TERRAIN ANALYSIS

OF

THE DEMPSTER PIPELINE ROUTE

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CONSULTING ENGINEERING & TESTING

HARDY ASSOCIATES (1978) LTD.

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THE DEMPSTER PIPELINE ROUTE

For

Foothills Pipe Lines (Yukon) Ltd.

By

Hardy Associates (1978) Ltd.

February, 1979

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1.0 INTRODUCTION

1.1 General

Terrain analysis, which includes terrain classification and mapping, was conducted by Hardy Associates (1978) Ltd., Calgary, Alberta, along the Dempster route of Foothills Pipe Lines (Yukon) Ltd. Basic information obtained during terrain classification and mapping describes and identifies 1) the bedrock and soils materials near ground surface, 2) geologic and engineering properties of these materials, 3) stratigraphy and permafrost characteristics of surficial materials, 4) geologic history of terrain units and landforms, 5) topography and drainage characteristics of landforms.

1.2 Sources of Data

Terrain analysis is based on airphoto interpretation and supplemented by published information, field investigations, and drilling programs. Terrain classification and mapping information appears as the photomosaic portion of the alignment sheets. Geological and geophysical field investigations and drilling programs conducted during 1977 and 1978 provided field information to substantiate airphoto interpretation.

Ground reconnaissance and field surveys included observations on landforms, geologic materials, permafrost, vegetation, topography, drainage, and present erosional features.

Drilling and laboratory work provided information on soil and rock type, permafrost, moisture content, grain size, and other engineering properties. Thermistor strings were installed at selected localities to provide ground temperature data.

Reports and maps by the Geological Survey of Canada, Department of Energy, Mines and Resources, were the largest source of published information on bedrock and soil materials along the Dempster pipeline corridor. Principal works are referred to in this report and are listed in the References Section.

1.3 Presentation of Terrain Data

The photomosaic alignment sheets prepared by Hardy Associates (1978) Ltd. during 1978 show the distribution and characteristics of terrain units along the pipeline corridor. This information is supplemented by reports on geophysical surveys and drilling programs which were prepared for Foothills Pipe Lines (Yukon) Ltd. and have these titles:

1) Test Hole Logs, Dempster Highway Pipeline Route, December 20, 1977, Klohn Leonoff Consultants Ltd.

2) Dempster Lateral Drilling Program, Volumes I and II, October 1978, Klohn Leonoff Consultants Ltd.

3) Dempster Lateral Gas Pipeline Project - Permafrost Delineation Geophysical Survey, December 1978, Hardy and Associates (1978) Ltd.

Further information on the terrain typing system developed for the Dempster route is described in this report. Also data on physiography, geologic history, geologic processes, and major terrain units along the pipeline corridor are discussed here.

2.0 TERRAIN MAPPING

2.1 Principles of Terrain Mapping

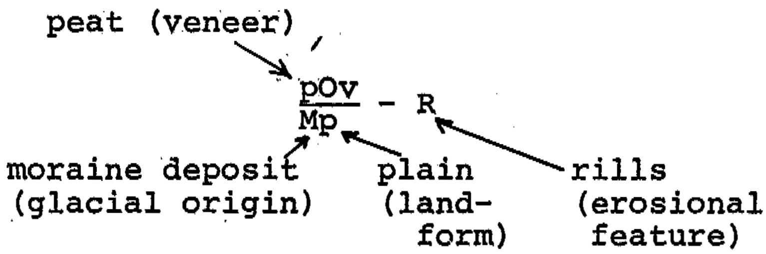
Terrain analysis for the proposed Dempster pipeline route was based on a review of published geological and geographical information and on recognition, and classification of landforms visible on airphotos.

A landform is the most significant recognizable unit that can be seen when vertical airphotos are examined with a stereoscope. Landforms have distinctive topographic and geomorphic expression, geologic origin and material, drainage and vegetation characteristics. Following identification, landforms are mapped as terrain units or terrain types on the basis of their environment of deposition. Each terrain unit is then described in a legend with a list of characteristic properties.

Terrain mapping not only outlines the boundaries of various terrain units but also forms a necessary base for use in choosing specific areas where field investigations can provide additional information for characterizing terrain units. Field investigations, including geological and geophysical surveys and geotechnical drilling and sampling programs, may then be carried out to determine the geological and engineering properties of the units, for example, material type and ground ice content. Variability of these properties within each terrain unit can also be determined during field studies.

2.2 Terrain Mapping Legend

The legend developed for terrain mapping of this pipeline route makes use of letters to symbolize terrain units of different geologic origin, specific landforms and erosional features, for example:



When two or more terrain units cannot be differentiated at the scale of mapping, they are shown as a complex, for example, $Lb_8.pO_2$, where subscripts indicate the relative proportion of each. Where subscripts are absent proportions are approximately equal. Graphic symbols are used to show the location of prominent geologic or man-made features, e.g.,  (escarpment) or  (borrow pit).

Dominant material, topography, drainage, and permafrost characteristics of terrain units, as estimated from airphotos, geophysical surveys, and a limited number of drill hole logs, are described on the terrain legends.

Soil and bedrock types were identified and described on the basis of published data and the logs of boreholes drilled for Foothills Pipe Lines (Yukon) Ltd. during 1977 and 1978.

Soil type may vary within terrain units which had a similar environment of deposition, due to differences in underlying bedrock, climate, topography, and geologic history. Such regional variations between similar terrain units are accounted for by means of legends developed for the major physiographic regions crossed by the route. These regions, from north to south, are:

Region Number	Name
I	Mackenzie Delta
II	Anderson Plain
III	Peel Plain
IV	Peel Plateau
V	Richardson Mountains
VI	Porcupine Plateau
VII	Ogilvie Mountains
VIII	Tintina Trench
IX	Yukon Plateau

Topography and drainage have been estimated from airphoto interpretation. The topographic description is based on average slopes occuring within a terrain unit, as follows:

Topography	Slope Angles	Terrain Unit Example
Depressional or flat to undulating	0-5°	Lb
Undulating to rolling	5-10°	Mm
Hummocky and ridged	5-15°	Mh
Gently to moderately sloping	5-15°	Cb(P)
Moderately to steeply	>15°	Cm

Drainage, as estimated from airphotos, is classified as poor, fair, or good.

The estimates of expected ice contents (unfrozen, low, medium, or high) contained in the terrain legends were arrived at by reviewing the 1977 and 1978 soils logs which include data on ice lens thickness and spacing, NRC ice descriptions, and moisture contents. Where logs were unavailable ice content information has been extrapolated from terrain units in the same area with similar materials and physical settings.

3.0 PHYSIOGRAPHIC SETTING

The Dempster pipeline route is located in divisions of the Arctic Coastal Plain, the Interior Plains, and the Cordilleran physiographic regions of western Canada. The pipeline route and the physiographic divisions that it crosses are shown on Figure 1 and are categorized from north to south as follows:

TABLE 1: Physiographic Elements

Major Region	Physiographic Division on Alignment Sheet		Alignment Sheet Numbers as of December, 1978
Arctic Coastal Plain	I.	Mackenzie Delta	1-11, 9a, 9b
Interior Plains	II.	Anderson Plain	12, 13, 13A, 13B, 13C, 13D, 13E(part), 14
	III.	Peel Plain	13E(part), 13F, 15, 16
	IV.	Peel Plateau	16A, 17, 18(part)
Cordillera (Eastern System)	V.	Richardson Mountains	18(part), 19, 20, 20A, 20B, 20C, 20D, 20E
	VI.	Porcupine Plateau (Eagle Plain)	20F, 20G, 21, 22, 22A, 22B, 22C, 22D, 22E, 23, 24, 25, 26(part)
Cordillera (Interior System)	VII.	Ogilvie Mountains	26(part), 27, 27A, 27B, 27C, 27D, 27E, 27F, 27G, 27H, 27I, 28, 29, 30, 31, 32, 33

VIII.	Tintina Trench	33A, 33B, 34, 35, 36, 37, 38, 39, 40
IX.	Yukon Plateau	41, 41A, 41B, 41C, 41D, 42, 43, 44, 45, 46, 47, 48, 48A, 48B, 48C, 48D, 48E, 48F, 48G, 48H, 48I, 49, 50 also 48E-1-6

The characteristics of each of the physiographic elements crossed by the pipeline are described below.

3.1 Arctic Coastal Plain

3.1.1 Mackenzie Delta

The Mackenzie Delta division of the Arctic Coastal Plain covers that part of the pipeline route from Richards Island to 4.4 km south of Noell Lake and includes the Parsons Lake and Niglintgak laterals. It consists of the modern Mackenzie Delta and the Pleistocene Delta. The flat-lying modern Mackenzie Delta is a vast deposit of silt and sand that fills the Mackenzie Trough and extends seaward (Hughes, et al., 1973). It lies a few metres above sea level and is flat and channeled with numerous levees and lakes.

The Pleistocene Delta is a complex of older deltic, fluvial, glacial and marine sediments up to 30 m thick overlying poorly consolidated Tertiary sandstone, mudstone, and conglomerate. Elevations in the old delta reach 200 m ASL. The Mackenzie Delta division is in the continuous permafrost zone (Brown, 1967). Thick permafrost and thermokarst lakes and peat-filled depressions are common. Taliks are encountered beneath major streams.

3.2 The Interior Plains

The Anderson Plain, Peel Plain and Peel Plateau of the Interior Plains are south of the Arctic Coastal Plain and east of the Cordillera.

3.2.1 Anderson Plain

The Anderson Plain is the northernmost of these divisions. It extends along the pipeline corridor from 4.4 km south of Noell Lake to the east side of the Mackenzie River. The drift covered Anderson Plain is dissected and undulating. It rises in elevation inland and, along its southern boundary elevations may reach 300 m ASL (Hughes, et al., 1973). However, along the pipeline corridor elevations range from 30 to 150 m ASL.

The eastern part of the Anderson Plain (east of 130°30'W Long) is underlain by Middle Devonian limestone and shale with some plateau summit areas capped by Cretaceous sandstone and shale. The western part is underlain by Upper Devonian sandstone and shale. The Anderson Plain is in the continuous permafrost zone and has thick permafrost, thermokarst lakes and peat-filled depressions. Taliks are encountered beneath major stream channels.

3.2.2 Peel Plain

Peel Plain lies between the Mackenzie and Peel Rivers and is bounded on the north by the Mackenzie Delta and in the south by Peel Plateau, Mackenzie Plain and the Franklin Mountains. Peel Plain is a flat-lying and poorly drained glaciated plain with two localized areas of greater relief, the Grandview Hills and a moraine belt between Arctic Red River and Fort McPherson. Along the pipeline route elevations are in the order of 30-60 m ASL, but in Grandview Hills, south of the pipeline, elevations can reach 300 to 450 m ASL. The southern and central parts of Peel Plain are underlain by flat-lying Lower Cretaceous shale and minor sandstone. In the north flat-lying Devonian shale and sandstone are present. In the vicinity of the pipeline route Peel Plain lies within the continuous permafrost zone and has fairly thick permafrost, peat-filled depressions, and thermokarst lakes.

