZIE VALLEY REGION*

EXTREME MAXIMUM TEMPERATURES

	Return Period (years)							
Station	**1.1**	**2**	**5**	**10**	**20**	**30**	**40**	**50**
Norman Wells A	29	30	31	32	33	33	33	33
Fort Good Hope 2	28	31	32	33	34	35	36	36
Fort Good Hope	29	31	32	33	34			
Wrigley A	28	31	33	34	36			
Fort Simpson	29	32	33	34	36	37	37	37
Fort Smith	29	32	33	34	36	36	37	37
Fort Smith A	29	31	33	34	35	36	36	37

EXTREME MINIMUM TEMPERATURES

	Return Period (years)							
Station	**1.1**	**2**	**5**	**10**	**20**	**30**	**40**	**50**
Norman Wells A	-44	-47	-49	-52	-53	-54	-54	-55
Fort Good Hope 2	-47	-51	-53	-54	-56	-57	-58	-58
Fort Good Hope	-47	-49	-52	-53	-54			
Wrigley A	-43	-46	-49	-52	-53	-54	-54	-55
Fort Simpson	-42	-46	-50	-53	-55	-57	-57	-58
Fort Smith	-43	-47	-52	-54	-56	-58	-58	-59
Fort Smith A	-44	-46	-48	-49	-50	-52	-52	-52

*** Source: Burns, (1973).**

The air flow in the Mackenzie Valley is principally influenced by topography. Winds are channelled along valleys, causing localized patterns which are often different from the prevailing winds of the region. The wind speed and direction in each valley is determined by its orientation to prevailing winds, as well as each valley's narrowness, depth, length and straightness. Diurnal katabatic, anabatic and lake breezes also introduce variations in prevailing winds. The baroclinic zone (thermal gradient) along the western side of the Mackenzie Valley (Section 1.1.5.1) reinforces the channelling of winds along the Valley. Occasionally, favourable atmospheric conditions may result in chinooks and mountain lee waves which produce cross-valley winds and local subsidence.

Wind speeds and seasonal wind directions recorded at Norman Wells and Fort Simpson are illustrated in Figures 1.1-6 and 1.1-7. These data indicate that within the Mackenzie Valley, maximum mean wind speeds generally occur during the summer at Norman Wells and during the spring and autumn at Fort Simpson. Wind speed extremes occur in both winter and summer in the Norman Wells area. Wind speed extremes generally occur only during winter months at Fort Simpson.

Calms occur with greater frequency and persist for longer periods at Fort Simpson than at Norman Wells. From December to February, calms at Fort Simpson occur 26.7% of the time as compared with

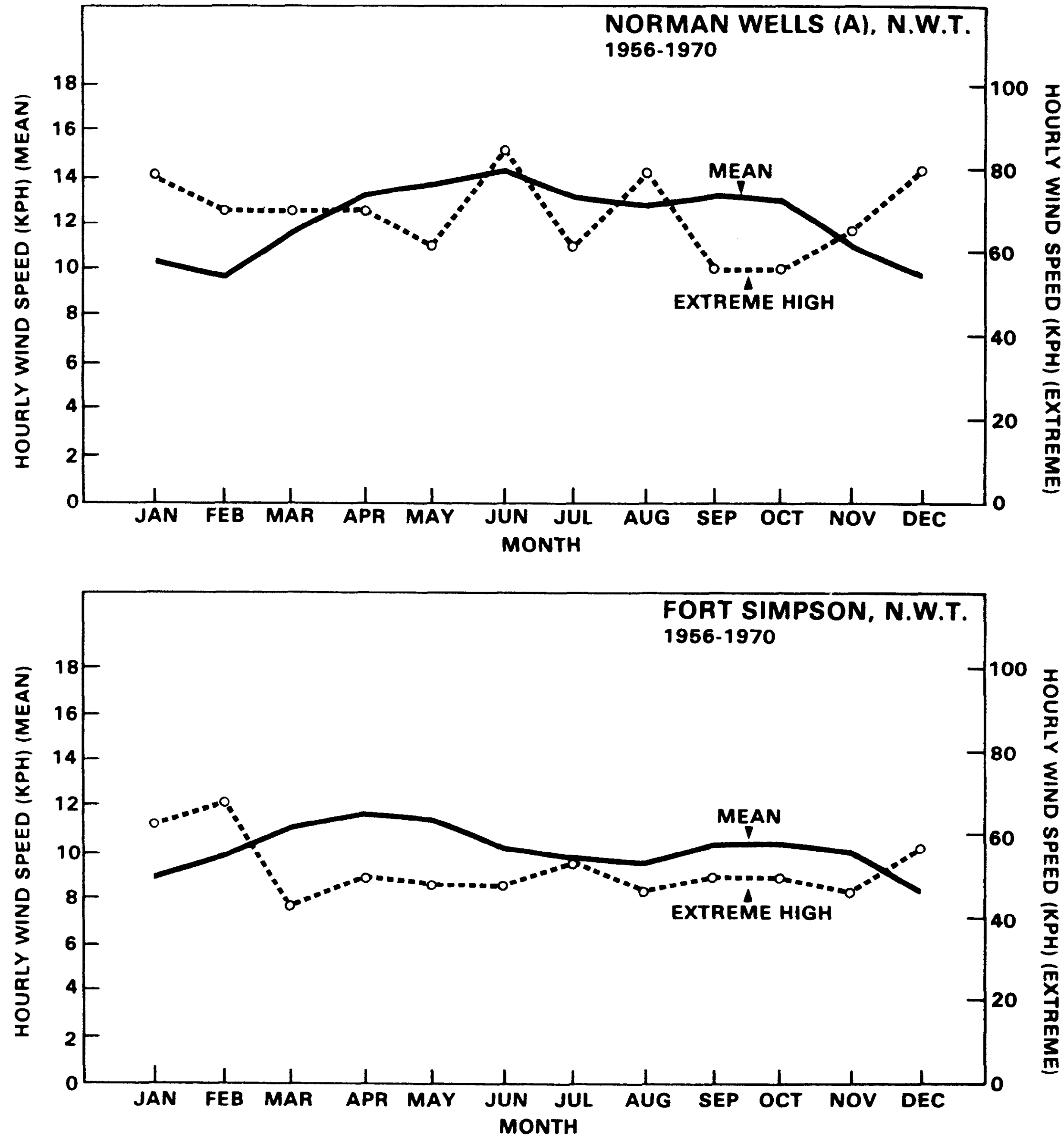


FIGURE 1.1-6 *Mean and extreme hourly wind speeds (km/hr) recorded at Norman Wells Airport and Fort Simpson, N.W.T. (Source: Burns, 1973). Maximum mean wind speeds generally occur during the spring and autumn at Fort Simpson and during the summer further north at Norman Wells.*

9.3 to 16.7% at other times of the year. The maximum duration of winter calms at Fort Simpson is 50 to 55 hours, while maximum duration of calms in summer is limited to approximately 23 hours (Burns, 1973). The maximum duration of a particular wind speed decreases with increasing wind speed. Persistence of winds is longest in winter and spring and shortest in summer for all wind speed categories. Extreme winds (in excess of 65 km/h) generally do not persist for more than 4 hours in the Mackenzie Valley (Burns, 1973).

Table 1.1-6 presents return periods for computed annual maximum hourly wind speeds based on data from selected locations. The data suggests a decrease in the frequency of extreme high winds from the lower to the upper Mackenzie Valley.

1.1.5.3 Precipitation

To a large extent precipitation within the Mackenzie Valley and adjacent areas is directly related to topography. There is little variability in the mean annual

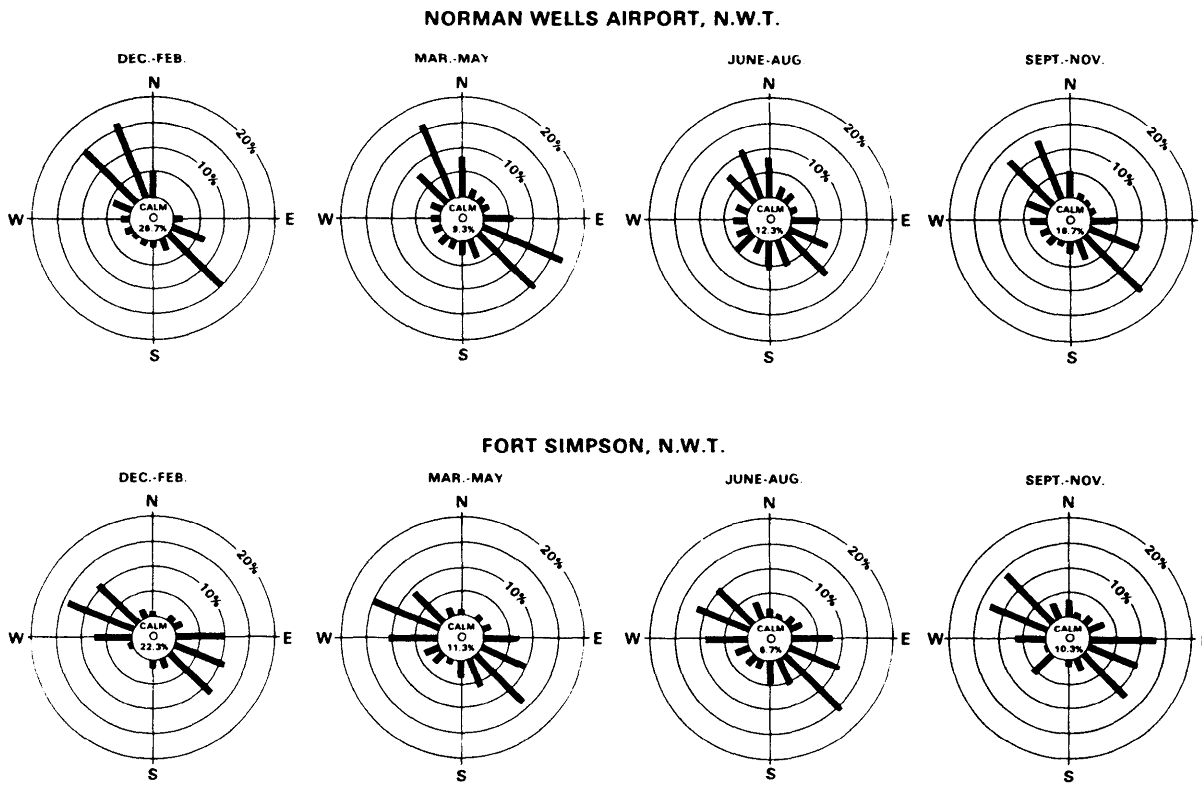


FIGURE 1.1-7 *Average seasonal wind direction frequencies (%) recorded at Norman Wells Airport and Fort Simpson, N.W.T. (Source: Atmospheric Environment Service 1975c). Winds are most frequent from the northwest and southeast in all seasons.*

TABLE 1.1-6

EXTREME MAXIMUM HOURLY WIND SPEEDS (km/h) AND ASSOCIATED RETURN PERIOD FOR METEOROLOGICAL STATIONS IN THE MACKENZIE VALLEY REGION

Source: Burns (1973)

	Return Period (years)							
Station	**1.1**	**2**	**5**	**10**	**20**	**30**	**40**	**50**
Norman Wells A	42	56	68	76	84			
Wrigley A	37	48	58	66				
Fort Simpson	35	43	50	55	60			
Fort Smith A	37	46	54	59	66	69	70	72

totals of rainfall, snowfall, or total precipitation between stations along the length of the river, except that stations north of Fort Good Hope have lower precipitation than stations to the south. However, all stations lie at elevations between 40 and 200 metres above sea level. Burns (1974) estimated that the percentage increase in precipitation per 1,000 ft (330 m) within the Valley south of Fort Good Hope would be approximately 20%, while the increase would be only about 15% per 1,000 ft. north of Fort Good Hope. In the mountains to the west of the Mackenzie Valley the percentage increase in precipitation with elevation ranges between 25 and 35% per 1,000 feet. Therefore, all figures provided in this section should be considered as representative of the lowest precipitation amounts likely to be encountered in the Valley, and should be increased for areas at higher elevations.

Examples of the yearly precipitation cycle at two stations (Norman Wells A, Fort Simpson A) are given in Figure 1.1-8. The coefficient of variability for total monthly precipitation ranges from 15 to 20%. However, in any month of the year individual totals of rainfall or snowfall may vary from zero to almost double the mean (Burns, 1974). The mean annual total precipitation ranges from a low of 283.8 mm at Fort Good Hope to a high of 345.5 mm at Fort Simpson townsite. Most other locations receive approximately 330 mm precipitation each year. July and August are the months with highest total precipitation (Figure 1.1-8). Stations in the south of the region record peak monthly precipitation in July, while stations in the north have greatest precipitation in August. The annual mean number of days with measurable precipitation varies from approximately 100 to 130 days (Table 1.1-7). Precipitation is most frequent during the winter, when it occurs as light snowfalls. However, the bulk of it is in the form of rainfall during the months from June to September accounting for between 45 and 55% of the annual mean total. Rainfall is dominant at low elevations and latitudes, while snowfall becomes progressively more important at higher elevations and latitudes.

Table 1.1-8 shows the computed return periods for greatest 24-hour precipitation at various stations within the Mackenzie Valley region. It may be assumed that the magnitude of maximum 24-hour precipitation will be greater at higher elevations, although there is no way to estimate its increase.

(a) Rainfall

Rain falls in this region between April and November, with peak rainfall generally occurring from June to August. There is very little rainfall in either March or

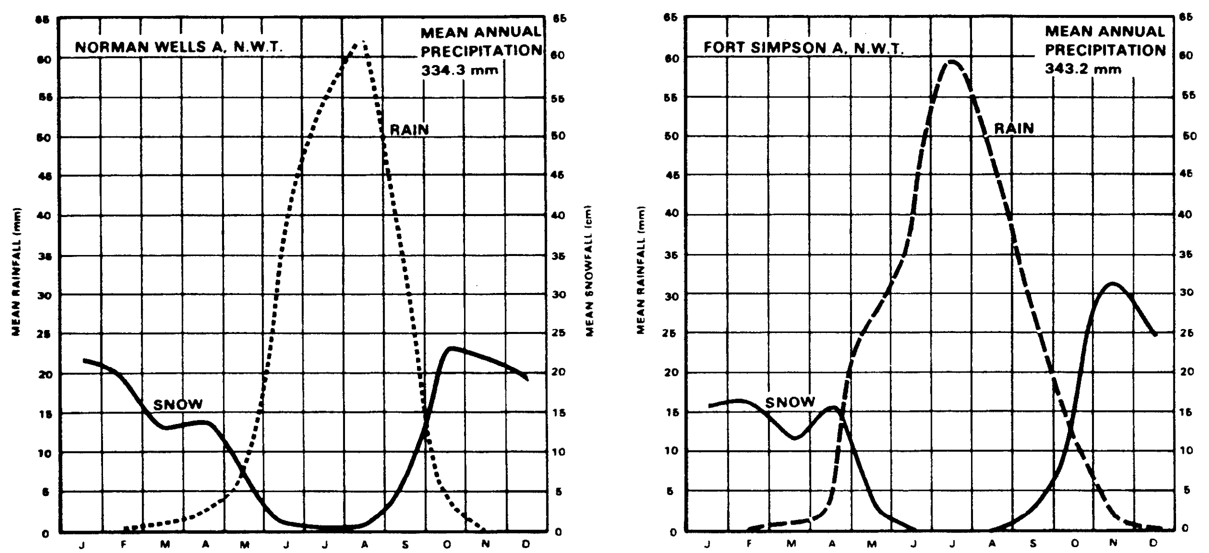


FIGURE 1.1-8 *Annual cycle of mean monthly precipitation at Norman Wells Airport and Fort Simpson Airport, N.W.T. (Source: Atmospheric Environment Service, 1975b). July and August are the months with the highest total precipitation which falls as rain. Stations in the north have greatest precipitation in August while those in the south record their peak monthly precipitation in July. Precipitation is most frequent in winter when it occurs as light snowfall.*

TABLE 1.1-7

SEASONAL DIFFERENCES IN THE NUMBER OF DAYS WITH MEASURABLE PRECIPITATION IN THE MACKENZIE VALLEY REGION

Source: Atmospheric Environment Service (1975b).

Station	J	F	M	A	M	J	J	A	S	O	N	D	Total
Fort Good Hope	9	8	8	5	5	7	8	11	9	11	10	10	101
Fort Good Hope 2	9	9	9	7	6	9	10	13	11	11	11	10	115
Norman Wells A	13	12	10	8	7	10	11	12	11	13	14	12	133
Wrigley A	10	9	8	6	7	9	11	10	9	9	11	9	108
Fort Simpson	11	10	10	7	7	10	10	10	9	9	11	12	116
Fort Smith A	13	11	10	7	7	9	10	10	11	11	14	14	127

TABLE 1.1-8

MAXIMUM 24-HOUR PRECIPITATION (mm.) AND ASSOCIATED RETURN PERIOD FOR METEOROLOGICAL STATIONS IN THE MACKENZIE VALLEY REGION

Source: Burns (1974)

	Return Period (years)							
Station	**1.1**	**2**	**5**	**10**	**20**	**30**	**40**	**50**
Fort Good Hope	2.5	20.3	38.1	50.8	61.0			
Fort Good Hope 2	15.2	25.4	35.6	43.2	48.3	53.3	55.9	58.4
Norman Wells	15.2	25.4	35.6	43.2	53.3	58.4	63.5	63.5
Wrigley A	17.8	25.4	33.0	38.1	43.2			
Fort Simpson	15.2	27.9	43.2	50.8	61.0	66.0	68.6	71.1
Fort Smith A	15.2	25.4	33.0	38.1	43.2	45.7	48.3	50.8
Fort Smith	12.7	25.4	35.6	43.2	50.8	55.9	58.4	61.0

December, and only trace amounts are recorded in January and February. Approximately 50% of the rain falls between May and July in northern areas, and between March and July in southern areas. However, the coefficient of variation on mean rainfall statistics is very high, ranging from 25 to 30%.

The annual mean number of days with measurable rainfall varies from between 30 and 40 in the lower Mackenzie Valley to between 40 and 55 in the upper Mackenzie Valley. Rainfall is expected to occur on between 30 and 70 days per year in the mountains to the west (Burns, 1974). Total annual mean rainfall ranges from approximately 100 mm in the extreme north of the region to about 200 mm in the extreme south.

Thunderstorms are relatively rare in the northern sections of the Mackenzie Valley, but they occur more often with distance southward. Most thunderstorms occur in July, when they last, on average, for three hours at Norman Wells, five hours at Fort Simpson and nine hours at Fort Smith. Higher elevations may be expected to experience more frequent thunderstorms.

Significant amounts of both rain and snow occur during April and October (Figure 1.1-8). Norman Wells and Fort Simpson report freezing precipitation from September to December, with a peak frequency of occurrence of about 1% in October. Freezing precipitation rarely occurs from December to May. On the other hand, in the extreme southern sector of the upper Mackenzie Valley, around Fort Smith, freezing precipitation occurs much more frequently from September to April, with a maximum frequency of about 2% in November, and a secondary maximum of about 0.4% in February. At Norman Wells, the occurrence of freezing precipitation is relatively evenly distributed throughout the day. However, in the extreme northern sections of the lower Mackenzie Valley frequent overnight occurrences of freezing precipitation are more common due to the influence of the Beaufort Sea.

(b) Snowfall

At Fort Simpson, only light snowfalls or trace amounts may be expected in June and August, but none in July (Figure 1.1-8). At least trace amounts of snow may be recorded in every month of the year in the lower Mackenzie Valley.

Mean annual snowfall does not vary much over most of the Mackenzie Valley, ranging from 120 to 140 cm per year. However, large variations in snowfall occur between years and regions within the same winter. Most stations in this region record snowfall on between 60 to 90 days of the year, with higher elevations experiencing more frequent snowfall events. The lower Mackenzie Valley has a mean maximum snowfall in October, while the upper Mackenzie Valley records mean maximum snowfalls in November. The greatest variabilities in amounts of snowfall occur in the months with maximum snowfall. Extreme 24-hour snowfalls usually range from 25 to 35 cm in the region, although Fort Norman has recorded as much as 61.5 cm in one 24 hour period.

The majority of snowstorms are of short duration, lasting less than 24 hours. Most of these short snowfalls occur in the early morning. In addition, most stations within the Mackenzie Valley have recorded at least one snowstorm which lasted more than 72 hours. The longest snowstorms are likely to occur during the period from November through January.

The earliest date for the establishment of first snow cover to a depth of at least 2.5 cm ranges from August 31 to September 20 in the lower Mackenzie Valley. Within the upper Mackenzie Valley region the corresponding range is from September 10 to 30. Continuous snow cover (that is, months with no breaks in cover) generally lasts from November through April over most of the Mackenzie Valley, although in the extreme south continuous snow cover is limited to December through March. The latest date of last snow cover over most of the valley ranges from May 20 to 30. In the extreme northern sector of the lower Mackenzie Valley, snow cover may last until approximately June 10. The mean number of days of continuous snow cover ranges from 200 days in the south to 250 days in the north.

1.1.5.4 Visibility

Visibility within the Mackenzie Valley is generally good throughout the year. Visibility is most likely to be restricted during fall and winter as a result of fog or blowing snow.

From September to February, fog occurs at Fort Simpson and Norman Wells between 4 and 7% of the time. The lowest frequency of fog is during March, when both stations record less than 1% occurrence. There are no statistics on the relative frequency of ice fog in this region, but it may be assumed that at populated locations it has been reported under the general category of fog and is also represented by these statistics.

Blowing snow occurs most frequently during December and January, with its frequency of occurrence ranging from a high of 5% at Norman Wells to less than 2% at Fort Simpson.

Figure 1.1-9 shows the percentage frequency of

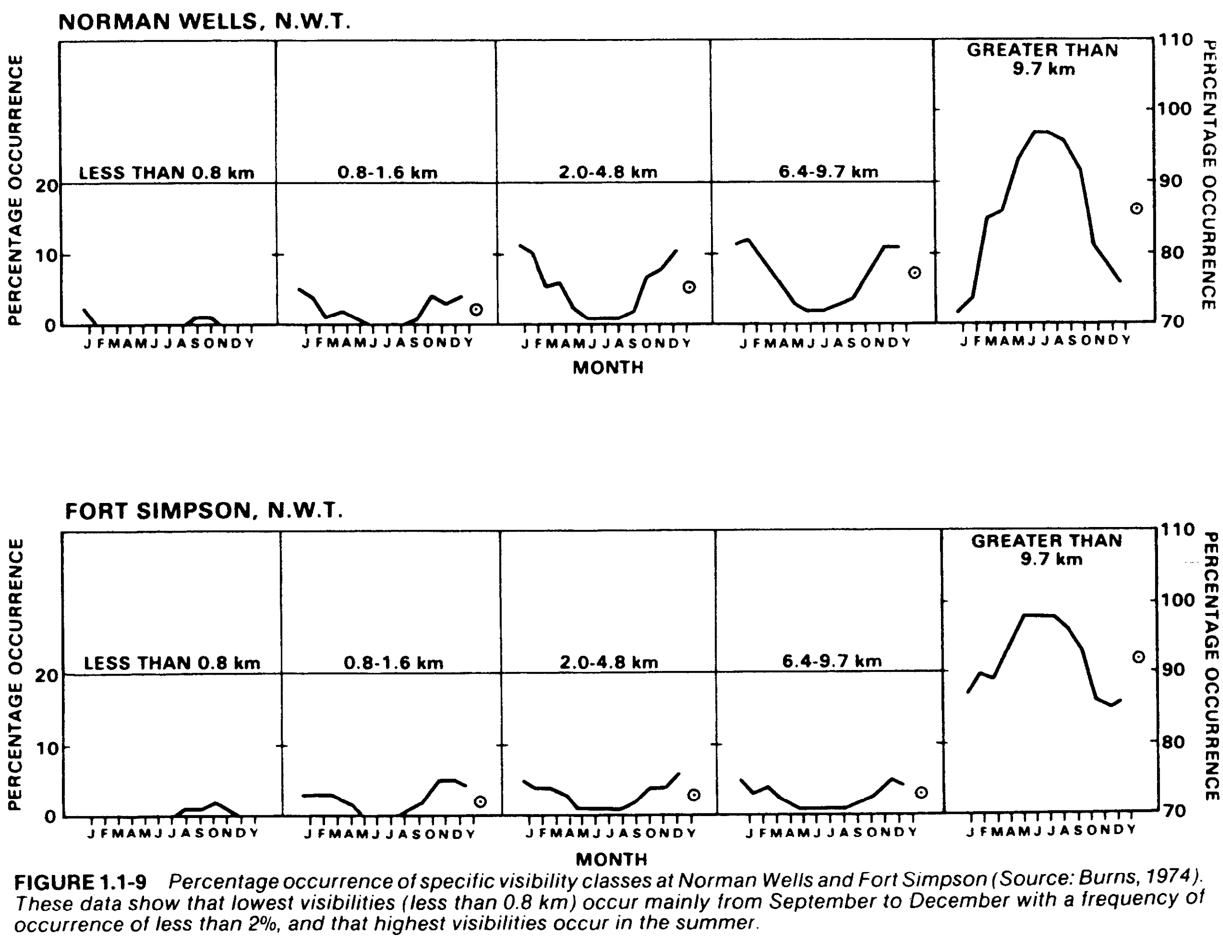


FIGURE 1.1-9 *Percentage occurrence of specific visibility classes at Norman Wells and Fort Simpson (Source: Burns, 1974). These data show that lowest visibilities (less than 0.8 km) occur mainly from September to December with a frequency of occurrence of less than 2%, and that highest visibilities occur in the summer.*

occurrence of specific visibility classes, while Figure 1.1-10 shows the maximum duration of each visibility class for various stations within the region. These data indicate that visibility of less than 0.8 km occurs mainly from September to December, with a maximum relative frequency of less than 2%. The maximum duration of limited visibility (less than 0.8 km) category ranges from 10 to 18 hours.

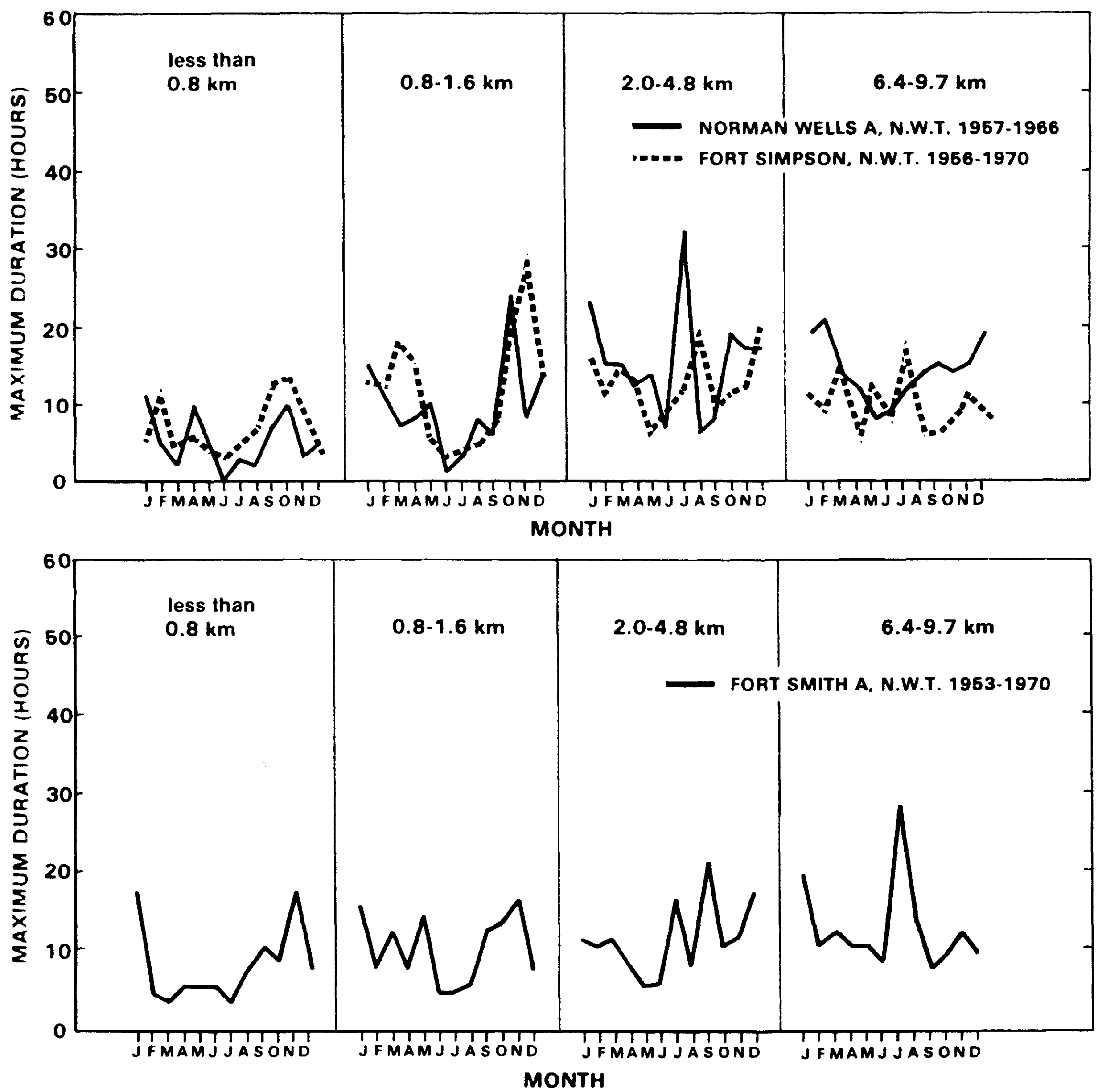


FIGURE 1.1-10 *Maximum duration of specific visibility classes at Norman Wells and Fort Simpson. (Source: Burns, 1974). The maximum duration of limited visibility (less than 0.8 km) ranges from 10 to 18 hours.*

1.2 GEOLOGY

The geology of the terrain within the Mackenzie Valley corridor is reviewed in this section. The review describes the geology in three separate narrow sub-regions encompassing the corridor, generally on the east side of the river. These are shown in Figure 1.2-1 as the Mackenzie Valley North, the Mackenzie Valley South and the Great Slave Plain-Alberta Plateau sub-regions. Figure 1.2-2 locates the places and water bodies named in the text. The reader can also refer to Table 1.2-1, which lists geological terms used, and to Table 1.2-2 which shows geological eras, periods and epochs occasionally referred to in the text.

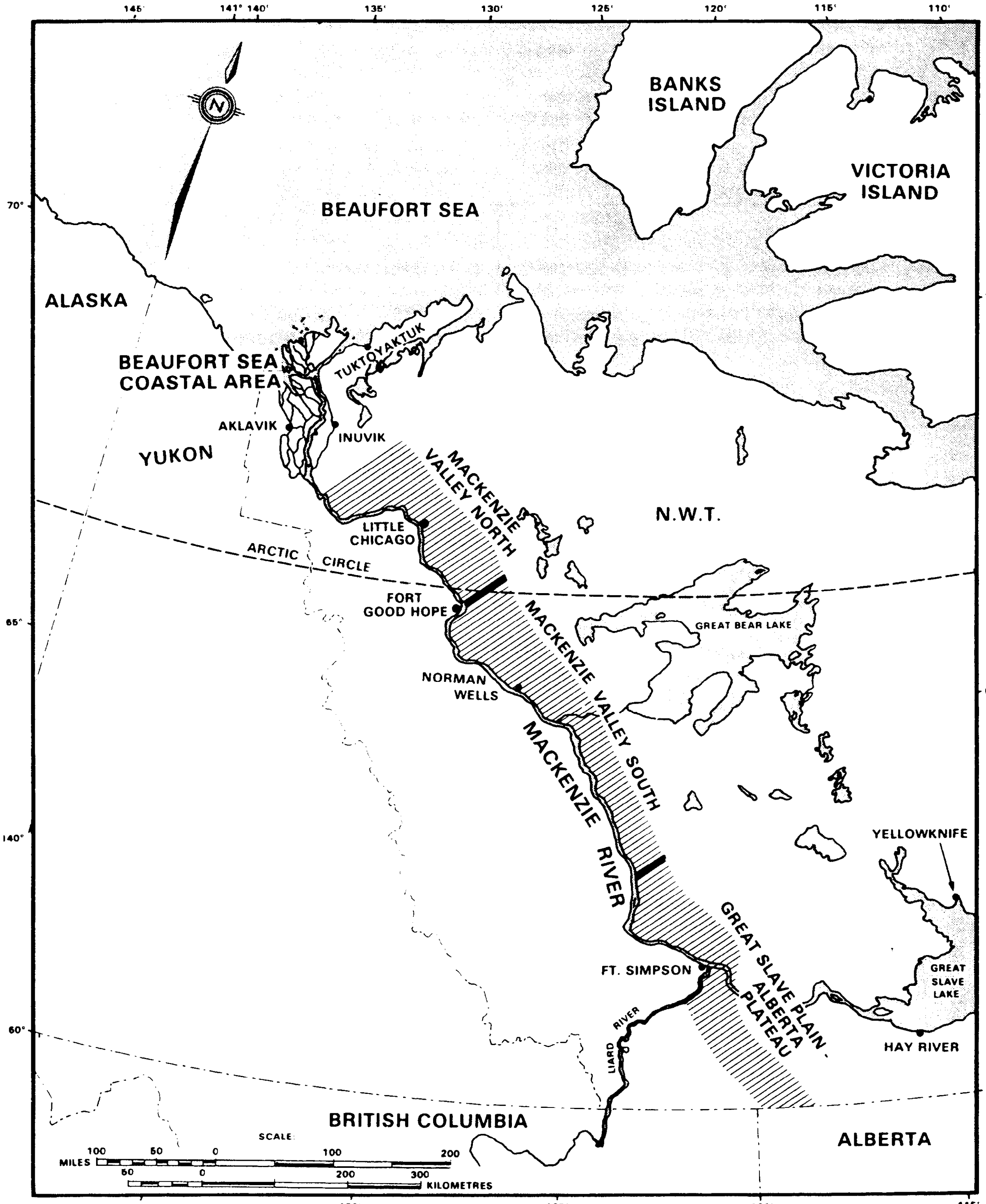


FIGURE 1.2-1 *Sub-regions of the Mackenzie Valley Corridor. Geological descriptions in the text are separated under the three sub-region headings: Mackenzie Valley North, Mackenzie Valley South, and Great Slave Plain-Alberta Plateau.*

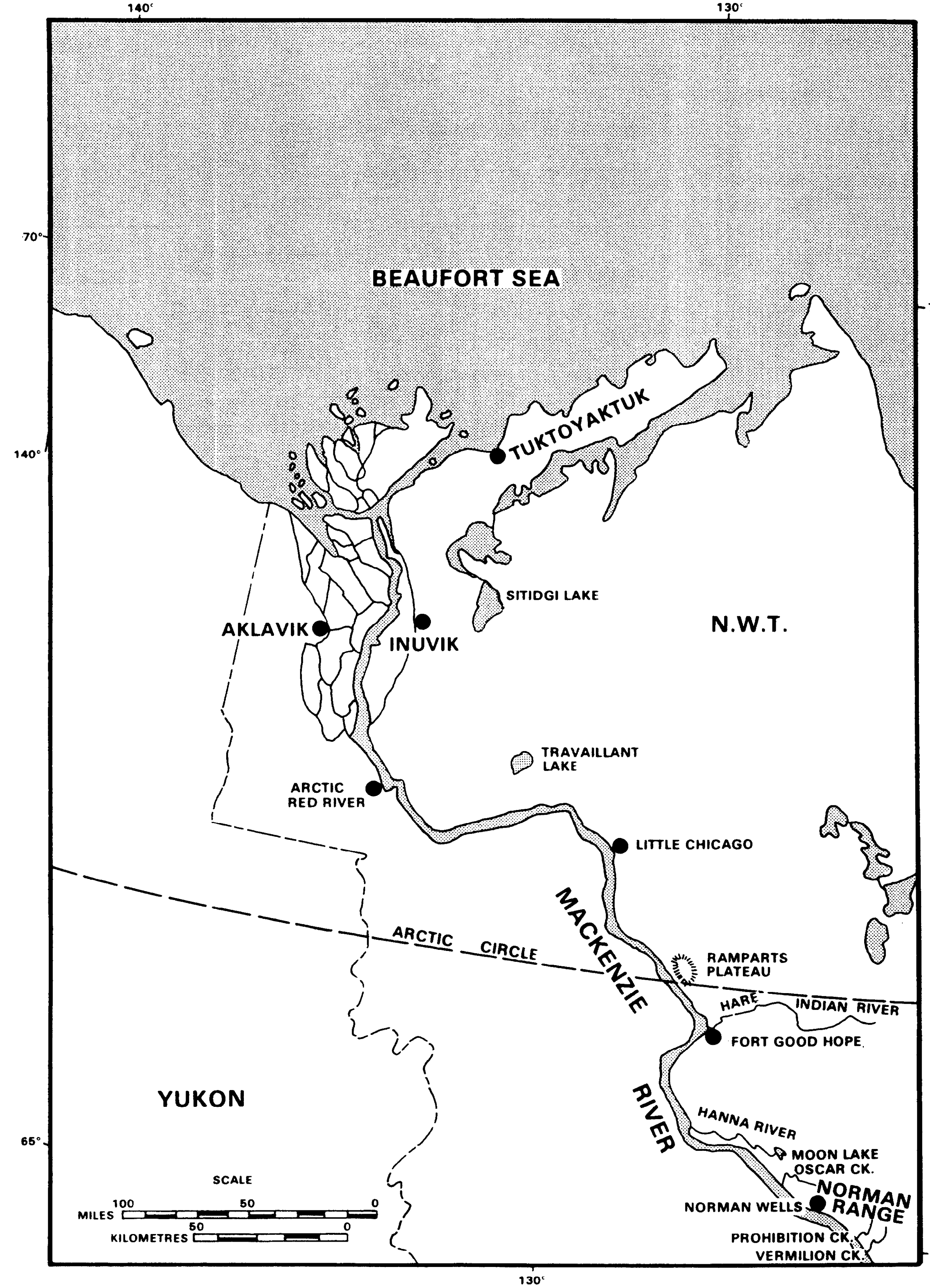


FIGURE 1.2-2 *Location of places named in the text.* (Continued next page).

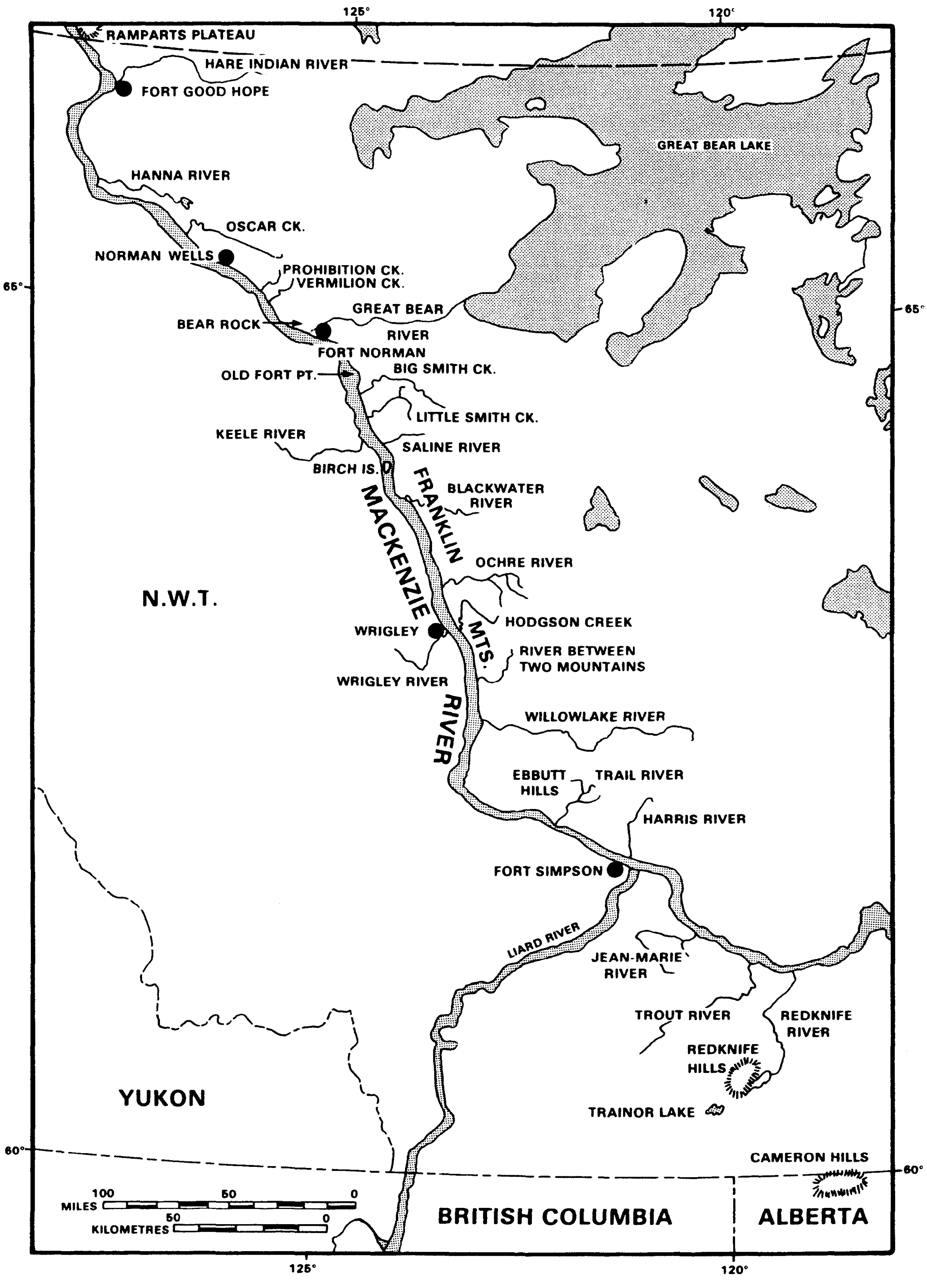


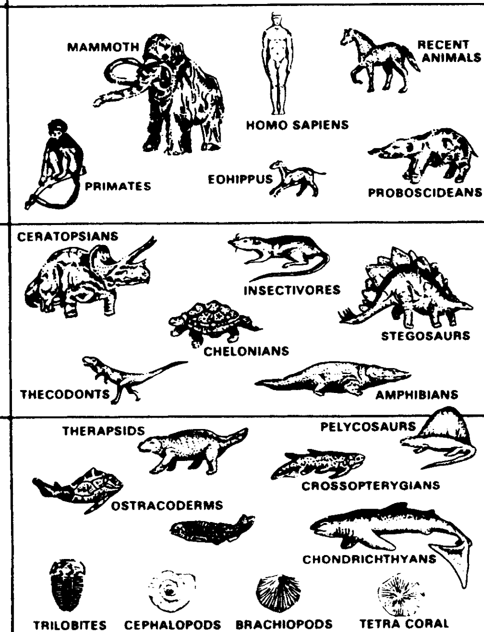
Figure 1.2-2 Continued

TABLE 1.2-1

GLOSSARY OF GEOLOGICAL TERMS

ACTIVE LAYER DETACHMENT SLIDE	A flow in which a thin unfrozen layer of vegetation and mineral soil (the active layer) slides over a frozen inclined surface.
ALLUVIAL	Refers to stratified deposits of gravel, sand and silt moved by modern streams from higher to lower ground.
ARGILLITE	A compact rock, generally of massive structure, derived from shale or mud.
COLLUVIAL	Describes sediments which are deposited at the base of steep slopes, either by mass wasting or surface flows.
CONGLOMERATE	A course grained, sedimentary rock, which includes rounded to subangular fragments embedded within a fine-grained rock.
CORDILLERAN	Pertaining to, or originating in, the (Western) Cordillera.
DELTA	A land form, generally triangular in shape, consisting of alluvial or glaciofluvial deposits.
DRUMLIN	An elongate or oval hill of glacial drift, commonly unstratified, deposited by glacier ice and having its long axis parrallel to the direction that the glacier moved.
ESKER	A long, sinuous ridge of sand and gravel, unrelated to the surrounding topography.
GLACIAL	Related to, deposited by, or originating from a glacier.
GLACIOFLUVIAL	Related to the meltwater streams flowing from glacier ice, and especially the deposits and landforms produced by such streams.
GLACIOLACUSTRINE	Related to glacial lake conditions, as in glaciolacustrine deposits; sediments deposited in lakes marginal to a glacier.
GLACIOMARINE	Pertaining to glacial processes and deposition in a marine environment.
ICE, AGGRADATIONAL	Additional newly-formed or incorporated ground ice resulting from a raising of the permafrost table or lowering of its base.
ICE, EPIGENETIC	Ground ice that formed after the deposition of the earth material in which it occurs.
ICE, GROUND	Ice in pores, cavities, voids or other openings in soil or rock, including massive ice.
ICE RETICULATE	Network of horizontal and vertical ice veins forming a three-dimensional rectangular or square lattice, commonly found in frozen glaciolacustrine sediments.
ICE VEIN	A seam or vein of ice occupying a crack that cuts across soil or rock layers.
ICE WEDGE	A massive, generally wedge-shaped, body of ice with its apex pointing downward.
KAME	A short irregular ridge, hill or mound of stratified drift deposited in contact with glacier ice by meltwater.
LACUSTRINE	Pertaining to, produced by, or formed in a lake; such as fine grained sediments deposited in lakes.
LAURENTIDE	Pertaining to, or originating in, the Laurentian Shield.
MARINE	Pertaining to, produced by, or formed in the sea; notably sediments deposited therein.
MORAINE	An accumulation of earth materials carried by and finally deposited by a glacier.
PEDIMENT	A plain or eroded bedrock, between a mountain and a plain, with or without a veneer of alluvial and colluvial material.
PERMAFROST	The thermal condition of soil or rock which is cooler than 0°C for more than one year.
PERMAFROST CONTINUOUS	Permafrost occurring everywhere beneath the esposed ground surface throughout a region.
PERMAFROST DISCONTINUOUS	Permafrost occurring in some areas beneath the ground surface in a region,but where other areas are free of permafrost.
PHYSIOGRAPHIC	Pertaining to the study of the beginning and evolution of land forms.
PINGO	A conical mound or hill, that occurs in continuous and discontinuous permafrost zones, and has a core of massive ground ice and exists for at least two winters.
PREGLACIAL	Occurring before a major glaciation.
RETROGRESSIVE-THAW FLOW SLIDE	A slide consisting of a steep head wall, which retreats through the melting of ground ice, and a debris flow which slides down the head wall to its base.
SOLIFLUCTION	The slow, viscous downslope flow of saturated, unfrozen, earth over a frozen surface.
STRATIGRAPHY	The branch of geology that deals with the definition and description of rocks.
TALIK	Unfrozen ground within the permafrost.
THERMOKARST (TOPOGRAPHY)	The irregular topography resulting from the thaw settlement of caving due to melting of ground ice.

TABLE 1.2-2
GEOLOGICAL TIME SCALE



ERAS	PERIODS	EPOCH	MILLIONS OF YEARS AGO (APPROX.)	EARLIEST RECORD OF ANIMALS	EARLIEST RECORD OF PLANTS
CENOZOIC	QUATERNARY	RECENT PLEISTOCENE	0-1	MAMMOTH, HOMO SAPIENS, RECENT ANIMALS	
	TERTIARY	PLIOCENE MIOCENE OLIGOCENE EOCENE PALEOCENE	1-13 13-25 25-76 36-58 58-63	PRIMATES, EOHIPPUS, PROBOSCIDEANS	GRASSES AND CEREALS
MESOZOIC	CRETACEOUS		63-135	CERATOPSIANS, INSECTIVORES	FLOWERING PLANTS
	JURASSIC		135-181	CHELONIANS, STEGOSAURS	PINES AND CYPRUS
	TRIASSIC		181-230	THECODONTS, AMPHIBIANS	CYCADS AND GINKGOES
PALEOZOIC	PERMIAN		230-280	THERAPSIDS, PELYCOSAURS	
	PENNSYLVANIAN		280-310	CROSSOPTERYGIANS	CONIFERS
	MISSISSIPPIAN		310-345	OSTRACODERMS	VASCULAR PLANTS
	DEVONIAN		345-405		MOSSES SPORES GYMNOSPERMS
	SILURIAN		405-425	CHONDRICHTHYANS	
	ORDOVICIAN		425-500		
	CAMBRIAN		500-600	TRILOBITES, CEPHALOPODS, BRACHIOPODS, TETRA CORAL	
PROTEROZOIC	PRECAMBRIAN			INVERTEBRATES FOSSILIZED REMAINS ONLY. WORMS, JELLYFISH, ALGAE	BACTERIA & ALGAE

1.2.1 MACKENZIE VALLEY NORTH

The Mackenzie Valley North sub-region is an area extending along the east side of the Mackenzie River from the southern edge of the Delta to the Franklin Mountains (Figure 1.2-1). Hughes *et al.*,(1973) provide the major source of geological information for this sub-region; other sources are identified in the text.

1.2.1.1 Topography and Relief

The general relief of the Mackenzie River Drainage Basin is shown in the simplified relief map of Figure 1.2-3. Corresponding physiographic regions are shown in Figure 1.2-4. The northern portion of the Mackenzie Valley corridor traverses the Anderson Plain physiographic region (Bostock, 1969). The terrain of the Anderson Plain south of Inuvik is relatively flat and featureless, with only a few areas having hummocky and drumlinoid topography. Elevations range from about 300 metres above sea level (asl) on the Anderson Plain north of Fort Good Hope to about 90 metres asl within the narrow lowland immediately adjacent to the Mackenzie River. With the exception of the prominent scarp which borders the river and lowland area to the east, slopes are generally less than 10 degrees.

1.2.1.2 Bedrock Geology

The western section of the Anderson Plain physiographic region is underlain by shales of the Upper Devonian Imperial Formation (Cook and Aitken, 1969). Included within the shale sequence are thinly interbedded layers of sandstone and argillite. However, the formation as a whole consists mainly of clay.

The southern portion of the Anderson Plain has greater relief than the west owing to the occurrence of limestone cappings over Middle Devonian shale (Cook and Aitken, 1969). Limestone outcrops also occur along the west side of the Ramparts Plateau and in cliffs along the Mackenzie River near Fort Good Hope. The bedrock geology of the MacKenzie Valley is shown in Figure 1.2-5.

1.2.1.3 Surficial Geology

The surficial geology of the northern section of the Mackenzie Valley corridor is shown in Figure 1.2-6. Detailed surficial geology is provided by the Geological Survey of Canada (1979). The surficial geology of the western Anderson Plain is relatively complex (Fulton, 1970) and is described in more detail in Section 1.3.1. Between Inuvik and the vicinity of

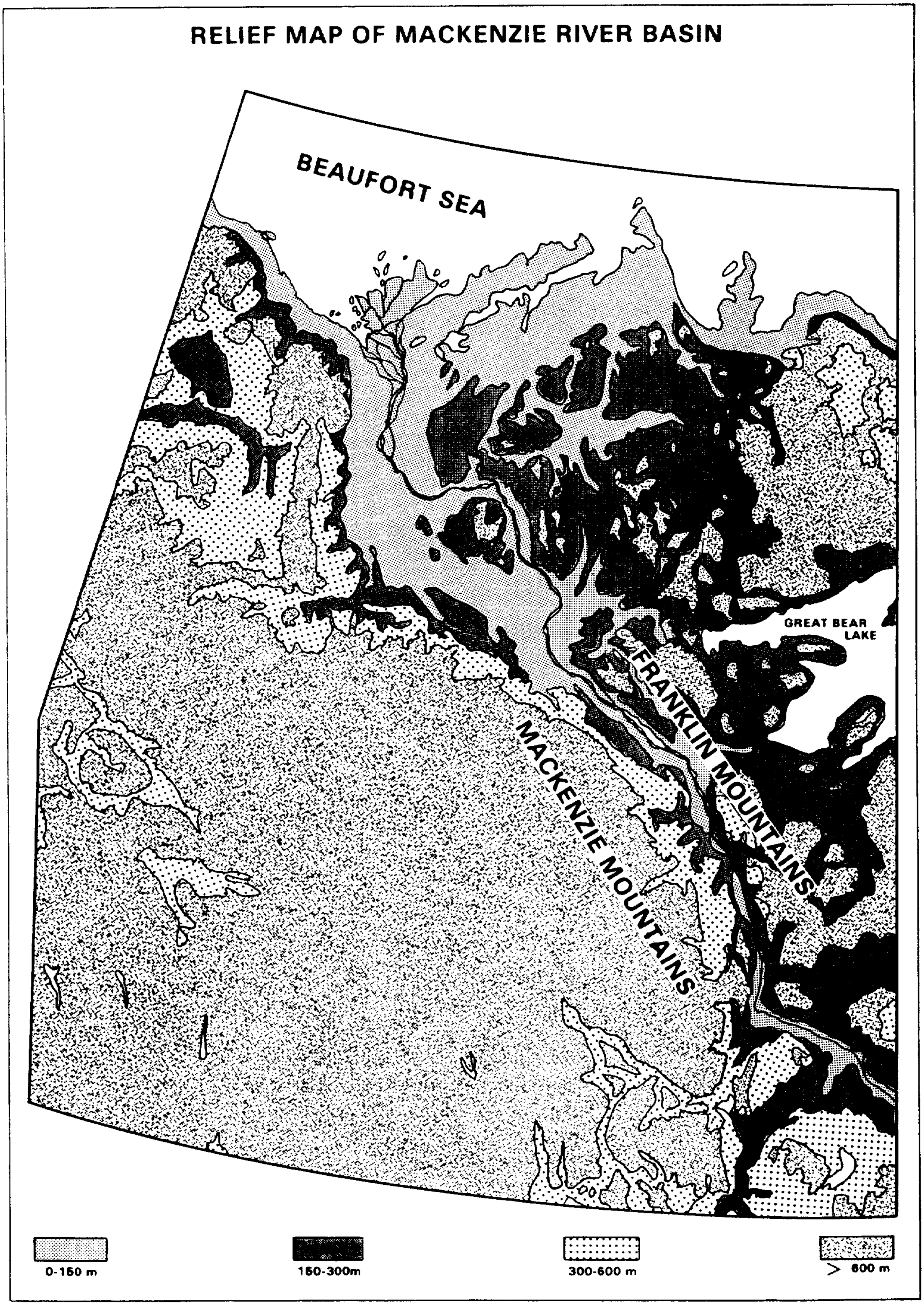


FIGURE 1.2-3 *General relief of the Mackenzie River Drainage Basin. Emphasis is placed on low altitude topography in this simplified relief map. (Source: Mackenzie River Basin Committee, 1981).*

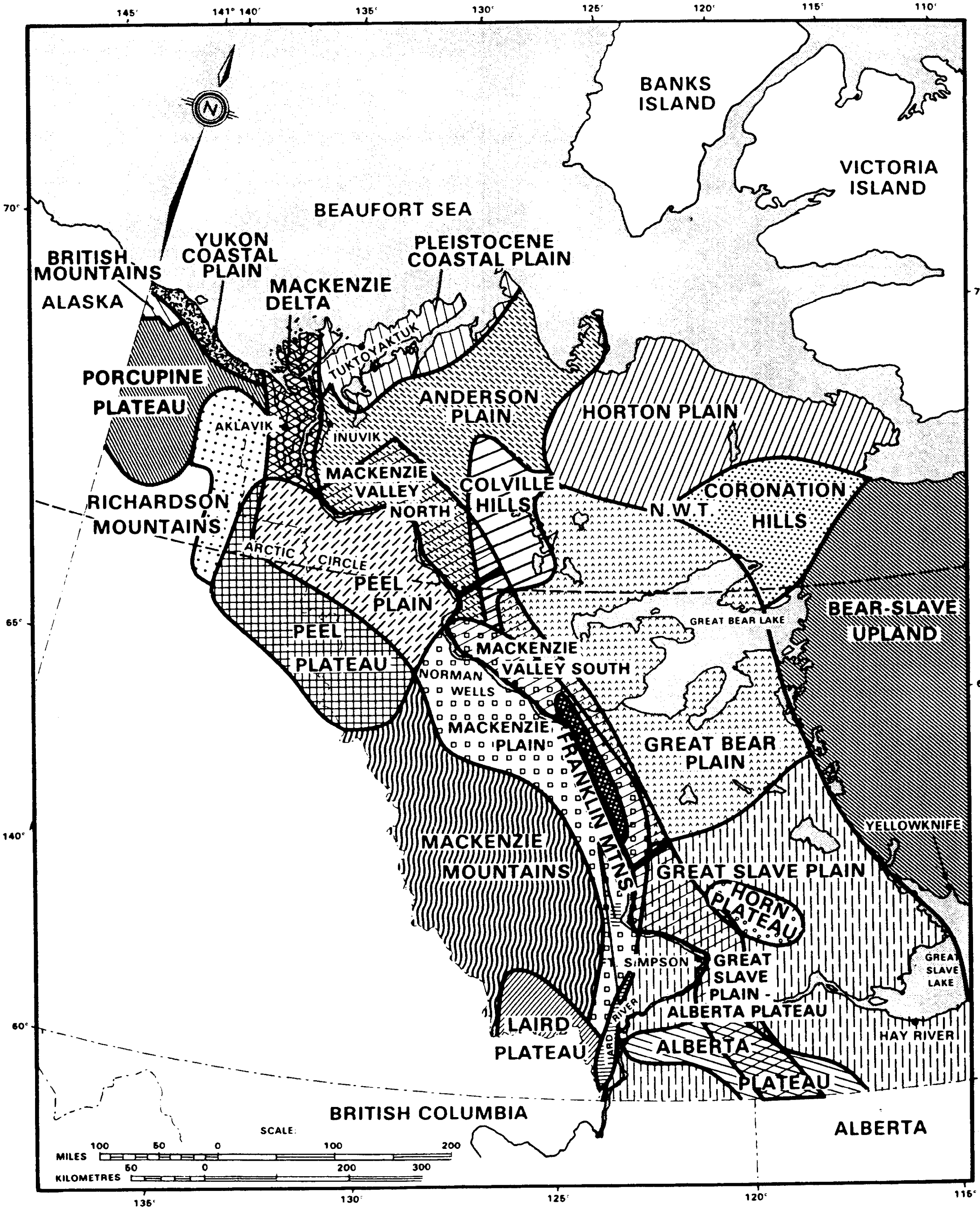


FIGURE 1.2-4 *Physiographic regions of the Mackenzie Valley (from Bostock, 1969; Fyles et al., 1972). The northern portion of the Mackenzie Valley corridor is within the Anderson Plain physiographic region, which south of Inuvik is relatively flat and featureless. Further south, the central part of the corridor is within the eastern part of the Mackenzie Plain which also includes the Norman and McConnell ranges of the Franklin Mountains. The latter ranges have bedrock controlled topography. The southerly part of the corridor crosses two further physiographic regions: the Great Slave Plain and the Alberta Plateau.*

Travaillant Lake, the corridor traverses a lowland, underlain predominantly by hummocky moraine with some areas of glaciolacustrine silt and clay. Colluvium-veneered bedrock is widespread to the east and southeast of Travaillant Lake. Areas of organic bog and fen occur throughout this region, while thermokarst depressions in the hummocky moraine areas are infilled with organic-rich silts and clays.

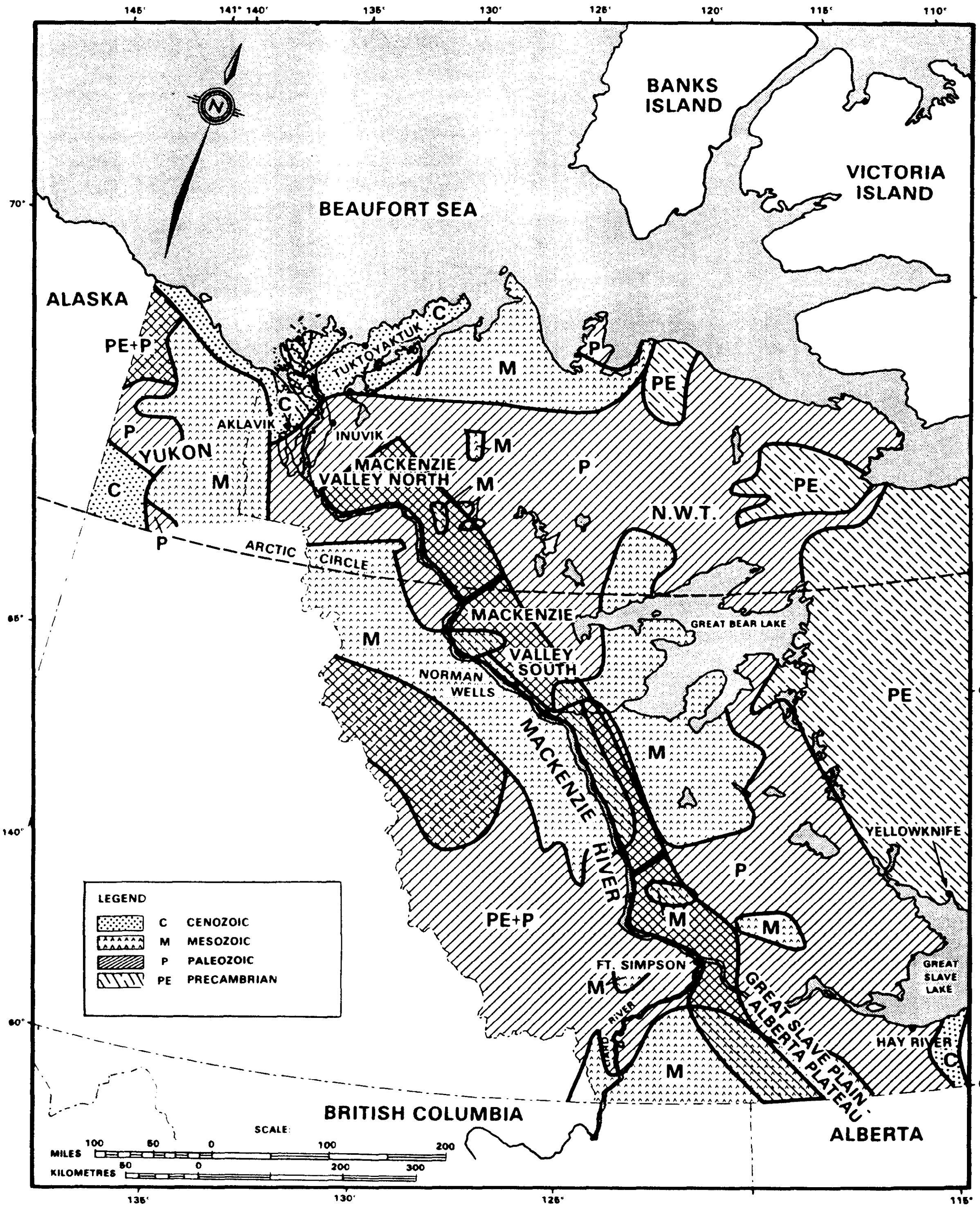


FIGURE 1.2-5 *Bedrock Geology of the Mackenzie Valley Corridor (from Douglas, 1969). Shown superimposed, are the three corridor sub-regions: Mackenzie Valley North, Mackenzie Valley South, and the Great Slave Plain-Alberta Plateau.*

The upland region extending south from the Travaillant Lake area to the Little Chicago area is underlain by shallow moraine (till) and, locally, colluvium over bedrock. Isolated areas of thicker, hummocky moraine are also present.

Between the Little Chicago area and Fort Good Hope, the corridor traverses a lowland underlain by till, with frequent intervening areas of organic terrain. In general, the terrain consists of subdued drumlinoid (till) areas, although the occurrence of organic bogs and fens increases markedly toward the

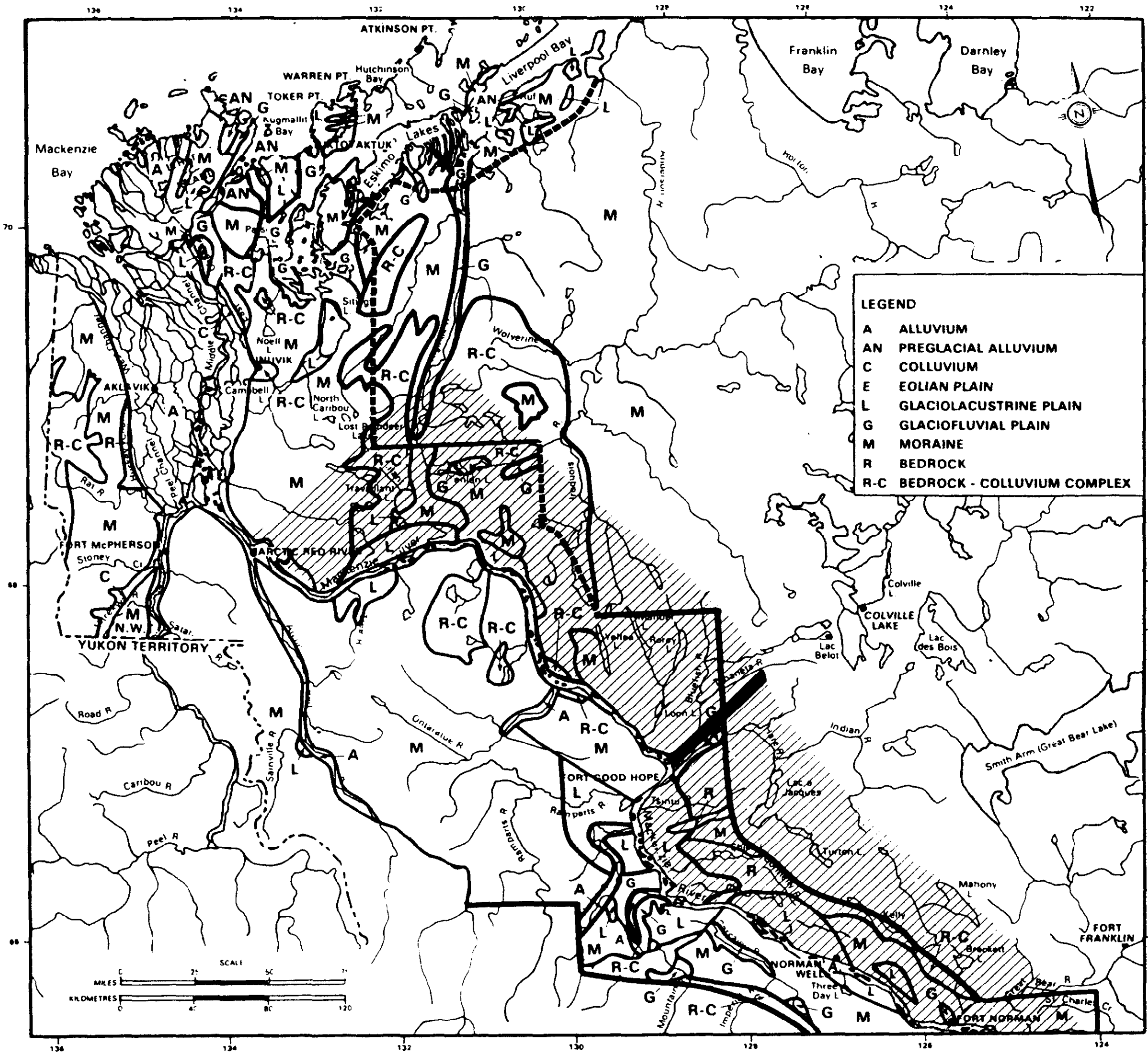


FIGURE 1.2-6 *Surficial Geology of the Mackenzie Valley Corridor (from Hughes et al., 1973; Rutter et al., 1973). The three corridor sub-regions: Mackenzie Valley North, Mackenzie Valley South, and the Great Slave Plain-Alberta Plateau are shown superimposed on the surficial geology.* (Continued next page)

south.

South of Fort Good Hope a moraine plain with locally abundant organic deposits underlies most of the Mackenzie Valley corridor (Rutter *et al.*, 1973). A poorly drained glaciolacustrine plain with frequent thermokarst areas occurs close to the river.

1.2.1.4 Glacial History

The northern portion of the Mackenzie Valley was glaciated at least twice by ice sheets of continental or Laurentide origin (Hughes, 1972). Prest *et al.*(1970) reported that ice movements during the earlier and most extensive glaciation were predominantly to the northwest, and that the entire area was glaciated. The region was also covered to a lesser extent by a further Laurentide ice advance during the Wisconsin period (Hughes *et al.*, 1973).

The Wisconsin ice sheet retreated approximately 11,000 to 12,000 years ago (Prest *et al.*, 1970), after which a large glacial lake occupied the lower part of the Mackenzie Valley and adjacent areas. Thick sequences of silt and clay, with local areas of sand and gravel, were deposited during this period. Downcutting by the Mackenzie River and its tributaries resulted in drainage of the glacial lake and the subsequent development of terrace and floodplain deposits adjacent to present-day watercourses (Hughes *et al.*, 1973).

In addition to the laying down of alluvial deposits during the postglacial period, organic materials infilled terrain depressions and permafrost was developed. Formation of colluvial deposits and deposition of eolian blankets and dunes have been other active processes since the retreat of the Wisconsin ice sheet.

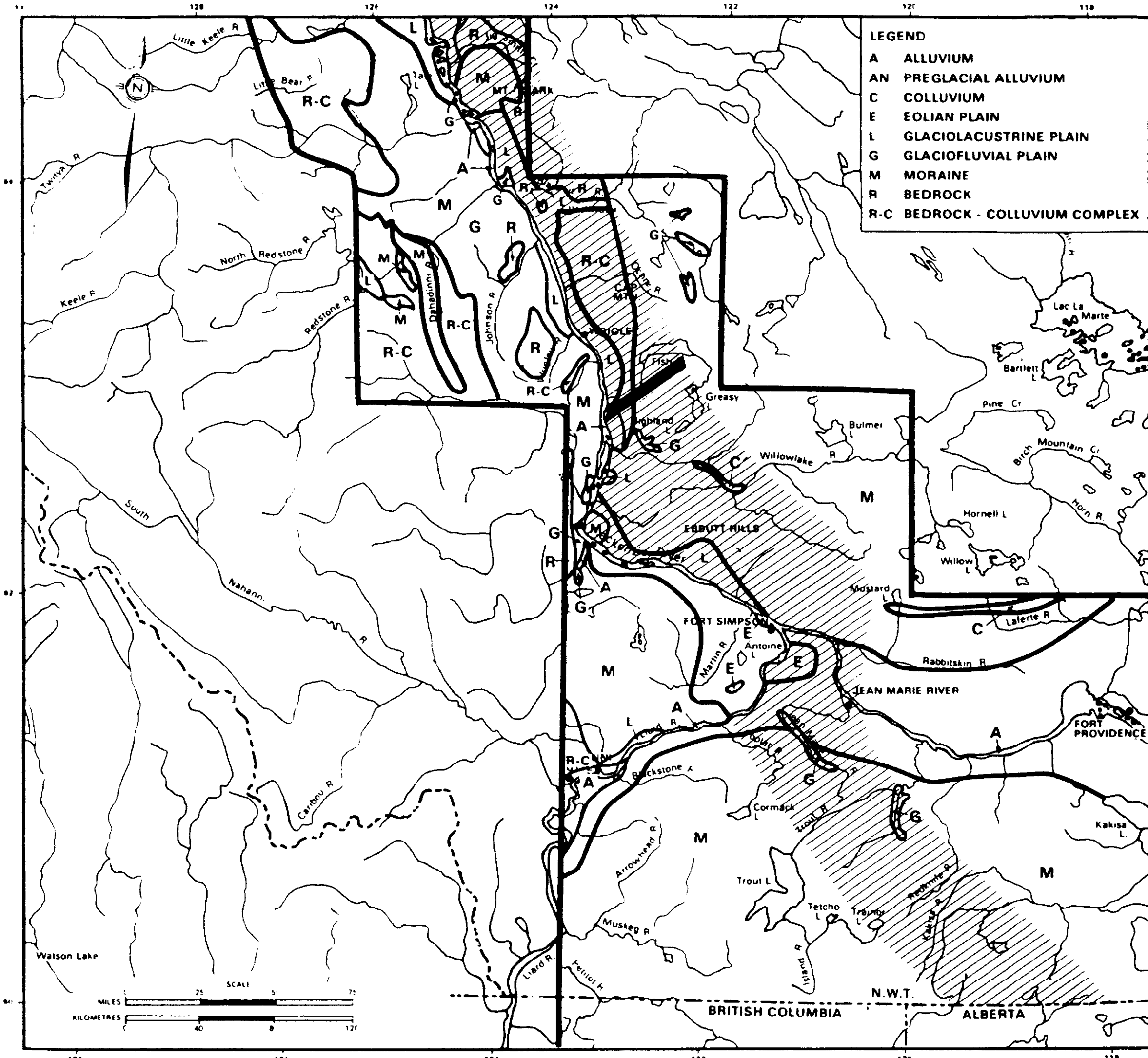


Figure 1.2-6 Continued.

1.2.1.5 Permafrost and Ground Ice

According to Brown (1967) (Figure 1.2-7), the northern portion of the Anderson Plain lies within the continuous permafrost zone, while permafrost is discontinuous but widespread in the southern Anderson Plain. Data regarding the thickness of frozen ground are limited, although measured permafrost depths range from about 100 m in the north to 30 m in the south (Judge, 1973). Extensive patches of unfrozen ground are found in the southern Anderson Plain near Fort Good Hope.

In a general way, the nature and occurrence of ground ice are related to surficial material type. For example, till in plains and drumlinoid moraine areas generally has a low to medium ice content. Thin seams of ground ice are common in the upper 1.5 m to 3 m. However, these irregular seams usually comprise much less than 25% of the material by volume. Thicker ice lenses and massive ice accumulations are uncommon in these two surficial material types (Mackay, 1966).

On the other hand, glaciolacustrine silts and clays usually contain up to 50% ice by volume (Mackay, 1966). In these fine-grained sediments ice occurs both as a reticulate network of thin lenses and inclusions and as layers up to a metre or more in thickness. In varved clay deposits ice typically occurs as uniform layers from 2 to 7 mm thick between successive clay layers.

Glaciofluvial deposits within the Anderson Plain have a thick active layer or remain unfrozen. Generally the isolated frozen areas have low ice content, with ice occurring as small inclusions. However, thicker ice lenses and high ice-content deposits are present locally.

