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DEPARTMENT OF MINES, RESOURCES AND
ENVIRONMENTAL MANAGEMENT

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GEOLOGICAL REPORT 77-2

QUATERNARY GEOLOGY AND GRAVEL RESOURCES
OF THE LEAF RAPIDS LOCAL GOVERNMENT DISTRICT

by
Susan Ringrose and Peggy Large

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PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND
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CONTENTS

	Page
INTRODUCTION	
TOPOGRAPHY	1
BEDROCK GEOLOGY	1
PREVIOUS WORK	2
ACKNOWLEDGEMENTS	2
QUATERNARY GEOLOGY	
MAPPING METHODS	2
BEDROCK FEATURES (UNIT 1)	4
Ice Advance Indicators	
EARLY GLACIAL, GROUND MORaine, TILL (UNIT 2)	5
GLACIAL, GLACIOFLUVIAL SEDIMENTS (UNIT 3)	6
LATE GLACIAL, GLACIOLACUSTRINE SEDIMENTS (UNIT 4)	7
SHORELINE SEDIMENTS (UNIT 5)	7
EOLIAN SEDIMENTS (UNIT 6)	7
POST GLACIAL, ORGANIC AND SWAMP DEPOSITS (UNITS 7 AND 8)	7
Organic Deposits (Unit 7)	
Swamp, Fen (Unit 8)	
SEDIMENT ASSEMBLAGES ASSOCIATED WITH ESKERS	8
Leaf Rapids Esker	8
Glaciofluvial Deposits, Unit 3	
Glaciolacustrine Deposits, Units 4b and 4c	
Shoreline Deposits, Units 5a and 5b	
Eolian Deposits, Unit 6	
Grass Lake Esker	17
Glaciofluvial Deposits, Unit 3	
Glaciolacustrine Deposits, Units 4b and 4c	
Shoreline Deposits, Units 5a and 5b	
Penguin Lake Esker	23
Glaciofluvial Deposits, Unit 3	
Glaciolacustrine Deposits, Units 4b and 4c	
Shoreline Deposits, Unit 5a	
Rat River Esker	25
Glaciofluvial Deposits, Unit 3	
Glaciolacustrine Deposits, Units 4b and 4c	
Shoreline Deposits, Unit 5a	
SUMMARY OF GLACIAL HISTORY	26

	Page
ECONOMIC EVALUATION OF SURFICIAL DEPOSITS	
LOCATION AND STATUS OF PRESENT PITS	30
ECONOMIC USE OF MATERIALS	31
Gravel, Sand and Clay	
Peat	
EVALUATION OF SAND AND GRAVEL DEPOSITS	32
Previous Work	
Analysis of Aggregate Deposits	
Quality of Sand and Gravel	
Quantity of Sand and Gravel	
Distance of Haulage	
Demands for Gravel Deposits	
EVALUATION OF CLAY AND PEAT DEPOSITS	39
Clay Potential for Brick and Tile Manufacture	
Peat	
GEOLOGICAL DATA FOR LAND-USE PLANNING	39
General Construction Conditions	
Waste Disposal	

LIST OF FIGURES

		Page
FIGURE 1	Air-photo lineaments in relation to glaciofluvial features.	3
FIGURE 2	Per cent frequency of photo lineaments.	4
FIGURE 3	Association of wave-washed till and clay — Pit B32N.	6
FIGURE 4	Morphology of Leaf Rapids esker.	9
FIGURE 5	Schematic relations of sand and clay on western margin of Leaf Rapids esker.	12
FIGURE 6	Reworked shoreline sediment — Leaf Rapids esker.	16
FIGURE 7	Morphology of Grass Lake esker.	18
FIGURE 8	Sand-silt contact at B63S.	20
FIGURE 9	Grass Lake esker, northern bead — location 66-67 north.	22
FIGURE 10	Morphology of Penguin Lake and Rat River eskers.	24
FIGURE 11	Chronology of ice retreat — northern Manitoba.	27
FIGURE 12	Relative thicknesses of sediments and generalized stratigraphy.	28
FIGURE 13	Elevations of Glacial Lake Churchill.	29
FIGURE 14	Particle size curves — channel samples.	35
FIGURE 15	Temperature gradient furnace test — lacustrine clay.	40

LIST OF TABLES

		Page
TABLE 1	Quality of Aggregate	34
TABLE 2	Sand and Gravel Resources	37
TABLE 3	Estimated Future Demand for Sand and Gravel	38

LIST OF APPENDICES

		Page
APPENDIX 1	Photographs	46
APPENDIX 2	Log of pits and sections	66
APPENDIX 3	Drift lithologies	77
APPENDIX 4	Highway pit data	79
APPENDIX 5	Resistivity survey	82
APPENDIX 6	Engineering characteristics of sediments	87
APPENDIX 7	Physical analyses — sand and gravel deposits	90
APPENDIX 8	Temperature gradient furnace results — lacustrine clay	92
APPENDIX 9	Heavy mineral analyses	93

LIST OF MAPS

MAP A:	Surficial Geology of the Leaf Rapids Local Government District — West Half	in pocket
	Surficial Geology of the Leaf Rapids Local Government District — East Half	in pocket
MAP B:	The Surficial Geological Basis for Land-use Planning in the Leaf Rapids Local Government District — West Half	in pocket
	The Surficial Geological Basis for Land-use Planning in the Leaf Rapids Local Government District — East Half	in pocket

LIST OF PHOTOGRAPHS

PLATE 1A:	Crescentic fractures at South Bay Road near benchmark 209. Ice direction from left to right. Knife 22 cm.
PLATE 1B:	Section of Notigi till (between lines), directly above bedrock, covered by 3 to 4 m of lacustrine clay. Location: Highway 391 at Notigi Control Structure. Section: 5.0 m.

- PLATE 2A: Lag cobbles on crest of Leaf Rapids esker — Deposit 1 (B9E).
- PLATE 2B: Massive cobbles in sand matrix (subfacies 3a) — Leaf Rapids esker. Location: B45W2. Person: 1.60 m.
- PLATE 3A: Glaciofluvial gravel exposed at the southernmost limit of Leaf Rapids esker at B6W. Hammer: 25 cm.
- PLATE 3B: Coarse pebbles, granules and sand, with some indication of parallel horizontal bedding at B45W1. Section is 2 m.
- PLATE 4A: Horizontally bedded pebbles and sand at Leaf Rapids esker crest (subfacies 3b) B47W. Exposed section is 1.0 m.
- PLATE 4B: Beds of coarse to medium sand and pebbles dipping at 10° eastwards on east side of Leaf Rapids esker — B55E. Section is 14 m high.
- PLATE 5A: Details of normal faults in horizontally bedded sand and pebble units 5 to 8 cm thick in B55E, southwest wall. Exposed section 1.5 m.
- PLATE 5B: Eastern margin of Leaf Rapids esker showing upward warping of sand-silt unit, with high angle reverse fault — Mine Road-Cut 1.
- PLATE 6A: Massive silt grading upwards into varve-like couplets of silt and clay — ditch section, east of B29W. Section 2.0 m.
- PLATE 6B: Convolute silt and clay couplets with intercalated glaciofluvial sediments at B46E. Section is 2 m.
- PLATE 7A: Lag gravel overlying parallel bedded sand at B47W, west side. Section is 5.0 m.
- PLATE 7B: Detail of foreshore stratification, showing graded beds and fragmented pebbles. Glaciofluvial pebbles and granules at base of section. Location: B59W1. Section: 3.0 m.
- PLATE 8A: Parallel laminated and accretionary foreshore sand overlying coarse glaciofluvial sediments. Note wavecut notch at B49W. Measured section 1.0 m.
- PLATE 8B: Detail of dune sand, on crest of Leaf Rapids esker, showing horizontal laminations of medium to fine sand at 391 Townsite A. Section: 1.3 m.
- PLATE 9A: Section of rounded cobbles, pebbles and coarse sand (Unit 3a) of Grass Lake esker at B65AN. Pebbles show evidence of imbrication. Person: 1.55 m.
- PLATE 9B: Coarse gravel deposits capped by massive silt, which merges laterally into clay (under trees in background) at B65S. Silt and gravel — 3.0 m high.
- PLATE 10A: Unit 3 glaciofluvial gravel exposed at base of thick laminated silt and clay section (Unit 4).
- PLATE 10B: Subfacies 3c of northern bead of Grass Lake esker: very coarse sand, with medium scale cross-stratification grading upwards to fine silty sand. Heavy mineral laminae at contact. Current direction from left to right. Location: B65S. Section: 1.5 m.

- PLATE 11A: Glaciofluvial gravel (1) capped by silt (3) with rippled subfacies 3c sand at contact (2). Location: 66-67 north. Measured exposure: 1.50 m.
- PLATE 11B: Climbing ripple drift cross-stratified sand merging into interfering ripple drift cross-stratification (at shovel handle). Location: Grass Lake. Shovel is 1.0 m.
- PLATE 12A: Climbing ripple drift cross-stratification, showing toeset development. Flow direction from left to right. Location: Grass Lake esker north of B63S. Knife blade 11 cm.
- PLATE 12B: (1) Massive grey silt and sandy silt (facies 4c) overlying (2) parallel laminated and ripple drift cross-stratified sand (facies 3c) — note preserved sand ripples at contact. Location: northern portion of Grass Lake esker, south of pit B65S. Section: 1.80 m.
- PLATE 13A: Detail of contact between silt and glaciofluvial sand and gravel towards base of section at 66-67 north. Paleoflow direction in medium-fine ripple drift cross-stratified sand indicates current from right to left in photo (from north-east to southwest). Scale in centimetres.
- PLATE 13B: Detail of Penguin Lake B: lower cross-bedded sand, small scale cross-stratification in truncated sets. Current direction from right to left (east to west).
- PLATE 14A: Faulted contact between upper cross-bedded sand and underlying silt on crest of esker. Location: Penguin Lake B. Scale in centimetres.
- PLATE 14B: Coarse rounded gravel of the Rat River esker, exposed on peninsula. Shovel is 67 cm.
- PLATE 15A: Disused garbage area on esker margin — B53E.
- PLATE 15B: Disused clay borrow pit — B32N.
- PLATE 16A: Equipment excavating gravel from B45W2 for Department of Highways' contract.
- PLATE 16B: Crushing and screening of gravel from B45W2 for Department of Highways' contract.
- PLATE 17A: Leaf Rapids Corporation Pit: overlooking Churchill River; remnants of stockpile in middle ground.
- PLATE 17B: Gravel extraction for concrete manufacture — B55E.
- PLATE 18A: Peat excavation along South Bay Road for use as topsoil in Leaf Rapids residences.
- PLATE 18B: Disintegrating pebbles from B6W.
- PLATE 19A: Equipment used in resistivity profile work: meter, coils, 30 m tape and electrodes spaced according to the Wenner configuration. Location: eastern margin of Leaf Rapids esker.

INTRODUCTION

The Local Government District of Leaf Rapids lies between Thompson and Lynn Lake in northern Manitoba. The townsite area was developed in 1971 by the Leaf Rapids Development Corporation, a subsidiary of Manitoba Development Corporation. The town of Leaf Rapids was established in response to the opening of a zinc-copper mine at Ruttan Lake in 1970. A road was initially constructed from the mine to Leaf Rapids townsite with extensions to Lynn Lake and later to South Bay on Southern Indian Lake. In 1973 the highway to Thompson was completed, connecting Leaf Rapids to the provincial highway network.

The object of the present work is to provide a map of the surficial geology and to report on the origin and nature of Pleistocene deposits in the District. Particular emphasis is placed on the delineation and description of areas which show the greatest potential as sources of granular aggregate materials. Section I of the report deals with the Pleistocene geology and Section II with an evaluation of granular material. This study is a pilot project aimed at providing data for aggregate resource management in the province.

TOPOGRAPHY

The topography of the Local Government District and surrounding area is shown on parts of the 1:50 000 NTS map sheets numbered 64B/5, 64B/6, 64B/11, 64B/12, 64C/8 and 64C/9. These have a contour interval of 25 feet (7.6 m). Elevations are taken directly from these map sheets, supplemented by recently plotted bench mark heights (1974 Geodetic Survey). The highways were plotted from remote sensing imagery, at a scale of 1:126 720.

The southern and western portions of the area have the highest elevations, which average 312 to 320 m decreasing gradually towards the northwest into the Churchill River basin which has an elevation of around 260 m. In the southeast, the height of land drops to 250 m towards the basin of the southward flowing Rat River. Manitoba Hydro is diverting waters from the Churchill River into the Rat basin by breaching the watershed through Issett Lake to the east of the Local Government District.

The overall relief of the area is subdued and typical of the Precambrian Shield. Positive elements include bedrock ridges and knolls, with up to 30 m relief, some of which are covered by veneers of drift. Glaciofluvial features form prominent ridges with positive relief up to 18 m.

Negative landscape elements include depressions deepened by glacial erosion, the most extensive of which now contain lakes; others contain smaller creeks and swamps. Many of the lowlying areas are basins in which greater thicknesses of drift and organic debris have accumulated.