3.2.3 Peel Plateau

Peel Plateau is south and west of Peel Plain and east of the Richardson and Mackenzie Mountains. It rises in steps from Peel Plain to the mountains. The southeastern part of Peel Plateau, which is adjacent to the Mackenzie Mountains, consists of broad mesa-like uplands which are developed on resistant Cretaceous sandstone (Hughes, et al., 1973). The pipeline crosses the northern and western part of Peel Plateau which, preglacially, was a rather uniformly sloping piedmont slope developed on shale and sandstone. Ice from the east deposited till on all of the Peel Plateau during the Pleistocene. In postglacial times it was dissected by meltwater channels and by streams which have incised their courses to considerable depth (up to 300 m). The Peel Plateau lies within the continuous permafrost zone and in the northern part of the "widespread" discontinuous permafrost zone. Drill holes and geophysical data indicate that most surficial materials are frozen.

3.3 Cordillera (Eastern System)

The Richardson Mountains and the Porcupine Plateau are the two divisions of the eastern Cordillera that are crossed by the pipeline corridor.

3.3.1 Richardson Mountains

The Richardson Mountains are adjacent to Peel Plateau and begin about 40 km west of Peel River. Their western boundary along the corridor is situated approximately 20 km north of the Eagle River. The northern and southern Richardsons have slightly different physiographic and geologic characteristics. North of latitude 67° the mountains are more rugged with several peaks to 1525 m ASL. Sandstone, shale, conglomerate, and carbonate rock of Paleozoic and Mesozoic age form this structurally complicated part of the mountains. South of latitude 67° the Richardsons are developed on a broad, faulted anticline with relatively resistant carbonate, chert and argillite of the Road River Formation on the east and west flanks and a central core of siltstone and mudstone. Elevations in this part of the mountains are at 1220 m ASL. Several low points, e.g. MacDougall Pass, along the Richardson Mountains were glaciated by tongues of ice from the east. The part of the Richardson Mountains crossed by the pipeline route lies within the "widespread" discontinuous permafrost zone. Drill hole logs and geophysical surveys indicate that most surfical sediments in this area are frozen.

3.3.2 Porcupine Plateau

The Porcupine Plateau begins at the western edge of Richardson Mountains approximately 20 km north of the Eagle River and extends southward toward the Taiga and Ogilvie Ranges. The southern boundary of the Porcupine Plateau has been placed at Churchward Hill near the Ogilvie River. However, it should be noted that between Churchward Hill and Chapman Lake inliers of both the Mackenzie Mountains (Taiga Ranges) and the Porcupine Plateau are also present within the Ogilvie Mountains region. Included in the Porcupine Plateau are unglaciated plains, uplands, and mountains which are quite diverse. The pipeline corridor is situated mostly in the southern portion of the Porcupine Plateau known as the Eagle Plain. The Eagle Plain is a broadly dissected unglaciated plain developed on flat-lying or gently deformed sandstone and shale of Mesozoic age. In this area long even-topped ridges have broad, gently rounded summits. Elevations reach 760 m ASL on some ridges.

At lower elevations throughout Eagle Plain nonglacial alluvial deposits fill valleys and colluvial deposits blanket slopes. The Porcupine Plateau lies within the "widespread" discontinuous permafrost zone. Most subsurface data indicate that surficial materials are frozen throughout this area.

3.4 Cordillera (Interior System)

3.4.1 Ogilvie Mountains

The Ogilvie Mountains physiographic division begins at the south end of the Porcupine Plateau (Eagle Plain) and extends southward to the Tintina Trench. This division has two parts (1) the northern area which includes Central Ogilvie Ranges, Taiga Ranges, Ogilvie Valley, and Taiga Valley, and (2) the southern area or Southern Ogilvie Ranges. The northern area extends from Porcupine Plateau to a point about 16 km south of Chapman Lake and consists of sedimentary and metamorphic strata of Paleozoic and Precambrian age. Plateaux with elevations near 900 m ASL are underlain by less resistant formations and mountains with elevations of 1500 m ASL by more resistant units. Some of this area was glaciated during the Pleistocene by valley glaciers.

The southern area of the Ogilvies begins about 16 km south of Chapman Lake and consists of a belt of metamorphic and igneous rock. Large streams flow normal to this belt of mountains and cut it into segments. The mountains have a rugged appearance and consist of long branching ridges connecting jagged peaks. Elevations on the peaks range from 1525 m to 2130 m ASL and in the river valleys elevations are approximately 760 m ASL. Pleistocene valley glaciers existed in the interior of these ranges. However, they did not extend beyond the southern borders of the mountains and decreased in extent and number to the west (Bostock, 1948). Cirques are located in the Ogilvies, but they have no existing glaciers. The Ogilvie Mountains are within the "widespread" discontinuous permafrost zone. North of North Fork Pass drill holes and geophysical surveys indicate permafrost is found in most deposits. South of North Fork Pass permafrost is still common especially in fine grained deposits and on north facing slopes, but some unfrozen drill holes were present.

3.4.2 Tintina Trench

Tintina Trench physiographic division lies southwest of the Ogilvie Mountains. It is bounded on the northeast and south by subdivisions of the Yukon Plateau. The

Tintina Trench is a broad valley feature comparable to the Rocky Mountain Trench. It extends from near longitude 130° northwest across longitude 141° into Alaska. The pipeline corridor crosses this region between Benson Creek east of Dawson and Stewart Crossing southwest of Mayo. The Tintina Trench has straight walled sides and accordant floor levels with elevations from 425 m to 820 m ASL. The trench is a zone of intense fracturing, faulting, and shearing with the geology on either side being dissimilar (Bostock, 1963). In the mountain ridges on the northeast side metamorphic phyllite, quartzite, marble, slate, and paragneiss of Precambrian and Paleozoic age predominate. Some Mesozoic intrusive granites are also present. Southwest of Stewart River, in the trench floor and in the first hills of the upland, Mesozoic intrusives including granites and volcanics predominate. Further southwest into the hills Precambrian schists, gneisses and quartzites are present.

The trench itself is floored by broad terraces of Tertiary gravels and Pleistocene drift in which larger creeks are entrenched, exposing outcrops in the bases of their cutbanks (Bostock, 1948). The trench was glaciated at least twice by coalescing valley glaciers in early Pleistocene time and drift from the later of these two glaciations is at ground surface. The Tintina Trench lies within the "widespread" discontinuous permafrost zone. Drill holes and geophysical surveys indicate that permafrost is present in areas with thick organic cover or fine grained deposits. Coarse grained deposits without surface cover of organic or eolian material are often unfrozen.

3.4.3 Yukon Plateau

The Yukon Plateau division lies both northeast and southwest of the Tintina Trench. The pipeline enters the Yukon Plateau southwest of Tintina Trench near Stewart Crossing and stays in this region all the way to its connection with Foothills South Yukon pipeline near Whitehorse. The Yukon Plateau is characterized by uplands with accordant summit levels broken by isolated ranges and mountains. Upland areas are separated by a net of main valleys entrenched 405 m ASL or more below the plateau surface. The Lewes Plateau is the subdivision of the Yukon Plateau that is crossed by the pipeline between Stewart Crossing and Whitehorse. Lewes Plateau is a broad depression between Pelly Mountains on the east and gently rising plateau areas on the other sides. The western boundary of Lewes Plateau is drawn along the limit of glaciation. The Lewes Plateau is subdivided into a northern and southern section with a line through Carmacks dividing the two areas. In the northern part of Lewes Plateau the land rises steeply to tableland areas that slope and diminish in size northward. Elevations in this area range from 750 to 1370 m ASL. Northern Lewes Plateau is underlain by Precambrian metamorphic rock on the northeast and a belt of Mesozoic rock on the southwest. Both rock types have been intruded by granite plutons and contain some small bodies of Tertiary volcanics.

The southern part of Lewes Plateau consists of a broad, irregular depression underlain by relatively non-resistant, folded Mesozoic sediments flanked by tougher Mesozoic volcanics that form Semenoff Hills on the northeast and Miners Range on the southwest. In this part of Lewes Plateau the upland surface is reflected in the accordance of summit levels. The average elevation 1060 m to 1220 m ASL, about 150 m lower than the surrounding plateau area.

Several areas northeast of Carmacks and in Miners Range appear to have escaped glaciation in Pleistocene time, but elsewhere Lewes Plateau was completely covered by ice. The Lewes Plateau portion of Yukon Plateau lies within the "southern fringe" of the discontinuous permafrost zone. Permafrost is found at some localities but it is generally sporadic in occurrence and is usally fairly thin. It is most often found in areas with thick eolian silt or organic cover and on north-facing slopes.

4.0 GEOLOGIC HISTORY

4.1 Bedrock Geology

4.1.1 Arctic Coastal Plain, Interior Plains and Cordillera (Eastern System)

Bedrock along the route is varied and ranges in age from Precambrian to Tertiary. In the Arctic Coastal Plain (Mackenzie Delta), Interior Plains (Mackenzie Delta, Anderson Plain, Peel Plain, and Peel Plateau), and Eastern Cordillera (Richardson Mountains and Porcupine Plateau), the bedrock consists of Paleozoic, Mesozoic, and Tertiary sedimentary formations. Sediments deposited in shallow marine, continental, and marginal marine environments formed these rocks which include limestone, mudstone, siltstone, shale, sandstone, argillite, conglomerate, chert, limestone, and dolomite. In the Arctic Coastal Plain and Interior Plains most of the area has remained undisturbed or has experienced only minor folding, faulting, and uplift. However, in the Richardson Mountains and Porcupine Plateau the formations mentioned above and older strata have been uplifted during periods of crustal movement to form the Richardson Mountains and the hills of Porcupine Plateau.

4.2.2 Cordillera (Interior System)

The Interior System of the Cordillera (Ogilvie Mountains, Tintina Trench, Yukon Plateau) includes folded and faulted sedimentary and volcanic strata, massive metamorphic rock, small and large bodies of igneous intrusives, and local areas of flat-lying volcanics.

Ogilvie Mountains

The northern part of the Ogilvie Mountains consists of sedimentary and metamorphic formations of Precambrian, Paleozoic, and Mesozoic ages. Sedimentary rocks include limestone, dolomite, chert, conglomerate, sandstone, shale and argillite. Precambrian sedimentary rocks, e.g. argillite and limestone, were derived from well-sorted arenaceous and argillaceous sediments and dolomite-rich arenaceous sediments, which were eroded and deposited during the Precambrian and deformed during the Racklan Orogeny shortly after their deposition. Structures produced during this orogeny range from block faults through open folds to complex folds (Green, 1972).