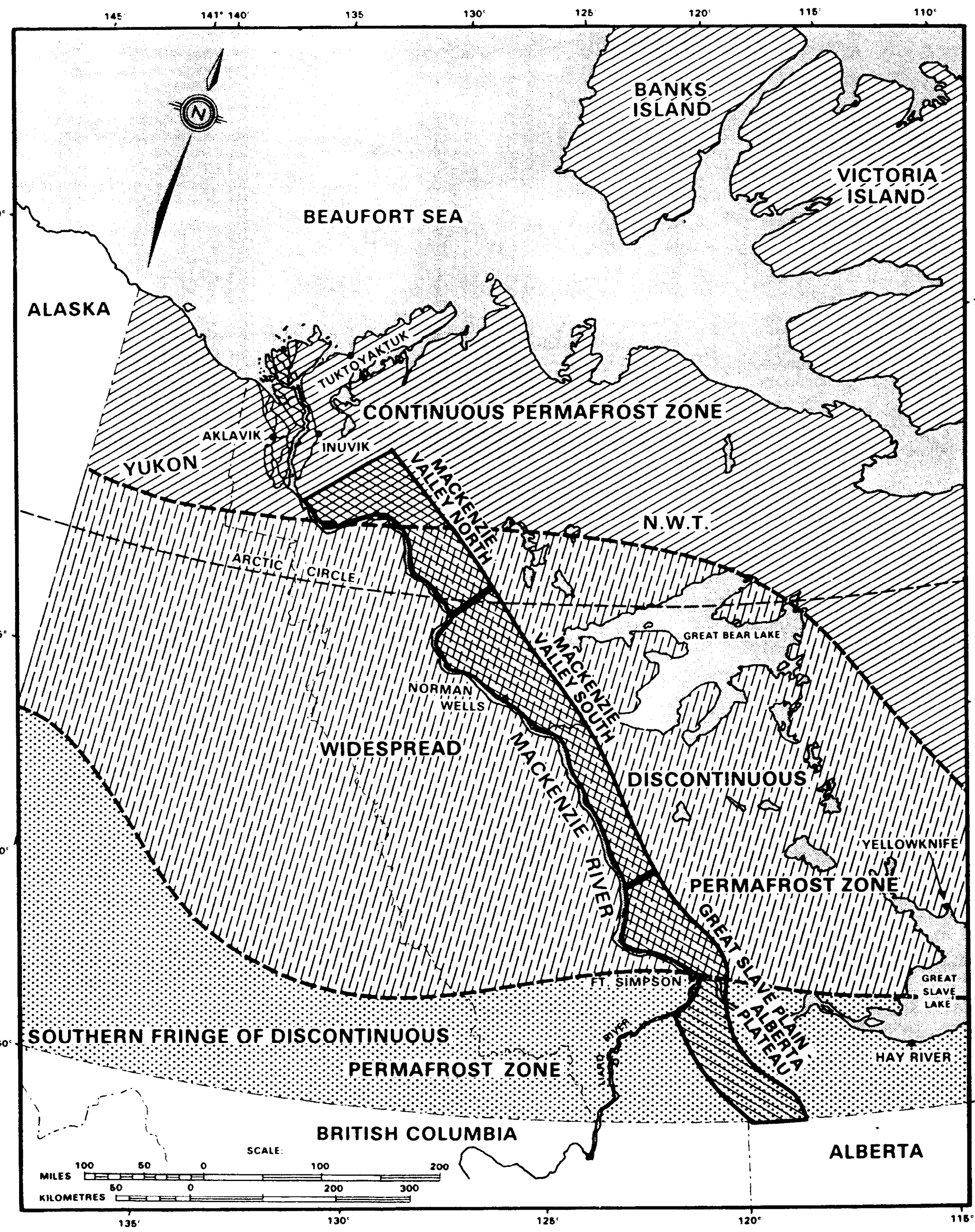


FIGURE 1.2-7 *Permafrost Zones in the Mackenzie Valley (from Brown, 1967). In the northern continuous permafrost zone, the measured frozen ground thickness ranges from 100 metres in the north end of the corridor to 30 metres at the southerly limit of the zone. In the discontinuous permafrost zone at Norman Wells, permafrost thickness averages 50 metres thick to more than 100 m thick to the east away from the influence of the river.*

Mackay (1966) reported that ground ice conditions in alluvial deposits are variable. Deposits in active river channels usually have a thick active layer or are unfrozen, while ground ice (occurring as thin irregular lenses) is common in the floodplains of high energy streams. Thick layers of segregated ground ice are rare. High ground ice content and associated formation of thermokarst ponds and lakes are widespread in fossil floodplains, terraces and floodplains of low energy streams.

Eolian deposits of wind-blown sand and silt, which occur as well-drained ridges, are generally unfrozen. Isolated frozen north-facing slopes have a low ice content, while in depressions with a thick organic cover ground ice may be encountered both in the organic deposits and in the underlying sands and silts.

1.2.1.6 Terrain Stability and Sensitivity

A number of areas exhibiting active slope instability are scattered throughout the Anderson Plain (McRoberts and Morgenstern, 1974). Therefore, thermokarst lakes are common in glaciolacustrine terrain and in depressions in the ground moraine (till) areas. Small slumps are also evidence of active collapse along the shores of some lakes and ponds. River banks in the glaciolacustrine and ground moraine areas, particularly along rivers, are also subject to active-layer detachment sliding and retrogressive thaw-flow slides.

Areas of hummocky moraine are often characterized by steeply sloping terrain. Retrogressive flow slides are not common, but do occur in these areas as well as along steeper shorelines in the vicinity of thaw ponds and lakes.

Other localized areas within the Anderson Plain appear to be especially susceptible to instability (McRoberts and Morgenstern, 1974). For example, the scarp which separates the lowland from the upland near Little Chicago is subject to active-layer detachment slides, while old slump scars, apparently involving Cretaceous shales, occur along the meltwater channel north of Little Chicago. The thick peatland deposits south of Fort Good Hope also have collapsed banks and wet depressions with degrading banks.

1.2.2 MACKENZIE VALLEY SOUTH

The central portion of the Mackenzie Valley corridor extends from the northern edge of the Franklin Mountains to Willowlake River (Figure 1.2-1). Work by Rutter *et al.* (1973) and Hughes *et al.*,(1973) is the primary source of information for this region.

1.2.2.1 Topography and Relief

Physiographically this region encompasses the eastern part of the Mackenzie Plain (east of the Mackenzie River) and the adjacent Norman and McConnell ranges of the Franklin Mountains (Figure 1.2-4) (Bostock, 1969).

The Mackenzie Plain is characterized by level to undulating topography. Elevations are uniformly about 150 metres asl, with slopes of 5 to 10° maximum. Somewhat steeper slopes occur within the piedmont areas immediately adjacent to the flanking mountain ranges, as well as on cliffs close to the Mackenzie River. Near the southern ends of the Norman and McConnell ranges elevations increase to between 200 and 300 metres asl. (Plate 1.2-1).

Rugged bedrock-dominated topography is characteristic of the Norman and McConnell ranges (Hughes *et al.*, 1973). Elevations in excess of 1,000 metres asl, with slopes of 50° or greater, characterize both ranges. Maximum elevations within the corridor are about 975 metres asl and 1,460 metres asl in the Norman and McConnell ranges, respectively.

1.2.2.2 Bedrock Geology

In the north the Mackenzie Plain is underlain by bentonitic clay shales and sandstones of Lower Cretaceous age (Cook and Aitken, 1969). Between Oscar Creek and Bear Rock this bedrock unit forms a narrow belt (5 km to 13 km wide) between the Norman Range and the Mackenzie River. Creeks in this area have often eroded small canyons into the bedrock, while minor exposures of limestone from the Devonian Ramparts Formation also outcrop in isolated ridges within this physiographic unit. Limestone outcrops and occasional sink holes are evident along Vermillion Creek.

In the southern part of the Mackenzie Plain gently dipping shales, with minor amounts of limestone, dolomite, sandstone and evaporites, underlie the broad valley of the Mackenzie River and within the flanking upland areas (Douglas and Norris, 1963). The shale is mostly of the Upper Devonian Fort Simpson Formation and the Lower Cretaceous Fort St. John Group.

The Norman and McConnell ranges, which are both components of the Franklin Mountains, are composed of folded and faulted Ordovician, Silurian and Devonian carbonate strata (Douglas, 1969). These units consist primarily of highly resistant dolomites and limestones, with minor amounts of shale, sandstone and conglomerate. Limestone bedrock is quarried and used for roadway construction in the Norman Wells area.

1.2.2.3 Surficial Geology

The surficial deposits of the Mackenzie Plain between the Mackenzie River and the Franklin Mountains consist mainly of glacial tills and glaciolacustrine sediments (Figure 1.2-6). Organic, eolian and glaciofluvial deposits, such as outwash plains, eskers and kames, have a more limited distribution in this physiographic region (Hughes *et al.*, 1973; Rutter *et al.*, 1973).

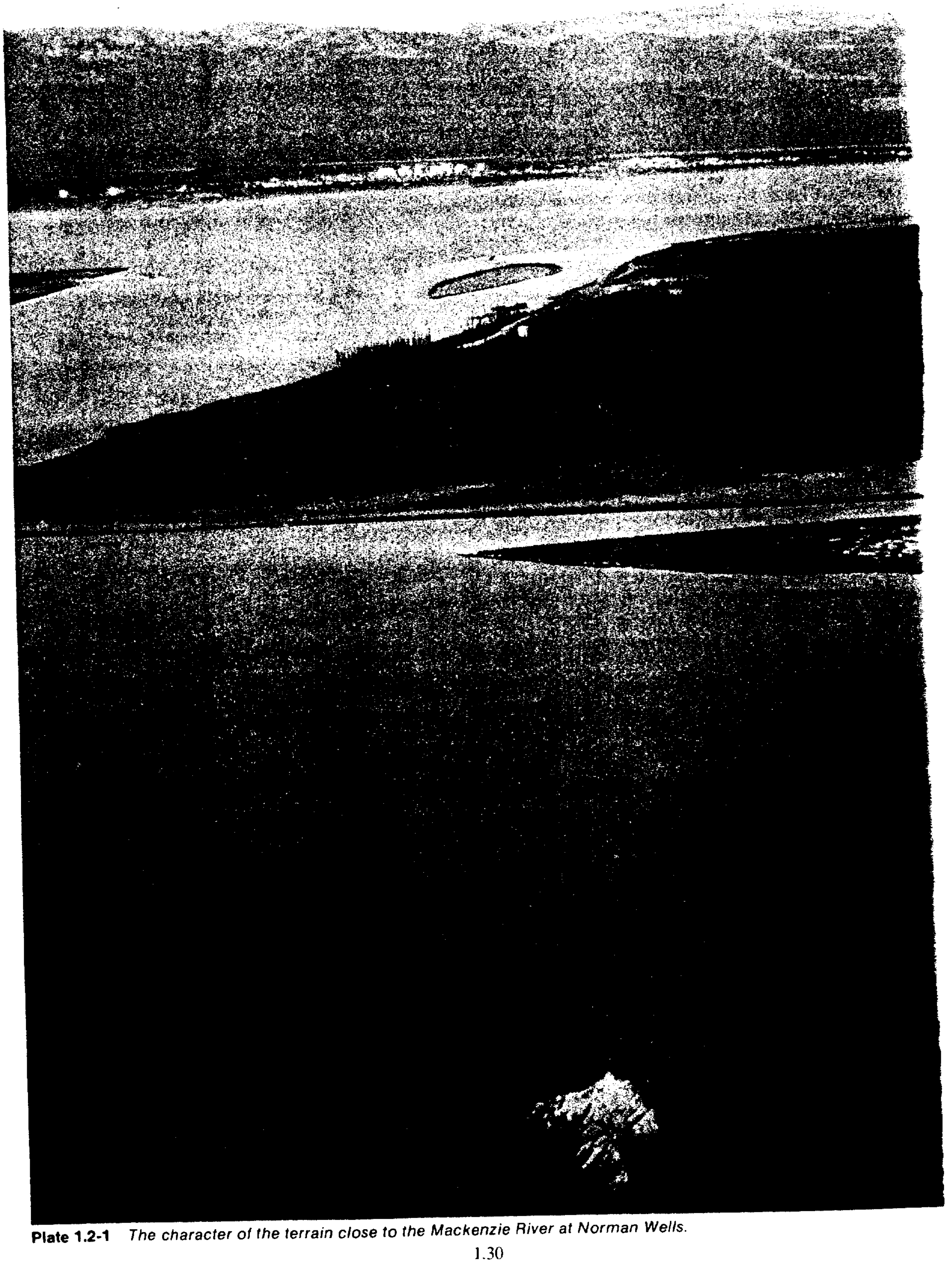


Plate 1.2-1 *The character of the terrain close to the Mackenzie River at Norman Wells.*

Two types of glacial deposits flank the west side of the Norman Range from Oscar Creek to the Great Bear River (Hughes *et al.*, 1973). Between elevations of about 150 to 300 metres asl, bedrock is predominantly covered by glacial till, while below 150 metres, glaciolacustrine silts and fine sands form a discontinuous veneer over the till. Bedrock outcrops are widespread above an elevation of about 300 metres asl. Locally, for example in the low lying area between Prohibition Creek and Bear Rock, the glaciolacustrine sediments are thicker and there is some development of thermokarst lakes and ponds. Small beach ridges and alluvial fans of gravel and sand are also scattered throughout this region.

A wide glaciolacustrine plain speckled with thermokarst lakes and ponds occurs south of Great Bear River as far as Big Smith Creek. Poor drainage throughout much of this region has resulted in widespread development of peatland and fenland terrain. In some areas the glaciolacustrine silts and clays are overlain by sand, while north of Old Fort Point dunes have developed on the deltaic sands.

From Big Smith Creek to the vicinity of Birch Island a gently sloping till plain rises above the glaciolacustrine plain adjacent to the river. This extends as far as the McConnell Range to the east. Between Big Smith Creek and Little Smith Creek a small beach ridge, less than 3 metres high, can be traced for over 10 km and marks the upper limit of a glacial lake which formerly existed in this area.

Glaciolacustrine sediments are widespread along the southern portion of the Mackenzie Plain from Birch Island to Wrigley. Organic terrain usually overlies these sediments, and irregular peat plateaus up to 1.5 metres high are present.

The surficial geology of the Mackenzie Plain between Wrigley and Willowlake River is complex (Rutter *et al.*, 1973). Upland areas are primarily underlain by till which occurs as drumlinoid and hummocky moraine, while organic deposits (peat) up to 3 metres thick overlie the till in poorly drained areas. Glaciofluvial deposits are prevalent throughout the area between Two Mountains and Willowlake River (Rutter *et al.*, 1973). These deposits include crevasse fillings, eskers, kames and outwash plains. The thickness of granular materials varies from a few metres in crevasse fillings to over 15 metres in kames and eskers, although the average depth is probably in the order of 6 to 9 metres. Abandoned meltwater channels are also present in this southern section of the Mackenzie Plain.

Moraine (till) and colluvium are the dominant surficial deposits within the Norman and McConnell ranges of the Franklin Mountains (Rutter *et al.*, 1973). Colluvium is widespread on the steep-sided, bedrock-dominated ridges, while till occupies the intervening valleys, generally forming a veneer over bedrock. Glaciolacustrine deposits have a very limited distribution (such as north of Norman Wells), while some organic terrain occurs in the south near the Willowlake River.

1.2.2.4 Glacial History

The glacial history is described in some detail by Rutter *et al.* (1973). Stratigraphic and morphologic evidence indicates that the area was invaded from the east at least twice by Laurentide ice. The first and most extensive glaciation is evidenced by a grey-black stony till exposed as the basal unit in sections from various locations in the region, particularly along tributaries of the Mackenzie River. Glacial erratics, considered to have been deposited by this ice advance, are found to an elevation of 1,500 metres asl in the Mackenzie Mountains to the west, indicating that the glacier crossed the summit areas of the mountains.

The surface evidence of the second Laurentide advance is a light grey-brown stoney till which varies locally in texture and is separated from the lower till by an erosional surface or stratified sand and gravel. The ice was apparently thinner than during the earlier advance and was controlled topographically to the extent that it was deflected by the Norman and McConnell ranges.

The last Laurentide ice sheet retreated toward the northeast in the south of the Mackenzie Plain, and eastward in the north. Withdrawal of the ice into the plains area created large scale damming, forming major lakes along the Mackenzie Valley. Relatively thick layers of fine-grained sediments were deposited during this period. As the ice retreated further back onto the plains and uplands till was deposited, forming wide areas of hummocky moraine and distinct moraine ridges that still indicate former ice front positions.

Unlike the Laurentide ice sheet, the only evidence that Cordilleran ice penetrated westward onto the Mackenzie Plain is in the form of till (without erratics) which was apparently derived from parent rock to the east (Rutter *et al.*, 1973).

After deglaciation and drainage of the glacial lakes, alluvial terraces and floodplains were laid down by present-day streams, while terrain depressions infilled with organic material. Eolian dunes and blankets have resulted from wind transport of glaciolacustrine silt and sand, and colluvial deposits have formed within steeper terrain segments.

1.2.2.5 Permafrost and Ground Ice

The Mackenzie Valley South section of the corridor lies within the discontinuous permafrost zone (Figure 1.2-7; Brown, 1967). Perennially frozen ground is widespread, being almost continuous in the northern portion of this region but increasingly discontinuous toward the south. According to Mackay (1967) and Judge (1973), permafrost thickness ranges from an average of 50 metres in the Norman Wells area to greater than 100 metres further to the east, away from the influence of the Mackenzie River.

In general, tills in the northern part of the region are frozen, having low to medium ice content with small ice inclusions, seams and lenses. In the south the crests of flutings and drumlinoid ridges may be unfrozen. Similarly, in organic terrain areas, permafrost is often absent where the organic veneer is less than 1 to 1.5 m thick. Glaciofluvial deposits usually have low ice content or remain unfrozen. Major exceptions to this trend are some meltwater channels where a near-surface peat stratum frequently develops and promotes permafrost and ground ice development.

In the northern and central parts of the region permafrost and ground ice are widespread in glaciolacustrine deposits (Mackay, 1966). In these areas ground ice occurs as inclusions and lenses up to 60 cm thick, generally in the upper part of the deposit. Ice typically occupies up to 40% of the surficial material by volume.

Permafrost is generally absent from extensive low-lying fenland areas, but does occur in boggy peat lands. In the southern Mackenzie Valley, peat plateaus are frequently undergoing active thermokarst subsidence which results in a very sporadic distribution of permafrost.

1.2.2.6 Terrain Stability and Sensitivity

Local areas of terrain instability are evident within the Mackenzie Plain segment of the corridor, particularly in the steeper slope terrain adjacent to the Mackenzie River. Many of the drainage channels in the region are gullied and have minor slumps and active skin slides (Hughes *et al.*, 1973).

Thermokarst lakes are abundant within glaciolacustrine terrain areas, especially on the broad low-lying plain between Great Bear River and Big Smith Creek. Small slumps provide evidence of active thermally-induced collapse in sandy sediments along the shores of lakes and ponds. Where a thick stratum of sand is present at the surface, slopes bordering the Mackenzie and Great Bear rivers are also subject to slumping, or to retrogressive thaw-flow slides where the top stratum is composed of glaciolacustrine silt and clay (McRoberts and Morgenstern, 1974).

1.2.3 GREAT SLAVE PLAIN - ALBERTA PLATEAU

This region, between Willowlake River and the Northwest Territories - Alberta border, is the southernmost section of the Mackenzie Valley corridor (Figure 1.2-1). The prime source of information for the northern portion of the region is Rutter *et al.* (1972), while Rutter *et al.* (1973) discusses the geology of the entire physiographic region. Glacial lakes in the area have been described by Craig (1965).

1.2.3.1 Topography and Relief

From a physiographic point of view the southern section of the Mackenzie Valley corridor crosses two divisions of the Interior Plains, the Great Slave Plain and the Alberta Plateau (Figure 1.2-4; Bostock, 1969).

The topography of most of the Great Slave Plain is level to gently undulating, with slopes of less than 10 degrees. Between Willowlake River and Fort Simpson elevations range from about 150 to 180 metres asl close to the river and rise gradually toward the east (in the Ebbutt Hills, maximum elevation is about 600 metres asl). South of Fort Simpson the terrain rises gradually from about 150 metres asl to approximately 750 metres asl in the Redknife Hills along the southern boundary between the plain and the Alberta Plateau.

Level to gently undulating topography and slopes of less than 10 degrees are characteristic of the Alberta Plateau. Elevations decrease gradually southward from the Redknife Hills and average about 450 metres asl within the plateau itself.

1.2.3.2 Bedrock Geology

The northern part of the Great Slave Plain is underlain predominantly by fine-grained strata of the Upper Devonian Fort Simpson Formation (Figure 1.2-5). This unit consists of soft and fissile clay shale, with minor amounts of siltstone, sandstone and limestone (Stott, 1960; Douglas and Norris, 1963).

Further south, within the Great Slave Plain, the overlying Fort St. John Group of Lower Cretaceous age is the uppermost bedrock unit (Douglas, 1959). This unit has a similar lithology to the Fort Simpson Formation. However, in some local areas such as near Trainor Lake, the bedrock consists of sandstone, siltstone and shale of the Upper Cretaceous Dunvegan Formation. In addition, isolated areas of Upper Devonian limestone are present south of Jean Marie Creek.

Clay shales of the Lower Cretaceous Fort St. John Group constitute the uppermost bedrock unit of the Alberta Plateau (Douglas, 1959). These strata are overlain by a thick succession of surficial materials, often in excess of 20 m deep.

1.2.3.3 Surficial Geology

Between Willowlake River and Fort Simpson, in the Great Slave Plain, glacial till is the dominant surficial deposit (Figure 1.2-6) (Rutter *et al.*, 1973). This gives rise to a variety of landforms including hummocks, drumlinoid ridges and flutings, and crevasse fillings. The till is generally greater than 12 metres thick, except at higher elevations near the Ebbutt Hills. Glaciolacustrine silts and sands occur at lower elevations along the Mackenzie River, spreading out to the east onto the till. The distribution of organic terrain in the northern part of the Great Slave Plain is scattered, but is most widespread between Trail River and Harris River. Although the thickness of organic material in peat plateaus may reach up to 4.5 metres, it is generally less than 2 metres thick.

Between Fort Simpson and the vicinity of Jean Marie Creek, two types of surficial deposits predominate (Rutter *et al.*, 1973). In the north, between the Mackenzie and Liard rivers, glaciolacustrine silts and eolian sands are widespread. The sandy areas comprise stabilized fields of longitudinal dunes and overlie glaciolacustrine fine sands and silts. The thickness of eolian sand may exceed 15 metres in dunes and 6 metres in the intervening depressions. Further south the Great Slave Plain region is overlain by glaciolacustrine silts which are generally over 6 metres thick. Thick organic deposits are also present in poorly drained depressions throughout this area. Glacial till underlies the silts and sands and is exposed at the surface in some scattered hummocks and small ridges.

South of Jean Marie Creek, within the Great Slave Plain physiographic region, bedrock is overlain by thick surficial deposits, mostly till averaging over 6 metres thick (Rutter *et al.*, 1973). This till is widespread throughout the area, but is generally thickest at lower elevations. It forms a relatively featureless plain with many low east-west trending drumlinoid ridges (the average relief is less than 15 metres), low crevasse-filling ridges (averaging 1.5 metres high) and subdued hummocks. Organic deposits are scattered throughout the region and in many places peat plateaus cover extensive areas. Organic material in peat plateaus can reach depths of 6 metres or more.

Most of the Alberta Plateau physiographic division is underlain by 10 to 20 metres thick deposits of moraine (till) (Rutter *et al.*, 1973). Crevasse-filling ridges are abundant. Terrain depressions, as well as the inter-ridge areas, are filled by organic bog and fen deposits. These organic deposits may be relatively thick, particularly in the northern section of the Alberta Plateau.

1.2.3.4 Glacial History

The glacial history of the Great Slave Plain - Alberta Plateau region is similar to that of areas further north. The region was overriden by two ice sheets of Laurentide (continental) origin and these gave rise to two distinct glacial tills (Rutter *et al.*, 1973). Glacial lake formation during deglaciation of the area was very extensive (Craig, 1965). The ice sheets and glacial lakes, respectively, resulted in the deposition of the till, silt and clay materials characteristic of the Great Slave Plain and Alberta Plateau physiographic regions.

Formation of organic deposits in terrain depressions has been widespread since the retreat of the ice sheets of the last (Wisconsin) glaciation. Alluvial floodplain and terrace formation, and deposition of eolian deposits were processes of only local importance during this period.

1.2.3.5 Permafrost and Ground Ice

This southern most section of the Mackenzie Valley corridor lies within the discontinuous permafrost zone (Figure 1.2-7; Brown, 1967). The distribution of perennially frozen ground becomes increasingly sporadic from north to south within this region.

Permafrost is relatively widespread between Willowlake River and Fort Simpson on the Great Slave Plain. Frozen ground with ground ice is usually present in peat plateaus and it often extends into the underlying till, especially when there is less than about 1.2 metres of organic cover is present (Taylor and Judge, 1974). Frozen till generally has a low ice content, although ice lenses and segregated ground ice may occur in some areas. Till in the better drained areas, with less than about 30 cm of overlying organic material, is generally unfrozen.

Permafrost rapidly becomes much less prevalent south of Fort Simpson (Brown, 1967). In general the better drained till areas (that is, ridges and drumlins) and dunes are unfrozen. However, permafrost does occur in depressions between dunes and crevasse-filling ridges, and may often be present in glaciolacustrine sediments.

Permafrost distribution is sporadic on the Alberta Plateau (Brown, 1967). It occurs most frequently in areas with deep organic deposits, and only occasionally extends into the underlying till and glaciolacustrine sediments.

1.2.3.6 Terrain Stability and Sensitivity

Stability and sensitivity of the terrain within the northern section of the Great Slave Plain, between the Willowlake and Mackenzie rivers, are similar to those of the Mackenzie Plain (see Section 1.2.2.6). In areas overlain by glaciolacustrine sediments, development of thermokarst lakes is widespread and active-layer detachment slides are common. Slopes bordering the major river valleys, such as the Willowlake, Mackenzie and Liard, are subject to local instabilities of the multiple-retrogressive, bimodal flow and block slide types (McRoberts and Morgenstern, 1974).

South of Fort Simpson, the southern Great Slave Plain and Alberta Plateau have low relief and frequently are free of permafrost, making the development of terrain instabilities uncommon. Organic bogs often contain areas of degrading permafrost. Areas of "speckled bog," consisting of an alternating sequence of frozen and thawed areas, are evidence of the sensitivity of the terrain in these areas.

1.2.4 SEISMICITY

Seismic zones of the Mackenzie Valley are illustrated in Figure 1.2-8 (National Research Council, 1975). Sources of regional and site-specific information on the seismicity of this region include Basham *et al.* (1977), Stevens and Milne (1974), LeBlanc and Hasegawa (1974) and LeBlanc and Wetmiller (1974). This information has been described in Section 2.2.4 of Volume 3A.

As indicated by Figure 1.2-8, seismicity decreases from north to south along the Mackenzie Valley corridor. Seismic Zone 3 covers the northern-most part of the corridor. A short 20 km section of the corridor is in Seismic Zone 2; then south to Fort Simpson the corridor is in Seismic Zone 1. The remaining southerly section is in Seismic Zone 0. The zone boundaries shown in Figure 1.2-8 are definied by acceleration ratios, A_{100}, where A_{100} is the maximum predicted acceleration with respect to the acceleration due to gravity, g, on firm soil for a return period of 100 years (with a probability of exceedance of 1% per year, ignoring uncertainty factors). In Seismic Zone 3, A_{100} is up to 10% of g in the northern most part of the corridor, elsewhere in the corridor, A_{100} is 3% of g or less (National Research Council, 1975).

Historical earthquake data were reviewed by Stevens and Milne (1974). They concluded that earthquakes are concentrated in the Richardson, Mackenzie and St. Elias mountains. This distribution was confirmed by the results of field investigations undertaken by LeBlanc and Hasegawa (1974). The maximum recorded magnitude for seismic events during the period of record (1899 to 1970) was 6 to 6.5 for earthquakes near Fort McPherson (1940), the St. Elias Mountains (1974) and Mackenzie Mountains (1950's).

Stevens and Milne (1974) also prepared a strain release map for the Yukon and adjacent areas, including the northern section of the Mackenzie Valley corridor, based on records for the period 1899 to 1970. This map confirmed the high level of seismic activity in the three mountain areas identified above. It also indicated that, taking into account uncertainty factors, the maximum strain release within the corridor has been equivalent to between two and nine events of magnitude 6 and not more than two events of magnitude 7, over a period of 100 years.

The United States Federal Task Force on Alaska Oil Development (1971) and the Alyeska Pipeline Service Company (1971) have conducted lengthy studies on design and other pipeline-related problems anticipated in an area where earthquakes of 5.5 to 8.5 (Richter Scale) may be expected.

Stevens and Milne (1973, 1974) made extensive studies on the seismic risk and integrity of pipelines in the Mackenzie River Valley and adjacent regions. Subsequent work (Wetmiller and Forsyth, 1978) located the highest seismic risk area to be west of the corridor, although not completely beyond it. The corridor does not traverse over any apparent active faults.

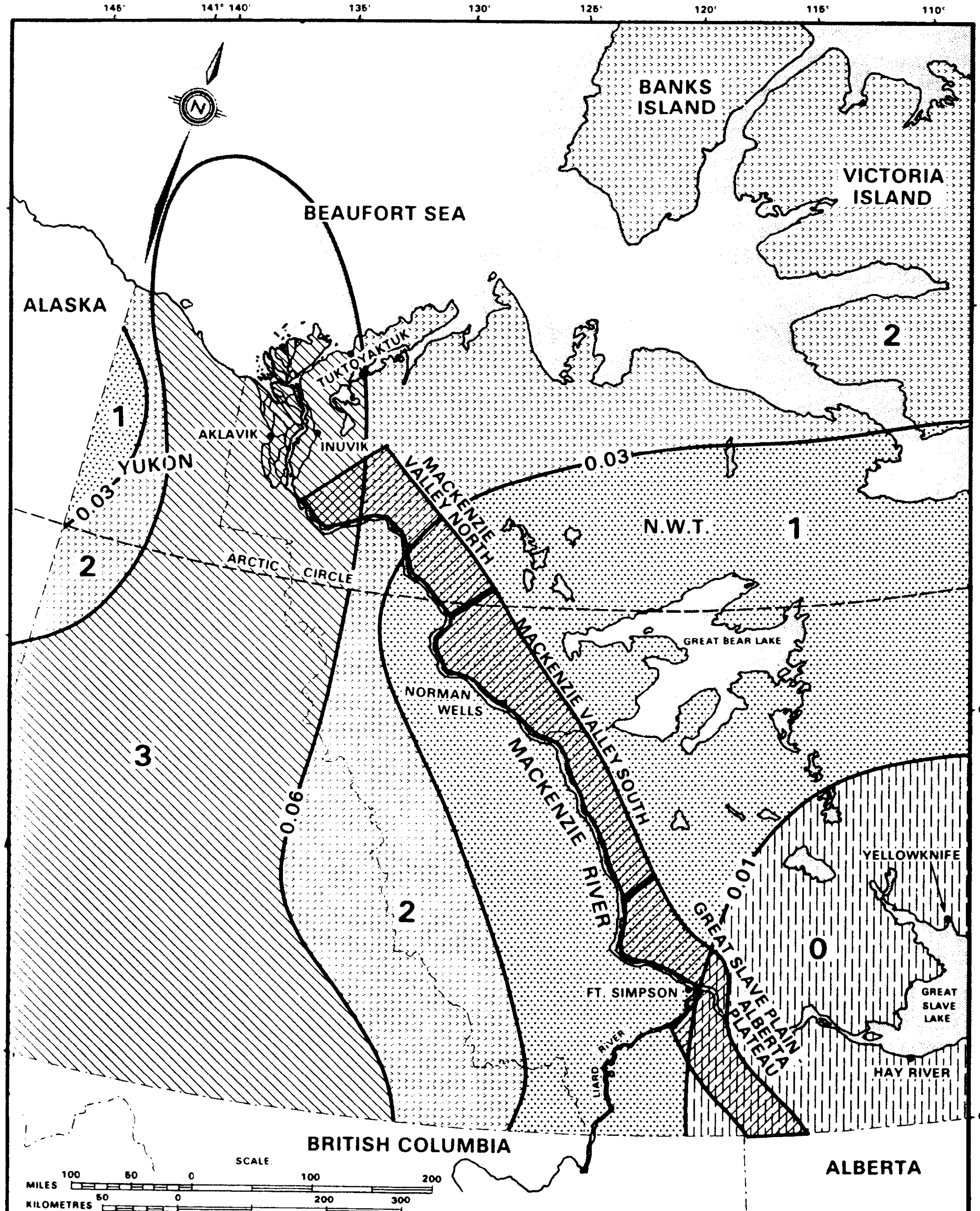


FIGURE 1.2-8 *Seismic Zones of the Mackenzie Valley. (Source: National Research Council, 1975). Zone boundaries are defined by A_{100} values, where A_{100} is the 100 year return period ground acceleration with respect to the acceleration due to gravity, with a probability of exceedance of 1% per year.*

1.3 SOILS

This section provides information on soils in the Mackenzie Valley corridor. The discussion is divided into three subsections covering the Mackenzie Valley North, the Mackenzie Valley South, and the Great Slave Plain-Alberta Plateau regions (Figure 1.2-1). Places referred to in this section are located in Figure 1.2-2. The major physiographic regions and landforms of the Mackenzie River Valley are shown in Figure 1.2-4. A more detailed discussion of soil profiles characteristic of each of these regions, as well as the response of soils to natural and man-caused disturbances, is provided in a supporting document (Esso Resources, 1982). Soils of the Mackenzie Delta and Tuktoyaktuk Peninsula are discussed in Volume 3A, Section 2.3. Soil terminology and the classification system used in this discussion are based on the system developed by the Canada Soil Survey Committee (1978). A list of common terms and their definitions are presented in Table 1.3-1 and the surficial geology of the Mackenzie Valley corridor is shown in Figure 1.2-6.

TABLE 1.3-1

DEFINITIONS OF COMMON SOIL TERMS

BRUNISOL	Refers to soils which have developed under the influence of forest, alpine or tundra vegetation in a cool moist climate. Their common characteristic is a brownish mineral horizon near the surface which has developed in response to weak weathering processes. Soils classified as Eutric Brunisols usually occur on basic (or calcareous) parent materials while Dystric Brunisols usually occur on acidic parent materials.
COLLUVIUM	A hetergeneous mixture of material that has moved down a slope under the influence of gravity.
CRYOSOL	Refers to mineral and organic soils where permafrost remains close to the surface (within 1 or 2 m). An Organic Cryosol is composed of 30 percent or more organic matter. A Turbic Cryosol displays evidence of frost heave, which a Static Cryosol soil shows no evidence of frost heave.
CRYOTURBATION	Refers to the physical movement and disruption of the soil or active layer as a result of freezing and thawing processes in permafrost terrain.
ELUVIATION	The downward or lateral movement of soil material in soil water suspension or solution.
EOLIAN	Sand or silt or both deposited by wind.
FIBRIC	Refers to relatively undecomposed organic soils.
GLEYSOL	Refers to mineral soils which have features indicative of periodic or prolonged saturation with water. A Rego Gleysol lacks development horizons.
HUMIC	Refers to highly decomposed organic soils.
LUVISOL	Refers to mineral soils which display features indicative of moderate development and weathering. They generally have light colored horizons under the forest leaf-layers from which slicate clays have been removed through weathering processes and have moved downward and accumulated in a brownish-colored horizon.
MESIC	Refers to moderately decomposed organic soils.
ORTHIC	The normal or basic soil subgroup within a specific great group and soil order.
REGOSOL	Refers to mineral soils having little or no development. A Cumulic Regosol soil has layers that vary in color, texture, thickness, or organic matter that have resulted from intermittent depositon of waterborne mateirals.
THERMOKARST	Settling of the gournd due to the melting of ground ice.
TYPIC	Refers to the normal or basic soil subgroup within a specific great group.

Source: Canada Dept. of Agriculture (1976) and Canada Soil Survey Committee (1978).

1.3.1 MACKENZIE VALLEY NORTH

The Mackenzie Valley North area includes portions of the Anderson and Peel plains along the Mackenzie River between Fort Good Hope and Arctic Red River. Investigations in this sub-region of the Mackenzie Valley corridor have mainly been concerned with the relationships among soils, landforms and vegetation rather than on the distribution of soils. Studies by Zoltai and Pettapiece (1973) and Zoltai and Tarnocai (1974) are the primary sources of information used in this discussion.

The mean annual temperature of the Mackenzie Valley North is well below freezing (see Section 1.1) and the ground is perennially frozen where any insulating mat is present. The northern half of the sub-region lies in the continuous permafrost zone above the Arctic Circle (Figure 1.2-7). Nearly all medium and fine textured soils in this area have permafrost within 1 m of the surface and are strongly cryoturbated.

Soils in this area have developed on parent materials derived predominantly from till deposits (Figure 1.2-6). Other less prevalent landforms include glaciolacustrine deposits in the Mackenzie River lowlands, bedrock and colluvial deposits in the Anderson Plain, and organic terrain generally developed over glaciolacustrine deposits, and small areas of alluvial and glaciofluvial materials along the Valley.

Cryosolic soils with near-surface permafrost dominate the Mackenzie Valley North area, occurring on most mineral and organic terrain, although they may be absent from rapidly and very poorly drained sites. Approximately 80% of the mineral soils in this region are cryoturbated to some extent. Landform-soil drainage relationships in the Mackenzie Valley North are summarized in Table 1.3-2, while detailed soil descriptions are provided in Esso Resources (1982).

1.3.1.1 Soils on Mineral Parent Materials

The dominant soils on mineral parent materials in this sub-region are Turbic Cryosols which have developed on fine textured soil and glaciolacustrine deposits.

(a) Soils on Moraine and Glaciolacustrine Deposits

Morainal and glaciolacustrine landforms are the most dominant deposits in the Mackenzie Valley North area. The topography is flat to gently sloping in the ground moraine and glaciolacustrine plains, and rolling in the deposits of hummocky moraine. The surface soil texture ranges from clay-loam to silty clay in most areas, although coarse textured deposits occur on moraine ridges and hummocks. Drainage is rapid on coarse textured hills and hummocks, but poor on flat lowland plains and in thermokarst basins. However, most of the landscape is imperfectly drained during the growing season.

The dominant soils (greater than 40% in extent) on mineral parent materials of the Peel and Anderson plains (Figure 1.2-4) are Turbic Cryosols, under open black spruce vegetation. Brunisolic, Orthic and Regosolic subgroups occur on moderately well to imperfectly drained upland locations, while the Gleysolic subgroup is found in imperfectly to poorly drained areas.

These earth hummock soils are characterized by a 10 to 30 cm microrelief, with surface peaty horizons up to 20 cm in thickness over a strongly cryoturbated mineral profile. Soils in the Regosolic subgroups may have a gleyed horizon immediately above the frozen layer, while soils in the Gleysolic subgroups have gleyed or mottled layers throughout the mineral portion of the profile. Ice-rich layers are usually present in these surficial deposits.

Hummock size indicates the degree of cryoturbation, which is strongly influenced by texture and drainage (Zoltai and Pettapiece, 1973). Cryoturbation is most evident on imperfectly drained, fine textured soils, and least in well drained coarse textured deposits.

(b) Soils on Bedrock and Colluvium

The upland region east of the Mackenzie River within the Anderson Plain is characterized by a mixture of shallow glacial till deposits, and colluvium and bedrock outcrops. Glacial till material with rolling bedrock-controlled slopes (3 to 15°) dominate this region, although local bedrock outcrops with associated colluvium may occur on prominent ridges, scarps and hills. The surface soil texture of these deposits is silty clay-loam to clay, with local sand, gravel and peat deposits occurring in some areas (Zoltai and Pettapiece, 1973).

Turbic Cryosols have developed on the fine-textured, deeper deposits in this region, while Static Cryosols occur on shallow colluvial deposits over bedrock. Soils on medium to fine textured deposits contain relatively shallow, cryoturbated active layers under a 10 to 30 cm thick peaty surface horizon. Coarse textured soils in this portion of the Anderson Plain are deep and free of permafrost. The detailed character of these soil types is described in Esso Resources (1982).

(c) Soils on Glaciofluvial Deposits

Soils on parent materials derived from the coarse textured deposits described above are often unfrozen in the surface metre. They are classified as predomi-

TABLE 1.3-2
DOMINANT LANDFORMS, DRAINAGE, AND ASSOCIATED VEGETATION OF THE MACKENZIE VALLEY NORTH.
(Sources as cited in text.)

Landform	Drainage	Soils	Vegetation
Moraine (50%)	Rapid	Eutric Brunisol Regosolic Static Cryosol	Black Spruce-White Birch/Lingonberry
	Well-Mod Well*	Regosolic Orthic -- Turbic Cryosol Brunisolic	Black Spruce-White Birch/Lingonberry Black Spruce/Feathermoss
	Imp†-Poor	Gleysolic (Static) Cryosol (Turbic)	Open Black Spruce/Labrador tea/Lichen Sparse Black Spruce/Sphagnum-Lichen Black/Spruce/Feathermoss
Organic (15%)	Imp-Poor	Fibric Cryosol Mesic Cryosol	Sparse Black Spruce/Sphagnum-Lichen Sphagnum Bog Sedge Fen
Bedrock and Colluvium (15%)	Rapid	Eutric Brunisol Regosolic Static Cryosol	Black Spruce-White Birch/Lingonberry White Spruce-White Birch/Alder
	Well-Mod Well	Orthic (Static) Cryosol Brunisolic (Turbic)	Black Spruce-White Birch/Lingonberry Black Spruce/Feathermoss
	Imp-Poor	Gleysolic (Static) Cryosol (Turbic)	Open Black Spruce/Labrador tea/Lichen Sparse Black Spruce/Sphagnum-Lichen
Glaciolacustrine (15%)	Well-Mod Well	Regosolic Orthic -- Turbic Cryosol Brunisolic	Black Spruce/Feathermoss
	Imp-Poor	Gleysolic (Static) Cryosol (Turbic)	Open Black Spruce/Labrador tea/Lichen Sparse Black Spruce/Sphagnum-Lichen Sedge Fen
Alluvial 2%	Well-Mod Well	Cumulic Regosol Brunisolic Static Cryosol	White Spruce/Feathermoss Black Spruce/Feathermoss
	Imp-Poor	Gleysolic (Static) Cryosol (Turbic)	Open Black Spruce/Labrador tea/Lichen Sedge Fen Black Spruce/Feathermoss
Glaciofluvial (3%)	Rapid	Eutric Brunisol	Black Spruce-White Birch/Lingonberry White Spruce-White Birch/Alder
	Well-Mod Well	Regosolic Orthic -- Static Cryosol Brunisolic	Black Spruce-White Birch.Lingonberry
	Imp-Poor	Orthic Brunisolic -- Static Cryosol Gleysolic	Open Black Spruce/Labrador tea/Lichen Black Spruce-Tamarack/Lingonberry/Moss Sedge Fen

* Moderately
† Imperfectly

nantly Regosols and Brunisols. Where permafrost does occur within 1 m of the surface, soils are generally not cryoturbated and are classified as Regosolic Static Cryosols and Orthic Static Cryosols.

(d) Soils on Alluvial Deposits

Alluvial deposits occur along the Mackenzie River and its tributaries, as well as along streams flowing from the uplands of the Anderson Plain to the Arctic Ocean. The two main landforms associated with these deposits are low lying, modern floodplains and higher, older alluvial terraces.

Cumulic Regosols are common on level, rapidly-drained floodplains; they consist of alternating layers of variable-textured material (usually sand and silt) and have buried former surface horizons. Cobbles may be encountered within 1 m of the surface. The thickness of the surface horizon ranges from 0 to 5 cm, depending on the time since the most recent flooding. Frequently flooded terraces are vegetated by willow, while white spruce - feathermoss communities are common on older terraces (Table 1.3-2).

Most older floodplains are vegetated by stunted open spruce with a sedge-heath-cottongrass understory. Gleysolic Static Cryosols are common on these level poorly drained floodplains. These plains have permafrost within 30 to 40 cm of the surface and have silty loam textured gleyed mineral horizons under a thick (10 to 20 cm) surface peat layer.

1.3.1.2 Soils on Organic Parent Materials

Organic landforms are common in the Mackenzie Valley North area, being distributed throughout lacustrine and morainal landforms. Zoltai and Pettapiece (1973) have estimated that 10% of the Anderson Plain and 30% of the Peel Plain are covered with organic terrain, with about half of this area being covered by a thin veneer less than 1 m deep.

Zoltai and Tarnocai (1974) classified the organic terrain in this region as bogs or fens. Bog peatlands are raised above the level of neighbouring wetlands and are largely unaffected by surface and groundwater runoff. This results in soils which have high acidity and are low in nutrients. Conversely, fens are located in topographic depressions with gentle slopes, and act as water collectors. As a result, they are comparatively nutrient-rich and have a neutral pH.

Bogs are the dominant type of organic landform in the Mackenzie Valley north region. These bogs are all frozen within the surface metre and are classified as peat plateaus and palsas. In the northern part of this region the peat plateaus are dissected by ice wedges forming a polygonal surface pattern. Mesic and Fibric Organic Cryosols have developed on these landforms (Esso Resources, 1982), with a characteristic vegetation cover of *Sphagnum*- heath or black spruce - lichen. The depth of the active layer on bog landforms averages 40 cm in the southern portion of the region and 30 cm in the north.

It is commonly accepted that the organic material of this terrain was initially derived from sedges during the water-filled early development stage of low centre polygons. During later stages, *Sphagnum* becomes the dominant vegetation and the peat build-up continues, raising the centre of the polygon in relation to the trench. These raised centres gradually become ice-cored.

The surface fibric-*Sphagnum*-organic material has accumulated under recent climatic conditions. However, subsurface layers of mesic sedge-peat may be indicative of times when permafrost was absent. The lower portions of most organic soils are also more humified, suggesting that a warmer climatic period may have preceeded present environmental conditions (approximately 2,500 to 3,000 years ago).

Fens (bogs) occur on saturated level, or depressed land. On very gentle slopes they occur as saturated, stringed or ribbed fens. These organic deposits are usually unfrozen and very poorly drained, and their soils are classified as Typic and Fibric Mesisols. These soil types are described in more detail by Esso Resources (1982).

1.3.2 MACKENZIE VALLEY SOUTH

The Mackenzie Valley South sub-region includes portions of the Mackenzie Plain and the Franklin Mountains along the Mackenzie River between the mouth of the Willowlake River and Fort Good Hope (Figure 1.2-4). Large scale soil surveys have not been completed in this region although site-specific studies have been conducted by Day and Rice (1964), Tarnocai (1973), Zoltai and Pettapiece (1973), Gubbe and Janz (1974), Reid and Janz (1974), Zoltai and Tarnocai (1974), and Walmsley and Lavkulich (1975).

The dominant soils of the Mackenzie Valley South area are Cryosols. They occur on imperfectly to poorly drained sites and on most organic terrain. Well drained uplands contain mostly unfrozen soils, including Brunisols in the north, and Brunisols and Luvisols in the south. Regosols are common along rivers and creeks. Detailed descriptions of selected soils can be found in Esso Resources (1982), while landform - soil drainage relationships are shown in Table 1.3-3.

Soils of the Mackenzie Valley South area are better developed than those of the Mackenzie Valley North area (Section 1.3.1) since higher temperature and greater precipitation result in a greater degree of weathering and eluviation. Soils here are generally deeper and less influenced by permafrost, particularly south of Fort Norman. In addition, the process of cryoturbation of mineral soils is much less prevalent in this area than further north. Approximately 20 to 50% of the mineral soils show evidence of cryoturbation, compared with 80% in the Mackenzie Valley North area.

The Mackenzie Valley South portion of the corridor lies within the zone of widespread discontinuous permafrost. Permafrost is much more prevalent within 1 m of the surface in the northern half of the area (Fort Norman to Fort Good Hope) than south of Fort Norman. Within this region the major landforms, in order of dominance, are moraine plains

TABLE 1.3-3
DOMINANT LANDFORMS, DRAINAGE, SOILS AND ASSOCIATED VEGETATION OF THE MACKENZIE VALLEY SOUTH.
(Sources as cited in text.)

Landform	Drainage	Soils	Vegetation
Moraine (45%)	Rapid	Brunisolic Gray Luvisol	Black Spruce-White Birch/Lingonberry
	Well-Mod* Well	Orthic Gray Luvisols Brunisolic Turbic Cryosol	Black Spruce-White Birch/Lingonberry White Spruce/White Birch/Alder White Spruce-Aspen/Alder
	Imp†-Poor	Brunisolic Turbic Cryosol Gleyed Brunisolic Gray Luvisol Rego Gleysol Gleysolic Static Cryosol	Open Black Spruce/Labrador tea/Lichen Sparse Black Spruce/Sphagnum-Lichen
Bedrock and Colluvium (30%)	Rapid	Orthic Regosol Orthic Eutric Brunisol	Black Spruce-White Birch/Lingonberry
	Well-Mod Well	Orthic Eutric Brunisol	Black Spruce-White Birch/Lingonberry White Spruce-White Birch/Alder Subalpine White Spruce-Tamarack/ Mountain Avens
	Imp-Poor	Gleyed Regosol Gleyed Brunisol Rego Gleysol	Open Black Spruce/Labrador tea/Lichen Black Spruce/Feathermoss
Organic (10%)	Imp-Poor	Typic Mesisol Mesic Cryosol Fibric Cryosol	Sparse Black Spruce/Sphagnum-Lichen Open Black Spruce/Labrador tea/Lichen Sphagnum Bogs
Glaciolacustrine (10%)	Well-Mod Well	Brunisolic (Static) Cryosol (Turbic)	Black Spruce-White Birch/Lingonberry Black Spruce/Feathermoss
	Imp-Poor	Gleysolic (Static) Cryosol (Turbic)	Open Black Spruce/Labrador tea/Lichen Sparse Black Spruce/Sphagnum-Lichen Sedge Fen
Alluvial (3%)	Rapid	Eluviated Eutric Brunisol Cumulic Regosol	White Spruce-Aspen/Alder Balsam Poplar/River Alder/Horsetail
	Well-Mod Well	Orthic Eutric Brunisol Cumulic Regosol	White/Spruce/Feathermoss Balsam Poplar/River Alder/Horsetail
	Imp-Poor	Rego Gleysol Gleysolic Static Cryosol	Black Spruce/Feathermoss Open Black Spruce/Labrador tea/Lichen Sedge Fen
Glaciofluvial (2%)	Rapid	Eluviated Eutric Brunisol	Black Spruce-White Birch/Blueberry Moss Pine/Soapberry/Twinflower
	Well-Mod Well	Orthic Eutric Brunisol	Black Spruce-White Birch/Lingonberry White Spruce-Aspen/Alder
	Imp-Poor	Gleyed Eutric Brunisol Rego Gleysol Gleysolic Static Cryosol	Open Black Spruce/Labrador tea/Lichen Sedge Fen

*Moderately
†Imperfectly

(mostly west of the Mackenzie River), glaciolacustrine plains (bordering the Mackenzie River), colluvial slopes and bedrock (on and near the Franklin and Mackenzie mountains), and alluvial and glaciofluvial plains and terraces (near rivers and streams) (Figure 1.2-6).

1.3.2.1 Soils on Mineral Parent Materials

The dominant soils in the Mackenzie Valley South area are Turbic Cryosols developed on till and glaciolacustrine deposits (Figure 1.2-6). Orthic Brunisols, developed on well drained uplands, are extensive.

(a) Soils on Moraine Plains and Hummocky Moraine

The topography of these landforms ranges from flat to gently sloping on the Mackenzie Plain, to steeply sloping on hummocky or rolling moraine, while the texture of the till material varies from silt loam to clay loam with a few stones. Topography and drainage have the greatest influence on soil development. Cryosols predominate on imperfectly and poorly drained depressions and plains, while Brunisols and Luvisols have developed on well-drained uplands, primarily south of Fort Norman.

Cryosolic mineral soils have permafrost within 1 m of the surface and have thick peaty surface horizons developed from *Sphagnum* or forest peat. Most are affected by cryoturbation, which is evident from their hummocky external surfaces and by the disruption of their soil horizons internally. The depth to permafrost in these mineral soils ranges from 75 cm on imperfectly to well drained sites to 50 cm in poorly drained sites. Cryosolic soils are represented by Brunisolic Turbic Cryosols on moderately well drained fine textured sites, and by Gleysolic Static and Turbic Cryosols on imperfectly to poorly drained sites (Esso Resources, 1982).

Well drained unfrozen upland areas are covered by Luvisols and Brunisols. Here Brunisolic and Orthic Gray Luvisols have developed on fine textured, well drained, moderately to strongly calcareous till under mixed deciduous-coniferous forests, while Orthic, Eutric and Dystric Brunisols have developed on medium to coarse textured well drained moraine ridges and hummocks.

(b) Soils on Glaciolacustrine Deposits

Glaciolacustrine plains form a continuous belt adjacent to the Mackenzie River (Figure 1.2-6). The regional topography of this landform is flat to gently sloping with local thermokarst features. Textures are medium to fine and free of stones. These landforms are generally imperfectly to poorly drained and contain permafrost within 1 m of the surface. Gleysolic Static and Turbic Cryosols are the dominant soils on glaciolacustrine landforms, and these usually show some degree of cryoturbation, particularly north of Fort Norman. Brunisolic and Regosolic Turbic and Static Cryosols are common south of Fort Norman where active layers are thicker and drainage is better.

(c) Soils on Alluvial and Glaciofluvial Deposits

Alluvial and glaciofluvial plains and terraces are common at lower elevations along the Mackenzie River Valley. These landforms are gently sloping, and may be interrupted by shallow channels and low terraces. The parent materials are medium to coarse textured and are generally better drained than moraine or glaciolacustrine materials. Regosols and Brunisols without permafrost and Static Cryosols with permafrost are the dominant soils on these landforms. Earth hummocks and cryoturbation are uncommon.

Regosolic and Brunisolic soil development are characteristic of well to imperfectly drained coarse to medium textured soils in the northern half of the Mackenzie Valley south region, while Luvisols are more common in the south. Eluviated and Orthic Brunisols are representative soil types in moderately well to rapidly drained locations. Gleysolic Static Cryosols and Rego Gleysols are typically found on floodplains which remain saturated for part or most of the growing season.

(d) Soils on Bedrock and Colluvial Deposits

Soils which have developed on colluvial and bedrock materials are found in the Franklin Mountain region where the topography is moderately to steeply sloping and soils are generally shallow and coarse textured. Most of the landscape is well to moderately well drained, and the associated soils are predominantly classified as Regosols and Brunisols. Where patterned ground is evident soils usually have permafrost within 1 m of the surface and are classified as Brunisolic and Regosolic Turbic Cryosols.

1.3.2.2 Soils on Organic Parent Materials

Organic terrain is defined as wetland where organic matter accumulation is greater than 50 cm thick (Zoltai and Pettapiece, 1973). Approximately 30% of the land surface in the Mackenzie Valley south region is covered by organic terrain, most of which is bogland (peat plateaus and palsas) and some fenland. This terrain is extensive north of Fort Norman and is often associated with thermokarst topography. Most bog and forest-type peatlands have permafrost within 1 m of the surface, usually within 30 to 65cm.

Organic soils on plateaus and palsas are generally classified as Mesic and Fibric Organic Cryosols because they are undecomposed. Fenlands and saturated depressions are usually unfrozen within the surface metre and are classified as Typic Mesisols (Esso Resources, 1982).

1.3.3 GREAT SLAVE PLAIN - ALBERTA PLATEAU

The Great Slave Plain - Alberta Plateau portion of the Mackenzie Valley corridor extends from the mouth of the Willowlake River in the north southeastward along the Mackenzie Valley to the Alberta border in the south (Figure 1.2-1). It is a featureless plain interrupted by several prominent hill complexes. A large area of glaciolacustrine deposits, some of which have been reworked by wind to form dunes, is located near Fort Simpson, extending northward along the Mackenzie River Valley toward the Willowlake River. Till plains occur at slightly higher elevations along either side of the glaciolacustrine deposits of the Mackenzie River Valley. The region between Willowlake River and Fort Simpson is within the zone of widespread discontinuous permafrost (Figure 1.2-7), while the area south of Fort Simpson is a vast plain dominated by till within the scattered, discontinuous permafrost zone.

The Great Slave Plain - Alberta Plateau area is the only portion of the Mackenzie Valley corridor where soils have been surveyed at the reconnaissance level. These surveys have primarily focussed on soils along major river lowlands with agricultural potential. Day (1966, 1968) conducted surveys and prepared maps of the Liard River Valley and Upper Mackenzie River area. Rostad *et al.* (1976) conducted a soil survey along the Liard River and upper Mackenzie River to Camsell Bend, while the agricultural potential of this region was evaluated by Rostad and Kozak (1977). Other studies conducted in the Great Slave Plain - Alberta Plateau region include the investigations of Lavkulich (1972), Crampton (1973), Tarnocai (1973), Reid (1974), Reid and Janz (1974), and Rowe *et al.* (1974).

Most of the Great Slave Plain - Alberta Plateau region is covered by moraine plains consisting of silty clay tills. Mineral soils which occupy approximately 50% of the till plains on the numerous low relief moraine landforms are predominantly Luvisols and Gleysols, while Organics and Organic-Cryosols are found on the remaining low-lying areas with organic materials over till. Glaciolacustrine plains along river lowlands have a variety of soil types, including Organic soils with permafrost and Brunisols and Luvisols at various stages of development depending on drainage and texture. Alluvial and eolian deposits, which cover about 5% and 2% of the terrain respectively, contain mostly Regosols and Brunisols. In general coarser textured soils tend to have Brunisolic profiles, while those with higher clay content often form Luvisolic profiles (Rostad *et al.*, 1976).

Soils which have developed on mineral parent materials usually remain unfrozen within a metre of the surface and, of those that are frozen, only 5% are affected by cryoturbation processes. Because most mineral soils are unfrozen in the surface metre, soils are deeper and better developed than those of the northern Mackenzie Valley. In southern latitudes (including this region) mineral soils develop primarily in response to the normal processes of weathering and leaching, in contrast to northern permafrost areas where cryoturbation and drainage largely determine how soils develop. Detailed soil descriptions for this region are provided in Esso Resources (1982), while major landform - soil relationships are indicated in Table 1.3-4.

1.3.3.1 Soils on Mineral Parent Materials

(a) Soils on Till

Soils classified within the Gray Luvisol great group are the dominant soils on glacial till parent materials in the Great Slave Plain -Alberta Plateau region. They occur on calcareous, well to imperfectly drained silt-loam to clay-loam moraine landforms which are most prevalent in the numerous slightly elevated, upland areas. Associated forest vegetation includes deciduous, mixed deciduous-coniferous and coniferous forests. On well drained sites Orthic and Brunisolic Gray Luvisols are the dominant soils while gleyed subgroups may occur on imperfectly drained slopes and in depressions.

Other soils which occur in unfrozen areas are included in the Rego Gleysol subgroup of the Gleysolic great group. These soils are more extensive in the southern portion of the Great Slave Plain than further north, and are found on slopes between poorly drained frozen Organic soils and well drained unfrozen mineral soils.

(b) Soils on Glaciolacustrine Deposits

Glaciolacustrine deposits occur adjacent to the Mackenzie and Liard rivers. The parent materials on these landforms are predominantly medium to fine textured, and in some areas may be less than a metre thick over glacial till. Day (1966, 1968) reported that about 30% of the soil on these deposits are Orthic and Eluviated Eutric Brunisols in well drained areas; 20% are some variation of the Gleysol great group; and 20% are Organic; while only 5, 4 and 2% are Regosols, Luvisols and Podzols, respectively. Rostad *et al.* (1976) mapped lacustrine deposits in the same general region as being predominantly Eluviated Eutric Brunisols with lesser amounts of Rego Gleysols.

Brunisols have developed on well and imperfectly drained medium textured soils under mixed deciduous and coniferous forests. Eluviated and Orthic

TABLE 1.3-4
DOMINANT LANDFORMS, DRAINAGE, SOILS, AND ASSOCIATED VEGETATION OF THE GREAT SLAVE PLAIN - ALBERTA PLATEAU
(Sources as cited in text.)

Landform	Drainage	Soils	Vegetation	Forest Capabilities
Moraine (50%)	Rapid	Eluviated Eutric Brunisol	Pine/Soapberry/Twinflower	5-6
	Well-Mod* Well	Brunisolic Gray Luvisol	White Spruce-Aspen/Alder	5
		Orthic Eutric Brunisol	White Spruce/Rose/Feathermoss	5
			Black Spruce/Feathermoss	5
	Imp†-Poor	Gleyed Brunisolic Gray Luvisol	Open Black Spruce/Labrador tea/Lichen	7
		Peaty Gleysol	Black Spruce/Feathermoss	7
		Gleysolic Static Gleysol	Sedge Fen	—
Organic (25%)	Imp-Poor	Fibric Organic Cryosol	Sparse Black Spruce/Sphagnum-Lichen	0
		Typic Mesisol	Sedge Fen	
			Open Black Spruce/Labrador tea/Lichen	0
Glaciolacustrine (15%)	Well-Mod Well	Brunisolic Gray Luvisol	White Spruce-Aspen/Alder	5
		Eluviated Eutric Brunisol	Aspen/Rose	5
			White Birch/Willow	4
	Imp-Poor	Gleyed Brunisolic Gray Luvisol	Open Black Spruce/Labrador tea/Lichen	7
		Peaty Gleysol	Black Spruce/Feathermoss	6
		Gleysolic Static Cryosol	Sparse Black Spruce/Sphagnum-Lichen	7
Eolian (5%)	Rapid	Eluviated Eutric Brunisol	Pine/Soapberry/Twinflower	5-6
	Well-Mod Well	Orthic Eutric Brunisol	Pine/Soapberry/Twinflower	5
			White Spruce-Aspen/Alder	5
			White Spruce/Rose/Feathermoss	
	Imp-Poor	Gleyed Eutric Brunisol	Sedge Fen	
		Rego Gleysol	Open Black Spruce/Labrador tea/lichen	
			Black Spruce/Feathermoss	
Alluvial (2%)	Rapid	Orthic Regosol	White Spruce-Aspen/Alder	5-6
		Cumulic Regosol		
	Well-Mod Well	Orthic Eutric Brunisol	White Spruce-Aspen/Alder	5
		Cumulic Regosol	White Spruce/Rose/Feathermoss	5
	Imp-Poor	Gleyed Regosol	Open Black Spruce/Labrador tea/Lichen	7
		Rego Gleysol	Sedge Fen	—
Glaciofluvial (3%)	Rapid	Eluviated Eutric Brunisol	Pine/Soapberry/Twinflower	5-6
	Well-Mod Well	Orthic Eutric Brunisol	White Spruce-Aspen/Alder	5
			Aspen/Rose	5
	Imp-Poor	Gleyed Eutric Brunisol	Open Black Spruce/Labrador tea/Lichen	6
		Peaty Gleysol	Sedge Fen	4-5
			Black Spruce/Feathermoss	—

* Moderately
† Imperfectly

Eutric Brunisolic subgroups have developed on the well drained upper slopes in association with the slightly finer textured Gray Luvisols, while Eluviated and Orthic Dystric Brunisols may occur on coarser textured beach ridges.

(c) Soils on Alluvial Deposits

Undeveloped soils (Regosols) occur on recent alluvial deposits on low floodplains. Medium aged soils (Brunisols) are found on higher floodplains, while well developed Luvisols and Brunisols occur on the highest floodplains. The surface metre of most soils on alluvial floodplains and terraces is unfrozen. These soils have developed on calcareous gravel. sand and silt materials.

In well drained areas, well developed Eutric Brunisols and Gray Luvisols occur under mixed deciduous-coniferous forests. On imperfectly to poorly drained lands, Rego Gleysols and Gleyed Brunisols occur in younger and older sediments, respectively.

(d) Soils on Eolian and Glaciofluvial Deposits

The soils on eolian and glaciofluvial deposits are well drained coarse textured Eluviated Eutric Brunisols. Rego Gleysols, under black spruce and feathermoss-shrub vegetation, have developed under less well drained conditions on slopes near the perimeters of these landforms.

1.3.3.2 Soils on Organic Parent Materials

Organic soils are very common in the Great Slave Plain - Alberta Plateau region. Most organic terrain occurs in low-lying plains between upland ridges and hills on morainal and lacustrine deposits. Permafrost is particularly common in bog and forest-type peatlands, but is very uncommon in fen-type landforms.

Unfrozen organic soils, classified as Typic Mesisols, are common in fens of glaciolacustrine plains. Typic Mesisols occur on flat to gently sloping terrain and sometimes form a reticulate network of low ridges (patterned fen). The moderately decomposed peat is usually greater than one metre thick and is developed from decomposing sedge, tamarack and moss material under sedge, dwarf birch and tamarack vegetation. The surface pH of these soils is generally neutral and decreases with depth.

Much of the organic terrain in this region is frozen in the upper metre. Soils are classified as Fibric and Mesic Organic Cryosols. The moderately decomposed peat is usually greater than one metre thick and consists of *Sphagnum* peat derived from black spruce-heath-lichen-*Sphagnum* (or feathermoss) vegetation. These soils are commonly associated with peat plateaus and palsas. Unlike Typic Mesisols, the surface pH of these soils is very acidic (less than 5.0), and increases with depth.

1.3.3.3 Agricultural Capability

Rostad and Kozak (1977) have evaluated the agricultural potential of the terrain along the upper Mackenzie River to Camsell Bend and south along the Liard River. The main factor limiting seeded agricultural crops in the region is the cool summer temperatures. The low-lying floodplains and lacustrine terraces have the best climate within the area and are rated Class 3 for agricultural capability (soils with moderately severe limitations that restrict range of crops or require special conservation practices)(Canada Land Inventory, 1972). The well to imperfectly drained soils of these landforms are suitable for annual grain crops or cool season vegetables. However, the cost of clearing trees and lack of an economically viable market for crops have deterred agriculture in this region. The lacustrine soils at higher elevations and all morainal soils are rated Class 5 due to climatic limitations (very severe limitations that restrict their capability to producing perennial forage crops). All Gleysolic Cryosols are rated Class 5 to 7 in terms of agricultural capability (soils or land types with no capability for arable culture or permanent pasture), while organic soils are not suitable for agricultural production.

1.4 HYDROLOGY

1.4.1 DRAINAGE SYSTEM, WATER BALANCE AND FLOW REGIMES

The Mackenzie River basin, the largest in Canada, has a total drainage area of 1.8×10^6 km^2 and covers approximately 18% of Canada's land area (Figure 1.4-1). The length of the Mackenzie River from Great Slave Lake to the Beaufort Sea is approximately 1,700 km. The estimated local water balance between precipitation, evapo-transpiration and runoff within the Mackenzie River basin north of Great Slave Lake is shown in Table 1.4-1. Statistics used in this overview are derived from Energy, Mines and Resources Canada and Information Canada (1974), Supply and Services Canada and Environment Canada (1978) and Water Survey of Canada (1980b).

Figure 1.4-2 shows a schematic representation of the major flow components of the Mackenzie River. The mean annual river flow reaching the Beaufort Sea is approximately 10,000 m^3/s. About 42% originates from Great Slave Lake, 26% from the Liard River, 8% from the Peel River, 5% from the Great Bear River, and the remaining 19% from various tributaries between Fort Simpson and the Delta.

The monthly average flows (hydrographs) of the two principal components, the upper Mackenzie River out of Great Slave Lake, and the Liard River from British Columbia and the Yukon are very different (Figure 1.4-3). The topography of the Liard River basin consists mainly of mountains and hills without large storage areas and, therefore, the river responds

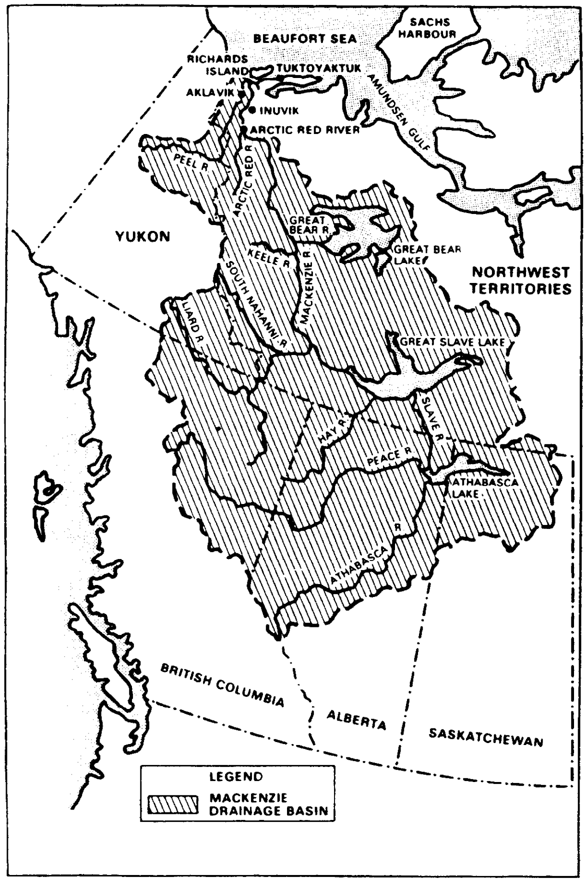


FIGURE 1.4-1 *Mackenzie River Drainage Basin (source: Energy, Mines and Resources Canada, 1974). The Mackenzie River Drainage Basin, the largest in Canada, drains approximately 18% of Canada's land area. The length of the Mackenzie River from Great Slave Lake to the Beaufort Sea is about 1,700 km.*

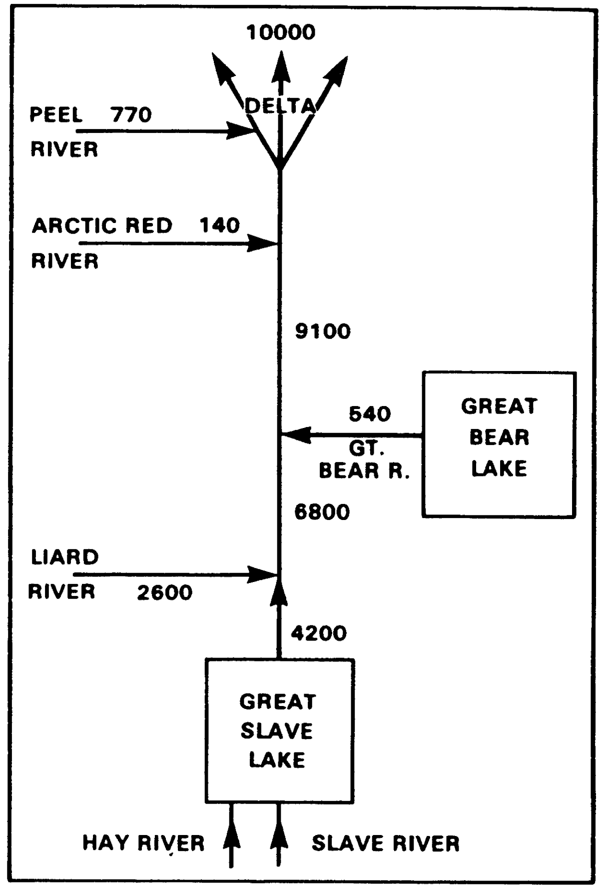


FIGURE 1.4-2 *Schematic representation of the major flow components of the Mackenzie River. Flows are in cubic metres per second. About 42% originates from Great Slave Lake, 26% from the Liard River, 8% from the Peel River, 5% from the Great Bear River, and the remaining 19% from various tributaries north of Fort Simpson.*

TABLE 1.4-1

APPROXIMATE WATER BALANCE WITHIN THE MACKENZIE RIVER DRAINAGE BASIN

Location	Annual Precipitation mm	% Precip. as snow	Annual Evapotranspiration mm	Annual Runoff mm
Great Slave Lake	400	30	300	100
Below Liard River	400	40	200	200
Mackenzie Delta	300	50	100	200

Source: Supply and Services Canada and Environment Canada (1978)

quickly to spring snowmelt and summer rainfall. On the other hand, the upper Mackenzie River hydrograph reflects the large storage capacity of Great Slave Lake. The Mackenzie system is presently affected by artificial water storage only on the upper Peace River in British Columbia, far upstream of Great Slave Lake. There are plans to develop water storage reservoirs on two Mackenzie River tributaries - the Slave River in Alberta and the Liard River in British Columbia.

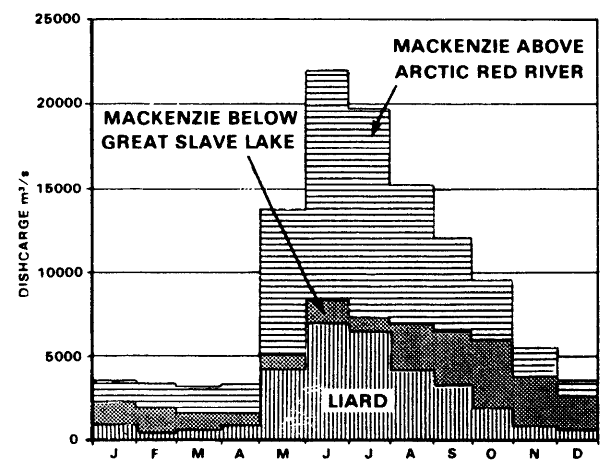


FIGURE 1.4-3 *Monthly average flow distributions for the upper Mackenzie, Liard, and lower Mackenzie rivers (Source: Water Survey of Canada, 1980b). The Liard River responds quickly to spring snowmelt and summer rainfall whereas the upper Mackenzie River monthly flows reflect the large storage capacity of Great Slave Lake.*

According to Environment Canada (1981) the proposed impoundment of the Liard River would appear to pose considerable concern with regard to possible downstream effects. These could include: a possible increase in Mackenzie River ice thickness during the winter, due to the release of impounded water at this time, and a decrease in spring flows entering the Mackenzie River from the Liard basin due to impoundment. These possible effects could in turn influence water levels and spring break-up in the Mackenzie River and Delta. This will be discussed further in Volume 4 of the Environmental Impact Statement.

Because of the large area of Great Bear Lake in relation to the river's drainage basin, the Great Bear River is almost totally regulated. Flows vary only about 10% from the average flow throughout the year. Other tributaries on the east side of the Mackenzie, like the Willowlake River, have relatively little storage and exhibit large differences between summer and winter flows. Details of monthly flows, including mean and extreme values at a number of stations on various tributaries, and on the Mackenzie mainstem are given in Table 1.4-2.

Surface water in the form of lakes and ponds is not a dominant feature of the terrain in the Mackenzie Valley. Along the corridor, surface water covers only between 4% and 10% of land areas.