BEDROCK GEOLOGY

Detail of the bedrock geology of the Leaf Rapids area is contained in reports by Campbell (1972), Kendrick (1972) and Steeves and Lamb (1972). Three major groups of the Precambrian Churchill Province are represented, namely the Wasekwan Group, the Pre-Sickle intrusions and Post-Sickle intrusions. The bedrock outcrops (indicated on surficial geology map (Map A), in pocket) control the general morphology of the area. The granitic (post-Sickle intrusions) outcrops of the southern and western portions of the area appear to be more resistant to erosion, providing relatively prominent ridges and deeply incised valleys. The Wasekwan lithologies in general have a basin or plateau-like character, with more subdued relief. Comments on the relative properties of certain rock types and their ability to withstand erosion emanate from bedrock reports (Milligan, 1960). Further work is required to assess the

relative erodability of Wasekwan and pre-Sickle rocks in the light of glaciological theory.

PREVIOUS WORK

Pleistocene and Holocene deposits of the NTS map sheet area (Uhlman Lake Sheet 64B) were mapped as part of a reconnaissance survey by Klassen and Netterville (1973), using aerial photographic mosaics.

Interpretations of the broad glacial history have been undertaken by McInnes (1913), Antevs (1931) and Elson (1967) and in map form by Prest (1969). The Churchill basin probably contained a broad re-entrant of the Laurentide ice front, which retreated rapidly by calving and direct melt into the waters of a proglacial lake. The area is thought to have become free of ice around 9700 — 9600 years B.P.

Other works of interest include information on the climate of the Lynn Lake area. Milligan (1960, p. 21) indicates approximate design temperatures which are applicable to the Local Government District of Leaf Rapids. Details of the soils and vegetation of the Churchill and Rat River drainage areas are discussed by Beke, Veldhuis and Thie (1973, pp. 23 — 42) and Ritchie (1962). Some indication of the surficial geology cover is given in these reports.

ACKNOWLEDGMENTS

Mapping of the area took place in the summer of 1974, during which time the authors received assistance from Mr. Riddell, Resident Administrator, LGD of Leaf Rapids and Lorne Dixon, Conservation Officer. Help in the field was provided by Diane Law who undertook most of the drift lithology identification. Laboratory analyses were undertaken by M. Milinkovic. The Manitoba Department of Highways, Materials and Testing Section is thanked for the loan of Bison EARM Resistivity equipment.

Special thanks are extended to Barry Bannatyne, Industrial Minerals Geologist, who critically read the report, and to Leah McKnight for typing the manuscript.

Dr. Ian Haugh is gratefully acknowledged for the conception of this project, and with it the initiation of Quaternary studies by the Province.

QUATERNARY GEOLOGY

MAPPING METHODS

The Quaternary Geology Map (Map A in pocket) shows the areal extent of surficial deposits. Most of the area is covered by thicknesses of glaciolacustrine clay (Unit 4) which is modified by organic accumulation or fen growth in depressions. In the vicinity of the eskers (named on Figure 1) the deposits alter rapidly, both horizontally and vertically, and in mapping, minor changes had to be neglected.

Mapping was undertaken by direct plotting on panchromatic mosaics (1:31 680) supplemented by airborne remote sensing flown in 1973 (the main sensor, 2445 film — true colour — with HF filter) at an altitude of 10 700 m or 35 000 feet. Cultural data (including pit locations) were plotted from the airborne remote sensing imagery. Field checking took place by traversing in from lakes and roads and by helicopter reconnaissance. Information on the depth of drift was obtained from cancelled assessment data (on file: Mineral Resources Division) and resistivity survey information. Additional information was obtained from a consultant's report on the proposed townsite (Ripley,

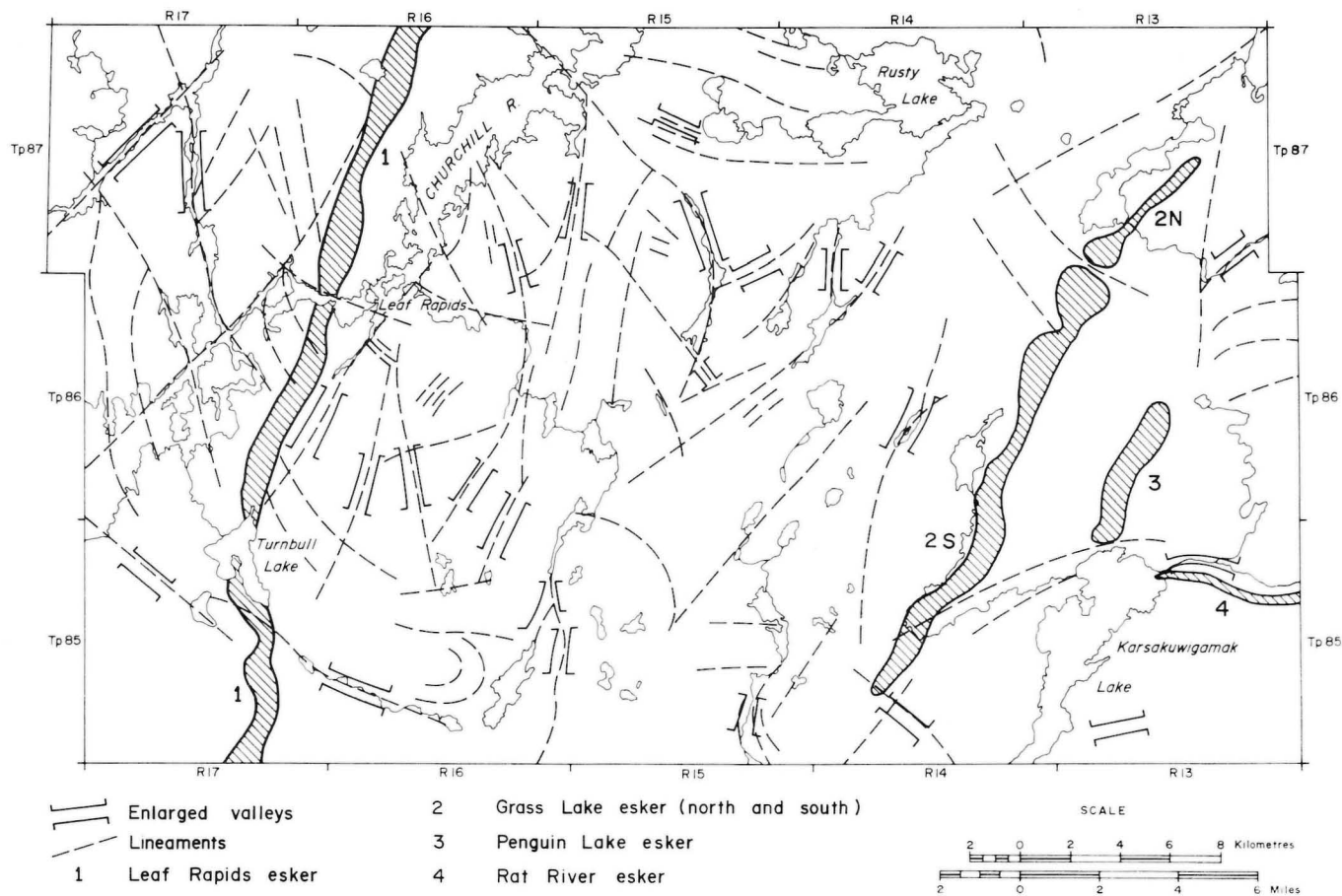


Figure 1: Air-photo lineaments in relation to glaciofluvial features

Klohn and Leonoff, 1971), and from Manitoba Hydro test auger probes. Exposures were examined in roadcuts and opened gravel pits; in addition, test pits were dug and augered into the more remote eskers. Two maps were compiled: Map A showing the surficial geology of the area and Map B showing pit, sample and drillhole locations and outlines of the economically significant deposits.

In subsequent sections of this report the elements of the Quaternary geology (Units 1 to 8) are described generally for the entire map sheet area. Following this are detailed descriptions of the sediment assemblages associated with the major eskers. Map A illustrates the inter-relationship between the surficial geology cover of the entire map area and the units directly associated with the eskers.

BEDROCK FEATURES (UNIT 1)

Bedrock is indicated as Unit 1 on Map A and is exposed throughout one-tenth of the area.

The extent to which bedrock controls the present day morphology is indicated by mapping structural lineaments. The photo-lineaments map (Figure 1) was plotted directly from airborne remote sensing imagery and used in conjunction with existing data published by Campbell (1972). Most of the lineaments are straight or gently curved features visual through their tonal contrast with the surrounding area. Per cent frequency of lineaments at fifteen degree intervals was used to plot a rose diagram from which major trends are distinguishable (Figure 2): 330° — 345°, dominant trend; 000° — 015° and 030° — 045°, secondary trends; and 270° — 285°, tertiary trend.

The lineament density in any portion of the study area is related directly to the thinness of the surficial cover, as fewer lineaments are distinguishable in the deeper basins (confirmed by Babcock, 1974, p. 102). Visual checking with Campbell's findings (1972, Figure 9, p. 28) indicates a close correspondence between lineaments and jointing, the latter derived from measurements taken in the field. Campbell states that few of the lineaments are attributable to faults since most are confined to single rock units.

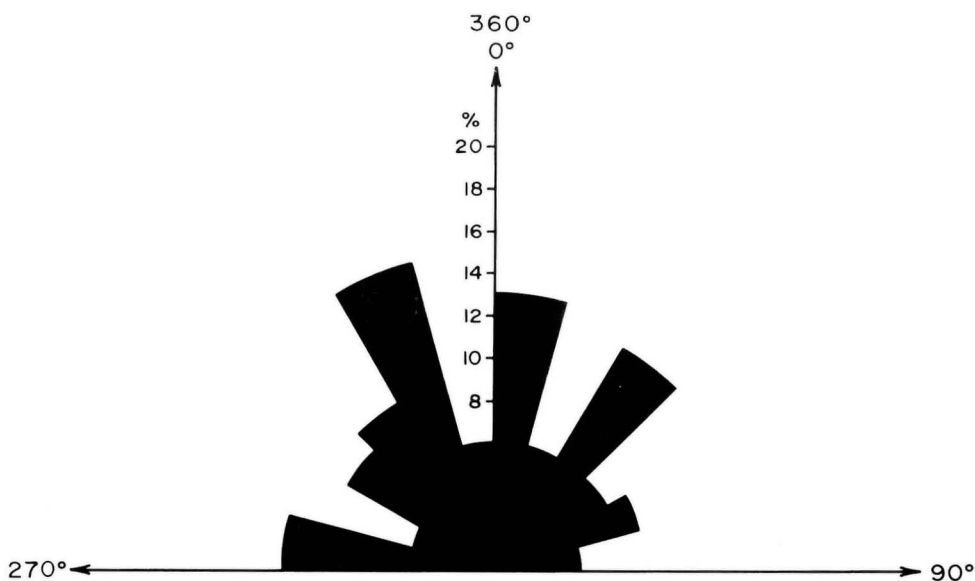


Figure 2: Per cent frequency of photo lineaments

The lineaments reflect structures in the bedrock which provide natural depressions used as preglacial, glacial and present drainage channels and define the shoreline configuration of many lakes. Three sets, the 330° — 345°, 030° — 045°, and 270° — 285°, define the Granville Lake — Churchill River complex, with its tributary lakes and streams; the 030° — 045° trend defines the north shore of Turnbull Lake. Other small lakes have developed where lineaments intersect, as shown on Figure 1.

Ice Advance Indicators: Striations which are generally rectilinear were observed on the South Bay Road at pits B32N and B33N*, at Karsakuwigamak Lake and by the Leaf Rapids esker. Two major sets were recorded, the more prominent between N41°E and N48°E and a less prominent set around N70°E. Most of these are approximately 20 to 30 cm long and a few millimetres deep. Striations at N35°W and ice-gouged fractures were found south of the Rat River.

Crescentic fractures were observed on outcrops along the South Bay Road and in the vicinity of Karsakuwigamak Lake. The fracture surfaces are concave in the direction of ice movement and nested in rows parallel to glacial flow (see Plate 1A)† indicating a general ice flow direction from N45°E.

A minor bedrock feature resembling a "roche moutonnée" form was observed north of the Rat River (UTM Northing 6250340 Easting 472850) and oriented at N65°W. A rounded abrasion feature in metabasalt is evident up-ice from the zone of quarrying. A granite erratic remains in the quarried zone.

Most of the ice advance indicators are oriented at around N41°E to N70°E suggesting the latest ice advance and, therefore, possibly the most prevalent till deposit was derived mainly from the Labradorean lobe. In the area, fewer indicators suggest ice advance from the north-west, presumably associated with a prevalent Keewatin lobe. The next section assesses the chronology of the two ice advance directions in terms of till deposits.

EARLY GLACIAL, GROUND MORaine, TILL (UNIT 2)

Ground moraine was deposited during a major period of ice advance and during subsequent ice melting throughout the area. Only one thin till sheet overlies the bedrock surface in the study area. It occurs as weathered till on exposed bedrock surfaces and as unweathered till between lacustrine clay and bedrock. The high degree of weathering and reworking of the exposed till and the lack of definitive evidence of late stage ice re-advance, suggest the two phases are in fact contemporaneous.