From the Late Precambrian to the next major orogeny in Cretaceous time (Laramide Orogeny), poorly sorted clastic sedimentary units, chert, limestone and dolomite were deposited. The Laramide Orogeny deformed these Paleozoic and Mesozoic units as well as the underlying Precambrian formations. Deformation was not as strong in the northern Ogilvies as in the southern belt and areas of relatively open folds separate structurally complex areas.

In the southern Ogilvies (beginning approximately 16 km south of Chapman Lake) sedimentary units include chert, shale, argillite, and conglomerate with minor limestone and dolomite which were deposited in Precambrian, Paleozoic and Mesozoic time.

During the late Precambrian and early Paleozoic, volcanic activity resulted in deposition of tuff, volcanic breccia, agglomerate, and andesite in this part of the Ogilvies. In early Mesozoic time more shale and limestone were deposited and in the Cretaceous diorite and gabbro sills were intruded into these sediments prior to the major period of deformation. The Laramide Orogeny was strongest in the southern Ogilvies resulting in the formation of complex folds, and intrusion of granitic stocks. Metamorphic units, including quartzite, schist, and phyllite, were formed at this time from sedimentary units that were folded, faulted and intruded.

Tintina Trench

Tintina Trench is filled with a thick sequence of Tertiary gravels and Pleistocene glacial deposits. Bedrock structures related to formation of the trench are present along its northeast side. Some bedrock (Mesozoic granite and volcanic rock) occur near the surface in the trench southwest of Stewart River. These formations also form the principal element in the upland south of the trench (Bostock, 1963). Further south in these hills Precambrian metamorphic schist, gneiss, and quartzite predominate. Some of these metamorphic rocks are of Paleozoic age and there is no evidence of an earlier period of orogenic activity predating them or of the presence of a crystalline basement (Green, 1972). The metamorphic rocks have been intruded by Mesozoic granite which has produced granite-gneiss. A string of ultrabasic intrusions also lies in a belt parallel to and southwest of Tintina Trench. After Mesozoic intrusive activity, volcanics and associated sedimentary rocks were deposited at scattered localities. These units have been subsequently folded or tilted after the main period of deformation. Still later, planation, tilting, and deep weathering occurred.

Northeast of Tintina Trench, uplands consisting of metamorphic phyllite, quarzite, marble, slate and paragneiss of Precambrian and Paleozoic ages occur. There is no direct correlation with rock units southwest of the trench; however, some units have certain similarities. Units to the southwest have higher metamorphic rank than those to the northeast.

Yukon Plateau

The southwestern Yukon Plateau (Lewes Plateau division), which is crossed by the pipeline corridor south of Tintina Trench, is underlain by Precambrian metamorphic rocks including schist, quartzite, and phyllite which are overlain in some localities, particularly south of Minto, by Mesozoic clastics and carbonates. Granitic intrusions of Mesozoic age and Tertiary volcanics and clastic sedimentary formations are also present.

In the northern section of the Lewes Plateau, schist, quartzite, and phyllite of the Yukon River Group represent metamorphosed sediments and volcanics which have been intruded by granite plutons in Precambrian and early Paleozoic time. Mesozoic granites and granodiorites were also emplaced in these rocks during the Laramide Orogeny. Precambrian formations and Mesozoic intrusives occur at the surface along the pipeline corridor from south of Stewart Crossing to Minto.

Mesozoic conglomerate, sandstone, shale, coal, arkose, and tuff of the Tantalus and Laberge Series overlie Precambrian metamorphic units between Minto and Carmacks. Mesozoic granitic intrusives are also present.

The southern section of Lewes Plateau begins near Carmacks and extends southward to Whitehorse. In this area, Mesozoic clastic and volcanic rocks including the Laberge Series (conglomerate, sandstone, shale, tuff, coal), the Tantalus Formation (conglomerate, sandstone, shale, coal), the Lewes River Group (sandstone, argillite), Mt Nassen Volcanics (basalt, andesite, dacite, breccia, and tuff), Hutshi Group Volcanics (andesite, basalt, breccia, and tuff) and Tertiary volcanics of the Carmacks Formation predominate. Some Mesozoic granite intrusives occur in this portion of the corridor just north of Whitehorse.

4.2 Quaternary Geology

The portion of the Northwest Territories and the Yukon that is crossed by the Dempster pipeline corridor has had a diverse history since Tertiary time.

4.2.1 Arctic Coastal Plain and Interior Plains

The Arctic Coastal Plain (Mackenzie Delta), Interior Plains (Anderson Plain, Peel Plain, Peel Plateau) and MacDougall Pass in the Richardson Mountains underwent erosion from Tertiary until Quaternary time and were glaciated at least twice during the Pleistocene epoch by continental or Laurentide ice-sheets moving from the south and east. Drift associated with the last glacial advance and retreat is commonly at ground surface throughout these areas. Drift includes all rock and soil material deposited directly from glacier ice and all types of materials deposited by water associated with the melting of glacier ice-sheets. Till derived directly from glacier ice and deposited in morainal landforms is the major type of drift which covers bedrock throughout the Arctic Coastal Plain and Interior Plains physiographic regions. Stratified drift including ice contact stratified drift (eskers, kames, kame terraces), proglacial sediments (glaciofluvial plains and terraces, glaciolacustrine, and deltaic plains), and glaciomarine materials have been deposited from water associated with melting of the Laurentide ice-sheet. The ice-contact stratified drift deposits commonly overlie till deposits and are scattered throughout the area. Proglacial deposits including glaciofluvial, deltaic, and glaciomarine materials are found mostly near the Beaufort Sea in the Mackenzie Delta division of the Arctic Coastal Plain and glaciolacustrine deposits are found at some isolated localities overlying till deposits in the Anderson Plain.

Laurentide ice moved generally northwestward across the Arctic Coastal Plain and Interior Plains during the last Wisconsin glaciation. However, during its retreat the development of minor lobations controlled by low relief features in the Mackenzie lowlands produced a complicated pattern of ice-flow features (Hughes, 1972). Major halts or readvances are inferred from moraines like the one near Fort McPherson. In these ridged and hummocky moraine landforms, drift can be up to 30 m thick. However, in large areas of Anderson Plain, Peel Plain, and Peel Plateau morainal deposits can be less than 2 m thick.

After the glacial retreat and draining of glacial lakes, weathering processes continued to erode bedrock and soil materials. Alluvial plains and terraces formed along rivers and streams, and deltaic sedimentation continued along the mouth of the Mackenzie River. Water erosion and mass wasting resulted in the formation of colluvial deposits along river and stream valleys. Topographic lows were the site of deposition of fine grained sediments from slopewash and small streams. Organic deposits also accumulated in these low areas. Permafrost formed in surficial materials and in some areas where permafrost had thawed thermokarst features developed.

4.2.2 Cordillera (Eastern System)

The Eastern System of the Cordillera including Richardson Mountains and southern Porcupine Plateau have undergone erosion and weathering from the Teritary until the present. No Cordilleran or Laurentide ice-sheets covered the area except for a tongue of Laurentide ice which entered MacDougall Pass from the east. Also peaks south of MacDougall Pass with elevations of 1525 m supported restricted cirque glaciers. Because Richardson Mountains and southern Porcupine Plateau were not glaciated, the character of local terrain is determined mainly by the lithology and structure of subjacent bedrock. Mountain slopes are mostly covered with detritus ranging from silty gravel to coarse blocky debris which appears to have little segregated ice. Lower slopes are mantled by finer slopewash sediments with high ice contents. Alluvial plains and terraces consisting of sands and gravels are found along mountain valley streams.

In the southern Porcupine Plateau (Eagle Plain) sediments and low hills rise toward high hills and mountains. The low hills and sediments are developed mainly on sandstones, carbonates, siltstones and shales. Pediments are mantled by 1 to 2 m of silty, poorly sorted gravel overlain by 1 to 2 m of organic silt which is generally ice-rich. The low hills typically have a thin mantle of stoney silt to silty gravel (1 to 2 m thick) with local accumulations of ice-rich slopewash silts (1 to 10 m thick) on gently slopes and valley bottoms. The relationships of pediments to modern rivers suggests that erosion kept pace with local upwarping that may have begun during or just after pediment development (Hughes, 1972).

Permafrost has formed in colluvial and alluvial deposits throughout the Richardson Mountains and southern Porcupine Plateau. Organic deposits have also accumulated in areas where fine grained materials are present, e.g. lower slopes on pediment surfaces and alluvial deposits along rivers.

4.2.3 Cordillera (Interior System)

The Interior System of Cordillera including the Ogilvie Mountains, Tintina Trench, and Yukon Plateau had related yet slightly different histories during the Quaternary. All three divisions have been glaciated.

Ogilvie Mountains

Valley glaciation occurred in the Ogilvies and evidence for this is best displayed in the vicinity of the headwaters of Ogilvie River where at least three glacial advances have been recorded (Hughes, 1972). Deposits left by these advances include:

a) fresh, sharp-ridged moraines (last glaciation of Vernon and Hughes, 1966)

b) moraines that are subdued but still recognizable (intermediate glaciation)

c) patches of till with little or no characteristic moraine form (old glaciation)

Ricker in detailed mapping of the North Klondike and East Blackstone Valleys also inferred two advances from moraines in the vicinity of Chapman Lake (Hughes, et. al, 1972). Each successive glacial advance was less extensive than the previous one.

Morainal deposits associated with the valley glaciation described above begin along the pipeline route near Chapman Lake and are common as far south as North Fork Pass. These deposits include undifferentiated morainal materials, ablation moraine, hummocky moraine, rolling moraine, ridged moraine, and moraine veneer deposits. Some glaciofluvial and scattered glaciolacustrine deposits are also associated with these morainal materials. Postglacial windblown silt and organic deposits overlie morainal and glaciofluvial materials throughout the area. Permafrost is present in almost all glacial and nonglacial surficial materials throughout the northern Ogilvies.

From North Fork Pass southward to the beginning of Tintina Trench, scattered morainal and glaciofluvial deposits related to a piedmont glacier that occupied North Klondike Valley are found along the valley walls. However, along this section of the route the most common materials include postglacial alluvial plain deposits of the North Klondike River and alluvial fan and colluvial deposits which originated in the mountains adjacent to the North Klondike Valley. Varying thicknesses of postglacial windblown silt cover these deposits and organic materials are found in some areas. Permafrost is found in most deposits throughout this section, but some unfrozen coarse materials are also present.