1.4.2 RIVER CROSSINGS

From north to south, the pipeline corridor crosses the following major rivers: East Channel in the Mackenzie Delta , Great Bear River near Fort Norman, and the Mackenzie River upstream of Fort Simpson (Figure 1.4-4). Other rivers to be crossed are relatively minor from a hydrological viewpoint, the most important being the Hare Indian River near

TABLE 1.4-2

MONTHLY FLOWS AT SELECTED RIVER STATIONS

Location and Details	Monthly Discharges m^3/s											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
MACKENZIE RIVER ABOVE ARCTIC RED RIVER												
Drainage Area: 1,660,000 km^2												
Period of Record: 1972-1979												
Mean	3880	3640	3400	3510	13900	21900	19300	15300	12000	9490	5340	3700
Highest for each month	4720	4410	4290	4290	18800	23900	22100	21800	13700	11200	8210	4740
Lowest for each month	3530	3250	2870	2720	8820	19100	15900	12100	10300	6760	3640	2550
GREAT BEAR RIVER AT OUTLET OF GREAT BEAR LAKE												
Drainage Area: 146,000 km^2												
Period of Record: 1938-1979												
Mean	504	494	481	457	482	501	515	533	545	519	505	514
Highest for each month	597	600	551	540	577	691	724	749	745	687	645	647
Lowest for each month	178	174	163	149	166	185	228	240	247	211	172	175
MACKENZIE RIVER AT FORT SIMPSON												
Drainage Area: 1,270,000 km^2												
Period of Record: 1938-1979												
Mean	2790	2480	2370	2830	9740	14100	12700	9940	8430	7240	4410	2900
Highest for each month	3950	3530	3360	3960	12300	19500	18700	16900	14900	10100	5780	3610
Lowest for each month	2060	1670	1590	1880	6690	9810	9430	5270	3040	2610	2760	2430
LIARD RIVER NEAR THE MOUTH												
Drainage Area: 277,000 km^2												
Period of Record: 1972-1979												
Mean	468	459	447	561	4150	8120	6630	4230	2740	1790	672	498
Highest for each month	616	838	816	783	5520	11000	9130	5910	3700	2270	1010	640
Lowest for each month	337	322	321	382	2880	5030	3520	2900	2140	1520	490	359
MACKENZIE RIVER NEAR FORT PROVIDENCE												
Drainage Area: 971,000 km^2												
Period of Record: 1958-1979												
Mean	2160	1970	1820	1860	4820	6920	7160	6800	6380	5880	3930	2490
Highest for each month	2840	2670	2560	2490	6100	7940	8610	8840	8420	7920	5990	3290
Lowest for each month	1280	1190	1270	1220	3900	5700	5560	5090	4770	4310	3280	1500

Source: Water Survey of Canada (1980b)

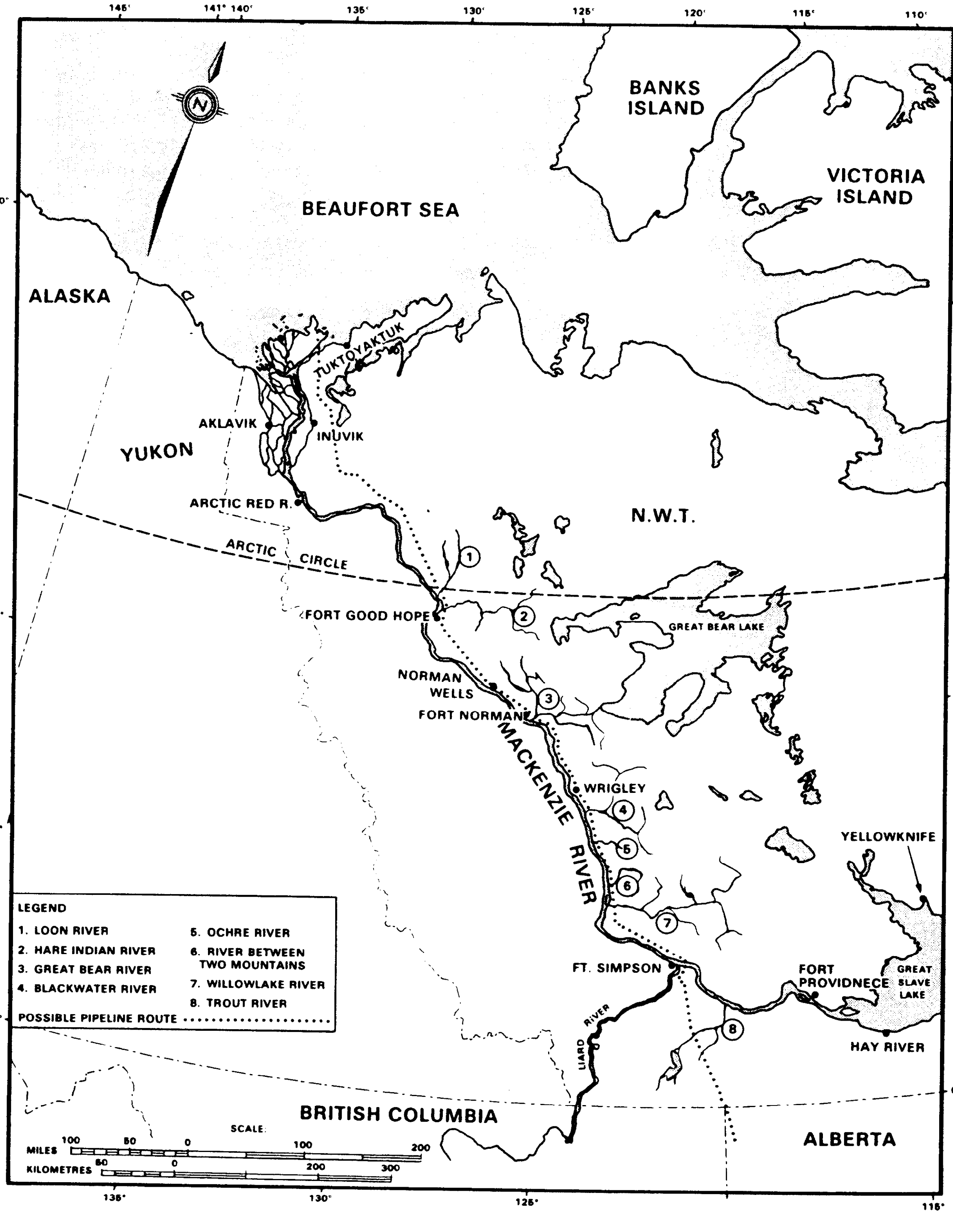


FIGURE 1.4-4 *River crossings for a possible pipeline route. (Source: Northern Engineering Services Ltd., 1974). Major river crossings are the East Channel in the Delta, the Great Bear River near Fort Norman and the Mackenzie River upstream of Fort Simpson.*

Fort Good Hope, the Blackwater River between Fort Norman and Wrigley, the Willowlake River between Wrigley and Fort Simpson, and the Trout River between Fort Simpson and 60° N. The Great Bear, upper Mackenzie, Willowlake and Trout rivers all have reliable flow records. Sites near all of the river crossings have been studied previously in connection with earlier pipeline proposals (Northern Engineering Services Ltd., 1974).

Some characteristics of the principal river crossings are listed in Table 1.4-3, including drainage areas, river widths, river types and statistics or estimates of key flows.

TABLE 1.4-3

CHARACTERISTICS OF PRINCIPAL RIVER CROSSINGS

River	Approx. Drainage Area (km^2)	Approx. Crossing Width (m)	River Type	Valley Type in Relation to River	Flow Estimates (m^3/s)	
					Mean Annual maximum	Mean Annual minimum
Mackenzie Delta East Channel	N.A.	2000	Meandering, sandy delta	N.A.	9000	800
Loon	2,500	45	Straight, gravel bed	Narrow, stable	100	0
Hare Indian	15,000	300	Meandering, sand bed	Narrow, partial floodplain	450	2
Great Bear	157,000	400	Sinuous, entrenched	Narrow, deep	550	430
Blackwater	10,000	135	Irregular entrenched meanders, gravel & boulders	Narrow, deep	350	2
Ochre	2,200	80	Entrenched meanders, gravel & boulders	Narrow, deep	120	0
River between Two Mountains	2,900	60	Entrenched meanders, gravel & boulders	Narrow, deep	150	0
Willowlake	22,000	250	Meandering, gravel, sand	No defined valley	600	3
Mackenzie	993,000	700	Straight, stable	Fairly wide	7500	2000
Trout	6,700	120	Meandering	Wide, shallow	200	0

Source: Northern Engineering Services Ltd. (1974).

1.4.3 ICE CONDITIONS IN RIVERS AND LAKES

The principal ice conditions of interest are dates of freeze-up and break-up, late winter ice thicknesses, and special phenomena such as ice jams, particularly if they may occur near river crossings.

Timing of freeze-over and ice clearance, and ice thicknesses for three river locations along the corridor are shown in Table 1.4-4. Tabulated values include both means and extremes over the record period. Freeze-over timing refers to attainment of a complete ice cover, while ice clearance timing refers to attainment of an open water condition. At some river locations slush ice, up to several metres thick, may be present under the solid cover. Ice thicknesses refer to the greatest thickness of solid ice attained in late winter. Mean ice cover timing dates and thicknesses for four lake locations are shown in Table 1.4-5.

Ice jamming and shoving, accompanied by abrupt rises in water levels, are features of spring break-up along the Mackenzie River which tend to recur at certain locations year after year. These are particularly prominent in certain years when high spring streamflows from the Liard River encounter thick, hard ice (Blench and Assoc. Ltd., 1974a, 1974b, 1975). Locations and heights of jamming were first documented by MacKay and Mackay (1973a,b) who presented a diagram based on field observations which indicated heights of maximum ice shove and associated flood levels all along the Mackenzie River. Especially high levels were shown below the Liard confluence, at the mouth of the Great Bear River and at the Ramparts near Fort Good Hope. Upstream of the Liard River, break-up conditions are relatively quiescent.

1.4.4 EROSION AND SEDIMENTATION

Data on sediment loads of the Mackenzie River basin tributary waters are scarce. The following statistics are based on Neill and Mollard (1980), Water Survey of Canada, (1980b) and Mollard and Assoc. (1981). The average quantity of sediment carried into the Delta by the Mackenzie and Peel rivers together is estimated to be 150 x 10^6 tonnes per year. About 10% of this consists of sand, carried partly in suspension and partly as bed-load, while the other 90% consists of silt and clay carried entirely in suspension. The mean suspended sediment concentration of the lower

TABLE 1.4-4

MACKENZIE RIVER ICE CONDITIONS

Location	Dates of Freeze-Over			Dates of Ice Clearance			Ice Thicknesses (max. in winter)		
	Earliest	Mean	Latest	Earliest	Mean	Latest	Lowest	Mean m	Highest
East Channel @ Inuvik	Oct 2	Oct 19	Oct 28	May 31	June 5	June 12	1.0	1.35	1.7
Mackenzie @ Norman Wells	Oct 28	Nov 14	Dec 5	May 21	May 28	June 10	1.3	1.7	2.0
Mackenzie above Liard River	Nov 15	Nov 27	Dec 15	May 16	May 25	May 31	0.9	1.6	2.3

Source: Allen (1977)

TABLE 1.4-5

LAKE ICE CONDITIONS

Location	Mean Date of freeze-over	Mean Date of ice clearance	Mean Ice Thickness (winter max.) m
Near Beaufort Sea Coast	Oct. 5	June 27	1.75
Near Norman Wells	Oct. 10	June 22	1.6
Near Fort Simpson	Oct. 20	June 5	1.4
At 60th Parallel	Oct. 23	May 26	1.3

Sources: Supply and Services Canada and Environment Canada (1978), Allen (1977)

Mackenzie River is about 350 mg/L, with maximum concentrations near 10,000 mg/L being recorded during flood conditions in 1974. Roughly half of the sediment carried into the Delta by the Mackenzie River originates from the Liard River basin. The remainder comes mainly from tributaries on the west side of the river between Fort Simpson and the Delta.

Although the Mackenzie is not a classical meandering river, in places it is characterized by the common fluvial processes of bank erosion, bar deposition, and shifting of channels and islands. The most common types of bank erosion involve local collapse by undercutting and surficial sloughing, but deep-seated rotational and translational slides also occur (Chyurlia, 1973; Neill, 1973). Areas with high rates of bank recession are generally quite localized. For example, near Norman Wells recession rates up to 10 m per year have been detected at certain points, but other locations have been stable for decades (Northwest Hydraulic Consultants Ltd., 1979). In the Mackenzie Delta, local bank erosion rates up to 30 m per year have been recorded for some Delta channels (Outhet, 1974). However, lower rates were observed for these channels by Hollingshead and Rundquist (1977).

The banks of tributaries on the east side of the Mackenzie River are relatively stable and exhibit little erosion or sedimentation activity. However, bank slides occur locally on the Great Bear River (Neill, 1973). Also, much older and less pronounced slope movements have occurred in the past along several of the tributary valleys such as the Saline, Ochre, and Blackwater valleys. More active slope conditions have been noted along some of the smaller, more northerly tributaries such as Hanna Creek.

1.4.5 WATER QUALITY

Background data on water quality are presented in Table 1.4-6 for the Mackenzie River from Fort Providence to Arctic Red River. Data for four Mackenzie tributaries, the Trout, Willowlake, Blackwater and Hare Indian rivers, are also included. Over 60 parameters, including aesthetic parameters, nutrient levels and heavy metals have been compiled by the Water Quality Branch (1981) of Environment Canada. The values summarized here are the averages of results reported over a number of years. For comparative purposes federal water quality guidelines are shown in Table 1.4-7.

1.4.5.1 Water Quality of Selected Rivers Along the Mackenzie Valley Corridor

(a) Trout River

The Trout River joins the Mackenzie River between Fort Providence and Fort Simpson. The colour is high at 28 True Colour Units (TCU) and turbidity averages 49.1 Jackson Turbidity Units (JTU), with a

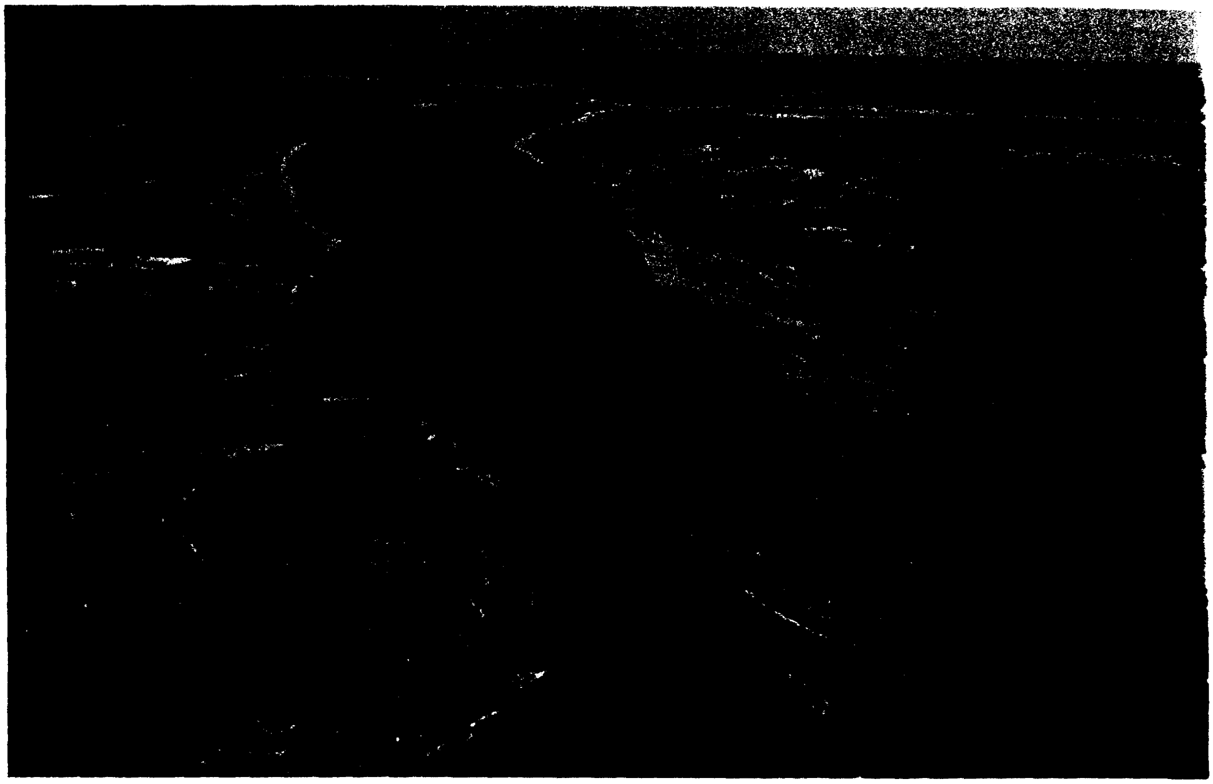


PLATE 1.4-1 *The Mackenzie River and its delta. The lower Mackenzie River is highly turbid, carrying an average suspended sediment concentration of 350 mg/L. The quantity of sediment carried into the Delta by the Mackenzie and Peel Rivers together is estimated to be 150 million tonnes per year.*

high of 650 JTU. The water is medium-hard and has a good buffering capacity as shown by an alkalinity of 89.6 mg/L. The pH is slightly alkaline, averaging 8.3. All other parameters are within the recommended values given for water use.

(b) Willowlake River

The Willowlake River joins the Mackenzie River upstream of Wrigley. It is characterized by generally high turbidity (20.2 JTU), colour (61 TCU) and hardness (120 mg/L). Total dissolved solids are also relatively high at 234 mg/L. The alkalinity averages 87.0 mg/L and shows good buffering capacity, while the pH is slightly alkaline at 8.2

(c) Blackwater River

The Blackwater River joins the Mackenzie River downstream from Wrigley. The colour and turbidity of water from this river are slightly higher than recommended, as are total dissolved solids (336 mg/L), hardness (220.3 mg/L) and alkalinity (100.9 mg/L). These parameters are the only ones which exceed the desirable concentrations for water quality.

(d) Hare Indian River

The Hare Indian River joins the Mackenzie River at Fort Good Hope. Total dissolved solids, hardness and alkalinity are all high in samples from this river, while colour is slightly high and turbidity is within the recommended range.

(e) Mackenzie River

Mackenzie River water samples generally have a slightly alkaline pH in the 8.2 to 8.7 range. The colour exceeds the water quality guideline value of 15 TCU, ranging between 22 and 82 TCU. Turbidity is generally high (8.9 to 86.9 JTU, (based on a recommended standard of 5.0 JTU). Total dissolved solids (124 to 153 mg/L), hardness (96.5 to 123.2 mg/L) and alkalinity (77.3 to 91.6 mg/L) are relatively high but within recommended limits. These parameters show that the water has a good buffering capacity. Copper content, at 0.004 to 0.03 mg/L, exceeds the recommended guideline value (0.005 mg/L) for preservation of aquatic life. All other parameters are within the recommended values. The influence of the four rivers joining the Mackenzie can be seen in the variation of colour, conductivity, total dissolved sol-

TABLE 1.4-6

SUMMARIES OF WATER QUALITY DATA FROM MACKENZIE RIVER SAMPLING STATIONS AND STATIONS ON THE TROUT, WILLOW LAKE, BLACKWATER AND HARE INDIAN RIVERS (WATER QUALITY BRANCH, 1981)

Parameter	Mackenzie River	Other Rivers	Range From Table 1.4-7
Conductivity (uS/cm)	197-269	255-765	
pH	8.2-8.7	8.2-8.4	6.5-9.0
Colour (TCU)	22-82	23-61	15.0
Turbidity (JTU)	8.9-96.9	4.5-49.1	5.0
Saturation Index	0.4-1.0	0.8-1.3	
Total Dissolved Solids	124-153	124-512	500-3000
Hardness	96.5-123.2	102.6-417.3	120
Alkalinity	77.3-91.6	87.0-112.6	
Potassium	0.9-1.3	0.9-1.6	
Sodium	7.0-8.3	5.2-65.4	270
Calcium	27.7-35.6	33.0-140.6	200-1000
Carbonate	0	0	
Bicarbonate	94-118	101-133	
Chloride	7.0-13.8	2.2-99.3	250
Sulphate	23.4-45.7	15.1-295	500-1000
TKN	0.04-0.6	0.5-0.7	
Nitrate/Nitrite	0.08-1.8	0.056-0.139	10.0
Total Dissolved Phosphorus	0.003-0.09	0.003-0.024	0.1
Total Inorganic Phosphorus	0.004-0.29	0.003-0.021	0.065
Total Phosphorus	0.039-3.31	0.015-0.018	0.2
Total Organic Carbon	7.3-10.8	9.9-16.8	
Total Inorganic Carbon	15.3-18.1	16.0-16.3	
Dissolved Oxygen	10.6-14.0	10.4-15.5	>4.0
Boron	0.04-0.05	0.05-0.09	5.0
Lithium	0.005-0.008	0.005-.028	
Vanadium	0.046-0.053	0.05-0.054	0.1
Chromium	0.011-0.013	0.01-0.011	0.05-1.0
Manganese	0.003-0.011	0.006-0.02	0.05
Iron	0.02-0.172	0.052-0.077	0.3
Nickel	0.002-0.009	0.002-0.005	0.025
Copper	0.004-0.03	0.001-0.006	(0.005)** 0.5-1.0
Zinc	0.004-0.013	0.002-0.014	(0.03)** 5.0-25.0
Arsenic	0.005-0.0057	0.004-0.008	0.05-0.5
Cobalt	0.002-0.004	0.002-0.002	1.0
Molybdenum	0.05-0.08	0.05-0.06	0.01*
Cadmium	0.001-0.002	<0.001-0.001	0.003-0.01
Barium	<0.1-0.1	<0.1	1.0
Mercury (ug/L)	<0.05-0.06	0.06-0.07	0.2-2.0
Lead	<0.01-0.016	0.002-0.004	0.05-0.1
Fluoride	0.09-0.13	0.06-0.23	1.4-2.0
Aluminum	0.027-0.047		5.0

*Livestock Requirement.
**Fresh Water Aquatic Requirement.
Units as mg/L except where noted.

ids, hardness and turbidity values.

The data show that in general, the water quality of the Mackenzie system is good. Only values for colour, turbidity and hardness exceed the guideline values quoted. Nutrient levels are very low and metal concentrations are generally well within the guideline values.

1.4.6 GROUNDWATER

Although permafrost has previously been regarded as an impermeable barrier to groundwater flow, according to Harlan (1974) this is not strictly correct. Harlan estimated the rate of water movement through frozen ground to be on the same order as that through partially saturated unfrozen soils. Movement is driven by a thermal gradient which is analogous to a hydraulic gradient.

Within the Mackenzie River Valley significant quantities of groundwater are found only at depth beneath the permafrost, and in unfrozen zones beneath larger lakes and rivers which do not freeze to the bed across their full width. Thus, while water movement through frozen ground may be possible, the areal extent and thickness of permafrost severely restricts this movement. Supra-permafrost groundwater (that which flows through the active layer within a few metres of the ground surface) is only significant during the thaw season.

Substantial quantities of groundwater do flow within the unfrozen alluvial deposits of larger streams and in some cases are manifest by continuous winter streamflow, cool springs, open water, and aufeis conditions in the stream bed.

Warm water springs are relatively common within the valleys of Mackenzie River eastern tributary streams between the Donnelly and Blackwater rivers. These springs are considered to be discharges of groundwater from below the permafrost with sources in the Mackenzie Mountains to the west. The dissolved mineral content of spring water varies widely and is likely related to the distance it has travelled and the lithology along the flow path.

Much of the present knowledge of groundwater discharges in the Mackenzie Valley results from investigations by Van Everdingen (1973, 1974) who reported on springs in the valleys of Mackenzie tributaries, including the Saline, Little Smith, Vermillion, Prohibition, Canyon, Bosworth, Hodgson, Oscar and other streams. The springs had flows up to 190 L/s, with temperatures up to 8° C. Some of the springs cause open water for up to several kilometres downstream and/or aufeis conditions. Van Everdingen (1974) mapped numerous springs along the base of the Norman Range between Oscar Creek and the Hanna River. These springs feed several ponds and small lakes in the area. Several other springs which contribute to extensive aufeis have been observed in the Gibson pass area. Detailed surveys of spring discharge, open water and ice conditions in late winter were also reported by McCart *et al.* (1974).

TABLE 1.4-7

GUIDELINES FOR WATER QUALITY

Parameter	Canadian Drinking Water Guidelines	Acceptable Raw Water Quality For Supply of Drinking Water	Guidelines For Live-stock & Wildlife Watering	Guidelines For The Protection of Fresh Water Aquatic Life
Colour (TCU)	15	15		
Turbidity (JTU)	5	5		
pH (pH Units)	6.5-8.5	6.5-8.3		6.5-9.0
Total Dissolved Solids	500	1000	3000	
Hardness	80-100	120		20
Alkalinity		30-500		
Sodium		270		
Calcium		200	1000	
Magnesium		150		
Chloride	250	250		
Sulphate	500	500	1000	
Ammonia Nitrogen		0.5		0.02
Nitrate/Nitrite	10.0	10.0	100	
Nitrite	1.0	1.0	10	
Total Inorganic Phosphorus		0.065		0.05
Total Phosphate		0.1		0.10
Total Phosphorus		0.2		0.025
Dissolved Oxygen				4.0
Fluoride	1.5	1.4	2.0	
Boron	5.0	5.0	5.0	
Vanadium			0.1	
Chromium (6)	0.05	0.05	1.0	0.1
Cobalt			1.0	
Manganese	0.05	0.05		
Iron	0.3	0.3		0.3
Nickel				0.025
Copper	1.0	1.0	0.5	0.005
Zinc	5.0	5.0	25.0	0.03
Arsenic	0.05	0.5	0.2	
Molybdenum			0.1	
Cadmium	0.005	0.01	0.05	0.003
Barium	1.0	1.0		
Mercury (μg/L)	1.0	2.0	10 mg/L	0.2
Lead	0.05	0.05	0.1	
Selenium	0.01	0.01	0.05	
Silver	0.05			
Cyanide	0.2	0.01		0.005
Sulphide	0.05	0.3		0.002
Aluminum			5.0	
Beryllium				0.011

Maximum values are quoted. All units are mg/L except where noted.

Sources: Health and Welfare Canada, (1979); McNeely et al., (1979).

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CHAPTER 2

PLANTS AND ANIMALS

This part of Volume 3C summarizes existing information on the plants and animals of the Mackenzie Valley corridor, generally illustrated in Figure 1.-1. For certain key species, which may migrate into and out of the region (eg. Bluenose caribou), the area covered is extended. Separate sections provide the most relevant information on the mammals, birds, aquatic resources and vegetation of the region. Section 2.5 reviews the resource harvesting activities of people living in the region, while Section 2.6 identifies areas of special interest within the corridor.

Additional information on all these subjects can be found in Volume 3A, the various supporting documents to the Environmental Impact Statement, and the literature cited in the text. To assist the reader, Table 2-1 is provided; it defines many of the more important biological terms used throughout this chapter.

2.1 MAMMALS

There are at least 45 species of mammals known to occur in the Mackenzie Valley pipeline corridor (Table 2.1-1). Their local and regional distributions and abundances vary considerably, depending upon habitat availability and access to terrain suitable for various life history phases such as calving and denning. The following discussion emphasizes species which are considered important to the subsistence hunting and trapping economy of the people of the Mackenzie Valley.

A description of the general biology, distribution and abundance of each species follows. Geographic names referenced in these descriptions are shown in Figure 2.1-1. The primary sources of information on distribution and abundance were obtained from reports of several other pipeline proposals for the Mackenzie Valley and Yukon North Slope, proposals for petroleum exploration and development in the Mackenzie Delta and the coastal Beaufort Sea, and proposals related to the Mackenzie Highway. However, harvest statistics provide the only source of information on the distribution and abundance of some species.

2.1.1 UNGULATES

2.1.1.1 Caribou

Three of the five subspecies of caribou currently recognized in Canada occur in the Mackenzie Valley. There is a herd of domesticated European reindeer *(Rangifer tarandus tarandus)* on the Mackenzie Delta and in the Tuktoyaktuk Peninsula region (Banfield, 1974). The barren-ground caribou *(R. t. groenlandicus)* inhabits the continental tundra zone in the Northwest Territories as well as Baffin and Bylot islands. The woodland caribou *(R. t. caribou)* occupies the boreal forest regions of southern Canada from Newfoundland and Labrador to British Columbia, and occurs as far north as the tree line in the Northwest Territories and the Ogilvie Mountains in the Yukon.

(a) Reindeer

As caribou had disappeared from the Mackenzie Delta area by the early part of this century (Porsild, 1945), the Canadian government purchased 3,000 reindeer from Alaska (Nowasad, 1973) to provide residents of the Delta with a reliable food supplement. A herd of semi-domesticated reindeer was established east of Inuvik in 1935 (Scotter, 1969), and has been managed by various federal agencies until recently when it was sold to private interests. The herd is currently owned by Canadian Reindeer (1978) Ltd. and is operated out of Tuktoyaktuk by Mr. William Nasogaluak. The herd numbered approximately 5,100 at round-up in 1973 (Slaney, 1974a), increasing to between 9,000 and 10,000 by the autumn round-up of 1978 (V. Hawley, pers. comm.; R. Hawkins, pers. comm.). In 1980, the herd numbered 13,000 animals (Nasogaluak and Billingsley, 1981).

The area designated for use by the reindeer herd was expanded in 1952 and presently covers 46,620 km^2 known as the Mackenzie Reindeer Grazing Reserve (Figure 2.1-2). In recent years the herd has wintered in a broad area west of Eskimo Lakes and Sitidgi Lake and has calved in the vicinity of Parsons Lake during April and early May (W. Nasogaluak, pers. comm.). The reindeer are herded to the summer range in the north of the Tuktoyaktuk Peninsula in early June. However, a few animals may remain in the Parsons Lake area in summer (R. Hawkins, pers. comm.; Slaney, 1974a). In October the herd is moved westward back to its winter range.

Although the normal range of the reindeer herd occurs to the east of the Mackenzie Valley corridor (Figure 2.1-2), a few feral animals may be present along the route on Richards Island (Slaney, 1974a) and in the Caribou Hills (Prescott *et al.*, 1973a). For example, about 150 reindeer were estimated to inhabit Richards Island in 1973 (Slaney, 1974a). Their distribution during winter is less well known, but they were observed on the northern part of the island during March 1972 and in April 1973 (Slaney, 1974a, 1974b). Richards Island was previously used as the primary summer range for the herd until the

TABLE 2-1

GLOSSARY OF BIOLOGICAL TERMS

Algae	A group of aquatic one-celled, colonial or many-celled plants which contain chlorophyll, e.g. seaweed, pond scum.
Anadromous	Fish that return from the ocean to freshwater to reproduce (spawn), e.g. salmon.
Autotrophic	The capability of an organism to make its own food, e.g. photosynthesis by plants.
Benthos	Plants or animals that live on or in the bottom of the sea (or lake).
Bloom	The production of large numbers of plankton or epontic organisms in a relatively short time period.
Cellulose	The fundamental constituent of the cell wall of all green plants.
Copepodite	A stage in the life of some young invertebrates.
Demersal	Fish that live on and/or near the bottom of the sea (or lake).
Detritus	Accumulation of fine material worn away or broken off rocks. Also material suspended in the water column including fragments of small plants and animals, and waste products of small animals living in the water.
Detritivores	Organisms that utilize detritus for food.
Epifauna	Animals that live on the surface of the bottom sediments in the sea. Some epifauna may be mobile and may occasionally burrow into the bottom substrate, but usually they occupy the surface.
Epontic	The under surface of the ice.
Estuarine	A coastal area where freshwater (usually originating from a river) is mixed and diluted by seawater.
Euphotic Zone	A zone near the surface of the sea into which sufficient light penetrates for photosynthesis to occur.
Euryhaline	The ability to tolerate a wide variation in the salt content of the water.
Fauna	Animals in general, or animal life as distinguished from plant life.
Fecal pellets	The solid or semi-solid wastes from zooplankton and some other invertebrates.
Flagellates	Organisms which have a fine long thread-like projection which they use for movement (Dinoflagellate = flagella).
Food Web	A diagramatic presentation of a natural community, which indicates what each member eats. The bottom of the web are plants and bacteria and large carnivores are the top of the web.
Flora	Plants in general or plant life as distinguished from fauna (animal life).
Fry	Young fish, usually less than one year old.
Herbivore	An animal that feeds on plants.
Heterotrophic	An organism whose food is organic material produced by other organisms.
Infauna	Animals that live buried in the bottom sediments of the sea (or lake).
Invertebrate	An animal without a backbone, e.g. worms.
Larvae	The pre-adult form in which some animals hatch from the egg.
Macrophytes	Large aquatic plants (algae) which usually grow only where a solid substrate for attachment is available.
Meiofauna	Very small animals that live on and/or in the bottom of the sea.
Microbial	Microscopic organisms.
Nauplii	A stage in the life of some young invertebrates.
Nonspawners	Adult fish that are sexually mature, but will not reproduce during that year.
Oleoclastic	Organisms which can utilize oil for food.

TABLE 2-1 (Cont'd)

GLOSSARY OF BIOLOGICAL TERMS

Pelagic	Inhabiting the open water of the sea (or lake), in contrast to the seabottom.
Photic Zone	A zone near the surface of the sea into which sufficient light penetrates for photosynthesis to take place (= euphotic).
Photosynthesis	The formation of organic compounds by plants from water and carbon dioxide using the energy absorbed from sunlight by chlorophyll.
Phytoplankton	Aquatic plants (algae) that live in the water column.
Plankton	Small plants and animals that live in the water column.
Predation	Preying on other animals, as opposed to eating (grazing on) plants.
Primary Product (ion) (ivity)	The energy produced by plants through photosynthesis.
Psychrotrophs	Organisms that can tolerate cold temperatures.
Psychrophiles	Organisms that grow best at cold temperatures.
Respiration	The taking of oxygen from the environment and giving off of carbon dioxide. For example, pumping air in and out of lungs, or water over gills.
Secondary Product (ion) (ivity)	The energy produced by animals which eat plants.
Spawn	The eggs (roe) and sperm (milt) from fish, or the act of depositing these products during periods of fish reproduction.
Taxonomic	The scientific classification of living things.
Trophic (Levels)	Related to feeding, refers to the position of an animal in the food web.
Vertebrate	An animal with a backbone.
Zoobenthos	Animals that live on or in the seabottom.
Zooplankton	Small animals that live in the water column.

early 1960's, but overuse of northern areas of the range eventually forced the herders to abandon it (Cody, 1963). However, Richards Island may again be used as either summer (Slaney, 1974a) or winter range in the future if existing habitats become depleted (R. Hawkins, pers. comm.). Feral reindeer may also be included in a population of 1,000 to 2,000 animals (undetermined subspecies) which migrate between the summer range near the Eskimo Lakes and the winter range around Travaillant Lake (Prescott *et al.*, 1973a; Watson *et al.*, 1973).

(b) Barren-ground Caribou

Barren-ground caribou make regular long distance migrations from wintering ranges in the northern boreal forest to summer ranges on the coastal tundra. They typically congregate in large herds during late winter just prior to their spring migration, in mid summer during and shortly after calving, and in the autumn prior to their autumn migration and rutting (Banfield, 1974).

The habitat needs of barren-ground caribou change seasonally because of their food requirements. During winter these caribou usually inhabit the mature boreal forest (Banfield, 1974) where they forage on lichen and moss undergrowth (Thompson and McCourt, 1981). They often frequent the edges of frozen lakes for sunning (Banfield, 1974). The diet of mosses and lichens is gradually replaced by one of sedges and shrubs (primarily willow species) during the period from spring migration to late summer. For example, Thompson and McCourt (1981) found that cottongrass *(Eriophorum spp.)* comprised the bulk of the diet of caribou of the Porcupine herd during spring migration and calving. The leaves of deciduous shrubs constituted most of their food after calving and in mid summer, and about 20% of their late summer diet.

Caribou calve from late May through early June and rut from mid September through October. Females do not usually breed until at least 28 months of age, and frequently not until they are 40 months old

TABLE 2.1-1

TERRESTRIAL MAMMALS IN THE MACKENZIE VALLEY CORRIDOR

Common Name	Scientific Name
Masked shrew	Sorex cinereus
Dusky shrew	Sorex monticolus
Arctic shrew	Sorex arcticus
Water shrew	Sorex palustris
Pygmy shrew	Microsorex hoyi
Little brown bat	Myotis lucifugus
Snowshoe hare	Lepus americanus
Least chipmunk	Eutamias minimus
Woodchuck	Marmota monax
Arctic ground squirrel	Spermophilus parryii
American red squirrel	Tamiasciurus hudsonicus
Northern flying squirrel	Glaucomys sabrinus
American beaver	Castor canadensis
Deer mouse	Peromyscus maniculatus
Northern red-backed vole	Clethrionomys rutilus
Gapper's red-backed vole	Clethrionomys gapperi
Heather vole	Phenacomys intermedius
Brown lemming	Lemmus sibiricus
Northern bog lemming	Synaptomys borealis
Collared lemming	Dicrostonyx torquatus
Muskrat	Ondatra zibethicus
Meadow vole	Microtus pennsylvanicus
Tundra vole	Microtus oeconomus
Chestnut-cheeked vole	Microtus xanthognathus
Meadow jumping mouse	Zapus hudsonius
Porcupine	Erethizon dorsatum
Coyote	Canis latrans
Wolf	Canis lupus
Arctic fox	Alopex lagopus
Red fox	Vulpes vulpes
American black bear	Ursus americanus
Grizzly bear	Ursus arctos
American marten	Martes americana
Fisher	Martes pennanti
Ermine	Mustela erminea
Least weasel	Mustela nivalis
American mink	Mustela vison
Striped skunk	Mephitis mephitis
Wolverine	Gulo gulo
River otter	Lutra canadensis
Lynx	Lynx canadensis
White-tailed deer	Odocoileus virginianus
Mule deer	Odocoileus hemionus
Moose	Alces alces
Caribou	Rangifer tarandus

Sources: Banfield, 1974; Youngman, 1975; Jones, et al, 1979.

(Skoog, 1968). About 80% of the adult females produce one calf each year so that calves typically form 26 to 35% of the population in a herd with a sex ratio of 1 male to 2 females. Recruitment of calves which survive until one year of age is estimated to be 15% of the caribou population although it is often lower (Thompson *et al.*, 1980).

The Bluenose herd is the only population of barren-ground caribou that ranges within the Mackenzie Valley corridor (Plate 2.1-1). (The Porcupine caribou herd does not frequent the corridor. Details of this herd are provided in Volume 3A, Section 4.1). The range of the Bluenose herd includes the mainland of the Northwest Territories between the Coppermine and Mackenzie rivers north of Great Bear Lake (Hawley *et al.*, 1976) (Figure 2.1-2). Several studies during the past 25 years have resulted in a variety of herd population estimates ranging from 35,000 to 40,000 in the 1950's (Kelsall, 1968); 39,900 in the mid 1960's (Hawley and Pearson, 1966); 19,000 in 1967 (Thomas, 1969); to 92,000 in 1974 (Hawley *et al.*, 1976); 42,000 in March 1977 (Wooley and Mair, 1977); 33,000 in June 1978 and 37,000 in June 1979 (Brackett *et al.*, 1978, 1979); 58,000 in March 1980 and 38,000 in February 1981 (Carruthers and Jakimchuk, 1981). This herd is presently considered to be stable at about 40,000 animals (D. Heard, pers. comm.).

The most frequently used winter range of the Bluenose herd is between the Kugaluk River and Horton Lake and along the northeast shore of Great Bear Lake (Figure 2.1-2). Kelsall (1968) reported that some caribou crossed the Mackenzie River near Fort Norman in the winter of 1950-51, although similar movements have not been documented recently (Prescott *et al.*, 1973a). A westward expansion of the winter range was reported in the mid 1970's (Decker, 1976; Hawley *et al.*, 1976). Surveys conducted by Wooley and Mair (1977) to determine the potential for interaction between the Bluenose herd and the proposed Arctic Gas pipeline revealed numerous caribou wintering north of Colville Lake, but very few animals west of the Miner River. These authors concluded that, if the herd continued to winter in the same locations as used in 1976-1977, they would not encounter the pipeline. They expected that a few 'resident' caribou would encounter the pipeline, with interactions most likely occurring between Sitidgi Lake and the Thunder River.

Some barren-ground caribou may be included in a group of undetermined species that winters near Travaillant Lake and summers just south of Eskimo Lakes. This group has been estimated to number between 1,000 and 2,000 animals, and may also include woodland caribou and feral reindeer (Prescott *et al.*, 1973a). Although they approach the Mackenzie River near Travaillant Lake during winter, most occur to the north and east of the lake.

Spring migration of the Bluenose herd may begin as early as mid to late February, along routes from their winter range to calving grounds on the Bathurst Peninsula, in the Melville Hills, and near Bluenose Lake (Hawley *et al.*, 1976) (Figure 2.1-2). Post-

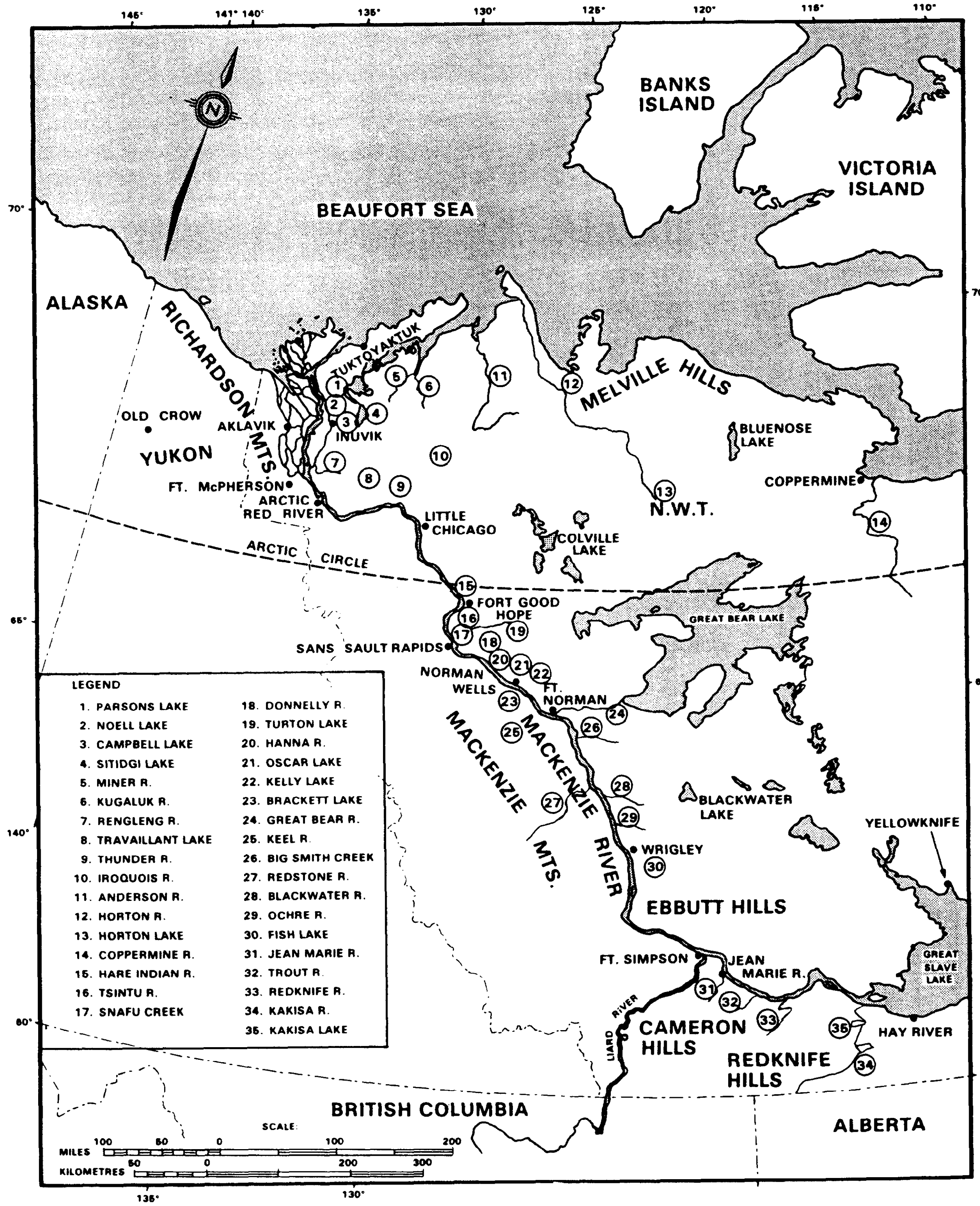


FIGURE 2.1-1 *Geographic names referred to in descriptions of mammals.*

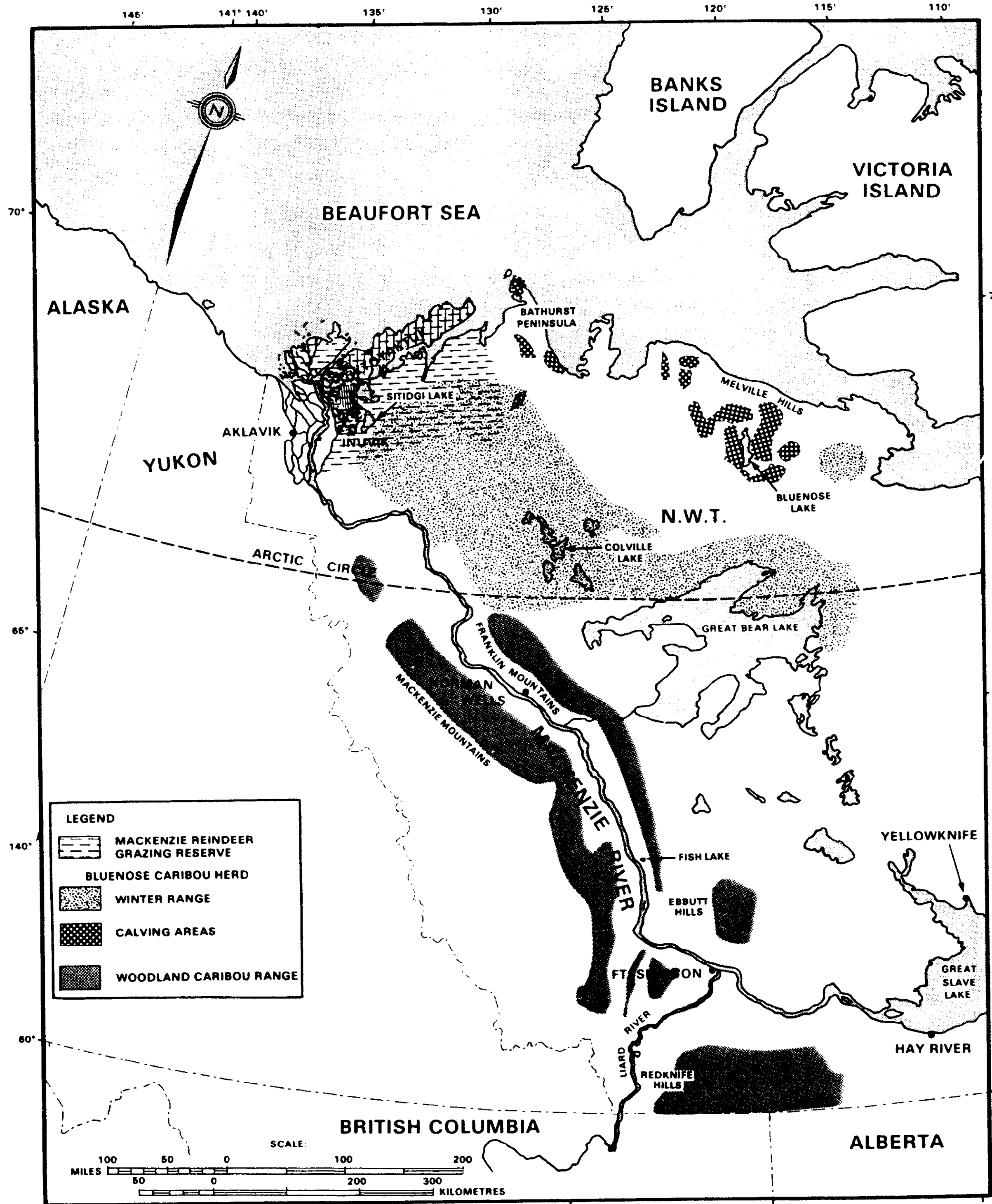


FIGURE 2.1-2 *The Mackenzie Reindeer Grazing Reserve, winter range and calving areas of the Bluenose caribou herd, and woodland caribou range in the vicinity of the Mackenzie Valley corridor. (Sources: Hawley et al., 1976; Prescott et al., 1973a).*

PLATE 2.1-1 *The Bluenose herd is the only population of barren-ground caribou that ranges within the Mackenzie Valley corridor. Although the population of this herd has varied over the years, it is presently considered stable at about 40,000 animals. (Courtesy, Northwest Territories Wildlife Service).*

calving aggregations are usually near calving areas (Figure 2.1-2) and caribou of this herd would not occur along the corridor during summer. However, both spring and autumn migrants that winter in the western-most areas of their range may intersect parts of the corridor, but the maximum number of these migrants is expected to be small.

(c) Woodland Caribou

Woodland caribou have similar habitat preferences and some behavioural traits similar to those of barren-ground caribou. Their preferred winter habitat includes open bogs and open mature spruce-lichen forest. In mountainous areas alpine tundra is preferred for summer feeding and calving. In areas of hilly terrain without alpine tundra, higher elevations are probably favoured summer range (Soper, 1970; Jacobson, 1979). Although information on the behaviour of woodland caribou in the Northwest Territories is limited, studies conducted in the Mackenzie Mountains (Archibald, 1976; Simmons, unpublished data) suggest that caribou calve on open tundra and complete calving within about two weeks.

Numerous authors suggest that woodland caribou are relatively solitary compared with barren-ground caribou, and that their seasonal movements are relatively short (Freddy and Erickson, 1975; Stardom, 1975; Shoesmith and Storey, 1977; Fuller and Keith, 1980). The winter food of woodland caribou is primarily terrestrial and arboreal lichens, while their more varied summer diet consists of grasses, sedges, herbs, deciduous shrubs and lichens (Simkin, 1965; Ahti and Hepburn, 1967; Bergerud, 1972).

The reproductive potential of woodland caribou is similar to that of other caribou, since females do not usually breed until 28 months of age and frequently not until they are 40 months old (Bergerud, 1971, 1974). On the average about 80% of the adult females produce one calf each year. At birth calves typically form 26 to 35% of the population, although recruitment of calves surviving to one year of age is considerably lower (for example, 17%, for a woodland caribou population located north of Fort McMurray, Alberta) (Fuller and Keith, 1980). The most important ranges for woodland caribou are their wintering and calving areas, although the winter range is extensive and not entirely utilized each winter.

The range of woodland caribou in the Mackenzie River Valley is shown in Figure 2.1-2. This species may occur as far north as the tree line on the east side of the Mackenzie River (Prescott *et al.*, 1973a). With the exception of an unknown number of woodland caribou within the group of 1,000 to 2,000 animals that occur in the Travaillant - Eskimo lakes region (Prescott *et al.*, 1973a), concentrations of woodland caribou have not been identified from Richards Island to Norman Wells. However, from Norman Wells to Fort Simpson there is caribou range adjacent to the McConnell Range of the Franklin Mountains, the Ebbutt Hills and the Horn Plateau. The 'open black spruce-lichen' forest along the Mackenzie Valley, particularly in areas with flat to slightly rolling topography near uplands, constitutes favorable winter range (Prescott *et al.*, 1973a; Wooley and Wooley, 1976; R. Decker, pers. comm.). Suspected calving grounds are located in the McConnell Range between Big Smith River and Fish Lake, and in the Ebbutt Hills (R. Decker, pers. comm.). Slaney (1974c) reported a major woodland caribou wintering area in the Ebbutt Hills in November 1973.

Woodland caribou range exists along the Mackenzie Valley corridor from Fort Simpson south to 60°N near the Redknife Hills, near the Redknife and Kakisa rivers, which drain the area, and near the Cameron Hills at 60° N (Figure 2.1-2) (Prescott *et al.*, 1973a). Caribou are believed to summer in uplands and winter in flat lowlands where there is black spruce forest. Wooley and Wooley (1976) observed woodland caribou in large open fens adjacent to black spruce forest near the Kakisa River in February 1972. Surveys along this section indicate a scattered population consisting of small bands of caribou, but no areas of concentration. In 1979 caribou were seen wintering in the Trout Lake area (Donaldson and Fleck, 1980). Aerial surveys conducted east of Trout Lake and west of the Redknife Hills in February 1979 indicated population densities of 0.09 ± 0.041 caribou/km^2 (Donaldson and Fleck, 1980).

2.1.1.2 Moose

Moose are represented by a single subspecies *(Alces alces andersoni)* in the Northwest Territories (Banfield, 1974). They are generally solitary, commonly ranging throughout the boreal forest and occasionally into forest-tundra transition areas or onto tundra (Kelsall, 1972). Moose are widely distributed in climax and sub-climax boreal forests that provide forage and shelter (Le Resche *et al.*, 1974). The twigs of shrubs, especially willow, form the bulk of their diet, except during summer when they forage on aquatic vegetation. Early successional vegetation, such as that on recent burns or riparian areas, provides good quality winter range. Animals associated with river-edge habitats often develop migration traditions and come from adjacent uplands to riparian areas to overwinter. Good winter habitat is extremely important for moose because in winter they exist on a negative energy balance and additional or alternative habitat may be limited (Gasaway and Coady, 1974). Where there is little suitable winter range small congregations of moose may be found.

Moose breed annually from about the age of 30 months, although some yearlings are known to breed. Twinning is fairly common, especially in expanding populations. The average annual recruitment of yearling moose (Plate 2.1-2) usually falls between 12 and 25%, probably averaging 15 to 17% (Peterson, 1955).

Important moose range (Class 1 and 2) along the Mackenzie River is indicated on Figure 2.1-3. Although moose have been plentiful historically on the Mackenzie Delta, (Clarke, 1944), heavy hunting pressure in recent years has drastically reduced them (Prescott *et al.*, 1973b). The Delta has been classified as poor moose winter range (Class 3) because of frequent flooding, deep snow and the lack of shelter from winds (Prescott *et al.*, 1973b). However, there is an important area along Holmes Creek and the lowlands adjacent to the East Channel of the Mackenzie River (Prescott *et al.*, 1973b).

In general, the uplands along the east and south sides of the Mackenzie Delta provide insignificant (Class 4) wintering habitat for moose. Some streams along the northeast and southeast portions of Campbell Lake and the lower portions of the Rengleng River were rated as poor moose wintering range (Class 3) (Prescott *et al.*, 1973b). A survey along the proposed route of the Dempster Lateral gas pipeline in this area indicated a density of 1.92 moose/100 km^2 (Foothills Pipelines (Yukon) Ltd., 1979).

Moose are common in summer along the Mackenzie River from Travaillant Lake to Norman Wells. However, they probably move to the Mackenzie River Valley and islands during the winter (Watson *et al.*, 1973). Most of the islands in the Mackenzie River and bordering lowlands to the west are considered to be important moose winter range (Class 1 and 2) (Prescott *et al.*, 1973b). Watson *et al.* (1973) speculated that, since there are fewer moose wintering areas on the east than on the west side of the Mackenzie River, it is probably those moose which summer along the east side that move to their winter range on the west side in the autumn, reversing this trek in the spring. Walton-Rankin (1977) estimated peak winter densities of 0.8 moose/km^2 on the islands of the Mackenzie River between the mouths of the Keele and Redstone rivers, and 1.4 moose/km^2 along the Sans Sault Rapids.

The Little Chicago area and several tributaries of the Mackenzie River north of Norman Wells also pro-

PLATE 2.1-2 *Moose range throughout the boreal forest areas along the Mackenzie Valley corridor. The average annual recruitment rate for yearling moose, shown here, usually falls between 12 and 25%. (Courtesy, McCourt Management).*

vide important winter range for moose. The more notable tributaries include the Tsintu River, the Donnelly River, the Hanna River and Oscar Creek. Forty moose were observed in Oscar Creek Gap in March 1974 (L. Rankin, pers. comm.; cited in Wooley *et al.*, 1974).

From Norman Wells to Fort Simpson, there is good winter range for moose on islands in the Mackenzie River and some areas of adjoining shoreline between Fort Norman and the Blackwater River (Figure 2.1-3) (Prescott *et al.*, 1973b). Concentrations of moose have been reported on Mackenzie River islands in this area (Plate 2.1-3) by several authors (Prescott *et al.*, 1973b; Ruttan, 1974a; Walton-Rankin, 1977). In 1972, for example, 16 moose were observed on one island in the Mackenzie River between Little Smith Creek and the Saline River. During surveys in March 1973, Slaney (1974c) reported 0.8 to 1.0 moose/km^2 on the Mackenzie River islands between Blackwater River and Old Fort Point. At the same time they reported 0.12 to 0.19 moose/km^2 along the adjacent Mackenzie Highway right-of-way. Moose had dispersed from these islands by March 28, 1973, but were observed congregating again on October 4 and November 22, 1973. It is possible that many of the moose wintering on the islands may use the area along the pipeline corridor as summer range. However, Slaney (1974c) reported that in 1973 most moose tracks approached the Mackenzie River from the west, except for near a large island in the Mackenzie River between Little Smith Creek and the Saline River, where most tracks approached from the east.

Two areas of fairly important moose winter range (Class 2) occur east of the Mackenzie River along the Ochre River valley and along an unnamed creek approximately 8 km north of the Ochre River. South of Wrigley important moose winter range (Class 1) exists on all major islands and along some shorelines of the Mackenzie River, while other areas adjacent to the Mackenzie River are considered fair winter range (Class 2) (Prescott *et al.*, 1973b). This region receives fairly heavy hunting pressure from Fort Simpson residents (see Section 2.5). Wetlands east of the Mackenzie River provide poor winter range for moose (Class 3), but these areas may become more important during summer, when aquatic plants become available for food.

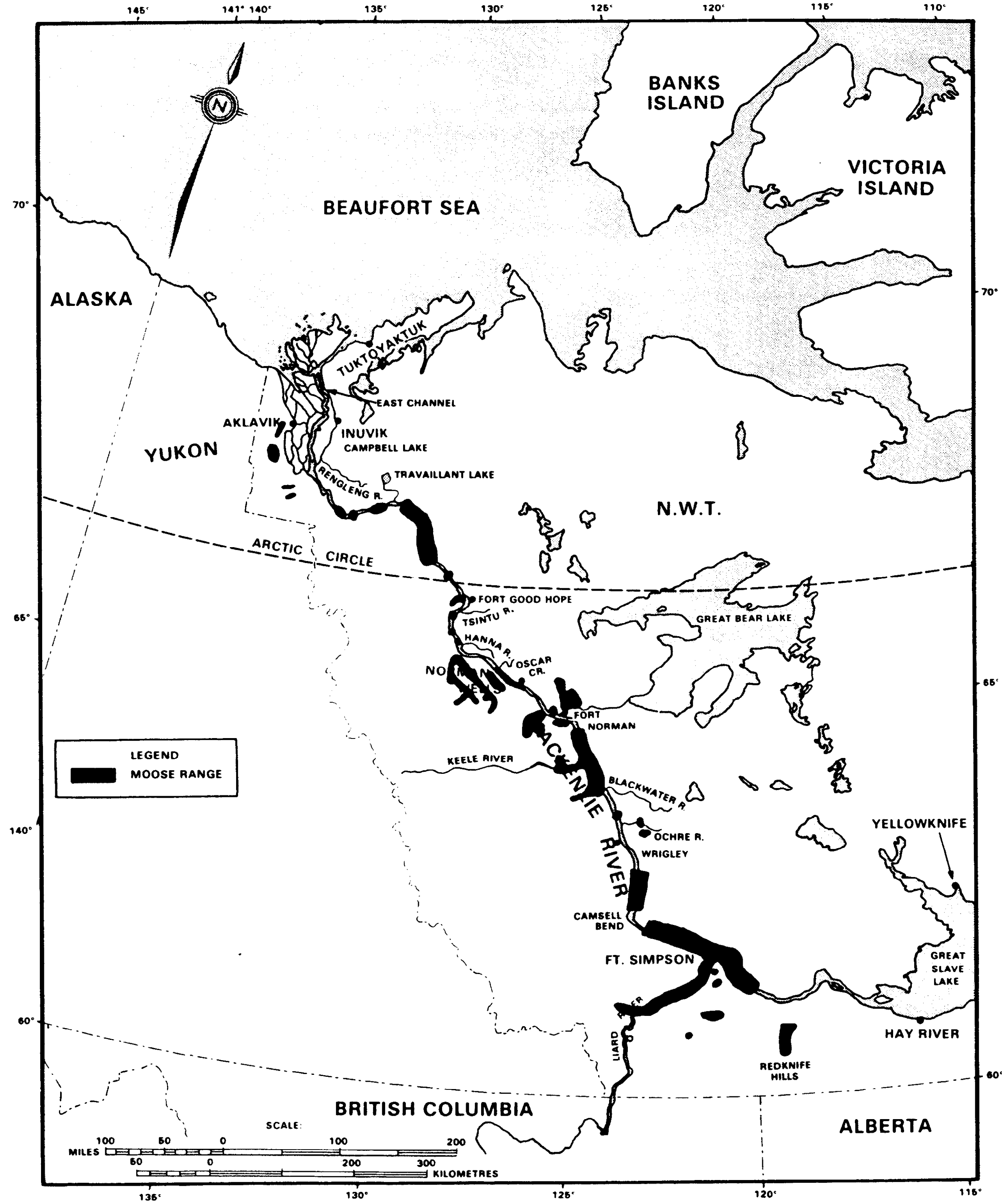


FIGURE 2.1-3 *Important and fair (Class 1 and 2) moose winter range near the Mackenzie River. (Source: Prescott et al., 1973a).*

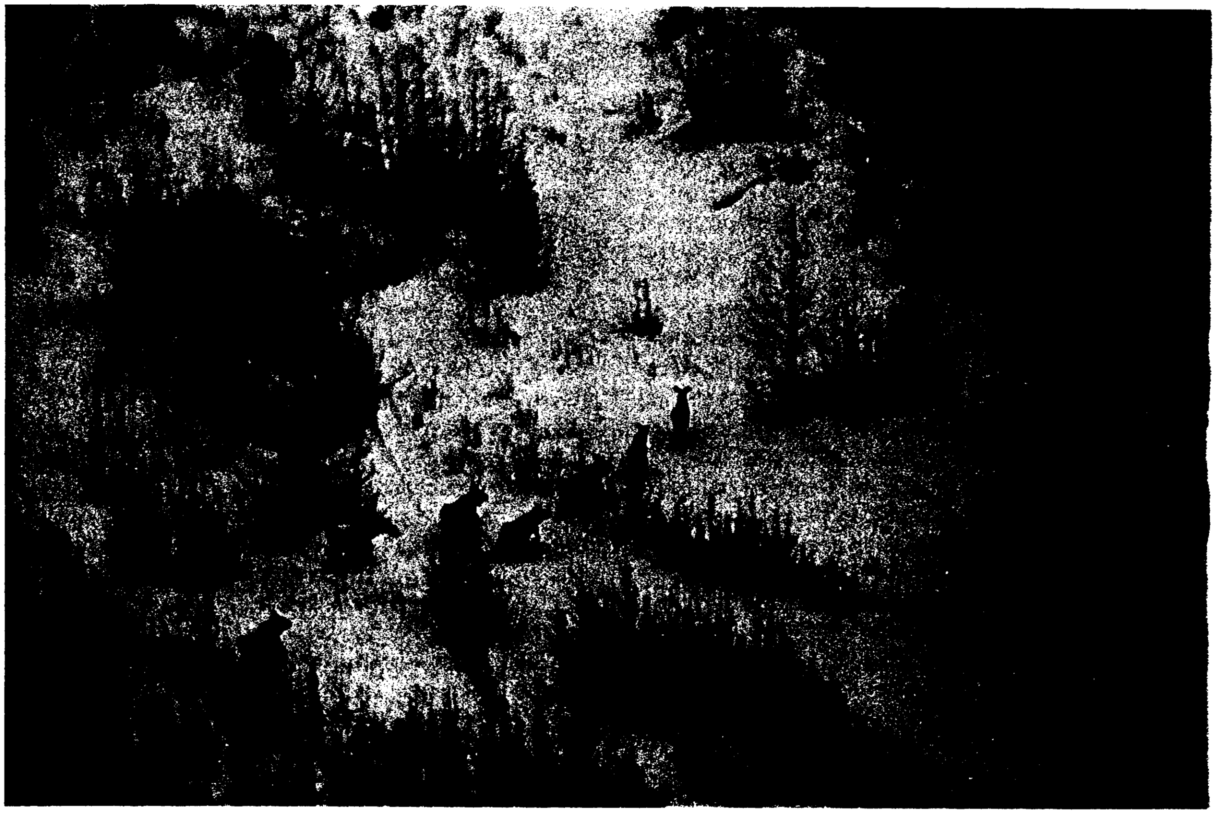


PLATE 2.1-3 *Although moose are generally solitary, concentrations of moose have been reported on Mackenzie River islands between Norman Wells and Fort Norman. (Courtesy, McCourt Management).*

Winter use of Mackenzie River islands varies considerably. Slaney (1974c) found that during the winter of 1973, moose density on Mackenzie River islands from Camsell Bend to McGern Island was 0.10 moose/km^2, while along the Mackenzie Highway right-of-way there were only 0.03 moose/km^2. The moose observed on Mackenzie River islands by Slaney were not seen in February 1976 by Wooley and Wooley (1976), who surveyed the McGern Island area and saw only two animals.

Survey data show that moose densities from Fort Simpson south to 60° N are low in comparison with those on the aforementioned islands in the Mackenzie River downstream from Fort Simpson. No Class 1 moose winter range occurs in the area, and only small areas of Class 2 winter range exist along sections of Jean Marie Creek and the Trout River (Figure 2.1-3). Surveys of this area in the winter of 1975-76 indicated a density of 0.01 moose/km^2 (Wooley and Wooley, 1976), while surveys in 1979 yielded densities of 0.08 moose/km^2 near Redknife Hills, and 0.13 moose/km^2 in the area of the Liard River and its tributaries, just west of the corridor (Donaldson and Fleck, 1980). Calves comprised 12% of the moose counted during these surveys, indicating relatively low recruitment.

2.1.1.3 Mule Deer

Mule deer *(Odocoileus hemionus)* are rare in the Northwest Territories, but occur in the Rocky Mountains foothills and rolling country north and east of mountainous regions (Banfield, 1974). This species forages for shrubs, herbs and grasses, although they are usually browsers (Wallmo, 1978). Their diet varies considerably between seasons. The mule deer is moderately gregarious and may form large bands during the winter (Banfield, 1974). In mountainous regions mule deer migrate to different elevations, and even in rolling terrain they tend to select lower ground in winter than in summer. Mule deer also tend to select areas with the least snowfall in winter. Preferred habitats include open coniferous forest, open aspen woodland, river valleys, and sub-climax brush (Banfield, 1974).

Mule deer confine themselves to the southwestern Mackenzie District in the Northwest Territories but do not occur there in large numbers (Banfield, 1974; Scotter, 1974). Scotter (1974) reported seeing three mule deer at the probable northern limit of their range along the South Nahanni River, about 35 km north of Fort Providence. There are no available estimates of population sizes or densities for this species in the Northwest Territories. In addition, owing to infrequent sightings, important mule deer ranges have not been documented in the Mackenzie Valley.

2.1.1.4 White-tailed Deer

White-tailed deer *(O. virginianus)* have been observed along the South Nahanni River (Scotter, 1974) and periodically in the Fort Smith region (Kuyt, 1966). This species has apparently expanded its range substantially from the north-central Alberta distribution identified by Banfield (1974). Northern range extensions typically occur in mature forests along rivers where diverse habitats are available. White-tailed deer have similar foraging preferences and habits to those of mule deer, although the former tend to be more solitary and use more open habitats. Population sizes and densities of this species have not been documented but are probably relatively small. Areas of importance to this species in the Mackenzie Valley have also not been determined.

2.1.2 BEARS

2.1.2.1 Grizzly Bear

Two distinct populations (or ecotypes) of grizzly bears *(Ursus arctos)* inhabit the area, the barren-ground grizzly and the northern interior grizzly (Banfield, 1974). The latter ecotype prefers rough broken terrain in mountainous regions and occurs in central and southern parts of the Mackenzie Valley, but rarely in the low-lying areas. The barren-ground grizzly prefers flatter ground and the open tundra north of the boreal forest, although some may also inhabit the forest-tundra transition zone (Watson *et al.*, 1973). The barren-ground grizzly bear was classified as a rare species by the International Union for Conservation of Nature and Natural Resources (IUCN), and is considered a 'species at risk' by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

The behavior, distribution and movements of grizzly bears are determined by their diet and food availability. They are omnivorous, feeding on roots, berries, herbs, ground squirrels, fish and ungulates. In mountainous regions they change altitude primarily to take advantage of vegetation production in different zones (Miller and Barichello, in prep.). Tundra-dwelling bears use low-lying coastal areas in June and move into the higher hills a few kilometres inland during July, August and September (Pearson and Nagy, 1976). Similar movements were observed for grizzlies on Richards Island (Slaney, 1974a). Low-lying marshy areas provide nesting waterfowl and an abundance of sedges and herbs, while uplands have an abundance of ground squirrels and berry-producing shrubs (Slaney, 1974a).

Den sites are particularly important to grizzly bears, since the lack of suitable ones can limit bear numbers (Pearson, 1975). Grizzly bears normally den from mid October or November to April or May. During this time pregnant females give birth to one to three cubs. Pearson (1972) reported a minimum breeding age for the northern interior grizzly bear in the Yukon of approximately 6 years for females and an average litter size of 1.58 cubs.

Grizzly bears were common in the Mackenzie Delta between 1927 and 1935 (Porsild, 1945). Since then, bears that have been attracted to the reindeer herds have been destroyed by the herders. Grizzly bear sightings had sufficiently declined by 1943 to warrant establishment of a closed season, and in 1949 the closure was declared year-round. The frequency of grizzly bear sightings increased substantially during the 1950's as they expanded their range or began reoccupying areas from which they had formerly been eliminated (Macpherson, 1965). There is currently a relatively large population of grizzly bears in the Delta area. Twenty-three animals were estimated to inhabit Richards Island and the adjacent lowlands in 1973, and 15 to 20 bears in 1974 (Slaney, 1974a). In 1973 an additional 9 grizzlies were seen near Holmes Creek and Parsons Lake (Slaney, 1974a). More recently grizzly bear densities have been estimated at one animal per 106 km^2 on Richards Island (Harding, 1976) and one per 199 km^2 between Sitidgi Lake and Tuktoyaktuk (Pearson and Nagy, 1976).

Between Tuktoyaktuk and Inuvik bears tend to select dens along lake shores and stream banks having slopes greater than 30° (Pearson and Nagy, 1976). Clarke (1944) reported that the countless cutbanks of the Mackenzie Delta provide suitable sites for grizzly bear dens. Similarly, on Richards Island 78% of the grizzlies selected dens in banks of waterbodies with moderate slopes (30% to 50% grade) (Harding, 1976). The soil texture was usually sandy or silty, but was generally consolidated enough to endure at least one season's use. Den sites in the Richards Island and Tuktoyaktuk Peninsula areas have been mapped (Slaney, 1974b; Pearson and Nagy, 1976) although concentrations of den sites were not reported. The availability of suitable sites for den construction suggests that dens are not a limiting factor to the population growth of grizzly bears along the tundra portion of Richards Island and the Tuktoyaktuk Peninsula (Pearson and Nagy, 1976).

From Richards Island and the southern portion of the Tuktoyaktuk Peninsula to Inuvik, and from just south of Campbell Lake to Arctic Red River, grizzly bear habitat has been rated as Class 2 (common use but less than optimum habitat) (Nolan *et al.*, 1973a). Reports of grizzly bears are rare further upstream along the Mackenzie River. Ruttan, 1974b reported that trappers had seen grizzly bears along Hare Indian River and several other tributary streams near Fort Good Hope, while he had made observations of a grizzly bear on the Travaillant River and of tracks along both the Rengleng and Travaillant rivers. The Mackenzie River Valley from Norman Wells to Fort Simpson provides relatively unsuitable habitat for grizzly bears, although some occasional use areas (Class 3) occur in the Franklin Mountains (Nolan et*et al.*, 1973a). Grizzly bears are not known to occur from Fort Simpson south to 60° N.

2.1.2.2 Black Bear

The black bear *(Ursus americanus)* is widely distributed throughout forested lands of North America (Banfield, 1974). Individuals occasionally range onto the open forest-tundra transition zone, but are rarely found on open tundra itself. Competition with and predation by grizzly bears in areas where their ranges overlap appears to play a major role in determining black bear distribution. In North America habitat loss and human intolerance have led to low populations in some areas, while locally high populations are often related to low hunting pressure or enhanced food supplies (such as garbage dumps) (Jonkel, 1978).

Black bears are omnivorous and relatively nonselective in what they eat. They typically feed opportunistically in a variety of forest habitats in any particular season. Horsetail *(Equisetum sp.)* is popular in spring, while berries are eaten whenever they are ripe. Banfield (1974) reported that the annual diet of black bear may consist of these items in the following proportions: vegetation 76.7%, insects 7.4%, carrion 15.2%, and small mammals 0.7%. Ruttan and Wooley (1974) reported intensive consumption of horsetail from riverbanks by black bears in the area between Arctic Red River and Sans Sault Rapids. Fish, berries, beaver, young Canada geese and moose carrion supplement their diet.

Black bears are typically solitary, but may occur as family units, sow and cubs, or in groups at localized food sources such as garbage dumps. Winter and early spring are periods of particular importance to black bears (Jonkel, 1978). They hibernate from October through April in dens made under windfalls, in hollow trees, in caves, or in previously used dens. Pregnant females give birth to one or two young during late winter. Den sites are generally abundant, suggesting that such sites may not be limiting for this species. Slaney (1974a) indicated that the distribution of suitable winter denning sites might result in seasonal concentrations of black bears. Early spring is considered a critical time for the bears because of limited food availability.

A substantial population of black bears occurs in suitable boreal forest habitats along the Mackenzie Valley (Watson *et al.*, 1973). Early historical records differ on the abundance and distribution of this species in the Valley. For example, Preble (1968) thought that black bears were abundant throughout the forested Mackenzie region, while Clarke (1944) indicated that black bears were widely distributed but sparse in timbered areas. Clarke (1944) also noted that their numbers fluctuated greatly as shown by their unusual abundance at Fort Norman and Fort Providence in 1942 and 1943.

The black bear is uncommon south of the tree line in the Mackenzie Delta region and rare north of the tree line (Martell and Casselman, 1975). However, the range may be extending onto tundra regions (Jonkel and Miller, 1970). Although the species is more common in the forested areas south of the Mackenzie Delta, there is little available information on actual numbers or local distributions in this region. The annual harvest of black bears (reported from 1964 to 1976 General Hunting Licence Returns) has varied from 0 to 19 (mean = 4) at Arctic Red River, and from 6 to 44 (mean = 23) at Fort Good Hope (see Section 2.5.1). (The records are unclear as to whether or not these totals included any grizzly bears.) Areas of particular importance to black bears have not been identified, although Schultz International (1974) found a concentration of 10 black bear dens along the Thunder River.

Black bears are widely distributed in the forested areas from Norman Wells south to Fort Simpson. Substantial populations probably occur near lakes and streams immediately south of Fort Norman (Ruttan and Wooley, 1974). Between 1964 and 1972, annual harvests ranged from 1 to 34 bears in the Fort Norman area, 3 to 29 bears near Wrigley, and 45 to 71 bears in the vicinity of Fort Simpson (Bissett, 1974). The average annual bear harvests estimated from General Hunting Licence Returns between 1964 and 1976 were 14.9 at Fort Norman and Norman Wells, 13.8 near Wrigley, and 50.7 for the Fort Simpson and Jean Marie River area (see Section 2.5.1). Trout Lake residents take an average of two black bears annually. Areas of particular importance for black bears from Fort Simpson south to 60°N have not been identified. However, the relatively large harvests from the Fort Simpson area indicate that black bears are probably abundant there.

2.1.3 AQUATIC FURBEARERS

2.1.3.1 Muskrat

The muskrat *(Ondatra zibethicus)* is the widest ranging of all North American furbearers, inhabiting diverse environments ranging from drainage ditches along cornfields in temperate regions, to lakes along the Arctic Ocean. Muskrats are unable to control water levels like beavers. Nevertheless, this species is extremely adaptable and resourceful when constructing lodges and selecting food.

A wide variety of aquatic plants and occasionally carrion are eaten. Water horsetails (goosegrass), sedges, bulrushes, and cattails are major emergent food species, while submerged aquatic foods include yellow pond lily, pond weeds, duckweed, and white water lily. Emergent species are also used for the construction of muskrat houses, while the submerged plants are often used as constituents for pushups (winter feeding huts). Submerged aquatic plants are the most important foods during the winter in standing waterbodies, but emergent plants are preferred by muskrats during the summer and along stream channels in the winter. The accessibility of aquatic plants is the most important factor governing their use by muskrats for both food and lodge construction. Water horsetail is a highly preferred food in northern latitudes owing to its wide availability (except in some winter habitats) and excellent nutritional value.

Muskrat houses are typically found in marshes in southern regions, but are almost totally absent along the corridor. Alternatively, muskrats dig bank burrows along lakeshores or stream channel margins, and may extend their winter range by constructing pushups in small lakes. Pushups are small vegetation domes built over holes in the ice which enable animals to haul up submerged plants and feed without returning to their main house.

On the Peace-Athabasca delta, Surrendi and Jorgenson (1971) found that mean winter depths of 1.45 m (water and ice combined) were optimal to permit over-winter survival of muskrat populations in small lakes, while survival in total depths of less than 0.76 m was very reduced. Ambrock and Allison (1973) found the lower critical limit of water depth before freeze-up to be 0.61 m for several lakes on the Peace-Athabasca delta.

On the Mackenzie River Delta more severe climatic conditions place even greater restrictions on the suitability of waterbodies to support muskrats. Stevens (1955) found that optimum winter habitat for muskrats occurred in lakes 2 m deep, and Hawley and Hawley (1974) reported depths of 1.2 to 3 m to be optimum. One further requirement in northern latitudes is that lakes have steeply sloping banks, permitting ready access to food supplies in unfrozen portions of the lake from bank dens along the shore.