Pockets of weathered till above exposed bedrock are composed of sandy drift material, indicated on Map A. Exposures of sandy till above west-northwest trending bedrock ridges were sampled at locations A1A, A2A and A4A (Map B). The strongly iron-stained sand is often only 2 cm deep, overlying a coarser granular layer of mixed rock types overlying weathered parent material. Towards the eastern shores of the lake at UTM Northing 6246500 Easting 447500, 30 cm of very fine micaceous sand was observed, associated with a stone content of strongly weathered schist, and relatively unweathered granitic and pegmatitic rock types.

North of the South Bay Road similar till is exposed at the bedrock-clay contact and has been reworked into localized beds of sand and gravel, notably at pits B32N, B45S, B47N, B60S and B61N. The profile (Figure 3) represents the association of sand veneer (unweathered till) and reworked till (sand and angular granules) at B32N at an elevation of 312 m. The reworked sand is

* Refer to pit code in Appendix 4 and Map B.

† Photographs appear in Appendix 1.

oxidized (10YR 4/4 dark yellowish-brown)*.

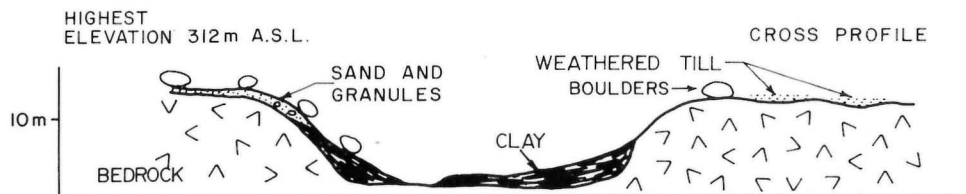


Figure 3: Association of wave-washed till and clay. Pit B32N

The till sheet is not consistent in texture throughout the area. The Notigi section 90 km south of the Local Government District reveals a relatively unweathered compacted loam lodgement till under 4 to 6 m of lacustrine clay. It occurs intermittently on the bedrock surface and is characterized by linear partings (see Plate 1B). It has a clastic content of angular granules and pebbles in a highly calcareous matrix composed of very fine sand with silt lumps. The colour of the matrix ranges from 2.5Y 6/4 to 5/4 moist, light yellowish-brown to light olive-brown. The pebble content (2.5 to 5.0 mm long diameter) includes dark quartzites, pegmatite and granite fragments. One dark quartzite found is round and broken. Small granules (2.0 mm) comprise angular fragments of carbonate and pegmatite rocks.

The basal till represents the products of the latest glacial advance. The till was intermittently deposited as ground moraine on bedrock surfaces and in depressions. The Notigi till is thought to be characteristic of unexposed basal till throughout the Leaf Rapids area. The highly calcareous nature of the till suggests that the last ice advance came from the north-northeast quadrant. There is no depositional evidence of an early advance from the north-west. The exposed till has been intensely weathered during 7000 years oxidation, leaching and resorting so that much of its original fabric is lost.

At one section in the study area (UTM Northing 6258750 Easting 458200), transported till occurs within a wedge of contorted silt and clay. The till is compacted, fissile, non-calcareous and mottled. Enclosed clasts range in length between 2.5 and 9.0 cm (granite, gneiss, pegmatites) in a sandy-silt matrix. This till is similar to the weathered till in the area, with a non-calcareous matrix and high sand content. Its occurrence in relation to the contorted surrounding sediments suggests an origin as 'iceberg till' (Dreimanis, 1976, p. 41), and that the till was transported to its present location during later lacustrine intervals.

GLACIAL, GLACIOFLUVIAL SEDIMENTS (UNIT 3)

The eskers are mapped as Unit 3 sediments on Map A and form linear intermittent concentrations of coarse gravel and sand, overlain by glaciolacustrine clay (4), shoreline sand (5) and eolian sand (6). The features in their entirety are broadly, though imprecisely, described in this report as 'eskers'. The four major sand and gravel landforms are referred to as the "Leaf Rapids" esker, the "Grass Lake" esker, the "Penguin Lake" esker and the "Rat River" esker (see locations, Figure 1).

Glaciofluvial sediments were deposited at the ice front partially in subglacial tunnels during ice melt from the immediate vicinity.

Unit 3 sediments were deposited in a linear beaded form at the ice front.

* Munsell colour standard

The deposits are characterized by thick, 5 to 30 m massive gravel (cobble to pebble size)* which grades laterally and downstream to horizontally bedded pebbles and sand and finally into horizontally and cross-bedded sand.

LATE GLACIAL, GLACIOLACUSTRINE SEDIMENTS (UNIT 4)

Late glacial deposits include those whose deposition started towards the end of glaciation but while the ice was still in the immediate vicinity and whose rapid melting exerted a strong influence on the depositional sequence.

The glaciolacustrine sediments are predominately rhythmites deposited in a large proglacial lake. The lake deposits cover 65% of the map sheet area overlying till and glaciofluvial sediments. The sedimentary unit is of variable thickness, deepening (to about 20 m) in pre-existing bedrock basins (particularly the Churchill River, Rusty Lake, Grass Lake and Karsakuwigamak Lake depressions) and wedging onto bedrock highs and eskers.

The clay was examined in road cut and borrow pit exposures. The texture is extremely uniform throughout the area, consisting of up to 20 m silt and clay laminae overlain by massive dark brown clay (up to 3 m thick). The colour is a uniform dark brown when dry, and mottled in depressions where percolation-saturation conditions prevail. The clay is naturally moist, plastic and has a characteristic moist colour of 10YR 4/3 (between brown and dark brown) and dry colour of 10YR 7/3 (very pale brown). It has a weakly developed planar fissility and is blocky or crumbling in structure. The crumb faces are frequently stained by a dark brown ferric or magnesium oxide, similar to that reported by Wicks (1965) in Lake Agassiz clays. Analysis of a clay sample (from B21BS) by X-ray diffraction showed that the predominant clay mineral is montmorillonite, with minor chlorite and illite, and less mica and quartz.†

SHORELINE SEDIMENTS (UNIT 5)

Shoreline sediments accumulated after the ice melted in the immediate vicinity. There remained a large proglacial lake on the margins of which reworked glaciofluvial sediments were mobilized and redeposited along the esker margins.

Contemporaneous with Unit 5 sedimentation are coarse shoreline lag deposits and coarse storm beach ridges, situated towards the esker crest. Below these are Unit 5a, parallel-bedded coarse to fine foreshore sands, with minor ridge and terrace morphology. These grade laterally to offshore sediments mapped as Unit 5b fine sand and silt. Unit 5a sand has a characteristic colour of 10YR 6/4 moist, light yellowish-brown.

EOLIAN SEDIMENTS (UNIT 6)

Dune sand was deposited as a result of wind activity on the exposed esker margins, after the proglacial lake had drained from the immediate vicinity.

Unit 6 sand was deposited in longitudinal and crescentic dunes, consisting of medium to fine sand, with fine parallel bedding separated by heavy mineral laminae.

POST-GLACIAL ORGANIC AND SWAMP DEPOSITS (UNITS 7 AND 8)

Post-glacial deposits include those whose growth started towards the end of late-glacial time after the proglacial lake had finally drained leaving large depressional areas occupied by standing water. The enlarged glacially gouged channels became prime locations for swamp vegetation development and peat accumulation.

* Sizes refer to the Wentworth Classification.

† Analysis by Paul Lenton, Mineral Resources Division

Organic Deposits (Unit 7): Large areas which are low or flat lying, but slightly higher than the saturated fens are classified as peat areas. The peat may be up to 2.0 m deep, occasionally intermixed with inorganic (mineral) sediment. The peat is frequently frozen at about 30 cm below ground surface and water-logged during summer above the frozen layer. It comprises both sphagnum moss peat and forest peat and is characterized by an irregular hummocky micro-relief with hummocks 30 to 50 cm high, and interspersed with collapsed pothole areas containing water. Some of the hummocks were found to contain frozen (permafrost) cores. This is referred to in the literature as ice-cored peat terrain wherein differential melting of the ice produces irregular surface relief.

Organic terrain in this vicinity is discussed more extensively by Beke, Veldhuis & Thie (1973). These are complex environments, warranting detailed specialized study.

Swamp, Fen (Unit 8): Areas designated as swamp zones occur peripheral and adjacent to present day lakes or misfit streams. They comprise floating or partially stabilized hydrophytic vegetation, mainly reed and sedge species.

These are associated on their landward side with recent muds representing floodplain (alluvial) deposits of present day streams, for examples, the Turnbull Creek and Vermilion River. The muds are deposited resulting from increased spring flow, following the break-up of ice.

SEDIMENT ASSEMBLAGES ASSOCIATED WITH ESKERS

In subsequent portions of the report the major glaciofluvial and post-glacial features are described in terms of their depositional history, using the sedimentary facies concept. The glaciofluvial deposits were laid down by water in contact with and flowing from the retreating ice front. The ridges were built up essentially at the ice front in or under the ice in subglacial tunnels. Evidence suggests that the glaciofluvial material was deposited almost directly into a standing water lacustrine environment, and that the proglacial lake level apparently rose as the ice retreated. Such modifications in the physical environment are reflected in the post-glaciofluvial sedimentary record.

Leaf Rapids Esker:

The Leaf Rapids Esker (Map A, West Half) is approximately 32 km in length and 3000 to 7000 m wide. It comprises an elongate granular ridge, oriented north-south to the north of Turnbull Lake, with one tributary west of the Leaf Rapids townsite. The esker is breached by the Churchill River north of the townsite. North of the river, the esker rises to 335 m. It is straight-sided and linear with a multiple ridge morphology and pitted by elongate kettle holes (illustrated in Figure 4). The ridge sides slope at 25° and rise to 15 m above the adjacent plain. Immediately south of the river, the ridge rises 10 to 12 m above the surrounding terrain. The feature provides the main source of sand and gravel in the area, so much of the original morphology has been destroyed.

In the vicinity of Turnbull Lake the ridge which is composed mainly of sandy material drops in elevation to 290 m. South of Turnbull Lake the esker rises to 308 m, at least 15 m above surrounding swamps. Here the esker is narrower in width and more sinuous in outline.

Towards its southern limit the esker has a multiple ridge form 1500 m in width. Three ridges are readily identified. The central one is characterized by a coarse cobble lag on the esker surface (Plate 2A). At its southern limit the esker reaches a height of 343 m, thereby increasing in altitude 'downstream'.

A tributary of the main esker is located 2 km west of the townsite (Chur. 51). The tributary, rising to 274 m, 8 m above the level of the Churchill River, is composed of coarser granular material and slopes at 27° to the river.

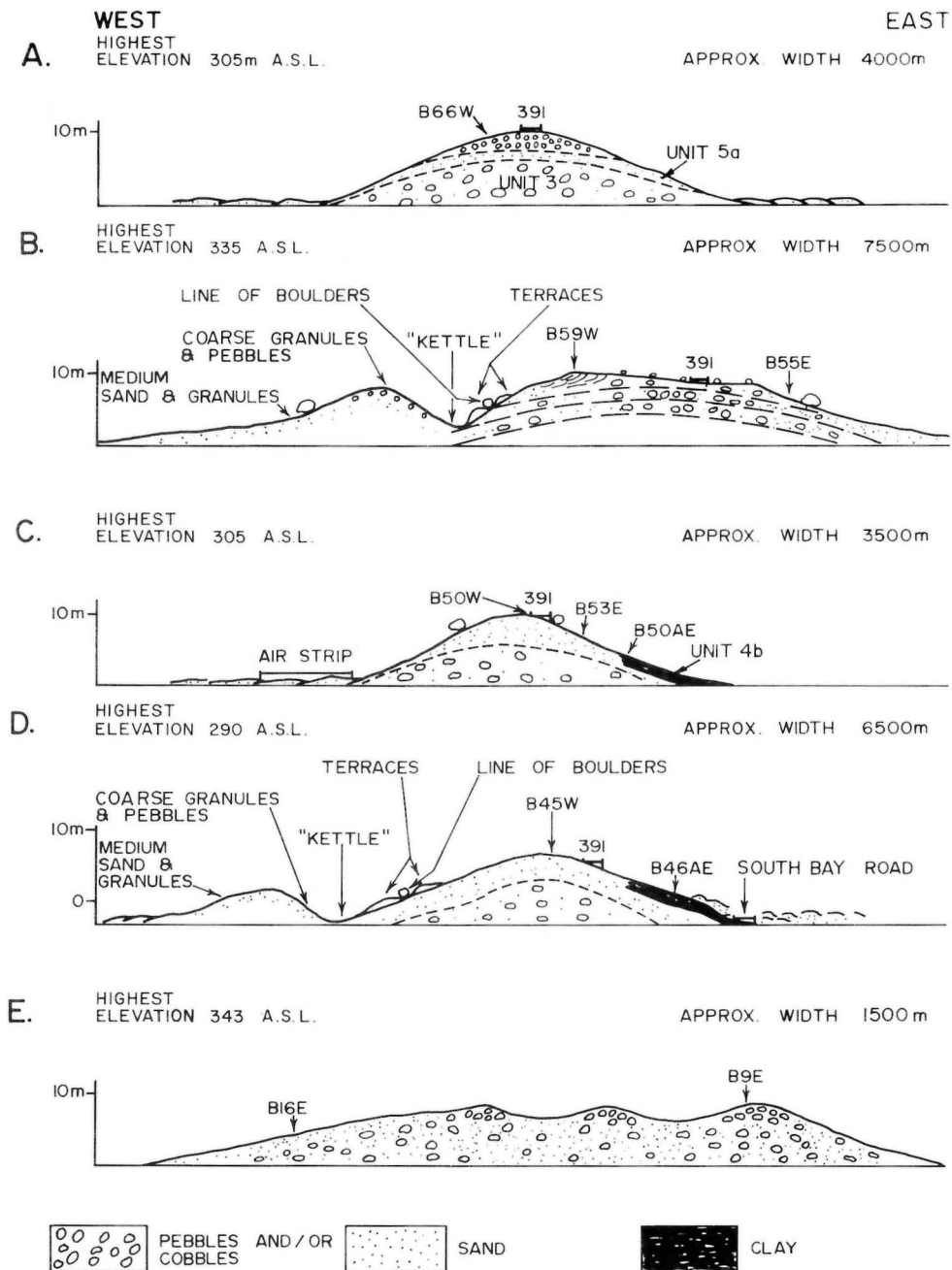


Figure 4: Morphology of Leaf Rapids esker

The sedimentology of the esker is complex as indicated in pit faces throughout the length of the feature. At each pit, (see pit locations, Map B), the stratigraphy is described and relationships between beds noted. Details of the measured sections are listed in Appendix 2.