In the Ogilvie Mountains north of Chapman Lake, the most prominent materials along the pipeline are sedimentary rock, thin and thick colluvium on pediment slopes, and alluvial plain, fan and terrace deposits. Glacial deposits seem to be absent from this portion of the Ogilvies. Permafrost is found in most surficial deposits.

Tintina Trench

Tintina Trench and the Stewart River Valley are filled with thick glacial deposits (up to 180 m) which represent several advances of the Cordilleran ice-sheet during the Pleistocene.

The youngest glacial materials were deposited during the McConnell Glaciation. The youngest of the older drift units, the Reid, extends westward down Stewart Valley about 64 km beyond the McConnell limit and displays glacial features including an end moraine (Reid end moraine). West of this moraine in lower Stewart Valley, glacial landforms are not visible but grey silty to clayey till and erratics of the older Klaza Glaciation are present. The Klaza Glaciation extended at least 40 km beyond the Reid limit and in lower Stewart Valley the oldest glacier (the Nansen) extended 40 km beyond the Klaza. This oldest glaciation is represented by thick hummocky drift which is extensively weathered (Douglas, 1968).

Thick glacial deposits near the Klondike River in Tintina Trench include 90 m of glaciolacustrine sediments overlain by 120 m of glaciolacustrine or morainal deposits which is overlain by a surface deposit of gravels. These surface gravels are from a Pre-Reid or Pre-Wisconsin glaciation and are overlain by a thin cover of loess of McConnell age (Hughes, et. al., 1972). These materials near the Klondike River originated from piedmont glaciers in the North Klondike and Klondike Valleys. Similar surficial gravels and silts are found along the pipeline corridor between Klondike River and a point north of McQuesten River. In this area organic deposits have accumulated where thick loess deposits and poor drainage are present. Alluvial deposits have formed along steams and colluvium has accumulated on valley walls. Permafrost exists throughout this area in localities with thick loess and organic cover.

Just north of McQuesten River, outwash material from the Reid Glaciation is present in a terrace. Loess which mantles the terrace surface is of McConnell age. From McQuesten River to Stewart Crossing, traces of McConnell age outwash and older glacial deposits lie along the route. Post-glacial alluvial plains and terraces of Stewart River are also prominent. In some poorly drained portions of the terraces, organic deposits have accumulated. Permafrost is present beneath these organic deposits and in areas with thick loess.

Yukon Plateau

The Yukon Plateau begins just south of Stewart Crossing and extends southward to Whitehorse. The pipeline crosses drift of Reid age between Stewart Crossing and Minto. This drift includes moraine veneer, moraine plain, hummocky and rolling moraine deposits, glaciofluvial plain materials, and some glaciolacustrine deposits. Organic deposits have formed in low-lying areas and eolian dunes were created from glaciolacustrine materials in at least one locality. Permafrost is found where organic deposits are thick and beneath thick fine grained eolian silts or glacio-lacustrine silts and sands. Colluvial deposits have formed on slopes and alluvial deposits have developed adjacent to major rivers like the Pelly.

From Minto southward to Whitehorse the pipeline crosses drift of McConnell age. The entire area, except for highlands like Miners Range, was covered by ice during the McConnell or Wisconsin Glaciation. In some localities loess and White River ash cover glacial deposits. These deposits include extensive glaciofluvial hummocky, rolling, plain and terrace deposits, moraine veneer and plain deposits, and glaciolacustrine materials.

Colluvial deposits have formed on bedrock and on valley walls. Alluvial plains and terraces are present along rivers. Organic deposits have accumulated in low-lying areas. Permafrost is confined to north-facing slopes and localities where fine grained materials or organic deposits are present.

5.0 CHARACTERISTICS OF TERRAIN UNITS BY PHYSIOGRAPHIC REGION

Soil types and other geologic characteristics may vary within terrain units which had a similar environment of deposition because of differences in underlying bedrock, climate, topography, and geologic history. For example, a moraine plain at the northern end of the route (Anderson Plain) will consist of silty clay till while the same unit at the southern end (Tintina Trench) will contain gravelly sandy till. Both units were deposited by glacier ice but the northern moraine plain originated as the late Wisconsin Laurentide ice-sheet eroded and redeposited earlier glacial deposits and sandstone and shale. The southern moraine plain deposits in Tintina Trench were deposited by Cordilleran ice during a pre-Wisconsin glaciation. This glacier eroded and deposited earlier glacial deposits as well as igneous and metamorphic rock.

The variation of soil types and other geologic characteristics of terrain units can be seen on Tables 1-9 which follow. Terrain units on these tables are grouped by physiographic region according to their geologic origin with the most recently deposited unit listed first.

Map Symbol	Terrain Type	Landform Characteristics					Surface Drainage and Groundwater	Engineering Considerations
		Soil Description	Thicknesses	Ground Ice	Topography	Slope		
Ap_1	Active Floodplain	Stratified silt, sand gravel		Unfrozen	Flat	<3°	Fair drainage, some standing water	Frequently inundated
Ap_2	Inactive Floodplain	Stratified silt, sand, gravel		Unfrozen - can be frozen under organic cover	Flat	<3°	Good drainage	Periodically inundated
At	Alluvial Terrace	Stratified sand and gravel, silt veneer		Usually unfrozen, low ice content where frozen	Flat to gently undualting, steep frontal scarps	<3° except for scarps	Good drainage	Possible source of granular borrow
Av	Alluvial Veneer	Stratified silt, sand and gravel		Unfrozen	Flat to undulating	<3°	Good drainage	
Lb	Lacustrine Basin	Stratified silt and clay, minor sand and organics		Patches of permafrost where present they are ice-rich	Flat to depressional	<3°	Poorly drained, some standing water	Buoyancy controls required where extensive
Lp	Glacio-lacustrine Plain	Stratified silt and clay, minor sand, organics in depressions		Permafrost where present is high ice content	Flat to very gently undulating, thermokarst depressions	<3°	Poor drainage water in depressions	Buoyancy controls may be required Frozen areas should be avoided due to thaw settlement potential

TABLE 1: PHYSIOGRAPHIC REGION I - MACKENZIE DELTA

(Alignment Sheets 1-11, 9 at 9b)

Map Symbol	Terrain Type	Soil Description	Landform Characteristics Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
fO	Fen	Peat and organic silt		Unfrozen; small areas of high ice	Flat to depressional	<3°	Poor drainage, standing water,	Buoyancy control required if extensive
pO	Bog	Peat		High	Flat to depressional	<3°	Poor drainage, standing water	Buoyancy control may be required if extensive
pOv	Bog Veneer	Peat	<2 m	High	Level to depressional may reflect underlying material locally	<3°	Poor drainage, standing water	Buoyancy control may be required locally
Cm	Colluvial Slopewash	Colluvium predominantly silt and sand; gravel locally		Low to medium	Gently to steeply sloping	3°to>15°	Fair to good drainage	
Ad	Alluvial Delta	Stratified silt, clay and sand, minor organics		Medium to high	Flat to undulating, channelled	<3°	Generally good with high water table, poor in channels	Buoyancy control and deep burial may be required
Ap	Alluvial Floodplain	Stratified silt, sand and gravel, silt dominant in Delta area		Medium to high; locally unfrozen	Flat to gently undulating, channelled	<3°	Good drainage generally, high water table, poor in channels	Buoyancy control and deep burial may be required

TABLE 1: PHYSIOGRAPHIC REGION I - MACKENZIE DELTA

Map Symbol	Terrain Type	Landform Characteristics: Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
At	Alluvial Terrace	Stratified silt, sand, and gravel, silt veneer		Low to medium	Flat; steep frontal scarps	<3° except in scarps	Good drainage	Potential source of granular borrow
Lb	Lacustrine Basin	Stratified silt and clay, minor sand and frequent organics		High	Flat to depressional	<3°	Poor drainage, standing water	Buoyancy control may be required
Lp	Glacio-lacustrine Plain	Stratified silt and clay, some sand, organics in depressions		High	Flat to gently undulating	<3°	Poor drainage, standing water in depressions	Buoyancy control may be required locally
Lv	Lacustrine Veneer	Stratified silt and clay, some sand and organics	<2 m	High	Topography is a reflection of underlying deposit	<3°to5°	Poor drainage, frequent standing water	
Gh	Hummocky Outwash	Stratified sand and gravel, minor silt		Low (locally high in ridges)	Hummocky, some ridges	9° to 15°	Good drainage	Potential source of granular borrow
Gp	Glacio-fluvial Plain	Stratified sand and gravel, minor silt		Low (some ice wedges)	Flat to undulating, locally pitted	3° to 9°	Good drainage	Potential source of granular borrow

TABLE 1: PHYSIOGRAPHIC REGION I - MACKENZIE DELTA

Map Symbol	Terrain Type	Landform Characteristics: Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
Gt	Glacio-fluvial Terrace	Stratified sand and gravel, frequent silt veneer		Low (some ice wedges)	Undulating, with steep frontal scarp	<3° up to 30° on scarps	Good drainage	Potential source of granular borrow
Md	Drumlinoid Moraine Plain	Silty clay till		Low on ridges, high between ridges	Flat to undulating, occasional elongate steep-sided ridges	Up to 15°	Good drainage	
Mh	Hummocky Moraine	Silty clay till; sand and gravel lenses, organics in depressions		Medium to high	Hummocky	9° to 15°	Generally good surface drainage, poor in depressions	
Mm	Rolling Moraine	Silty clay till; organic veneer in depressions		Medium to high	Undulating to rolling	Up to 9°	Good, high water table in depressions	
Mp	Moraine Plain	Silty clay till		Low to high; mostly medium	Flat to undulting	3° to 9°	Fair to good drainage	
Mv	Moraine Veneer	Silty clay till	<2 m	Low to high; mostly medium	Topography reflects that of underlying material	Up to 20°	Good drainage, high water table in depressions	Ease of excavation depends on depth to bedrock and bedrock type

TABLE 1: PHYSIOGRAPHIC REGION I - MACKENZIE DELTA

Map Symbol	Terrain Type	Landform Characteristics					Surface Drainage and Groundwater	Engineering Considerations
		Soil Description	Thicknesses	Ground Ice	Topography	Slope		
R	Bedrock			None to low			Good drainage	Excavation may be difficult
	(ss) - - - - - -	Sandstone & conglomerate						

TABLE 2: PHYSIOGRAPHIC REGION II - ANDERSON PLAIN

(Alignment Sheets 12, 13, 13A - 13E (part))