In the Mackenzie Valley there is an abundance of abandoned channels and small ponds within the floodplain which support year-round populations of muskrats. The greatest densities, however, occur on the Mackenzie River Delta, where the fluctuating hydrologic regime ensures an abundant supply of aquatic plants and suitable waterbodies.

Muskrats have a high reproductive potential. Females on the Old Crow Flats produce an average of more than seven embryos and sometimes produce two litters annually (Ruttan, 1974c). Muskrats also suffer high natural mortality which offsets this high productivity (Stevens, 1953).

Important muskrat range (Class 1 and 2) along the Mackenzie River is indicated in Figure 2.1-4. The greatest population densities occur in standing water habitats. Even though muskrat are at the northernmost limit of their range on the Mackenzie Delta, the Delta is well known for its high production of this species. Habitat within the Delta is considered to be the best possible (Class 1) (Dennington *et al.*, 1973), although habitat varies from the best in the southwest quarter of the Delta, to the poorest in the northwest quarter (Hawley, 1968). Habitat is much less suitable (Class 3 or 4) in the uplands east of the Delta. Slaney (1974a) found that muskrat populations on Richards Island were highest on the southern end of the island and that pushup densities in the Parsons Lake area were higher than in similar upland lakes on Richards Island. South of Little Chicago, some islands and floodplain areas associated with the Mackenzie River provide Class 2 habitat for muskrats (Dennington *et al.*, 1973). Except for the Class 2 areas around Oscar Lake and a lowland area bordering the east side of the Mackenzie River between Ogilvie Island and Norman Wells, the area east of the Mackenzie River from Little Chicago to Norman Wells is poor (Class 3) or insignificant (Class 4) muskrat habitat.

From Norman Wells to Fort Simpson prime (Class 1) muskrat habitat occurs around Brackett Lake and in the lowlands south of Brackett Lake between the Brackett River and the Great Bear River. The remainder of this section of the corridor is considered poor (Class 3) or insignificant (Class 4) muskrat habitat (Dennington *et al.*, 1973). The same applies to the region to the south. With the exception of Class 2 habitat along the Redknife and Kakisa rivers, muskrat habitat along the section from Fort Simpson south to 60°N is considered either poor or insignificant.

2.1.3.2 Beaver

Beavers *(Castor canadensis)* are widely distributed over North America and are found from coast to coast south of the tree line in Canada.

Both the physical characteristics and types of vegeta-

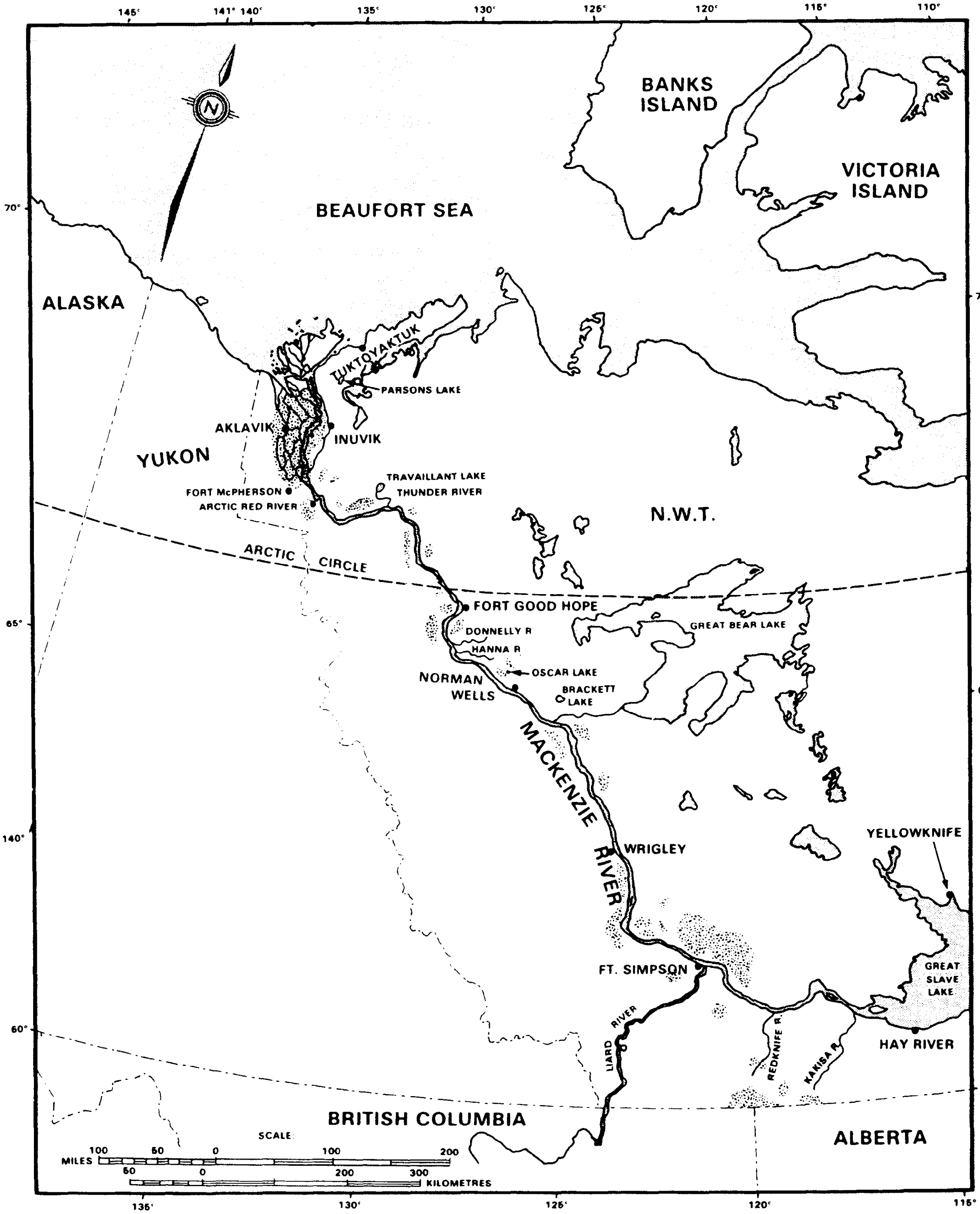


FIGURE 2.1-4 *Class 1 and 2 range for beaver and/or muskrat in the Mackenzie Valley corridor. (From: Dennington et al., 1973).*

tion of an area determine its suitability as beaver habitat (Slough and Sadleir, 1977). Although beavers occur in a wide variety of geographical areas ranging from mountains to prairies to boreal forest, there are certain environmental constraints to their successful colonization of new habitat. Only slow-flowing streams and rivers can be colonized, since fast-flowing water will wash away dams and food caches (Standfield and Smith, 1971; Banfield, 1974). Beavers usually live in streams with gradients of less than 6% and they are most successful in wide valleys with meandering streams and rivers (Retzer *et al.*, 1956). Marshes and ponds with appropriate food supplies are prime habitats, while creeks and small rivers are often dammed to create ponds (Retzer *et al.*, 1956; Banfield, 1974). Beavers prefer shallow lakes with shores rising gently enough to support aquatic and terrestrial vegetation (Hall, 1971; Standfield and Smith, 1971). Rivers that have widely fluctuating water levels and those carrying ice that scours shorelines in the spring are considered poor beaver habitat (Nash, 1951). Beavers need certain minimum stable water depths to prevent their lodges from flooding and the pond from freezing to the bottom in winter, thus blocking access to their food cache (Plate 2.1-4). These conditions may be established by constructing dams (Retzer *et al.*, 1956). In the northern part of their range along the Mackenzie River system, beavers are more abundant in bog drainages than in the Mackenzie Delta drainage area, since the former are more stable (Novakowski, 1965).

Although beavers will cut and consume virtually every available plant species within their range, they prefer aspen (*Populus* spp.), willow (*Salix* spp.), birch (*Betula* spp.), and various aquatic plants such as water lilies (*Nuphar* spp.). Pine (*Pinus* spp.) and spruce (*Picea* spp.) are starvation diet items (Aleksiuk, 1970). Beavers can live in areas of poor food supply, but colonies and individuals found there are typically smaller and have lower reproductive rates (Gibson, 1957; Hay, 1958; Gunson, 1970). Slough and Sadleir (1977) found that the presence of alder, willow, and aspen were the most important factors in predicting beaver use of an area.

PLATE 2.1-4 *Beavers need certain minimum stable water depths to prevent their lodges from flooding and the pond from freezing to the bottom in winter, thus blocking access to their food cache. A typical beaver lodge and food cache are shown in this photo. (Courtesy, McCourt Management).*

Important beaver habitat (Class 1 and 2) along the Mackenzie River is shown in Figure 2.1-4. Beavers are at the northern-most limit of their range in the Mackenzie Delta region (Hawley and Aleksiuk, 1973). Most habitat on Richards Island and in the Parsons Lake area is considered poor (Class 3) or insignificant (Class 4) (Dennington *et al.*, 1973). The Mackenzie Delta lowlands, extending from Richards Island to Norman Wells, provide intermediate quality habitat (Class 2) for beaver (Dennington *et al.*, 1973). An estimated 1,600 beaver colonies (or 6,400 to 6,900 individuals) were present on the Mackenzie Delta in 1965 (Hawley, 1968), while approximately 400 colonies (1,600 to 2,400 beavers) occurred within the Mackenzie Delta in 1970 (RRCS, 1972). Beaver colony densities within the most suitable habitat in the Mackenzie Valley were 0.3 to 0.4 colonies/km^2 between 1962 and 1965, and 0.1 colonies/km^2 in 1968 and 1969 (Hawley and Aleksiuk, 1973).

Wooley (1974a) reported 0.04 active beaver lodges/km^2 in the Inuvik area, while Boles (1975; cited in Dickinson and Herman, 1979) calculated colony densities of 0.08 colonies/km^2 and 0.03 colonies/km^2 in the Fort McPherson and Arctic Red River areas, respectively.

South of the Mackenzie Delta region Class 2 (intermediate quality) beaver habitat occurs along the headwaters and tributaries of the Thunder and Iroquois rivers. Beaver habitat of similar quality also occurs in the lowlands bordering the east side of the Mackenzie River just south of the junction of the Thunder River and from Little Chicago to Payne Creek (Dennington *et al.*, 1973). Wooley (1974a) reported that the occupied beaver colony density in the Travaillant Lake area was 0.14 colonies per km of transect.

South of Fort Good Hope, beaver habitat of intermediate quality (Class 2) occurs in the wetland complex bordering the east side of the Mackenzie River from the Tsintu River to Snafu Creek. Class 2 habitat also occurs just west of Gibson Ridge, near Oscar Lake on the east side of the Norman Range, on the lowlands bordering the east side of the Mackenzie River between Ogilvie Island and Norman Wells, and on the stream-lake complex between Kelly Lake and Turton Lake (Dennington *et al.*, 1973). A density of 0.14 occupied colonies per km of transect was recorded in the area of the Donnelly and Hanna rivers (Wooley, 1974a).

From Norman Wells south to Fort Simpson prime beaver habitat (Class 1) occurs around Brackett Lake and in the lowlands south of the lake between the Brackett and Great Bear rivers, while intermediate beaver habitat (Class 2) occurs in the lowlands bordering the Mackenzie River between Police Island and the mouth of Big Smith Creek. Aerial surveys of the latter areas indicated beaver densities between 0.11 to 0.17 colonies per km of stream (Wooley, 1974a). Other areas of Class 2 beaver habitat occur from Birch Island to the mouth of the Blackwater River and just south of the Blackwater River (Dennington *et al.*, 1973).

Several areas of Class 1 and 2 beaver habitat occur along the Trail and Harris rivers and their tributaries, two unnamed tributaries of the Mackenzie River between Camsell Bend and the Trail River, and wetland areas east of the Mackenzie River between McGern Island and Camsell Bend (Dennington *et al.*, 1973). The average density of beaver colonies in streams near Camsell Bend in 1972 was 0.45 occupied colonies per km (Wooley, 1974a). In productive portions of some streams the density reached 0.83 colonies per km.

From Fort Simpson south to 60° N, Class 2 beaver habitat occurs along and in the vicinity of Jean Marie Creek and the Kakisa River (Dennington *et al.*, 1973). Surveys near Jean Marie Creek indicated an average of 0.34 colonies per km of stream, while surveys of the Kakisa River drainage had a density of 0.35 occupied colonies per km of stream (Wooley, 1974).

2.1.4 TERRESTRIAL FURBEARERS

2.1.4.1 Arctic Fox

The Arctic fox *(Alopex lagopus)* has a panarctic distribution and is common throughout tundra and forest-tundra transition zones and on landfast ice. They occupy breeding dens just before the young are born and remain there during the relatively snowfree period from May through August. Populations from coastal areas typically disperse onto the sea ice during the winter (Macpherson, 1969). Arctic fox movements and population fluctuations vary with the abundance and availability of prey species (Macpherson, 1969; Banfield, 1974; Dickinson and Herman, 1979).

The Arctic fox is an important source of cash income for residents of both tundra and coastal regions (Section 2.5.1). The white fur is especially valuable because there are no economically viable alternative species. Arctic foxes trapped on the Mackenzie Delta are primarily white phase in winter (a small percentage are blue phase), while summer fur of both phases is patchy and brown (Plate 2.1-5).

The range of the Arctic fox overlaps with the range of the red or coloured fox (Sec. 2.1.4.2). Preferred den sites for both species include well drained consolidated soils in areas where the snow melts early,

PLATE 2.1-5 *The Arctic fox is an important source of cash income for residents of both tundra and coastal regions. During summer the fur of Arctic foxes becomes patchy and brown. (Courtesy, McCourt Management).*

although Arctic foxes typically avoid areas of dense shrub vegetation (Nolan *et al.*, 1973b). All Arctic fox den sites reported by Nolan *et al.* (1973b) were in open areas with low relief. Den sites have been recorded in pingos on Mackenzie Delta islands, in sand dunes, in frost heaves and at the tops of lake, river and stream banks.

Arctic foxes are efficient scavengers and prey on a variety of animals. Primary food items include lemmings and other small rodents, ringed seal pups, seal and caribou carrion, and birds, especially eggs and nestlings. The diet of Arctic foxes changes with seasonal availability of prey and the habitat occupied. For example, while lemmings are the primary food source during summer (Chesemore, 1968; Macpherson, 1969; Banfield, 1974), foxes from coastal populations forage on seal pups and carrion on the sea ice during winter. Nesting birds, as well as their eggs and young, also form a major part of fox summer diets in some areas (Burgess, 1979). The winter diet of inland fox populations is primarily lemmings, although caribou carrion may also be eaten. Arctic foxes may follow caribou herds to take advantage of wolf kills (Manning, 1943; Macpherson, 1969) or follow polar bears on the winter sea ice to scavenge on the remains of seals left by bears (Blood, 1977). Arctic foxes have become habituated to community garbage dumps.

Arctic fox productivity is closely related to levels of prey populations. For example, females usually produce large litters (with an average of 10.6 whelps each in the central Arctic population), although the mean size of weaned litters varies between years. In years of lemming abundance, an average of 9.6 whelps are weaned, while in years when lemmings are scarce, few whelps are weaned (Macpherson, 1969). However, on sea ice, where foxes have access to ringed seal carrion and pups, such natural population fluctuations may be offset by the presence of these alternative food sources (Smith, 1976).

Areas of particular importance for Arctic foxes include suitable den sites and winter range. Den sites are often traditional and form the major focus for the activities of the breeding season (Macpherson, 1969; Banfield, 1974). Habitat for den sites is limited in areas with permafrost and where frequent spring flooding occurs, such as in the Mackenzie Delta. Fall and winter movements are probably caused by food scarcity, and regions of high prey abundance may be very important for winter survival. Sea ice areas with numerous polar bear prey species would be particularly important to wintering Arctic foxes.

There are no available estimates of Arctic fox population densities or sizes from Richards Island south to Norman Wells. Slaney (1974a) recorded only two possible Arctic fox dens on Richards Island during extensive surveys in 1973, although Porsild (1945) had reported that this species was common along the coast in 1927 and 1928 and rare inland. Arctic foxes are considered the most abundant denning species on deltaic islands south of, and including, Kendall Island (McEwen, 1955; cited in Gulf Oil, 1975). The area from Parsons Lake to the tip of Richards Island is classified as important habitat (Class 2) for Arctic foxes, while areas south to near Inuvik and along the east margin of the Mackenzie River are considered of little importance (Class 3) (Nolan *et al.*, 1973b). The region south of Inuvik and the entire Mackenzie Delta proper is considered unimportant habitat for Arctic foxes (Class 4) (Nolan *et al.*, 1973b). Arctic foxes do not occur from Norman Wells south to 60° N.

The distribution and movements of Arctic foxes in the northern areas of the Mackenzie Valley are probably similar to those of other coastal populations (that is, out to the sea ice in winter and back to land for denning in spring), although Porsild (1945) noted that Arctic foxes tend to follow the reindeer herd, to feed on reindeer carrion and weak fawns.

2.1.4.2 Red Fox

The red fox *(Vulpes vulpes)* is widely distributed in northern latitudes and occurs throughout the mainland Northwest Territories (Banfield, 1974). Population densities are typically greater in forest and in forest-tundra transition zones than on tundra.

The three colour phases of red foxes are red, cross and silver. This species is important to the trapping economy of the Mackenzie District, particularly of the Mackenzie Valley (Section 2.5.1). Porsild (1945) noted that during the 1930's the red fox was second only to the muskrat in importance as a furbearer on the Mackenzie Delta. Since 1970-71, fur harvest records indicate a substantial increase in the harvest of red foxes throughout the Northwest Territories (Section 2.5.1) (Dickinson and Herman, 1979).

Although there is little information on the biology of the red fox in the Northwest Territories, this species has been studied in forested areas elsewhere. Soper (1964) observed that red fox litters had from 4 to 9 whelps and that populations appear to follow a ten year cycle in northern Alberta and Wood Buffalo National Park. The natural fluctuations in numbers are extreme and are caused, in part, by rabies epidemics which decimate populations. However, this species reproduces rapidly so that their numbers are restored quickly.

Like those of Arctic foxes, red fox activities during the summer are centred around the breeding den. Den sites are frequently traditional, and are located in well drained areas such as in the steep slopes of river banks, ridges, eskers and moraines. Den sites are selected in consolidated soil consisting primarily of sands, gravels or sandy loams. Red fox dens usually face south and have entrances obscured by shrubby vegetation (Slaney, 1974a).

The red fox is broadly omnivorous and consumes small mammals, birds, insects and berries (Banfield, 1974). Slaney (1974a) found the following prey remains (in decreasing frequency) at Richards Island fox dens: ptarmigan, duck, unidentified birds, small mammals, ground squirrels, foxes, fish, swans, muskrats, reindeer, insects and berries.

Information on the population size and local distribution of this species along the Mackenzie River is sparse. Twenty-two of 24 active fox dens on Richards Island counted during 1973 and 1974 were reportedly red fox dens (Slaney, 1974a). Areas of Richards Island along the corridor include a large proportion of land ranging from medium to high suitability for den sites (Slaney, 1974a), although habitat around Parsons Lake has been classified as having low suitability. Slaney (1974a) reported that red foxes were observed in open upland habitat throughout most of the year, but preferred shrubby areas where ptarmigan occur during winter.

Although there is little information on red fox populations from Norman Wells south to Fort Simpson, the diverse habitats probably support small populations. High quality habitat for all upland furbearers, including foxes, occurs immediately south of Fort Norman (Ruttan and Wooley, 1974). However, very few animals are harvested by residents of communities along this portion of the corridor, which is probably indicative of their low population level (Section 2.5.1).

Suitable red fox habitat is available along the corridor from Fort Simpson south to 60° N, but densities and population levels have not been documented. Annual red fox harvests reported for communities in this area are also low (Section 2.5.1).

2.1.4.3 Wolf

Although the wolf *(Canis lupus)* was formerly widely distributed throughout North America, it has vanished from much of its former range except for wild northern areas (Plate 2.1-6). In the Mackenzie Valley corridor wolves occur in forested and tundra habitats, and are primarily associated with ungulates such as caribou and moose. Subgroups of the northern wolf population have developed different behav-

PLATE 2.1-6 *In the Mackenzie Valley corridor wolves occur in forested and tundra habitats, and are primarily associated with ungulates such as caribou and moose. (Courtesy, McCourt Management).*

ioural and habitat selection strategies in response to the movements, distribution and abundance of prey species (Dickinson and Herman, 1979).

A few wolves are harvested, making them of moderate importance to the trapping economy of the Northwest Territories (Section 2.5.1.) (Dickinson and Herman, 1979). Recently substantially more have been taken and the average value per pelt has increased. Since this species has not been intensively studied in the Mackenzie River Valley, harvest data provide the only historical estimates of the local wolf populations.

Most wolves occur in packs. If the predominant prey species is migratory (such as barren-ground caribou), wolf packs follow them, except during spring, when their activities are centred around breeding dens. In contrast, if the predominant prey species is essentially non-migratory (such as moose), wolf packs establish well defined territories and confine their activities within them. This pattern may be modified in the Mackenzie Valley since moose that move to, and winter, on islands in the Mackenzie River may be followed by wolf packs.

Prey species determine seasonal habitats selected by wolf packs. During the winter hunting packs often travel long distances following ridges, trails, seismic lines, lake shores and frozen lakes and rivers (Mech, 1970; Peters and Mech, 1975). If the prey species is concentrated, wolves may concentrate also. During the summer wolves typically restrict their movements since they frequently return to the pup-rearing areas.

Den and rendezvous sites are selected to provide security for the pups. In Arctic Alaska, Stephenson (1974) found that the majority of dens were excavated in well drained and usually sandy soil, and were situated on moderate to steep south-facing slopes near a water supply. Den sites are commonly traditional (Mech, 1970; Stephenson and Johnson, 1972). Rendezvous sites are large areas (ranging up to 0.64 km^2) usually located near open water and an open understory of grass and sedges (Kolenosky and Johnston, 1967).

Most wolf packs prey on ungulates, although other prey may include beavers, snowshoe hares, other small mammals, birds, and vegetation (Theberge and Cottrell, 1977; Stephenson, 1978). Wolves feed opportunistically and will eat garbage.

Important habitats for wolves include traditional pup-rearing areas and ranges that overlap those of their primary prey ungulate species. There may be several den sites in a single wolf pack territory since the adults move young from one site to another in the same season (Mech, 1970).

Historically wolves were scarce in the tundra region of the Mackenzie Valley. Porsild (1945) reported that wolves were uncommon in the Mackenzie Delta region in 1927 and 1928, although they occasionally moved into the area from the west to prey on snowshoe hares. In the tundra and Delta regions wolves primarily range with caribou and reindeer herds, while in the forested areas they are associated with moose (Wooley, 1976). There is no information on population densities or areas of particular importance for wolves from Richards Island south to Norman Wells, although reindeer herders have kept wolf numbers low near their herd. The relatively large populations of moose on Mackenzie River islands during winter probably attracts many wolves.

There is suitable habitat from Norman Wells south to Fort Simpson to support moderate wolf populations, although reported wolf harvests are low for communities in this region (Section 2.5.1).

From Fort Simpson south to 60° N, good habitat for wolves and other upland furbearer populations is available (Ruttan and Wooley, 1974). However, low harvests are reported by residents of communities in this area. Donaldson and Fleck (1980) reported that one or possibly two wolf packs inhabited their study area along the Liard River southwest of Fort Simpson.

2.1.4.4 Marten

The marten *(Martes americana)* occurs throughout the boreal forests of North America (Banfield, 1974), although their range extends as far north as Tuktoyaktuk (Clarke, 1944). In general their principal range is confined to continuously forested areas south of the tree line, with uplands and foothills having the largest populations (Thurlow, 1973; Wooley, 1974b).

This species is the most economically important furbearer in the wooded Mackenzie Valley and is the species taken in greatest numbers (Section 2.5.1). Although marten are not currently being overharvested, this species has been over-exploited locally in the past (Dickinson and Herman, 1979). During the mid 1940's a territory-wide closure on marten trapping was enforced for several years. However, Hawley (1968) concluded that there is still insufficient information on marten populations in the Northwest Territories to effectively regulate harvesting and prevent this situation from recurring.

Intensive studies of marten populations in the southern Mackenzie District have indicated that the largest populations are found in large unbroken tracts of mature upland coniferous-dominated mixed wood forest (Wooley, 1974b). Marten are not selective in their choice of forest type, although they often travel along river and stream valleys where prey populations are high.

Marten are efficient predators of small mammals, hares and birds, but may also supplement their diets with insects, carrion and fruit (Banfield, 1974). In years of abundant prey, marten tend to be more sedentary and consequently are more difficult to trap (Lensink *et al.*, 1955).

Marten dens or rearing areas occur in a wide variety of sites such as hollow trees, rock piles or overturned trees (Banfield, 1974). Consequently, denning habitat is not usually a limiting factor for this species. In general marten are solitary, although families may be seen together during the rearing period.

The mature upland forests from Richards Island south to Norman Wells provide good habitat for marten. This species is abundant near Travaillant Lake (Bissett, 1967) and the Thunder River (Wooley, 1976), with greatest densities probably occurring in riparian mixed-wood forests dominated by white spruce (Ruttan and Wooley, 1974). Studies conducted in the Chick Lake and Moon Lake regions indicated relatively high (0.25 - 0.54 marten/km^2) densities of marten (Wooley and Douglas, 1974). However, marten are rare on the tundra.

Trapping data from communities from Norman Wells south to Fort Simpson suggest that the marten population is relatively large (Section 2.5.1). However, the distribution and abundance of marten between Norman Wells and Fort Simpson has not been documented.

Wooley (1974b) found marten densities ranging from 0.13 marten/km^2 at Dogface Lake to 0.86 marten/km^2 in the Redknife Hills. No areas of concentration for this species have been identified from Fort Simpson south to 60°N, although communities in this area report relatively high numbers trapped (Section 2.5.1).

2.1.4.5 Lynx

Lynx *(Lynx canadensis)* occur primarily in the boreal and Rocky Mountain forests of North America. In the Northwest Territories they are usually confined to mixed-wood forests, particularly dense mature stands (Banfield, 1974). They are considered the second-most economically important furbearer in the Mackenzie Valley, although relatively few are trapped. Lynx are susceptible to over-harvesting when their population cycle is low (Berrie, 1973).

Lynx population levels parallel the 10 year cycle of hares, a species upon which they depend as primary prey (Elton and Nicholson, 1942). Estimates of lynx density are not available for the Northwest Territories, but population fluctuations may be comparable to those recorded in central Alberta by Brand *et al.* (1976). These authors reported a minimum of 2.3 lynx per 100 km^2 (1966-67) and a maximum of 10.0 lynx per 100 km^2 (1971-72), and noted that minimum and maximum densities of hares had occurred one year earlier in the same area.

Lynx usually frequent areas that are inhabited by their major prey, the snowshoe hare, and possibly avoid recent burn areas and other locations where hares do not occur. Although lynx are widely distributed throughout the boreal forest, they will be found beyond the forest edge during years of high population (Boles, 1975). Usually lynx are sedentary, but they may migrate many kilometres if food is scarce (Banfield, 1974). The lynx is a solitary animal, associating with other lynx only when breeding and early in the rearing period. Dens are not excavated, but are located in protected areas such as windfalls or natural ledges. Lynx may occasionally concentrate where hares are plentiful, particularly if prey in general, is scarce.

In addition to the snowshoe hare, lynx will feed on birds such as ducks, ptarmigan, or songbirds, and mammals such as voles, ungulate carrion, young ungulates, foxes, and squirrels. However, the showshoe hare is preferred by far, comprising 70% to 80% of lynx diets in northern Alberta and the Mackenzie District (van Zyll de Jong, 1963; Nellis *et al.*, 1972).

Lynx have never been abundant in the Mackenzie Delta region (Porsild, 1945). Slaney (1974a) reported sighting two lynx during a two year study in the vicinity of Richards Island and Parsons Lake. Although no quantitative estimates of population size or density are available from Richards Island south to Norman Wells, Ruttan and Wooley (1974) reported that lynx were plentiful along the Mackenzie River and in the forested Valley in general.

Fur harvest records (Section 2.5.1) and observations by Ruttan and Wooley (1974) suggest that lynx are relatively abundant from Normán Wells south to Fort Simpson. However, no quantitative estimates of population size or density are available.

Harvest Export Tax Returns from Fort Simpson for 1974-75 indicated that 381 lynx were taken from near Fort Simpson. Ruttan and Wooley (1974) noted that lynx were common along this portion of the corridor in 1971, but data on population size and density are not available.

2.1.4.6 Other Terrestrial Furbearers

Other furbearers which are trapped by residents of communities in the Mackenzie Valley include mink, weasel, squirrel, wolverine, otter, fisher and coyote. Of these, mink is the most abundant and economically important (Plate 2.1-7). Weasel and squirrel are common, but contribute little to the trapping economy (Section 2.5.1). Wolverine, otter, fisher and coyote are relatively uncommon.

2.1.5 OTHER MAMMALS

Other mammals found in the Mackenzie Valley include five species of shrews, the snowshoe hare, the striped skunk, three species of lemmings, six species of voles, two species of mice and five other species of rodents.

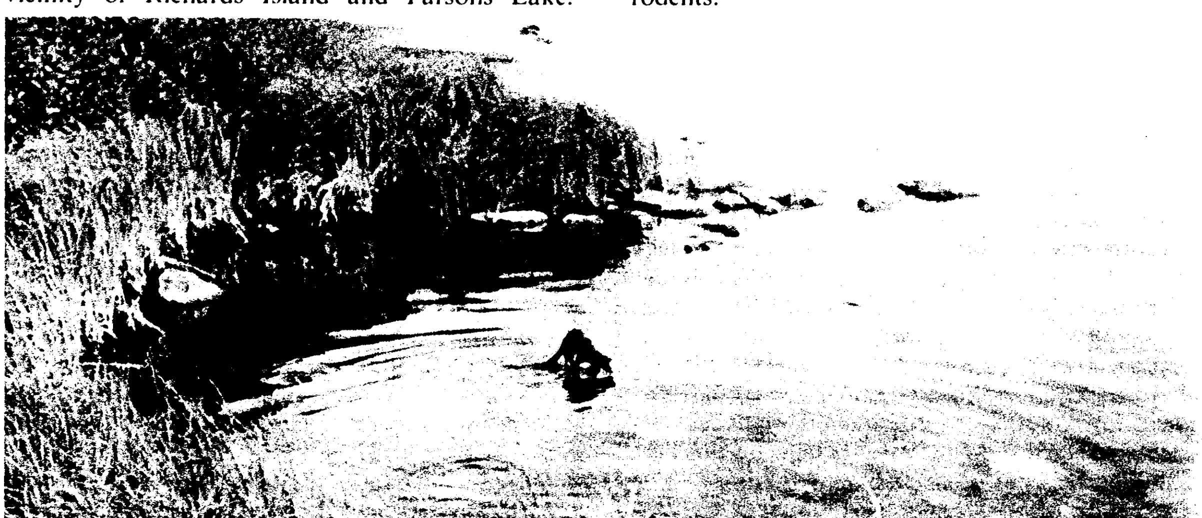
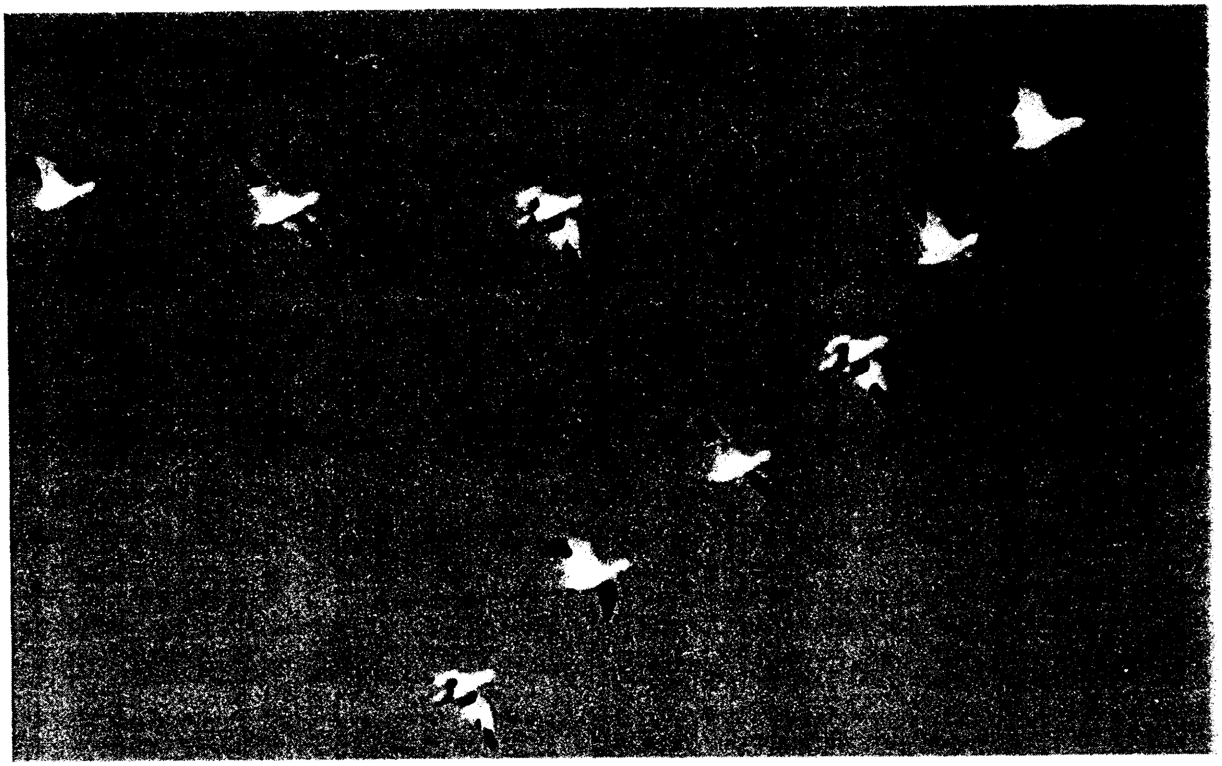


PLATE 2.1-7 *Mink are the most abundant and economically important of the smaller terrestrial furbearers. Here a mink is seen fishing. (Courtesy, McCourt Management).*



2.2 BIRDS

This section summarizes the distribution, abundance and life history of the major bird species that are found in the Mackenzie Valley and that may be affected by developments there. For general biological information on the species discussed in this section the reader is referred to Tull and Koski (1981).

The Mackenzie Valley is a major migration corridor in spring and autumn, both for birds that move through enroute to and from Arctic breeding areas and for birds that breed within the Mackenzie Valley. Spring migration generally occurs from mid to late April until the end of May or early June. It is rapid for most species, but some, especially the earlier-arriving species, use traditional staging areas for a period of time before moving on to their nesting grounds.

Autumn migration generally occurs from early August to early or mid October. For some species this migration is prolonged, with the different sexes and ages moving south at different times. Many waterbodies in the Mackenzie Valley are traditional staging areas where waterbirds build up energy reserves before or during migration south.

Many bird species nest in the Mackenzie Valley. Nesting birds are generally widely dispersed within suitable habitat. This is especially so for terrestrial birds, while waterbirds may be more concentrated in wetland areas because of the more restricted nature of these habitats. A few species nest in small colonies, but there are no large colonies of nesting birds along the Mackenzie Valley. June is the peak of nesting activity in the Mackenzie Valley, although some nesting begins in May and the young of some raptors are still in the nest during August. The peak of brood-rearing activities for most waterbirds is from mid July to mid August. Few bird species overwinter in the Mackenzie Valley.

More than 170 species of birds occur regularly in the Mackenzie Valley and many other species have been recorded irregularly or accidentally. Of these species, the swans, geese, ducks and raptors are of greatest interest. Three species of swans and geese, namely the whistling swan, white-fronted goose and snow goose, use the Mackenzie Valley only during spring and fall migration. During the period from mid to late May, large numbers of snow geese (up to 130,000), white-fronted geese (up to 15,000) and whistling swans (up to 7,700) stage along the Mackenzie River on the islands that extend from just south of Norman Wells to the Thunder River. (See Figure 2.2-1 for geographic names). The birds use these spring staging areas to build up or to maintain the energy reserves that they need to nest successfully. During fall migration these same populations, as well as white-fronted geese from the Alaskan North Slope, use the Mackenzie Valley as a migration corridor. Few birds stop within the area during fall migration. A fourth species, the Canada goose, nests in the Valley in low numbers.

Ducks are the most abundant group of waterfowl in the Mackenzie Valley but densities of breeding birds are low throughout most of the area (generally less than 5 ducks/km^2), with the exception of prime wetland areas, such as the Mackenzie Delta, the Ramparts River area, and the Great Bear River-Loche River-Kelly Lake area, where densities may be as high as 20 to 35 ducks/km^2. During most years diving ducks, consisting primarily of scaup and scoters, are more abundant than dabbling ducks, which are mostly pintails, wigeon and mallards. However, during years of drought in the prairies, dabbling ducks that normally nest there move to northern wetlands areas and may be more abundant than diving ducks. Spring migration of ducks into and through the Valley follows the Mackenzie River. Birds disperse from the river to adjacent lakes and ponds as they thaw. During fall migration they use the lakes and ponds near the Mackenzie River as staging areas; the most important lakes for fall staging are Brackett Lake, Tate Lake and the Mills-Beaver lakes area.

Concern has been expressed for several species of raptors because their numbers are low or declining. The greatest concern has been expressed for the two subspecies of peregrine falcon that occur regularly in the Mackenzie Valley. The *anatum* subspecies, which breeds in the Mackenzie Valley, is considered to be endangered. A significant number of pairs of this subspecies breed in the Mackenzie Valley. Forty-four nest sites were known in 1975, of which 25 were active. The *tundrius* subspecies, which occurs in the Mackenzie Valley only during migration, is considered to be threatened. Both subspecies have declined in numbers during the last 30 years over most of their ranges primarily because persistent pesticides such as DDT have caused a decline in productivity. Golden eagles, which nest primarily on cliffs, cutbanks and outcrops, nest sparsely along the Mackenzie Valley. Bald eagles, which nest primarily in large trees near water, nest commonly in the southern Mackenzie Valley but less commonly farther north. The osprey, which nests mostly in trees near water, is a sparse nester in the Mackenzie Valley.

The following descriptions provide more detail on individual species that occur in the Mackenzie Valley. Table 2.2-1 lists the common and scientific names of these birds. Emphasis is placed on water-associated birds such as the waterfowl mentioned above and on the raptors because of the often restricted nature of their habitat.

TABLE 2.2-1
COMMON AND SCIENTIFIC NAMES OF BIRDS DISCUSSED IN SECTION 2.2 OF VOLUME 3C

Common Name	Scientific Name
Loons	
Common loon	Gavia immer
Yellow-billed loon	Gavia adamsii
Arctic loon	Gavia arctica
Red-throated loon	Gavia stellata
Grebes	
Red-necked grebe	Podiceps grisegena
Horned grebe	Podiceps auritus
Swans and Geese	
Whistling swan	Olor columbianus
Canada goose	Branta canadensis
White-fronted goose	Anser albifrons
Brant	Branta bernicla
Snow goose	Chen caerulescens
Dabbling Ducks	
Mallard	Anas platyrhynchos
Pintail	Anas acuta
Gadwall	Anas strepera
American wigeon	Anas americana
Northern shoveler	Anas clypeata
Blue-winged teal	Anas discors
Green-winged teal	Anas crecca
Diving Ducks	
Redhead	Aythya americana
Canvasback	Aythya valisineria
Ring-necked duck	Aythya collaris
Greater scaup	Aythya marila
Lesser scaup	Aythya affinis
Common goldeneye	Bucephala clangula
Barrow's goldeneye	Bucephala islandica
Bufflehead	Bucephala albeola
Harlequin	Histrionicus histrionicus
Oldsquaw	Clangula hyemalis
White-winged scoter	Melanitta deglandi
Surf scoter	Melanitta perspicillata
Ruddy duck	Oxyura jamaicensis
Common merganser	Mergus merganser
Red-breasted merganser	Mergus serrator
Raptors	
Goshawk	Accipiter gentilis
Sharp-shinned hawk	Accipiter striatus
Marsh hawk	Circus cyaneus
Rough-legged hawk	Buteo lagopus
Red-tailed hawk	Buteo jamaicensis
Swainson's hawk	Buteo swainsoni
Golden eagle	Aquila chrysaetos
Bald eagle	Haliaeetus leucocephalus
Osprey	Pandion haliaetus
Gyrfalcon	Falco rusticolus
Peregrine falcon	Falco peregrinus
Merlin	Falco columbarius
American kestrel	Falco sparverius
Great horned owl	Bubo virginianus
Long-eared owl	Asio flammeus
Short-eared owl	Asio otus
Snowy owl	Nyctea scandiaca
Great gray owl	Strix nebulosa
Hawk owl	Surnia ulula
Boreal owl	Aegolius funereus (cont'd)

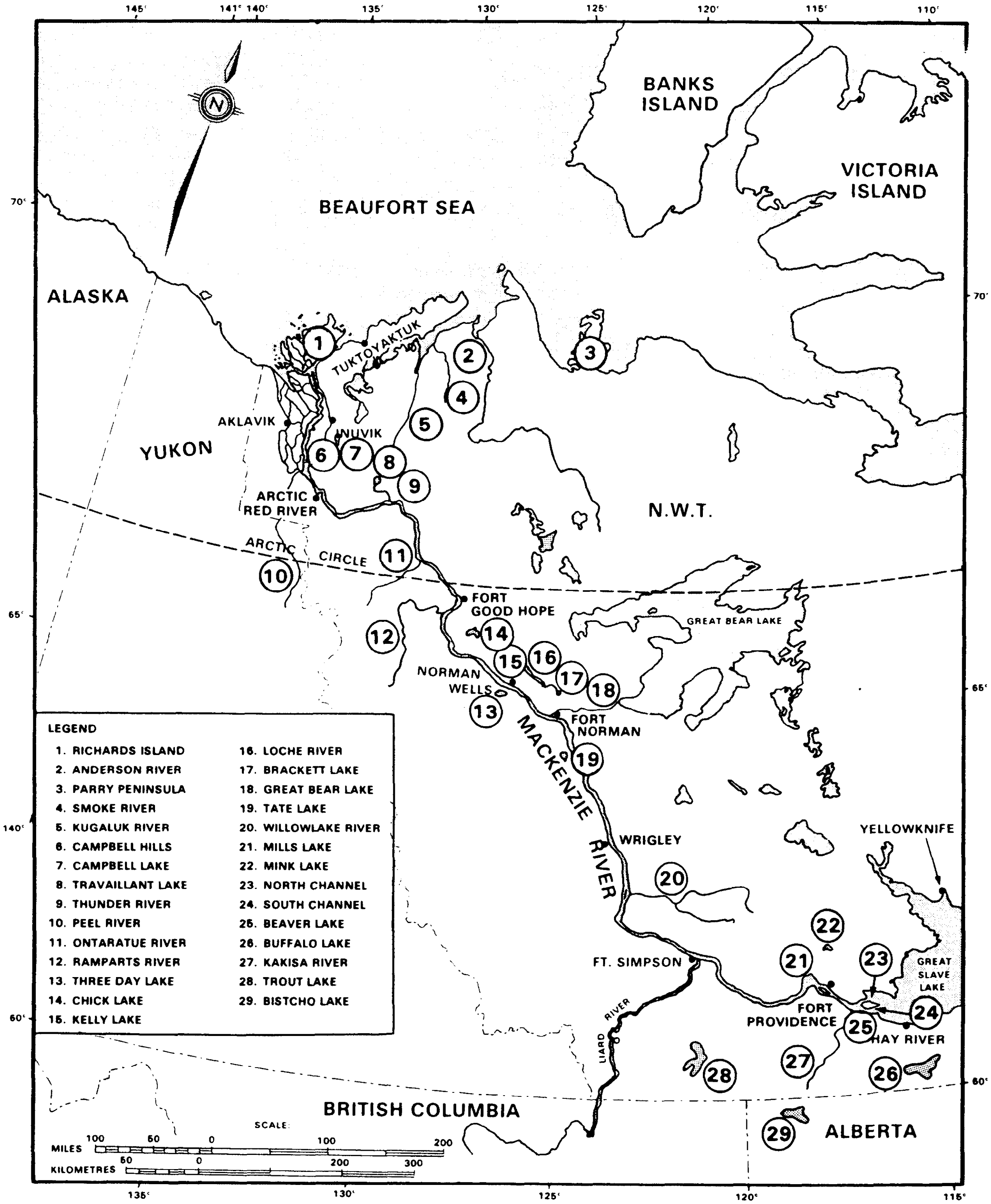


FIGURE 2.2-1 *Geographic names in the descriptions of birds.*

TABLE 2.2-1 (Cont'd)

COMMON AND SCIENTIFIC NAMES OF BIRDS DISCUSSED IN SECTION 2.2 OF VOLUME 3C

Common Name	Scientific Name
Grouse	
Spruce grouse	Canachites canadensis
Ruffed grouse	Bonasa umbellus
Sharp-tailed grouse	Pedioecetes phasianellus
Willow ptarmigan	Lagopus lagopus
Rock ptarmigan	Lagopus mutus
Cranes	
Sandhill crane	Grus canadensis
Whooping crane	Grus americana
Shorebirds	
American golden plover	Pluvialis dominica
Whimbrel	Numenius phaeopus
Eskimo curlew	Numenius borealis
Greater yellow-legs	Tringa melanoleuca
Stilt sandpiper	Micropalama himantopus
Short-billed dowitcher	Limnodromus griseus
Upland sandpiper	Bartramia longicauda
Buff-breasted sandpiper	Tryngites subruficollis
Solitary sandpiper	Tringa solitaria
Spotted sandpiper	Actitis macularia
Wilson's phalarope	Steganopus tricolor
Red phalarope	Phalaropus fulicarius
Northern phalarope	Lobipes lobatus
Gulls and Terns	
Glaucous gull	Larus hyperboreus
Herring gull	Larus argentatus
California gull	Larus californicus
Ring-billed gull	Larus delawarensis
Mew gull	Larus canus
Bonaparte's gull	Larus philadelphia
Thayer's gull	Larus thayeri
Arctic tern	Sterna paradisaea
Common tern	Sterna hirundo
Caspian tern	Sterna caspia
Black tern	Chlidonias niger
Other Waterbirds	
Parasitic jaeger	Stercorarius parasiticus
Long-tailed jaeger	Stercorarius longicaudus
American bittern	Botaurus lentiginosus
Sora	Porzana carolina
American coot	Fulica americana
Passerines and 'Near-Passerines'	
Common nighthawk	Chordeiles minor
Belted kingfisher	Megaceryle alcyon
Hairy woodpecker	Picoides villosus
Cliff swallow	Petrochelidon pyrrhonota
Gray jay	Perisoreus canadensis
Common raven	Corvus corax
Northern shrike	Lanius excubitor
Tennessee warbler	Vermivora peregrina
Yellow warbler	Dendroica petechia
Dark-eyed junco	Junco hyemalis
Chipping sparrow	Spizella passerina

2.2.1 LOONS

Loons are migratory and spend their winters in near-shore marine waters of the Atlantic and Pacific coasts. Migration of the Arctic-nesting species is mainly coastal, but there is some movement of loons along inland routes (Palmer, 1962). Although loons may occur in flocks in wintering areas, they usually occur singly or in small flocks during migration (Palmer, 1962). Loons feed primarily on fish, but also take various types of marine and freshwater invertebrates (Palmer, 1962).

Four species of loons (common, yellow-billed, Arctic and red-throated) occur in the Mackenzie Valley (Plate 2.2-1). The yellow-billed loon possibly migrates through the area in spring enroute from wintering areas on the Pacific coast to breeding areas east of the Valley (Palmer, 1962; Griffiths, 1973). The common and Arctic loons are common breeding species in the Mackenzie Valley, whereas the red-throated loon is an uncommon breeding species. The Arctic loon nests primarily north of Wrigley while the common loon is most abundant south of Wrigley (Campbell and Weber, 1973; Salter, 1974a; Salter and Davis, 1974; Tull *et al.*, 1974; Ward, 1975; Wiseley and Tull, 1977). Tate (1981) lists the common loon on the 'blue list' of North American 'species of concern.' An explanation of this list and the statuses assigned to species by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) are given in Table 2.2-2.

The Arctic loon nests on lakes and large ponds, while the common loon nests on small or large lakes (Palmer, 1962). Palmer (1962) gives the time taken from egg-laying to fledging as approximately three months for the common loon, but it may be as little as 70 days for the Arctic loon (cf. Johnson *et al.*, 1975).

The Mackenzie Valley is a spring migration corridor for common and Arctic loons. These two species first arrive in the southern Mackenzie Valley during early May (May 6-7 in 1973; Salter *et al.*, 1974). In 1973 the peak of the Arctic loon migration was May 16 at Fort Simpson and May 23 at Wrigley; the peak of common loon migration at Norman Wells was May 25 (Salter *et al.*, 1974). Red-throated loons were uncommon migrants during this study and yellow-billed loons were not recorded.

Several aerial surveys have been conducted on the numbers of waterbirds along proposed pipeline routes through the Mackenzie Valley. Estimates of loon population densities have ranged from a low of 0.01 loons/km^2 between Willowlake River and Bistcho Lake during late May and early June, 1975 (Patterson and Wiseley, 1977), to a high of 0.20 loons/km^2 between Norman Wells and Richards Island in 1973 (Salter, 1974a).

The above values are deceptively low because the area surveyed included both dry and wetland habitats. More realistic numbers were generated in a study of only wetland habitat along the proposed Arctic Gas Pipeline corridor from Richards Island to the Alberta border by Poston (1977). In late May and early June, Poston recorded 0.92 loons/km^2 of wetland south of the Willowlake River, 4.49 loons/km^2 of wetland between the Great Bear and

TABLE 2.2-2

DEFINITIONS OF STATUS FOR SPECIES WITH DECLINING POPULATIONS

Status as defined by Committee On the Status of Endangered Wildlife In Canada (COSEWIC)

Species:	any species, subspecies, or geographically separate population.
Rare Species:	any indigenous species of fauna or flora that, because of its biological characteristics, or because it occurs at the fringe of its range, or for some other reason, exists in low numbers or in very restricted areas in Canada but is not a threatened species.
Threatened Species:	any indigenous species of fauna or flora that is likely to become endangered in Canada if the factors affecting its vulnerability do not become reversed.
Endangered Species:	any indigenous species of fauna or flora whose existence in Canada is threatened with immediate extinction through all or a significant portion of its range, owing to the action of man.

Status for inclusion on the Blue List of American Birds*

1. those species that may or may not be declining now, but may be in jeopardy in the foreseeable future;
2. those species that occur in such small numbers that their status should be monitored;
3. those species for which there are no scientific data to determine whether or not they are declining, but for which there is definite concern; or
4. those species that give definite evidence of non-cyclical declines in all or part of their ranges.

*The journal American Birds has prepared and updates yearly an unofficial 'blue list' of North American bird species that are not endangered, but that are considered to be of concern, for the reasons listed in this table.

Willowlake rivers, 1.75 loons/km^2 of wetland between Fort Good Hope and the Great Bear River, 5.79 loons/km^2 of wetland between Campbell Lake and Fort Good Hope, and 2.57 loons/km^2 of wetland between Richards Island and Campbell Lake.

The Mackenzie Valley is also a corridor for fall migration of common, Arctic and red-throated loons (Salter, 1974b). These migrations are generally underway by the second half of August (Salter, 1974b), continuing at least until the end of September. In 1972 the peak of loon migration at Tate Lake (south of Fort Norman) occurred on September 14 and 15. Some of the larger lakes are important staging areas for loons during the autumn. More than 1,000 loons were recorded on Stewart Lake (south of Tate Lake) in the third week of September 1971, and 150 loons were present on Trout Lake during late September 1972 (Davis, 1974).

2.2.2 GREBES

The red-necked and horned grebes both breed throughout the Mackenzie Valley (Godfrey, 1966). As the status of the red-necked grebe is of some concern it is included on the 'blue list' of North American species (Tate, 1981).

Grebes are migratory. They winter in marine waters of the Atlantic and Pacific coasts and migrate through the interior to summer in the north. They frequently occur in small flocks at staging areas (Palmer, 1962). In freshwater locations grebes feed primarily on small fish, insects and some crustaceans (Palmer, 1962).

Grebes moving to and from breeding areas in the Mackenzie Valley probably use the Valley as a migra-

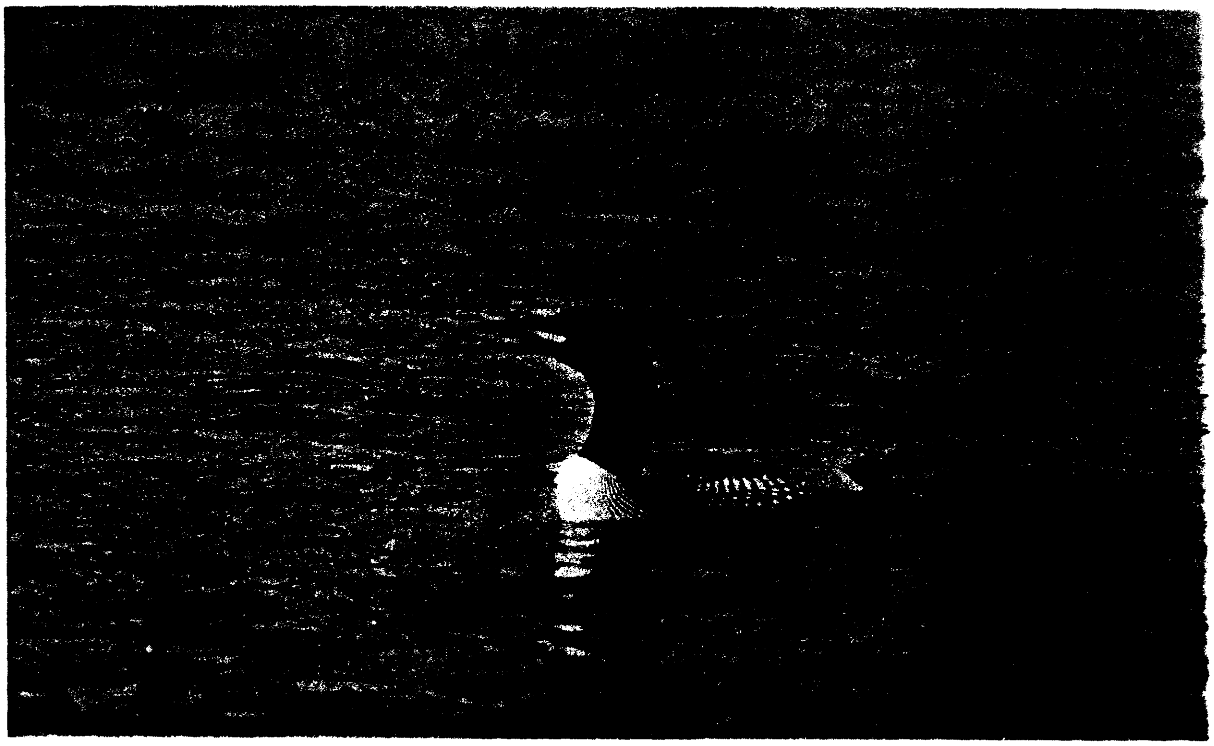


PLATE 2.2-1 *A common loon with its young. In the Mackenzie Valley the common loon is most abundant south of Wrigley. (Courtesy, J. Kristensen, LGL Ltd.).*

tion corridor. Salter *et al.* (1974) recorded northward spring movement of horned grebes at Fort Simpson (after some initial upriver movement) and of red-necked grebes at Wrigley and Norman Wells. In 1973 both species arrived during the first week of May with the peaks of spring migration occurring from May 16 to 24 (Salter *et al.*, 1974).

The two species usually nest as dispersed pairs on freshwater lakes and ponds but the red-necked grebe occasionally nests in small loose colonies (Palmer, 1962). Nesting probably begins during late May in the southern Mackenzie Valley or in early June further north (Wiseley and Tull, 1977). Their floating nests are constructed from plants and are usually placed in emergent vegetation. Incubation and fledging require at least 70 days for the red-necked grebe (Palmer, 1962). Red-necked grebes take at least two years to mature, whereas horned grebes first breed at one year of age.

The red-necked grebe (Plate 2.2-2) is apparently the more common species of grebe in the northern Mackenzie Valley (Salter, 1974b; Salter *et al.*, 1974). Nesting densities of grebes are available from aerial surveys of waterbirds along proposed pipeline routes, and such densities have usually been very low when upland and wetland areas are combined. Davis (1974) recorded grebe densities in 1972 of 0.01 grebes/km^2 (on the west side) and 0.05 grebes/km^2 (on the east side) along the Mackenzie River between approximately Fort Good Hope and Fort Simpson, but recorded slightly higher densities of grebes (0.04 to 0.09/km^2) along transects through adjacent areas of prime wetland habitat. Salter (1974a) and Wiseley *et al.* (1977) recorded no grebes in 1973 and 1975, respectively, along routes north of this area and between Norman Wells and Richards Island. In surveys conducted during late May and early June 1975, Patterson and Wiseley (1977) recorded a density of 0.02 grebes/km^2 between the Willowlake River and Bistcho Lake, Alberta.

Poston (1977), surveyed wetland basins along the proposed Arctic Gas pipeline corridor from Richards Island to the Alberta border in 1973 and expressed his results in birds/km^2 of aquatic habitat surveyed. From late May to early June they found 0.59 grebes/km^2 of wetland south of the Willowlake River, 0.86 grebes/km^2 of wetland between Great Bear and Willowlake rivers, 0.60 grebes/km^2 of wetland between Fort Good Hope and the Great Bear River, and 0.57 grebes/km^2 of wetland between Campbell Lake and Fort Good Hope. However, no grebes were found on wetland habitat between Richards Island and Campbell Lake.

Red-necked grebes begin to disperse from their

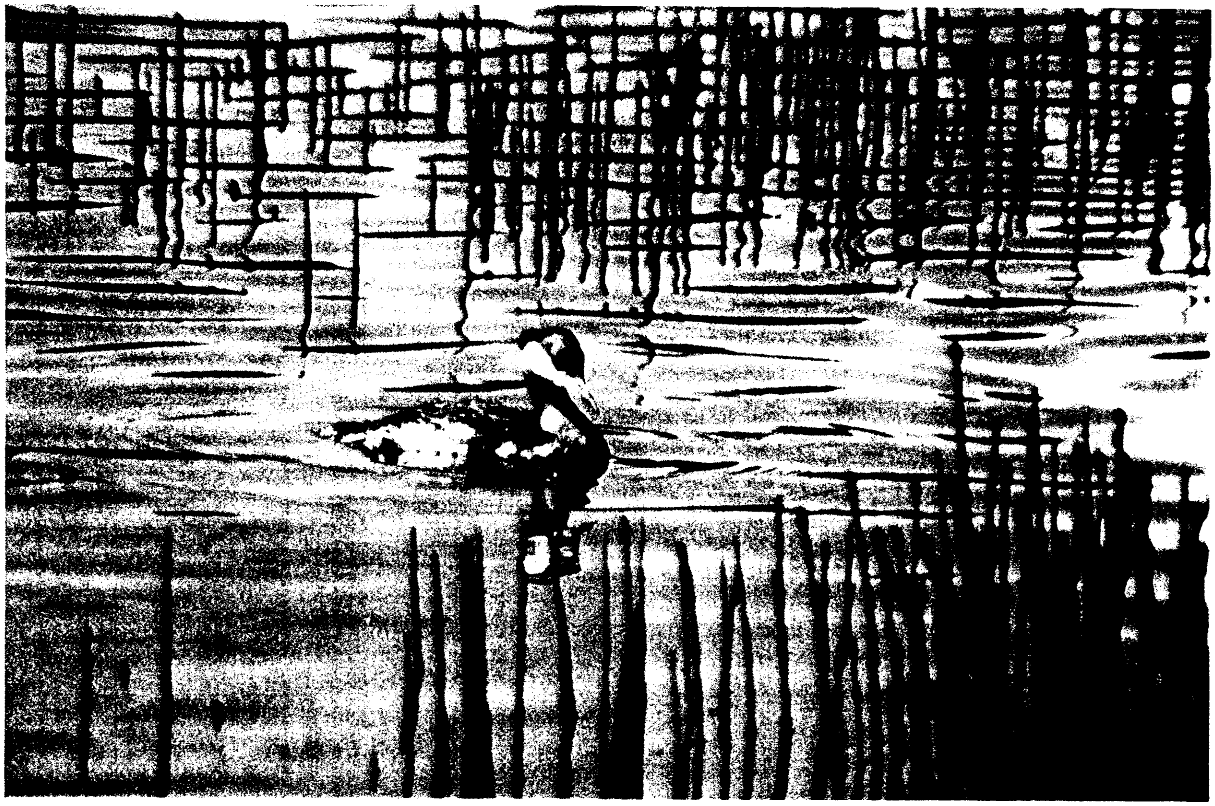


PLATE 2.2-2 *The red-necked grebe, shown here, nests throughout the Mackenzie Valley and is the more common species of grebe in the northern part of the Valley. (Courtesy, J. Kristensen, LGL Ltd.).*

breeding grounds in July and August, although the earliest to leave are probably failed breeders or non-breeders (Palmer, 1962). Horned grebes do not disperse until late August or September (Palmer, 1962). Fall-migrant horned grebes were observed at Tate Lake between August 25 and September 25, 1972, while fall-migrant red-necked grebes were observed at Kelly Lake, Tate Lake, Brackett Lake and Fort Providence between August 15 and October 1, 1972 (Salter, 1974b).

2.2.3 WHISTLING SWAN

Whistling swans are common solitary nesters in coastal areas of the Beaufort Sea, including the Mackenzie Delta. However, in most of the Mackenzie Valley, whistling swans occur only as migrants (Figure 2.2-2). Most of these birds winter along the Atlantic coast in Chesapeake Bay and the area from Back Bay, Virginia, to Lake Mattamuskeet and Pamlico Sound, North Carolina (Sladen, 1973). Section 4.2.3 of Volume 3A addresses the status of this population.

Whistling swans feed primarily on aquatic plants usually found in the shallow water of ponds, lakes and slow-moving waters (Bellrose, 1976; Palmer, 1976a).

Whistling swans usually arrive in the southern Northwest Territories in the vicinity of the Slave River delta in late April or early May (Soper, 1942, 1957; Salter, 1974c). The largest numbers are found on mudflats and sandbars on the outer fringe of the Slave River delta, while use of other nearby areas varies from year to year. For example, on May 16, 1974, Kemper *et al.* (1975) found more than 1,500 swans along the north and south channels exiting from Great Slave Lake and smaller numbers (less than 500) at other lakes in the area. Salter *et al.* (1974) recorded 365 swans on Mills Lake on May 9, 1973 and 1,175 swans on Beaver Lake (including the north and south channels) on May 17.

From the Great Slave Lake area, whistling swans migrate northwest (east of the Norman Range and over Brackett Lake) to the Mackenzie River, primarily from Fort Good Hope to Little Chicago (Jacobson, 1974). Large numbers of swans (up to 7,670 on May 20, 1972) gather at open water areas near islands and sandbars on the Mackenzie River between Norman Wells and Arctic Red River from mid to late

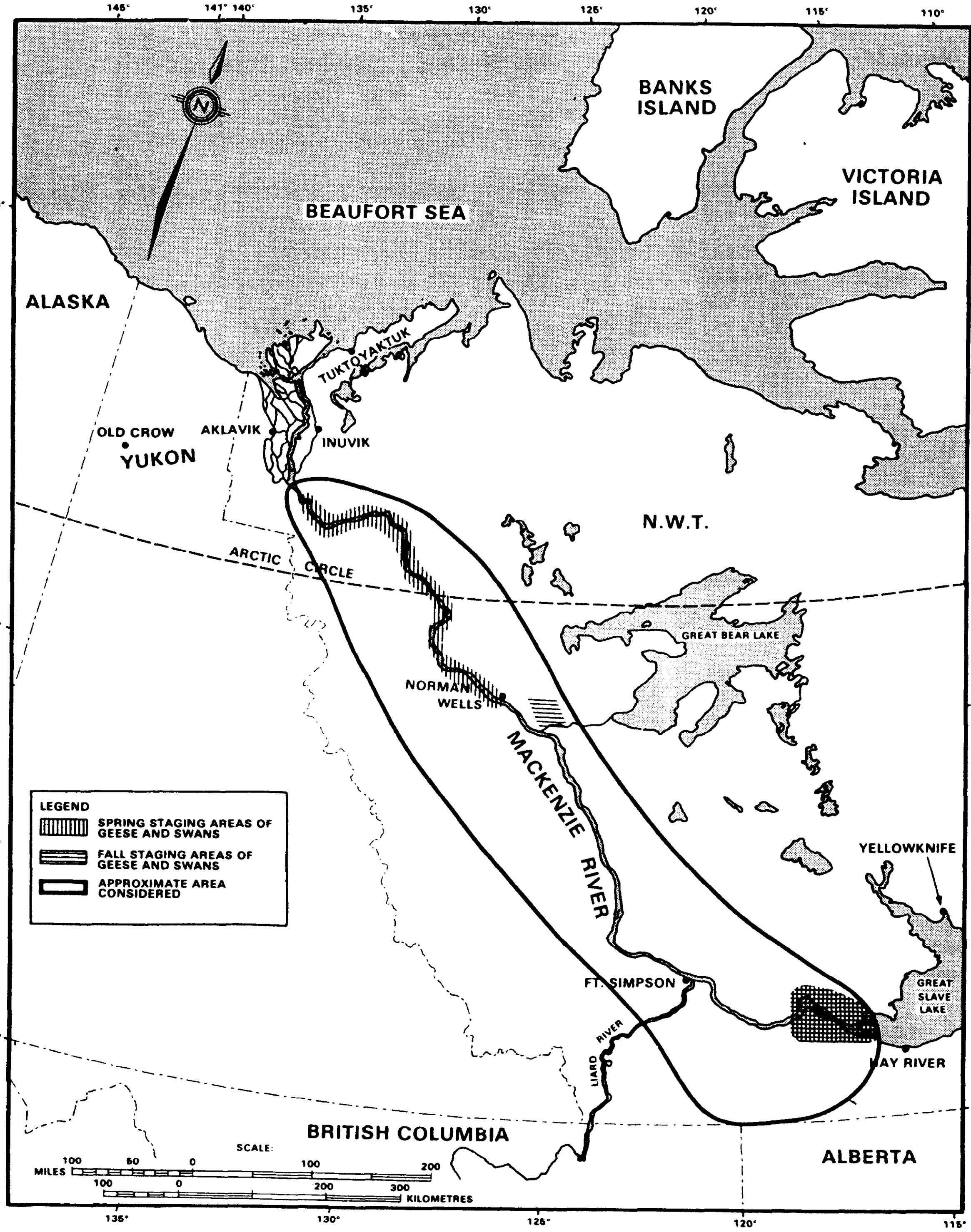


FIGURE 2.2-2 *Migration staging areas of geese and swans in the Mackenzie Valley.*

May (Campbell and Shepard, 1973). Here the birds feed and mate before proceeding to their northern breeding areas. More information on whistling swan breeding can be found in Section 4.2.3 of Volume3A and in Koski and Tull (1981).

Whistling swans leave their northern staging areas in coastal regions of the Beaufort Sea in mid to late September and migrate southeastward over Brackett Lake to the Mills-Beaver lakes area and the Great Slave Lake delta. In 1972 Brackett Lake was heavily used by whistling swans (up to 1,500 on September 18) for resting and feeding (Salter, 1974b), whereas on September 24, 1975, 800 swans were present. Only 63 remained by September 29 (Finney and Smith, 1976). The Mills and Beaver lakes areas receive much heavier use in the autumn than during the spring. From September 20 to 22, 1972, a total of 7,600 whistling swans were recorded on Mills (2,190), Beaver (4,470) and Mink lakes (940), and smaller numbers were recorded on other lakes in the area prior to and during these surveys (Salter, 1974b). However, Fawn, Mink and Second lakes (north of Mills Lake) and North and South channels of Great Slave Lake were used more heavily in 1974 than either Mills or Beaver lakes (Kemper *et al.*, 1975). In 1975, 2,050 swans were present in the Mills-Beaver lakes area on September 24 and 5,600 were present on October 5 (Finney and Smith, 1976).

2.2.4 GEESE

Three of the four species of geese that nest in the western Canadian Arctic are common migrants through the Mackenzie Valley (Figure 2.2-2). The fourth species, the brant, occurs only as an occasional straggler in the Mackenzie Valley (Barry, 1967). The breeding status of all species is addressed in Section 4.2.4 of Volume 3A. Goose numbers and nesting chronology for the Mackenzie River Delta are also provided in that section.

2.2.4.1 Canada Goose

The Canada goose is found in low numbers throughout the Mackenzie Valley. One subspecies *(Branta canadensis parvipes)* nests within the Mackenzie Valley, while a second *(B. c. hutchinsii)* is a common migrant through the area. Canada geese from the Mackenzie Valley winter in southeastern Colorado and the Texas Panhandle (Jacobson, 1974).

Canada geese are the earliest of the geese to arrive in spring, first appearing in the southern Mackenzie Valley in late April and early May (Soper, 1957; Salter *et al.*, 1974). Moderate numbers have been recorded in the vicinity of Mills Lake. For example, 503 Canada geese were seen on May 1,1973 (Salter *et al.*, 1974) and 405 unidentified geese that were probably Canada geese were seen on May 16, 1974, (Kemper *et al.*, 1975). Larger numbers probably occur on the Mackenzie River islands between Norman Wells and Thunder River. For example, on May 20, 1972, 4,900 dark geese were recorded there; an unknown percentage of these birds were Canada geese (Campbell and Shepard, 1973). On May 5, 1980 and May 3, 1981, 3,500 and 1,183 dark geese, respectively, were present on Goose Island in the vicinity of Norman Wells (R. Webb Environmental Services Ltd., 1980, in prep.).

Because geese arrive at breeding areas early in the spring before food is abundant, they are heavily dependent on energy reserves accumulated at spring staging areas during the period of territory establishment and nesting. For example, Raveling (1979) found that weights of adult female Canada geese increased by about 46% between early April and when they arrived at their breeding grounds, but by the time they started incubating their eggs, most of these increases had been lost. Canada geese are primarily vegetarian and feed mainly by grazing on a wide variety of plants (Palmer, 1976a).

Canada geese are solitary nesters and nesting birds disperse throughout available habitat soon after their arrival. Densities of nesting birds are low along the Mackenzie Valley. Davis (1974) recorded 0.046 geese/km^2 during aerial surveys from the Alberta border to Arctic Red River between May 26 and June 3, 1972, while Salter (1974a) recorded 0.019 dark geese/km^2 (probably Canada geese) during aerial surveys from Norman Wells to Richards Island in May and June, 1973.

Incubation takes 24 to 28 days (MacInnes, 1962; Bellrose, 1976). Fledging varies according to the subspecies, with that for *B. c. hutchinsii,* a similar sized subspecies as *B. c. parvipes,* being 52 to 60 days (MacInnes, 1962, in Bellrose, 1976). When the young have hatched, family groups form into brood flocks until the young have fledged and the adults have moulted (MacInnes, 1962). Non-breeding and some failed-breeding birds gather in large numbers in traditional moulting areas that are often far from breeding areas (Sterling and Dzubin, 1967; Zicus, 1981). In the case of the Mackenzie Valley, most non-breeding birds probably migrate to moulting areas such as Queen Maud Gulf, Thelon River, Kugaluk River or Smoke River (see Sterling and Dzubin, 1967), although small numbers of moulting birds, possibly a southern-nesting subspecies of Canada goose, have been recorded on the Willowlake River and the Mackenzie River (Salter and Davis, 1974).

Canada geese begin their southward migration in late August and early September. During 1972 studies, the peak of migration was observed between September 16 and 21 at Tate Lake (Salter, 1974b), with the peak rate of movement being 116 birds/hr on September 19. Some birds use the islands in the Mackenzie River as stopover points, but the numbers of birds involved are unknown (Salter, 1974b; Finney and Smith, 1976). During some years the Fort Providence-Mills Lake area is used by moderate numbers of birds, particularly in mid September. During aerial surveys conducted in 1972, peak numbers recorded were 1,412 on Mills-Beaver lakes (September 18), 1,120 on Mink Lake (September 14) and 2,460 on Buffalo Lake (September 16) (Salter, 1974b). In 1974 fewer Canada geese used these areas. Kemper *et al.* (1975) found peak numbers of 615 (September 9 and 10) at Mills-Beaver lakes and 405 (September 16 and 17) at Mink Lake. However, in 1975 Finney and Smith (1976) recorded much larger numbers of Canada geese in the Mills-Beaver Lake region (6,491 on September 24).

Canada geese are usually gone from the area by early October, as indicated by last sightings in the Mills Lake area on October 2 in 1972 (Salter, 1974b) and September 26 in 1974 (Kemper *et al.*, 1975) although they were still numerous on October 5 in 1975 (Finney and Smith, 1976).

2.2.4.2 White-fronted Goose

The white-fronted goose is circumpolar in its breeding distribution (Bellrose, 1976; Palmer, 1976a). North American populations breed in Alaska, the Yukon and the Northwest Territories, and winter along the coast of the Gulf of Mexico, in central Mexico and in central California. The North American wintering population has averaged about 200,000 birds in recent years and appears to be relatively stable. The white-fronted goose is a migrant through most of the Mackenzie Valley, but nests in the Mackenzie Delta.

White-fronted geese are solitary, dispersed nesters, but yearlings remain close to their parents throughout the breeding season. Birds first breed at three years of age, but in exceptionally good years some two-year-old birds will breed (Barry, 1967). Birds nest both on tidal flats and on higher, drier areas, usually near lakes or rivers (Bellrose, 1976). Clutch sizes vary from 2 to 10; they averaged 5 to 7 on the Anderson River delta (Barry, 1967) and 4.75 on the Yukon delta (Lensink, in Bellrose, 1976). Incubation takes 23 to 25 days and is done exclusively by the female. The young leave the nest within 24 hours of hatching and move to the nearest water. Young white-fronted geese take about 45 days to fledge.

Like other goose species, non-breeding white-fronted geese gather at traditional moulting areas. As non-breeding birds regain flight, some move to premigratory staging areas. Departure is gradual, with birds travelling long distances non-stop between staging areas.

Northward migration from wintering areas starts in early February and is gradual. White-fronted geese do not arrive at the Peace-Athabasca delta until late April to mid May. In 1973 they were first recorded at Fort Providence on April 26, but were not recorded in large numbers until the May 10 to 14 period (1,873 plus 2,138 dark geese). At the same time they were recorded moving through Norman Wells in large numbers (430 plus 9,932 dark geese, May 8 to 14) (Salter *et al.*, 1974). During 1972, peak numbers of dark geese were recorded along the Mackenzie River between Norman Wells and Thunder River during surveys conducted on May 20 and 25 (4,900 and 4,789 respectively; Campbell and Shepard, 1973). Migration was earlier in 1980 and 1981. Peak numbers of dark geese were observed at Goose Island, adjacent to Norman Wells, on May 5 in 1980 (3,500 geese) and on May 3 in 1981 (1,183 geese). In both these years, dark geese were present when surveys were initiated (May 4 in 1980 and April 29 in 1981) (R. Webb Environmental Services Ltd., 1980, in prep.). Much larger numbers of white-fronted geese stage along the Mackenzie River in some years; Barry (1967) estimated that 15,000 white-fronted geese staged on the islands along the Mackenzie River between Fort Good Hope and Arctic Red River in 1965.