Glaciofluvial Deposits, Unit 3: Glaciofluvial deposits may be subdivided into three major subfacies: 3a, massive coarse cobble and pebble gravel; 3b, parallel-bedded pebbles and sand; and 3c, coarse to medium cross-bedded sand.

Subfacies 3a consists of cobble and pebble gravel, representing the coarsest portion of the Leaf Rapids esker, as recognized in pits B59W2, B49W, B45W, B17W, B9E and B6W, at intermittent locations throughout the crest of the esker. At B45W2 and Mile 5 the unit is massive, up to 15 m thick and poorly sorted with no internal bedding (Plate 2B).

Faint parallel bedding is apparent in sections at B6W (Plate 3A) and B45W1 (Plate 3B). Although the observed maximum thickness of the beds is 15 m, drill hole records indicate that coarse gravel facies in the vicinity of the Churchill River extended a further 25 m (Underwood, McLellan & Associates, 1969).

The coarse clasts are rounded to subrounded ranging in size from pebbles to boulders, although the cobble size predominates. Most of the clasts are unweathered. In most cases voids are infilled with granules and minor coarse sand. One example of open work cobbles was noted at B45W2. The predominant rock content is pink granite, granodiorite and gneiss with a high proportion of amphibolites (see Appendix 3). There is no evidence of sulphide mineralization.

At B6W (Plate 3A), in 5 m of coarse gravel exposed at the southernmost limit of the esker, weathered schist fragments, carbonate incrustations and the development of iron-oxide agglomerates were noted. These characteristics are deleterious substances known to affect the quality of gravel used in the construction industry.

The coarse gravel facies is observed only at intermittent locations throughout the Leaf River esker. In places the facies is not evident, for example, in the most northerly portion of the esker, immediately north of the Churchill River, south of the townsite and in the Turnbull Lake depression. In places, the apparent absence may be attributable to a lack of suitable exposures.

The rounding of the coarse clastic particles suggests that gravel deposition was associated with rapid meltwater flow from a subglacial tunnel, normal to the ice front. The lack of good bedding is a function of the rapid sedimentation (O'Donnell, 1966). Clastic debris assumed to have been derived from englacial drift, appears to have been deposited in mound-like elongated bodies probably in a subaqueous environment. The margins of the feature were probably banked up against retreating ice. Deposition occurred following a reduction in the competence of the streams and deposition may have taken place in the conduit beyond the ice front, as suggested by the linear portions of the northern half of the esker. As rapidly moving meltwater discharged into standing water, the decelerated flow caused initial deposition of very coarse delta-front or bar-front sediment. This facies may be identified at six locations throughout the length of the esker, mainly in the southern two-thirds. The facies frequency suggests intermittent periods of ice halt, leading to coarse sediment deposition, alternating with periods of ice retreat and erosion or non-deposition of 3a sediment.

Subfacies 3b is a pebble gravel, which consists of pebble to medium sand sizes, in which parallel bedding is developed in longitudinal section and low angle cross-bedding in transverse section. The beds are 16 to 18 m thick and

found particularly well exposed on the eastern margin of the esker. The facies persists along the crest at intermediate locations between and lateral to the coarser beds, subfacies 3a. Horizontally bedded pebbles are recognized at B47W (Plate 4A), B69E, B67W, B50W (airport) and B44E. In a particularly well exposed section (B55E) cross-stratified sand and gravel beds dip eastward at 10° from the esker crest (Plate 4B) becoming more horizontal farther to the east. Within these beds, a series of normal faults has developed (Plate 5A).

Evidence suggests that the kind of sedimentation involved in the deposition of subfacies 3b relates to the retreat of the glacier or to the build-up of delta-front (or downstream gravel bar) sediments since the sand and pebbles were deposited laterally and mainly downstream from the massive central core sediments. The beds are assumed to have been formed as a result of the high sediment content and fluctuating meltwater flow; whereas more distal and finer grained sediments were deposited progressively in the same lateral plane of accretion beyond the ice margin. The cross-bedded units of B55E may represent the foreset structures within a deltaic sequence.

The normal faults of B55E may have resulted from the rapid sedimentation in deep water (12 m deep) at an unstable angle, peripheral to the coarse core at the ice contact. The sediment was later subjected to differential compaction and settlement as the deposits dried out. This, in conjunction with marginal melting along the ice contact slope, may have caused a later extension or lateral redistribution of backed up sediments.

Subfacies 3c is a medium to coarse massive sand (2 to 5 m thick) interbedded with or intercalated between clay beds. A sequence of interbedded clay and sand was observed at one location, B50AE on the eastern margin of the esker. The section comprises coarse massive sand with two discrete silt and clay layers. The silt and clay are internally laminated, suggesting that lacustrine sedimentation was prevalent to a present elevation of 302 m.

A similar sequence of interbedded clay and sand, in the form of a clay wedge, was inferred from drill hole data to the west of the Leaf Rapids townsite* (Figure 5). Clay was intersected both in the vicinity of the townsite (at 290 m) and the western margin of the esker, at 275 m. The nature of associated glaciofluvial sand was not discerned at these locations.

East of the townsite, (Mine Road Cut 1, Map B) subfacies 3c is represented by a 4 m sequence of sand, interbedded with silt on the margin of the esker. Plate 5B shows the relationships of these beds which, from the top comprise:

- 0.5 m silt and clay laminae (differential loading into sand below);
- 1.0 m medium to fine sand, parallel bedding;
- 0.5 m massive silt, with sand inclusions towards the base;
- 2.0 m medium to fine sand in six tubular co-sets.

The sequence is interesting, but difficult to interpret because of the lack of lateral continuity. To the west, the beds are in folded vertical contact with a thick sequence of contorted rhythmites. The slumping of the adjacent beds appears to have caused folding in subfacies 3c beds.

In detail the lower tabular sets vary in thickness from 12 to 24 cm, and wedge out eastwards. The distinct large scale cross-bedding represents subaqueous dune lee-face structures created from bedload material in the lower flow regime within an open channel system (Simons et al., 1965). Good preservation suggests an abundance of sediment being fed into the system, probably in gradually deepening water. Ultimately, the flow was sufficiently reduced to allow deposition of silt from suspension. The upper parallel bedded sand is thought to result from a later stage of greater discharge as

* Drill data — Ripley, Klohn and Leonoff, 1971

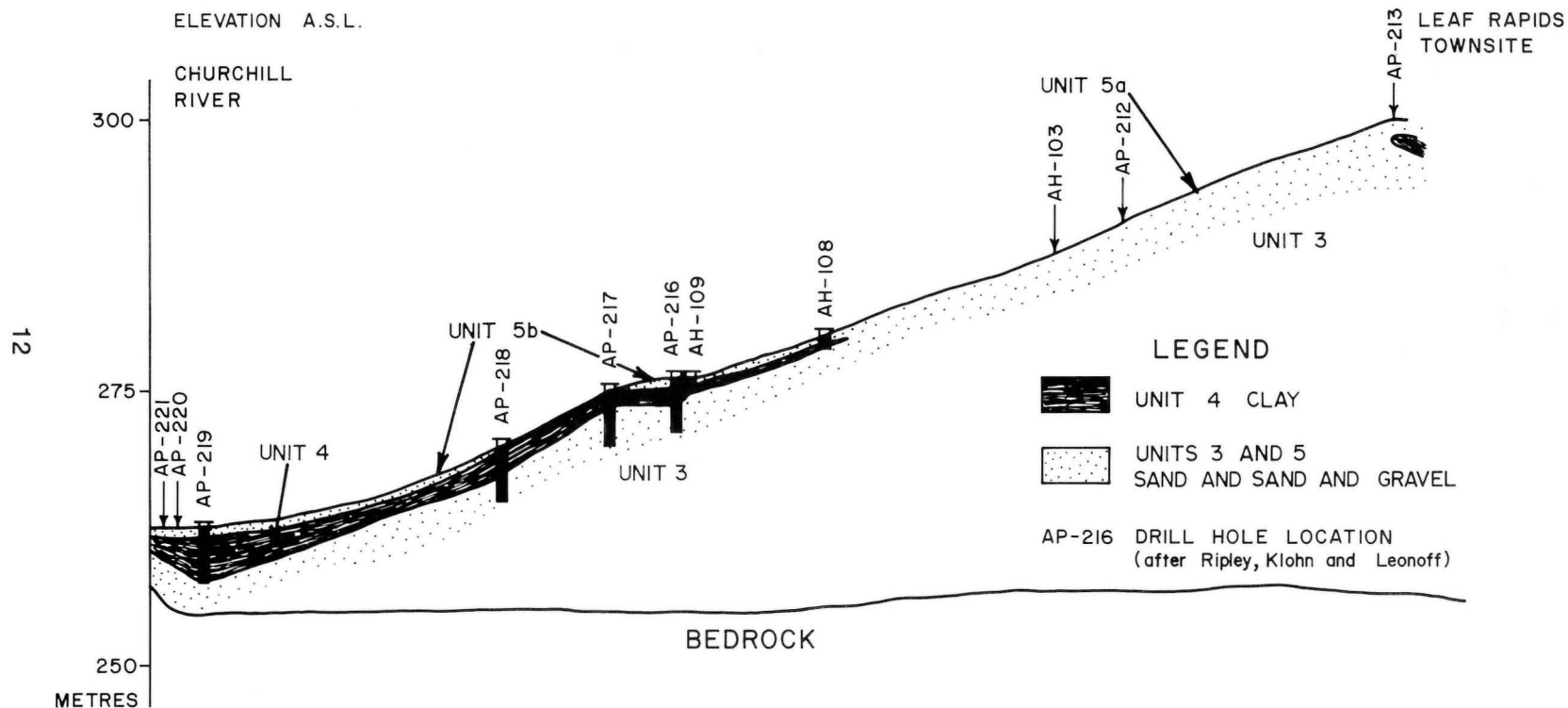


Figure 5: Schematic relations of sand and clay on western margin of Leaf Rapids esker

substantiated by the presence of minor scouring at the top of the silt unit. Current flow is predominantly west to east and therefore at variance with the assumed meltwater flow direction. The beds represent part of the more distal, finer grained sediments, whose preservation is due to development at or near the lake bottom in the distal portion of the gravel bar or delta front as meltwater flow almost entirely ceased.

The entire sequence, from 3a to 3c represents a facies change downstream which takes place over a distance of 1 to 5 km. The sequence is recognized from B59W1 to the river crossing; from south of the crossing to Turnbull Lake; from B17W to 2 km south of B17W; and from B15E to beyond B6W. The sequences are incorporated distinct sedimentological and morphological beads, deposited to different elevations but under similar conditions at successive locations as the ice retreated from the area (see Banerjee and McDonald, 1975). This mechanism also accommodates the increase in altitude southward through the length of the esker.

Glaciolacustrine Deposits, Units 4b and 4c. Glaciolacustrine sediments comprising mainly silt and clay were deposited in varve-like couplets at intermittent locations along the esker crest and margins. Sequences are particularly thick and cover the esker to the immediate north of Turnbull Lake (288 m) and towards the northern limit of the Lead Rapids townsite (284 m). There is an absence of silt and clay on the esker crest north of the Churchill River. Units 4b and 4c clays are laterally continuous with and similar in character to 4a clay which is described in an earlier section of this report. Unit 4c clay overlies esker marginal sand and 4b clay overlies esker crest sand and gravel.