Map Symbol	Terrain Type	Soil Description	Landform Characteristics				Surface Drainage and Groundwater	Engineering Considerations
			Thicknesses	Ground Ice	Topography	Slope		
fo	Fen	Peat and organic silt		Unfrozen; local areas frozen with high ice content	Flat to depressional	<3°	Poor drainage, standing water	Buoyancy control may be required
fOv	Fen Veneer	Peat and organic silt	<2 m	Unfrozen	Flat to depressional	<3°	Poor drainage	Buoyancy control may be required
pO	Bog	Peat		High	Flat to depressional	<3°	Poor drainage, standing water	Buoyancy control may be required
pOv	Bog Veneer	Peat	<2 m	High	Flat to depressional	<3°	Poor drainage, standing water	Buoyancy control may be required locally
Cm	Colluvial Slopewash	Colluvium, predominantly silt and sand		Lower to medium	Gently to steeply sloping	3°to>15°	Fair to good drainage	
Cv	Colluvial Veneer	Gravity-transported mixture of clay to gravel sizes; mostly	<2 m	Medium to high	Reflection of underlying material, often bedrock	3°to>15°	Fair to good drainage	
Ap	Alluvial Floodplain	Stratified sand and gravel, minor silt		Medium to high, locally unfrozen	Flat gently undulating, channelled	<3°	Good surface drainage, high water table	Buoyancy control and deep burial may be required

TABLE 2: PHYSIOGRAPHIC REGION II - ANDERSON PLAIN

Map Symbol	Terrain Type	Landform Characteristics: Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
Ap_1	Active Floodplain	Stratified silt, sand, and gravel		Unfrozen; may be frozen	Flat	<3°	Poor drainage; open water	Frequently inundated; deep burial may be required
Ap_2	Inactive Floodplain	Stratified silt, sand and gravel		Medium to high	Flat	<3°	Poor drainage	Periodically inundated
At	Alluvial Terrace	Stratified silt, sand and gravel; silt veneer		Low to medium	Flat	<3° except in scarps	Good drainage	Potential source of granular material
Lb	Lacustrine Basin	Stratified silt and clay minor sand, frequently organic-rich		High	Flat to depressional	<3°	Poor drainage, standing water	Buoyancy controls may be required
Lp	Glacio-lacustrine Plain	Stratified silt and clay, some sand, organics in depressions		High	Flat to gently undulating	<3°	Poor drainage, standing water in depressions	Buoyancy controls may be required locally
Lv	Lacustrine Veneer	Stratified silt and clay, some sand and organics	<2 m	High	Flat, some reflection of underlying deposit	<3° to 5°	Poor drainage standing water, in depressions	

TABLE 2: PHYSIOGRAPHIC REGION II - ANDERSON PLAIN

Map Symbol	Terrain Type	Landform Characteristics: Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
Gm	Eskers	Stratified sand and gravel, minor silt		Low (locally high)	Steep-sided sinuous ridges	Up to 30°	Good drainage	Potential source of granular borrow
Gt	Glacio-fluvial Terrace	Stratified sand and gravel, silt veneer		Low	Flat ot undulating, steep frontal scarp	<3° up to 30° on scarps	Good drainage	Potential source of granular borrow
M	Moraine Undifferent-iated	Silty clay till		Variable	Masked by other deposits		Variable	
Md	Drumlinoid Moraine	Silty clay till		Low on ridges; high in depressions	Flat to undulating with ridges	9° to 15°	Good drainage	
Mh	Hummocky Moraine	Silty clay till with organics in depressions; gravel levels		Medium to high; high in depressions	Rolling to hummocky	9° to 15°	Good drainage, poor in depressions	
Mm	Rolling Moraine	Silty clay till with organics in depressions		Medium to high	Undulating to rolling	3° to 9°	Good; high water table in depressions	

TABLE 2: PHYSIOGRAPHIC REGION II - ANDERSON PLAIN

Map Symbol	Terrain Type	Landform Characteristics Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
Mp	Moraine Plain	Silty clay till		Low to high; mostly medium	Flat to gently undulating	3° to 9°	Fair to good drainage	
Mv	Moraine Veneer	Silty clay till	<2 m	Low to high; mostly medium	Topography reflects that of underlying bedrock	Up to 20°	Good drainage, high water table in depressions	Ease of excavation depends on depth to underlying rock and rock type
R	(Bedrock) s	Sedimentary rock undifferentiated			Undulating to rolling	Variable	Fair to good	May be ripped if mostly soft shale
R	sm	Siltstone, mudstone, shale, argillite			Undulating to rolling	Variable	Fair to good	May be ripped if softer rock predominates
R	ss	Sandstone and conglomerate			Undulating to rolling	Variable	Fair to good	Excavation may requrie blasting

TABLE 3: PHYSIOGRAPHIC REGION III - PEEL PLAIN

(Alignment Sheets 13E (part), 13F, 15, 16)

Map Symbol	Terrain Type	Landform Characteristics: Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
fO	Fen	Peat and organic silt		Unfrozen; small areas with high ice	Flat to depressional	<3°	Poor drainage, standing water	Buoyancy control may be required
fOv	Fen veneer	Peat and organic silt	<2 m	Unfrozen	Flat to depressional	<3°	Poor drainage, standing water	Buoyancy control may be required
pO	Bog	Peat		High	Flat to depressional	<3°	Poor drainage, Standing water	Buoyancy control may be required
pOv	Bog Veneer	Peat	<2 m	High	Flat to depressional	<3°	Poor drainage, standing water	Buoyancy control may be required
Cm	Colluvial Slopewash	Colluvium, predominantly silt, and sand		Low to medium	Gently to steeply sloping	3°to>15°	Fair to good drainage	
Ap	Alluvial Floodplain	Stratified silt, sand, and gravel		Medium to high; Locally unfrozen	Flat to undulating; channelled	<3°	Surficially well drained, high water table	Buoyancy control and deep burial may be required
Ap_1	Active Floodplain	Stratified silt, sand and gravel		Unfrozen; may be frozen locally	Flat	<3°	Poor drainage, open water	Frequently inundated; deep burial may be required

TABLE 3: PHYSIOGRAPHIC REGION III - PEEL PLAIN

Map Symbol	Terrain Type	Landform Characteristics						
		Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
Ap_2	Inactive Floodplain	Stratified silt, sand, and gravel		Medium to high	Flat	<3°	Poor drainage	Periodically inundated
Mh	Hummocky Moraine	Silty clay till occasional sand and gravel layers, organics in depressions		Medium to high; high in depressions	Hummocky	9 to 15°	Generally good poor in depressions	
Mm	Rolling Moraine	Silty clay till, organic veneer in depressions		Medium to high	Undulating to rolling	3° to 9°	Generally good, high water table in depressions	
Mp	Moraine Plain	Silty clay till		Low to high: mostly medium	Flat to gently undulating	3° to 9°	Fair to good drainage	
Mv	Moraine Veneer	Silty clay till	<2 m	Low to high; mostly medium	Topography is reflection of underlying bedrock	Up to 20°	Good drainage, high water table in depressions	Depth to bedrock and bedrock type may be factor in excavation
R	Bedrock sm	sm - siltstone, shale mudstone, argillite			Undulating to rolling	Variable	Good drainage	Ripping generally feasible, blasting may be required locally

TABLE 4: PHYSIOGRAPHIC REGION IV - PEEL PLATEAU

(Alignment Sheets 16A, 17, 18)

Map Symbol	Terrain Type	Landform Characteristics Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
fO	Fen	Peat and organic silt		Unfrozen; small areas frozen	Flat to depressional	<3°	Poor drainage, surface water,	Buoyancy control may be required
Cb(P)	Pediment	Silt, sand, clay, some coarse material and organics		Medium to high	Gently to moderately sloping	9° to 15°	Fair drainage	Depth to rock variable (1 to 12 m) excavation may be difficult where rock is shallow
Cf	Flow Slide	Clay to gravel sizes		Medium to high		Variable	Fair to poor	
Cm	Colluvial Slopewash	Colluvium, predominantly silt, sand, clay		Medium to high	Gently to steeply sloping	3°to>15°	Fair to good drainage	
Cv	Colluvial Veneer	Gravity-transported silt, clay, sand, some gravel	<2 m	Medium to high	Topography is reflection of underlying bedrock	Reflects under-lying rock	Fair to good drainage	
Ap	Alluvial Flooplain	Stratified sand and gravel, minor silt		Low; sometimes unfrozen	Flat to gently, undulating, channelled	<3°	Surficially well drained, high water table locally	Buoyancy control and deep burial may be required

TABLE 4: PHYSIOGRAPHIC REGION IV - PEEL PLATEAU

Map Symbol	Terrain Type	Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
		Landform Characteristics						
Ap_1	Active Floodplain	Stratified silt, sand, and gravel		Unfrozen	Flat	<3°	Poor drainage; open water	Frequently inundated
Ap_2	Inactive Floodplain	Stratified silt, sand, and gravel		Low to medium	Flat	<3°	Poor drainage	Periodically inundated
Mm	Rolling Moraine	Silty clay till		Medium to high	Undulating to rolling	3° to 9°	Good drainage, high water table in depressions	
Mp	Moraine Plain	Silty clay till		Low to high; Mostly medium	Flat to gently undulating	3° to 9°	Fair to good drainage	
Mv	Moraine Veneer	Silty clay till	<2 m	Low to high; mostly medium	Topography is a reflection of the underlying bedrock	Up to 20°	Fair to good drainage high water table in depressions	
R	Bedrock s	s - sedimentary rock undifferentiated			Flat to moderately sloping	Variable	Good drainage	Excavation may requirie blasting if rock is tough
R	Bedrock sm	sm - siltstone, mudstone, shale, argillite			Flat to moderately sloping	Variable	Good drainage	
R	Bedrock ss,sm	ss,sm - sandstone and conglomerate, some shale			Flat to moderately	Variable	Good drainage	Excavation may be difficult without blasting in tougher formations

TABLE 5: PHYSIOGRAPHIC REGION V - RICHARDSON MOUNTAINS

(Alignment Sheets 18(part), 19, 20, 20A -E)

Map Symbol	Terrain Type	Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
pOv	Bog Veneer	Peat	<2 m	High	Flat to depressional	<3°	Poor drainage; standing water	Buoyancy control may be necessary
Cb(P)	Pediment	Pebbly to bouldery, silt and silty fine sand some coarse angular material		Medium to high	Gently to moderately sloping	9° to 15°	Fair to good drainage	Depth to rock (1 to 12 m) variable. Excavation may be difficult
Cm	Colluvial Slopewash	Silt and sand, some clay		Medium to high	Gently to steeply sloping	3° to >15°	Fair to good drainage	
Ct	Talus	Gravity transported angular fine to coarse bedrock debris		Low	Steeply sloping	Up to 40°	Good drainage	Steeper slopes may be unstable if disturbed
Cv	Colluvial Veneer	Colluvium, predominantly silt and sand, some clay	<2 m	Medium to high	Topography is reflection of underlying bedrock	Reflects under-lying rock	Fair to good drainage	Depth to bedrock may influence ease of excavation
Af	Alluvial Fan	Poorly sorted sand and gravel		Low	Concave slope	5 - 15°	Good drainage, some subsurface flow	
Ap	Alluvial Floodplain	Stratified, sand and gravel, minor silt		Low, sometimes unfrozen	Gently undulating, channelled	>3°	Surficially well drained, high water table	Buoyancy control and deep burial may be required