Of the various goose species, the white-fronted goose begins its autumn southward migration the earliest. White-fronted geese have been recorded as far south as Saskatchewan by August 27 (Dzubin, in Barry, 1967), but the major movement occurs about mid September (Salter, 1974b). White-fronted geese migrate southward up the Mackenzie Valley without using any major stopover areas until they reach Mills Lake. Mills Lake has consistently high numbers of white-fronted geese during fall migration. On September 14, 1972, Salter (1974b) recorded 9,860, and on September 9 and 10, 1974, Kemper *et al.* (1975) recorded 9,631. Other lakes in the area generally had low numbers of white-fronted geese; maximum numbers reported elsewhere by Salter (1974b) were 500 and 700 white-fronted geese at Brackett and Three Day lakes, respectively, during mid September 1972. Patterson and Wiseley (1977) recorded only 9 geese ($0.05/km^2$) during aerial surveys conducted in the Fort Simpson area on September 4, 1975, while Finney and Smith (1976) did not record any during a survey along the Mackenzie River between Norman Wells and Fort Simpson on September 24, 1975. The latter authors also recorded low numbers (265 and 30, respectively) on September 20 and 22, 1975 during surveys conducted between Norman Wells and Inuvik.

2.2.4.3 Snow Goose

Two distinct subspecies of the snow goose are found in North America. The lesser snow goose *(Chen caerulescens caerulescens)* is the only subspecies found in the Mackenzie Valley. This subspecies nests from Baffin Island to Wrangell Island, Siberia, with the only major nesting area in the Canadian Beaufort region being located on Banks Islands (see Section 4.2.4 of Volume 3A).

Snow geese have two colour phases: a dark blue phase, and a white phase. The snow geese occurring in the western Arctic are primarily white phase birds. Weights of birds leaving wintering areas, which average 1,786 g for adult females (Flickinger and Bolen, 1979), are much lower than those of birds arriving on the breeding grounds in the spring, which average 2,950 g for adult females (Ankney and MacInnes, 1978). The spring staging areas are, therefore, of paramount importance to the accumulation of energy reserves required for successful breeding. Northern staging locations are also important for mating.

Snow geese feed almost entirely on vegetable material: they feed primarily by grazing in terrestrial areas on the seeds, stems and roots of grasses and sedges, although they also feed on berries and aquatic plants (Palmer, 1976a; Prevett *et al.*, 1979).

Snow geese first arrive in the Mackenzie Valley in late April to mid May. The most southerly spring staging areas in the Northwest Territories are the Slave River delta (Soper, 1957; Barry, 1967), Mills Lake (Salter *et al.*, 1974) and several small lakes near Mills Lake (Kemper *et al.*, 1975). Large numbers of birds rest and feed at these locations before proceeding northward along the Mackenzie Valley. Snow geese stop next at the islands near Norman Wells and between Fort Good Hope and Arctic Red River, where peak numbers have been recorded from early to late May (Campbell and Shepard, 1973; R. Webb Environmental Services Ltd., 1980, in prep.; Geddes and McCourt, 1982). Although maximum numbers have varied from 90,000 (Campbell and Shepard, 1973) to 130,000 (Barry, 1967), most of the western Canadian snow goose population probably uses these islands during the spring staging period (estimates of 160,000 to 350,000 birds; Koski, 1977a). However, some birds may not stage at the islands along the Mackenzie River, proceeding instead directly to the base of the Parry Peninsula from the Slave River delta or northern Alberta (Hohn, 1959). Snow geese leaving the islands of the Mackenzie River either proceed northward to spring staging areas on the upper Anderson River or migrate northwestward along the Mackenzie River to spring staging areas in the Mackenzie Delta. They then move on to their breeding colonies.

Before moving southward in autumn, snow geese gather in large flocks at premigratory staging areas. Geese greatly increase their nutrient reserves while at these staging areas as these reserves are important for their southward migration (Patterson, 1974; Wypkema and Ankney, 1979).

Southward migration is rapid. Most snow geese leave traditional autumn staging areas in the northern Yukon and outer Mackenzie Delta in mid to late September and fly non-stop to staging areas on the Slave River delta, the Hay-Zama lakes in northwestern Alberta or the Peace-Athabasca delta in northeastern Alberta (Plate 2.2-3). Small numbers of snow geese (up to 8,500 birds) are regularly seen at Mills Lake during fall migration (Salter *et al.*, 1974; Kemper *et al.*, 1975; Finney and Smith, 1976). During years of early freeze-up other areas, such as Brackett Lake, may be used by a few hundred to several thousand birds.

2.2.5 DABBLING DUCKS

Six species of dabbling ducks occur regularly in the Mackenzie Valley and an additional species, the gadwall, has been recorded in very low numbers. Three other species have been recorded incidentally. Of the six regularly occurring species, the mallard is the most common species encountered in the southern Mackenzie Valley, but it occurs only in low numbers in the northern section. Pintail and American wigeon are found in moderate densities throughout the Mackenzie Valley, while green-winged teal are found in moderate numbers in the southern section but in low numbers in the northern section. Northern shovelers are found in low numbers throughout the Mackenzie Valley, and blue-winged teal are found in low numbers in the southern section but are rare in the northern Mackenzie Valley (Tull and Koski, 1981).

Foods eaten by 'dabblers' vary widely among species but vegetation forms the greater part of their diet. Food items include seeds, perennial storage organs, and occasionally other parts of aquatic and semi-aquatic plants; cereal grains; insects; molluscs; and crustaceans (Bellrose, 1976; Palmer, 1976a).

Dabbling ducks do not nest colonially. All species most commonly nest on the ground, but individuals of some species may nest in floating emergent vegetation. The best breeding habitat for all species is in the forest-grassland ecotone or the grassland areas of western Canada and the northern United States (Bellrose, 1976).

Densities of dabbling ducks are generally low to moderate in the Mackenzie Valley. During years of drought in prairie regions, however, major displace-

PLATE 2.2-3 *Migrant snow geese in the Peace-Athabasca delta in northeastern Alberta. Southward migration along the Mackenzie Valley in autumn is rapid in most years with snow geese flying non-stop from staging areas in the Beaufort Sea region to staging areas on the Slave River delta or in northern Alberta. (Courtesy, J. Kristensen, LGL Ltd.).*

ments of ducks to northern areas occurs (Hansen and McKnight, 1964; Henny, 1973; Calverley and Boag, 1977; Derksen and Eldridge, 1980). Although the reproductive success of ducks displaced to the north is generally lower than that of ducks remaining in the south (Pospahala *et al.*, 1974; Calverley and Boag, 1977), the importance of northern areas to dabbling ducks is greater during such years.

Male dabbling ducks abandon the females at the onset of incubation and move to moulting areas on large bodies of water. Moulting areas are generally close to breeding areas, but for some species such as the pintail, moult migrations of several hundred miles are suspected to occur (Bellrose, 1976). Incubation requires 21 to 30 days and female dabbling ducks generally raise their broods alone, with the exception of wigeons which commonly form creches. Young dabbling ducks are capable of flight 34 to 60 days after hatching.

Dabbling ducks migrate into the Mackenzie Valley from northern Alberta and Saskatchewan, following the Valley northward. Early migrants arrive in the Valley in mid to late April. In 1973, Salter *et al.* (1974) recorded all six major species of dabbling ducks at Fort Providence on April 26 and 27, while at Mills Lake on April 27, 126 mallards and 150 pintails were recorded. Peak rates of migration at Fort Providence were observed on May 2 for pintails and mallards, May 9 for American wigeon and May 15 for northern shovelers. Movements of green-winged teal were gradual with the peak being recorded at Fort Simpson on May 14. Peak rates of migration were observed one to two weeks later at Norman Wells (Salter *et al.*, 1974).

The Mackenzie River is important during the early part of the season because it is the first area where open water is found. As nearby lakes become ice-free, ducks disperse to them to breed. Davis (1974) found that Brackett Lake and areas adjacent to the Ramparts, Loche and Great Bear rivers had higher densities of both breeding and staging ducks than did adjacent areas along the Mackenzie River.

Although nesting of dabbling ducks starts as early as May 5 for early nesting mallards and May 8 for early nesting pintail in the Yellowknife-Rae area (Murdy, 1963), nest initiation for most dabblers probably occurs from mid May to mid June. Nesting may begin as much as two weeks later in the northern section of the Mackenzie Valley (Thompson, 1975; Finney and Smith, 1976).

Based on aerial surveys, the densities of breeding dabbling ducks are relatively low throughout the boreal forest areas along the Mackenzie Valley. In surveys conducted at the end of May in 1975, Patterson and Wiseley (1977) recorded 0.05 dabbling ducks/km^2 (56% mallard) along a proposed pipeline route from the Willowlake River to Bistcho Lake, Alberta. In late May and early June 1972 Davis (1974) recorded densities of 0.76 dabbling ducks/km^2 (33% wigeon, 23% mallard, 22% teal, 21% pintail) and 0.52 dabbling ducks/km^2 (45% mallard, 22% teal, 16% wigeon, 14% pintail) along proposed pipeline routes on the west and east sides, respectively, of the Mackenzie River between approximately Fort Good Hope and Fort Simpson. On June 1, 1973, Salter (1974a) recorded 0.22 dabbling ducks/km^2 (42% pintail, 38% wigeon, 19% mallard) along a proposed pipeline route from Richards Island to Norman Wells. In early June 1975, Wiseley *et al.* (1977) recorded a density of 0.25 dabbling ducks/km^2 (53% pintail) along a proposed pipeline route from Richards Island to Travaillant Lake.

Breeding densities of dabbling ducks are higher in extensive wetland areas. Davis (1974) surveyed areas of prime wetland habitat in early June 1972. He recorded 1.39 dabbling ducks/km^2 (39% mallard, 27% pintail, 26% wigeon) in the Ramparts River area and 3.71 dabbling ducks/km^2 (76% wigeon, 17% pintail) in the Great Bear River-Loche River-Kelly Lake area (Figure 2.2-1), although some of these birds were probably migrants. Poston (1977) surveyed wetland basins along the proposed Arctic Gas pipeline corridor in 1973. In late May and early June he recorded 4.31 dabbling ducks/km^2 of wetland south of the Willowlake River, 7.60/km^2 of wetland between the Great Bear and Willowlake rivers, 11.34/km^2 of wetland between Fort Good Hope and the Great Bear River, 9.94/km^2 of wetland between Campbell Lake and Fort Good Hope, and 8.70/km^2 of wetland between Richards Island and Campbell Lake.

Most duck broods are on lakes and ponds by mid to late July. Poston (1977) conducted aerial surveys of wetlands during this period in 1973 along the proposed Arctic Gas pipeline route. The results undoubtedly include moulting birds as well as brood-rearing birds. Poston (1977) recorded 9.08 adult dabbling ducks and 1.74 broods/km^2 of wetland south of the Willowlake River, 12.9 adults/km^2 and 4.12 broods/km^2 of wetland between the Great Bear and Willowlake rivers, 9.55 adults/km^2 and 4.11 broods/km^2 of wetland between Fort Good Hope and the Great Bear River, 109.0 adults/km^2 and 5.58 broods/km^2 of wetland between Campbell Lake and Fort Good Hope, and 8.60 adult dabbling ducks and 1.52 broods/km^2 of wetland between Richards Island and Campbell Lake. Patterson and Wiseley (1977) surveyed a proposed pipeline route south of the Willowlake River in mid July of 1975. Because they surveyed both wetland and upland areas along the pipeline route instead of restricting their surveys to wetland areas, their densities are much lower than those of Poston (1977). They recorded 0.04 adult dabbling ducks/km^2 and 0.02 broods/km^2. Somewhat higher densities were recorded on nearby lakes (0.35 adult dabbling ducks and 0.25 broods/km^2 of lake area).

Autumn migration of dabbling and diving ducks is more protracted than their spring migration, and the birds are more dispersed because of the greater number of waterbodies available to them (Finney and Smith, 1976). Ducks may be found in small numbers on most waterbodies; preferred waterbodies have an abundant food supply and extensive emergent vegetation. Fall migration in the Mackenzie Valley begins in early August, and in the southern Valley it may extend to mid October (Finney and Smith, 1976). The peak migration of dabbling ducks in 1972 was during the second half of September (Salter, 1974b).

2.2.6 DIVING DUCKS

Fifteen species of diving ducks occur regularly in the Mackenzie Valley. Lesser scaup and greater scaup are the most common ducks in the Mackenzie Valley. White-winged scoters and surf scoters are common throughout the Valley, while oldsquaw are common in the northern Valley. The canvasback, ring-necked duck, common goldeneye, bufflehead, red-breasted merganser and common merganser are generally less common, whereas the redhead, Barrow's goldeneye, harlequin duck and ruddy duck are scarce but probably occur regularly in the Mackenzie Valley (Tull and Koski, 1981). The canvasback is on the 'blue list' of North American birds because its population is at a low level (Tate, 1981).

Diving ducks feed on a wide variety of aquatic organisms, including aquatic plants, aquatic insects, molluscs, crustaceans and fish (Bellrose, 1976; Palmer, 1976b).

Most diving ducks nest as dispersed pairs. Most species nest on the ground on islands, in emergent vegetation, or on shore near water, but some species may nest at a considerable distance from the water. Goldeneyes, buffleheads and common mergansers commonly nest in cavities in trees (Godfrey, 1966). Some, but not all, redheads lay their eggs in the nests of other ducks (Weller, 1959).

Male diving ducks leave the females after the eggs are laid and move to moulting areas, where they usually gather in large flocks. Males of some species migrate a long distance to moulting areas, while others move only short distances. Female diving ducks incubate the eggs and raise the broods. Incubation varies with the species of diving duck, ranging from 22 to 34 days (Godfrey, 1966). Several species often merge their broods into creches of several females and numerous young (cf. Bellrose, 1976). The young of most species are able to fly 45 to 70 days after hatching, but oldsquaws hatched in the Arctic may be able to fly after only 30 to 35 days (Bellrose, 1976). Females moult during or immediately after the rearing of their broods.

Most species migrate north across the prairie provinces and along the Mackenzie Valley. Oldsquaws may also move south along the Mackenzie River after migrating either eastward along the Beaufort Sea coast or eastward across interior Alaska (cf. Salter *et al.*, 1974; Johnson *et al.*, 1975).

Diving ducks arrive as soon as open water is available in spring. Arrival dates and timing of migration are quite variable, depending on weather conditions. Migration is fairly protracted during early springs but proceeds more rapidly during delayed springs (Finney and Smith, 1976). Common goldeneyes, buffleheads, oldsquaws and mergansers are the first diving ducks to arrive. In 1973 all were present in the Mackenzie Valley between April 25 and 27 (Salter *et al.*, 1974), but Finney and Smith (1976) indicated that ducks may arrive in the Mackenzie Valley by mid April. Scaup first arrived in early May in 1973; the peak of migration occurred during May 17 to 22 (Salter *et al.*, 1974). Migration of scoters is comparatively late. Although they were first observed on May 5 in 1973, they were not observed in some areas until May 17 and their peak migration was not until May 21 to 23 (Salter *et al.*, 1974).

Migration proceeds slowly northward along the Mackenzie Valley. Diving ducks did not become common in the northern Mackenzie Valley in 1972 until the last third of May (Campbell and Shepard, 1973), and migration of most species probably continues into early June.

The Mackenzie River provides important spring habitat for diving ducks because it opens early. During an aerial survey from Norman Wells to Arctic Red River on May 25, 1972, Campbell and Shepard (1973) recorded 11,000 scaup and scoters. Diving ducks disperse to lakes away from the river as they become open. Areas such as those adjacent to Brackett Lake and the Ramparts River are important staging locations in early June (Davis, 1974).

Courtship begins during spring migration. Females begin egg-laying shortly after their arrival at breeding areas. Some birds are already nesting while others are still migrating. Commencement of nesting in one area may occur over an extended period as some species and individuals begin egg-laying well before others. The range of commencement dates is much more protracted in the southern Mackenzie Valley than it is in more northern areas such as the Mackenzie Delta (cf. Finney and Smith, 1976). In the Yellowknife-Rae area diving ducks may begin nesting as early as May 11 or as late as early July (Murdy, 1963). In comparison, at Chick Lake north of Norman Wells, the earliest nests are initiated about May 27 (Thompson, 1975).

The numbers of breeding diving ducks that have been recorded on aerial transect surveys through the boreal forest areas along the Mackenzie Valley are relatively low, even when allowing for incomplete detectability. In surveys conducted at the end of May in 1975, Patterson and Wiseley (1977) recorded an uncorrected density of 0.81 diving ducks/km^2 (62% scaup, 13% bufflehead, 11% goldeneye, 7% scoters) along a proposed pipeline route from the Willowlake River to Bistcho Lake, Alberta. In late May and early June 1972, Davis (1974) recorded densities of 3.82 diving ducks/km^2 (64% scaup, 26% scoters, 6% bufflehead) and 4.49 diving ducks/km^2 (55% scaup, 36% scoters, 5% bufflehead) along proposed pipeline routes on the west and east sides, respectively, of the Mackenzie River between approximately Fort Good Hope and Fort Simpson. On June 1, 1973, Salter (1974a) recorded 3.30 diving ducks/km^2 (55% scaup, 33% scoters, 11% oldsquaw) along a proposed pipeline route from Richards Island to Norman Wells. In early June 1975, Wiseley *et al.* (1977) recorded a density of 2.73 diving ducks/km^2 (48% scaup, 20% scoters, 13% oldsquaw) along a proposed pipeline route from Richards Island to Travaillant Lake.

Breeding densities of diving ducks are considerably higher in favourable wetland areas. Davis (1974) surveyed areas of prime wetland habitat in early June 1972. He recorded 9.36 diving ducks/km^2 (56% scaup, 40% scoters) in the Ramparts River area and 28.1 diving ducks/km^2 (69% scaup, 25% scoters, 3% oldsquaw) in the Great Bear River-Loche River-Kelly Lake area, although some of these birds were probably migrants. Poston (1977) surveyed wetland basins along the proposed Arctic Gas pipeline corridor in 1973. In late May and early June he recorded 44.0 diving ducks/km^2 of wetland south of the Willowlake River, 70.8/km^2 of wetland between the Great Bear and Willowlake rivers, 63.9/km^2 of wetland between Fort Good Hope and the Great Bear River, 68.1/km^2 of wetland between Campbell Lake and Fort Good Hope, and 44.5/km^2 of wetland between Richards Island and Campbell Lake.

Hatching of eggs probably does not occur until late

June or July and it may occur as late as early August (Finney and Smith, 1976). Most broods of diving ducks are on lakes and ponds by mid to late July. During this period in 1973, Poston (1977) recorded 43.9 adult diving ducks and 5.05 broods/km^2 of wetland south of the Willowlake River, 77.0 adults/km^2 and 7.53+ broods/km^2 of wetland between the Great Bear and Willowlake rivers, 33.0 adults/km^2 and 7.98 broods/km^2 of wetland between Fort Good Hope and the Great Bear River, 22.4 adults/km^2 and 6.57 broods/km^2 of wetland between Campbell Lake and Fort Good Hope, and 6.90 adults/km^2 and 1.28 broods/km^2 of wetland between Richards Island and Campbell Lake. Patterson and Wiseley (1977) surveyed a proposed pipeline route south of the Willowlake River in mid July 1975. Because they surveyed both upland and wetland areas combined instead of restricting their surveys to wetland areas, their densities were much lower than those of Poston (1977). Patterson and Wiseley (1977) recorded 0.01 adult diving ducks/km^2 and 0.006 broods/km^2. Their densities were much higher on nearby lakes (17.48 adult diving ducks and 0.27 broods/km^2 of lake area).

In autumn diving ducks and other waterfowl generally stage on lakes and ponds rather than on the Mackenzie River. The most important staging areas in the Mackenzie Valley are regions around and including Brackett Lake, Tate Lake and Mills-Beaver lakes. For example, Finney and Smith (1976) recorded 1,189 diving ducks (75% scaup, 24% scoters) on Brackett Lake on September 29, 1975. Several other studies have revealed high numbers of diving ducks staging on Mills and Beaver lakes during September and early October (Salter, 1974b; Finney and Smith, 1976; Stepney and Thompson, 1978). Diving ducks were still present on October 9 and 10, 1972, although their numbers were much reduced by this time (Salter, 1974b). Some of the hardier diving duck species may remain until freeze-up.

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2.2.7 RAPTORS

A number of raptors (eagles, hawks, falcons and owls) occur in the Mackenzie Valley. Raptors are specialized predators which are adapted to taking particular types of prey. The type taken varies widely with the species. Some species such as the peregrine falcon prey primarily on birds, some such as the red-tailed hawk prey on mammals, some such as the osprey feed on fish and others such as the American kestrel prey on insects. Raptor populations are dependent on the populations of their prey species, and food supply is one of the most important factors influencing breeding success and productivity (Brown and Amadon, 1968; Newton, 1979). Populations that depend on prey whose numbers fluctuate from year to year (such as hares, microtine rodents, or ptarmigan) also undergo fluctuations in numbers and may move from one location to another in response to prey availability. Many raptor species migrate from northern areas in the winter because their prey have either migrated from the area or have become difficult to obtain under the snow.

Raptors are usually solitary nesters and most species do not gather in large flocks during migration. Nests are placed in trees, on ledges or in cavities of cliffs, or on the ground. The type of nest site chosen depends on the species and available habitat. Some raptors, particularly those that nest on cliffs and some that build in trees, may use the same nest year after year or may return to the same nest after an absence of several years or longer.

Most raptors attend their nest sites for a comparatively long period of the year. This period usually includes the time necessary for pair formation, courtship, egg-laying, incubation and fledging of young. The young are fed in the nest for a considerable period of time before they fledge (for example, peregrine falcons fledge approximately 40 days after hatching) (Roseneau *et al.*, 1981). They may also remain in the vicinity of the nest for several weeks after fledging.

Some species of raptors are of concern because their populations have declined in recent years. Table 2.2-3 summarizes the most recent report on the population trends and relative abundances of 18 raptor species that occur in the Mackenzie Valley, and Figure 2.2-1 shows the locations of the geographic names mentioned in the following descriptions of raptors.

2.2.7.1 Golden Eagle

The golden eagle is a widespread species in western and northern North America. Golden eagles usually migrate south in autumn and the majority winter primarily in the southwestern United States and

TABLE 2.2-3

POPULATION STATUS OF RAPTORS IN THE YUKON AND NORTHWEST TERRITORIES*

Common Name	Population Trends	Relative Abundance
Goshawk	fluctuating	medium-high
Sharp-shinned hawk	unknown	low
Marsh hawk	fluctuating	low-medium
Rough-legged hawk	fluctuating	medium-high
Red-tailed hawk	unknown	low-medium
Golden eagle	stable	low-medium
Bald eagle	stable	low-medium
Osprey	stable	low
Gyrfalcon	stable	low-medium
Peregrine falcon	declining	rare-low
Merlin	unknown	low
American kestrel	stable	low-medium
Great horned owl	stable	high
Short-eared owl	fluctuating	low
Snowy owl	fluctuating	low-high
Great gray owl	unknown	rare-low
Hawk owl	unknown	low-medium
Boreal owl	fluctuating	low

*from Fyfe (1976)

Mexico (Boeker and Ray, 1971). However, a few birds periodically remain in northern areas throughout the year (Godfrey, 1966; Campbell and Davies, 1973).

Golden eagles are both predators and scavengers. They feed mainly on mammals, but also take birds and carrion when available. Common prey items recorded at Alaskan nests have included ground squirrels, marmots, snowshoe hares, ptarmigan and waterfowl (Roseneau *et al.,* 1981). Snowshoe hares were the predominant prey in the Richardson Mountains (Campbell and Davies, 1973). Carrion, particularly big game animals, may be especially important in spring and autumn (Roseneau *et al.,* 1981).

Golden eagles normally lay two eggs, but usually fledge only one young (Brown and Amadon, 1968). Breeding success may be affected by prey availability, and golden eagles may not breed at all in some years, presumably owing to lack of prey (cf. Brown and Amadon, 1968; Mosher and White, 1976). In northern areas golden eagles nest primarily on cliffs, cutbanks and outcrops. They also occasionally nest in trees (Fyfe and Beebe, cited in Campbell and Davies, 1973; various observers cited in Roseneau *et al.,* 1981). Although nests are traditional and may be used from year to year, pairs usually have several (and may have up to 14) alternate nest sites (Brown, 1976). The birds may move 1 to 8 km to an alternate site in consecutive years (Nelson and Nelson, 1978). Within their respective breeding ranges, golden eagle nests are often used by nesting gyrfalcons and are sometimes used by nesting peregrine falcons and rough-legged hawks (Cade, 1960; Roseneau, 1972).

Golden eagles nest sparsely along the Mackenzie Valley. Fyfe and Prescott (1973) reported six golden eagle nests within 8 km of the proposed Mackenzie Highway route between Fort Simpson and Inuvik, while Campbell and Davies (1973) reported three nests in the Fort Good Hope and Campbell Lake areas. Ealey and McCourt (1980) reported four apparently active nests and several other possible nests along the proposed Interprovincial PipeLine (NW) Ltd. route from Norman Wells to the Hay-Zama lakes in northwestern Alberta. Koski (1977b) reported four golden eagle nests in the western McConnell Range and Finney and Lang (1976) identified the Norman Range as a nesting area. Most of these nests were located in mountainous areas away from the Mackenzie River. In a 1977 survey along the Mackenzie River between Great Slave Lake and Fort Good Hope, no golden eagles or their nests were seen (Stepney and Thompson, 1978).

Fyfe and Prescott (1973) gave the time of arrival of golden eagles on their territories in the Richardson Mountains as mid April in 1973. Roseneau *et al.* (1981) stated that arrival and courtship of golden eagles in interior and Arctic Alaska ranges from mid March to the end of April. Migrant golden eagles are common in the Alberta foothills in mid March (Dekker, 1970) and likely arrive in the southern Mackenzie Valley by late March or early April. Arrival times probably depend on the weather. Some birds were apparently still on migration through the Mackenzie Valley as late as May 13 in 1972 (Salter *et al.,* 1974).

Fyfe and Prescott (1973) indicated that egg-laying generally occurs during the first two weeks of May, hatching during the first two weeks of June and fledging during the last two weeks of July. Finney and Lang (1976) estimated that egg-laying in the Mackenzie Valley occurs from April 7 to May 15, hatching from May 25 to June 30 and fledging from July 15 to August 31. A third time frame provided by Roseneau *et al.* (1981) indicated that egg-laying in Arctic and interior Alaska occurs from April 10 to May 15, that hatching is complete by June 20 and that fledging is complete by September 10. The young may remain in the vicinity of the nest for two weeks after fledging (Brown and Amadon, 1968).

The birds usually begin to migrate south during September (Campbell and Davies, 1973; Roseneau *et al.,* 1981). Four golden eagles were seen during migration watches at Tate Lake from August 25 to September 25, 1972, and three were seen at Fort Providence from September 9 to October 1 (Salter, 1974b). Southward migrating golden eagles are again common in the Alberta foothills from mid September through mid October (Dekker, 1970).

2.2.7.2 Bald Eagle

The bald eagle nests throughout much of forested North America (Plate 2.2-4). The northern subspecies *(Haliaeetus leucocephalus alascanus)* is the subspecies which breeds in Canada and Alaska. The southern subspecies *(H. l. leucocephalus)*, which breeds in the United States, is considered to be endangered (U.S. Dept. Interior, 1973). Although Godfrey (1970) included the bald eagle in his list of Canadian endangered birds, the northern subspecies does not appear to be endangered. Its status has not yet been considered by COSEWIC. The Alaskan population is relatively large, numbering approximately 7,500 pairs (Lincer *et al.*, 1979) and the population in the Yukon and Northwest Territories is considered to be stable and of low to medium abundance (Table 2.2-3) (Fyfe, 1976).

PLATE 2.2-4 *An adult bald eagle above its nest. This species nests throughout the Mackenzie Valley but apparently is most common south of Fort Simpson where large numbers have been recorded at lakes near the Alberta-NWT border. (Courtesy, J. Kristensen, LGL Ltd.).*

Bald eagles are opportunistic feeders; they are both predators and scavengers. Fish are particularly important prey. On the Pacific coast bald eagles feed heavily on dead and dying salmon when available. In some regions bald eagles also take various species of birds and mammals. The birds include waterfowl and seabirds that may be taken as carrion, as wounded birds or as uninjured birds (Roseneau *et al.*, 1981). Bald eagles also pirate prey from other raptors, especially ospreys.

Bald eagles nest primarily in trees where available, but also nest occasionally on cliffs (a nest was found on a rock outcrop in the McConnell Range in 1977) (Koski, 1977b). Nests are usually built in large trees near rivers, lake shores or large areas of wetlands containing lakes, ponds or marshes (Roseneau *et al.*, 1981). Only some trees are suitable for nesting. The most frequently used are large mature trees that are broken or deformed, that are unusually bushy (especially spruce trees), or that have lost sufficient limbs to have a partially open canopy (Roseneau *et al.*, 1981). Other important features of good nest trees appear to be clear flight paths to the nearby waterbodies, an open view of the surroundings, and the occurrence nearby of good perch trees (Snow, 1973). In northern areas nests are almost always in white spruce or balsam poplar trees but are occasionally in aspens (D.G. Roseneau, pers. comm.). A pair may have up to six nests within a territory and a different nest site may be used from one year to the next (Brown, 1976). These nests may be as much as 3 km apart (Howell and Heinzman, 1967), but are usually less than 1 km apart (Frenzel *et al.*, 1973; Grier, 1973; Gerrard, 1973).

Bald eagles nest throughout the Mackenzie Valley, but are apparently most common south of Fort Simpson. They nest commonly around the lakes near the Alberta-Northwest Territories border. The maximum numbers of nests and birds recorded around the larger lakes in this area in 1973 were 55 birds (32 adults) and 20 nests (13 active) on Bistcho Lake, 23 birds (18 adults) and seven nests (2 active) on Trout Lake, and 16 birds (14 adults) and five nests (4 active) on Kakisa Lake (Salter, 1974d,e; Schaafsma, 1975). Forty bald eagles (36 adults) and 20 nests (9 active) were found during surveys in 1977 along the Mackenzie River between Great Slave Lake and Fort Good Hope, and all but one bird and one inactive nest were located upstream from Fort Simpson (Stepney and Thompson, 1978). Finney and Lang (1976) and Ealey and McCourt (1980) each reported several bald eagle nests in their surveys of pipeline routes along the Mackenzie Valley, while Koski (1977b) found one nest on a cliff in the western McConnell Range. The population of nesting bald eagles in the Mackenzie Delta has been estimated at less than 50 pairs (Campbell and Davies, 1973). Presumably, most of these birds occur in the inner forested portion of the Mackenzie Delta.

Some bald eagles begin to return to interior Alaska by mid March (Roseneau *et al.*, 1981), and peak migration in Alberta occurs during mid to late March (Sadler and Myres, 1976). Bald eagles probably begin to arrive in the southern Mackenzie Valley by late March or early April. Porsild (1943) reported a bald eagle on the Peel River in the vicinity of the Mackenzie Delta on April 7.

Fyfe and Prescott (1973) indicated that egg-laying occurs in the Mackenzie Valley during May 10 to 15, that the birds hatch around June 12 and that fledging takes place between August 21 and September 4. Finney and Lang (1976) reported similar observations, while Roseneau *et al.* (1981) indicated that most egg-laying in interior Alaska occurs from March 20 to May 10, that hatching is complete by June 30 and that fledging is complete by September 15.

Autumn migration in the Mackenzie Valley begins in September and most birds have left the northernmost breeding grounds by early October (Campbell and Davies, 1973). During migration bald eagles are found in relatively large numbers at many of the lakes in the Mackenzie Valley that are frequented by waterfowl such as Brackett Lake, Mills Lake and Beaver Lake (Salter, 1974b; Finney and Lang, 1976). In central Alberta they remain around such lakes until they freeze over (early November) and they may behave similarly in the Mackenzie Valley. Migrants probably move to the United States or the Pacific coast to winter. A few bald eagles overwinter in the interior of Alaska near open water (Roseneau *et al.*, 1981), and it is possible that a few overwinter in the Mackenzie Valley during mild winters.

2.2.7.3 Osprey

The osprey breeds in temperate and tropical regions throughout most of the world. In Canada it breeds in most forested portions of the country (Godfrey, 1966). There has been considerable concern about the osprey in the United States where populations were declining in the 1960's. Godfrey (1970) included the osprey in his list of endangered Canadian birds. Recently Spitzer *et al.* (1978) and Spitzer and Poole (1980) have indicated that osprey populations are recovering slowly in the United States, although there is still concern for their welfare. The osprey is probably not endangered or threatened in Canada. COSEWIC has not yet officially considered its status, but it is on the 'blue list' of North American species (Tate, 1981). The population in the Yukon and Northwest Territories is considered to be low but stable (Table 2.2-3) (Fyfe, 1976).

Ospreys are migratory and winter in the southern United States or further south (Godfrey, 1966; Henny and Van Velzen, 1972). They feed almost exclusively on live fish captured in shallow dives (Brown and Amadon, 1968). Ospreys may forage up to 11 km from their nests (Weir, cited in Newton, 1976).

Ospreys nest primarily in the tops of trees, but they may also nest on cliffs and on man-made structures (Gabrielson and Lincoln, 1959; Brown and Amadon, 1968). Nests are constructed of sticks and are added to each year; with time they may become so large that the supporting structure collapses. Ospreys may have several alternate nests in a territory, and these nests may be as much as 6 km apart (Green, 1976). Nests are usually found near the sea coast, near river or lake shores, or in wetland areas with marshes and ponds (Roseneau *et al.*, 1981). They may however, be up to 5 km from water (Henny, 1977).

The osprey is a comparatively scarce nesting species in the Mackenzie Valley. Only three adult ospreys, two occupied nests and three unoccupied nests were observed in a 1977 survey of the Mackenzie River from Great Slave Lake to Fort Good Hope, and only one of the inactive nests was north of Fort Simpson (Stepney and Thompson, 1978). Fyfe and Prescott (1973) recorded only one nest in their survey along the proposed Mackenzie Highway route from Fort Simpson to Inuvik, while Finney and Lang (1976) recorded one suspected nest near Fort Good Hope in their survey of the proposed Foothills Pipe Line Ltd. route. Ealey and McCourt (1980), in their survey of raptors along the proposed Interprovincial PipeLine (NW) Ltd. route south from Norman Wells, recorded one suspected osprey nest but they did not see any ospreys. The osprey is quite rare as far north as the Mackenzie Delta area where it has been recorded only once, in the Travaillant Lake area, on June 12 and 13, 1975 (Patterson *et al.*, 1977). In studies of spring and fall migration, ospreys were observed regularly only at Fort Providence, and these birds may have been nesting there (Salter, 1974b; Salter *et al.*, 1974).

Ospreys do not return to the north in spring until open water is readily available. Finney and Lang (1976) indicated that they arrive in the Mackenzie Valley during mid to late May, while Roseneau *et al.* (1981) recorded their arrival in interior Alaska between April 20 and May 15.

Finney and Lang (1976) stated that egg-laying occurs in the Mackenzie Valley during the first half of June, that hatching takes place during late June to mid July and that fledging occurs during mid to late August. In interior Alaska, egg-laying, hatching and fledging occur one to two weeks earlier than in the Mackenzie Valley (Roseneau *et al.*, 1981). Ospreys are thought to migrate out of the Mackenzie Valley during September (Finney and Lang, 1976; Roseneau *et al.*, 1981).

2.2.7.4 Gyrfalcon

The gyrfalcon nests infrequently, if at all, in the Mackenzie Valley (Godfrey, 1966; Martin, 1978). Fyfe and Prescott (1973) indicated that the Norman Range contains suitable nesting habitat, but that the forested nature of the Mackenzie Valley generally makes it unlikely habitat for nesting gyrfacons. Gyrfalcons may occur in the Mackenzie Valley during migration and some may winter in the area in suitable locations where ptarmigan are available (Koski, 1977b). For additional information on this species the reader is referred to Koski and Tull (1981).

2.2.7.5 Peregrine Falcon

Two subspecies of the peregrine falcon are generally recognized as frequenting the Mackenzie Valley-Beaufort Sea area. *Falco peregrinus anatum,* which breeds south of the tree line, is considered by COSEWIC to be 'endangered' in Canada. *F. p. tundrius,* which breeds north of the tree line, is considered by COSEWIC to be 'threatened' in Canada. In the United States, both subspecies are classified as 'endangered' under the U.S. Endangered Species Act (U.S. Dept. Interior, 1973).

Both subspecies have undergone declines over much of their North American breeding ranges since the second world war (Hickey, 1969; Cade and Fyfe, 1970; Fyfe *et al.*, 1976). The decline resulted primarily from a decline in productivity. A major cause of this was thought to be the widespread presence of pesticides such as DDT in the environment (Peakall, 1976). The decreased use of these substances in Britain has resulted in peregrine population increases (Ratcliffe, 1980). With similar reductions in pesticide use in North America, there is hope that these populations of peregrine falcons will also recover. There has been some very recent evidence to suggest that the numbers and productivity of both subspecies of peregrine falcon in Alaska have slowly begun to recover (Roseneau *et al.*, 1981). In Canada there is similar evidence of a slow recovery only for *F. p. anatum* in the north-central Yukon while elsewhere in Canada peregrine populations appear to be generally holding at their reduced levels (R. W. Fyfe, pers. comm.).

Peregrines migrate out of the Mackenzie Valley for the winter months. Migration routes and timings are not well known, but some locations where peregrines regularly pass or spend time are documented. Banding returns indicate that northern peregrines winter primarily in Latin America, and that the more northerly birds winter farthest south.

Peregrine falcons feed mostly on other birds that are caught while in flight. They are opportunistic feeders taking a wide variety of prey. The most frequently taken are shorebirds, waterfowl and passerines (Cade, 1960; Cade *et al.*, 1968). Rosenau *et al.* (1981) list 70 species of birds that have been taken as prey by *F. p. anatum* in interior Alaska and 43 species that have been taken by *F. p. tundrius* in Arctic Alaska. *F. p. tundrius* took primarily shorebirds and passerines. Jaegers were important prey, as were waterfowl, which were taken less frequently but provided much more biomass per individual. Ptarmigan were important prey in some years. *F. p. anatum* took primarily shorebirds, passerines and waterfowl. Peregrines also take some mammalian prey (Roseneau *et al.*, 1981).

Peregrines hunt primarily over open areas (such as large rivers) where prey species have little opportunity to find cover. Breeding birds will often hunt from a high perch point, waiting for vulnerable prey to enter the hunting area (Roseneau *et al.*, 1981). Breeding birds and migrating birds also hunt from considerable heights, or by flying low and fast over open areas in order to surprise and flush prey species (Dekker, 1980; Roseneau *et al.*, 1981). Roseneau *et al.* (1981) list the principal hunting habitats for nesting peregrines in Alaska as lakes, marshes and wetlands for *F. p. tundrius,* and river valleys, lakes and marshes for *F. p. anatum.*

Hunting ranges of breeding peregrines vary greatly in size and in location relative to their nests. The size and location depend on the distribution of suitable hunting habitat. For example, one male peregrine in Arctic Alaska hunted over a territory that averaged about 11 km in radius (White, 1974), whereas several birds of the subspecies *F. p. anatum* in interior Alaska and Canada were recorded as hunting primarily within 1.5 to 5 km of their respective nest sites (Roseneau *et al.*, 1981). A bird whose territory was along the Mackenzie River travelled as far as 48 km from its nest site (Windsor: cited in Roseneau *et al.*, 1981).

Cliffs are the primary nesting habitat for peregrine falcons, although they also nest on man-made structures (such as buildings), in trees and on level ground (Cade, 1960; Hickey, 1969; Campbell and Davies, 1973; Newton, 1976). Large cliffs are used quite extensively, but slopes and cutbanks are also used, particularly in the Arctic. Not all cliffs make good nesting habitat. Cliffs must have suitable ledges, cavities or old stick nests on which the birds can nest, and must be near sufficient prey. Cliffs with vegetation on the cliff-face may be preferred because the vegetation provides stable ledge areas (White and Cade, 1971; Roseneau *et al.*, 1981).

Nests generally overlook rivers, lakes or the sea, although the occasional nest is located on a rock outcrop away from any waterbodies. Peregrine falcon nest sites are found at lower altitudes than those of other cliff-nesting raptors (cf. White and Cade, 1971; Roseneau, 1974). In Alaska peregrines have not been recorded to nest higher than approximately 800 m above sea level (Cade, 1960), although they have nested above 900 m in the central Yukon (Mossop, cited in Roseneau *et al.*, 1981).

Nest sites are often traditional sites that are used year after year, although in some cases a nest site may remain unoccupied for a few years or longer. The site may be unoccupied because an alternative nest site within the territory is being used, or because the territory itself is unoccupied. Unused nest sites are, however, likely to be occupied by new pairs in a future year (Ratcliffe, 1980).

The spring migration routes of peregrine falcons in the Mackenzie District are not well known, but birds of the subspecies *F. p. anatum* that nest along the Mackenzie Valley, and some individual *F. p. tundrius* birds that nest in coastal areas of the Beaufort Sea, probably migrate north along the Mackenzie Valley. Migration begins in April and continues into May. Fyfe and Prescott (1973) indicated that peregrines first arrive at their territories from May 1 to 14. Some birds probably arrive earlier in some years. In 1972 peregrines were first recorded at Fort Good Hope on April 29 (Campbell and Davies, 1973), whereas at similar latitudes in interior Alaska, Roseneau *et al.* (1981) reported that the peak period of arrival was April 20 to May 10, with the earliest record of arrival being March 29.

The timings given for various nesting activites are approximate because of the variation that occurs from year to year, and the variations that occur due to geographic location and to differences among individual birds. Fyfe and Prescott (1973) gave the following time intervals for nesting activities in the Mackenzie Valley: egg-laying May 7 to 20; hatching June 28 to July 8; and fledging August 7 to 20. They indicated that the nesting cycle was later in the more northern parts of the Mackenzie Valley. Finney and Lang (1976) give similar but slightly broader date ranges for the same area. However, Roseneau *et al.* (1981) provided average dates of nesting activities in interior Alaska that are much broader: egg-laying April 25 to May 17; hatching June 10 to 30 June; and fledging July 15 to August 10.

The breeding peregrine falcons of the Mackenzie Valley have been comparatively well surveyed because of the various proposals for development along the river valley (cf. Fyfe and Prescott, 1973; Finney and Lang, 1976; Koski, 1977b; Stepney and Thompson, 1978; Ealey and McCourt, 1980; Ealy, 1981). Windsor and Richards (1976) reported 44 known nest sites along the Mackenzie River in 1975. Of these, only 25 sites were active. Surveys in 1980 suggested that the population in the Mackenzie Valley was holding at approximately the 1975 level (R.W. Fyfe, pers. comm.)

The most important areas where peregrines breed or formerly bred along the Mackenzie Valley include the Norman Range, the Ramparts area of the Mackenzie River, and the Campbell Hills. For example, Windsor (1977) found nine breeding pairs, two or three non-breeding pairs, and one lone female in the Campbell Hills in 1974.

Fyfe and Prescott (1973) indicated that peregrines migrate southward from their nest sites in the Mackenzie Valley between September 7 and 15, while Roseneau *et al.* (1981) reported that most departure dates from interior Alaska occur between August 25 and September 25. Other observations support these reports (Manning *et al.*, 1956; Campbell and Davies, 1973; Salter, 1974b; Salter *et al.*, 1980). In the Mackenzie Valley migration probably continues through September and possibly into early October. *F. p. tundrius* is thought to be the first to migrate. Although the routes of autumn migrants are not well known, the Mackenzie Valley is probably an important migration corridor, in part because of the numbers of prey species that follow this route. Salter (1974b) observed two peregrines at Kelly Lake, four at Brackett Lake, and one at Fort Providence during fall migration studies in 1972.

2.2.7.6 Other Raptors

Seven other species of hawks and falcons, and seven species of owls occur regularly in the Mackenzie Valley (Table 2.2-1) (Godfrey, 1966). The population trends and relative abundance of several of these species is summarized in Table 2.2-3. The great gray owl is considered by COSEWIC to be a 'rare' species in Canada. It is widely but sparsely distributed in the boreal and mountain forests of Canada (Nero, 1979). Tate (1981) lists the sharp-shinned hawk, Swainson's hawk, marsh hawk, merlin, American kestrel, and short-eared owl on the most recent 'blue list' of North American species.

The times during which most of the above-mentioned species of hawks and falcons are expected to be in the Mackenzie Valley are: sharp-shinned hawk - mid April to late September; red-tailed hawk - mid April to late September; rough-legged hawk - mid April to mid October; marsh hawk - mid April to mid October; merlin - early May to early October; and American kestrel - early May to early October (Finney and Lang, 1976). The seventh species, the goshawk, is the only one that regularly winters in the Mackenzie Valley (Godfrey, 1966). The nesting and hunting habits of these hawks and falcons are summarized in Table 2.2-4.

TABLE 2.2-4

NESTING HABITAT, HUNTING HABITAT AND PREFERRED FOOD OF SEVEN HAWKS AND FALCONS THAT NEST IN THE MACKENZIE VALLEY*

	Nesting Habitat	Hunting Habitat	Preferred Food
Goshawk	*In secluded, extensive tracts of timber; prefer nearby openings and waterbodies; prefer deciduous forest; nests 6-25 m above ground	Heavy forests and woodlands, perhaps preferring mixed woods	Birds and small mammals
Sharp-shinned hawk	Prefers coniferous trees, 6-18 m up, in relatively dense woods	Relatively dense woods	Largely birds; occasionally small mammals or insects
Red-tailed hawk	*Small deciduous or coniferous trees; cliffs when trees not available	Woods and open country	Small mammals
Rough-legged hawk	*Cliff ledges, boulders, steep river banks; occasionally trees or flat ground	Meadows and tundra	Primarily rodents (ground squirrels, rabbits, mice); carrion occasionally when preferred foods scarce
Marsh Hawk	On ground, usually in moist meadows or marshy places	Variable; open country	Mice, lemmings, small birds
Merlin	Coniferous or deciduous trees; occasional tree cavity or hollow in ground	Variable; open deciduous or coniferous woods, occasionnally dense woods	Mostly birds
American kestrel	Natural cavity or woodpecker hole in tree; occasionally cliff cavity, bank burrow	Variable; open country	Larger insects, mice small birds

*Nest usually is, or has been known to be, used by same species (and possibly individuals) in successive years.

*Adapted from Finney and Lang (1976).

The snowy owl occurs in the Mackenzie Valley during migration to and from its Arctic breeding area, and some birds may winter in the Mackenzie Valley. The long-eared owl and short-eared owl both breed in the Mackenzie Valley but the long-eared owl breeds only in the southern part. Both migrate south during winter (Godfrey, 1966). The other species of owls, including the great-horned owl, hawk owl, great gray owl and boreal owl are year-round residents of the forests of the Mackenzie Valley (Godfrey, 1966), although they may move south in years of poor winter food supply.

2.2.8 GROUSE

Five species of grouse, the ruffed grouse, spruce grouse, sharp-tailed grouse, willow ptarmigan, and rock ptarmigan, occur within the Mackenzie Valley (Godfrey, 1966). The sharp-tailed grouse is included on the
'blue list' because of population declines in some regions (Tate, 1981).

Grouse have specially adapted digestive tracts that allow them to digest vegetation such as deciduous buds and the needles of conifers. Willow buds and twigs are the most important winter food of willow ptarmigan (West and Meng, 1966; Weeden, 1969), and the buds and catkins of dwarf birch are the most important winter food of rock ptarmigan (Weeden, 1969).

Grouse are generally dispersed when they nest, and ruffed and spruce grouse are dispersed throughout the year. The other species concentrate during part of the year: sharp-tailed grouse during spring when birds gather at their dancing grounds, and ptarmigan during winter.

The ruffed grouse and spruce grouse are forest species. The spruce grouse occurs rarely as far north as the southern Mackenzie Delta, and the ruffed grouse only in the southern Mackenzie Valley (Godfrey, 1966). The sharp-tailed grouse is a bird of bogs and open burn areas within the coniferous forest (Godfrey, 1966). It occurs regularly as far north as the wooded portion of the Mackenzie Delta (Martell and Dickinson, 1981).

Sharp-tailed grouse gather to perform communal courtship and mating activities (leks) on specific open areas (dancing grounds or arenas) that are

PLATE 2.2-5 *The ruffed grouse, shown here, occurs only in the southern Mackenzie Valley. (Courtesy, J. Kristensen, LGL Ltd.).*

usually less than 1 to 2 ha in size (Lumsden, 1965). An arena may support from 2 to 36 males (Pepper, 1972; Rippin and Boag, 1974). Females are sensitive to disturbance when they visit arenas and if disturbed may not return until the next day (Moyles, 1977). Although arenas are used most heavily in spring, in southern areas male sharp-tailed grouse also visit them during the autumn. Similar use of arenas in northern areas such as the Mackenzie Valley is possible.

Ptarmigan are birds of tundra areas, although the willow ptarmigan also breeds in northern forested areas. The willow ptarmigan breeds in the northern Mackenzie Valley (Godfrey, 1966), while the rock ptarmigan possibly breeds in mountainous areas of the Mackenzie Valley (Roe, 1975).

Willow and rock ptarmigan form flocks by late summer and remain in flocks until April. Flocks of willow ptarmigan may include up to 400 or more birds (Slaney, 1974a; Platt, 1976). The flocks are quite mobile, moving readily from one feeding area to another (Slaney, 1974a) and often moving far south of their summer range. Both ptarmigan species may occur in the Mackenzie Valley during winter (Godfrey, 1966). Adult males usually predominate in the flocks that remain farthest north (Martell and Dickinson, 1981).

2.2.9 CRANES

Two species of cranes, the sandhill crane and whooping crane, have been recorded in the Mackenzie Valley. Cranes are terrestrial in habit and prefer open country such as plains, marshy areas and tundra (Landsborough Thomson, 1964; Walkinshaw, 1973). Cranes are solitary nesters in remote areas, and globally, many species have declined as man has encroached on their breeding areas (Landsborough Thomson, 1964). In Canada, cranes are migratory and congregate in large flocks during migration and on the wintering grounds in the southern United States and Mexico (Godfrey, 1966).

The cranes that nest in Canada have a low reproductive potential. They are a long-lived species that take several years to mature. They nest on the ground and typically produce a clutch of two eggs (Godfrey, 1966). Recruitment of young birds into the adult population is low (cf. Miller and Hatfield, 1974).

Cranes feed on vegetation and small animals (invertebrates, birds, mammals) that they take opportunistically.

2.2.9.1 Sandhill Crane

The Mackenzie Valley is an important migration corridor for sandhill cranes (Plate 2.2-6). In 1973 migration was noted between April 27 and May 23, with peak movements between May 5 and 15 (Salter *et al.*, 1974). Fort Providence and Wrigley were the sites where most migrants were seen in 1973. The birds make some use of lake and river-edge habitat during their migration (Salter *et al.*, 1974). Sandhill cranes may arrive in the Mackenzie Delta as early as May 8 (Porsild, 1943).

PLATE 2.2-6 *Sandhill cranes are solitary nesters and nest in small numbers in marshes and bogs throughout the Mackenzie Valley. (Courtesy, J. Kristensen, LGL Ltd.).*

Sandhill cranes nest in small numbers in marshes and bogs throughout the Mackenzie Valley (cf. Salter *et al.*, 1974; Salter and Davis, 1974; Ward, 1975; Wiseley and Tull, 1977) and more commonly in tundra areas on the outer Mackenzie Delta (Campbell and Weber, 1973; Slaney, 1974b; Wiseley *et al.*, 1977). They begin nesting in the Mackenzie Delta by the end of May (Campbell, 1973a). Incubation lasts approximately one month (Godfrey, 1966) and the precocial young take approximately two months to fledge.

In late August and early September sandhill cranes apparently congregate for premigratory staging in the Blow River-Shallow Bay area of the Mackenzie Delta (Campbell and Weber, 1973; Wiseley *et al.*, 1977). Autumn migration in 1972 was observed in the Mackenzie Valley between August 18 and September 20, with the peak migration occurring between September 2 and 9 (Salter, 1974b).

2.2.9.2 Whooping Crane

The whooping crane is considered by COSEWIC to be 'endangered' in Canada. The world population of this 'high profile' species is currently about 120 individuals. The only area where whooping cranes nest naturally at the present time is in Wood Buffalo National Park on the Alberta-Northwest Territories border, but stragglers have been reported near Fort Good Hope (Kuyt, cited in Finney and Kondla, 1976) and along the Anderson River (Hohn, 1959).

2.2.10 SHOREBIRDS

Twenty-three species of shorebirds regularly occur in the Mackenzie Valley, ten of which breed there while the others only pass through during migration (Godfrey, 1966; Salter, 1974b; Salter and Davis, 1974; Salter *et al.*, 1974; Tull *et al.*, 1974; Ward, 1975; Wiseley and Tull, 1977; Martell and Dickinson, 1981). Of these species, the Eskimo curlew is considered to be 'endangered' by COSEWIC, and the upland sandpiper is on the most recent 'blue list' of North American species (Tate, 1981).

Shorebirds nest throughout Canada, although most species nest north of the tree line. All of the species found in the Mackenzie Valley winter in the southern United States, the tropics, or in southern South America.

The Mackenzie Valley is an important migration corridor for shorebirds during both spring and autumn. Some of the hardier species, all of which nest in the Mackenzie Valley, return in late April or early May. The peak of spring migration apparently occurs during the second half of May (Salter *et al.*, 1974). Spring migration is rapid and any stopovers are brief.

Shorebirds may begin laying their eggs within one week of arrival at their breeding grounds. Shorebirds normally lay a clutch of four eggs in a scrape on the ground (Palmer, 1967). Nesting may occur in many habitats, including wet, marshy tundra in the cases of the stilt sandpiper and the whimbrel; dry, upland tundra for the buff-breasted sandpiper and the American golden plover; bogs and muskeg areas for the greater yellowlegs and short-billed dowitcher;

and wooded lakeshores in the case of the spotted sandpiper (Plate 2.2-7) (Palmer, 1967). One species, the solitary sandpiper, nests near wooded lakes and ponds in the old nests of passerines (Godfrey, 1966). The species of shorebirds that nest in the Mackenzie Valley do so primarily in bog and muskeg areas, and along the shorelines of lakes, ponds and rivers. Overall densities of nesting shorebirds along the Mackenzie Valley are generally low in comparison to densities in tundra areas.

The nesting cycle is very short among shorebirds. Incubation ranges from 18 to 27 days for the species that nest in northern Canada (Godfrey, 1966). The young are precocial. They leave the nest shortly after hatching and feed themselves. The young of most species are capable of flying within two to three weeks of hatching.

Autumn migration southward is protracted, partly because different age and sex classes leave the breeding areas at different times. In some species one of the adults departs as soon as the clutch has been laid, while in other species the two adults leave the young at different stages of the brood-rearing period. The adults of most species leave the breeding range prior to the young birds (Parmelee *et al.*, 1967; Alliston *et al.*, 1976).

The protracted autumn migration begins in July and probably continues through late September or early October. Many shorebirds stage prior to their southward migration or at stopover points during their migration. Staging shorebirds frequently occur in mixed flocks of several species. The location of fall staging areas in the Mackenzie Valley are not well known. Preferred staging areas are generally on mudflats and wet grassy areas, but some stage in open uplands.

2.2.10.1 Eskimo Curlew

The Eskimo curlew is the only species of Mackenzie Valley shorebird whose status has been examined by COSEWIC. It is considered to be 'endangered' in Canada, the only country where it nests. This species is near extinction, in part because of hunting (Banks, 1977). Gollop and Shier (1978) estimate that there are fewer than 20 birds. There were five sightings of the species during the 1970's - one from the lower Anderson River, one from James Bay and the other three from the United States (Gollop and Shier, 1978). In 1980, there was one sighting in Manitoba (Gollop, 1980), and one sighting in the lower Anderson River (T. Barry, pers. comm.).

The Eskimo curlew formerly migrated north in spring via the prairie provinces and possibly via the Mackenzie Valley (Gollop and Shier, 1978). It once bred in the northwestern portion of the Mackenzie District, from the Coppermine River to the Anderson River and south to Fort Simpson. However, no

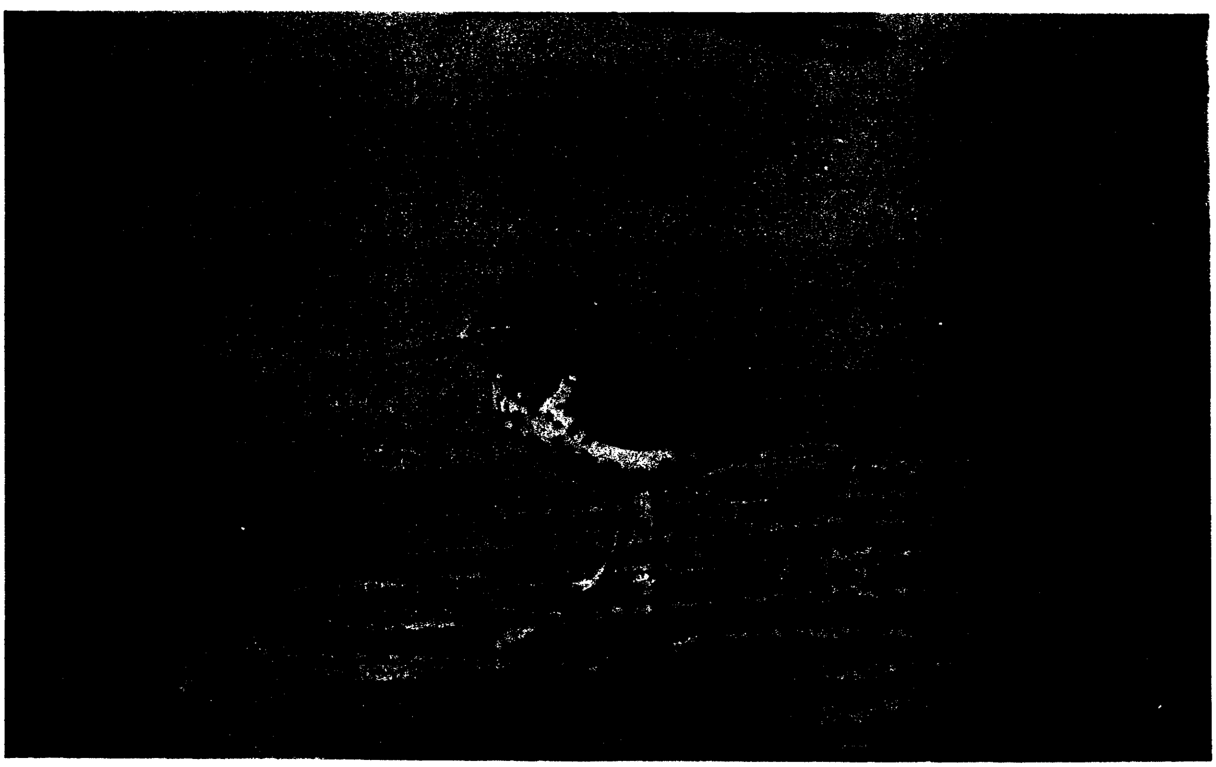

PLATE 2.2-7 *A spotted sandpiper. Shorebirds nesting in the Mackenzie Valley do so primarily in bog and muskeg areas, and along the shorelines of lakes, ponds and rivers.*

nests have been reported in more than 100 years (Gollop and Shier, 1978). The current breeding area(s) are unknown, but several recent sight records from the Anderson River suggest that breeding might occur there. Southward migration in autumn was formerly via Hudson Bay and Labrador. Present spring and fall migration routes are unknown.

2.2.10.2 Phalaropes

Phalaropes are unique among shorebirds in that they habitually swim. Only one species, the northern phalarope, occurs regularly in the Mackenzie Valley (Godfrey, 1966; Salter and Davis, 1974). A second species, Wilson's phalarope, has been recorded rarely in the southern Mackenzie Valley (Wiseley and Tull, 1977). Red phalaropes have not been recorded, but scattered records from the prairie provinces indicate that stragglers may migrate through the Mackenzie Valley (Goosen and Busby, 1979) .

Some northern phalaropes follow a coastal migration route to and from the Beaufort Sea, although this species is also common along an interior migration route across the prairie provinces and presumably some of the latter birds migrate down the Mackenzie Valley. Northern phalaropes probably arrive in the Mackenzie Valley by mid to late May.

The northern phalarope is an abundant breeding bird in wet tundra areas close to the Beaufort Sea coast (Barry, 1967; Koski, 1975; Patterson *et al.*, 1977), but also occurs inland in smaller numbers (Salter and Davis, 1974; Ward, 1975). Its breeding range also includes the Mackenzie Delta and areas to the east and west of the Mackenzie Valley. However, breeding has not been documented along the Mackenzie Valley in areas south of the Delta (Godfrey, 1966). Records of single males adjacent to lakes between Norman Wells and Fort Good Hope in the vicinity of the upper Ontaratue River during June 1972 (Salter and Davis, 1974) suggest that breeding may occur there.

Southward migration from nesting areas starts by mid July. The peak southward movement through Alberta is in August (Sadler and Myres, 1976).

2.2.11 GULLS AND TERNS

Three species of gulls, herring gull, mew gull and Bonaparte's gull, occur regularly throughout the Mackenzie Valley (Godfrey, 1966; Salter and Davis, 1974; Ward, 1975). The glaucous gull occurs regularly in the Mackenzie Valley only in tundra areas in and near the outer Mackenzie Delta (Godfrey, 1966; Martell and Dickinson, 1981). The Thayer's gull probably migrates regularly, at least in part, through or across the Mackenzie Valley, but its status in the area is not well known (cf. Johnson *et al.*, 1975). The ring-billed gull and California gull both occur regularly on Great Slave Lake (Godfrey, 1966) and the ring-billed gull was seen regularly at Fort Providence during spring migration studies (Salter *et al.*, 1974). However, neither species appears to occur regularly further downriver. Several other species of gulls occur rarely in the Mackenzie Valley.

The Arctic tern occurs regularly throughout the Mackenzie Valley (Godfrey, 1966), while the black tern breeds in the southern Mackenzie Valley (Salter and Davis, 1974; Wiseley and Tull, 1977). The common tern occurs rarely in the southern Mackenzie Valley (Wiseley and Tull, 1977) and the Caspian tern occurs on Great Slave Lake (Godfrey, 1966). The Caspian tern is considered to be 'rare' by COSEWIC and the common and black terns are both included on the 'blue list' of North American species (Tate, 1981).

Gulls and terns feed on fish and aquatic invertebrates. Many species of gulls are highly opportunistic feeders that will take whatever food is available. Gulls in particular, are scavengers commonly seen at garbage dumps.

Herring gulls frequently nest in colonies, but will also nest as single pairs. They usually nest on the ground on islands or on rocks in lakes (Godfrey, 1966). Mew gulls nest in colonies or as single pairs, usually on the ground on islands or around lakeshores, but occasionally in trees (Godfrey, 1966). Bonaparte's gulls (Plate 2.2-8) usually nest singly in coniferous trees near muskeg ponds or lakes (Godfrey, 1966). The Arctic tern nests colonially or singly on the ground on beaches, spits and islands. The black tern nests on floating marsh vegetation (Godfrey, 1966). The locations of nesting colonies of gulls and terns in the Mackenzie Valley are generally not known.

Gulls and terns are migratory and leave the Mackenzie Valley in the fall. Most species of gulls probably winter on the Pacific coast from Alaska to California. The black tern winters in the tropics, whereas the Arctic tern winters on southern oceans as far south as the Antarctic Ocean (AOU, 1957; Godfrey, 1966). Gulls frequently occur in flocks during migration and at migration stopover locations. Mixed flocks of several species are a common occurrence.

Gulls first return to the southern Mackenzie Valley during late April or early May (possibly earlier), although they did not arrive at Norman Wells in 1973 until May 10 to 15 (Salter *et al.*, 1974). The peak of mew gull migration was during the second and third weeks of May and that of Bonaparte's gulls was during the third week of May. Terns (presumably Arctic terns) first returned to the Mackenzie Valley in 1973 on May 7, but the peak of the downriver migration was on May 23 at Fort Providence and after May

25 at Wrigley and Norman Wells (Salter *et al.*, 1974).

PLATE 2.2-8 *Bonaparte's gulls occur regularly throughout the Mackenzie Valley, nesting singly in coniferous trees near muskeg ponds or lakes.*

Densities of nesting gulls and terns have been obtained during a number of aerial surveys of waterbirds along proposed pipeline routes in the Mackenzie Valley. In mid July 1975 (when tern numbers were at a peak) Patterson and Wiseley (1977) recorded densities of 0.02 gulls/km^2 and 0.01 terns/km^2 along a route from the Willowlake River to Bistcho Lake, Alberta. Davis (1974) recorded densities in 1972 of 0.08 gulls/km^2, but no terns, along a route on the west side, and 0.12 gulls/km^2 and 0.006 terns/km^2 on the east side of the Mackenzie River, between approximately Fort Good Hope and Fort Simpson. Davis also recorded 0.43 gulls/km^2 and 0.06 terns/km^2 along a route south of Fort Simpson. Salter (1974a) recorded densities of 0.07 gulls/km^2 and 0.004 terns/km^2 in late June, 1973, along a route between Norman Wells and Richards Island. Davis (1974) recorded higher densities during aerial surveys of selected wetland habitat. In mid July 1972 he recorded 0.87 gulls/km^2 and 1.85 terns/km^2 of wetland along the Ramparts River, 1.08 gulls/km^2 and 0.25 terns/km^2 of wetland in the Great Bear River-Loche River-Kelly Lake area, and 0.45 gulls/km^2 and 0.61 terns/km^2 of wetland along the Mackenzie River between Fort Simpson and Inuvik.

Terns probably begin to leave the Mackenzie Valley during August. Only one tern (Caspian) was seen during fall migration studies in the southern half of the Mackenzie Valley from August 15 to October 1 in 1973 (Salter, 1974b). It is not known if Arctic terns that nest in the Mackenzie Valley follow the Valley south, but they are very rare in Alberta (Salt and Salt, 1976). Black terns have migrated out of Alberta by the end of August (Salt and Salt, 1976). Gulls are recorded quite commonly during autumn in the Mackenzie Valley. Mew gulls are the most common gull in the Valley during the second half of August (Salter, 1974b). Most gulls have probably left the Mackenzie Valley by the end of September.

2.2.12 OTHER WATERBIRDS

The parasitic jaeger and the long-tailed jaeger probably occur regularly in very small numbers in the Mackenzie Valley when they migrate to and from their tundra nesting areas (Salter, 1974b; Salter *et al.*, 1974). Their presence in the Mackenzie Valley is supported by their irregular occurrence in Alberta on migration (Sadler and Myres, 1976; Salt and Salt, 1976).

Three other species of waterbirds or water-associated birds occur in the Mackenzie Valley: sora, American bittern and American coot. The sora and the American bittern are marsh birds that usually occur only as individuals or pairs. Their distributions and phenologies in the Mackenzie Valley are not well known. The sora has been encountered fairly commonly during ground transect surveys. A nest was found at the Willowlake River and there are several records from the general latitude of Chick Lake (Godfrey, 1966; Salter and Davis, 1974; Richardson and Tull, 1977). The American bittern was recorded only rarely during ground transect and migration studies and nearly all records were at or south of Wrigley (Salter and Davis, 1974; Salter *et al.*, 1974; Ward, 1975; Wisely and Tull, 1977). However, Roe (1975) recorded a bittern at Snafu Lake, just north of Chick Lake. The American bittern is on the'blue list' (Tate, 1981).

The American coot is a waterbird that nests and feeds in marshes interspersed with areas of emergent vegetation and open water. Nesting is, to some degree, colonial (Godfrey, 1966) and coots often occur in flocks during staging and migration. Coots often occur in mixed flocks with various species of waterfowl and often use the same wetland areas. The timing of coot occurrences in the Mackenzie Valley is probably similar to the general timing of other waterfowl occurrences.

During the early 1970's, coots were rarely recorded in the Mackenzie Valley but some were seen as far north as the Chick Lake area near Fort Good Hope (Figure 2.2-1) (Roe, 1975; Richardson and Tull, 1977). However, coots may be displaced to northern areas during years of drought conditions on the prairies. Although no coots were observed during aerial surveys of Beaver Lake in either 1972 (Salter, 1974b) or 1974 (Kemper *et al.*, 1975), several hundred coots were found in this area during mid to late September 1977 (Stepney and Thompson, 1978).

2.2.13 PASSERINES AND 'NEAR-PASSERINES'

Passerines are a very large and diverse group of birds that occur in virtually all terrestrial habitats. Woodpeckers, kingfishers and goatsuckers are treated here as 'near-passerines' because they are similar to passerines in many of their characteristics.

At least 90 species of passerines and near-passerines probably occur regularly in the Mackenzie Valley (Godfrey, 1966; Salter and Davis, 1974; Tull *et al.*, 1974; Roe, 1975; Ward, 1975; Wiseley and Tull, 1977). Additional species have been recorded rarely. Most of these 90 species breed in the Mackenzie Valley, but a few pass through to Arctic breeding areas. Many species reach the northern-most limits of their breeding ranges within the Mackenzie Valley.

Tate (1981) includes four of the species that occur regularly in the Mackenzie Valley on the most recent 'blue list' of North American species, because of population declines in many parts of their North American ranges. These are the common nighthawk, the hairy woodpecker, the cliff swallow and the yellow warbler. However, all of these species remain widely distributed and numerous in North America.

Passerines and near-passerines have a wide range of feeding habits. Many species are entirely insectivorous, including woodpeckers, flycatchers, swallows, vireos, and warblers, while most other species prey heavily on insects during the breeding season. Many other species are primarily seed eaters (for example finches). The northern shrike preys on small birds and mammals. The gray jay and the common raven will scavenge for food and often become more numerous where they have access to garbage. The belted kingfisher feeds mainly on small fish.

The Mackenzie Valley is an important corridor for migrating passerines and near-passerines. Most spring migration occurs in May but some of the hardier species migrate north through the Valley in April. Some of the insectivorous species may not migrate north until early June (Salter *et al.*, 1974).

Passerines and near-passerines breed in forest, scrub, muskeg and open habitats throughout the Mackenzie Valley. Several ground transect studies of bird numbers and densities, primarily of passerines and near-passerines, were conducted at numerous sites in the Mackenzie Valley during the period from 1972 to 1975 (Salter and Davis, 1974; Tull *et al.*, 1974; Ward, 1975; Patterson *et al.*, 1977; Wiseley and Tull, 1977). The number of species recorded per site was greater in the southern Mackenzie Valley than in the northern Mackenzie Valley (Salter and Davis, 1974). Densities of birds, however, appeared to be comparable throughout the Mackenzie Valley. In the southern Mackenzie Valley the highest densities were usually recorded in closed deciduous scrub, while the lowest densities occurred in scattered spruce muskeg habitats. Densities were quite variable in forested habitats. Four species, the Tennessee warbler, the gray jay, the chipping sparrow and the dark-eyed junco constituted 54% of the birds recorded on transects in the southern Mackenzie Valley (Wiseley and Tull, 1977).

Autumn migration begins in August (Campbell, 1973b; Salter 1974b) and is probably complete by early October. Although most species winter in southern Canada, the United States or the tropics, a few winter in the Mackenzie Valley. Carbyn (1968) recorded seven species in winter in the southern Mackenzie Valley; six additional species have been recorded regularly on the Hay River Christmas bird count, and another two species have been recorded rarely. The number of species that winter regularly in the Mackenzie Valley is probably no more than 20. Overwintering species frequently occur in small flocks that are either quite mobile or are regularly found at artificial feeding sites such as feeders or garbage dumps.

2.3 AQUATIC RESOURCES

2.3.1 FACTORS CONTROLLING AQUATIC PRODUCTIVITY

In northern freshwater environments several factors limit primary productivity, including reduced winter light, low water temperatures, high sediment loads, and low nutrient levels (McCart and Den Beste, 1979). While these factors directly influence primary production, additional factors also influence the productivity of higher trophic levels, such as drainage, discharge patterns, species composition, microhabitats and human use. Except on a broad scale, it is not yet possible to clearly demonstrate the relationship between primary production in northern waters and the productivity of the highest aquatic trophic level, fish. In addition to these factors, fish are highly mobile and are able to exploit areas of high productivity. They also require special habitats, are irregularly distributed, and, when exploited, may suffer drastic changes in population.

With increasing latitude winter light decreases and limits aquatic productivity. Northern portions of the Mackenzie Valley are without direct sunlight from early November through February, while the southern border of the Northwest Territories receives only 4 hours of sunlight at the winter solstice. Productivity drops to zero or near zero without direct sunlight

(Kalff and Welch, 1974) so that from south to north winter productivity probably declines.

Similarly, colder water in the north tends to reduce the metabolic rate of aquatic organisms, resulting in slower growth and lower production. The Mackenzie River moderates this effect somewhat by carrying warmer water from the south northward. However, in general, water temperatures in the Valley change little, although tributary streams are often cooler than the Mackenzie mainstem. Despite this moderating influence, winter water temperatures remain at or near 0°C for 6 to 7 months of the year, serving to further limit productivity during this period.

Sedimentation also affects aquatic production by limiting light penetration, by burying aquatic organisms, by interfering with respiration, and by eliminating or reducing available habitat (Cordone and Kelly, 1961; Phillips, 1971). Studies of the effects of sedimentation on aquatic habitats in the Valley have been done by Brunskill *et al.* (1973), McCart and de Graaf (1974), Porter *et al.* (1974), Rosenberg and Snow (1975) and McCart *et al.* (1979). In each case the authors show that sedimentation modifies communities and reduces populations in lower trophic levels. While sedimentation has been clearly demonstrated to adversely affect specific aspects of fish life history including spawning, overwintering and emergence, fish in the Mackenzie River system live in waters which periodically carry suspended sediment loads reaching 2,000 mg/L during the summer months (Brunskill *et al.*, 1973). Highly migratory fish species (anadromous species) have developed strategies to avoid high sediment levels to some extent by using clear tributary streams and coastal waters. Further information on sediment transport in the Mackenzie River is provided in Section 1.4 (Hydrology).

Nutrient levels in the waters of northern drainage systems are generally low. This is because of extensive bedrock material; limited runoff, which restricts the transport of nutrients; a slow microbial breakdown of organic material and recycling of nutrients; and the general absence of thunderstorms which promote the nitrification process (McCart and Den Beste, 1979).

Concentrations of nutrients in the Mackenzie River tend to be higher than in most other Arctic streams and rivers owing to the sedimentary nature of the riverbed and the steady input of nutrients from southern part of its drainage (McCart *et al.*, 1974; McCart and Den Beste, 1979). Data on macronutrient concentrations in the Mackenzie River system have been collected by Brunskill *et al.* (1973), Reeder (1973), McCart *et al.* (1974) and Reid *et al.* (1975). Portions of these data are summarized in Table 2.3-1 for the Mackenzie River tributaries shown in Figure 2.3-1. More southerly tributaries are generally higher in total dissolved nitrogen, but total dissolved phosphorus values are low throughout the Valley. As in most unpolluted fresh water, phosphorus availability is probably a major factor limiting primary production.

Nutrient values for tributary streams within the Mackenzie Valley corridor are typical mid summer concentrations and provide no indication of seasonal variation. Reid *et al.* (1975) provided a discussion of the spatial and temporal variations in concentrations of nitrogen (N), phosphorus (P), and total organic carbon in the Mackenzie River mainstem (Table 2.3-2). Total nitrogen concentrations were high in the Mackenzie River at Fort Providence and increased further downstream toward Wrigley. Concentrations were lower near Norman Wells owing to the low nitrogen concentrations added by the Keele and Great Bear rivers. Downstream of Fort Good Hope, nitrogen concentrations remained constant, with little influence from tributary streams.

Total phosphorus concentrations tended to increase steadily between the sources and the mouth of the Mackenzie River drainage. This steady increase results from a gradual phosphorus-loading of the mainstem by tributary streams.