Adjacent to the Leaf Rapids esker, two subfacies of 4b clays are recognized, subfacies 4b(i): parallel bedded clay and silt units, and subfacies 4b(ii): convoluted clay and silt units.

To the north of Turnbull Lake silt and boulders were observed capping glaciofluvial gravel. The silt was traced eastwards and westwards to the esker margins. The massive silt and associated clasts form the basal unit of subfacies 4b(i). In a roadside ditch section due east of B29W, the silt beds (Plate 6A) were examined in greater detail. Silt comprises massive undivided beds which grade upwards into varve-like couplets of silt and clay towards the top of the section.

Individual silt beds at the base of the section are (5Y 5/3 moist) olive in colour and greater than 20 cm thick, highly calcareous, generally massive but with faint parallel laminations accentuated by white calcareous partings. Infrequent clasts in the section are highly weathered and encircled by secondary iron-oxidation haloes. Towards the centre of the section the silt and clay laminae are of equal thickness (0.5 cm). At the top of the section, the sequence terminates into 1 m massive brown plastic clay.

Silt deposits accumulated following the cessation of rapid meltwater deposition as the ice was retreating from the immediate vicinity. The fact that silt and relatively coarser clasts (proximal varves) occur towards the base of the section grading upwards into finer laminated silt and clay (distal varves) is highly indicative of gradual ice retreat from the depositional basin. The silt and clasts were deposited mainly from suspended sediment, originating as meltwater flowed from the ice front.

The calcareous nature of the silt deposits may be genetically associated with the calcareous nature of the englacial drift. In the Notigi section, the unweathered till is highly calcareous. It should be noted that the coarse massive gravel is generally non-calcareous although there is evidence of dissolved carbonates in the form of pebble incrustations. Carbonate ions are

assumed to have entered the lake water in solution and later precipitated out during the silt depositional interval, giving rise to white partings particularly noticeable in the lower silt unit of the Turnbull ditch section. Detrital carbonate is likely present in the silt size fraction. The absence of free carbonate in the clay units is suggestive of reduced carbonate-saturated conditions in the lake waters. This leads one to suspect the clay laminae were deposited during a time of low sediment yield associated with fall or winter (low saturation, probably frozen) lake water conditions (agreeing with the work of Sutton, Lewis and Woodrow, 1974). Conversely, the presence of carbonates in the silt unit is indicative of high spring-summer meltwater flow and carbonate-saturated lake waters. It, therefore, appears likely that the main mechanism of silt and clay deposition was direct suspension controlled by seasonal meltwater flow.

Subfacies 4b(ii) comprise silt and clay laminae deposited in varve-like couplets, essentially as subfacies 4b(i) deposits but these were later modified by slope flow mechanisms. Contorted silt and clay laminae were examined at two locations on the eastern margin of the Leaf Rapids esker where the esker is morphologically lower in elevation (285 m). This allowed the encroachment of otherwise deeper water lake clay onto the esker margins.

Contorted varve-like couplets consisting of equidimensional silt and clay laminae were examined at pit location B46E (Plate 6B). The silt and clay couplets directly overlie Unit 3b pebbles and sand, and at the contact, sand and gravel has been washed into the overlying clay. The central portion of the section consists of 30 cm parallel bedded silt and clay, with minor folds and few interbedded clasts. More strongly folded couplets with few overturned folds are evident towards the top of the section.

Extremely contorted varve-like couplets, which consist of thick clay units and relatively thin silt units, were examined in the Mine Road section. The section is 3 m thick, and in vertical contact (laterally) with 3c sand, described above. The section consists of compounded overturned and recumbent folds.

A direct relationship may be inferred between degree of folding and depth of sediment. In the 3 m thick Mine Road section greater potential for complex folding exists, compared to the minor folding in the 60 cm, B46E section. However, the mechanism inducing movement was probably the same in both cases. Sediment deformation in these sections is assumed to have resulted from lateral gravitational plastic flow induced downslope during compaction and dewatering of the sediments. As dewatering takes place beyond a critical limit, shear stress forces in the weakened sediment cause downslope flow (Harms and Fahnestock, 1965). The turbidity flow hypothesis equally cannot be disregarded. Active turbidity flows have been examined in proglacial Malaspina Lake by Gustavson (1975, p. 28). The density currents obtain velocities sufficient to cause deformation of hydro-plastic bottom sediments, such as those occurring on the Leaf Rapids esker.

Shoreline Deposits, Units 5a and 5b: Shoreline deposits are present along the margins of the Leaf Rapids esker. Shoreline deposits have been recognized as being developed towards the crest of the esker, and extend up to 1600 m beyond the esker margin. Three subfacies are recognized: the first consisting of clastic storm beach and lag deposits; the second (Unit 5a), parallel bedded sand; and the third (Unit 5b), organic-rich silty sand.

Coarse cobbles and pebbles in a silty-sand matrix occur as discrete linear beds towards the crest of the esker. These beds were not mapped as a separate unit. Some indication of the subfacies was intended by the use of a dashed line symbol indicating shoreline deposits on Map A.

Lag gravel was examined at pit locations B69E (305 m) and B47W (274 m),

also noted at B64W (305 m), B61E (297 m), B55E (297 m), B53E (297 m) and B9E (305 m). Cobble-pebble associations overlying parallel bedded sand are typically exposed at these pit locations. At B69E two metres of pebbles and cobbles overlying parallel bedded sand (subfacies 3c) were examined. The cobble-pebble constituents are 1.5 m deep and composed of unsorted rounded clasts in a silty-sand and sand matrix. A similar bed was found at the top of a measured section at B47W, in which 0.3 m granular material overlies subfacies 3c sand (Plate 7A). At B53E, a coarse cobble lag deposit is associated with large boulders. This relationship is common in the area. Portions of the esker which appear at first sight to consist of thicknesses of gravel, in fact, consist of up to 3.0 m of coarse granular material overlying parallel bedded sand.

At B59W, on the crest of the esker, a shoreline sequence was examined. Beds are defined by alternating granule to pebble sub-units which grade upwards to coarse and medium sand (Plate 7B). Coarse broken pebbles are evident in the gravel beds. At least four graded cycles are evident which dip at 3° and 5° westward off the esker crest.

The graded beds overlie coarse glaciofluvial deposits (Unit 3b), which were examined at the base of the section. The shoreline facies differ from the glaciofluvial facies in the following respects: foreshore deposits show westward low angle cross-stratification; glaciofluvial sediments are horizontally bedded; foreshore sediments are highly oxidized, orange in colour with abraded and weathered clasts; glaciofluvial sediments are un-oxidized, grey in colour and the pebbles are rounded and more sound.

Shoreline sand (Unit 5, Map A) occupies a broad zone as much as 1600 m wide on the eastern and western margins of the Leaf Rapids esker. The sand wedges out towards the esker crest, masks the esker side at 30° to 40° and thickens towards the base of the esker, generally in the form of a series of minor terraces. The sand is bedded in coarse to fine laminae with coarser sand, associated with a lag pebble laminae concentrated on the steps of the terraces. The sand is non-calcareous yellowish-brown in colour (10YR 5/4, moist) being particularly stained towards the surface due to secondary iron-oxide migration.

Boulders are associated with the shoreline sand, generally concentrated in linear zones above the terrace levels. Care should be exercised during excavation of this zone since partially buried boulders may be intercepted by earth moving equipment.

A well developed wedge of shoreline sand is exposed on the north wall of pit B49W where 5a sand directly overlies subsurface 3a gravel. The contact is erosional in nature. Shoreline mechanisms have eroded a notch in the gravel to the left of the scale in Plate 8A. Reworked, and re-deposited glaciofluvial sediment initially resulted in the deposition of a 2 cm heavy mineral* bed at the contact, overlain by parallel coarse sand and pebbles. Later accretion deposited coarse foreshore sand, 20 cm thick. These deposits are gently dipping (1° to 5° lakeward) medium to fine shoreline sand. The elevation of the contact is 335 m.

The Unit 5a sand merges laterally, both eastwards and westwards, with Unit 5b sand.

Unit 5b deposits are composed of fine sand and silt, 0.2 to 2.0 m thick, which generally have a high organic content. Towards the 5a contact is a higher proportion of intercalated medium sand and granules. The 5b sand is poorly sorted, highly micaceous, frequently mottled and is characterized by dark carbonaceous streaks. This generally occurs beyond the morphological

* See Appendix 9 for per cent heavy minerals

limits of the esker, merging out laterally over lacustrine clay.

The entire shoreline sequence consists of pebble subfacies, 5a medium sand and 5b fine sand. The uppermost storm beach and lag deposits are associated with initially high lake levels, as suggested by features along the esker crest. Simultaneously, finer material from the crest was washed lakeward and subsequently deposited as coarser foreshore sand (Unit 5a), and finer offshore sand (Unit 5b). The activity of waves during sand deposition formed a series of ridges and runnels resembling terraces on the esker margins (Figure 6).

Ultimately, the lake level dropped from 335 m, its highest known elevation. There is evidence of two or three lower levels in lag gravel at 305 m and 297 m. Lower shoreface sands, with a terrace morphology, occur at elevations around 290 m on the eastern margins of the esker.

No fossil evidence was found to enable the lake levels, or existence of the lake, to be accurately dated or verified. The history of the assumed lake, referred to as glacial Lake Churchill, is incorporated into the glacial history section towards the end of this report.

Eolian Deposits. Unit 6: Fine parallel laminated sand in longitudinal and crescentic dune-like forms was found on the Leaf Rapids esker crest and margins. These features are mapped as Unit 6 on Map A where the sand has an appreciable lateral extent; otherwise, they are indicated by dune symbols.

Exposures of esker sand were examined in a dune face, close to Leaf Rapids at the location 391, Townsite A (Map B). The dune is 8 to 10 m high. The upper 2 m were examined (Plate 8B). The section consists of graded medium to fine sand in horizontal laminae 0.5 to 2 cm thick. Darker horizons occurring intermittently through the section have a high concentration of heavy minerals. The dune beds are superimposed on Unit 5a and 5b foreshore and offshore sands.

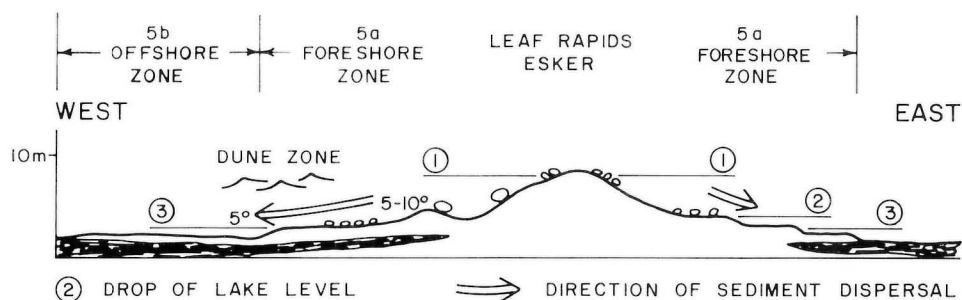


Figure 6: Reworked shoreline sediment-Leaf Rapids esker

The available wind blown sand was probably derived from shoreline sand which became dessicated and later selectively entrained as the wind blew along the exposed esker margins. Sand dune accumulation may represent a much later stage in the evolution of the Leaf Rapids feature, most likely following the glacial lake interval and preceding establishment of vegetation.

Grass Lake Esker:

The Grass Lake Esker (Map A, East Half) is the second largest glaciofluvial feature in the LGD of Leaf Rapids. The esker morphologically consists of two beads: a thin narrow northeastern bead, 11 km long and 0.5 km wide and a wider (up to 3000 m) southwestern bead, 21 km long. The feature comprises a central core of sand and gravel, overlapped by silt and clay and wave-washed sand. Between the two beads is an extensive sand plain area. In the northern portion of the esker elevations range from 274 m in the northeast to 267 m in the centre and rise to 275 m in the south. The bead stands 7 m above the surrounding terrain. The southern portion of the esker ranges in elevation from 281 m to 320 m and stands an average 10 m above the surrounding terrain (Figure 7).

The northern portion of the esker is essentially a single, linear, steep-sided ridge with modified morphology due to the South Bay Road having been constructed on its crest. The morphology of the southern portion of the esker changes from a multiple ridge and kettle form towards the north of the bead merging to a single ridge towards the south. The ridge is unevenly crested and steep-sided at about 25°.

The sediment content of the esker was discerned from pit exposures, and from hand dug pits and auger holes in the remote portion of the esker (Map B). Details of measured sections are listed in Appendix 2.

Glaciofluvial Deposits, Unit 3: Glaciofluvial deposits in the Grass Lake esker are subdivided into two subfacies: 3a, consisting of massive coarse cobble and pebble gravel (essentially the equivalent of 3a and 3b in the Leaf Rapids Esker); and 3c, coarse to medium sand.

Subfacies 3a consists of coarse cobble and pebble gravel, representing the coarsest portion of the Grass Lake esker, as recognized in pits B65AN, B65S, location 66-67 north and from drill hole records* in the northernmost esker bead, and at the locality Esker Lake H in the southernmost bead.