TABLE 5: PHYSIOGRAPHIC REGION V - RICHARDSON MOUNTAINS

Map Symbol	Terrain Type	Landform Characteristics: Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
Ap_1	Active Floodplain	Stratified silt, sand, gravel		Unfrozen, may be frozen locally	Flat	<3°	Poor drainage, open water	Frequently inundated
Ap_2	Inactive Floodplain	Stratified silt, sand, and gravel; silt veneer		Low	Flat	<3°	Fair to good drainage	Periodically inundated
At	Alluvial Terrace	Stratified silt, sand, gravel; silt veneer		Low	Flat	<3° except in scarps	Good drainage	
Av	Alluvial Veneer	Stratified sand, and gravel, minor silt	<2 m	Low	Topography reflects underlying material	<3°	Good drainage	
Gp	Glacio-fluvial Plain	Stratified sand and gravel, minor silt		Low	Flat to undulating	3° to 9°	Good drainage	Possible source of granular borrow
Mv	Moraine Veneer	Silty clay till	<2 m	Low to medium	Topography is a reflection of underlying bedrock	Up to 20°	Fair to good drainage, high water table in depressions	

TABLE 5: PHYSIOGRAPHIC REGION V - RICHARDSON MOUNTAINS

Map Symbol	Terrain Type	Landform Characteristics: Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
R	Bedrock s	s - sedimentary undifferentiated			Gently to steeply sloping	Variable	Good drainage	Sandstone layers may be difficult to rip
R	sm	sm - mudstone, siltstone, shale, argillite			same as above	Variable	Good drainage	
R	ss	ss - sandstone and conglomerate			Same as above	Variable	Good drainage	May be difficult to rip
R	ss,sm	- sandstone and conglomerate, minor shale			Same as above	Variable	Good drainage	May be difficult to rip
R	sm,ss	- mudstone, siltstone, shale argillite, minor sandstone			Same as above	Variable	Good drainage	

TABLE 6: PHYSIOGRAPHIC REGION VI - PORCUPINE PLATEAU (EAGLE PLAIN)

(Alignment Sheets 20E, 20F - G, 21, 22, 22A - E, 23, 24, 25, 26 (part))

Map Symbol	Terrain Type	Landform Characteristics: Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
fO	Fen	Peat, organic silt		Unfrozen, some areas with high ice	Flat to depressional	<3°	Poor drainage	Buoyancy controls may be required
fOv	Fen veneer	Peat, organic silt	<2 m	Unfrozen	Flat to depressional	<3°	Poor drainage	Buoyancy controls may be required
pO	Bog	Peat		High	Flat to depressional	<3°	Poor drainage	Buoyancy controls may be required
Cb(p)	Pediment	Pebbly to bouldery silt and silty fine sand; some coarse angular material		Medium to high	Gently to moderately sloping	9° to 15°	Fair to good drainage	Depth to rock variable (1-12 m) excavation may be difficult
Cm	Colluvial Slopewash	Colluvium predominantly silt and sand		Medium to high	Gently to steeply sloping	3°to>15°	Fair to good drainage	High ice content materials are present near base of slopes in valley bottom
Ct	Talus	Gravity transported angular bedrock debris; silt and sand matrix		Low	Steeply sloping	Up to 40°	Good drainage	Steeper slopes may be unstable if disturbed
Cv	Colluvial Veneer	Colluvium predominantly silt and sand	<3 m	Medium to high	Topography is a reflection of underlying bedrock	Reflects under-lying rock	Good drainage	Depth to bedrock may determine ease of excavation

TABLE 6: PHYSIOGRAPHIC REGION VI - PORCUIPINE PLATEAU (EAGLE PLAIN)

Map Symbol	Terrain Type	Landform Characteristics					Surface Drainage and Groundwater	Engineering Considerations
		Soil Description	Thicknesses	Ground Ice	Topography	Slope		
Af	Alluvial Fan	Poorly sorted silt to gravel sizes, grading from gravel at apex to sand and silt at base		Low	Concave slope	5° to 25°	Good drainage, some subsurface flow	
Ap	Alluvial Floodplain	Stratified sand and gravel, minor silt		Low or unfrozen	Gently undulating, channelled	3° to 5°	Surficially well drained, high water table	Buoyancy control and deep burial may be required
Ap_1	Active Floodplain	Stratified silt, sand and gravel		Unfrozen; some frozen	Flat	<3°	Poor drainage, open water	Frequently inundated
Ap_2	Inactive Floodplain	Stratified silt, sand and gravel		Low to medium	Flat to undulating	<3°	Fair to good drainage	Periodically inundated
At	Alluvial Terrace	Stratified sand and gravel, silt veneer		Low	Gently undulating, steep frontal scarps	<3° except scarps	Good drainage	Possible source of granular borrow
Av	Alluvial Veneer	Stratified silt sand, gravel		Low	Flat to undualting	<3°	Good drainage	
Lv	Lacustrine Veneer	Stratified silt and clay, minor sand and organics	<3 m	High	Flat with some expression of underlying deposits	<3° to 5°	Poor drainage, some standing water	

TABLE 6: PHYSIOGRAPHIC REGION VI - PORCUIPINE PLATEAU (EAGLE PLAIN)

Map Symbol	Terrain Type	Soil Description	Landform Characteristics Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
R	Bedrock s	- sedimentary undifferentiated			Rolling to moderately sloping	Variable	Good drainage	Extensive sandstone layers may be difficult to excavate, shale generally rippable
R	sm	- shale,			Same as above	Variable	Good drainage	
R	sm, ss	- shale, etc; some sandstone			Same as above	Variable	Good drainage	
R	ss, sm	- sandstone, some shale, etc.			Same as above	Variable	Good drainage	ss may be difficult to rip

TABLE 7: PHYSIOGRAPHIC REGION VII - OGILVIE MOUNTAINS

(Alignment Sheets 26, 27, 27A - I, 28, 29, 30 (part) 31, 32, 33)

Map Symbol	Terrain Type	Landform Characteristics					Surface Drainage and Groundwater	Engineering Considerations
		Soil Description	Thicknesses	Ground Ice	Topography	Slope		
fO	Fen	Peat and organic silt		Unfrozen, small areas with high ice	Flat to depressional	<3°	Poor drainage	Buoyancy controls may be required
fOv	Fen Veneer	Peat and organic silt	<2 m	Unfrozen	Flat to depressional	<3°	Poor drainage	Buoyancy controls may be required
pO	Bog	Peat		High	Flat to depressional	<3°	Poor drainage, standing water	Buoyancy controls may be required
pOv	Bog Veneer	Peat	<2 m	High	Flat to depressional some reflection of underlying material	<3°	Poor drainage, standing water	Buoyancy controls may be needed
Cb(P)	Pediment	Pebbly and bouldery silt and silty fine sand, some angular fragments and clay		Medium to high	Gently to moderately sloping	9° to 15°	Fair to good drainage	Depth to rock variable, excavation may be difficult
Cm	Colluvium	Colluvium, predominantly silt and sand		Medium to high	Gently to steeply sloping	3°to<15°	Fair to good drainage	
Cr	Rock Glaciers	Bedrock fragments with interstital ice		Variable	Gently to steeply sloping, uneven surface	Up to 25°	Good drainage	These rock glaciers are probably stabilized, further study needed

TABLE 7: PHYSIOGRAPHIC REGION VII - OGILVIE MOUNTAINS

Map Symbol	Terrain Type	Landform Characteristics: Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
Ct	Talus	Gravity - transported angular bedrock fragments		Low	Steeply sloping	Up to 45°	Good drainage	Steeper slopes may be unstable if disturbed
Cs	Rock slide	Angular rock fragments		Low	Moderately to steeply sloping	>15°	Good drainage	May be unstable and subject to more sliding
Cv	Colluvial Veneer	Colluvium predominantly sand and silt		Medium to high	Reflection of underlying material	Reflects under-lying rock	Fair to good drainage	
Ev	Eolian Veneer	Wind blown sand or silt	<2 m	Medium to high	Reflects underlying deposit	3° to 9°	Good drainage	High ice contents in this material
Af	Alluvial Fan	Poorly sorted silt to gravel sizes, increasingly fine grained from apex to base		Low	Concave slope	5° to 25°	Good drainage, may be some subsurface flow	
Ap	Alluvial Floodplain	Stratified cobbles, gravel, silt, and sand		Low or unfrozen, small frozen patches	Flat and channelled	<3°	Good drainage, high water table	Buoyancy control and deep burial may be required
Ap_1	Active Floodplain	Stratified silt, sand and gravel		Unfrozen; some frozen patches	Flat	<3°	Fair drainage standing water	Frequently inundated

TABLE 7: PHYSIOGRAPHIC REGION VII - OGILVIE MOUNTAINS

Map Symbol	Terrain Type	Landform Characteristics: Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
Ap_2	Inactive Floodplain	Stratified silt, sand and gravel		Low	Flat to undulating channelled	<3°	Good drainage	Periodically inundated
At	Alluvial Terrace	Stratified sand and gravel, silt, veneer		Low	Flat with steep frontal scarps	<3° frontal scarps	Good drainage	Possible source of granular borrow
Av	Alluvial Veneer	Stratified silt, sand and gravel		Low	Flat to gently undulating	<3°	Good drainage	
Lb	Lacustrine Basin	Stratified silt, and clay, some sand and organics		High	Flat to depressional	<3°	Poor drainage, some standing water	Buoyancy control may be required
Lp	Glacio-lacustrine Plain	Stratified silt and clay, some sand, and organics		High	Flat to gently undulating	<3°	Poor drainage	Buoyancy controls may be required locally
Lv	Lacustrine Veneer	Stratified silt and clay, minor sand and organics	<2 m	High	Reflects underlying material	<3°	Fair to poor drainage	
Gm	Kame	Complexly stratified sand and gravel, minor silt, occasional till lenses		Low or unfrozen	Small conical hills and ridges	Up to 15°	Good drainage	Possible source of granular borrow