Reported total organic carbon concentrations ranged from below detectable limits (less than 1.0 mg/L) to 23 mg/L in the study by Reid *et al.* (1975). While total organic carbon concentrations were usually less than 15 mg/L in the Mackenzie mainstem, higher values were recorded for tributaries upstream of Wrigley.

Nitrogen, phosphorus, and total organic carbon concentrations were generally lower during winter than in summer, indicating that the principal source of these nutrients was surface runoff. Frozen substrates prevent organic decomposition during the long winter months, greatly reducing the overall nutrient loading. Exceptions to this trend occurred in drainages downstream of Great Bear, Great Slave and Trout lakes, where summer and winter nutrient concentrations remained comparable owing to the stabilizing effect on nutrient output of these large lakes (Reid *et al.*, 1975).

2.3.2 PRIMARY PRODUCTION

Phytoplankton, (free floating microalgae) periphyton, (attached microalgae) and aquatic macrophytes form the basis of all food webs in freshwater systems. In northern waters, these organisms produce biomass at a much slower rate than in more temperate regions, thus limiting the productivity of all higher trophic levels.

The low productivity of northern fresh waters has

TABLE 2.3-1

SUMMARY OF NITROGEN AND PHOSPHORUS DATA FOR TRIBUTARIES WITHIN THE MACKENZIE VALLEY CORRIDOR.

River*	NO_3 mg/L	Total Dissolved Nitrogen mg/L	PO_4 mg/L	Total Dissolved Phosphorus mg/L
3. Trout River		.154-.742		.010-.028
4. Jean-Marie Creek		.017-.756		.010-.046
6. Rabbitskin River		.028-1.442		.008-.021
8. Harris River		.140-1.036		.004-.017
9. Trail River		.083-1.078		.007-.033
10. Willowlake River		.017-.882		.003-.050
11. River Between Two Mountains	0.25			
12. Smith Creek	0.01			
14. Hodgson Creek	0.15-0.28		<0.003	
15. Ochre River	0.21		0.097	
16. Stream 40-1 (S)	0.04			
18. Blackwater River		.115-.672		.013-.018
20. Birch Island Creek	0.01			
21. Saline River		.154-.714		.009-.029
22. Little Smith Creek	0.23			
25. Brackett River		.113-.448		.019-.029
26. Great Bear River		.130-.476		.005-.007
29. Jungle Ridge Creek	0.02			
31. Note Creek	<0.01			
33. Vermillion Creek	<0.01-0.04		0.003	
34. Prohibition Creek	<0.01		0.003	
37. Canyon Creek	0.08		0.003	
38. Bosworth Creek	0.15			
42. Oscar Creek	0.02			
47. Hanna River		.182-.196		.047-.084
49. Gibson Creek	0.06-0.29		0.003	
52. Donnelly River	<0.01			
56. Hare Indian River		.091-.560		.008-.018
57. Bluefish River		1.680		.050

* Number preceding stream name refers to location on Figure 2.3-1.

Sources: Brunskill *et al.* (1973), McCart *et al.* (1974) and Reid *et al.* (1975).

not been apparent to many observers since these waters often support large populations of consumer organisms, particularly fish. However, these localized areas of high fish density are generally the result of migratory activities, limited overwintering habitat, the return of anadromous fish from marine waters, or any number of other factors not related to local productivity. A wide range of feeding dispersal strategies have evolved to compensate for the generally small share of the already low productivity which each year class of fish receives.

There are few published studies describing primary productivity of aquatic ecosystems in the Northwest Territories. McCart *et al.* (1979) presented data from Ya-Ya Lake in the Mackenzie Delta, indicating maximum summer production rates of 1.4 to 129 mg $C/m^2/d$, (milligrams carbon per square metre per day) while Sheath *et al.* (1975a) report summer production ranging from 11.6 to 46 mg $C/m^2/d$ in a shallow tundra pond near Tuktoyaktuk. Studies in progress by the Department of Fisheries and Oceans along the Tuktoyaktuk Peninsula indicate that a

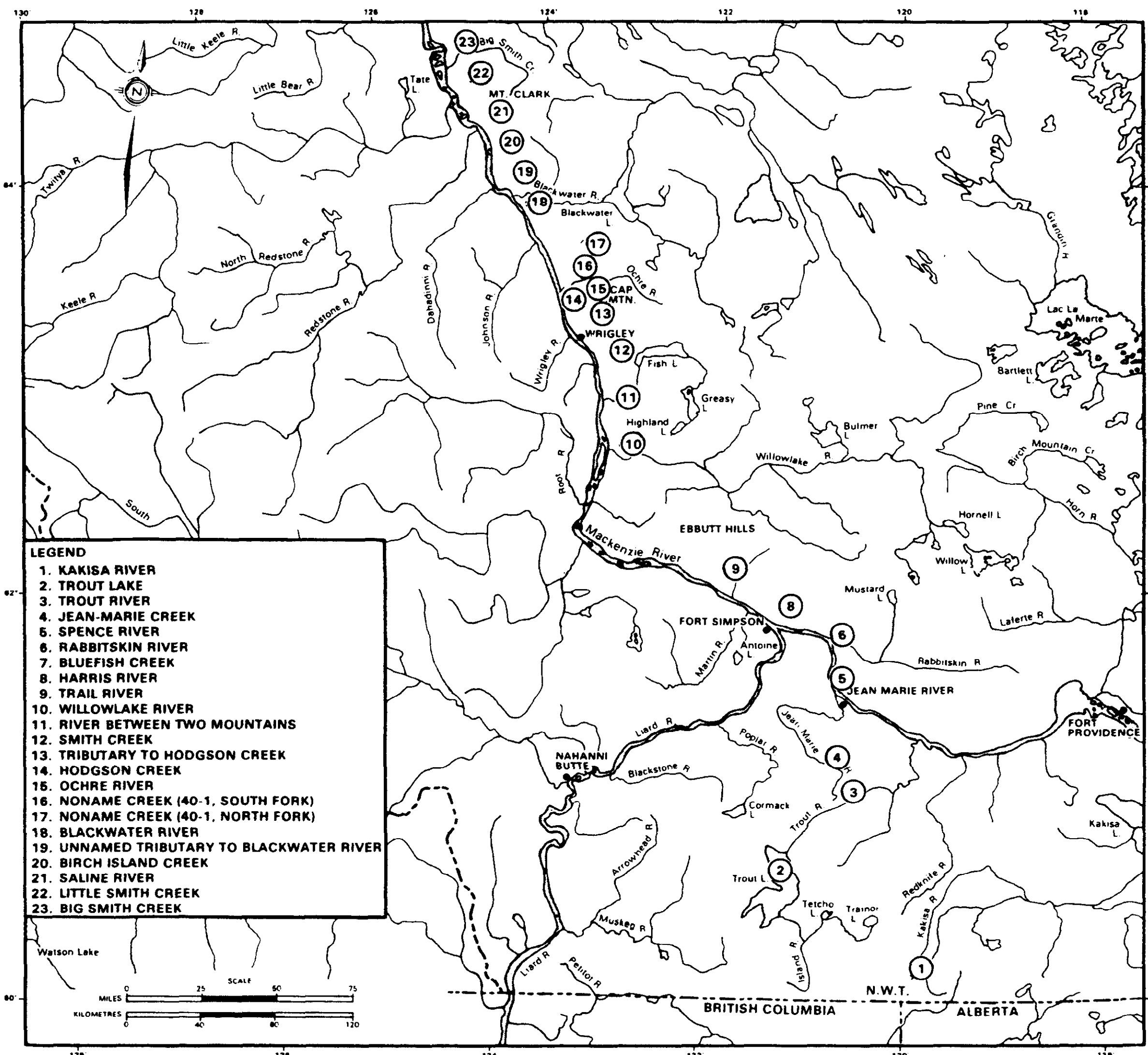

FIGURE 2.3-1 *Locations of major waterbodies in the Mackenzie Valley Corridor as identified in Tables 2.3-1, 2.3-4, 2.3-5 and 2.3-6. (Continued)*

number of lakes in this region have a similar range in daily summer primary production (L. de March, pers. comm.).

Average daily summer production from other northern Canadian Shield lakes ranges from 15 to 48 mg $C/m^2/d$ (Schindler, 1972; Kalff and Welch, 1974; de March *et al.*, 1977). Production at sewage-polluted Meretta Lake on Cornwallis Island reached 173 mg $C/m^2/d$ as a result of high phosphorus concentrations. Southern portions of the Canadian Shield are considerably more productive, as evidenced by midsummer production values ranging from 179 to 1,103 mg $C/m^2/d$ in the Experimental Lakes Area (Schindler, 1972).

No data exist on annual primary production in the waterbodies of the Mackenzie Valley corridor but they are probably higher than those of lakes and streams on the Canadian Shield, owing to the higher nutrient loadings of the Mackenzie Valley drainage system. Daily primary production from the Mackenzie Delta region indicate that annual production rates probably lie within the oligotrophic (nutrient-poor) range of 0 to 100 g $C/m^2/yr$. In northern lakes located on the Canadian Shield, annual primary production rates range from 4 to 11 g $C/m^2/yr$ (Table 2.3-3). Comparable waterbodies in the Experimental Lakes Area of northern Ontario have average annual assimilation rates of 39 g $C/m^2/yr$ (Schindler, 1972).

Data from Meretta and Char lakes in the eastern Arctic near Resolute show that productivity of ben-

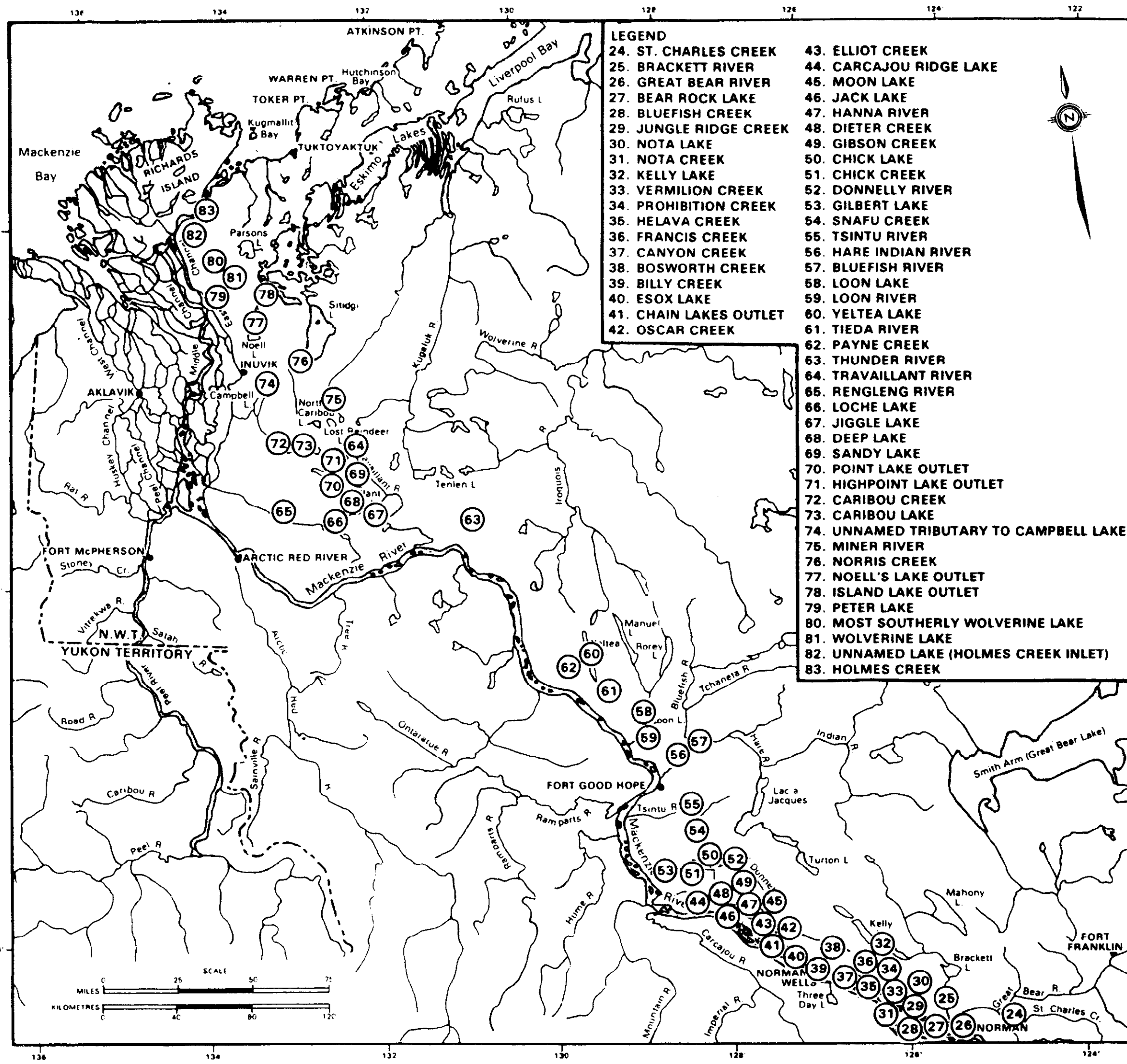

FIGURE 2.3-1 *Cont'd.*

thic algae may be much more important than phytoplankton production. Benthic algae contribute over 67% and 80%, respectively, to the total primary production of these lakes (Kalff and Welch, 1974; Rigler, 1974). However, it is not known if this pattern also occurs in the more nutrient-rich lakes of the Mackenzie River drainage system.

Seasonal changes in primary production have not been studied in lakes along the Mackenzie Valley corridor but studies from the eastern Arctic (Kalff and Welch, 1974; Rigler, 1974; Welch, unpublished data) suggest that maximum production occurs in the summer, coinciding with increased light intensity, water temperatures and nutrient levels. Primary production probably ceases between November and February, as in the eastern Arctic. In winter, productivity is likely to be greater in the southern portions of the Mackenzie Valley where conditions are less severe.

Information regarding species composition and relative abundance of phytoplankton and benthic algae (particularly near the Mackenzie Delta) is provided by Slaney (1974, 1977), Sheath *et al.* (1975b), McCart *et al.* (1976), Koivo and Ritchie (1978) and McCart *et al.* (1979). Information on lakes in more southerly portions of the Northwest Territories is provided by Moore (1978), who also provides data on lakes and streams near Yellowknife and for Great Slave and Great Bear lakes (Moore, 1977). However, site-specific information for streams and lakes within the corridor is generally lacking. Data regarding the species composition of periphyton on artificial substrates exposed to Norman Wells crude oil are provided by Roeder *et al.* (1975). These data indicate

TABLE 2.3-2

SUMMARY OF NUTRIENT CONCENTRATIONS IN THE MACKENZIE RIVER.
From: Reid *et al.*, 1975.

Location	Total P mg/L		Total N mg/L		Total Organic Carbon mg/L	
	open water	ice cover	open water	ice cover	open water	ice cover
Mackenzie River at Fort Providence	0.015	0.013	0.42	0.42	6	6
Mackenzie River at Fort Simpson	0.024	0.015	0.46	0.18	7	6
Mackenzie River near Wrigley	0.057	0.027	0.66	0.48	8	6
Mackenzie River 14½ mi. (24.17 km.) above Norman Wells	0.150	0.010	0.57	0.42	13	5
Mackenzie River 2½ mi. (4.17 km.) above Fort Good Hope	0.180	0.012	0.68	0.51	12	6
Mackenzie River Upstream of Arctic Red River	0.150	0.017	0.67	0.48	10	6

TABLE 2.3-3

ANNUAL ESTIMATES OF PRIMARY PRODUCTION
FROM SEVERAL NORTHERN LAKES DRAINING THE CANADIAN SHIELD

Lake	Latitude	Primary Productivity $gC/m^2/yr$	Source
Char (near Resolute)	75	4.2	Kalff & Welch (1974)
Meretta (near Resolute)	75	11.3	Kalff & Welch (1974)
Immerk	75	4.3	Minns (1977)
Fish	75	6.1	Minns (1977)
Stanwell-Fletcher	73	4.8	de March *et al.* (1977)
Eastern Great Bear	66	4	Schindler (1972)
McLeod Bay (Great Slave)	63	10	Schindler (1972)
Average of 11 Experimental Lakes, (northeastern Ontario)	50	39 (24-81)	Schindler (1972)

that northern phytoplankton and benthic algal communities are relatively cosmopolitan in distribution, including a large number of species common to more temperate locales.

2.3.3 INVERTEBRATES

Zooplankton (free-swimming invertebrates) and benthos (bottom-dwelling invertebrates) occupy intermediate positions in most aquatic food chains as primary, secondary or tertiary consumers, often altering their trophic position during various life history stages. Ultimately invertebrates are the link in food chains between primary producers and the higher trophic levels such as fish, birds and mammals. Therefore, changes to populations of aquatic invertebrates may have indirect effects on higher trophic levels.

2.3.3.1 Zooplankton

Studies of zooplankton communities in lakes within the Mackenzie Valley corridor are few. Numerous lakes near the Mackenzie Delta and Parsons Lake were studied by Slaney (1974, 1977) and McCart *et al.* (1976, 1979), and general information on species composition and on Arctic species distributions were compiled by Reed (1959). In the area south of the Arctic Circle studies have been conducted by Rawson (1956) in Great Slave Lake and by Johnson (1975) in Great Bear Lake. All of these studies suggest that zooplankton species of waters in the Mackenzie Valley corridor are widely distributed and are common to zooplankton populations elsewhere. However, since many environmental factors affect zooplankton populations, it is difficult to generalize for the corridor as a whole.

The most abundant zooplankton species are rotifers, copepods and cladocerans. McCart *et al.* (1976) reported that rotifers were the most abundant forms in upland Mackenzie Delta lakes, although copepods dominated some lakes during mid and late winter. These results are consistent with those of Slaney (1974, 1975) and McCart *et al.* (1979) for other lakes on the Delta. Copepods are a major food item of many fish species, particularly for lake-dwelling populations of least cisco, broad whitefish and lake cisco (Mann, 1975; McCart *et al.*, 1979).

Reported densities of zooplankton from lakes in the area are highly variable, depending upon a wide range of factors including water depth, temperature, nutrient and trace mineral concentrations, turbidity, currents, season, water sources, and other factors. The importance of most of these factors and the sensitivity of Arctic zooplankton communities to changes in their environment are not well understood. For instance, while there is evidence that zooplankton can thrive in some heavily silted waters (Daborn, 1975; de March *et al.*, 1977), studies by Slaney (1975) of the Mackenzie estuary indicated that copepods disappeared from some areas when the turbidity increased to between 540 and 680 ppm, but reappeared when turbidity declined from 400 to 250 ppm. Similarly, Rawson (1956) noted that occasional high turbidity owing to silt from the Slave River decreased plankton abundance at some Great Slave Lake stations.

Some studies of zooplankton in lakes of the Mackenzie system have demonstrated zooplanktonic behaviour patterns similar to those of southern populations. For example, summer studies of zooplankton communities in Ya-Ya Lake (in the Mackenzie Delta) demonstrated daily vertical migrations in response to changing sunlight intensities, despite 24 hour daylight (McCart *et al.*, 1979).

Data describing the annual zooplankton production for lakes in the Mackenzie Valley corridor are not available, nor has any relationship been established between primary production and the productivity of higher trophic levels. In temperate regions peak zooplankton abundance closely follows peak primary production. In northern freshwater systems such as the Mackenzie River drainage, most zooplankton species probably reproduce during the summer. By mid summer or early autumn, lake zooplankton populations are probably most diverse and are likely to contain their maximum standing stocks.

2.3.3.2 Benthos

Brunskill *et al.* (1973) conducted a detailed study of the benthos of the Mackenzie River and 31 tributary streams. In addition, site-specific surveys were conducted along the route of the Canadian Arctic Gas Pipeline, which includes most streams within the corridor (McCart *et al.*, 1974; Aquatic Environments Limited, unpublished data). Additional information regarding the benthos of lakes and streams in the Mackenzie Delta, in Parsons Lake and in lakes and streams of the Norman Wells area are provided by Slaney (1974, 1977), McCart and de Graaf (1974), McCart *et al.* (1976, 1979), de Graaf and Machniak (1977), and Envirocon (1980).

Four general conclusions were drawn from studies by Brunskill *et al.* (1973). They found that aquatic systems of the Mackenzie Valley as a whole were impoverished when compared with systems of more southerly areas, although they were rich in comparison with other drainages of the High Arctic. The species diversity and density of organisms (as measured using standard artificial substrates) both tended to decrease with increasing distance north. Chironomid larvae dominated zoobenthic faunas throughout the region. Finally, there were indications that both standing crop and species diversity decreased from tributary streams to the larger mainstems.

In addition to these general conclusions, studies in the vicinity of the Mackenzie Valley corridor indicate that streams with mean suspended sediment concentrations exceeding 15 mg/L during the summer months support less dense and less diverse benthic populations than do clear streams. Tributaries on the east side of the corridor generally support higher densities and a greater diversity of benthos than do tributaries on the west side of the Mackenzie River, owing to the lower turbidity on the east-side streams. Benthic drift declines during winter months in most small clear tributary streams, but remains largely unchanged through the winter in large streams and in the Mackenzie River mainstem. The abundance and diversity of benthic organisms are lowest near the mouths of streams in the corridor, as headwater reaches generally have higher standing crops per unit area than do downstream reaches. While the foregoing generalities probably describe the overall patterns of benthic distributions in the waters of the Mackenzie Valley corridor, the data base is sparse and frequent exceptions undoubtedly occur.

2.3.4 FISH

Beginning in the early 1970's the fish of the Mackenzie Valley were studied intensively by government and industry in conjunction with several proposed projects (Plate 2.3-1). These included the Mackenzie Highway, the Canadian Arctic Gas Pipeline Limited, the Beaufort-Delta Oil Project Limited, the Environmental-Social Program-Northern Pipelines, the proposed Mackenzie River dredging project, and the Norman Wells Expansion and Pipeline Project. Further studies on behalf of the oil industry on the Mackenzie Delta and in nearshore coastal areas have added to the fisheries information. As a result there is a substantial data base on fish populations along the Mackenzie Valley corridor.

2.3.4.1 Species Composition, Distribution, and Relative Abundance

To date 38 fish species are known to occur in the Mackenzie River drainage system north of 60° latitude (Table 2.3-4). This list includes some species which have not yet been captured within the Mackenzie Valley corridor, but whose widespread distributions suggest their occurrence. The large geographic area encompassed by the Mackenzie system provides habitat for a diverse fish fauna when compared with other rivers at similar latitudes. The Mackenzie system supports at least a dozen species at the northern-most limit of their ranges in North America. However, while the mainstem of the Mackenzie River and its larger tributaries support a diverse fish fauna, many of its smaller tributaries are either devoid of fish or support only one or two of the species listed in Table 2.3-4.

The Mackenzie River, particularly near the Delta, serves as an important migration route for anadromous species, including Arctic char, ciscos, and some whitefish species (Volume 3A; Section 3.4). Of these, ciscos and whitefish are more widespread and abundant than are char, and they are taken extensively in domestic and commercial fisheries, particularly in the Delta region. Arctic char only occur in tributaries of the Peel, the Rat and the Big Fish rivers and in the western Mackenzie Delta.

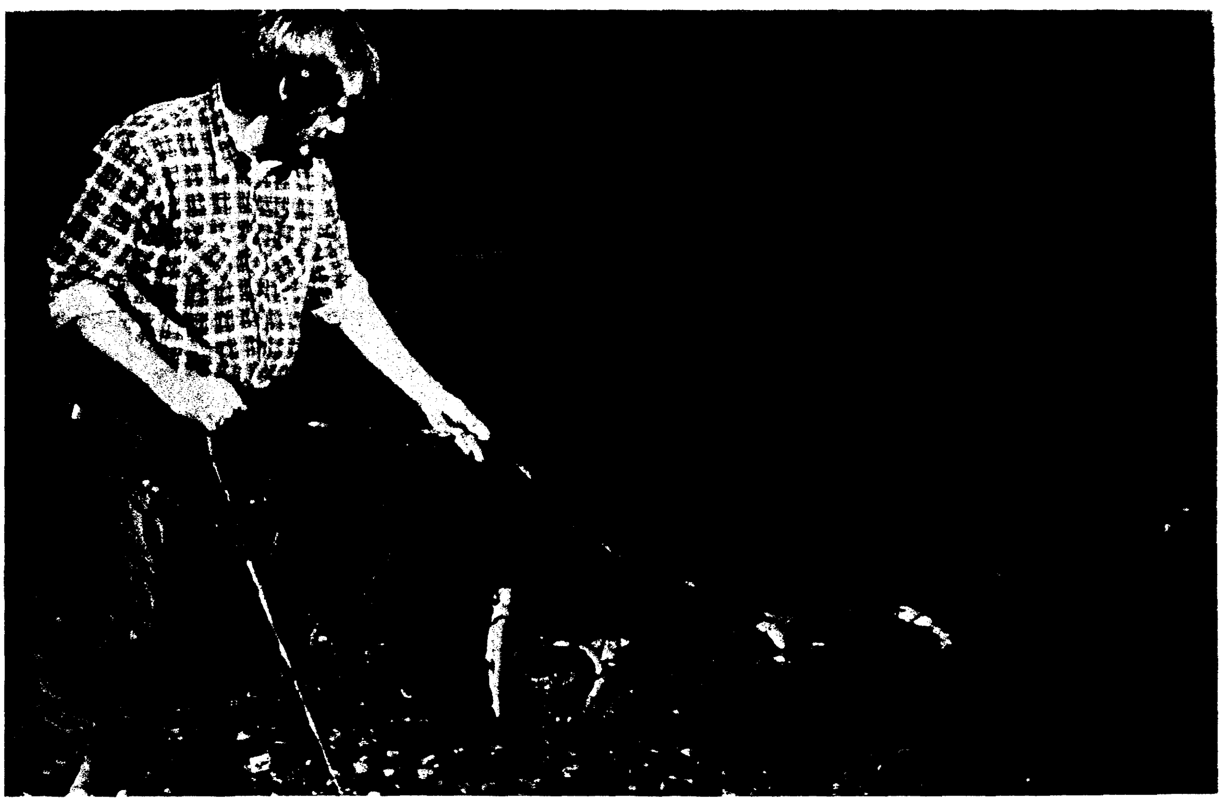

PLATE 2.3-1 *Researchers have conducted fisheries investigations in the Mackenzie Valley for over ten years in response to several proposed projects. Here a biologist is shown removing a gillnet laden with Arctic grayling and round whitefish from a tributary stream. (Courtesy, Aquatic Environments Ltd).*

TABLE 2.3-4

FISH SPECIES OF THE MACKENZIE RIVER VALLEY NORTH OF 60° LATITUTDE.

Common Name	Code	Scientific Name	Type[1]	Spawning Period[2]
Arctic lamprey	ARLM	Lampetra japonica (Martens)	A	S
Chum salmon	CHUM	Oncorhynchus keta (Walbaum)	A	F
Arctic char	CHAR	Salvelinus alpinus (Linnaeus)	A	F
Dolly Varden	DOLL	Salvelinus malma (Walbaum)	A	F
Lake trout	LKTR	Salvelinus namaycush (Walbaum)	F	F
Lake cisco	LKCS	Coregonus artedii (Le Sueur)	F	F
Arctic cisco	ARCS	Coregonus autumnalis (Pallas)	A	F
Least cisco	LSCS	Coregonus sardinella (Valenciennes)	A	F
Humpback whitefish	HMWT	Coregonus clupeaformis (Mitchill)	A	F
Broad whitefish	BDWT	Coregonus nasus (Pallas)	A	F
Round whitefish	RDWT	Prosopium cylindraceum (Pallas)	A	F
Mountain whitefish	MTWT	Prosopium williamsoni (Girard)	F	F
Inconnu	INCO	Stenodus leucichthys nelma (Pallas)	A	F
Arctic grayling	GRAY	Thymallus arcticus (Pallas)	F	S
Pond smelt	PONS	Hypomesus olidus (Pallas)	F	S
Boreal smelt	BORS	Osmerus eperlanus (Linneaus)	A	S
Goldeye	GOLD	Hiodon alosoides (Rafinesque)	F	S
Northern pike	PIKE	Esox lucius (Linneaus)	F	S
Northern redbelly dace	RBDC	Chrosomus eos (Cope)	F	S
Finescale dace	FNDC	Chrosomus neogeus (Agassiz)	F	S
Lake chub	LKCB	Couesius plumbeus (Agassiz)	F	S
Emerald shiner	EMSR	Notropis atherinoides (Rafinesque)	F	S
Spottail shiner	SPSR	Notropis hudsonius (Clinton)	F	S
Fathead minnow	FDMW	Pimephales promelas (Rafinesque)	F	S
Flathead chub	FLCB	Platygobio gracilis (Richardson)	F	S
Longnose dace	LNDC	Rhinichthys cataractae (Valenciennes)	F	S
Pearl dace	PLDC	Semotilus margarita (Cope)	F	S
Longnose sucker	LNSK	Catostomus catostomus (Forster)	F	S
White sucker	WHSK	Catastomus commersoni (Lacépede)	F	S
Burbot	BURB	Lota lota (Linneaus)	F	W
Brook stickleback	BKST	Culea inconstans (Kirtland)	F	S
Ninespine stickleback	NNST	Pungitius pungitius (Linnaeus)	F	S
Trout-perch	TRPH	Percopsis omiscomaycus (Walbaum)	F	S
Yellow perch	YWPH	Perca flavescens (Mitchill)	F	S
Yellow walleye	WALL	Stizostedion vitreum vitreum (Mitchill)	F	S
Slimy sculpin	SLSC	Cottus cognatus (Richardson)	F	S
Spoonhead sculpin	SPSC	Cottus ricei (Nelson)	F	S
Fourhorn sculpin	FHSC	Myoxocephalus quadricornis quadricornis (Linneaus)	M	S

[1]Type: A - Anadromous
F - freshwater
M - marine

[2]Spawning period: S - spring
F - fall
W - winter

In addition to these anadromous species, the Mackenzie Delta also supports anadromous boreal smelt (which spawn during spring in the fresh water of the Delta), pond smelt and several marine species which are occasionally captured on the outer Delta, particularly fourhorn sculpin and Pacific herring. All of these marine species occasionally use outer Delta habitats and do not occur further south.

Based on information from McCart *et al.* (1974) and some recent unpublished data, Table 2.3-5 summarizes the known distribution of fish in major waterbodies within the Valley south of the Mackenzie Delta. Arctic grayling are the most widely distributed species, closely followed by northern pike, longnose suckers, lake chub and slimy sculpin. Other species, including lake cisco, white sucker, emerald shiner, finescale dace, mountain whitefish, Dolly Varden char and yellow walleye only occur south of Norman Wells in habitats which are near the northern limit of their geographic ranges.

The relative abundance of fish along the Mackenzie Valley corridor is highly variable, depending on the size of the watercourse, the habitat type, the season, the other species present and other factors. Stein *et al.* (1973a,b) reported that, overall, northern pike were the most abundant species in gillnet catches from the larger tributaries and low-gradient regions of the mainstem Mackenzie River, despite the wider distribution of Arctic grayling throughout this region. On the other hand, in smaller streams, particularly within the southern portion of the corridor, Arctic grayling, longnose sucker, lake chub and slimy sculpin were more abundant (Shotton, 1971, 1973; McCart *et al.*, 1974). North of Norman Wells ciscos and whitefish (as well as northern pike) were particularly abundant (Stein *et al.*, 1973a,b; Slaney, 1975; de Graaf and Machniak, 1977).

The relative abundance of some fish species varies seasonally within the Mackenzie River system. For example, relatively non-migratory species such as northern pike, burbot, longnose and white suckers, walleye, and lake trout vary only slightly in seasonal abundance, while the numbers of anadromous species (including Arctic char, ciscos and whitefish) and highly migratory freshwater species (such as Arctic grayling) may fluctuate dramatically.

2.3.4.2 Life History Information of Common Species

The following provides a brief summary of the life histories of major fish species within the Mackenzie Valley. Life history information for anadromous species are also described in Volume 3A. The locations of places named in the text appear in Figure 2.3-1.

(a) Arctic Char

Within the Northwest Territories, the Western subspecies of Arctic char (McPhail, 1961) (Plate 2.3-2) is found only in the western portion of the Mackenzie Delta and its tributaries including the Big Fish River, the Rat River, and the lower Peel River (McCart and Bain, 1974; Jessop *et al.*, 1974; Jessop and Lilley, 1975). Both freshwater-resident and anadromous Arctic char populations are present, but only anadromous forms are found in the Delta.

The life history of anadromous Arctic char in the Northwest Territories and Yukon was summarized by McCart (1980) while Marshall (1977) compiled a survey of earlier relevant studies. Maximum ages reported for anadromous Arctic char are less than 10 to 14 years and their maximum size is rarely greater than 600 mm. The age at first reproduction for anadromous Arctic char ranges from 4 to 6 years (Plate 2.3-3). In all populations studied to date the percentage of spawning fish present each year is low, ranging from 2 to 15%, and mature individuals commonly spawn once every 2 or 3 years (Hunter, 1970; Campbell and Johnson, 1976; Sopuck, 1977; de March *et al.*, 1977).

Anadromous Arctic char typically spend their first 2 to 5 years in fresh water before undertaking the first seaward migration (Craig and McCart, 1975; Kendal *et al.*, 1975). Seaward migration begins in May or June (about the time of river break-up), while upstream migration from coastal waters occurs from mid summer to early fall (Stein *et al.*, 1973a,b; Bain, 1974; Glova and McCart, 1974). The major autumn run of Arctic char to Husky Channel of the Mackenzie River Delta occurs during late August and early September (Stein *et al.*, 1973a,b), and they overwinter in freshwater pools of western Mackenzie River tributary streams. Most Arctic char captured in the Mackenzie Delta enroute to spawning streams during the autumn had empty stomachs, indicating that they may cease feeding during migration (de Graaf and Machniak, 1977).

(b) Lake Trout

Lake trout, a species of char, are among the largest (up to 30 kg) and longest-lived of any freshwater species in the Northwest Territories (Plate 2.3-4). Because of its large size and palatability, lake trout are highly sought after by sport, subsistence and commercial fishermen.

Lake trout are primarily found in deep lakes and occasionally in rivers within the Mackenzie Valley. Marshall and Keleher (1970) prepared a bibliography on the distribution and economic utilization of lake trout, while their life history was summarized by McCart and Den Beste (1979).

TABLE 2.3-5

DISTRIBUTION OF FISH SPECIES IN WATERBODIES OF THE MACKENZIE VALLEY CORRIDOR

Four Letter Fish Codes are Identified in Table 2.3-4.

Locations indicated on FIGURE 2.3-1. (Sources identified in text).

Streams Within Corridor	Location	ARLM	CHAR	DOLL	LKTR	LKCS	ARCS	LSCS	HMWT	BDWT	RDWT	MTWT	INCO	GRAY	PONS	GOLD	PIKE	RBDC	FNDC	LKCB	EMSR	SPSR	FLCB	LNDC	LNSK	WHSK	BURB	NNST	TRPH	WALL	SLSC	SPSC
Kakisa River	1													X			X			X		X			X			X	X	X		
Trout Lake	2				X	X	X				X		X	X			X								X		X			X		
Trout River	3					X			X		X			X			X			X				X	X	X				X	X	
Jean-Marie Creek	4								X			X		X			X		X	X	X	X			X	X	X	X	X	X	X	
Spence River	5					X			X					X			X				X				X							
Rabbitskin River	6	X				X			X		X	X	X	X			X			X	X	X		X	X	X	X		X	X	X	X
Bluefish Creek	7													X			X															
Harris River	8								X	X				X			X			X	X				X					X		
Trail River	9												X	X			X			X		X	X	X	X				X	X		
Willowlake River	10					X			X		X	X		X			X	X		X	X	X			X	X	X		X	X	X	
River Between Two Mountains	11				X				X		X	X		X			X			X		X		X	X		X			X	X	
Smith Creek	12																								X						X	
Tributary to Hodgson Creek	13													X																	X	
Hodgson Creek	14										X			X						X		X			X					X	X	
Ochre River	15										X		X	X			X			X			X		X	X	X		X	X	X	
Noname Creek (40-1, South Fork)	16										X			X						X					X						X	
Noname Creek (40-1, North Fork)	17													X																	X	
Blackwater River	18										X			X						X		X			X						X	
Unnamed Tributary to Blackwater River	19			X							X			X																	X	
Birch Island Creek	20													X			X						X				X				X	
Saline River	21										X			X			X			X		X	X		X						X	X
Little Smith Creek	22			X						X	X			X			X			X			X		X		X			X	X	
Big Smith Creek	23										X	X		X			X			X					X				X		X	
St. Charles Creek	24												X	X			X			X					X				X		X	
Brackett River	25		X					X			X	X		X								X		X	X	X	X		X		X	
Great Bear River	26	X			X		X	X	X		X	X	X	X		X	X			X		X	X	X	X		X		X	X	X	
Bear Rock Lake	27				X																											
Bluefish Creek	28		X	X			X		X	X			X	X			X			X		X	X		X			X	X		X	X
Jungle Ridge Creek	29										X			X			X			X					X				X		X	
Nota Lake	30													X						X					X							
Nota Creek	31										X			X						X					X						X	
Kelly Lake	32				X				X					X																		
Vermillion Creek	33					X	X		X	X	X		X	X			X			X			X		X		X		X	X	X	
Prohibition Creek	34						X		X	X	X			X						X		X			X				X		X	X
Helava Creek	35													X			X			X											X	X
Francis Creek	36													X						X											X	
Canyon Creek	37												X	X						X					X						X	
Bosworth Creek	38																			X				X	X		X	X	X		X	
Billy Creek	39																X														X	
Esox Lake	40																X															
Chain Lakes Outlet	41																X															
Oscar Creek	42	X				X	X			X	X	X	X	X			X	X		X			X	X	X	X	X	X	X	X	X	
Elliot Creek	43													X						X											X	
Carcajou Ridge Lake	44				X												X															
Moon Lake	45								X		X			X			X										X				X	

(continued)

Streams Within Corridor	Location	ARLM	CHAR	DOLL	LKTR	LKCS	ARCS	LSCS	HMWT	BDWT	RDWT	MTWT	INCO	GRAY	PONS	GOLD	PIKE	RBDC	FNDC	LKCB	EMSR	SPSR	FLCB	LNDC	LNSK	WHSK	BURB	NNST	TRPH	WALL	SLSC	SPSC
Jack Lake	46																X															
Hanna River	47												X	X			X			X			X		X		X		X	X	X	
Dieter Creek	48													X																		
Gibson Creek	49													X																		
Chick Lake	50										X			X			X								X		X				X	
Chick Creek	51													X			X															
Donnelly River	52						X		X	X	X		X	X			X			X					X		X		X	X	X	
Gilbert Lake	53																X															
Snafu Creek	54													X	X		X								X							
Tsintu River	55						X		X					X			X			X					X					X	X	
Hare Indian River	56								X	X	X			X			X			X				X	X	X	X		X		X	
Bluefish River	57								X					X			X			X					X					X	X	
Loon Lake	58							X		X							X			X					X			X				
Loon River	59						X	X	X	X				X			X			X				X	X			X				
Yeltea Lake	60				X			X	X					X			X											X				
Tieda River	61				X				X		X			X			X			X					X			X				
Payne Creek	62													X																		
Thunder River	63				X				X	X	X			X	X		X								X							
Travaillant River	64								X				X	X						X					X			X	X	X		
Rengleng River	65							X		X			X	X	X		X			X		X			X		X		X	X	X	X
Loche Lake	66								X								X															
Jiggle Lake	67				X			X	X								X										X					
Deep Lake	68				X			X	X								X															
Sandy Lake	69				X				X	X				X			X															
Point Lake Outlet	70													X	X		X															
Highpoint Lake Outlet	71													X			X															
Caribou Creek	72								X					X	X														X			
Caribou Lake	73								X																							
Unnamed Tributary to Campbell Lake	74																X															
Miner River	75													X																		
Norris Creek	76													X																		
Noell Lake Outlet	77													X			X															
Island Lake Outlet	78													X																		
Peter Lake	79				X			X	X	X	X	X		X																		
Most Southerly Wolverine Lake	80													X																		
Wolverine Lake	81				X					X							X										X					
Unnamed Lake (Holmes Creek Inlet)	82				X					X	X																					
Holmes Creek	83							X	X					X			X															

(Table 2.3-5 continued)

The growth of lake trout in Great Slave Lake (Falk *et al.*, 1973), Great Bear Lake (Falk *et al.*, 1974), Lac La Martre (Bond, 1973), Kaminuriak Lake (Bond, 1975), and Ya-Ya Lake (Machniak, 1977; McCart *et al.*, 1979) is slow. They have a long life-span, some individuals being 30 years of age and others up to 60 years old, or more. Falk *et al.* (1973) reported a gradual decline in growth rate with increasing latitude.

Studies by Johnson (1972, 1976) indicated that many northern lake trout populations experience very low adult mortality, possessing a large number of old mature fish (greater than 10 years) with mean lengths of 500 to 600 mm. Recruitment of juveniles is usually low (McCart and Den Beste, 1979). Studies in the Northwest Territories indicate that earliest spawning occurs at age 8 and that some individuals do not spawn until age 22 (Falk *et al.*, 1973, 1974; McCart *et al.*, 1979). These studies also show that mature northern lake trout usually spawn only in alternate years or every third year, further limiting the reproductive potential of the species.

Lake-dwelling populations commonly move into shallow water less than 12 m deep to spawn, usually using coarse rock or rubble substrates (Scott and Crossman, 1973). Spawning occurs as early as mid August in Great Bear Lake (Miller and Kennedy,

PLATE 2.3-2 *Within the Northwest Territories, the Western sub-species of Arctic char shown here, is found only in the western portion of the Mackenzie Delta and its tributaries including the Big Fish, Rat and lower Peel rivers. (Courtesy, Aquatic Environments Ltd.).*

PLATE 2.3-3 *The age at first reproduction of anadromous Arctic char, a male shown here, ranges from 4 to 6 years. They typically spend their first 2 to 5 years in fresh water before heading out to sea for the first time. (Courtesy, Aquatic Environments Ltd.).*

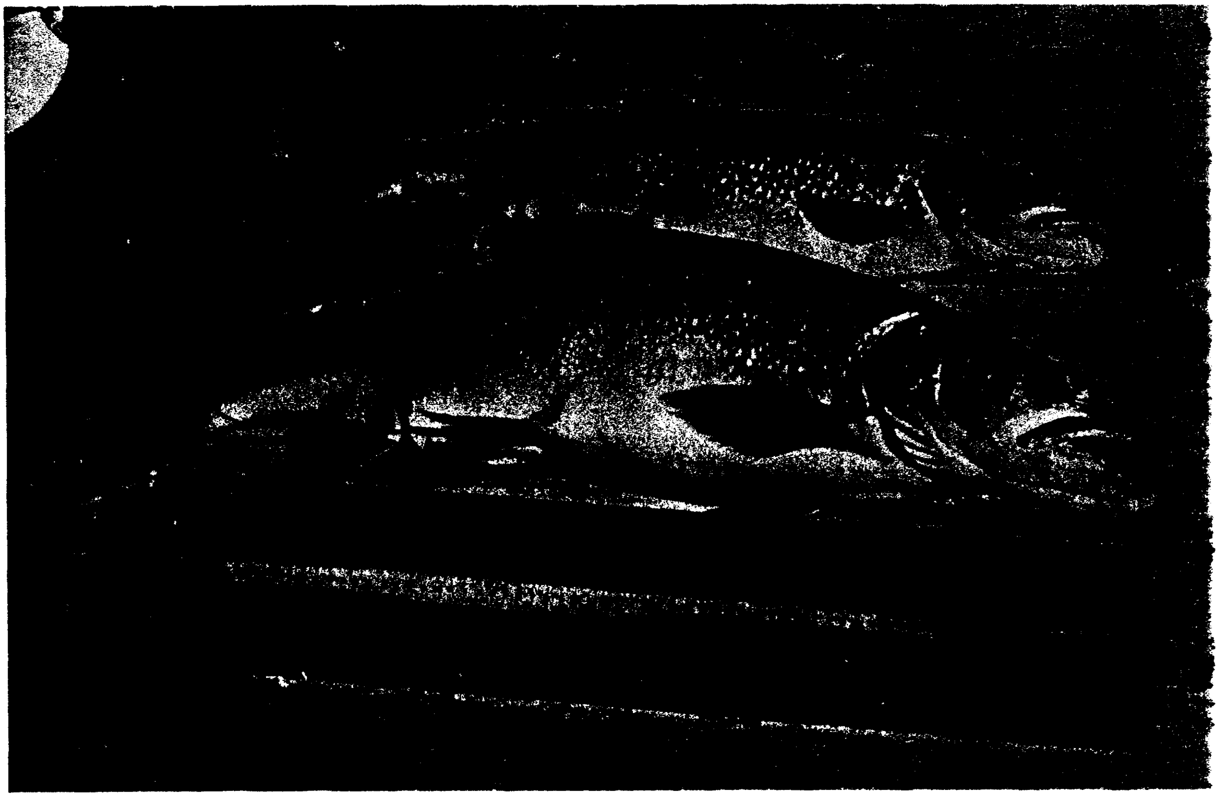

PLATE 2.3-4 *Lake trout, a species of char, are among the largest (up to 30 kg) and longest-lived of any freshwater species in the Northwest Territories. In the Mackenzie Valley, they are found mainly in deep lakes and occasionally in some of the rivers. (Courtesy, Aquatic Environments Ltd.).*

1948), but most authors report that spawning in northern areas occurs in late September or October. Little is known about spawning of stream-dwelling populations in the Mackenzie River mainstem or the Great Bear River. While there is some evidence that lake trout return to the same spawning areas, homing is generally considered to be incomplete (Martin, 1960). This, combined with the wide-ranging movements of the species, suggests that natural mixing of stocks and recolonization could offset impacts to local populations should they occur.

Juvenile lake trout feed predominantly on crustaceans and fish fry, while adults feed on other fish. Ciscos and whitefish are their most common prey, although many other species have been found in lake trout stomachs. Populations which feed exclusively on crustaceans are slower growing, have a smaller maximum size and have a shorter lifespan than populations feeding mainly on fish (Martin, 1960). Machniak (1977) and McCart *et al.* (1979) reported the occurrence of a slow-growing population in Ya-Ya Lake on the Mackenzie Delta.

(c) Broad and Humpback Whitefish

Whitefish comprise the greatest percentage of the total domestic fish harvest in the entire Mackenzie Valley (McCart and Den Beste, 1979). Broad and humpback whitefish make up the vast majority caught, but a few round whitefish are taken in the extreme southern part of the Mackenzie Valley.

The life histories of broad and humpback whitefish are similar, but the growth rates of both species vary greatly depending on their habitat and migratory behaviour. Mackenzie Delta populations are semi-anadromous, reaching sizes of 600 to 700 mm at maximum ages of 15 to 25 years. Within semi-anadromous populations, some undergo brief feeding migrations into brackish coastal waters, often using these waters as migration corridors to summer feeding areas in other coastal streams and lakes. Lake-dwelling and other completely freshwater forms of both species are generally somewhat slower growing than are semi-anadromous populations (Percy, 1975). Broad whitefish tend to be larger than humpback whitefish in the Mackenzie drainage system, and are more sought after in the Mackenzie Delta fisheries (Section 2.5.2).

Broad whitefish in the Mackenzie Delta mature as early as 3 to 4 years of age (Percy, 1975) or as late as 7 to 10 years of age (de Graaf and Machniak, 1977). There is evidence that spawning of Mackenzie Delta populations occurs during October in back eddies of the Mackenzie River near Arctic Red River (Jessop *et al.,* 1974) and in the lower reaches of the Peel River

(Jessop and Lilley, 1975). The upstream spawning migration through the Mackenzie Delta peaks in late September or early October (Stein *et al.*, 1973a,b; Jessop *et al.*, 1974; Jessop and Lilley, 1975; de Graaf and Machniak, 1977) and it is during this period that most of the annual domestic harvest is taken.

The life history of humpback whitefish in the lower Mackenzie River Delta has been described by Hatfield *et al.* (1972), Stein *et al.* (1973a,b), Jessop *et al.* (1974), Jessop and Lilley (1975), Percy (1975) and de Graaf and Machniak (1977). Whitefish movements to and from coastal summer feeding, spawning and overwintering areas are generally confined to the Mackenzie Delta area, but include the Beaufort Sea coast and upper Delta tributaries such as the Peel and Arctic Red rivers (Volume 3A, Section 3.4). Such movements occur within relatively restricted time periods, usually during the spring and autumn, and, as with broad whitefish, most of the annual domestic harvest occurs during the autumn.

The spawning success and early recruitment of Mackenzie River migratory whitefish populations are not well known. Fry and young juveniles are abundant in Delta lakes and channels, as well as near the mouths of several lower Mackenzie River tributaries (Jessop *et al.*, 1974; Jessop and Lilley, 1975; de Graaf and Machniak, 1977). Studies of Mackenzie River humpback whitefish indicate that they may reach sexual maturity between 7 and 20 years of age. Unlike broad whitefish or other anadromous species, humpback whitefish appear to spawn almost every year (de Graaf and Machniak, 1977; Percy, 1975).

(d) Arctic Cisco, Least Cisco and Lake Cisco

Ciscos, particularly Arctic and least ciscos, comprise a major portion of the domestic fish harvests of northern portions of the Mackenzie Valley corridor. Arctic cisco are generally faster growing and live longer than do other cisco species (Craig and Mann, 1974; Griffiths *et al.*, 1975, 1977; Jones and Den Beste, 1977). While Arctic cisco may reach 500 mm in length, the maximum sizes of least cisco and lake cisco rarely exceed 350 mm. Because of their larger size, Arctic cisco are more desirable in domestic fisheries.

Both Arctic and least cisco are anadromous, migrating to coastal waters during the open water season. Some lake populations of least cisco are non-migratory, remaining in fresh water throughout their lives (Mann, 1974). These non-migratory least cisco generally grow more slowly than migratory least cisco. Lake cisco are almost exclusively restricted to lakes in the southern portion of the Mackenzie drainage, although some populations are known to enter the sea in the eastern Arctic (Scott and Crossman, 1973).

All cisco species spawn in the autumn when water temperatures decline. Spawning areas for Arctic cisco have not been documented, but spawning is believed to occur on gravel substrates in tributaries of the Mackenzie River such as the Peel and Great Bear rivers. Least cisco and lake cisco spawn in both lakes and rivers on sand or gravel substrates.

In freshwater habitats ciscos usually feed on zooplankton, particularly copepods, although some aquatic and terrestrial insects are also taken. Ciscos provide important links in food chains as prey for larger fish such as northern pike, Arctic char and lake trout.

(e) Inconnu

Inconnu occur throughout the Mackenzie drainage system. Some populations are anadromous, entering coastal waters near the Mackenzie Delta during the summer months. Studies of the life history of inconnu in the Northwest Territories have been done by Hatfield *et al.* (1972), Stein *et al.* (1973), Jessop *et al.* (1974, 1975), Percy (1975), de Graaf and Machniak (1977) and Jones and Den Beste (1977).

Inconnu are the largest and fastest growing of the whitefish species. Individuals ranging from 5 to 15 kg in weight are common in Mackenzie Delta fisheries and specimens exceeding 20 kg have been taken in Great Slave Lake (Scott and Crossman, 1973). Females live longer and grow bigger than males (Alt, 1969), and de Graaf and Machniak (1977) reported that all fish in the Mackenzie Delta older than age 14 were females. Maximum ages for inconnu caught in the Northwest Territories are 22 years for the Mackenzie Delta (Stein *et al.*, 1973a,b) and 11 years for Great Slave Lake (Fuller, 1955). Inconnu mature between the ages of 6 and 14, with most individuals maturing between 8 and 11 years of age (de Graaf and Machniak, 1977).

Spawning movements of inconnu are not well known in the Northwest Territories. It has been reported that an upstream migration of both anadromous and non-anadromous spawners begins in late June in most areas and continues throughout the summer (Stein *et al.*, 1973a,b; Jessop *et al.*, 1974). Although tributaries of the Peel River, Arctic Red River, Rengleng River, Pierre Creek, Oscar Creek, Big Buffalo River, Taltson River, Slave River, Little Buffalo River and Hay River are suspected to be spawning areas, there have been no direct observations of spawning activity (Scott and Crossman, 1973; Stein *et al.*, 1973a,b; Jessop *et al.*, 1974; de Graaf and Machniak, 1977). In Alaska spawning occurs in late September in swift water with depths from 1.5 to 1.8 m over coarse gravel substrates (Alt, 1969). After spawning a large downstream run has been reported in rivers draining into Great Slave Lake and in the lower Mackenzie River. Mature inconnu are believed to spawn every 2 to 4 years, and they seldom venture into marine environments in the year of spawning (de Graaf and Machniak, 1977; Jones and Den Beste, 1977). Juveniles are abundant in coastal waters during the summer season, but return to fresh water to overwinter.

Inconnu feed primarily on fish, including other whitefish and smaller inconnu. In some areas inconnu are reported to gorge themselves with small inconnu (Scott and Crossman, 1973). The species also preys on northern pike, ninespine sticklebacks, sculpins and pond smelt (de Graaf and Machniak, 1977). Crustaceans and insects have been reported in inconnu stomachs from the Mackenzie River, but these items have generally been eaten along with fish.

(f) Arctic Grayling

The Arctic grayling is widely distributed in the Mackenzie River Valley (Plate 2.3-5). The most comprehensive data on the growth, reproduction, and food habits originate from studies conducted at Chick Lake (Aquatic Environments Limited, unpublished data) and Vermillion Creek (D. Tripp, unpublished data) in the Mackenzie Valley corridor. Information on the Donnelly River Arctic grayling population by Tripp and McCart (1974) and on Arctic grayling in Yukon coastal streams by de Bruyn and McCart (1974) were also used for the following life history summary.

Arctic grayling are considered too small for commercial fishing, but they are an important sportfishing resource. Domestic fishermen harvest the species during spring spawning runs and in the autumn when large aggregations gather in preparation for overwintering. The species is rarely taken in brackish waters as their migrations are generally restricted to between spawning and overwintering areas in tributaries of the Mackenzie system and in the Mackenzie River mainstem.

Growth of Arctic grayling is relatively slow, with mature individuals seldom exceeding 500 mm in fork length. Individuals generally mature by age 7, the maximum age being from 15 to 20 years. Spawning occurs in small tributary streams every year once maturity is reached.

Arctic grayling young-of-the-year and small juveniles feed in small tributaries, while adults feed in larger tributaries and in the mainstem of the Mackenzie River. Small lakes within the corridor are also used as summer feeding habitat. Food of Arctic grayling includes stream drift organisms, surface insects and, in some instances, juvenile Arctic grayling. It is thought that the use of different portions of watercourses by juvenile and adult Arctic grayling may limit competition between age groups.

PLATE 2.3-5 *Arctic grayling are widely distributed in the Mackenzie River Valley and are the most abundant fish in most small tributary streams along the corridor. (Courtesy, Aquatic Environments Ltd.).*

(g) Other Species

Northern pike (Plate 2.3-6), yellow walleye and longnose suckers are harvested in some commercial, domestic or sports fisheries. These species spawn in a wide variety of habitats within the Mackenzie system and all three species spawn in the spring, normally at the mouths of tributary streams or in lake shallows. Longnose suckers prefer clear swift-flowing streams with gravel substrates, while northern pike and walleye select areas of flooded vegetation. In the Mackenzie Valley these species grow more slowly than they do in more temperate latitudes. However, all three species are among the fastest growing freshwater fish in the Mackenzie River system. Northern pike commonly reach sizes of 600 to 900 mm by age 10 and they have been known to reach 26 years of age (de Graaf and Machniak, 1977), while longnose suckers average 400 mm at age 12 and have been reported to reach 22 years of age (Tripp and McCart, 1974). Yellow walleye commonly reach lengths of 500 mm and maximum ages from 15 to 18 years (Hatfield *et al.*, 1972).

Information on the growth and reproduction of other fish species of the Mackenzie River drainage system is sparse. Most species are widely distributed throughout the system but are of little importance to domestic and commercial fisheries.

2.3.5 SENSITIVE FISH HABITATS AND LIFE HISTORY STAGES

Pipeline construction in the Mackenzie Valley has the potential for affecting fish in ways which depend on the species, on the timing of the activity and on the type of habitat. Fish populations are generally considered susceptible during spawning, incubation, emergence, rearing, overwintering and migration. During other phases of their lives large juvenile and adult fish are widely dispersed and are not as sensitive to environmental disturbances.

During environmental studies related to previous development proposals in the Mackenzie Valley, sensitive fish habitats were identified in many waterbodies which intersect the Mackenzie Valley corridor. Table 2.3-6 summarizes the available information on such habitats for the larger waterbodies within and near the corridor. Information for the following summary is based on Shotton (1971, 1973), Hatfield *et al.* (1972), Stein *et al.* (1973a,b), McCart *et al.* (1974), McCart and McCart (1982a) and unpublished information from Aquatic Environments Limited. Table 2.3-6 emphasizes only those areas which have received intensive study and does not necessarily reflect all of the sensitive habitats within or near the corridor.

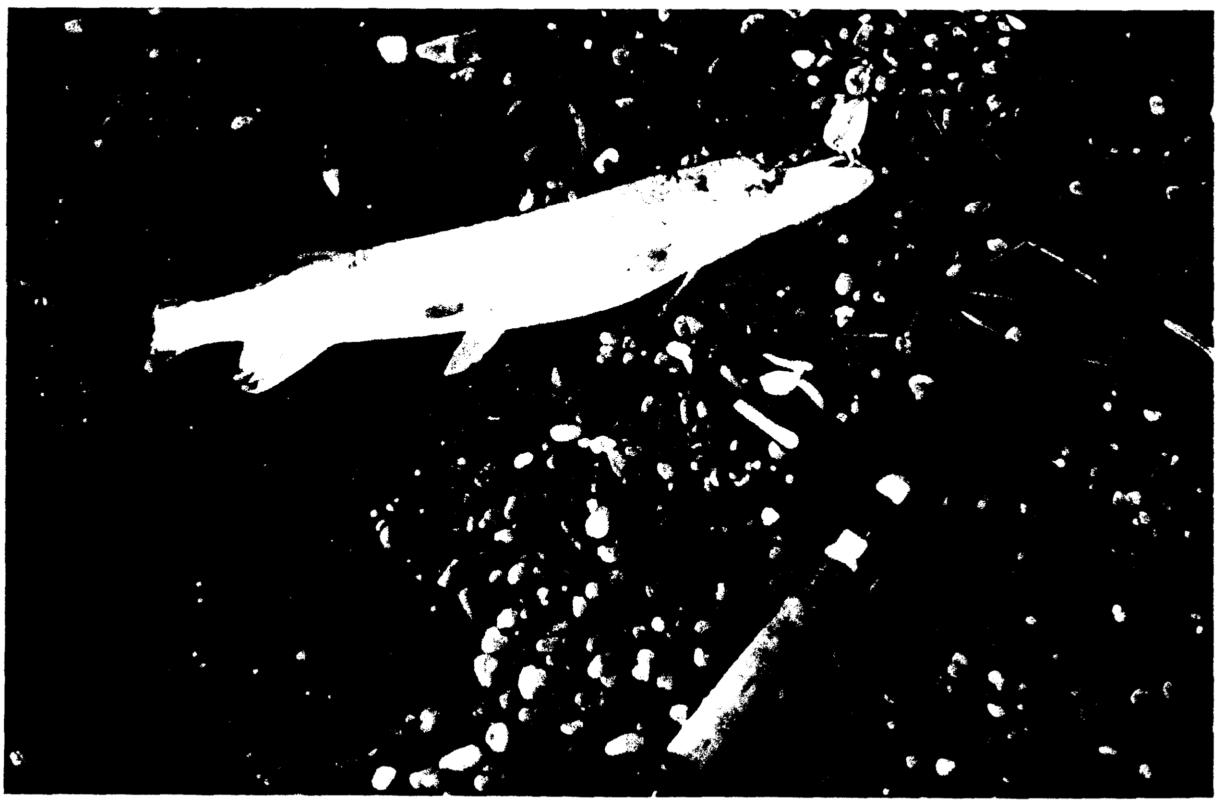

PLATE 2.3-6 *The northern pike is one of the other fish species which is harvested in some commercial, domestic or sports fisheries in the area of the Mackenzie Valley corridor. (Courtesy, Aquatic Environments Ltd.).*

TABLE 2.3-6

KNOWN HABITAT UTILIZATION OF MAJOR WATERBODIES SAMPLED TO DATE IN THE MACKENZIE VALLEY CORRIDOR
Four Letter Fish Codes are Identified in Table 2.3-4.

Data are from McCart *et al.* (1974) and unpublished Aquatic Environments Limited information. Locations indicated on FIGURE 2.3-1.

Streams Within the Mackenzie Valley Corridor	Location	Habitat Use and Sensitivity
Kakisa River	1	S[1] (GRAY, PIKE, LNSK, WALL); Srs[4] (fall spawners); F[8] (PIKE, LKCB, TRPH)
Trout Lake	2	Ss[2](LKTR, HMWT, PIKE, WALL); Sr[3](PIKE, LNSK, BURB, WALL); W[10](LKTR, LKCS, ARCS, RDWT, INCO, GRAY, PIKE, LNSK, BURB, WALL)
Trout River	3	S, N[5](GRAY, PIKE, LKCB, LNSK, WALL); F; Ws[11]
Jean-Marie Creek	4	Sr(*Coregonus* spp., *Prosopium* spp., GRAY, PIKE, *Catostomus* spp., WALL); S; F; N; W
Spence River	5	S, N(GRAY, PIKE, EMSR, LNSK); F
Rabbitskin River	6	S(MTWT, GRAY, PIKE, LNSK, WHSK, WALL); Ss(GRAY, Chub spp., BURB, TRPH, SLSC, SPSC); N(HMWT, GRAY, PIKE, LNDC TRPH); F, R[7](HMWT, INCO, PIKE, LNSK); W
Bluefish Creek	7	Ss(GRAY, PIKE); N(GRAY)
Harris River	8	Ss(WALL); S(GRAY, PIKE, LNSK); N(BDWT, HMWT, PIKE, LNSK); Ws
Trail River	9	S(GRAY, PIKE, LNSK); Ss(WALL); N(GRAY, LNSK, WALL); F; Ws
Willowlake River	10	S(RDWT, GRAY, PIKE, LNSK; M[9]; F(LKCS, HMWT, PIKE, RBDC, LKCB, EMSR, SPSR, LNSK, WHSK, BURB, TRPH, WALL, SLSC); W
River Between Two Mountains	11	S(RDWT, GRAY, LNSK, SLSC); Si[12](LNDC, SLSC); N(MTWT, LNSK); R(RDWT, GRAY, SLSC); F(RDWT, GRAY, PIKE, SLSC); W; Sr
Smith Creek	12	Ss; Ns[6]; Fs; Ws
Tributary to Hodgson Creek	13	S(GRAY, SLSC); F(GRAY)
Hodgson Creek	14	S(RDWT, GRAY, LKCB, LNSK, SLSC); N(LKCB, LNSK); Ns(GRAY); R(GRAY, PIKE, LKCB, LNSK, SLSC); F(GRAY, PIKE, LKCB, LNSK, SLSC); Ws
Noname Creek (40-1, South Fork)	16	S(GRAY, LKCB, SLSC); Ss(*Prosopium* spp.); R(GRAY, LKCB, SLSK); F(GRAY); Ws
Noname Creek (40-1, North Fork)	17	S, R, F, W(GRAY, SLSC)
Blackwater River	18	S(GRAY, SLSC); R(GRAY, SLSC); F(GRAY, LKCB, SPSR, LNSK, SLSC); M(GRAY, whitefishh spp.); Ws
Unnamed Tributary to Blackwater River	19	S(GRAY, SLSC); N; F(*Salvelinus* spp.): Ws(GRAY, SLSC)
Birch Island Creek	20	S(GRAY, SLSC); R(GRAY); F(GRAY, FLCB, SLSC); Ws(GRAY, SLSC)

(Table 2.3-6 continued)

Streams Within the Mackenzie Valley Corridor	Location	Habitat Use and Sensitivity
Saline River	21	Si(*Prosopium* spp., GRAY, LKCB, LNSK, SLSC); R(*Prosopium* spp., GRAY, LKCB, LNSK, SLSC); F(*Prosopium* spp., GRAY, LKCB, LNSK, SLSC); W(*Prosopium* spp., GRAY, LNSK)
Little Smith Creek	22	S(GRAY, LKCB, LNSK, BURB, WALL); Ss(RDWT); N; F(DOLL, RDWT, GRAY, PIKE, LKCB, FLCB, LNSK, SLSC); Ws
Big Smith Creek	23	S(GRAY, LKCB, SLSC); Ns; R(LKCB, SLSC); F(GRAY, PIKE); Ws
St. Charles Creek	24	S, N(GRAY)
Brackett River	25	Sr(Whitefish spp.); N; F; W
Great Bear River	26	Ss(ARCS, RDWT, INCO, GRAY, PIKE, LKCB, LNSK, BURB, Stickleback spp., Sculpin spp.); N(LKTR); Ns (ARCS, RDWT, INCO, GRAY PIKE, LKCB, LNSK, BURB, Stickleback spp., Sculpin spp.); Ms(GRAY, RDWT, INCO, GRAY, PIKE)
Bear Rock Lake	27	S, N, F, W(LKTR)
Bluefish Creek	28	*N(HMWT, BDWT)
Jungle Ridge Creek	29	S, R, F(GRAY, LNSK, SLSC)
Nota Lake	30	F(GRAY); Fi(LKCB, LNSK)
Nota Creek	31	S(GRAY, SLSC); R(GRAY, LKCB, SLSC); F(GRAY, LKCB, SLSC); Fi(LNSK)
Kelly Lake	32	S; N; F; W
Vermilion Creek	33	S(GRAY, LKCB, LNSK, SLSC); *N(ARCS, HMWT, BDWT, GRAY, WALL); R(GRAY, LKCB, LNSK, SLSC); F(HMWT, BDWT, RDWT, INCO, GRAY, FLCB, LNSK, BURB, TRPH, SLSC); W(GRAY, SLSC)
Prohibition Creek	34	S(GRAY, LKCB, SLSC); *N(HMWT, BDWT); R(GRAY, LKCB, SLSC); F(ARCS, HMWT, BDWT, RDWT, GRAY LKCB, SPSR, LNSK, TRPH, SLSC, SPSC); R(GRAY, LKCB, SLSC)
Helava Creek	35	S(LKCB, SLSC); F(GRAY, PIKE, LKCB, SLSC, SPSC); R(LKCB, SLSC)
Francis Creek	36	S(GRAY, SLSC); R(GRAY, SLSC); F(GRAY, LKCB, SLSC)
Canyon Creek	37	S, N(GRAY, LKCB, SLSC); F(GRAY, LKCB, LNSK, SLSC); Ws
Bosworth Creek	38	S(GRAY, LNSK); N; F(INCO, GRAY, LKCB, LNDC, LNSK, BURB, NNST, TRPH, SLSC)
Billy Creek	39	S, R, W(PIKE)
Esox Lake	40	S, R, F(PIKE)
Chain Lakes Outlet	41	Assessment unavailable
Oscar Creek	42	S, R, F(GRAY, LKCB, LNSK, WHSK); Srs(GRAY, PIKE, LNSK, WALL); N(Whitefish spp.); Ws
Elliot Creek	43	S, R, F(GRAY, LKCB, SLSC); Ws
Carcajou Ridge Lake	44	Ss, F, W(LKTR, PIKE)

(Table 2.3-6 continued)

Streams Within the Mackenzie Valley Corridor	Location	Habitat Use and Sensitivity
Moon Lake	45	S, R, F(GRAY); Ss, F(RDWT); Ws(HMWT, RDWT, GRAY, PIKE, BURB, SLSC)
Jack Lake	46	Ss, Rs(PIKE); F, W(PIKE)
Hanna River	47	S, F, Ws(GRAY, SLSC, PIKE); N(GRAY)
Dieter Creek	48	S, R(GRAY)
Gibson Creek	49	Ss, Ws(GRAY); Ns, Fs
Chick Lake	50	S, R, F(GRAY, PIKE, LNSK, BURB); Ws(PIKE, BURB)
Chick Creek	51	S, R, F(GRAY); F(PIKE)
Donnelly River	52	S, N, F(GRAY); Ss(RDWT, INCO, LKCB, TRPH, WALL); S(PIKE); S, N(LNSK)
Gilbert Lake	53	S, R, W(PIKE)
Snafu Creek	54	S, R(GRAY, PIKE, LNSK); F(SLSC)
Tsintu River	55	S, R(GRAY, LNSK, WALL, SLSC, PIKE)
Hare Indian River	56	S, N(GRAY, LNSK); F, W, M
Bluefish River	57	S, N, F, W
Loon Lake	58	Ss(LSCS, BDWT, Stickleback spp.); Fs(LNSK); Ws
Loon River	59	S, N(GRAY, PIKE, LNDC, LNSK); Ss(Cisco spp., Whitefish spp., LKCB, NNST); N(Cisco spp., Whitefish spp.); Ws
Yeltea Lake	60	Ss, W(LKTR, Whitefish spp., Stickleback spp.); N, F
Payne Creek	62	S, N(GRAY)
Thunder River	63	S, N, W(LKTR, HMWT, BDWT, RDWT, GRAY)
Travaillant River	64	Ss(GRAY, LNSK); R(LNSK)
Rengleng River	65	S, N(HMWT, BDWT, GRAY, PIKE); Ns(WALL); Ss(LNSK, BURB, WALL)
Loche Lake	66	Suggested use by burbot
Jiggle Lake	67	S, F, W(LKTR, LSCS, HMWT, PIKE, BURB)
Deep Lake	68	S, R, F(LKTR, LSCS, HMWT, PIKE)
Sandy Lake	69	S, F, W(LKTR, HMWT, BDWT, GRAY, PIKE)
Point Lake Outlet	70	S, R(GRAY, PIKE); F(Whitefish spp., PONS)
Highpoint Lake Outlet	71	S, R(GRAY); F(PIKE)
Caribou Creek	72	S, N(GRAY); F(HMWT, GRAY, PONS, TRPH)
Caribou Lake	73	Utilized by humpback whitefish
Unnamed Tributary to Campbell Lake	74	Sr(Whitefish spp.); utilization by northern pike
Miner River	75	S, F, N(GRAY)
Norris Creek	76	S, F, N(GRAY)
Noell's Lake Outlet	77	S, N(GRAY); R(PIKE)
Island Lake Outlet	78	S, N, F(GRAY)
Peter Lake	79	S, R(LKTR, LSCS, Whitefish spp.), F(GRAY); Ws; utilized by *Coregonus* spp.

(Table 2.3-6 continued)

Streams Within the Mackenzie Valley Corridor	Location	Habitat Use and Sensitivity
Most Southerly Wolverine Lake	80	F(GRAY); Ws
Wolverine Lake	81	Ss, F(LKTR, BDWT, PIKE, BURB)
Unnamed Lake (Holmes Creek Inlet)	82	S, R, W(LKTR, BDWT, RDWT)
Holmes Creek	83	S, R(GRAY); F(Whitefish spp., PIKE); Ms(LSCS)

[1] S - spawning
[2] Ss - suspected spawning
[3] Sr/M - spawning run/migratory route
[4] Srs/Ms - suspected spawning run/suspected migratory route
[5] N - nursery
[6] Ns - suspected nursery
[7] R - rearing
[8] F - summer feeding
[9] Fi - incidental feeding
[10] W - conditions suitable for overwintering
[11] Ws - possible overwintering/conditions appear suitable for overwintering
[12] Si - incidental spawning
* unable to distinguish between humpback and broad whitefish, therefore both present

(Table 2.3-6 continued)

2.3.5.1 Migration

The most important migration routes within the Mackenzie Valley corridor are the Mackenzie Delta channels, the mainstem of the Mackenzie River and the Great Bear River. Several tributaries on the west bank of the Mackenzie River are also known to be important migration routes.

Large numbers of anadromous fish, including a large proportion of spawners, swim downstream through the Mackenzie Delta at spring break-up, enroute to coastal waters. They generally return upstream to fresh water beginning in mid summer (Volume 3A, Section 3.4). Most of these anadromous fish, including Arctic char, ciscos, whitefish and inconnu, are autumn spawners. With the exception of Arctic char, these species concentrate in lower portions of the Mackenzie River mainstem during August and September (Stein *et al.,* 1973a,b). It is reported that Arctic cisco move upstream as far as Norman Wells during their spawning migrations. After spawning, they return downstream to their overwintering areas (Stein *et al.,* 1973a,b).

During spring and summer, spring spawners usually migrate short distances from the Mackenzie River mainstem and its larger tributaries into spawning areas in smaller tributaries, or from overwintering areas to summer feeding habitats. Concentrations of Arctic grayling and longnose suckers have been seen in small clear tributary streams within the corridor (Stein *et al.,* 1973a,b; McCart *et al.,* 1974; Tripp and McCart, 1974). Migrations of northern pike and yellow walleye are even shorter, often involving movements within a single watercourse in search of suitable spawning habitat. Post-spawning movements of adults to the Mackenzie River mainstem and larger tributaries are usually in late June. Migration from smaller tributaries to larger overwintering watercourses by summer resident adult and juvenile grayling occurs during the autumn (Stein *et al.*, 1973a, b). Ripe boreal smelt have been caught on the Mackenzie Delta through the ice (Mann, 1975; Percy, 1975), but little is known of their movements before, during or after spawning.

2.3.5.2 Spawning

Despite extensive sampling efforts in the Mackenzie River system spawning areas for many species have not yet been identified. Hatfield *et al.* (1972) classified areas of potential spawning habitat in major sub-drainages within the Mackenzie system but actual use of these areas remains unknown. High turbidity, brief spawning periods, poor access, and the large geographic area have hindered the definition of many spawning areas and the number of fish using them. However, observations of emerging juveniles, spawned-out fish and large pre and post-spawning migrations (in addition to a limited number of actual spawning observations), have enabled identification of the spawning streams listed in Table 2.3-6.

Spring-spawning species such as northern pike and longnose suckers spawn during periods of high stream discharge following spring break-up. This also coincides with high concentrations of suspended solids in the larger watercourses. As a result, Stein *et al.* (1973a,b) reported that some spring-spawning species such as Arctic grayling, yellow walleye and occasionally longnose suckers, may prefer spawning in clearer tributaries of the Mackenzie River to increase their spawning success. Young-of-the-year of spring spawners emerge from gravel or weed beds in July and move into nearby nursery areas. Spawning sites may, in part, depend on the availability of suitable nursery areas (Doran, 1974), and therefore streams may be sensitive to disturbances for long periods when spawning areas are close to nursery habitats.

Fall spawning species such as lake trout, ciscos, whitefish and inconnu may deposit eggs at any time during the autumn or winter. Eggs remain in the gravel over winter, with fry emerging at break-up in the spring. Owing to harsh conditions, including low oxygen concentrations, low stream discharges and ice scour, which may reduce survival in many areas, and because of the relatively long period of incubation (up to 7 or 8 months), eggs of fall spawning species are considered more vulnerable to environmental disruption than those of species which spawn in spring.

Streams which provide habitat for both spring and fall spawners are more sensitive to environmental disturbances throughout most of the year. Only during the late summer would these habitats be relatively insensitive.

As summer is shorter in the northern Mackenzie Valley than it is the southern region, there is a difference in timing for the onset of both spring and fall spawning. Spring spawning in the north is delayed by about two weeks, while northern fall spawning is earlier by about the same amount of time (Stein *et al.*, 1973a,b).

Table 2.3-6 lists the spawning streams within the Mackenzie Valley corridor. The Mackenzie River mainstem undoubtedly serves as a spawning area for several species, including whitefish, ciscos, northern pike, suckers, dace, shiners, chubs, sticklebacks, and trout-perch. Many of these species are believed to spawn in the river's back-eddies. Stein *et al.* (1973a,b) and McCart *et al.* (1974), and McCart (1982) also identified many suspected spawning areas within the corridor. However, numbers of fish using these areas are not completely known.