At B65AN the unit is massive, up to 8 m thick and comprised of poorly sorted cobbles and pebbles in a matrix of medium to coarse sand (Plate 9A). The clasts are rounded to subrounded, with granite and granodiorite types predominating (see Appendix 3). The overall unit is predominantly massive, with some imbrication of discoidal clasts throughout the section indicating flow from the north-northeast. There is no evidence of deleterious substances in the coarse clasts at this section.

At B65S the esker rises to the south of the South Bay Road to a height of 15 m to 20 m (see Plate 9B). The lower portion of this section is composed of very coarse pebbles which grade upwards into parallel bedded finer pebbles and granules, and finally into subfacies 3c sand.

At location 66-67 north, massive pebble gravel of the 3a subfacies underlies medium to fine sand and silt (see Plate 10A). The gravel consists of well rounded pebble size clasts, of predominant granite-granodiorite rock types, 4% schists and one clast showing garnet porphyroblasts. Finer pebbles are limestone-dolomite. Most of the clasts are unweathered with the exception of the schist fragments. Some of the larger clasts have accreted calcium carbonate incrustations.

In the southernmost bead subfacies 3a gravel was examined at two locations. At Esker Lake H the uppermost surface of at least 10 m of gravel was examined. The deposit appeared to consist of unsorted pebbles, granules and cobbles, similar to those exposed at B65AN.

Finer pebbles and very coarse sand, similar to that exposed at B65S, were

* At UTM Northing 6267650 Easting 971870, 2.4 m to 4.6 m clay over 3.0 m gravel

examined at locality Esker Lake F. At Esker Lake F cross-bedded very coarse sand and pebbles are overlain by medium to fine sand. It is not known whether the current-bedded gravel at this location grades downwards into coarser massive gravel.

The lack of good continuous exposure throughout the Grass Lake esker hinders the full identification of subfacies. Coarse units are present, and appear to represent broadly similar subfacies types to those identified in the Leaf Rapids esker. The degree of rounding, imbrication, and cross-bedding suggests that the association of subfacies may have resulted from similar depositional sub-environments as the Leaf Rapids esker.

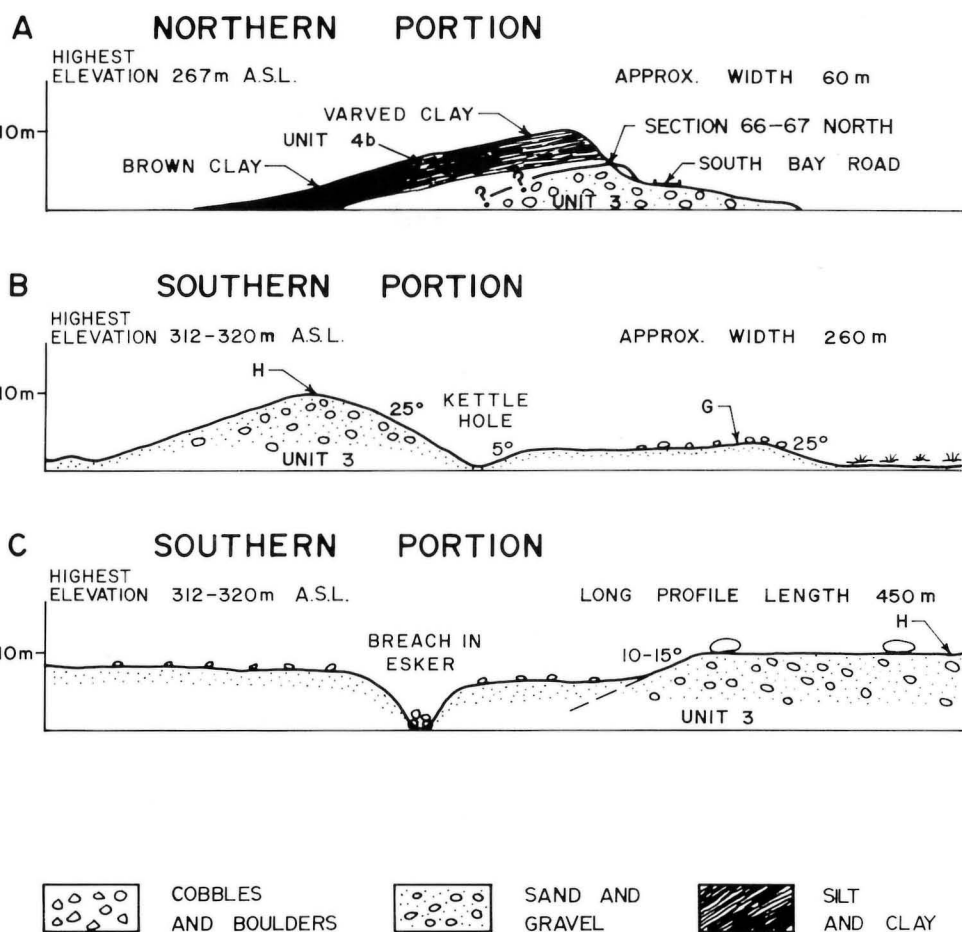


Figure 7: Morphology of Grass Lake esker

The Grass Lake esker is essentially linear therefore deposition may have taken place at the mouth of a conduit as meltwaters emerged from successive ice front positions at locality F, and later at B65AN, and even later at the roadside location between B66S and B67N. It is assumed that rapidly moving meltwater discharged into a standing water environment. Paleocurrent indicators suggest that this flow was from northeast to southwest. The lack of good bedding suggests at least initial rapid sedimentation, as a delta front or gravel bar front. As the ice front retreated more hydraulic sorting appears to have taken place as the coarse gravel grades upwards into finer cross-bedded gravel and later into current bedded sand. The equivalent upward grading of clasts was not apparent in the Leaf Rapids esker.

At a number of locations in the Grass Lake esker, subfacies 3a gravel and sand are associated with subfacies 3c sand. Subfacies 3c comprises medium to coarse, sometimes graded or cross-bedded sand. On the crest of the esker these beds are underlain by coarse esker gravels and overlain by silt and clay. On the margins of the esker such sand is inter-bedded with silt.

In the northern bead sand overlying esker gravel was examined at locations B65S (Plate 10B) and 66-67 south. The sand is graded coarse to fine upwards throughout the section. There is evidence of medium scale cross-stratification. At B65S this changes upwards into parallel laminae in which coarse heavy mineral horizons are evident.

A small horizon 20 cm in thickness of subfacies 3c sand was examined at location 66-67 north (see Plate 11A). Unsorted esker gravel is capped by coarse pebbles, which protrude into the overlying sand. The sand itself is medium to fine grained, initially plane bedded, then distinctly ripple bedded with stoss and lee-side preservation. The ripples which have a wavelength of 25 — 30 cm are preserved by an overlying clay drape. The current flow is parallel to the assumed direction of flow for the esker, that is, from the northeast.

At location B63S subfacies 3c sand is interbedded with silt lenses as illustrated by Figure 8. Initial deposition comprised massive sand above which the sand contains elongate silt lenses. Conditions changed as cross-bedded sand was deposited above the sand and silt lenses, and changed again as massive silt was deposited towards the top of the section. Similar cross-bedded sand associated with silt was examined to the north of pit B63S on the east side of the road. The ripple-drift laminated sand is 1.10 m thick, underlain and capped by massive silt (Plate 11B). Plate 12A illustrates the lowest ripples which show preservation of bottomset beds, extending laterally into the lee foresets (right of knife) with predominant stoss-side erosion. The upper portion of the bed represents a transition between ripple and dune bedforms as indicated by the increase in wave height. The paleocurrent indicators from this section and from B63S are at variance with the northeast-southwest "esker" flow. In the vicinity of B63S, flow diverges to southwest and east-northwest at the southern edge of the northern esker bead (Figure 8).

The 3c facies was observed at only two locations in the southern bead of the esker. Primary sedimentary structures are not well developed at either location. At Esker Lake F, 60 cm of massive medium to fine sand grades upward from 3a gravel, and at Esker Lake G, 60 cm of medium sand grades upward from glaciofluvial pebbles.

Subfacies 3c sand is better developed in the Grass Lake esker than the Leaf Rapids esker. It is deposited above and downstream from coarse 3a glaciofluvial gravel, and shows distinctive subaqueous current structures. It is assumed that the current bedding represents dune and ripple bedforms built up during the lower flow regime of an open channel system. The preservation of bedforms indicates that abundant sand was being fed into the system for a relatively long time period following the subaqueous build-up of coarse debris

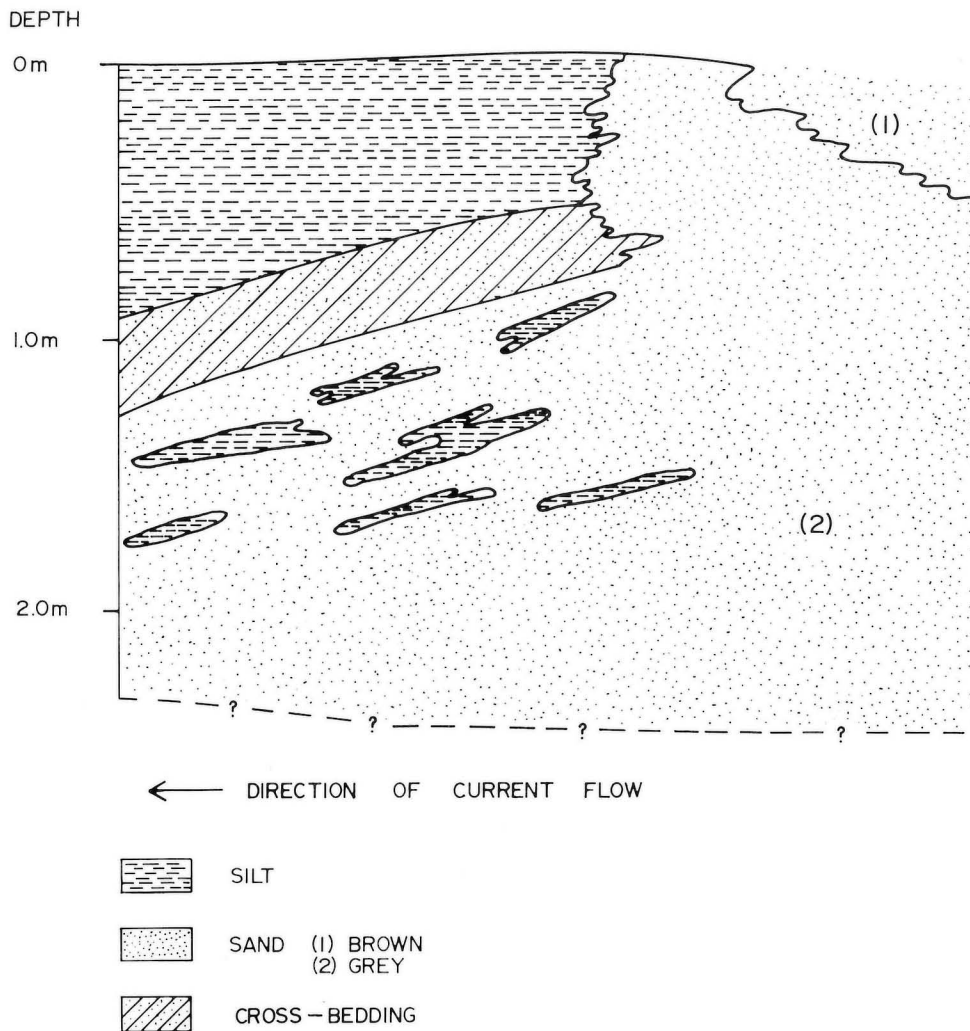


Figure 8: Sand-silt contact at B63S

as delta fronts and gravel bars, represented by 3a subfacies, at the ice front-lake contact. Finer sediment was deposited on top of the coarse base as the ice melted from the immediate area. On the crest of the esker the flow patterns are essentially aligned with current bedding in underlying glaciofluvial gravel. On the southern limit of the northern bead flow was deflected around pre-existing deposits as the water sediment system approached the lake bottom. The sand represents a transition to more distal glaciofluvial sediments as it merges laterally into silt.

Lake levels at the time of gravel bar or sand unit deposition can be inferred from the uppermost gravel or sand unit. At location 66-67 north, the prevalent lake level during clastic deposition is about 262 m; the equivalent altitude in the vicinity of B65S is 264 m and at Esker Lake H is 320 m. As the ice melted from

the vicinity of the Grass Lake esker, the lower ice-contact lake levels were later surpassed when the waters deepened, inducing the deposition of Unit 4b and 4c silt and clay over glaciofluvial gravel bars and associated sand.

Glaciolacustrine Deposits, Units 4b and 4c: Glaciofluvial sediments consisting mainly of silt, with some interbedded clay, were deposited predominantly along the margins and crest of the northern Grass Lake esker bead, and on the margins and intermittently on the crest of the southern esker bead. Thick silt and clay cover the northern bead to 290 m, and overlie the southern bead to 297 m.