TABLE 7: PHYSIOGRAPHIC REGION VII - OGILVIE MOUNTAINTS

Map Symbol	Terrain Type	Landform Characteristics						
		Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
Mr	Moraine Ridge	Gravelly sandy till		Medium high	moderately sloping	9° to 25°	Good drainage	
Mv	Moraine Veneer	Gravelly sandy till	<2 m	Medium to high	Topography reflects underlying bedrock	Up to 20°	Good drainage, high water table in depressions	Depth to bedrock determines ease of excavation
R	Bedrock s	- sedimentary undifferentiated			Hilly to mountainous	Up to 75° Variable	Good drainage, mostly impermeable	Difficult to excavate blasting may be required in all but shale and mudstone
R	sc	- limestone, dolomite			Same as above	Variable	Good drainage	Blasing probably required
R	sm	- shale, siltstone, mudstone, argillite			Same as above	Variable	Good drainage	
R	ss	- sandstone, conglomerate			Same as above	Variable	Good drainage	Blasting may be required
R	m	- metamorphic undifferentiated			Same as above	Variable	Good drainage	Blasting probably required
R	mq	- quartzite			Same as above	Variable	Good drainage	Blasting probably required
R	v	- volcanics undifferentaited			Same as above	Variable	Good drainage	Blasting probably required

TABLE 8: PHYSIOGRAPHIC REGION VIII - TINTINA TRENCH

(Alignment Sheets 33A - B, 34, 35, 36, 37, 38, 39, 40)

Map Symbol	Terrain Type	Landform Characteristics: Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
fO	Fen	Peat and organic silt		Unfrozen	Flat to depressional	<3°	Poorly drained, high water table	Buoyancy controls required, poor trafficability
fOv	Fen Veneer	Peat and organic silt	<2 m	Unfrozen	Flat to depressional	<3°	Poorly drained, high water table	Buoyancy controls required, poor trafficability
pO	Bog	Peat		High	Flat to depressional	<3°	Poorly drained, high water table	Buoyancy controls required thaw settlement may be a problem
pOv	Bog Veneer	Peat	<2 m	High	Flat to depressional	<3°	Poorly drained, high water table	Buoyancy controls required
Cm	Colluvial Slopewash	Colluvium predominantly silt and sand		Generally unfrozen; low to medium where frozen	Gently to steeply sloping	3°to>15°	Fair to good drainage	
Ct	Talus	Angular rock fragments, silt and sand matrix		Unfrozen	Steeply sloping	Up to 45°	Good drainage	Excavation may be difficult

TABLE 8: PHYSIOGRAPHIC REGION VIII - TINTINA TRENCH

Map Symbol	Terrain Type	Landform Characteristics: Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
Cv	Colluvial Veneer	Colluvium, predominantly silt and sand	<2 m	Usually unfrozen, low ice content if frozen	Topography reflects underlying bedrock	Reflects under-lying material	Good drainage	
Ev	Eolian Veneer	Wind-blown sand and silt	<2 m	Unfrozen or frozen, high ice content where frozen especially in lows	Topography reflects underlying deposits	3° to 9°	Good drainage	High ice contents
Af	Alluvial Fan	Mainly sand and gravel, grading from gravel at apex to sand and silt at base		Usually unfrozen, low ice content if frozen	Concave slope	9°to>15°	Good surface drainage, some subsurface flow	
Ap	Alluvial Floodplain	Stratified sand and gravel, some silt, organic veneer locally in inactive floodplain of Stewart River		Usually unfrozen, high ice content permafrost in patches beneath organics	Flat to gently undulating, channelled	<3°	Good drainage, high water table	Buoyancy control and deep burial may be required

TABLE 8: PHYSIOGRAPHIC REGION VIII - TINTINA TRENCH

Map Symbol	Terrain Type	Landform Characteristics: Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
Gm	Rolling Glacio-fluvial Plain	Stratified sand and gravel, minor silt		Generally unfrozen, low ice content if frozen	Undulating hummocky	3° to 15°	Good drainage	Possible borrow sources
Gp	Glacio-fluvial Plain	Stratified sand and gravel, minor silt		Generally unfrozen, low ice content if frozen	Flat to very gently undulating	<3°	Good drainage	Possible borrow source
Gt	Glacio-fluvial Terrace	Stratified sand and gravel, silt veneer		Generally unfrozen, low ice content if frozen	Flat to undulating, steep frontal scarps	<3°	Good drainage	Possible borrow source
Gv	Glacio-fluvial Veneer	Sand and gravel, minor silt, frequently as discontinuous patches	<2 m	Generally unfrozen, low ice content if frozen	Topography is a reflection of underlying soil or bedrock	<3°	Good drainage	Depth to bedrock will be a factor in ditch excavation
M	Moraine Undiffer-entiated	Gravelly sandy till			Reflects overlying deposits	Variable Reflects over-lying deposits	Variable	

TABLE 8: PHYSIOGRAPHIC REGION VIII - TINTINA TRENCH

Map Symbol	Terrain Type	Landform Characteristics					Surface Drainage and Groundwater	Engineering Considerations
		Soil Description	Thicknesses	Ground Ice	Topography	Slope		
Ma	Ablation Moraine	Gravelly sandy till		Generally unfrozen, patches of low to medium ice content material	Rolling	9° to 15°	Good drainage	
Mm	Rolling Moraine	Gravelly sandy till		Generally unfrozen, some patches of high ice content permafrost may occur in depressions	Undulating to rolling	3° to 9°	Good drainage except for depressions which have poor drainage	
Mp	Moraine Plain	Gravelly sandy till		Generally unfrozen, low ice content if frozen	Flat to gently undulating	<3°	Good drainage	
Mv	Moraine Veneer	Gravelly sandy till	<2 m	Generally unfrozen, low ice content if frozen	Topography reflects underlying bedrock	Up to 15°	Good drainage	Depth to bedrock will be a factor in ditch excavation

TABLE 8: PHYSIOGRAPHIC REGION VIII - TINTINA TRENCH

Map Symbol	Terrain Type	Landform Characteristics: Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
R	Bedrock							
	i	- igneous			Rolling to steeply sloping	Variable	Good drainage	Excavation of this bedrock type will be difficult
R	m	- metamorphic			same as above		Good drainage	Same as above
R	ss	- sandstone and conglomerate			same as above		Good drainage	Same as above

TABLE 9: PHYSIOGRAPHIC REGION IX - YUKON PLATEAU

(Alignment Sheets 41, 41A - D, 42, 43, 44, 45, 46, 47, 48, 48A - I, 49, 50, 48E 1 - 6)

Map Symbol	Terrain Type	Landform Characteristics: Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
fO	Fen	Peat and organic silt		Unfrozen	Flat to depressional	<3°	Poorly drained, high water table	Buoyancy controls required - poor trafficability
fOv	Fen Veneer	Peat and organic silt	2 m	Unfrozen	Flat to depressional	<3°	Poorly drained, high water table	Buoyancy controls required, poor trafficability
pO	Bog	Peat		High	Flat to depressional	<3°	Poorly drained, high water table	Buoyancy controls, possible thaw settlement
pOv	Bog Veneer	Peat	<2 m	High	Flat to depressional	<3°	Poorly drained, high water table	Buoyancy controls possible thaw settlement
Cf	Flow Slide	Gravity transported clay to gravel		Unfrozen	Moderately sloping	9°to>15°	Fair to poor drainage	May be unstable and erodible
Cm	Colluvial Slopewash	Silt and sand colluvium		Generally unfrozen	Gently to moderately sloping	5° to 15°	Fair to good drainage	
Cs	Rock Slide	Angular rock fragments		Unfrozen	Moderately to steeply sloping	<25°	Good drainage	Excavation may be difficult, more sliding possible

TABLE 9: PHYSIOGRAPHIC REGION IX - YUKON PLATEAU

Map Symbol	Terrain Type	Landform Characteristics						
		Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
Ct	Talus	Angular rock fragments silt and sand matrix		Unfrozen	Steeply sloping	>45°	Good drainage	
Cv	Colluvial Veneer	Mostly silt and sand	<2 m	Unfrozen; low ice if frozen	Reflects underlying rock	Reflects under-lying material	Good drainage	
Af	Alluvial Fan	Poorly sorted sand and gravel, grades from gravel at apex to sand and silt at base		Usually unfrozen, low ice content where frozen	Concave slope	9°to>15°	Good drainage, some subsurface flow	
Ap	Alluvial Floodplain (Undifferent-iated)	Stratified sand and gravel, minor silt, organics locally		Mostly unfrozen; may be frozen under organics	Flat to gently undulating	<3°	Good drainage, high water table	Buoyancy control and deep burial may be required
Ap_1	Active Flooplain	Stratified sand and gravel		Unfrozen	Flat, channelled	<3°	Fair drainage, some standing water	Frequently inundated
Ap_2	Inactive Floodplain	Stratified sand and gravel, some organics		Mostly unfrozen high ice content beneath organics	Flat to gently undulating	<3°	Fair to good	Periodically inundated

TABLE 9: PHYSIOGRAPHIC REGION IX - YUKON PLATEAU

Map Symbol	Terrain Type	Soil Description	Thicknesses	Ground Ice	Topography	Slope	Surface Drainage and Groundwater	Engineering Considerations
			Landform Characteristics					
Mh	Hummocky Moraine	Gravelly sandy till, granular lenses		Generally unfrozen	Hummocky	9° to 15°	Good drainage, high water table locally	
Mm	Rolling Moraine	Gravelly sandy till		Generally unfrozen	Rolling	3° to 9°	Good drainage, high water table locally	
Mp	Moraine Plain	Gravelly sandy till		Generally unfrozen	Flat	<3°	Fair to good drainage	
Mr	Moraine Ridge	Gravelly sandy till		Generally unfrozen	Ridges	9° to 25°	Good drainage	
Mv	Moraine Veneer	Sandy till		Generally unfrozen	Topography reflects underlying deposits		Good drainage	Depth to bedrock will affect ease of excavation
R	Bedrock i	igneous rock			Hilly to mountainous	Up to 75°	Good drainage	Bedrock, except for volcanic tuffs may be difficult to excavate in this region
R	m	Metamorphic rock			Same as above		Good drainage	Same as above
R	s	Sedimentary rock			Same as above		Good drainage	Same as above
R	ss	Sandstone			Same as above		Good drainage	Same as above
R	v	Volcanic rock			Same as above		Good drainage	Same as above

The occurrence of terrain units within a physiographic region can be determined quantitatively by measuring the kilometers of each terrain type within that region. Terrain typed alignment sheets with the pipeline routine and kilometer markers must be used for such a study. At the time of the writing of this report kilometer markers were unavailable so a quantitative study on terrain units was not carried out.

Respectfully Submitted,
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On October 27, 1978 the name of R. M. Hardy & Associates Ltd. was changed to Hardy associates (1978) Ltd. No change in ownership or scope of services is involved.

6.0 REFERENCES

Bostock, H. S., 1936: Carmacks District, Yukon; Geol. Surv. Can. Memoir 189.