2.3.5.3 Nursery Areas

Most lakes and streams which provide spawning habitat (Table 2.3-6) also provide nursery areas, although many small unnamed streams which do not support spawning appear to be used extensively as nursery areas, particularly for Arctic grayling, slimy sculpin, northern pike and longnose suckers.

Studies by de Graaf and Machniak (1977) indicate that the Mackenzie River Delta is a major nursery habitat for whitefish and ciscos which spawn upstream in the Mackenzie, Peel or Arctic Red rivers (Stein *et al.*, 1973a,b). Side channels and backwaters of the Mackenzie River mainstem also support relatively large numbers of young-of-the-year northern pike, longnose suckers, walleye, burbot and several other species (Stein *et al.*, 1973). Tributaries of the Great Bear River provide nursery habitat for Arctic grayling, northern pike, Arctic cisco, round whitefish, inconnu, longnose suckers, burbot, lake chub and other incidental species (Dryden *et al.*, 1973; McCart *et al.*, 1974), while many smaller tributary streams near Norman Wells provide nursery habitat primarily for Arctic grayling (D. Tripp, unpublished data). In the southern Mackenzie Valley the Trout, Jean-Marie, Martin, and Willowlake rivers provide nursery habitat for northern pike, yellow walleye and longnose suckers. Large numbers of juvenile whitefish also inhabit the latter three rivers (Stein *et al.*, 1973a,b; McCart, 1974).

2.3.5.4 Overwintering

Table 2.3-6 lists the known overwintering areas in the Mackenzie Valley corridor (McCart, 1974; McCart *et al.*, 1974; AEL, unpublished data).

Most of the data regarding overwintering habitat were collected in relation to the routing of the proposed Canadian Arctic Gas Pipeline. A recent winter survey along the Interprovincial Pipeline (NW) Limited route from Norman Wells to Zama Terminal verified many of the earlier findings (McCart and McCart, 1982b). The most important overwintering habitats appear to be in spring-fed streams, in lakes, in the Mackenzie River mainstem, in the Mackenzie Delta, and in larger tributaries with a year-round discharge. Overwintering potential elsewhere in the corridor is less well known. Stein *et al.* (1973a,b) classified the Mackenzie Delta as a "sensitive habitat," primarily owing to its ability to support fish through the winter. A later study of the Delta confirmed this, as whitefish and cisco species were reported to be very abundant in this region (Mann, 1975).

2.4 VEGETATION

Primary sources of Mackenzie Valley vegetation descriptions are reports by the Forest Management Institute (1972, 1974), Wallace (1972), and documents prepared for the Canadian Arctic Gas Study by Reid (1974), Reid and Janz (1974) and Gubbe and Janz (1974). Other sources of information were a description of vegetation types in the southwestern District of Mackenzie (Raup, 1947), a vegetation report for the proposed Interprovincial Pipeline corridor (Hardy Associates, 1980) and a description of vegetation along the Liard and Mackenzie rivers (Hardy Associates, 1981). Various descriptions of the terrain and landscape of the Mackenzie Valley were also utilized.

Maps of vegetation types of the Mackenzie Valley are available from the Forest Management Institute (1974), while maps for particular areas within the Valley are provided by Reid and Janz (1974) and Gubbe and Janz (1974).

Other general flora references used include those by Raup (1946), Cody (1960, 1963), Jeffrey (1961), Hulten (1968), Porsild and Cody (1968, 1980), Bird (1977), and Jasienuik and Johnson (1979). Vascular plants having restricted ranges in the Northwest Territories were catalogued by Cody (1979). Finally, forest resources of the Mackenzie Valley were described by Robinson (1960), Zoltai and Pettapiece (1973), and Hirvonen (1975).

To assist the reader the scientific and common name for each of the plant species discussed is provided in Table 2.4-1.

2.4.1 PRINCIPAL VEGETATION TYPES

The Mackenzie Valley corridor extends southward from the Mackenzie Delta to the border between Alberta and the Northwest Territories, crossing four geographic sections of the boreal forest region of Canada as defined by Rowe (1972). These sections are the lower Mackenzie, northwest transition, upper Mackenzie and Hay River sections (Figure 2.4-1).

The lower Mackenzie forest section includes the Valley and inner Delta of the Mackenzie River from near Reindeer Depot southward to Norman Wells, and is the least forested section. Stunted black spruce trees occur on large expanses of level, poorly drained terrain. Alaska birch is common on uplands together with some aspen and balsam poplar. White spruce trees up to 23 metres tall are found on some well drained benchlands, but they are generally scrubby within this forest section.

The northwest transition section extends along the east side of the Mackenzie Valley and is crossed by a short segment of the corridor between Fort Simpson and Willowlake River. It represents an area of transition between the Arctic tundra and forests further south. Within this forest section, bog, muskeg and barren rock are intermixed with open stands of dwarfed trees, principally black spruce. The distribution, abundance and size of these trees are reduced compared with those of regions further south.

The upper Mackenzie forest section includes the riverine forests of the Mackenzie Valley from Norman Wells south to the Alberta border. There are balsam poplar forests and excellent harvestable white spruce on alluvial flats and low terraces along the river (Rowe, 1972). Higher terraces and uplands are covered primarily by large patches of jack pine and aspen forest with occasional white spruce.

A small portion of the corridor lies within the Hay River forest section. This includes the uplands south of Fort Simpson to the Alberta border and is primarily characterized by black spruce forests, although lodgepole pine forests are also found.

The principal vegetation communities found within the aforementioned forest sections of the Mackenzie Valley are described below. The vegetation classification system used was developed for the Canadian Arctic Gas Study by Reid (1974), Reid and Janz (1974) and Gubbe and Janz (1974). These are compared with vegetation types described by other authors, particularly Jeffrey (1964) and the Forest Management Institute (1974). The geography of these vegetation communities was derived primarily from maps prepared by the Forest Management Institute (1974).

As described below, the vegetation of the Mackenzie River Valley is divided into 8 major vegetation types comprising a total of 19 principal plant communities (Reid, 1974; Reid and Janz, 1974; Gubbe and Janz, 1974).

2.4.1.1 Closed Coniferous Forest

The 'closed coniferous forest' is dominated by coniferous trees more than 2 metres tall with their crowns touching or overlapping. It is most extensive on uplands but is also found on alluvial flats adjacent to rivers and major streams. Four vegetation communities are found in this forest type (Reid, 1974; Reid and Janz, 1974). Two of these communities occur primarily on riparian sites, while the remaining two are found on uplands.

TABLE 2.4-1

COMMON AND SCIENTIFIC NAME EQUIVALENTS FOR PLANT SPECIES MENTIONED IN VEGETATION DESCRIPTIONS OF MACKENZIE VALLEY AREA

TREE SPECIES	
Aspen	Populus tremuloides Michx.
Birch, Alaska	Betula neoalaskana Sarg.
Birch, white	Betula papyrifera Marsh.
Pine, jack	Pinus banksiana Lamb.
Pine, lodgepole	Pinus contorta Dougl.
Poplar, balsam	Populus balsamifera L.
Spruce, black	Picea mariana (Mill.) B.S.P.
Spruce, white	Picea glauca (Moench.) Voss
Tamarack	Larix laricina (Du Roi) K. Koch
SHRUB SPECIES	
Alder, green	Alnus crispa (Ait.) Pursh
Alder, river	Alnus sinuata (Reg.) Rydb.
Birch, shrub	Betula glandulosa Michx.
Cinquefoil, shrubby	Potentilla fruticosa L.
Cranberry, lowbush	Viburnum edule (Michx.) Rag.
Dogwood, red-osier	Cornus stolonifera Michx.
Labrador tea	Ledum groenlandicum Oeder
Rose, prickly	Rosa acicularis Lindl.
Rosemary, bog	Andromeda polifolia L.
Soapberry	Shepherdia canadensis (L.) Nutt.
Willow	Salix spp. L.
Willow, Bebb's	Salix bebbiana Sarg.
Willow, feltleaf	Salix alaxensis (Anderss.) Cov.
Willow, glaucous	Salix glauca L.
Willow, plane-leaf	Salix planifolia Pursh
Willow, sandbar	Salix interior Rowlee
Willow, Scouler's	Salix scouleriana Barratt
HERB AND DWARF SHRUB SPECIES	
Avens, mountain	Dryas integrifolia M. Vahl.
Bastard toadflax	Geocaulon lividum (Richards.) Fern.
Baked-apple berry	Rubus chamaemorus L.
Bearberry, alpine	Arctostaphylos rubra (Rehd. & Wils.) Fern.
Bearberry, common	Arctostaphylos uva-ursi (L.) Spreng.
Blueberry, alpine	Vaccinium uliginosum L.
Buckbean	Menyanthes trifoliata L.
Bunchberry	Cornus canadensis L.
Camas, white	Zygadenus elegans Pursh.
Cinquefoil, marsh	Potentilla palustris (L.) Scop.
Cottongrass	Eriophorum spp. L.
Cranberry, small bog	Oxycoccus microcarpus Turez.
Fireweed	Epilobium angustifolium L.
Gale, sweet	Myrica gale L.

(continued)

TABLE 2.4-1 (Cont'd)

COMMON AND SCIENTIFIC NAME EQUIVALENTS FOR PLANT SPECIES MENTIONED IN VEGETATION DESCRIPTIONS OF MACKENZIE VALLEY AREA

Hedysarum	Hedysarum alpinum L.
Horsetail	Equisetum spp. L.
Horsetail, bog	Equisetum fluviatile L.
Horsetail, common	Equisetum arvense L.
Horsetail, woodland	Equisetum sylvaticum L.
Leather-leaf	Chamaedaphne calyculata (L.) Moench
Lingonberry	Vaccinium vitis-idaea L.
Rush, scouring	Equisetum scirpoides Michx.
Rush, spike	Eleocharis spp. R. Br.
Sedge	Carex spp. L.
Sedge, aquatic	Carex aquatilis Wahlenb.
Sundew	Drosera anglica Huds.
Twinflower	Linnaea borealis L. (Richards.) Fern.
Wintergreen	Pyrola spp. L.
Wintergreen, one-sided	Pyrola secunda L.
MOSS AND LICHEN SPECIES	
Feathermoss	Pleurozium schreberi (Brid.) Mitt.
	Hylocomium splendens (Hedw.) B.S.G.
	Ptilium crista-castrensis (Hedw.) De Not.
Feathermoss, layered	Hylocomium splendens (Hedw.) B.S.G.
Lichen	general; includes one or several of:
	Alectoria spp.
	Cetraria spp.
	Cladina spp.
	Cladonia spp.
	Parmelia spp.
	Stereocaulon paschale (L.) Hoffm.
	Thamnolia subuliformis (Ehrh.) W. Culb.
Moss, aulacomnium	Aulacomnium acuminatum (Lindb. et Arn.) Par.
Moss, campylium	Campylium spp. (Sull.) Mitt.
Moss, drepanocladus	Drepanocladus spp. (C. Mull.) Roth
Moss, scorpidium	Scorpidium scorpoides (Hedw.) Limpr.
Moss, sphagnum	Sphagnum spp. L.

(a) White Spruce/Rose/Feathermoss Community

The 'white spruce/rose/feathermoss' community is generally composed of white spruce with a mixture of deciduous trees including aspen, balsam poplar and white birch but may contain only pure stands of white spruce. The shrub layer beneath is moderately dense, composed mainly of river alder and prickly rose. Principal herbaceous and dwarf shrub species include bunch berry, bastard toad flax, horsetail, twinflower and bog cranberry. These are rooted in a thick carpet of mosses.

The 'white spruce/rose/feathermoss' community occurs predominantly on riparian sites in the southern Mackenzie Valley. Most of these sites are periodically flooded and, as a result, have relatively fertile, moderately well to imperfectly drained soils with alternating layers of alluvial silt and organic materials. Permafrost may occasionally occur within a metre of the surface where there is a dense spruce cover. Aspen trees are important only where active soil layers are thick or permafrost is absent. This

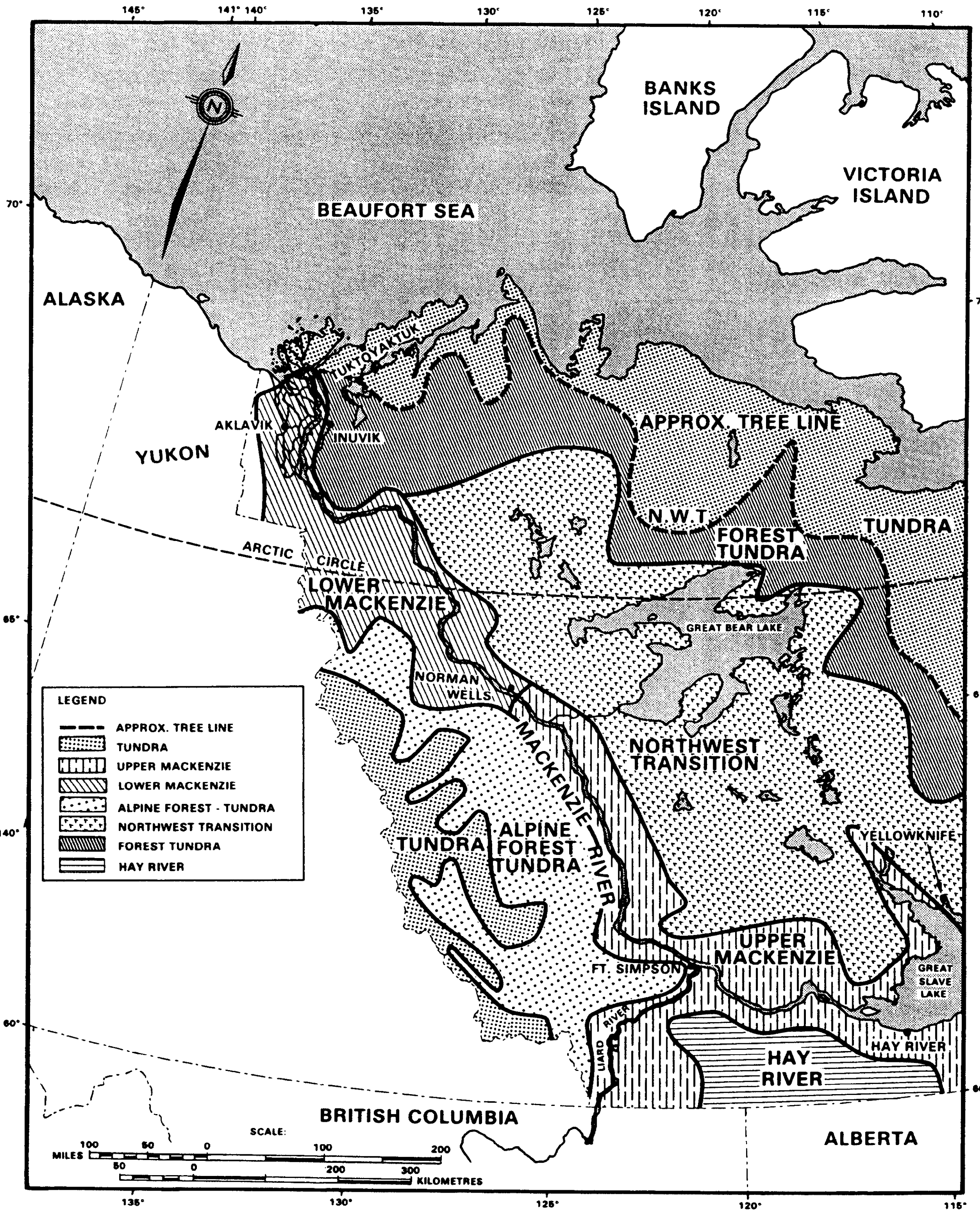

FIGURE 2.4-1 *The Mackenzie Valley corridor crosses four geographic sections of the boreal forest region of Canada. These are the lower Mackenzie, northwest transition, upper Mackenzie and Hay River sections.*

vegetation community is relatively rare within the corridor compared with other communities. It occurs primarily south of Fort Norman and is usually only found on narrow bands and patches of floodplain next to major rivers and streams. It is closely associated with the riparian 'balsam poplar/river alder/-

horsetail' and 'willow-alder/horsetail' communities which are found on recently deposited soils on levees and point bars.

[Jeffrey (1964) described two riparian forest types which were dominated by white spruce, the 'white spruce-balsam poplar' forest and the 'white spruce-white birch' forest. Both were characterized by a dense moss under-layer dominated by feathermosses and a shrub over-layer of primarily river alder and rose. Also, the Forest Management Institute (1974) described a riparian 'spruce-hardwoods' vegetation type which was very similar to the 'white spruce/-rose/feathermoss' community described by Reid and Janz (1974), and was the major riparian forest type in the southern part of the Mackenzie Valley.]

(b) White Spruce/Feathermoss Community

The 'white spruce/feathermoss' community has almost pure stands of white spruce which may contain widely scattered white birch trees, but rarely has aspen or balsam poplar. The shrub layer is usually sparse, being composed primarily of river alder and prickly rose. Principal herb and dwarf shrub species include bastard toad flax, wintergreen, and bog cranberry, which are rooted in a thick continuous carpet of mosses.

This vegetation community is confined to narrow bands bordering alluvial floodplains of major rivers and streams and is usually found in the central and northern portions of the Mackenzie Valley. In the southern Valley it grows on older, higher alluvial surfaces that are less frequently flooded than are areas where the 'white spruce/rose/feathermoss' community is found.

[The Forest Management Institute (1974) described a riparian 'spruce-feathermoss' vegetation type which was associated with older alluvial soils, but in which black spruce and white spruce were the principal canopy trees, while sphagnum mosses and Labrador tea were the main undergrowth plants where permafrost was close to the surface.]

(c) Black Spruce/Feathermoss Community

Dense stands of short to moderately tall black spruce trees are the main components of the 'black/spruce/-feathermoss' community (Plate 2.4-1). Other tree species, particularly white spruce, tamarack and white birch, occasionally grow within the forest canopy. The shrub layer is sparse to moderately dense and in southern parts of the Mackenzie Valley contains prickly rose and green alder (Reid and Janz, 1974). Further north Labrador tea and alpine blue-

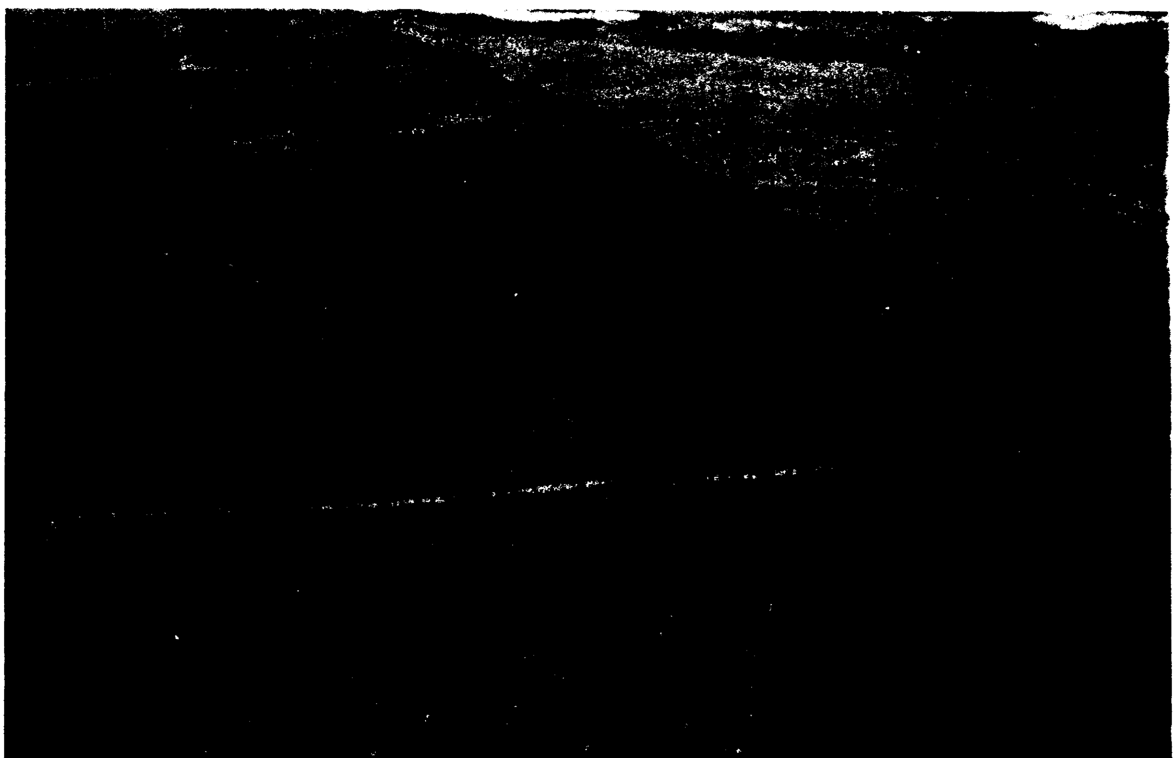

PLATE 2.4-1 *Closed to open forests of black spruce mixed with tamarack typify the area just north of Norman Wells. This photo also shows the effects of forest fires on the vegetation. (Courtesy, Hardy Associates, 1978, Ltd.)*

berry become increasingly common (Reid, 1974). The herbaceous layer is usually sparse. In the more southern areas principal herbs and dwarf shrubs include horsetail, bog cranberry and twinflower (Reid and Janz, 1974). In the central and northern Mackenzie Valley bearberry forms much of the herbaceous layer (Reid, 1974). The ground surface is covered by layered feathermoss on moist soils, and tomenthypnum moss and scattered lichens on wetter soils. The 'black spruce/feathermoss' community is most extensive on moderately well to imperfectly drained silt loam to silty clay soils of upland forests where the landforms are glaciolacustrine, till and outwash plains. Soils associated with this community have an organic layer 10 to 15 cm thick (in the southern Valley) and up to 30 cm thick in the northern Valley, (Reid, 1974; Reid and Janz, 1974).

[The Forest Management Institute (1974) described an 'upland spruce/feathermoss' vegetation type which is very similar to the 'black spruce/feathermoss' community described above except that the principal canopy species was white spruce. Aspen was reported to be a common component of this vegetation type south of Norman Wells, while white birch was more common north of here.]

(d) Lodgepole or Jack Pine/Soapberry/Twinflower Community

The upland 'lodgepole or jack pine/soapberry/twin flower' community occurs only as far north as Fort Norman within the Mackenzie Valley corridor. Here it is composed primarily of jack pine, while further south near Fort Simpson lodgepole pine, jack pine and their hybrid are present (Reid and Janz, 1974). The shrub layer is primarily green alder in the northern areas of the Valley, while near Fort Simpson soapberry is more common. Prickly rose and Labrador tea are ubiquitous. The dwarf shrub-herbaceous under-layer is characterized by twinflower in the north and bearberry in the south. Bog cranberry, bunchberry and wintergreen are found in the sparse herbaceous layer throughout the range of this vegetation community. These forest communities grow on moderately well to rapidly drained upland soils developed on till, thin till over bedrock and glaciofluvial outwash deposits. These soils are sandy to silty clay in texture. Pine forest communities associated with till deposits are commonly found on well drained, mounds within poorly drained organic terrain supporting sparse black spruce communities.

[The Forest Management Institute (1974) described an 'upland spruce (or pine)/hardwoods, vegetation type. South of Fort Norman this community was frequently dominated by pine and was similar to a pine vegetation community described by Reid and Janz (1974). North of Fort Norman it is dominated by white and black spruce, and often grows on moderately well to rapidly drained sites following a fire.]

2.4.1.2 Closed Deciduous Forest

The 'closed deciduous' forest is characterized by a closed canopy of winter deciduous trees and a few evergreen species. Principal trees are trembling aspen, balsam poplar and white birch. Shrubs are a major component of the undergrowth vegetation (Reid and Janz, 1974). Four 'closed deciduous' forest communities, as published by Reid (1974) and Reid and Janz (1974) are described below. The 'closed deciduous' forest includes the deciduous-dominated portions of the 'riparian spruce-hardwood' and 'upland spruce (or pine)-hardwood' types described by Forest Management Institute (1974).

(a) Balsam Poplar/River Alder/Horsetail Community

The 'balsam poplar/river alder/horsetail' riparian community is found on narrow bands of floodplain beside major rivers and creeks. Balsam poplar dominates the forest canopy, varying in height from tall shrubs (under 8 m) to tall trees (over 15 m). The shrub layer is mainly composed of river alder with some stems reaching heights of 11 m. The herbaceous under-layer is characterized by a vigorous growth of horsetail. Mosses and lichens are sparse or absent. Soils under this vegetation are alluvial deposits of moderately well to imperfectly drained silts, sands and gravels, which usually show evidence of frequent flooding in the form of alternating mineral and organic layers. Most sites where this community exists are annually or periodically flooded making the soils relatively fertile. Permafrost is more than two metres below the surface (Reid, 1974). These riparian balsam poplar forests usually form a narrow band between the closed scrub community of willow and alder on recently exposed alluvial deposits and the riparian white spruce forests on older soils. At seven locations near the central Mackenzie and lower Liard rivers, balsam poplar forests were found at 6.9 to 7.8 m above the August river level (Hardy Associates, 1981).

[Jeffrey (1964) identified and described two pure balsam poplar forests on recent floodplains of the lower Liard River. Both were similar to the 'balsam poplar/river alder/horsetail' community described by Reid (1974) and Reid and Janz (1974). Riparian balsam poplar forest communities were included in the 'riparian spruce/hardwood' vegetation type of the Forest Management Institute (1974).]

(b) Trembling Aspen/Rose Community

Within the Mackenzie Valley corridor, the 'trembling aspen/rose' community is most often found south of Wrigley (Reid and Janz, 1974). Balsam poplar and white birch may also be found within this community but they are rarely as numerous as aspen. These trees are all about the same age. Stands are dense when the trees are young, but they thin out with increasing age. The shrub undergrowth is moderately dense, being composed primarily of prickly rose and green alder with some soapberry and low bush cranberry. The herb and dwarf shrub layer is composed of bunchberry, bog cranberry and twinflower. Though occasionally present, mosses do not often form a ground cover. Aspen forests are less extensive than other upland forests such as 'white spruce-aspen mixed' forests, but occur on a wide variety of landforms including glaciofluvial plains, till plains and bedrock uplands. Their soils are usually well to imperfectly drained, consisting of loamy sands to silt-loams. On well drained uplands, aspen forests are usually associated with 'white spruce-trembling aspen' forests, while on imperfectly drained sites they accompany 'open black spruce' forest. Aspen forests occur on relatively warm sites (Zoltai and Pettapiece, 1973). Permafrost is usually more than a metre below the surface (Forest Management Institute, 1974).

[The Forest Management Institute (1974) included aspen forests within the 'upland spruce (or pine)-hardwood' vegetation type. This included both coniferous and deciduous forests on well drained uplands.]

(c) White Birch/Willow Community

'White birch' forests occur throughout most of the central and southern Mackenzie Valley, but they are not widespread (Reid, 1974; Reid and Janz, 1974). The forest canopy is usually a pure stand of white birch of uniform density but of variable height. On well drained sites prickly rose is a main component of the shrub layer, while on moister sites Bebb's willow and Scouler's willow dominate. The dwarf shrub-herbaceous under-layer is frequently dominated by bunchberry, bog cranberry and horsetail. Mosses and plant litter cover much of the soil surface. 'White birch' forest communities usually grow in small isolated areas in association with ponds and small lakes, peatland mounds or till slopes adjacent to bedrock ridges (Reid, 1974; and Reid and Janz, 1974). Soils under this community vary from well drained silts and sands to imperfectly drained clays. Permafrost is usually found within 1 m of the surface. 'White birch' forests are frequently associated with sedge fen, black spruce peatland, or closed spruce forests on palsas.

[According to Jeffrey (1964), white birch was very common in the lower Liard River area, but seldom formed pure stands except where a fire had occurred on older floodplains. The Forest Management Institute (1974) included white birch forest in the 'upland spruce (or pine)-hardwood vegetation type.]

2.4.1.3 Closed Mixed Forest

The 'closed mixed forest' vegetation type includes forests in which both tall evergreen and deciduous trees form the overstory, with their crowns touching or overlapping. Tree species which are usually dominant or codominant include white spruce, trembling aspen, white birch, black spruce and tamarack. The undergrowth is usually composed of shrubs, dwarf shrubs and mosses (Reid, 1974; Reid and Janz, 1974).

[The Forest Management Institute (1974) did not separate 'mixed forest' from 'evergreen forest' or 'deciduous forest,' including the 'closed mixed' forest type in their 'upland spruce (or pine)-hardwood' type.]

(a) White Spruce-Trembling Aspen/Alder Community

The 'white spruce-trembling aspen/alder' community is dominated by a mixture of white spruce and trembling aspen. Younger stands contain more aspen, while older stands contain more spruce. The shrub under-layer is moderately dense and is mainly green alder, prickly rose, low bush cranberry and soapberry. In older spruce-dominated communities the density of the shrub layer is reduced. The dwarf shrub-herbaceous layer includes bunchberry, bastard toad flax, fireweed, bog cranberry and twinflower. The density of dwarf shrubs and herbs is also low in spruce-dominated communities, while the density of mosses, especially layered feathermoss, is correspondingly high.

This vegetation community is usually found on uplands of the Alberta Plateau and southern Mackenzie Valley south of Fort Norman. It covers extensive areas on till plains, on thin till over bedrock, on glaciofluvial outwash plains and on deltas and ancient high terraces. Soils under this community are highly variable, but are most commonly well to imperfectly drained sandy loam to silty clay.

[Jeffrey (1964) described eight 'white spruce-aspen mixed forest' vegetation types along the lower Liard River, distinguished from one another largely by landform, soil texture and soil acidity. In most cases, green alder, low bush cranberry and rose dominated the shrub layer, while bunchberry and twinflower were the principal species of the dwarf shrub-herbaceous layer. The 'white spruce-white birch/alder' community was contained within the 'upland spruce (or pine)-hardwood' type described by the Forest Management Institute (1974).

(b) White Spruce-White Birch/Alder Community

White spruce and white birch form most of the overstory in the 'white spruce-white birch/alder' community (Reid, 1974). The shrub layer is moderately dense, being dominated by green alder, but the dwarf shrub-herbaceous under-layer is very sparse. The ground is covered primarily by litter and mosses (particularly *H. splendens*). This vegetation community grows on moderately dry ridges and sloping uplands, especially in the Norman Range from San Sault Rapids to Fort Norman. Soils associated with this community are mostly well drained gravelly silt-loam on thin till over bedrock.

[Jeffrey (1964) described three 'white spruce-white birch forest' vegetation types along the lower Liard River on steep terraces and floodplains. White spruce was the dominant species within each of these three types, while white birch usually formed a shorter layer below the upper canopy. On steep terraces, all undergrowth (except the moss layer) was sparse. On floodplains a moderately dense shrub layer composed of alder, red osier dogwood and low bush cranberry was found together with a dense herbaceous layer dominated by horsetail. The Forest Management Institute (1974) includes this community within the upland spruce (pine)-hardwoods vegetation type.']

(c) Black Spruce-White Birch/Lingonberry Community

Black spruce is the major overstory component of the 'black spruce-white birch/lingonberry' community, but white birch may be codominant, while trembling aspen is often present. The shrub layer is sparse to moderately dense and is dominated by green alder, Labrador tea and Bebbs' willow. The dwarf shrub-herb under-layer, also sparse, is composed of bog cranberry, bearberry and bastard toad flax. The ground cover is primarily layered feathermoss and lichens. Deltaic sands, glacial lake deposits, till and thin till over bedrock are the main materials under this vegetation community. Soils are mostly well drained sandy silt-loams. Permafrost is usually found within a metre of the surface.

[The Forest Management Institute (1974) included this community in the 'upland spruce (or pine)-hardwood' type.]

(d) Black Spruce-Tamarack/Lingonberry/Moss Community

The 'black spruce tamarack/lingonberry' community usually has an overstory of black spruce with some tamarack. The tamarack trees are often taller that the spruce but are more widely spaced. There is a shrub layer of Labrador tea and alpine blueberry. Mosses (particularly *H. splendens and Sphagnum* spp.) cover most of the ground.

This vegetation community grows in narrow strips and patches along small drainage-ways over flat to undulating ground at altitudes less than 150 m above sea level. Soils are imperfectly to poorly drained ice-rich silts and clays which contain some coarser materials. Principal associated landforms are fossil floodplains, high alluvial terraces, meltwater channels of outwash plains, glacial lake basins and moraine.

Permafrost is usually less than 50 cm below the surface in silt and clay, but may be deeper than 1 m in coarser materials.

[This vegetation community is similar in composition to the 'black spruce-bog' forest vegetation types described by Jeffrey (1964), and is probably included within the 'black spruce/sphagnum' vegetation type described by the Forest Management Institute (1974).]

2.4.1.4 Open Evergreen and Mixed Forests

Needle-leaf forests of black spruce and tamarack are the main species of the 'open evergreen and mixed forest' vegetation type. Black spruce is usually the dominant species but tamarack may be codominant. Crowns of trees do not overlap, usually being separated by a distance of less than twice their crown diameters (Reid, 1974; Reid and Janz, 1974).

[This vegetation type is included within the 'black spruce/sphagnum' and 'black spruce/lichen' vegetation types described by the Forest Management Institute (1974).]

(a) Open Black Spruce-White Birch/Lingonberry Community

The 'open black spruce-white birch/lingonberry' community combines the 'open black spruce/ledum/cladonia' community described by Reid (1974) and the 'open black spruce/Labrador tea/bearberry' community described by Reid and Janz (1974). Black spruce is the principal tree species, although tamarack is often present. The trees are short, with narrow crowns which generally do not overlap. The moderately dense shrub layer is composed of Labrador tea, alpine blueberry, shrubby cinquefoil and dwarf birch. There is a herbaceous-dwarf shrub under-layer of bearberry, bog cranberry, dwarf willow and horsetail. These plants are rooted in a thick hummocky layer of feathermosses on moist sites, and tomenthypnum and aulacomnium mosses on wetter sites. Lichens (particularly *Cladina mitis* and *Cladonia alpestris)* cover the organic hummocks and mounds.

This vegetation community is found primarily on flat to gently sloping terrain throughout the Mackenzie River Valley. It grows on ancient floodplains, on high alluvial terraces, and on till, lacustrine and outwash plains. Soils underneath are imperfectly to poorly drained, varying in texture from sandy loam to clay. Twenty to 30 cm of fibric organic material forms the surface layer. Silts and clays within the soils are frequently ice-rich, and permafrost is found within a metre of the ground surface.

[Jeffrey (1964) described two 'black spruce-bog forest' vegetation types along the lower Liard River. According to Raup (1947), 'bog forest' of primarily black spruce, tamarack, Labrador tea and sphagnum moss was one of the most common timber types in the Mackenzie basin. The Forest Management Institute (1974) included this vegetation community within either the 'black spruce/sphagnum' or 'black spruce/lichen' type, depending upon the percentage of cover provided by lichens within the ground layer. In the 'black spruce/lichen' type lichens covered 50 to 100% of the ground surface with mosses and shrubs occurring on raised plateaus, while mosses and sedges occupied wet low-lying areas. In the 'black spruce/sphagnum' type, sphagnum mosses and feathermosses covered 50 to 100% of the ground surface. The major shrubs included Labrador tea and species of bog cranberry, with high shrubs being sparse and low shrubs being dense.]

2.4.1.5 Sparse Evergreen Forest

The 'sparse evergreen forest' vegetation type includes short needle-leaved trees which are usually separated by more than twice their crown diameters. It is composed mainly of 'black spruce and tamarack bog forests' or muskeg, but may include gnarled 'subalpine white spruce' forests as well.

Two principal community types were described by Reid (1974) and Reid and Janz (1974) as follows.

(a) Sparse Black Spruce/Sphagnum/Lichen Community

The 'sparse black spruce/lichen' vegetation community has small widely spaced black spruce trees and hummocks of sphagnum mosses and lichens (Plate 2.4-2). The moderately dense shrub layer is usually composed of Labrador tea and short black spruce. Herbs and dwarf shrubs (particularly baked-apple berry, bog cranberry, dwarf willow and small bog cranberry, are scattered over the surface. While there are few grasses and sedges (Forest Management Institute, 1974), the ground cover is a thick, hummocky layer of mosses (especially sphagnum mosses) covered by lichens. This vegetation community includes the 'sparse black spruce/baked appleberry/lichen' community described by Reid and Janz (1974) for the southern Mackenzie Valley, and the

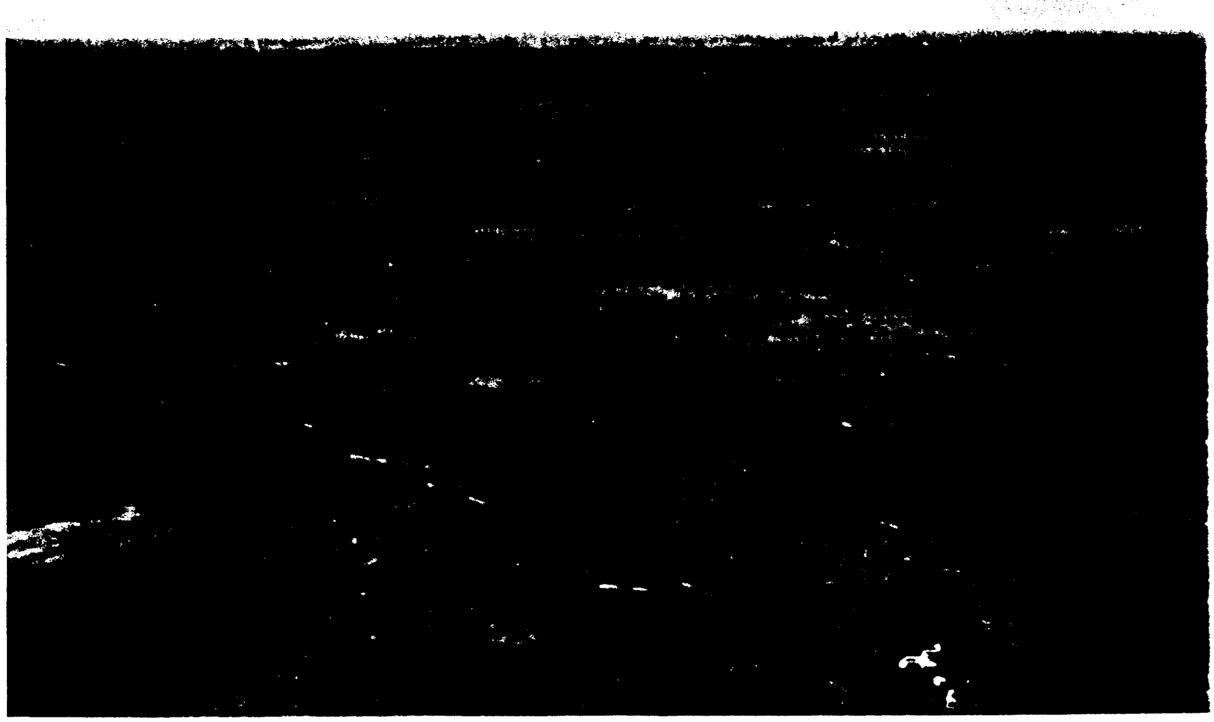

PLATE 2.4-2 *The 'sparse black spruce/sphagnum/lichen' community is widespread on level and low-lying land throughout the Mackenzie River Valley. (Courtesy, Hardy Associates, 1978, Ltd.).*

'scattered black spruce/cladonia/sphagnum' community described by Reid (1974) for the central Mackenzie Valley.

This community is widespread on level and low-lying land throughout the Mackenzie River Valley. It exists on imperfectly to poorly drained peat in glacial lake basins, on delta plains and on till plains. Soils in these areas are imperfectly to poorly drained organics, with permafrost being found within 75 cm of the surface.

[A 'bog forest' vegetation type described by Raup (1947) included this vegetation community, as well as the 'open black spruce/Labrador tea/lichen' community described in Section 2.4.1.4. Jeffrey (1964) also described two 'black spruce bog' ecosystem types on terraces and ancient floodplains along the lower Liard River. The species composition of each of these ecosystem types was similar to the 'sparse black spruce/sphagnum/lichen' community described by Reid (1974) and Reid and Janz (1974), except that the dominant mosses in Jeffrey's two ecosystem types were tomenthypnum moss and layered feathermoss, with a sparse cover of sphagnum mosses. 'Sparse black spruce/sphagnum/lichen' communities, having greater moss than lichen cover in the ground layer, are included within the 'black spruce/sphagnum' vegetation type described by the Forest Management Institute (1974). Such communities having greater lichen than moss cover in the ground layer are included within the 'black spruce/lichen' vegetation type.]

(b) Subalpine White Spruce-Tamarack/Mountain Avens Community

The tree species in the 'subalpine white spruce-tamarack/mountain avens' community are gnarled wind-pruned and often prostrate owing to the severe climatic conditions of high elevations. These trees usually grow in clumps in protected depressions or where snow collects, and are usually only 3 m tall when 150 years old. These clumps of trees are surrounded by a nearly continuous ground layer of the dwarf shrub mountain avens and lichens (particularly *Cetraria nivalis, C. laevigata, C. islandica, C. cucullata and Alectoria ochroleuca).* Other shrubs are dwarf birch and shrubby cinquefoil, while species found within the dwarf shrub-herbaceous underlayer include hedysarum, white camas and bearberry.

Within the Mackenzie Valley this community usually occurs on bedrock outcrops of the Norman Range at elevations higher than 450 m above sea level. Soils underneath the vegetation are well drained silt over bedrock in which frost boils, small polygons and solifluction lobes are common. This vegetation community also occurs on alluvial fans at lower elevations (Reid, 1974).

[This community is included within the 'timber line forest' vegetation type described by Jeffrey (1961, 1964).]

2.4.1.6 Closed Shrub

The 'closed shrub' vegetation type described by Reid and Janz (1974) is composed primarily of deciduous shrubs less than 2 m tall. It usually grows in narrow bands along major rivers and creeks and on uplands along small drainages. Its principal shrub species are willows and river alder. Other authors (Jeffrey, 1964; Hardy Associates, 1981) have described similar 'closed deciduous shrub' communities on riparian sites. However, the maximum reported heights of the shrubs in these communities are usually greater (sometimes more than 5 metres) than those reported by Reid and Janz (1974) for their 'closed shrub' vegetation type. There is one community within this vegetation type (Reid and Janz, 1974).

(a) Willow-Alder/Horsetail Community

Willows and alders identify the 'willow-alder/horsetail' community, but it also contains balsam poplar. Where this community occurs in the Mackenzie Valley south of Fort Norman, sandbar willow and Scouler's willow predominate. River alder is the principal alder species here, although green alder may also be present. The herbaceous under-layer is composed mainly of horsetail with some fireweed. This vegetation community is usually found on recent alluvial deposits which are frequently flooded by adjacent rivers or large creeks, but it occasionally also occurs along upland drainages. Soils associated with this vegetation type are free from permafrost within one metre of the surface.

[Jeffrey (1964) described three 'riparian shrub' ecosystem types which occured in three distinct zones adjacent to the lower Liard River. The ecosystem type found nearest the river was dominated by willows, while that in the central zone was codominated by river alder and willow. The ecosystem type furthest from the river contained mainly balsam poplar and river alder. The Forest Management Institute (1974) included the 'willow-alder/horsetail' community within the 'riparian pioneer' vegetation type which is flooded annually, thus providing new deposits of silt and sand. Hardy Associates (1981) also described five communities dominated by pioneer shrubs that are found on recent alluvial deposits along the lower Liard and Mackenzie rivers. These five communities are all included within the 'willow-alder/horsetail' community described by Reid and Janz (1974).]

2.4.1.7 Closed Sedge

The 'closed sedge' vegetation type is characterized by a closed cover of herbaceous species, primarily sedges less than one metre tall, and contains species usually found in fens. It includes that described by Reid and Janz (1974) and the 'closed grass' vegetation type described by Reid (1974) and Gubbe and Janz (1974). Within the 'closed sedge' vegetation type, two vegetation communities are identified and described as follows (Reid, 1974; Reid and Janz, 1974). [The 'closed sedge' vegetation type is similar to the 'sedge fen' vegetation type described and mapped by the Forest Management Institute (1974).]

(a) Sedge Fen Community

The 'sedge fen' vegetation community is composed primarily of aquatic herbs adapted to a wet mineral-rich environment (Gubbe and Janz, 1974). Near open water its main component is the sedge *Carex aquatilis*, although buckbean, sweet gale, horsetail and marsh cinquefoil are also found (Reid, 1974; Reid and Janz, 1974; Gubbe and Janz, 1974). Willows, bog rosemary, leather-leaf, sedge, and mosses (particularly *Scorpidium scorpioides and Sphagnum* spp.) are found on more soild substrates further from open water. Seedlings of black spruce and tamarack may be found within this community on drier land.

These fen communities are found in a variety of locations. 'Shore fens' are found next to streams and lakes, while 'pond fens' are located near permanent ponds and on recently flooded areas. 'Channel fens' are found in narrow bands along drainage-ways. In the Mackenzie Valley, 'fen' communities usually occur bordering shallow thermokarst ponds and lakes (Reid, 1974; Reid and Janz, 1974). Within the corridor they cover much of the lowlands of ancient floodplains, glacial lake basins and delta plains where peat varies in depth from 1 to 4 metres. Most often 'fen' communities occur between open water and either the 'sparse black spruce/sphagnum/lichen' community or the 'black spruce-tamarack/-lingonberry/moss' community. They grade into bog vegetation wherever peat has been built up higher than the surface of the water (Gubbe and Janz, 1974). Permafrost is absent within 1 m of the ground surface in substrates under fen communities south of 67°N, (Forest Management Institute, 1974).

(b) Patterned Fen Community

'Patterned fen' communities (also called 'string bogs' or 'ribbed fens') are characterized by ridges 10 to 30 cm high which are separated by saturated troughs crossing a slope at right angles to the direction of water flow (Gubbe and Janz, 1974). These ridges may join to form a reticulate pattern. The vegetation community found on these low ridges includes a few black spruce and tamarack trees, but is almost entirely dwarf shrubs and herbs such as bog rosemary, sedge, spike rush, cottongrass, and buckbean. In the ground layer, mosses are common. Shrub and herb species found in wet troughs are aquatic sedge marsh cinquefoil, horsetail, buckbean and sundew, together with some mosses.

'Patterned fens' occur only in drainage-ways on very gentle slopes. Too little water flow on very shallow slopes causes the fen community to gradually become a bog. On steeper slopes, as the ridges are shifted to run parallel to the slope and a defined drainage course is established, the fen community becomes a shrub community (Gubbe and Janz, 1974).

[The 'sedge fens' described by the Forest Management Institute (1974) were primarily 'patterned fens.' In their description the main species found on ridges were dwarf birch, willow, bog cranberry, sphagnum moss, sedges and sometimes tamarack, while grasses and sedges were found in the troughs.]

2.4.1.8 Closed Bryoid

A thick ground layer of mosses and liverworts growing on peat characterizes the 'closed bryoid' vegetation type (Reid, 1974; Reid and Janz, 1974). A few widely scattered short trees and shrubs may also be present. The single vegetation community described within this vegetation type is the 'sphagnum bog' (Reid, 1974; Reid and Janz, 1974). [This type includes the 'sphagnum bog' described by the Forest Management Institute (1974).]

(a) Sphagnum Bog Community

'Sphagnum bog' communities are found in water-saturated acidic environments which are usually nutrient deficient as the water used by the plants comes from precipitation, not groundwater (Sjors, 1961). Its main plant species are sphagnum mosses, particularly hummock-forming species such as *S. fuscum, S. warnstorfii and S. magellanicum.* Dwarf shrubs and herbs rooted in these mosses include bog rosemary, leather-leaf, and others such as blueberry, small bog cranberry and sundew. Some orchids are also found, as are aquatic sedge, cottongrass and spike rush. (Gubbe and Janz, 1974; Reid and Janz, 1974). Peat up to 5 m deep accumulates in these bogs. These peat layers are often formed over thinner fen peat as it accumulates above the level of the groundwater. In this way bogs are formed wherever there is sufficient surface water and an acidic substrate (Gubbe and Janz, 1974). These conditions occur within many types of terrain, but they are most common in glacial lake basins and on deltaic and till plains where thermokarst and runoff have created small ponds (Reid, 1974). 'Sphagnum bog' communities are often mixed with 'sparse black spruce forests,' with the areas covered by bogs being very small.

2.4.2 VEGETATION DISTRIBUTION ON PRINCIPAL LANDFORMS

This section provides an overview of the distribution and occurrence of the main vegetation types within the Mackenzie Valley corridor. It is divided into three subsections based on their vegetation characteristics, namely the Mackenzie Valley North, the Mackenzie Valley South, and the Great Slave Plain-Alberta Plateau (Figure 2.4-2). The principal vegetation types of each and the major surficial material types on which they are found are listed in Tables 2.4-2, 2.4-3 and 2.4-4. Table 1.3-1 defines geological terms used in the landform descriptions, while Figure 2.4-2 provides locations for the places mentioned in the following discussion.

The primary sources of information were landscape profiles and maps developed by Reid (1974), Reid and Janz (1974) Gubbe and Janz (1974) and Canadian Arctic Gas (1974), together with vegetation maps prepared by the Forest Management Institute (1974, 1975).

2.4.2.1 Mackenzie Valley North

The Mackenzie Valley North section of the corridor extends along the east side of the Mackenzie River from the village of Arctic Red River to Fort Good Hope (Figure 2.4-2). It lies entirely within the Anderson Plain, which is an undulating to rolling plain largely covered by glacial drift. The vegetation of the Anderson Plain within the Mackenzie Valley corridor is not as well documented as that of regions of the plain further south or north. Principal sources of information for this region are the vegetation maps prepared by the Forest Management Institute (1974), general descriptions of Anderson Plain vegetation by Canadian Arctic Gas (1974) and descriptions of vegetation on the Peel Plain between Fort McPherson and Arctic Red River by Reid and Janz (1974). Jacobson (1979) and Zoltai *et al.* (1979) also describe the vegetation of the Anderson Plain.

Rowe (1972) included the Mackenzie Valley North section of the Valley in the lower Mackenzie section of the boreal forest (Figure 2.4-1). Permafrost is thought to control the distribution of forest types in this region. Where the permafrost table is deep, saw-log sized white spruce trees may be found, but in areas where the permafrost table is near the surface, there are stunted black spruce mixed with some dwarfed white spruce.

The vegetation in the northern section of the Mackenzie Valley (Plate 2.4-3) is predominantly open and sparse black spruce forest, with a ground cover of mosses and lichens, although large sphagnum bogs are also present (Forest Management Institute, 1974) (Table 2-4-2). White birch is codominant with black spruce on better drained sites with white spruce-white birch forests occurring on eskers and other coarse textured well drained materials (Canadian Arctic Gas, 1974). Patterned fens occur in drainage-ways, while white spruce/feathermoss forests are found on the floodplains of rivers and larger streams (Canadian Arctic Gas, 1974).

The vegetation of the northern Mackenzie Valley frequently suffers natural burns. There are large burned areas north of Yeltea Lake and along the Mackenzie River south of the confluence with the Arctic Red River (Forest Management Institute, 1974).

(a) Vegetation on Till Landforms

Glacial till, most often deposited as ground moraine, covers nearly half of the corridor between Arctic Red River and Fort Good Hope. Vast expanses of scrubby black spruce forests, interspersed with sedge fens and sphagnum bogs, cover these materials. These forests are most extensive on undulating to gently rolling land having imperfectly drained soils. Principal communities are the 'open black spruce/-Labrador tea/lichen' forest and 'sparse black spruce/sphagnum/lichen' forest. Reid and Janz (1974) noted that, near Fort McPherson, the dominant community on till was an 'open black spruce/blueberry' forest. With the possible exception of somewhat more abundant blueberry, this community differs little in structure and composition from the 'open black spruce/Labrador tea/lichen' forest described by Reid (1974) for areas further south.

Better drained till ridges and knolls with deep active layers support substantial tree growth. 'Black spruce-white birch/lingonberry' forests occur frequently on well drained soils, while 'black spruce/ feathermoss' forests are common on moderately well and imperfectly drained sites. Drainage-ways over moraine are generally vegetated by a mixed forest of black spruce and tamarack ('black spruce-tamarack/lingonberry-/moss').

(b) Vegetation on Bedrock/Colluvial Landforms

Bedrock landforms usually having a thin veneer of till or colluvium dominate large portions of terrain in the Mackenzie Valley North section, especially north of Yeltea Lake. The vegetation is primarily scrubby black spruce forests of the 'open black spruce/Labrador tea/lichen' and 'sparse black spruce/sphagnum/lichen' community types. On better drained ridges and hills scattered among these scrubby forests are 'black spruce-white birch/lingonberry' and 'black

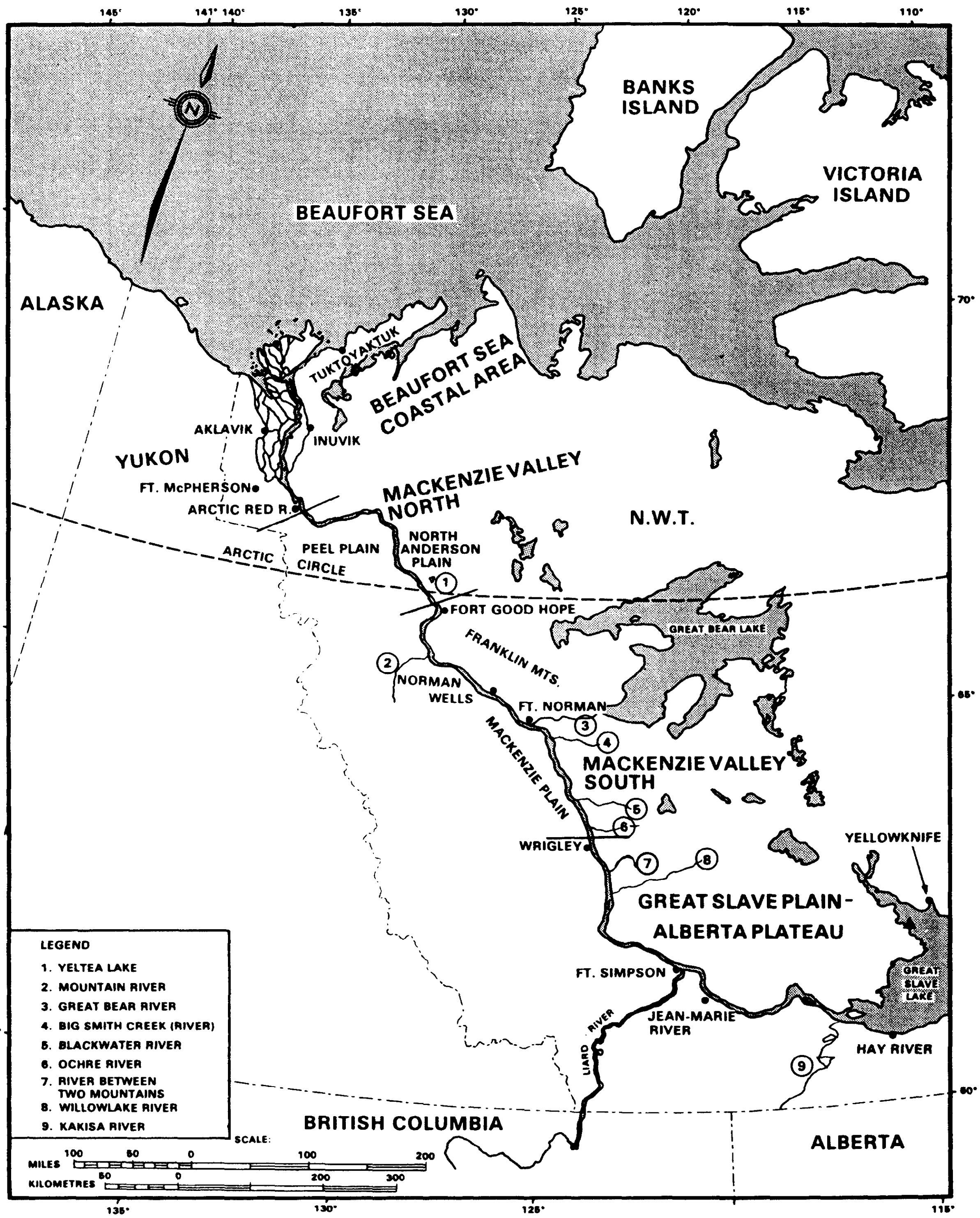

FIGURE 2.4-2 *The Mackenzie Valley Corridor can be divided into three subsections based on their vegetation characteristics, namely the Mackenzie Valley North, the Mackenzie Valley South, and the Great Slave Plain-Alberta Plateau.*

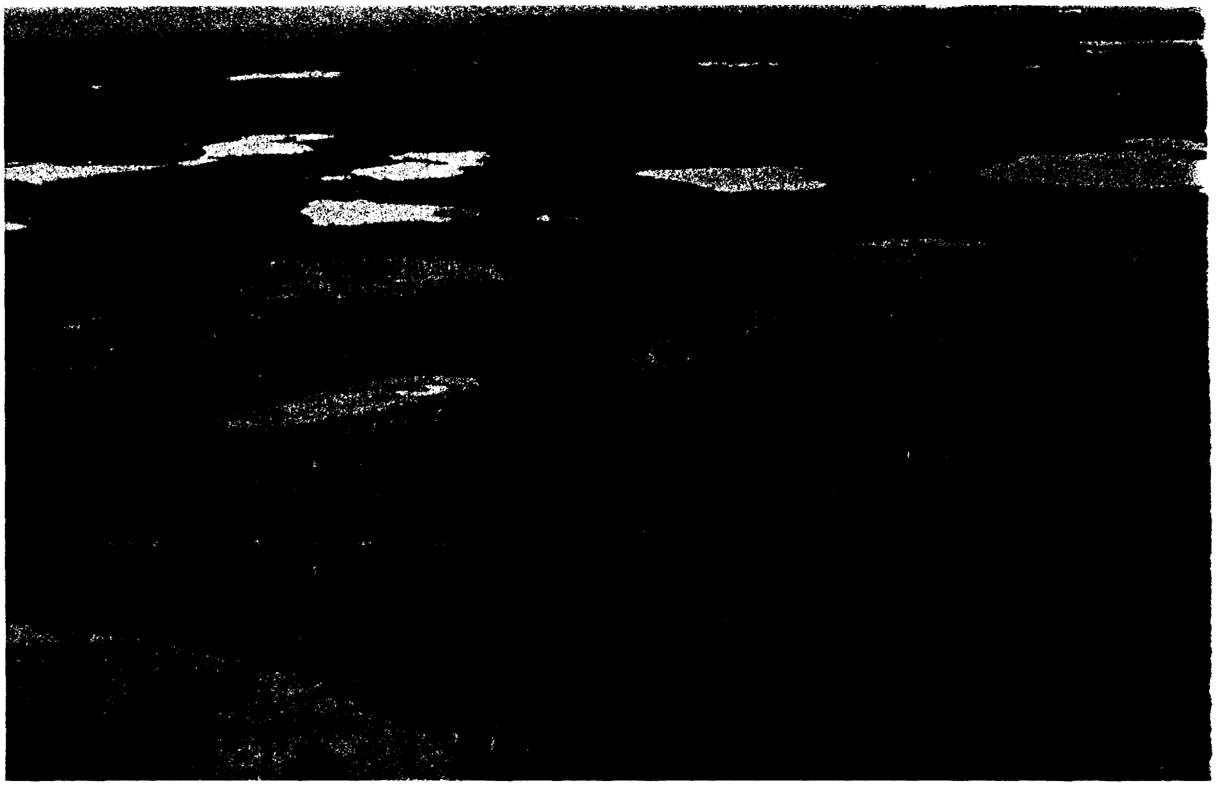

PLATE 2.4-3 *The vegetation in the northern section of the Mackenzie Valley is predominantly open and sparse black spruce forest, with a ground cover of mosses, lichens and often sphagnum (peat) bogs. (Courtesy, Hardy Associates, 1978, Ltd.).*

spruce/feathermoss' forests. 'White spruce-white birch/alder' forests may occur locally on coarse textured soils with a deep active layer.

(c) Vegetation on Organic Landforms

Peat accumulations of 1.5 to 5 m thick occur in poorly drained low-lying areas and in drainage-ways on till, glaciolacustrine and bedrock/colluvial landforms. Vegetation includes 'sparse black spruce/sphagnum/lichen' forests, 'sphagnum bogs' and 'sedge fens.' 'Sedge fens' are most extensive on the east side of the Mackenzie River near the mouth of the Arctic Red River (Forest Management Institute, 1974).

(d) Vegetation on Glaciolacustrine Landforms

Glacial lake sediments of silt and clay form much of the lowland plains bordering the Mackenzie River. These sediments are mostly moderately well to poorly drained. The vegetation on these soils is dominated by scrubby black spruce forests with numerous sedge fens. 'Black spruce/ feathermoss' forests are found on the moderately well to imperfectly drained materials of low mounds and hills. 'Open black spruce/Labrador tea/lichen' forests dominate imperfectly to poorly drained soils.

(e) Vegetation on Alluvial Landforms

Alluvial plains and terraces on islands and floodplains of the Mackenzie River are largely vegetated by 'white spruce/feathermoss' forests and 'black spruce/feathermoss' forests. These forests generally contain the largest trees of the Mackenzie Valley North section, some of which are 18 m or more in height (Forest Management Institute, 1974). Backswamps and depressions on alluvial plains are covered with 'sedge fens' and 'open black spruce/Labrador tea/lichen' forests. 'Black spruce-tamarack/lingonberry/moss' forests occur on drainage-ways.

(f) Vegetation on Glaciofluvial Landforms

'White spruce-white birch/alder' forests occur on the coarse grained well drained glaciofluvial deposits of the Mackenzie Valley North section (Canadian Arctic Gas, 1974). Other communities often found on these deposits include 'black spruce-white birch/lingonberry' forests on well drained deposits, and 'open black spruce/Labrador tea/lichen' forests and 'sedge fens' on imperfectly to poorly drained deposits (Reid, 1974).

2.4.2.2 Mackenzie Valley South

The Mackenzie Valley South section of the corridor extends along the east side of the Mackenzie River from Fort Good Hope to the Willowlake River (Fig-

TABLE 2.4-2

DOMINANT LANDFORMS AND VEGETATION OF THE MACKENZIE VALLEY NORTH SECTION

Landform	Soil Drainage	Vegetation
Moraine (50%)	Rapid	Black Spruce-White Birch/Lingonberry
	Well-Mod* Well	Black Spruce-White Birch/Lingonberry Black Spruce/Feathermoss
	*Imp-Poor	Open Black Spruce/Labrador tea/Lichen Sparse Black Spruce/Sphagnum-Lichen Black Spruce/Feathermoss
Organic (15%)	Imp-Poor	Sparse Black Spruce/Sphagnum-Lichen Sphagnum Bog Sedge Fen
Bedrock (15%)	Rapid	Black Spruce-White Birch/Lingonberry White Spruce-White Birch/Alder
	Well-Mod Well	Black Spruce-White Birch/Lingonberry Black Spruce/Feathermoss
	Imp-Poor	Open Black Spruce/Labrador tea/Lichen Sparse Black Spruce/Sphagnum-Lichen
Glaciolacustrine (15%)	Well-Mod Well	Black Spruce/Feathermoss
	Imp-Poor	Open Black Spruce/Labrador tea/Lichen Sparse Black Spruce/Sphagnum-Lichen Sedge Fen
Alluvial (2%)	Well-Mod Well	White Spruce/Feathermoss Black Spruce/Feathermoss
	Imp-Poor	Open Black Spruce/Labrador tea/Lichen Sedge Fen Black Spruce/Feathermoss
Glaciofluvial (3%)	Rapid	Black Spruce-White Birch/Lingonberry White Spruce-White Birch/Alder
	Well-Mod Well	Black Spruce-White Birch/Lingonberry
	Imp-Poor	Open Black Spruce/Labrador tea/Lichen Black Spruce-Tamarack/Lingonberry/Moss Sedge Fen

*Mod - Moderately
*Imp - Infrequently

ure 2.4-2). Principal physiographic features are the Mackenzie Plain which occurs as a narrow band along the River and the Franklin Mountains which reach an elevation of over 1,000 m above sea level in the Norman Range.

Vegetation from Fort Good Hope south to Fort Norman consists primarily of 'open black spruce/-Labrador tea/lichen' and 'sparse black spruce/-sphagnum/lichen' forests (Table 2.4-3). 'Closed black spruce/feathermoss' and 'black spruce-white birch/-lingonberry' forests occupy smaller portions of the area on well to imperfectly drained soils.

From Fort Norman south to the Willowlake River the vegetation includes a complex mosaic of types dominated by 'open black spruce' forests on imperfectly to poorly drained soils. However, an increasing

TABLE 2.4-3

DOMINANT LANDFORMS AND VEGETATION OF THE MACKENZIE VALLEY SOUTH SECTION

Landform	Soil Drainage	Vegetation
Moraine (45%)	Rapid	Black Spruce-White Birch/Lingonberry
	Well-Mod* Well	Black Spruce-White Birch/Lingonberry White Spruce-White Birch/Alder White Spruce-Aspen/Alder
	*Imp-Poor	Open Black Spruce/Labrador tea/Lichen Sparse Black Spruce/Sphagnum-Lichen
Bedrock and Colluvium (30%)	Rapid	Black Spruce-White Birch/Lingonberry
	Well-Mod Well	Black Spruce-White Birch/Lingonberry White Spruce-White Birch/Alder Subalpine White Spruce-Tamarack/ Mountain Avens
	Imp-Poor	Open Black Spruce/Labrador tea/Lichen Black Spruce/Feathermoss
Organic (10%)	Imp-Poor	Sparse Black Spruce/Sphagnum-Lichen Open Black Spruce/Labrador tea/Lichen Sphagnum Bogs
Glaciolacustrine (10%)	Well-Mod Well	Black Spruce-White Birch/Lingonberry Black Spruce/Feathermoss
	Imp-Poor	Open Black Spruce/Labrador tea/Lichen Sparse Black Spruce/Sphagnum-Lichen Sedge Fens
Alluvial (3%)	Rapid	White Spruce-Aspen/Alder Balsam Poplar/River Alder/Horsetail
	Well-Mod Well	White Spruce/Feathermoss Balsam Poplar/River Alder/Horsetail
	Imp-Poor	Black Spruce/Feathermoss Open Black Spruce/Labrador tea/Lichen Sedge Fen
Glaciofluvial (2%)	Rapid	Black Spruce-White Birch/Blueberry Moss Pine/Soapberry/Twinflower
	Well-Mod Well	Black Spruce-White Birch/Lingonberry White Spruce-Aspen/Alder
	Imp-Poor	Open Black Spruce/Labrador tea/Lichen Sedge Fen

*Mod - Moderately
*Imp - Infrequently

proportion of 'closed evergreen' forest ('black spruce/feathermoss' on well to imperfectly drained soils and 'pine/soapberry/twinflower' on rapidly to well drained soils) and 'closed mixed' forest ('white spruce-aspen/alder' and 'black spruce-white birch/-lingonberry') are present southward to the Willowlake River. 'Subalpine white spruce-tamarack/-mountain avens' forest occurs on the higher slopes of the Norman Range.

This section of the corridor includes the most productive forest lands of the study area. Riparian 'white spruce/rose/feathermoss' forests occur on alluvial sites along the Willowlake and Mackenzie rivers and frequently contain trees over 20 m tall.

(a) Vegetation on Till Landforms

Glacial till deposits are the dominant surficial materials on about half of the pipeline corridor in the Mackenzie Valley South section. Landforms are mostly ground, hummocky and drumlinoid moraine. The vegetation is predominantly 'open black spruce/-Labrador tea/lichen' forest on moderately well to poorly drained soils. Well to moderately well drained soils found on drumlins, knolls and low ridges typically have a cover of 'black spruce-white birch/lingonberry' forest, although some 'white spruce-white birch/alder,' 'white birch/willow and black spruce forests may also be found. 'White spruce-aspen/-alder' forests become increasingly common on well drained tills toward the southern end of the Mackenzie Valley South section. Poorly drained tills in depressions may be covered with 'sparse black spruce/ sphagnum/lichen' forest. The lower slopes of bedrock ridges with a thin till veneer typically support 'black spruce-white birch/lingonberry' and 'white spruce-white birch/alder' forests. Wet drainage-ways on moraine slopes have a 'black spruce-tamarack/ alpine blueberry/moss' cover. 'Sedge fens' are less abundant here than they are in the Great Slave Plain-Alberta Plateau section further south.

(b) Vegetation on Bedrock and Colluvial Landforms

Bedrock ridges and outcrops covered primarily by a thin layer of colluvium dominate the Franklin Mountains portion of the corridor. The vegetation on well drained soils below about 450 m above sea level is dominated by 'black spruce-white birch/lingonberry' forest, although 'white spruce-white birch/alder' forest becomes increasingly common toward the southern limits of this section. Imperfectly to poorly drained soils are vegetated by 'open black spruce/Labrador tea/lichen' and 'black spruce/ feathermoss' forests. At higher elevations (up to about 700 m above sea level) the 'subalpine white spruce-tamarack/mountain avens' community is dominant. At still higher elevations the trees disappear, and herbs and lichens cover only scattered patches of ground.

(c) Vegetation on Organic Landforms

Organic accumulations,1.5 to 5 m deep are common in depressions and low-lying areas of glacial lake plains and moraines. They are commonly frozen below a depth of 50 cm by the end of August (Reid, 1974). The predominant vegetation is the 'sparse black spruce/sphagnum/lichen' community. 'Sphagnum bogs' occur in thaw depressions, while small 'sedge fens' are common in thaw ponds on glacial lake plains.

(d) Vegetation on Glaciolacustrine Landforms

Glaciolacustrine plains occur above the fluvial lowlands and below the till plains along most stretches of the Mackenzie River in the Mackenzie Valley South section. The land is generally level to gently rolling with moderately well to poorly drained surface soils. Vegetation is dominated by 'open black spruce/Labrador tea/lichen' and 'black spruce-white birch/ lingonberry' forests. However, a mosaic of several community types are present according to local drainage and permafrost conditions. Well to moderately well drained mineral soils on low ridges and hills are covered with 'black spruce-white birch/lingonberry' forests. While palsa mounds and ridges with moderately well drained soils may be vegetated by 'white spruce/feathermoss' or 'black spruce/feathermoss' forests. Imperfectly to poorly drained soils support extensive stands of 'open black spruce/Labrador tea/lichen' forest. Thaw ponds have 'sedge fens' or 'sphagnum bogs.'

(e) Vegetation on Alluvial Landforms

Alluvial deposits cover only a small percentage of the pipeline corridor in the Mackenzie Valley South section, occurring on islands and floodplains of the Mackenzie River and its principal tributaries such as the Great Bear, Blackwater and Ochre rivers and Big Smith Creek.

A fringe of 'closed shrub' vegetation ('willow-river alder/fireweed') occurs along the edge of the River on recently exposed materials. Well to imperfectly drained soils on low terraces back from the shrub fringe have a zone of 'balsam poplar/river alder/-horsetail' forest followed by larger stands of 'white spruce/feathermoss' forest. Back-swamps on the terraces have 'sedge fens' in their early stages of succession and 'black spruce/feathermoss' forests in later stages. High terraces along the Mackenzie River are mainly vegetated by 'open black spruce/Labrador tea/lichen' forest, with 'black spruce-tamarack/-blueberry/moss' forest in drainage-ways.

(f) Vegetation on Glaciofluvial Landforms

Glaciofluvial deposits in the form of outwash plains and deltas, meltwater channels, eskers and kames cover a small proportion of the corridor in the Mackenzie Valley South section (Plate 2.4-4). They occur primarily in patches along major existing drainage channels. The vegetation is dominated by 'open black spruce/Labrador tea/lichen' and 'black spruce-white birch/lingonberry/moss' forests. Rapidly to well drained materials on ridges and knolls are mainly covered by 'black spruce-white birch/lingonberry/moss' forests, although south of Fort Norman 'pine/soapberry/twinflower' forests are found. 'Black spruce-white birch' forests also dominate the well to moderately well drained materials on outwash plains and deltas, although 'white spruce-aspen/alder' forests become common in the more southern portions of the section. Depressions and abandoned meltwater channels are dominated by 'open black spruce/Labrador tea/lichen' forest and 'sedge fens.' 'Black spruce-tamarack/lingonberry' forest occurs on drainage-ways.

2.4.2.3 Great Slave Plain-Alberta Plateau

This section of the Mackenzie Valley corridor extends from the Willowlake River south and east through the Fort Simpson area to the Alberta-Northwest Territories border (Figure 2.4-2). It is predominatly an upland section with extensive areas of imperfectly and poorly drained soils. The main foundation materials in the Great Slave Plain-Alberta Plateau section are glacial till, organic and glaciolacustrine deposits. Smaller areas of eolian, alluvial and glaciofluvial deposits also occur. Vegetation of this section is a complex mosaic of types reflecting local drainage patterns and soils. 'Open black spruce/-Labrador tea/lichen' forests on imperfectly to poorly drained soils dominate. These forests are regularly interspersed with 'closed evergreen' and 'closed mixed-wood' forests on hills and knolls with well to moderately well drained soils. On the wet poorly drained soils of depressions and drainage-ways 'sedge fens,' 'sphagnum bogs' and 'sparse black spruce/sphagnum/lichen' communities are common. Principal communities on well and moderately well drained soils are 'black spruce/feathermoss,' 'pine/soapberry/twinflower,' and 'white spruce-spen/ alder' forests (Plate 2.4-5).

The dominant vegetation types on soil drainage classes within each of the principal landform types is shown in Table 2.4-4.

(a) Vegetation on Till Landforms

In the Great Slave Plain-Alberta Plateau section gla-

PLATE 2.4-4 *Mixed forests of pine, aspen and birch on the uplands border white spruce on the alluvial flats beside the River Between Two Mountains in the Mackenzie Valley corridor between Wrigley and Fort Simpson. (Courtesy, Hardy Associates, 1978, Ltd.)*

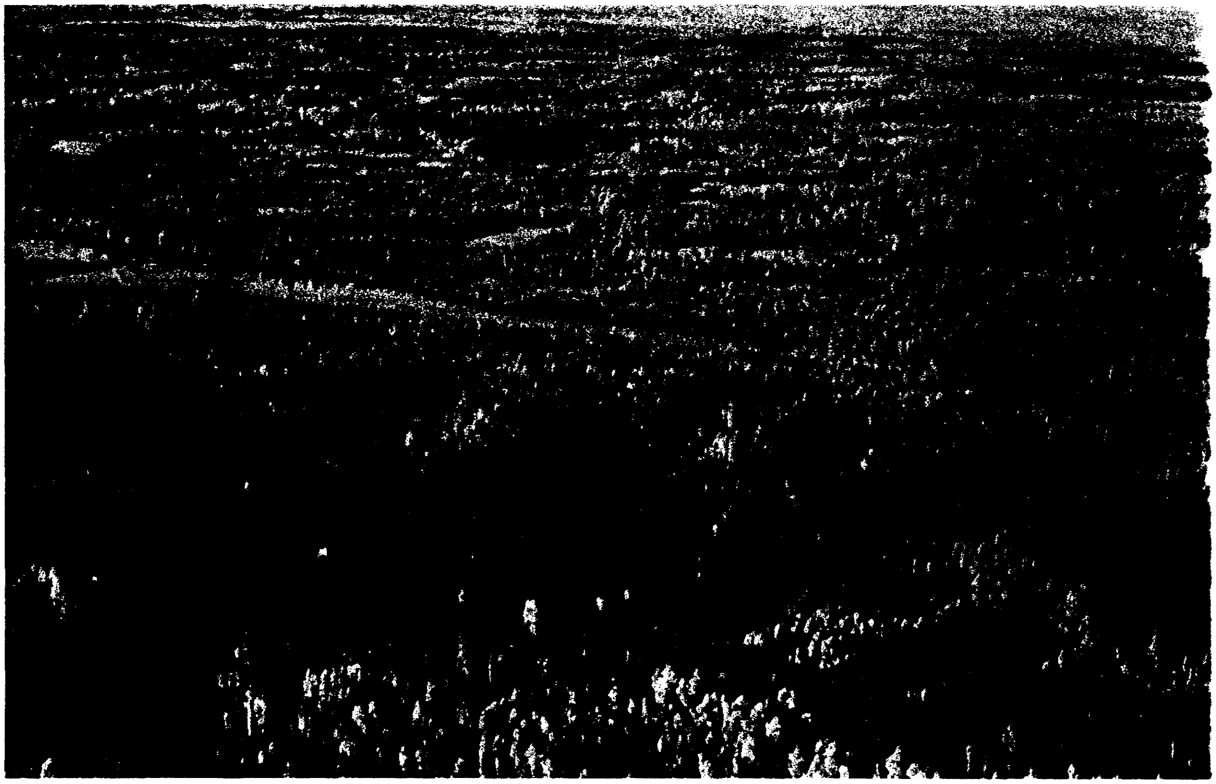

PLATE 2.4-5 *The Great Slave Plain-Alberta Plateau section is predominantly upland in nature, with extensive areas of imperfectly and poorly drained soils. Here closed forests of pine and aspen are interspersed with black spruce and tamarack on the undulating plains south of Fort Simpson. (Courtesy, Hardy Associates, 1978, Ltd.).*

cial till covers approximately 50% of the corridor. Principal landforms include ground moraine and hummocky moraine. The predominant vegetation on till is the 'open black spruce/Labrador tea/lichen' community. Frequent, but less extensive communities are the 'black spruce/feathermoss' and 'white spruce-aspen/alder' forests.