Units 4b and 4c silt and clay are laterally continuous therefore synchronous with 4a clay, described in an earlier section of this report.

The silt was examined in detail at B63S and to the north of B63S where massive silt is interbedded with glaciofluvial (3c) sand. The silt is generally light grey in colour 5Y 7/2 (dry) and highly calcareous, whereas the clay is 2.5Y 4/2 dark greyish-brown and very weakly calcareous.

Two examined sections indicate the later gradual deepening of lake-water environments with the retreat of ice from the immediate area. One section, to the south of pit B65S was examined in massive silt roadside bluffs, in which horizontally laminated and ripple drift cross-stratified sand is overlain directly by massive grey silt (see Plate 12B).

A second section was examined at 66-67 north, a massive silt road cut, standing 10 to 12 m above the South Bay Road. At the contact, ripple drift cross-stratified sand fines upwards into ripple drift silt, which is overlain by sand, silt and clay laminae (see Plate 13A). In the lower portion of the measured section (see Figure 9), below 1.75 metres, sand is interbedded between silt and clay laminae. Above 1.75 m, clay and silt are interbedded in varve-like couplets, although the silt beds are considerably thicker (to 5 cm) than the clay beds (1 to 2 cm).

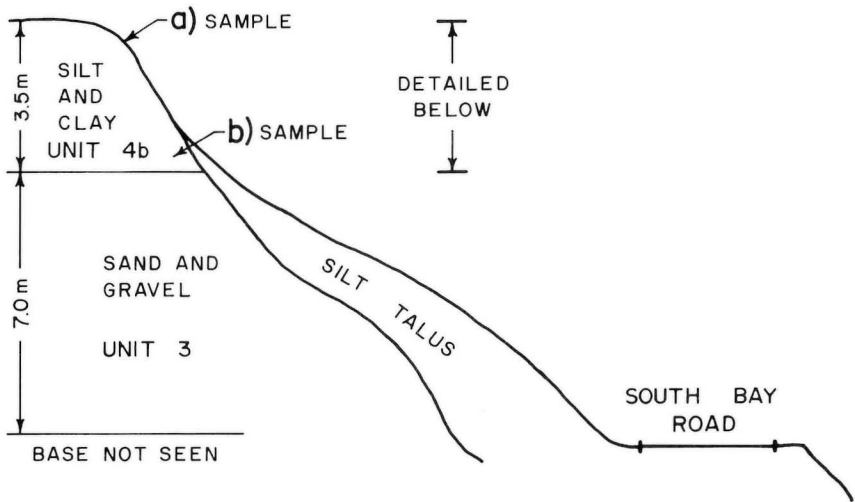
The Unit 4b and 4c silt, with interbedded sand and clay, was deposited as meltwater and sediments were discharged into an enlarged proglacial lake, as the ice continued to retreat from the immediate vicinity. The change from sand interbedded with silt, to clay interbedded with silt is indicative of this process. The silt and clay are assumed to have been deposited directly from suspension as seasonal rhythmites; the presence of graded bedding might indicate the occurrence of turbidity flow associated with inclined margins of gravel bars or delta fronts. The highly calcareous silt, and the calcareous nature of clastic glaciofluvial sediments in the Grass Lake esker towards the base of the section, and the calcareous nature of the Notigi till may well reflect a similar parent drift origin for all three sediment types. This is in contrast with the non-calcareous nature of the Leaf Rapids glaciofluvial deposits.

Shoreline Deposits, Units 5a and 5b: Shoreline deposits are present to a limited extent on the margins of the northern bead of the Grass Lake esker where their development is normally precluded by thick silt and clay beds overlying source glaciofluvial sand. On the margins of the higher southern bead extensive sand has accumulated a 3 km beyond the eastern, western and southern margins of the esker.

Marginal to the southern bead, essentially one subfacies was examined and mapped as the equivalent of Unit 5c on the Leaf Rapids esker and examined in detail at locations marked Esker Lake A and E on Map B.

The shoreline sand consists of horizontally bedded or massive medium to fine sand with terrace and runnel morphology. Alternatively, the sand occupies hollows between bedrock ridges. The sand is very micaceous, often with distinct heavy mineral laminae. It is generally highly oxidized, non-calcareous and yellowish-brown in colour. A lag horizon and angular pebbles up to 5 mm

A VERTICAL SKETCH OF ROADCUT



B DETAILS OF SILT AND CLAY

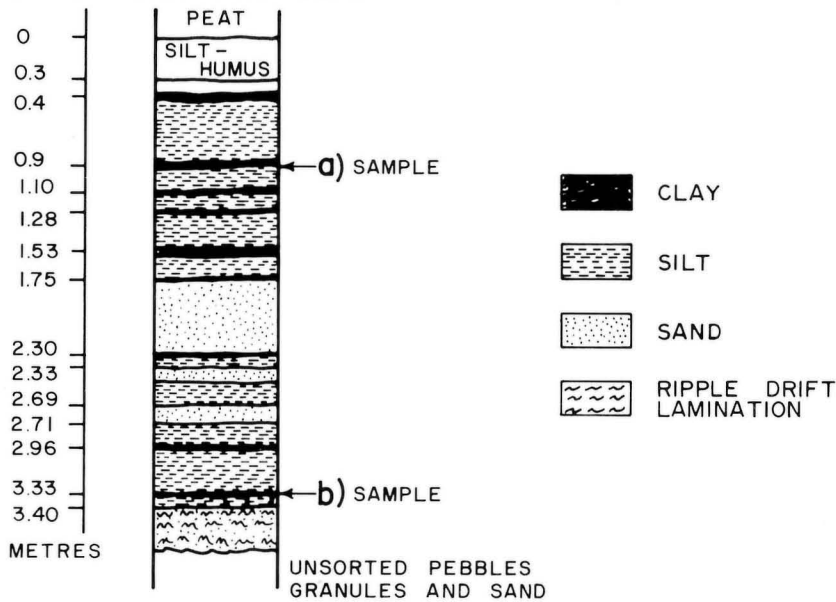


Figure 9: Grass Lake esker, northern bead
Location 66-67 north

in diameter frequently occur above the sand at the ground surface. The predominant clast type is granodiorite, aplite and basalt. The sand is noted to overlie directly Unit 4a clay in the area.

Shoreline subfacies 5b deposits occur to a limited extent on the northwestern margins of the esker, and extensively in a large sand plain between the Grass Lake and Penguin Lake eskers. The 5b sand was examined at location D, where 2.0 m of fine sand is horizontally bedded, with distinct heavy mineral laminations. Some surface clasts are present at this location.

The 5a and 5b shoreline facies were deposited during the later lowering of lake water levels following the deep water silt phase, described above. During the 4b silt phase the northern bead was completely submerged by lake water and the margins of the higher southern bead were washed by wave activity. The wave washing caused the selective removal of medium to fine glaciofluvial sand from the crest and margins of the esker, leaving essentially lag cobbles exposed as at location B. The sand was washed into and dispersed in gradually deeper water extending lakeward from the esker margins in a manner analogous to that described for the Leaf Rapids esker (see Figure 6). As the lake level dropped successively to the base of the esker, a series of strandlines or submerged bar ridges formed, giving the esker margin its ridge and runnel morphology.

Penguin Lake Esker:

The Penguin Lake Esker (Map A, East Half), is the larger of two minor eskers in the LGD of Leaf Rapids. The esker is 7 km in length, narrow and uneven crested, with single ridges broken into three segments or beads by transverse creeks. The elevation of the esker ranges from 282 m in the north, 274 m in the centre to 290 m in the south. The esker stands up to 12 m above the surrounding terrain and has steep narrow slopes of 25° (Figure 10).

The sediment content of the esker was examined entirely from hand dug pits as access to the feature is limited. Detailed logs from measured sections are listed in Appendix 2.

Glaciofluvial Deposits, Unit 3: Glaciofluvial deposits were examined along the crest of the esker and may be subdivided into 3a gravel and 3c sand, essentially the equivalents of glaciofluvial deposits in the nearby Grass Lake esker.

Subfacies 3a, coarse cobble and pebble gravel, representing the coarsest portion of the Penguin Lake esker was identified at location F, towards the northern limit of the esker. Coarse cobbles and pebbles in a matrix of sand characterized the sediment content of this portion of the esker. The cobbles and pebbles are rounded to subrounded, comprising predominantly granodiorite to granite lithologies with some hornblende schist. Many of the clasts were severely weathered, as a result of near surface exposure. The finer pebbles and sand are strongly calcareous.

The subfacies represents a further example of coarse core sedimentation resulting from subaqueous meltwater deposition at the ice front-lake water contact. Since the esker is linear, coarse clastic deposition may have accumulated up-ice from the mouth of the conduit, as well as downstream in a deltaic or gravel bar form.

Subfacies 3a gravel grades downstream into subfacies 3c sand. The 3c sand shows characteristic interbedding of sand and silt similar to that recognized in the Grass Lake esker at location B. In a 2 m opened section, 60 cm of massive silt was observed interbedded with cross-bedded sand (see Plate 13B).

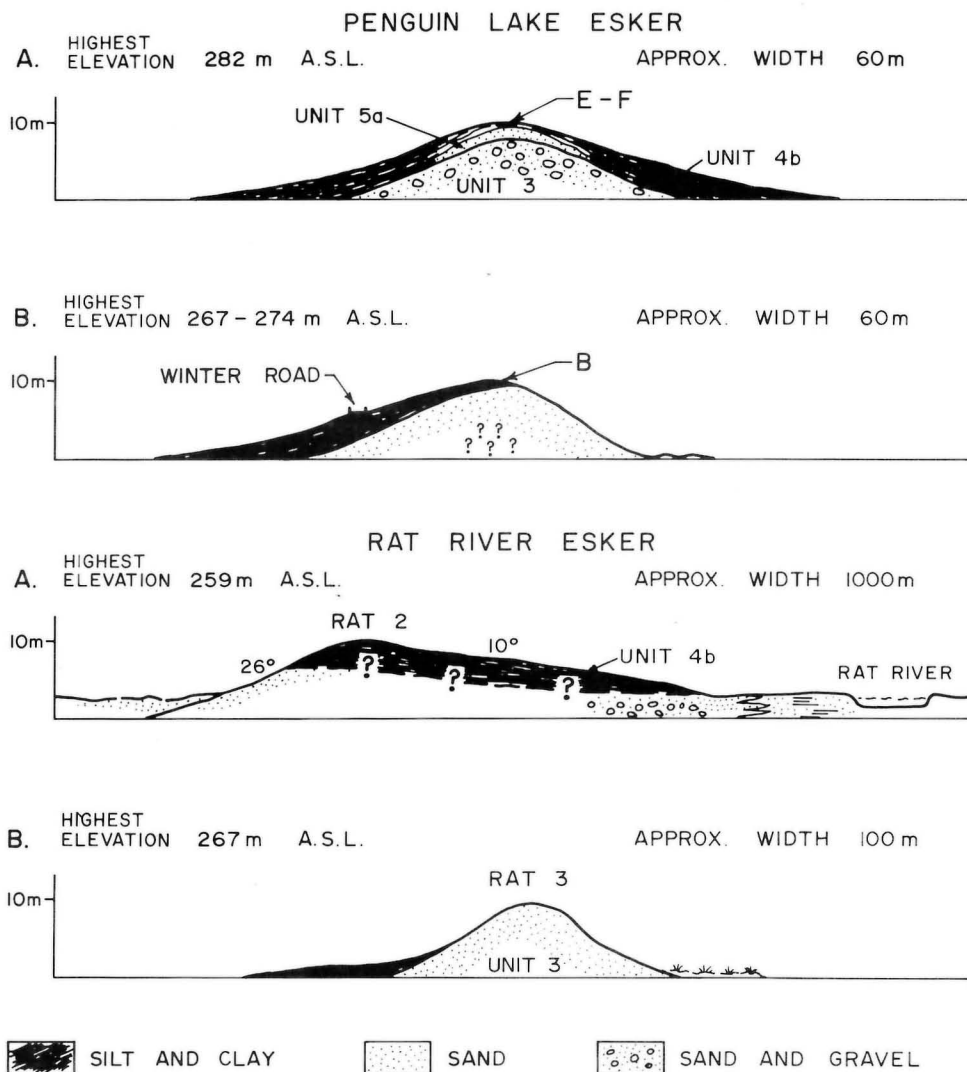


Figure 10: Morphology of Penguin Lake and Rat River eskers

The lower sand shows small scale cross-stratification in truncated sets. The paleocurrent flow direction appears to be from east to west. The lower sand is overlain directly by silt which shows very faint bedding. The silt has become moulded around the hemispherical esker crest with minor faulting on the western margin of the esker (see Plate 14A).

Directly above the faulted contact, the upper cross-bedded sand forms well developed ripple drift cross-lamination in at least three truncated co-sets. The current flow in these beds is from west to east, normal to the northeast-southwest assumed direction of esker flow.