_____, and Lees, E. J., 1938: Laberge map-area, Yukon; Geol. Surv. Can., Memoir 217.

_____, 1948: Preliminary Map, McQuesten, Yukon Territory; Geol. Surv. Can., Prelim. Map.

_____, 1948: Physiography of the Canadian Cordillera, with special reference to the area north of the fifty-fifth parallel; Geol. Surv. Can., Mem. 247.

_____, 1963: Geology McQuesten, Yukon Territory; Geol. Surv. Can., Map 1143A.

_____, 1966: Notes on glaciation in central Yukon Territory: Geol. Surv. Can., Paper 65-36.

_____, 1970: Physiographic subdivisons of Canada, in Geology and Economic Minerals of Canada; R. J. W. Douglas, Editor; Geol. Surv. Can., Economic Geology Report No. 1, pp. 10-30.

Brown, R. J. E., 1967: Permafrost in Canada; Geol. Surv. Can., Map 1246A.

Douglas, R. J. W., 1970: Geology and Economic Minerals of Canada, Geol. Surv. Can., Economic Geology Report 1.

Fyles, J. G., 1966: Quaternary stratigraphy, Mackenzie Delta and Arctic coastal plain, in Report of Activities, May to October, 1965; Geol. Surv. Can., Paper 66-1.

_____, 1967: Mackenzie Delta and Arctic coastal plain, in Report of Activities, May to October, 1966; Geol. Surv. Can., Paper 67-1, Pt. A.

_____, Heginbottom, J. A., and Rampton, V. N., 1972: Quaternary geology and geomorphology, Mackenzie Delta to Hudson Bay; XXIV Internat. Geol. Congr., Guidebook A-30.

Gill, D., 1972a: Modification of levee morphology by erosion in the Mackenzie River delta, Northwest Territories, Canada. Institute of British Geographers; Special Publication No. 4.

_____, 1972b: The point bar environment in the Mackenzie River Delta; Cdn. Jour. Earth Sci., V. 9.

Green, L. H., 1972: Geology of Nash Creek, Larsen Creek, and Dawson map-areas, Yukon Territory; Geol. Surv. Can., Memoir 364.

_____, and Roddick, J. A., 1962: Dawson, Larsen Creek and Nash Creek map-areas, Yukon Territory; Geol. Surv. Can., Paper 62-7.

Hughes, O. L. et al., 1969: Glacial limits and flow patterns, Yukon Territory, south of 65 degrees; Geol. Surv. Can., Paper 68-34.

_____, 1972: Surficial geology of northern Yukon Territory and N.W. District of Mackenzie. Includes map 1319A (NTS areas 106E, F, K, L, N; 107B, C): Geol. Sruv. Can., Paper 69-36.

_____, Hodgson, D. A., and Pilon, J., 1972: Surficial geology maps, scale 1:125,000 of NTS areas (106I, M, N); Geol. Surv. Can., Open File 97.

_____, Rampton, V. N., and Rutter, N. W., 1972: Quaternary geology and geomorphology, southern and central Yukon (northern Canada); XXIV Internat. Geol. Congr., Guidebook A-11.

_____, and Pilon, J., 1973: Surficial geology maps, scale 1:125,000, of NTS areas (116N, O, P). Geol. Surv. Can., Open File 167.

_____, Veillette, J. J., Pilon, J., Hanley, P. T. and Van Everdingen, R. O., 1973: Terrain evaluation with respect to pipeline construction, Mackenzie Transportation Corridor, Central Part, Lat. 64° to 68°N. Environmental-Social Program, Report No. 73-37, Information Canada.

Johnston, G. H., and Brown, R. J. F., 1964: Some observations on permafrost distribution at a lake in the Mackenzie Delta, N.W.T., Canada; Arctic, V. 17.

_____, 1965: Stratigraphy of the Mackenzie River Delta, Northwest Territories, Canada; Bull. Geol. Soc. Amer., V. 76.

Mackay, J. R., 1963a: The Mackenzie Delta area, N.W.T. Can. Dept. Mines Tech. Surv.; Geograph. Br., Mem. 8.

_____, 1966: Segregated epigenetic ice and slumps in permafrost, Mackenzie Delta area, N.W.T.; Geograph. Bull. (Canada), No. 8.

_____, 1967: Permafrost depths, lower Mackenzie Valley, Northwest Territories; Arctic, V. 20.

Monroe, R. L., 1974: Preliminary terrain classification and sensitivity maps, Scale 1:250,000; Geol. Surv. Can., Open File Nos. 117, 120, 121, 125, 131, 132, 144, 145, 157, 210.

Norris, D. K., Price, K. A., and Mountjoy, E. W., 1973: Geology, northern Yukon Territory and northwestern District of Mackenzie. Can. Geol. Surv., Map 10-1063.

Prest, V. K., Grant, D. R., and Rampton, V. N., 1967: Glacial map of Canada, <u>in</u> Geology and Economic Minerals of Canada, R. J. W. Douglas, ed. Geol. Surv. Can., Economic Geology Report, Map 1253A.

Rampton, V. N., 1970: Surficial geology maps, scale 1:250,000, of coastal areas, NTS areas 107B-W part, 117A, 117C, 117D; Geol. Surv. Can., Open File 21.

_____, 1972: Surficial geology map, scale 1:125,000, of NTS area 107B-E part; Geol. Surv. Can., Open File 119.

_____, 1972: Surficial geolgoy maps, scale 1:125,000, of NTS areas 97F, 107C, 107D and 107E; Geol. Surv. Can., Open File 96.

_____, 1974: Surficial geology and landform maps, scale 1:125,000, of NTS areas 107B-W1/2, 117A-E1/2, 117C, 117D; Geol. Surv. Can., Open File 191.

______, 1974: Terrain evaluation, Mackenzie Transportation Corridor northern part; Geol. Surv. Can. for the Environmental Social Program, Northern Pipelines, Report No. 73-47.

Richardson, N. W., 1974: The Dempster Highway - engineering in the Arctic; M.Sc. Thesis, Dept. of Civil Engineering, University of Saskatchewan, Saskatoon, Saskatchewan.

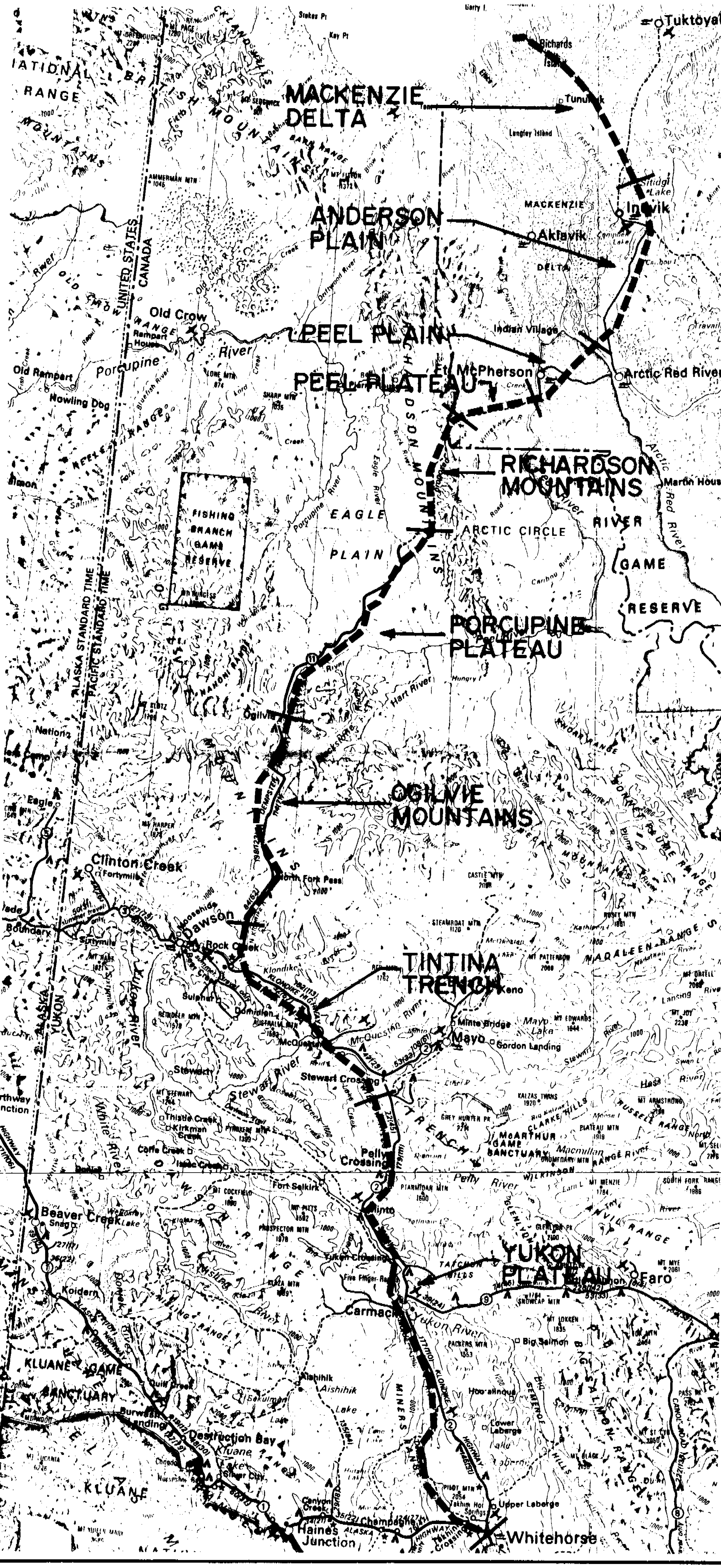
Ricker, K. E., 1968: Quaternary geology in the Southern Ogilvie Ranges, Yukon Territory; M.Sc. Thesis, Department of Geology, University of British Columbia, Vancouver, B.C.

______, 1977: Quaternary geology of the North Klondike and Upper Blackstone River systems, Southern Ogilvie Ranges, Yukon Territory, Canada, Dempster Highway (KM 0-139); Geol. Surv. Can. Open File Map and Legend 478.

Tempelman-Kluit, D. J., 1970: Stratigraphy and structure of the "Keno Hill Quartzite" in Tombstone River-Upper Klondike River map-areas, Yukon Territory; Geol. Surv. Can., Bull. 180.

Vernon, P. and Hughes, O. L., 1966: Surficial geology, Dawson, Larsen Creek and Nash Creek map-areas, Yukon Territory; Geol. Surv. Can., Bull. 136.

Wheeler, J. O., 1961: Whitehorse map-area, Yukon Territory; Geol. Surv. Can., Mem. 312.



LEGEND

▬ ▬ Dempster Pipeline

SCALE 1:2,500,000

0 10 20 30 40 50 miles

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PHYSIOGRAPHIC REGIONS AFTER BOSTOCK, 1967

Figure 1