Table 2.4-4 lists the predominant vegetation types on three drainage regimes of till. Rapidly to well drained till on the crests of hummocks, ridges or knolls are primarily vegetated by the 'pine/soapberry/twinflower' community. Low ridges and knolls are often only slightly raised above the surrounding 'open black spruce' forests and peatlands. Well to moderately well drained tills support diverse vegetation communities, the predominant ones being 'white spruce-aspen/alder,' 'black spruce/feathermoss' and 'white spruce/rose/feathermoss' forests. Imperfectly to poorly drained tills are extensive, being vegetated by 'open black spruce/Labrador tea/lichen,' 'sparse black spruce/sphagnum/lichen,' and 'black spruce/-feathermoss' forests and sedge fen.

(b) Vegetation of Organic Landforms

Organic deposits derived from accumulations of undecomposed sedge and moss peat in wet areas cover approximately 20% of the corridor in the Great Slave Plain-Alberta Plateau section. These deposits range from about 0.5 to 4 m in thickness. The vegetation is predominantly 'sparse black spruce/sphagnum/lichen' forest, 'sedge fen' and 'open black spruce/Labrador tea/lichen' forest. Sphagnum bogs occur in thaw depressions.

(c) Vegetation of Glaciolacustrine Landforms

Glacial lake deposits within this section of the corridor occur primarily south of the Mackenzie River near Fort Simpson. Most are imperfectly to poorly drained. Vegetation is predominantly 'open black spruce/Labrador tea/lichen' and 'black spruce/feathermoss' forests, with frequent, but much less extensive areas of 'white spruce-aspen/alder' forest.

Table 2.4-4 lists the main vegetation types on drainage classes of glaciolacustrine deposits. Well drained materials on the upper slopes of low knolls are primarily vegetated by 'white spruce-aspen/alder' forests. 'Aspen/rose' and 'white birch/willow' forests are less extensive. 'Black spruce/feathermoss' and, 'open black spruce/Labrador tea/lichen' forests and sedge fens dominate the extensive areas of imperfectly and poorly drained glaciolacustrine deposits.

TABLE 2.4-4

DOMINANT LANDFORMS AND VEGETATION
OF THE GREAT SLAVE PLAIN-ALBERTA PLATEAU REGION

Landform	Soil Drainage	Vegetation
Moraine (50%)	Rapid	Pine/Soapberry/Twinflower
	Well-Mod* Well	White Spruce-Aspen/Alder White Spruce/Rose/Feathermoss Black Spruce/Feathermoss
	*Imp-Poor	Open Black Spruce/Labrador tea/Lichen Black Spruce/Feathermoss Sedge Fen
Organic (25%)	Imp-Poor	Sparse Black Spruce/Sphagnum-Lichen Sedge Fen Open Black Spruce/Labrador tea/Lichen
Glaciolacustrine (15%)	Well-Mod Well	White Spruce-Aspen/Alder Aspen/Rose White Birch/Willow
	Imp-Poor	Open Black Spruce/Labrador tea/Lichen Black Spruce/Feathermoss Sparse Black Spruce/Sphagnum-Lichen
Eolian (5%)	Rapid	Pine/Soapberry/Twinflower
	Well-Mod Well	Pine/Soapberry/Twinflower White Spruce-Aspen/Alder White Spruce/Rose/Feathermoss
	Imp-Poor	Sedge Fen Open Black Spruce/Labrador tea/Lichen Black Spruce/Feathermoss
Alluvial (2%)	Rapid	White Spruce-Aspen/Alder
	Well-Mod Well	White Spruce-Aspen Alder White Spruce/Rose/Feathermoss
	Imp-Poor	Open Black Spruce/Labrador tea/Lichen Sedge Fen
Glaciofluvial (3%)	Rapid	Pine/Soapberry/Twinflower
	Well-Mod Well	White Spruce-Aspen/Alder Aspen/Rose
	Imp-Poor	Open Black Spruce/Labrador tea/Lichen Sedge Fen Black Spruce/Feathermoss

*Mod - Moderately
*Imp - Infrequently

(d) Vegetation of Eolian Landforms

Eolian deposits cover a relatively small portion of the corridor near the junction of the Mackenzie and Liard rivers. Vegetation is mainly 'sedge fen,' and 'white spruce-aspen/alder' and 'pine/soapberry/twinflower' forests. These communities occur in a complex mosaic reflecting slight elevation variations which result in soil and drainage changes. Rapidly and well drained soils on low dune ridges are vegetated by 'pine/soapberry/twinflower' and 'white spruceaspen/alder' forests, while the intervening flats and lowlands support 'sedge fens' with some 'open black spruce/Labrador tea/lichen' forest.

(e) Vegetation on Alluvial Landforms

Alluvial landforms also cover only a small porportion of the corridor, being found on islands and floodplains near the Mackenzie River in the Great Slave Plain-Alberta Plateau section. Although of limited area, these landforms support a disproportionately large percentage of the biggest trees. The predominant vegetation types on alluvial landforms are 'white spruce-aspen/alder,' 'white spruce/rose/-feathermoss' and 'open black spruce/Labrador tea/lichen' forests. Trees in mature 'white spruce' forests often exceed 20 m in height.

The distribution of vegetation on recent alluvial landforms is related to the age and to the drainage of the surficial materials. On well to moderately well drained recent materials a narrow zone of 'willow-alder closed scrub' occurs. This is followed by a zone of 'balsam poplar/river alder/horsetail' vegetation, mixed forests of white spruce and aspen or balsam poplar, and finally a 'white spruce/rose/feathermoss' forest on oldest materials. Imperfectly to poorly drained materials support a 'black spruce/-Labrador tea/lichen' forest or 'sedge fen.'

(f) Vegetation on Glaciofluvial Landforms

Glaciofluvial deposits of sorted sands and gravels occur locally in less than 5% the Great Slave Plain-Alberta Plateau section. Landforms include outwash plains, deltas and abandoned channels. Predominant vegetation communities on these materials are 'white spruce-aspen/alder,' 'pine/soapberry/twinflower' and 'open black spruce/Labrador tea/lichen' forests. Rapidly drained soils on ridges and knolls are vegetated with pine forests. 'White spruce-aspen/alder' and 'aspen/rose' forests characterize well to moderately well drained sites on low hills and side-slopes. Low wet areas between the ridges and hills support 'open black spruce/Labrador tea/lichen' forests and 'sedge fens.'

2.4.3 FOREST RESOURCES

Forest resources of the Mackenzie River Valley are described by Hirvonen (1975) based on forest cover maps prepared for most of the area between 1971 and 1972. Most of these maps are drawn to a scale of 1:125,000 and define areas of forested land, non-forested land and water. Forested land is divided into productive, non-productive, stunted or stagnated and protection forest. Areas of both productive and non-productive forest are mapped using tree species composition, height class and crown closure. Summary maps (1:1,000,000 approximate scale) divide areas of productive forest into those with stands less than 18.3 m (60 feet) tall and those with stands taller then 18.3 m (Hirvonen, 1975). The greater than 18.3 m tall stands occur primarily on sites adjacent to the Mackenzie River and its tributaries.

Hirvonen (1975) divided the Mackenzie Valley into three sections: northern, central and southern, based on tree species distributions, regional abundance of timber, and accessibility. The northern section extends south from near Aklavik on the Mackenzie Delta to Fort Norman, the central section extends from Fort Norman to Fort Simpson, and most of the southern section is south of Fort Simpson.

The percentage of each area covered by productive timber increases from north to south, being 11% in the northern section; 27% in the central section, and 44% in the southern section. Total wood volumes (all species) also increase from north to south with values of 21.6 x 10^6 m^3 (762 x 10^6 ft^3) in the northern section, 34.1 x 10^6 m^3 (1,205 x 10^6 ft^3) in the central section; and 95.8 x 10^6 m^3 (3,385 x 10^6 ft^3) in the southern section.

Most of the sawlog timber is in the southern two sections. Stands greater than 24.4 m (80 feet) tall contain only about 5% of the total wood volume in the Valley and all are within 240 km of the Alberta-Northwest Territories border. Many of the best timber stands in the region are adjacent to the Mackenzie River and its tributaries on recent alluvial sites. Here white spruce trees are as tall as 37 m in the south and 21 m in the north. A height of 18 m is reached in about 100 years of growth in the south, but requires about 200 years on the Delta (Hirvonen, 1975).

Reid (1974) and Reid and Janz (1974) reported average timber volumes and mean annual increments (MAI) for each of the vegetation types described in Section 2.4.1 for the Mackenzie Valley (Table 2.4-5). The data were collected from 275 stands. Average volumes varied from 343 m^3/ha in 'riparian white spruce' forests in the south, to 219 m^3/ha in 'upland white spruce-white birch' forests, and 10 m^3/ha in 'sparse black spruce' forests. MAI's for these vegetation types were 2.59, 2.11 and 0.16 m^3/ha/yr, respec-

TABLE 2.4-5

TREE DATA FOR VEGETATION TYPES OF THE MACKENZIE VALLEY.
SOURCE: REID (1974) AND REID AND JANZ (1974)

TREE DATA	wS/rose/ feathermoss	wS/ feathermoss	bS/ feathermoss	P/soapberry/ twinflower	tA/rose	wB/willow	bPo/river alder/horse-tail	wS-tA/alder	wS-wB/alder	bS-wB/ lingonberry	bS-tL/ lingonberry/moss	Open bS/ Labrador tea/ lichen	Sparse bS/ Sphagnum-lichen	Subalpine wS-tL/mountain avens
No. Stands	15	15	48	24	24	8	7	14	12	25	17	38	27	2
Mean d.b.h. (cm)	18.7	20.0	8.9	11.0	13.5	10.0	19.1	12.5	16.8	8.7	7.8	6.6	5.9	6.1
Mean Height (m)	15.9	17.6	7.9	11.9	14.3	10.3	15.7	12.2	11.7	6.9	5.5	5.2	4.7	2.7
Mean Age	133	185	119	68	70	61	88	91	104	123	152	133	111	149
Mean Density (stems/ha)	4293	2150	12899	7350	6250	3481	2450	6338	84331	10368	7775	9100	3980	—
Mean Volume (m^3/ha)	353	318	109	164	229	114	223	229	219	66	37	51	12	—
Ave. M.A.I. (m^3/ha/yr)	2.59	1.72	1.01	2.55	3.15	2.14	2.53	2.83	2.11	.54	.24	.44	.13	—
Productivity Class (C.L.I.)	5	6		5	5	6	5	5	6	7	7	7	7	7

wS - white spruce
bs - black spruce
p - pine (lodgepole and jack)
tA - trembling aspen
wB - white birch
bPo - balsam poplar
tL - tamarac

d.b.h. = diameter at breast height
MAI = Mean annual increment

Productivity Class (C.L.I.) -
5 Generally unsuited for cultivation
6 Unsuited for cultivation, could be used for pasture.
7 Totally unsuited for agriculture

tively. Maximum MAI's of 4.35 and 3.15 m^3/ha/yr were recorded for 'upland white birch' and 'trembling aspen' forest respectively.

2.4.4 AGRICULTURE AND FORESTRY

Current agricultural activities are limited to small vegetable gardens in each of the major communities, with some minor areas of forage crops near Fort Simpson. The upper Mackenzie and Liard valleys are the only areas along the Mackenzie Valley corridor where soil and climatic conditions combine to provide a potential for agriculture. Although good soils may be found in other locations, cool temperatures and a short frost-free growing season present severe climatic restrictions to agriculture.

Localized logging has taken place throughout the Mackenzie Valley. Most of the logging supplies local demands for building materials and occurs in the white spruce stands along the Mackenzie River and its major tributaries near Inuvik, Arctic Red River, Fort Good Hope, Norman Wells, Fort Norman, Wrigley and Fort Simpson. Some of the largest areas of saw-timber stands are found in the vicinity of Fort Simpson, but they have not been harvested owing to low demand and difficult access. The majority of the pipeline route is covered by pulpwood-size timber, scrub forest and recent burns. Although merchantable stands of timber are found along the route, the slow growth of trees (that is, 100 to 200 years to reach saw-log size) in this area generally precludes the development of a major forest industry.

2.5 RESOURCE USE

2.5.1 HUNTING AND TRAPPING

Trapping provides a full-time occupation or income supplement for many residents of communities located in the Mackenzie Valley corridor, from the Mackenzie Delta to 60° North Latitude. The following is a brief discussion of the harvest statistics and hunting/-trapping areas of these communities. Settlements include Inuvik, Fort Good Hope, Norman Wells, Fort Norman, Wrigley, Fort Simpson and Jean-Marie River (Figure 2.5-1). In addition, residents of Fort Franklin and Trout Lake regularly hunt and trap within the corridor and the harvests associated with these communities will also be discussed. Residents of other communities that occasionally hunt and trap in specific areas of the region are discussed incidentally in conjunction with various hunting and trapping areas such as Aklavik, Arctic Red River, Fort McPherson, Nahanni Butte, Fort Providence, Kakisa Lake, Indian Cabins and Meander River. Additional details associated with resource utilization by residents of the Mackenzie Valley are provided in Volume 5.

The numbers of active trappers in each community between 1967 and 1980 are listed in Table 2.5-1. Although there was a general decrease in the number of trappers between 1941 and 1971 (Gemini North, 1974a), their numbers have increased over the last decade as a result of a rising number of part-time participants.

Hunting is also important to the local economy, but primarily as a food source rather than as income (Bissett, 1974). Big game hunting by non-native residents and non-residents occurs in the Mackenzie River Valley, largely being confined to the Mackenzie Mountains. Hunting and trapping also provide recreation and a traditional lifestyle for the native population.

In general, trapping areas near communities receive greater harvest pressures than do less accessible areas because the part-time trappers use 'day' trap lines

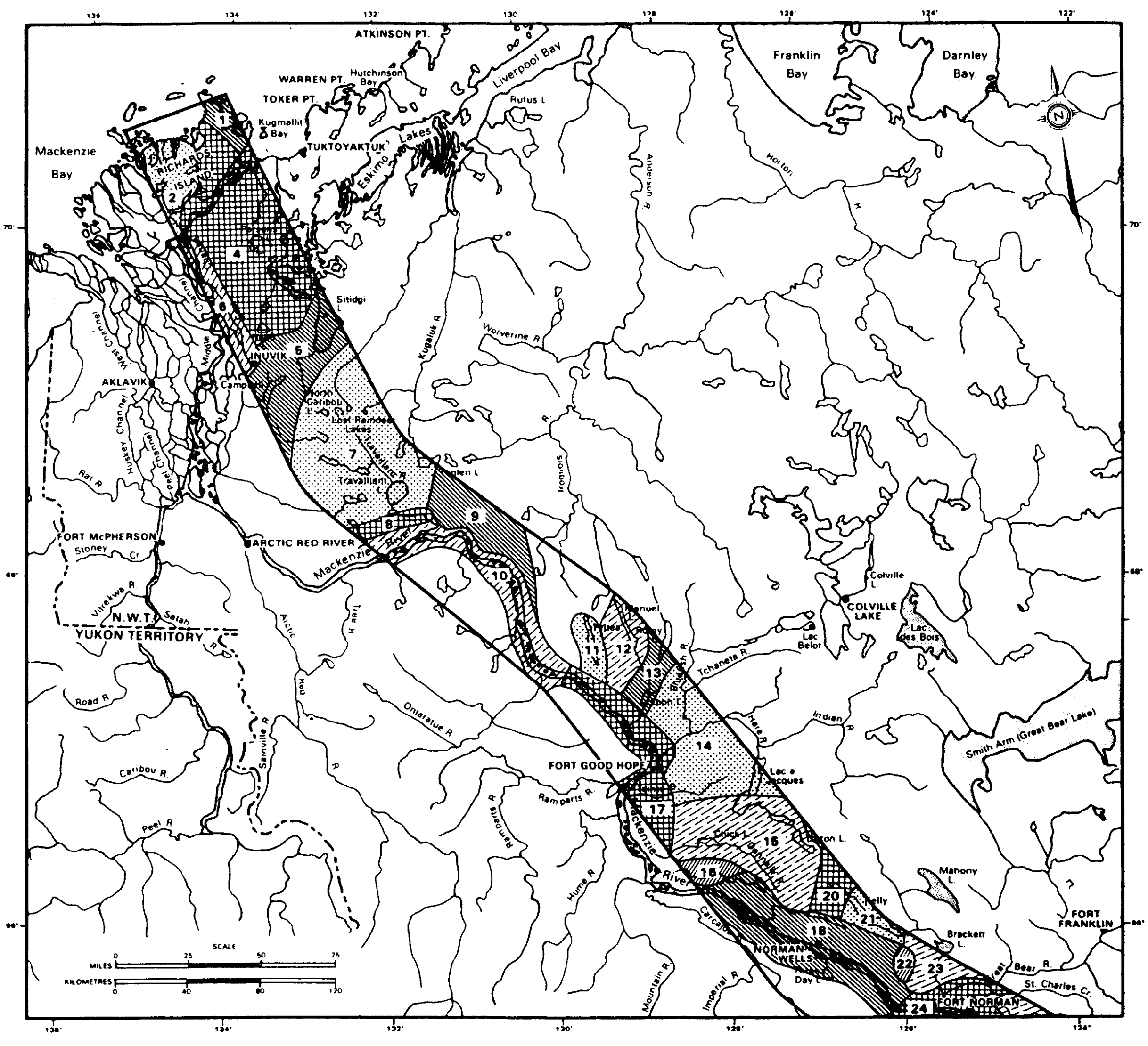

FIGURE 2.5-1 *Hunting and trapping areas used by residents of communities in or adjacent to the Mackenzie Valley corridor.*
(Continued)

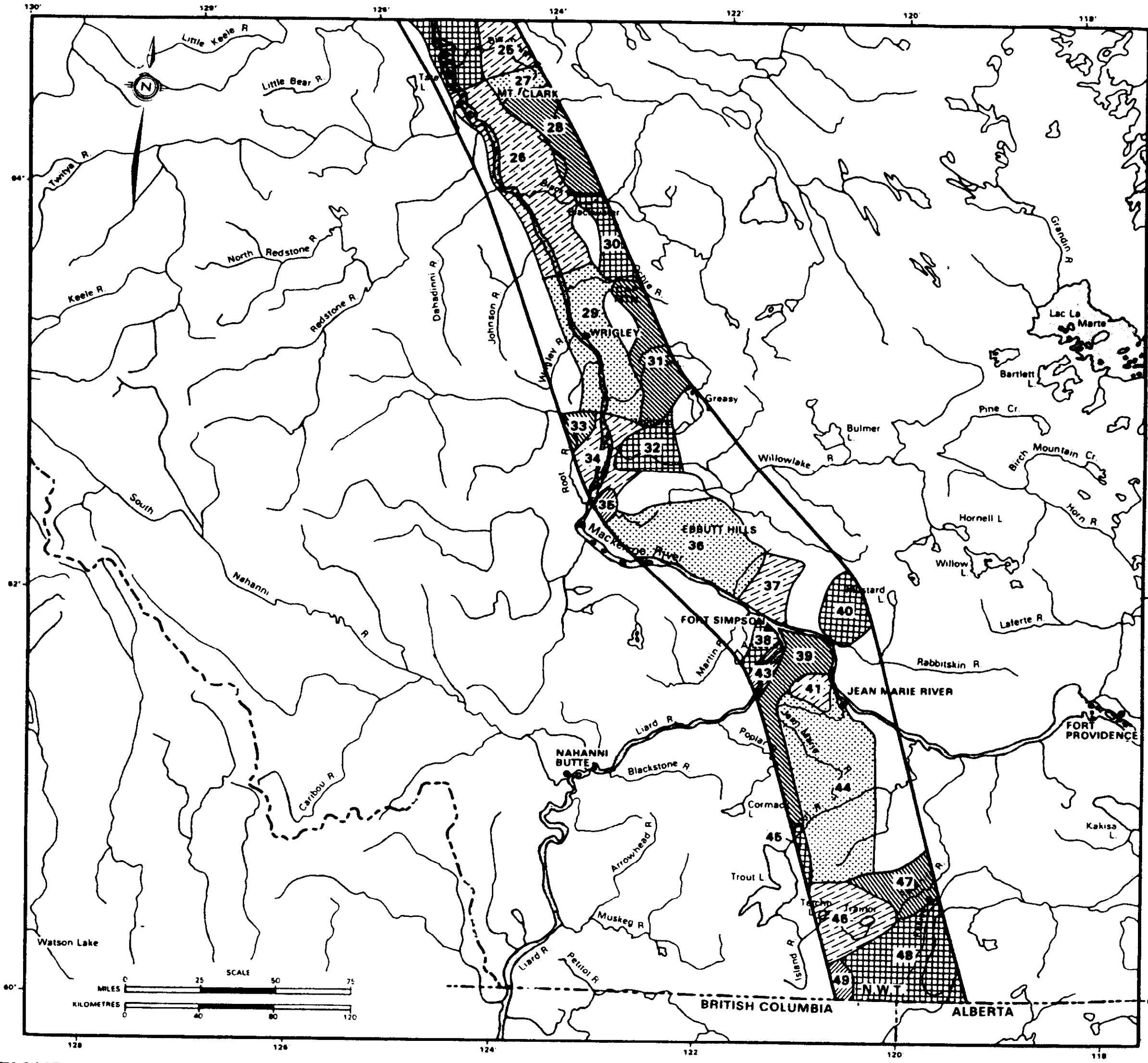

FIGURE 2.5-1 *Hunting and trapping areas used by residents of communities in or adjacent to the Mackenzie Valley Corridor. (continued)*

(day lines) that can be covered within a day. Consequently, hunting pressures are also greatest near communities as game is often taken opportunistically while working the trap line (Villiers, 1968).

2.5.1.1 Harvest Statistics

The seven most economically important furbearers to communities within the corridor (in decreasing order of importance) are marten, muskrat, lynx, beaver, coloured fox, mink and Arctic fox (Table 2.5-2) (Plate 2.5-1). However, 89% of the muskrat and 96% of the Arctic fox trapped here are exported from Inuvik. These statistics reflect the proximity of Inuvik to the Mackenzie Delta and Arctic coast where muskrat and Arctic fox are abundant. These species are much less important to the trapping economies of communities located in forested areas south of Fort Good Hope. If Inuvik data are excluded, the most important furbearers for the remaining communities within the Mackenzie River Valley (in order of decreasing importance) are marten, lynx, beaver, muskrat, mink, coloured fox and wolf.

The furbearer harvest data presented in Table 2.5-2 are taken directly from the Fur Export Tax Returns of the Northwest Territories and indicate the number of furs exported from the region by each community. Exports from smaller communities may be considerably lower than the actual harvest because trappers often sell their furs to buyers from large communities, who in turn export the furs. Consequently, furs are often mistakenly recorded as having been taken by the community from which they were exported. In addition, furs sold within the Northwest Territories or those retained for domestic purposes are not included in Fur Export Returns. Therefore, these figures must be interpreted with caution, and are used primarily to illustrate the relative economic importance of furbearers to different communities. The

TABLE 2.5-1
ACTIVE TRAPPERS (1967-1980) FROM COMMUNITIES WITHIN THE MACKENZIE VALLEY CORRIDOR.

Community	Population (19--)	1967 -68[a]	1968 -69[a]	1969 -70[a]	1970 -71[a]	1971 -72[a]	1972 -73[a]	1973 -74[b]	1974 -75[b]	1975 -76[b]	1976 -77[b]	1977 -78[b]	1978 -79[b]	1979 -80[b]
Inuvik	-	110			138		110	124 (22)	111 (11)	124 (44)	127 (42)	141 (55)	150 (52)	148 (52)
Fort Good Hope	-	94			63		67	73 (3)	76 (9)	92 (13)	80 (17)	99 (28)	103 (32)	121 (48)
Norman Wells	-							7 (2)	7 (1)	9 (1)	8 (0)	3 (1)	6 (3)	4 (3)
Fort Norman	-	54			44		29	38 (3)	42 (3)	35 (9)	45 (12)	42 (18)	46 (21)	53 (24)
Fort Franklin[c]	-							55 (16)	53 (6)	51 (10)	69 (19)	72 (29)	61 (27)	84 (44)
Wrigley	-		42		37		27	28 (2)	38 (7)	37 (3)	7 (3)	44 (13)	41 (10)	45 (22)
Fort Simpson	-	75			47		47	56 (12)	72 (2)	96 (2)	115 (17)	112 (20)	93 (25)	103 (33)
Jean-Marie River	-		8				7				12 (0)	8 (0)	9 (0)	9 (4)
Trout Lake[c]	-		19		11		16				12 (7)	12 (5)	14 (6)	19 (9)

a = Traders and Fur Record books,cited in Bissett (1974)
b = Trapper Incentive Program.
c = Does not occur within the corridor, but residents trap in the area.
() = number of trappers selling trapped furs totalling more than $1,000.00 anually.

PLATE 2.5-1 *The seven most economically important furbearers to communities within the Mackenzie Valley corridor (in decreasing order of importance) are marten, muskrat, lynx, beaver, coloured fox, mink and Arctic fox.*

TABLE 2.5-2
AVERAGE ANNUAL EXPORT AND VALUE OF FURS EXPORTED FROM COMMUNITIES WITHIN THE MACKENZIE VALLEY CORRIDOR.

Species	Inuvik		Fort Good Hope		Norman Wells		Fort Norman	
	Number[a]	Value[b]	Number	Value	Number	Value	Number	Value
Bear, polar	5.88	$ 6,198.46	0	$ 0	0.29	$ 305.71	0	$ 0
Bear, other	10.63	882.29	14.13	1,172.79	10.29	854.07	1.38	114.54
Beaver	102.50	2,857.70	508.00	14,163.04	29.00	808.52	178.88	4,987.17
Coyote	0	0	0	0	0	0	0	0
Fisher	0	0	0	0	0	0	0	0
Arctic Fox[c]	879.75	34,167.37	17.63	684.90	5.89	227.88	5.76	224.14
Coloured Fox[d]	340.14	33,305,94	50.14	4,719.55	17.29	1,624.94	26.02	2,353.37
Lynx	167.50	46,092.65	36.00	9,906.48	2.86	787.01	8.25	2,270.24
Marten	875.13	33,456.22	1,566.00	59,868.18	255.71	9,775.79	830.25	31,740.46
Mink	738.50	27,930.00	105.25	3,980.56	23.43	886.12	60.00	2,269.20
Muskrat	176.63	173,069.02	2,546.25	12,527.55	715.58	3,520.65	652.63	3,210.94
Otter	0.38	26.69	1.25	87.79	0.29	20.37	1.13	79.36
Squirrel	17.13	26.89	62.13	97.54	6.00	9.42	7.13	11.19
Weasel	372.75	503.21	75.50	101.93	4.71	6.36	13.50	18.23
Wolf	24.25	4,892.92	6.88	1,388.18	8.43	1,700.92	3.00	605.31
Wolverine	5.88	1,166.18	1.38	273.70	2.43	481.94	1.25	247.91
Years of data	8		8		7		8	

Species	FORT FRANKLIN		WRIGLEY		FORT SIMPSON JEAN-MARIE RIVER		TROUT LAKE	
	Number	Value	Number	Value	Number	Value	Number	Value
Bear, polar	0.29	$ 305.71	0	$ 0	0	$ 0	0	$ 0
Bear, other	3.00	249.00	1.50	124.50	13.50	1,120.50	0.33	27.39
Beaver	179.86	5,014.50	176.25	4,913.85	618.33	17,239.04	33.00	920.04
Coyote	0	0	0	0	1.17	69.66	0	0
Fisher	0	0	0.25	29.59	0.67	79.29	0	0
Arctic Fox[c]	21.14	820.87	0.25	9.71	0.83	32.23	0.17	6.82
Coloured Fox[d]	61.87	5,726.80	6.75	576.24	9.50	829.04	0.33	25.91
Lynx	6.57	1,807.93	39.25	10,800.82	177.83	48,935.26	18.17	5,000.02
Marten	2,026.57	77,475.77	668.50	25,556.76	1,145.33	43,785.97	37.00	1,414.51
Mink	96.29	3,641.69	46.00	1,739.72	138.83	5,250.55	4.83	182.67
Muskrat	867.71	4,269.13	190.75	938.49	418.17	2,057.40	13.83	68.04
Otter	1.86	130.63	1.00	70.23	3.00	210.69	0.17	11.94
Squirrel	37.14	58.31	132.50	208.03	624.33	980.20	14.17	22.25
Weasel	55.86	75.41	15.75	21.26	91.67	123.75	5.83	7.87
Wolf	4.14	835.33	2.00	403.54	8.33	1,680.74	1.00	201.77
Wolverine	0.57	113.05	2.75	545.41	8.17	1,620.36	0.33	65.45
Years of data	7		4		6		6	

a= The average of available data between 1971-72 and 1978-79 (Fur Export Returns).
b= The values are based on the mean of 1978-79 and 1979-80 prices paid for furs in the Northwest Territories.
c= Blue and white fox have been combined although value has been calculated separately for each colour phase and summed for this table.
d= Red, cross, and silver fox have been combined although value has been calculated separately for each colour phase and summed for this table.

total value of furs harvested for each community (Table 2.5-2) were derived from the Trappers Incentive Program and are based on records of fur buyers (R. Tingling, pers. comm.).

Moose, caribou (barren-ground and woodland) and black bear are the most important big game species hunted by residents of communities within the corridor (Tables 2.5-3, 2.5-4 and 2.5-5). Near Fort Good Hope and Inuvik caribou are hunted more extensively than are moose, while near Fort Norman and Norman Wells the number of caribou and moose

TABLE 2.5-3
CARIBOU HARVEST BY COMMUNITIES WITHIN THE MACKENZIE VALLEY CORRIDOR (1964-1976).

Community	1964 -65[a]	1965 -66[a]	1966 -67[a]	1967 -68[a]	1968 -69[a]	1969 -70[a]	1970 -71[a]	1971 -72[a]	1972 -73[b]	1973 -74[b]	1974 -75[b]	1975 -76[b]	1977 -78[b]	Average
Inuvik	133	52	72	328	129	135	110	149	195	273	344	134	120	167.23
Fort Good Hope[e]	389	496	276	497	272	399	926	587	352	359	33	166	514	405.08
Norman Wells									6	2	22	3	0	
and	216	143	181	119	105	N/R	N/R	N/R						93.10
Fort Norman									9	25	49	49	2	
Fort Franklin[d]	199	246	134	67	103	N/R	N/R	N/R	340	159	92	163	364	186.70
Wrigley	1	4	16	10	10	16	23	16	21	14	11	24	21	14.38
Fort Simpson														
and	39	35	54	28	45	38	44	26	19	N/R	56	104	67	46.25
Jean-Marie River						8[c]								
Trout Lake[d]	N/R	N/R	N/R	N/R	N/R	12[c]	N/R	N/R	1	N/R	3	10	N/R	6.50

a= General hunting licence returns, cited in Bissett (1974)
b= General hunting licence returns, kill statistics
c= DIAND/MPS (1973).
d= Hunting areas occur within the corridor
e= Fort Good Hope and Colville Lake combined
N/R = no recorded harvest or unknown.

TABLE 2.5-4
MOOSE HARVEST BY COMMUNITIES WITHIN THE MACKENZIE VALLEY CORRIDOR (1963-1976).

Community	1963 -64[c]	1964 -65[a]	1965 -66[a]	1966 -67[a]	1967 -68[a]	1968 -69[a]	1969 -70[a]	1970 -71[a]	1971 -72[a]	1972 -73[b]	1973 -74[b]	1974 -75[b]	1975 -76[b]	1977 -78[b]	Average
Inuvik	27	21	15	21	35	13	22	40	19	12	24	10	15	5	19.93
Fort Good Hope[f]	136	141	116	76	114	66	43	78	78	99	89[f]	16	29	100	84.36
Norman Wells										17	8	18	24	0	
and	191	125	104	92	93	95	17	28	11						69.07
Fort Norman										22	20	51	50	1	
Fort Franklin[e]	37	55	88	50	22	23	N/R	14	N/R	9	6	22	19	11	29.67
Wrigley	69	62	51	40	48	47	32	59	47	31	12	16	32	23	40.64
Fort Simpson															
and	135	140	64	177	160	150	67	139	120	55	4	52	64	103	102.14
Jean-Marie River							12[d]								
Trout Lake[e]	N/R	N/R	N/R	N/R	N/R	N/R	20[d]	N/R	N/R	7	N/R	4	12	N/R	10.75

a= General hunting licence returns, cited in Bissett (1974)
b= General hunting licence returns, kill statistics
c= General hunting licence returns, cited in Dickinson and Herman (1979).
d= DIAND/MPS (1973)
e= Hunting areas occur
f = Fort Good Hope and Colville Lake combined
N/R = no recorded harvest or unknown.

TABLE 2.5-5
BEAR HARVEST BY COMMUNITIES WITHIN THE MACKENZIE VALLEY CORRIDOR (1964-1976).

Community	1964 -65[a]	1965 -66[a]	1966 -67[a]	1967 -68[a]	1968 -69[a]	1969 -70[a]	1970 -71[a]	1971 -72[a]	1972 -73[b]	1973 -74[b]	1974 -75[b]	1975 -76[b]	1977 -78[b]	Average
Inuvik	3	3	2	4	0	1	1	5	9	6	4	2	0	3.08
Fort Good Hope[e]	27	15	25	17	21	16	44	22	32	30[c]	6	22	18	22.69
Norman Wells									3	0	3	3	0	
and	36	21	28	17	22	14	9	1						13.85
Fort Norman									0	6	8	8	1	
Fort Franklin[d]	16	12	8	3	0	N/R	1	0	3	0	2	4	2	4.25
Wrigley	10	18	3	16	14	29	27	9	16	8	0	15	9	13.38
Fort Simpson														
and	45	71	64	66	67	61	67	59	38	3	32	35	58	51.23
Jean-Marie River						7[c]								
Trout Lake[d]	N/R	N/R	N/R	N/R	N/R	5[c]	N/R	N/R	1	N/R	1	3	N/R	2.50

a= General hunting licence returns, cited in Bissett (1974)
b= General hunting licence returns, kill statistics
c= DIAND/MPS (1973).
d= Hunting Areas occur within the corridor
e= Fort Good Hope and Colville Lake combined
N/R = no recorded harvest or unknown.

taken are about the same. Reported harvests of both moose and caribou declined sharply throughout the area in the early 1970's. With the exceptions of Fort Simpson and Jean-Marie River, black bear are harvested considerably less frequently than are either moose or caribou (Table 2.5-5).

Harvest statistics for caribou, moose and bear are derived from General Hunting Licence Returns (Tables 2.5-3 to 2.5-5). However, holders of General Hunting Licences are not compelled to maintain and submit hunting records, and consequently the reliability of these estimates is unknown (R. Tingling, pers. comm.).

2.5.1.2 Hunting and Trapping Areas

Hunting and trapping areas used by residents of communities within or adjacent to the Mackenzie Valley corridor are indicated on Figure 2.5-1. The numbered areas on the Figure are based primarily on the Northern Land Use Information Series of maps (Environment Canada, 1976) and indicate areas with similar patterns and intensity of hunter and trapper use. Supplemental information was obtained from DIAND/MPS (1973), Bissett (1974), and Thompson *et al.* (1978).

(a) Inuvik

Inuvik is the most northerly and largest community within the Mackenzie Valley corridor. Most of its hunting and trapping activities are based inside the boundary of the Delta Registered Group Trapping Area (Environment Canada, 1976). Inuvik shares hunting and trapping privileges in the Mackenzie Delta (Area 6) with other communities, including Aklavik, Fort McPherson and Arctic Red River. Trapping areas used by residents of Inuvik include the eastern portion of the Mackenzie Delta and the area directly west and south of the community.

The Mackenzie Delta (Area 6) is the most heavily trapped area within the Mackenzie Valley corridor. Muskrat is the most economically important furbearer, accounting for an estimated average of 47% of the fur harvest income at Inuvik (Table 2.5-2). The majority of muskrat taken by trappers from Inuvik, Aklavik, Arctic Red River and Fort McPherson are trapped on the Mackenzie Delta between April and June. In addition, mink, beaver, lynx and coloured fox are trapped here during the winter trapping season (November through March). Moose are sometimes hunted on the Delta, particularly in years when caribou are scarce in the mountains.

Area 5, which includes Campbell and Sitidgi lakes, is occasionally visited by hunters and trappers from Inuvik and Aklavik during the winter. The major big game species hunted in this region include barren-ground caribou, grizzly bear and moose, while trapped species include Arctic fox, marten, mink and wolverine.

The large area north of, and including, Travaillant Lake (Area 7) is considered to be one of the most productive marten areas of the region, and has been trapped annually by men from Arctic Red River and Fort McPherson, as well as by several trappers from Aklavik and Inuvik. Area 7 is also trapped for mink, lynx, coloured fox, beaver and wolverine. Moose and barren-ground caribou are hunted opportunistically during these trapping activities.

Area 8, south of Travaillant Lake, has been visited occasionally by trappers from Inuvik and Fort McPherson, and is still used by trappers from Arctic Red River. The trappers come primarily during the spring to hunt and trap beaver and muskrat. Residents of Arctic Red River also hunt and trap in the lowlands of Area 10 where access via the Mackenzie River is good.

(b) Fort Good Hope

Major hunting and trapping areas within the corridor which are utilized by residents of Fort Good Hope are located primarily along the Mackenzie River and its tributary lowlands, and in the Yeltea, Manuel and Rorey lake regions. Marten is the most economically important furbearer to the community of Fort Good Hope, accounting for more then 50% of the fur harvest income (Table 2.5-2).

People from Fort Good Hope may hunt and trap along the Mackenzie River as far downstream as the Thunder River and as far upstream as the Oscar Creek area (Areas 10, 17 and 18). The northern portion of this lowland region (Area 10) is also heavily used by residents of Arctic Red River, while residents of Fort Norman also hunt and trap in the southern portion (Area 18). Camps are often established along the Mackenzie River because it is a major travel route within the region. Moose are hunted along the River during late summer and fall, while a few black bear are taken in spring. Caribou are harvested wherever they are encountered. Lowland areas (including the region south of the Tsintu River) are visited in spring for beaver and muskrat, while mink and lynx are trapped along the west bank of the River, particularly near Ogilvie Island (Environment Canada, 1976). Bissett (1974) reported heavy mink trapping between the Hare Indian and Tsintu rivers.

Area 9, located east of the Mackenzie River, is used by residents of Fort Good Hope to harvest marten, lynx, beaver, muskrat, mink, coloured fox, moose and caribou.

Yeltea Lake (Area 11), Manuel Lake (Area 12) and Rorey Lake (Area 13) are used by as many as six families each for the winter trapping of marten, mink, coloured fox and lynx. Beaver and muskrat are also taken at these locations during the spring, while moose and caribou are harvested opportunistically during trapping activities.

Area 14, in the vicinity of the Hare Indian River, is used less heavily than are some adjacent areas. The region is trapped for small game such as marten, mink, beaver, and muskrat, and the Hare Indian River provides a travel route to trapping areas further east. Some marten trapping and moose hunting occurs along trails between Fort Good Hope and Fort Norman in Area 15.

(c) Fort Norman, Norman Wells and Fort Franklin

Resource harvesting areas for residents of Fort Norman and Norman Wells extend from the Hanna River area south to the vicinity of the Blackwater River. Marten is the most economically important furbearer to these communities, accounting for an estimated 66% and 47% of fur harvest income at Fort Norman and Norman Wells, respectively (Table 2.5-2).

The residents of Norman Wells make frequent use of the Mackenzie River Valley and its associated lowlands both up and downstream from the community (Area 18). Base camps for hunting and trapping are often established along the River because the Mackenzie is a heavily used travel route. During spring the region between Norman Wells and Oscar Creek is hunted and trapped for beaver and muskrat. In winter mink and lynx are trapped along the west bank of the Mackenzie River, particularly near Ogilvie Island.

The Hanna River area (Area 16) is used in some winters by several residents of Fort Norman to trap lynx, marten, beaver and muskrat.

Area 20 occurs north of the Norman Range and includes the northern part of Kelly Lake. Bissett (1974) reported heavy trapping activity for mink in this region, and the area is known to be used annually by residents of Fort Norman to trap marten, lynx, fox and mink during winter, and beaver and muskrat in spring. Some Fort Franklin residents also occasionally visit the area for spring hunting and trapping. Residents of Fort Norman and Fort Franklin also occasionally trap marten in the uplands surrounding Kelly Lake (Area 21), and may hunt and trap in Area 22 between the Mackenzie River and Brackett Lake.

The lowlands around Brackett Lake (Area 23) are the most heavily trapped areas near Fort Norman and Fort Franklin, with as many as 15 trappers being involved. Most activity centres around spring hunting and trapping for beaver and muskrat, although winter trapping for marten and mink also occurs. Bissett (1974) reported that marten trapping is heavy in Area 23. Moose and caribou are taken opportunistically by trappers and hunters, and the large amount of trapping activity in the area probably results in substantial ungulate harvests.

Area 25, located just south of the Great Bear River, is used annually by a number of Fort Norman residents for the trapping of marten, mink, lynx and fox in winter, and beaver and muskrat in spring. Marten is the most abundant furbearer harvested in the Big Smith Creek and Saline River areas. This zone is also part of a traditional moose hunting area (DIAND/-MPS, 1973), and Fort Franklin residents occasionally visit to hunt this game.

Areas 24 and 26 are used heavily as travel routes, and consequently have some hunting and trapping pressure from residents of Fort Norman and Fort Franklin. Although very little trapping is reported from Area 27, several east-west trails through the region are used occasionally by people from Fort Norman and Fort Franklin. Marten are trapped in some winters in the vicinity of the Saline River (Area 28) by residents of Fort Norman, and the area is also used occasionally as an access route to the Blackwater Lake region.

(d) Wrigley

The hunting and trapping areas within the corridor utilized by residents of Wrigley extend along the Mackenzie River south from the Keele River to near the mouth of the Root River (Areas 26, 29 and 34). As for other areas, the Mackenzie River serves as a travel route for most residents of Wrigley, and hunting and trapping activities are often based from temporary camps established along its course. Marten is the most economically important furbearer to the community, accounting for an estimated 56% of furbearer harvest income (Table 2.5-2).

The lowlands adjacent to the Blackwater River are trapped for beaver in some years, while moose are hunted along the Mackenzie River during late summer/fall and caribou in winter.

A large area south of the Blackwater River and east of the Franklin Mountains (Areas 30 and 31) is used for trapping and hunting by many family groups. A number of former residents in the Blackwater Lake region still visit Area 30 to trap lynx, marten, mink, beaver and fox in winter and spring. Moose and caribou are also hunted, particularly in the area southeast of Blackwater Lake. Similarly, a number of families that formerly resided in the Fish Lake region still hunt and trap there. Families using cabins on the west side of Fish Lake hunt and trap along the eastern slopes of the mountains, while families on the east side of Fish Lake utilize areas to the east and northeast. Marten, mink, lynx and beaver are the main furbearers trapped. Moose are hunted to the north and east of Fish Lake, while caribou are taken to the west. Some of the families that live in permanent camps at the mouth of the River-Between-Two-Mountains also hunt and trap in Area 31.

Area 32 is used primarily by one family which lives at the mouth of the Willowlake River, although some Fort Simpson families also occasionally trap there. Lynx, marten and mink are the main species taken in winter, while beaver and muskrat are trapped in spring. Moose and caribou are taken when the opportunity arises.

One family from Wrigley spends most of each winter in Area 33 trapping lynx, marten and beaver, while the previously mentioned families that camp at the mouths of the Willowlake River and the River-Between-Two-Mountains also trap beaver and muskrat in Area 35. Wrigley hunters may also travel down to the Camsell Bend area of the Mackenzie River to hunt moose (Thompson *et al.,* 1978).

(e) Fort Simpson and Jean-Marie River

The size and number of specific areas used by hunters and trappers of Fort Simpson are considerably larger than for most other communities within the corridor. Residents of Fort Simpson occasionally hunt and trap along the Mackenzie River as far downstream as the Willowlake River, and as far south as the northern shore of Trout Lake. The hunting and trapping areas used by the residents of Jean-Marie River overlap considerably with those used by the people of Fort Simpson. The most economically important furbearer to the communities of Fort Simpson and Jean-Marie River is lynx, accounting for approximately 39% of the fur harvest income.

Areas 32, 33, and 34 receive relatively light use by residents of Fort Simpson. However occasional temporary camps may be established in locations where furbearers such as lynx, marten, mink, beaver and muskrat are trapped. Moose and caribou are taken opportunistically.

In most years residents of Fort Simpson trap beaver and muskrat in the lowlands of Area 35, and Area 36 is used annually by several Fort Simpson families that live in camps near the mouth of the Trail River for most of the year. Trap lines generally follow the creek valleys inland from the north shore of the Mackenzie River, and marten, mink, weasel, beaver and muskrat are taken. Moose are abundant in the Camsell Bend area (Thompson *et al.,* 1978) and are hunted there.

Area 37 is used regularly by several Fort Simpson families who live for most of the year at the mouth of the Harris River. Marten, mink and lynx, and occasionally wolverine, fox and wolf, are trapped in winter, while beaver and muskrat are taken in spring. Moose and woodland caribou are taken when encountered. The portions of Areas 37, 38 and 39 which are closest to Fort Simpson are used as day line areas by many trappers to harvest lynx, beaver, mink, coloured fox and marten.

Temporary camps are often established along the numerous trails which cross Area 39 and as many as 6 trappers from Fort Simpson, Jean-Marie River and Trout Lake may use the area each winter. Moose are also taken opportunistically in Area 39.

Several Fort Simpson families that formerly lived at the mouth of the Rabbitskin River now return there during winter and spring along with trappers from Jean-Marie River. Large numbers of marten and lynx are taken from winter trap lines which extend to the Mustard Lake region, while beaver and muskrat are trapped in the lowlands of the Rabbitskin River each spring. Trappers also hunt small game (such as hares, ptarmigan and grouse), moose and woodland caribou.

Residents of Fort Simpson hunt beaver and muskrat in spring and trap marten and lynx in winter in Area 40. Moose, caribou and small game are hunted on an opportunistic basis.

Area 41 is heavily harvested for beaver and muskrat by trappers from Jean-Marie River and a few from Fort Simpson. In addition, this lowland area is hunted year-round for moose and caribou.

A Fort Simpson family lives in Area 43 year-round, trapping primarily marten, lynx and beaver. Relatives and other families from Nahanni Butte and Trout Lake also occasionally trap in Area 43.

As many as 8 trappers from Jean-Marie River and Fort Simpson use the large region of rolling hills and lowland in Area 44 during winter and spring to harvest lynx, marten, mink, weasel, river otter, beaver and muskrat. Moose and small game are taken for food by the trappers. McGill Lake is the site of one of the regular camps in Area 44.

Fort Simpson residents occasionally travel into Area 45 where they establish temporary camps and trap lynx, marten, mink, beaver and muskrat.

(f) Trout Lake

Although Trout Lake does not occur within the corridor, much of the area used by residents of this community for trapping and hunting impinges on it. Lynx is the most economically important furbearer to Trout Lake, accounting for 63% of the fur harvest income (Table 2.5-2).

Residents of Trout Lake may occasionally travel up to the lower portions of the Liard River in Areas 39, 43 and 44. A wide variety of species may be trapped in Area 39. In Area 43 marten and lynx are the main animals trapped in winter, while beaver are hunted during spring in the lowlands near the river. Trappers from Trout Lake occasionally travel to Area 44 to hunt or trap lynx, marten, mink, weasel and muskrat.

Three family groups who use cabins along the north slope of Trout Lake have trap lines in Area 45. Trappers harvest lynx, marten, and mink during the winter, and beaver in the spring. Moose and caribou are taken opportunistically during trapping activities.

The area surrounding Tetcho and Trainor lakes (Area 46) is very productive and is used annually by several family groups from Trout Lake to trap lynx, marten, mink, beaver and muskrat. Moose and woodland caribou are abundant and are also hunted. Area 49 is used year-round by three family groups from Trout Lake to hunt and trap the same species found in Area 46.

In most years residents of Fort Providence and Kakisa Lake trap along the Redknife River (Area 47), while the Cameron Hills (Area 48) are visited irregularly by trappers from the settlements of Indian Cabins and Meander River in northern Alberta.

2.5.2 FISHERIES HARVEST

The Mackenzie River Valley, particularly the Delta region, contains the most productive domestic fishing waters of Canada's western Arctic (Withler, 1975), providing a staple source of protein for both people and their dogs (Plate 2.5-2). In addition, commercial and sport fisheries provide additional sources of income and recreation for residents. For the purposes of this document domestic fisheries include "all subsistence fishing by Indian, Inuit, or persons of mixed blood who use traditional methods to provide food for himself, his family, or his dogs" (Fisheries and Environment Canada, 1977). Commercial fishing is defined as "all fishing for the purpose of sale or barter" (Fisheries and Environment Canada, 1977). This includes fish sold locally and those exported through the Freshwater Fish Marketing Corporation (FFMC). Sport fishing is classified as a recreational experience and is not food-oriented.

The following discussion summarizes available information on the locations and extent of domestic, commercial and sport fisheries within three regions

PLATE 2.5-2 *The Mackenzie River Valley, particularly the Delta region, contains the most productive domestic fishing waters of Canada's western Arctic. Lake trout, shown here, are one of the more common species taken in the region between Fort Good Hope and Fort Franklin. (Courtesy, J. Cheng).*

of the Mackenzie Valley corridor, that is, the lower Mackenzie River and Delta, the central Mackenzie River, and the upper Mackenzie River regions (Figure 2.5-2), and is based largely on reports by Withler (1975), McCart and Den Beste (1979), and Corkum and McCart (1981). These reports contain detailed information on the importance of fishing activities in various regions of the Northwest Territories, harvest statistics, and yearly historical data on harvest activities since 1955.

2.5.2.1 Lower Mackenzie River And Delta Region

The Lower Mackenzie River and Delta region includes the settlements of Inuvik, Aklavik, Fort McPherson, Arctic Red River and Tuktoyaktuk. Together they represent one of the most important regions of domestic fishing in the Mackenzie Valley (Withler, 1975). From year to year, the locations of specific fishing areas vary somewhat; but typically fishing occurs in the river channels of the Delta along the Tuktoyaktuk Peninsula, as well as at Eskimo (Husky) Lakes, Noell Lake, Sitidgi Lake and Travaillant Lake (Figure 2.5-2).

Domestic catches for the lower Mackenzie region have been estimated since 1960 by a variety of investigators (Withler, 1975; Corkum and McCart, 1981). Estimates prepared by Wolforth (1966), Sinclair *et al.* (1967), Hunt (1972, 1973), DIAND/MPS, (1973), Jessop *et al.* (1974), Usher (1975) and Olesh (1979) suffer from a poor database and a lack of uniform data gathering methodology. Since 1978 some effort has been made to improve the quality of data available, including questionnaires sent to fishermen in the area (Corkum and McCart, 1981).

Overall domestic fishing has declined in the Mackenzie Delta and elsewhere in response to a number of socio-economic changes over the last 20 years (McCart and Den Beste, 1979). Data indicate that the total domestic harvest was roughly 100,000 kg annually in 1979 and 1980, while data from the early 1960's, although somewhat unreliable, indicate annual harvests nearly a full order of magnitude greater (Wolforth, 1966; Olesh, 1979).

Broad and humpback whitefish are the dominant species caught, accounting for at least 50% of the domestic harvests in the lower Mackenzie region (Corkum and McCart, 1981). Other major species include Arctic and least cisco, inconnu, northern pike and burbot, which together represent over 25% of the fish caught. Minor species fished in a few

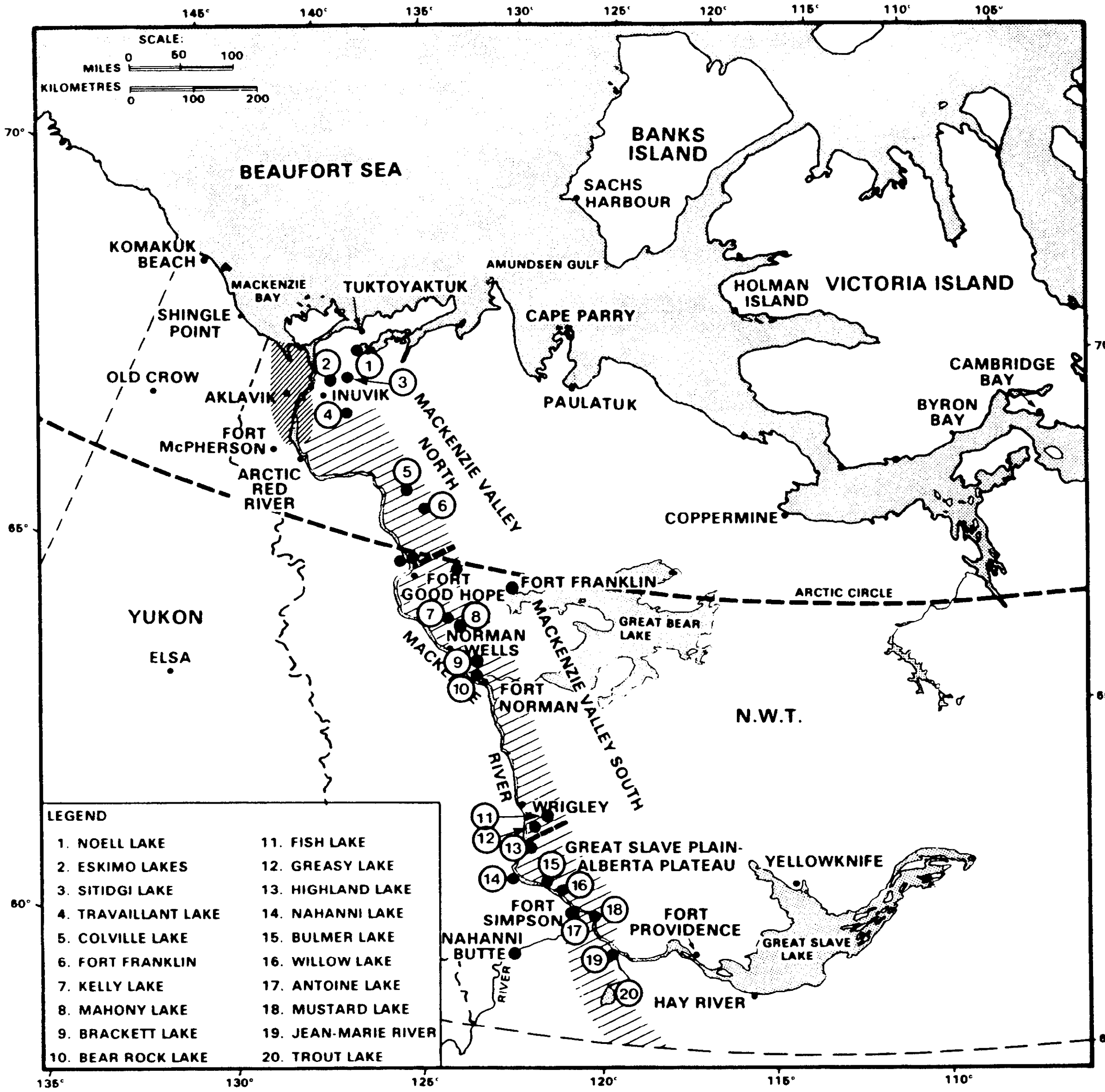

FIGURE 2.5-2 *Documented domestic fishing areas in the Mackenzie Valley corridor.*

locations include Arctic grayling, Arctic char, lake trout, chum salmon, longnose suckers, and Pacific herring (in Tuktoyaktuk only) (Corkum and McCart, 1981).

Arctic char are caught by residents of Aklavik and Inuvik in the western portions of the Delta. Fishing for other species is not distributed evenly but the entire Delta is used. Estimates of the domestic harvest from each of the five Mackenzie Delta management areas can be found in Corkum and McCart (1981).

Except for the period from 1967 to 1971, varying levels of commercial fishing have been documented in the Mackenzie Delta since 1955 (Corkum and McCart, 1981). However, these data suffer from the same problems encountered with domestic fishing data. Recent data indicate that commercial fisheries represent a relatively minor portion of fish harvests and often involve only small scale efforts to supply local markets. For example, data from 1979 indicate that approximately 10,000 kg of fish were exported to areas outside the Delta and approximately 12,000 kg of fish were sold locally (Corkum and McCart, 1981). This represents less than 25% of the reported domestic harvest for the region.

The dominant and preferred species of the Delta commercial fishery is the broad whitefish. Although humpback whitefish are also harvested, they usually have too many parasites for commercial use (Corkum and McCart, 1981). Other minor species include ciscos (Arctic and least), inconnu, Arctic char, northern pike and burbot. Locations of commercial fishing sites (Figure 2.5-3) are similar to those for the domestic fishery, being largely centred around Delta channels where whitefish populations migrate.

Historically there have been several attempts to establish larger fish export operations in the Delta, all of which ended in failure (McCart and Den Beste, 1979). While no records are available for local fish sales prior to 1977, these fish were probably included in early estimates of domestic fishing (Corkum and McCart, 1981).

Little information is available concerning sport fishing in this region. One lodge is located on Sitidgi Lake and generally operates only during summer. Other known areas of concentrated sport fishing are shown in Figure 2.5-4. Residents in this region periodically angle in the Mackenzie River mainstem, in accessible tributary streams, and occasionally in lakes (Corkum and McCart, 1981).

2.5.2.2 Central Mackenzie Region

Domestic fishing in the central Mackenzie region involves the settlements of Fort Good Hope, Colville Lake, Norman Wells, Fort Norman and Fort Franklin. The most common species taken are Arctic grayling, Arctic and least cisco, broad and humpback whitefish, lake trout, northern pike, inconnu, longnose suckers and burbot (Withler, 1975). Figure 2.5-2 shows the most important domestic fishing sites in

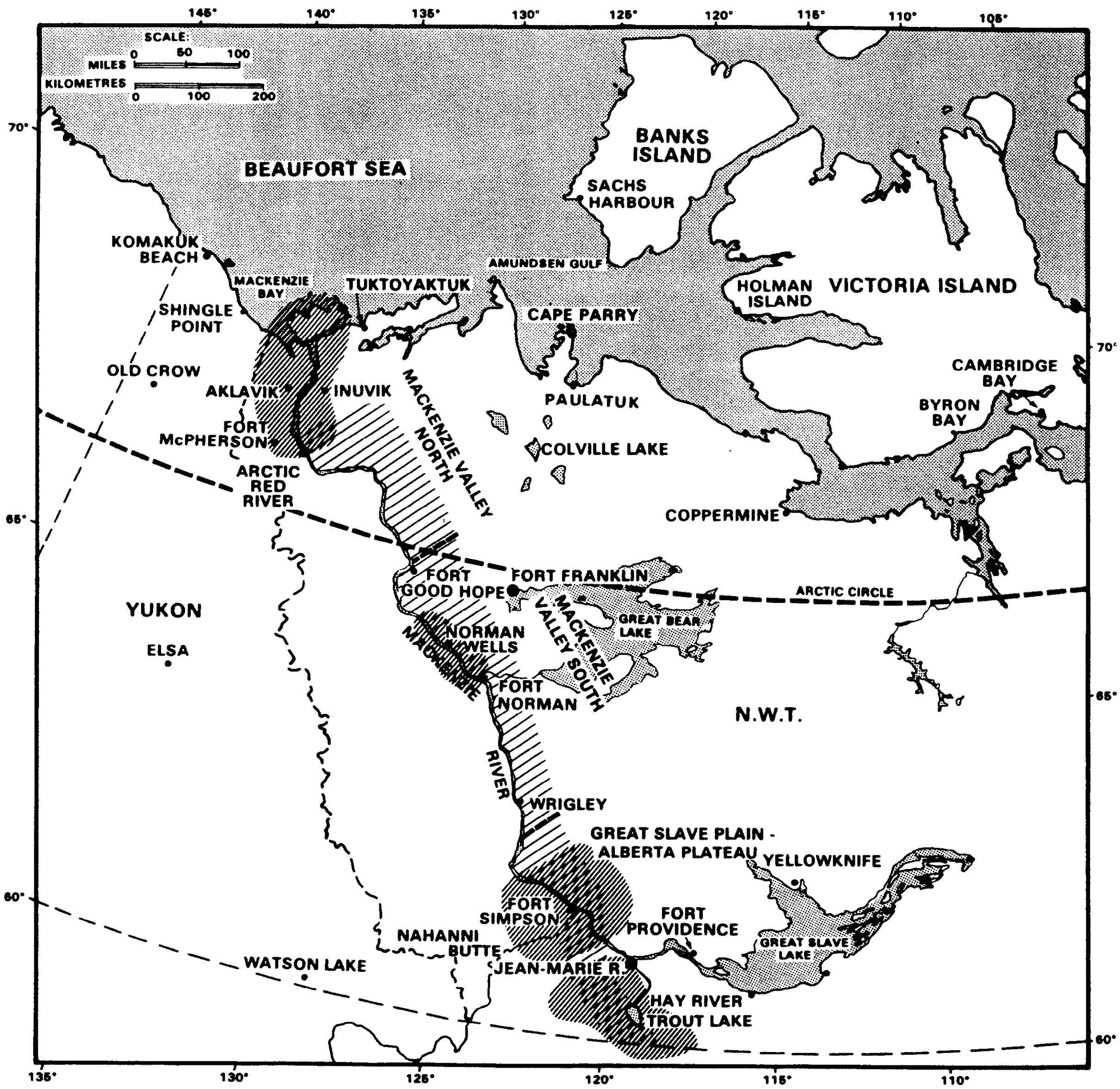

FIGURE 2.5-3 *Commercial fishing areas in the Mackenzie Valley corridor.*

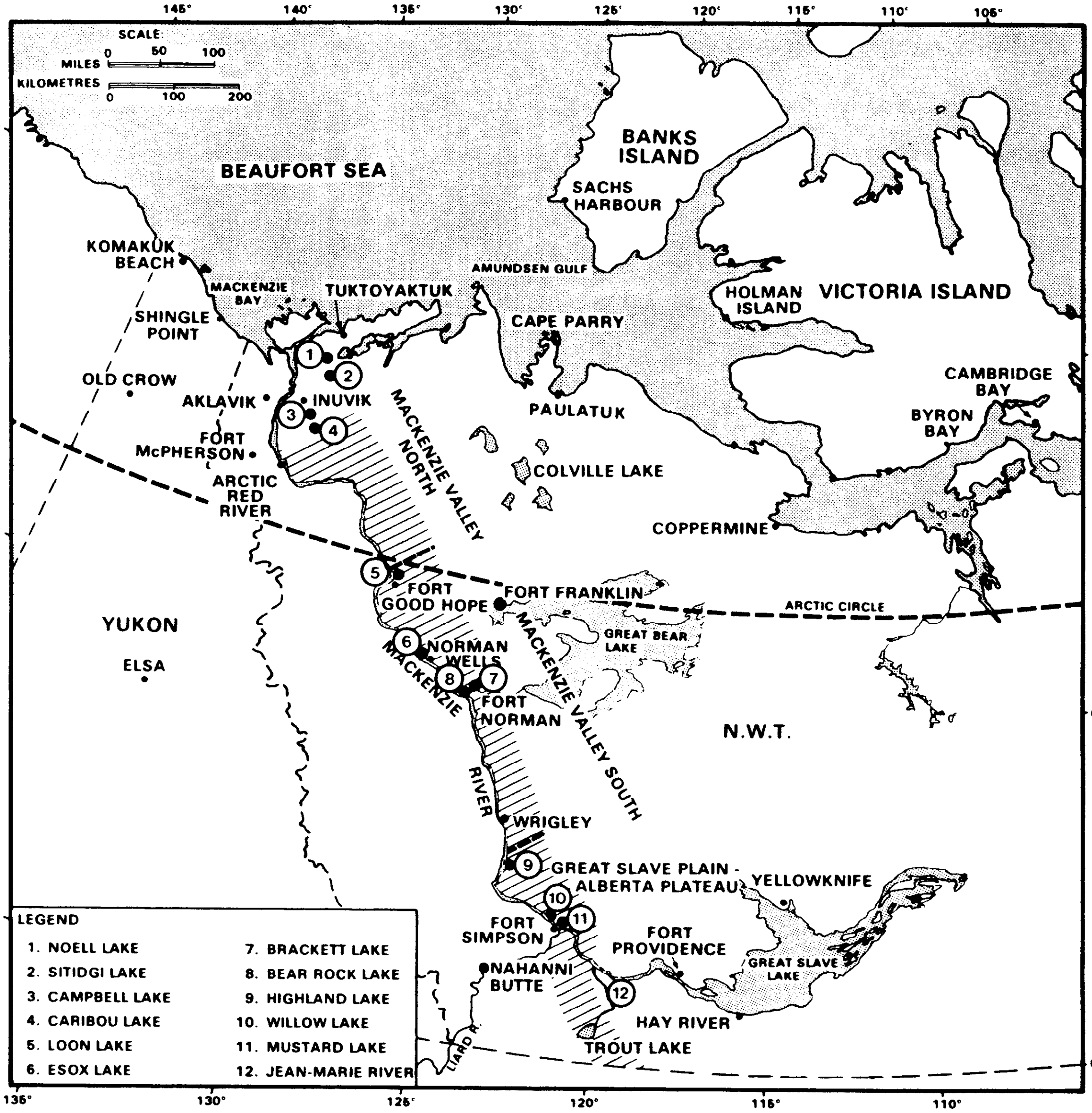

FIGURE 2.5-4 *Documented sport fishing areas in the Mackenzie Valley corridor.*

the central Mackenzie region.

Estimates of domestic fish harvests in this region have only been documented for 1961-62 (Sinclair *et al.*, 1967) and for 1972 (Gemini North Ltd., 1974b), and suggest that the total annual harvest ranged from 100,000 to 150,000 kilograms. Specific data on the relative importance of different species to the domestic harvest are not presently available.

There is no information available on commercial fishing in the central Mackenzie region, although it has occurred sporadically in the area between Norman Wells to Fort Norman (Figure 2.5-3).

There are no sport fishing lodges in the central region of the corridor, but sport fishing does occur near Fort Norman in the Mackenzie River and near the mouth of the Great Bear River (Figure 2.5-4). Residents of communities in this region angle in various lakes, the Mackenzie River mainstem, and near the mouths of tributary streams. Northern pike, Arctic grayling and whitefish are the most important species taken.

2.5.2.3 Upper Mackenzie Region

The upper Mackenzie region includes the settlements of Fort Simpson, Fort Providence, Nahanni Butte, Trout Lake, Wrigley, and Jean-Marie River. The major species taken in domestic fisheries from the Mackenzie River and nearby lakes include whitefish, northern pike, Arctic grayling and longnose suckers (Bissett, 1967; Stein *et al.*, 1973). Important fishing sites situated in or near the corridor are indicated in Figure 2.5-2.

Estimates of the total domestic fish harvested for communities in this region are available for 1961 through 1964 (Sinclair *et al.*, 1967), 1965-66 (Higgins, 1969) and (Gemini North Ltd., 1974b). These estimates suffer from a weak data base but suggest an annual harvest of between 50,000 and 100,000 kg, with residents of Fort Providence harvesting nearly 50% of the total. Specific data on the relative abundance of individual fish species taken in the domestic harvest are not available. Likewise no published information is available regarding commercial fishing activities for the upper Mackenzie region, although some occurred historically near Fort Simpson (Figure 2.5-3).

There are no sport fishing lodges within the corridor in this region, but it does occur near Fort Simpson in the Mackenzie River and by the mouths of the Liard and Trout rivers (Figure 2.5-4). Residents of other communities also angle in the Mackenzie River mainstem and at the mouths of major tributaries which are accessible by boat. Arctic grayling, northern pike, whitefish and a few walleye are caught (McCart and Den Beste, 1979).

2.6 SPECIAL AREAS

The Mackenzie Valley corridor crosses, or passes close to, six proposed International Biological Program (IBP) sites (Beckel, 1975). (Figure 2.6-1). The following is a brief description of these areas.

2.6.1 CARIBOU HILLS IBP SITE

The "Caribou Hills" IBP site covers 660 km^2 and is of interest because of two unique features - a steep eroding slope and the warming effect of the north-flowing Mackenzie River. These combine to provide a location where a wide diversity of plant life is found. The plants present there include Canadian Arctic, Siberian-Alaskan, Cordilleran and Prairie floras. At least four plant species are at, or near, the limit of their range at this site.

2.6.2 DOLOMITE-CAMPBELL LAKES IBP SITE

The "Dolomite-Campbell Lakes" IBP site covers an area of 310 km^2. The sharp-relief dolomite rocks found there provide unusual habitats for important, rare plants of Arctic and Siberian-Alaskan floras. The vegetation, which has been undisturbed by fire for several centuries, contains several examples of rare communities (Ritchie, 1976). Several endangered bird species also use this area for nesting.

2.6.3 MIDDLE MACKENZIE DELTA IBP SITE

The "Middle Mackenzie Delta" IBP site (52 km^2) represents the transition between the treeless northern Delta tundra and forested southern taiga areas. There are numerous aquatic and terrestrial habitat features. Permanent sample plots have been established here (Gill, 1971).

2.6.4 SOUTHERN MACKENZIE DELTA IBP SITE

The "Southern Mackenzie Delta" IBP site (150 km^2) contains flora and fauna characteristic of the southern Mackenzie Delta. It is considered a unique region in forming part of one of the largest and most-northerly river deltas in the world.

2.6.5 BRACKETT LAKE AND RIVER IBP SITE

The "Brackett Lake and River" IBP site (700 km^2) contains many good examples of bog and pond successions in relation to the formation or breakdown of peat and permafrost landforms. Extensive forest fires have burned much of the area, resulting in an interesting series of plant invasions, as well as an opportunity to examine the effects of fire on permafrost landforms. The area is an important autumn staging area for waterfowl, and river otters, which are uncommon elsewhere, are abundant there. Owing to the relative abundance of wildlife and fish, the area is used by northerners for hunting and fishing.

2.6.6 EBBUTT HILLS IBP SITE

The "Ebbutt Hills" (90 km^2) were proposed as an IBP site because the accumulated permafrost found there has resulted in peat landforms which are considered exceptional for the Great Slave lowlands. The region is considered a good area for studies of lichens and other vegetation for comparison with floral communities of the Horn Plateau to the south. These areas have similar altitude and precipitation regimes, but have very different landform and vegetation patterns owing to the influences of permafrost.

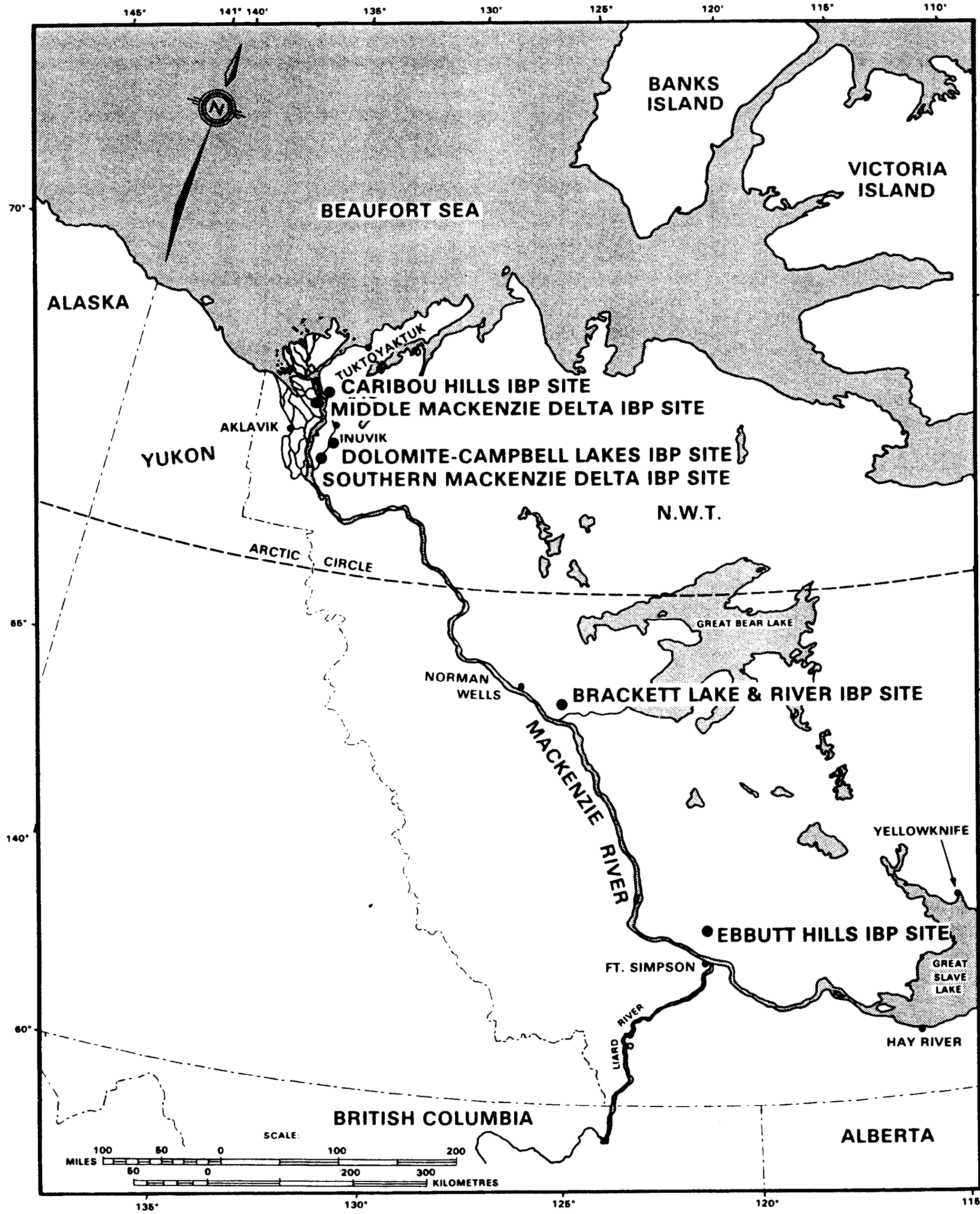

FIGURE 2.6-1 *IBP sites in or adjacent to the Mackenzie Valley corridor.*

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