The characteristics of subfacies 3c beds are similar to those recognized elsewhere in the study area. These beds appear to have been deposited at a later stage and downstream from 3a gravel (at location F). Progressive ice front

retreat is invoked to cause the general deposition of finer, more distal sediments into an essentially subaqueous environment. The preservation of ripple drift cross-lamination, and silt interbeds suggests submerged lake margin conditions with abundant sediment supply feeding into the system.

Glaciolacustrine Deposits, Units 4b and 4c: Units 4b and 4c silt and clay mask most of the esker margins, particularly on the western slope as indicated by Figure 10. The Penguin Lake esker was covered by silt and clay almost throughout its length. Lake water therefore submerged the esker to at least 282 m.

Shoreline Deposits, Unit 5a: Unit 5a sand is prevalent on the exposed northern and southern margins of the esker. Some terrace morphology was noted. The extent of the deposit is indicated on Map A.

Rat River Esker:

The Rat River Esker (Map A, East Half) is the smallest esker in the study area. It is 7 km long, 10 m wide, with steep slopes averaging between 24° and 26°. The ridge is sharp-crested and modified infrequently by small kettles. The esker rises 3 to 9 m above surrounding terrain, forming a prominent ridge to the south of the Rat River (Figure 10).

Observation of the feature was limited to travel down river. The sediment content is described from hand dug pits mainly into the crest of the feature. Detailed logs from measured sections are listed in Appendix 2.

Glaciofluvial Deposits, Unit 3: Glaciofluvial deposits were examined at the base of and along the crest of the esker and subdivided into 3a gravel and 3c sand.

Subfacies 3a, coarse cobble and pebble gravel, and the coarsest beds exposed along the Rat River esker, was examined where the esker forms a peninsula into Karsakuwigamak Lake. Along the shoreline coarse rounded cobbles and pebbles, 10 to 50 cm in diameter, were exposed (Plate 14B). The predominant lithologies present are granodiorite, biotite gneiss, apatite and quartz-monzonite. Some evidence of pyrite mineralization is present in the pebbles.

The subfacies were also encountered in drill holes on the esker margin. Cancelled assessment logs through the deposit note between 9.0 and 24.0 m of sand and 'boulders' capped by 8.0 m clay (C-3, Map A).

The location of the subfacies at the base of the section suggests early rapid sedimentation of coarse clasts possibly in a subaqueous environment at the lake water-ice contact. As the esker is linear and steep-sided, it is assumed that clastic deposition continued up-ice from the mouth of the conduit.

Subfacies 3a gravel, at location Rat 2, farther inland, grades upwards into massive medium to fine sand, with minor gravel beds. At location Rat 3, towards the crest of the esker, parallel bedded coarse sand predominates, with a surface layer of subrounded pebbles and granules. At this location, granodiorite pebbles predominate. Also present are amphibolites which contain disseminated pyrite.

Subfacies 3c beds in the Rat River esker appear to have been deposited after coarse 3a cobbles, that is, when hydraulic flow conditions in the immediate vicinity had become relatively tranquil. Such a sequence is in keeping with the theory of progressive ice-front retreat, in this case, eastwards away from the immediate area. Finer more distal sediments were deposited at a greater distance from the ice front and over pre-existing coarse delta front and gravel bar sediments.

Glaciofluvial Deposits, Units 4b and 4c: Units 4b and 4c silt and clay mask the western portion of the esker and are deposited over the esker flanks as indicated in Figure 10. The upper limit of the silt and clay is at 276 m. The esker was, therefore, submerged to at least 276 m, during the deepest water, lacustrine interval.

Shoreline Deposits, Unit 5a: Unit 5 sand is predominant on the exposed margins of the esker, particularly to the south and on the extreme eastern margin. Some ridge and runnel morphology was noted. The extent of the deposit is indicated on Map A.

The eskers, therefore, may be described in terms of four major sediment types: glaciofluvial, lacustrine, shoreline (littoral) and eolian, representing different sedimentological facies in a time transgressive sequence.

SUMMARY OF GLACIAL HISTORY

As indicated in the Introduction the broad glacial history of the Leaf Rapids area has been alluded to in work by McInnes (1913), Antevs (1931) and Elson (1967). In general the area is assumed to have been eroded during Kansan, Nebraskan, Illinoian and earlier Wisconsinan substages of the Pleistocene although there is no direct (depositional) evidence for these early glacial events. Striation evidence suggests early (pre-last glacial) ice advance directions from north-northwest. The latest ice advance is assumed, from the ice advance direction indicators and drift composition, to be from N41°E to N70°E.

Tangible ice advance direction evidence can usually be obtained from pebble count data, preferably from till sections. The characteristic Notigi till has a mixed Precambrian lithology and a low limestone-dolomite content. Carbonates are particularly apparent in the Grass Lake glaciofluvial sediments.

The carbonate source may have been derived from Hudson Bay Lowlands and the ice advance direction south-southwest.

The ice retreated from the area possibly quite rapidly as suggested by the abundance and coarse nature of meltwater sediment. Prest (1969) on his G.S.C. Map No. 1257A suggests that the Churchill River basin contained a broad re-entrant of the Laurentide ice front which retreated rapidly by calving and direct melt into the waters of a proglacial lake. A portion of Prest's map is reproduced as Figure 11. There is absence of end moraines and datable material in the Leaf Rapids area.

It is assumed that ice retreated from the area around 9700 — 9600 B.P.

Due to rapid melting in the vicinity of the present day Churchill River, the retreating ice became subdivided into two lobes referred to as the Reindeer lobe and the Nelson lobe. The retreating ice front was essentially oriented east-west to the north of Leaf Rapids and north-south to the east of Leaf Rapids. The highly calcareous nature of the drift from the easternmost lobe, as reflected in the Notigi till, Grass Lake, Rat River and Penguin Lake eskers, suggests coincidence with the Labradorean ice as ice from this centre is assumed to have crossed the Hudson Bay Lowlands thereby incorporating a substantial limestone-dolomitic fraction. The Leaf Rapids esker may represent drift material derived from ice with a more north to south flow component, and possibly derived from the Keewatin dispersal centre. The major eskers are, therefore, oriented normal to the assumed ice front orientation and are co-incidentally parallel to major lineament trends.

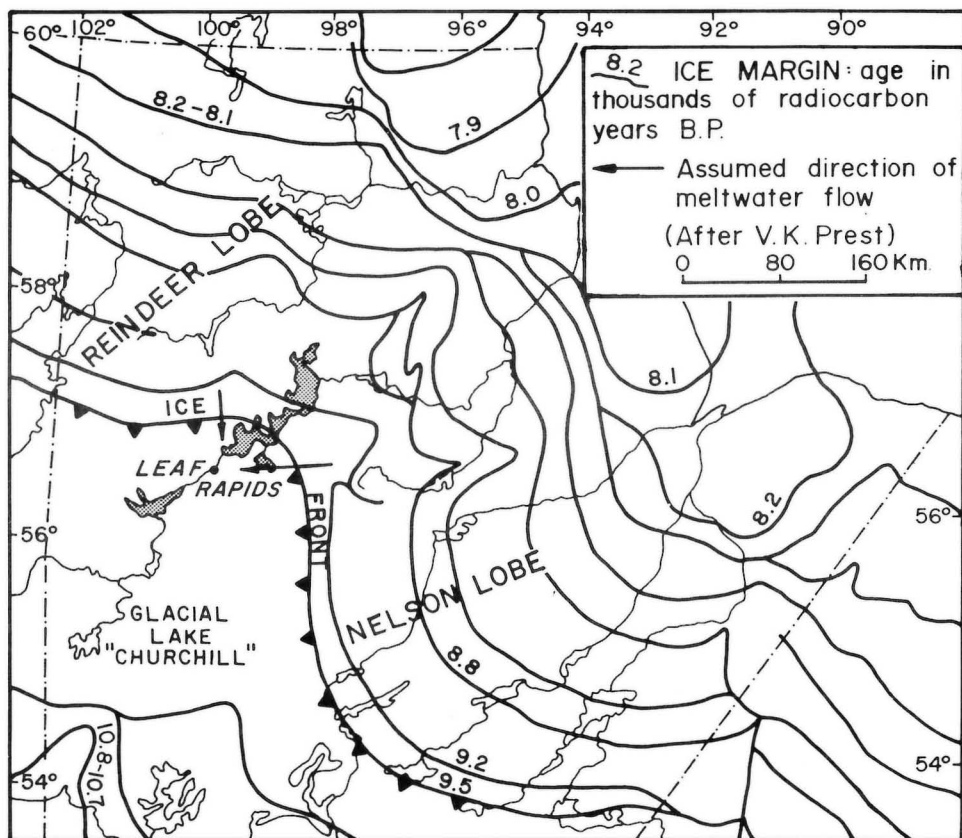


Figure 11: Chronology of ice retreat — northern Manitoba

The generalized glacial stratigraphy of the area is indicated in Figure 12. At the base of the section, a thin discontinuous till directly overlies Precambrian bedrock. As the ice retreated from the area, glaciofluvial sand and gravel was deposited directly on the pre-existing surface. Sedimentology evidence suggests that the coarse gravel facies was deposited as delta front or gravel bar sediments in a subaqueous environment, at the ice-lake water contact. This sedimentological component grades upwards and downstream into current bedded sand, which represents a more distal facies with respect to the retreating ice front, but still a subaqueous environment in which some of the flow directions diverge strongly from the main glaciofluvial flow direction. The bedded sand, in turn, grades upwards and downstream into lacustrine silt and clay which was deposited as ice left the immediate vicinity and deep still-water conditions prevailed.

The duration of the deep water lacustrine environment is not known, and can only be inferred from circumstantial evidence. Lake level elevations may be inferred from the silt and clay units, shorelines and delta top sets. From the schematic plotting of elevations of significant features (see Figure 13) it may be concluded that glacial Lake Churchill ranged from 335 m to 265 m. The Leaf Rapids esker was probably the first to form as its deltaic-gravel bars are graded to a significantly higher static water level than the equivalent features in the Grass Lake esker. The glacial lake progressively dropped in water level from 335 m, through 285 — 295 m (formation of Grass lake esker), then to 265 — 270 m during and following the formation of the minor eskers. The lake basin is at

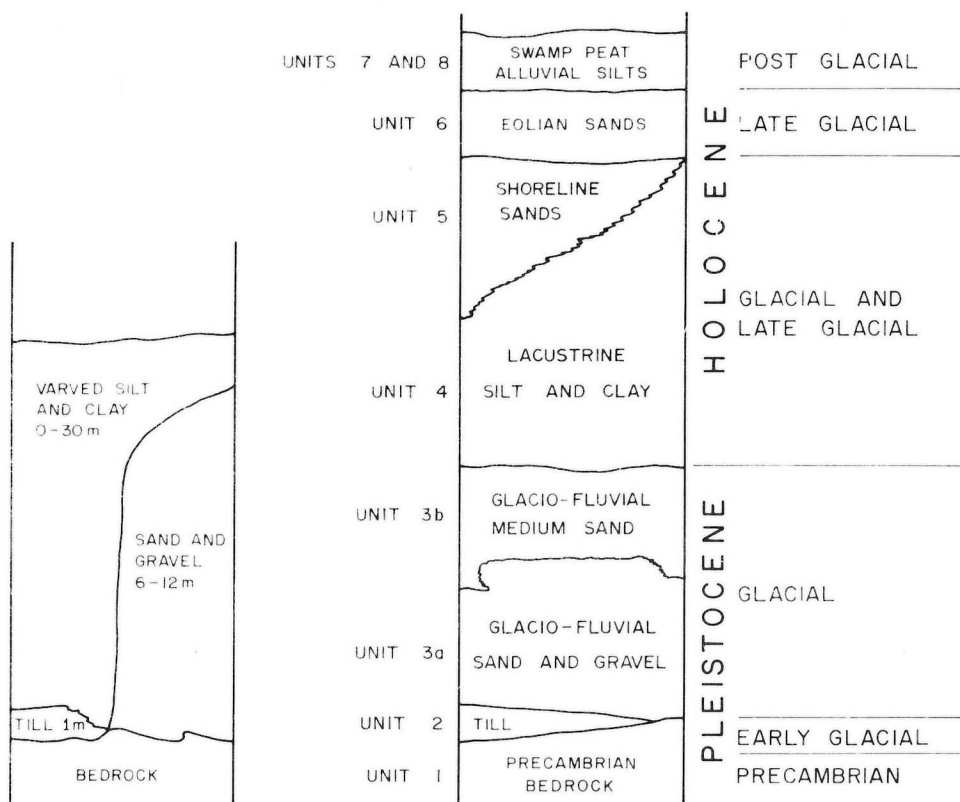


Figure 12: Relative thicknesses of sediments and generalized stratigraphy

least 50 m higher than the equivalent Grass River sedimentation basin to the south, and the lake clay of the Churchill basin is not contiguous at this longitude with those of the Grass River basin. They are, in fact, separated by bedrock ridges to elevations exceeding 350 m. Lacustrine clay is known not to extend west of Lynn Lake.

From this, it may be assumed that the proglacial lake which occupied the Churchill basin (referred to as glacial "Lake Churchill") in the late-glacial interval was higher and therefore not contiguous with the later known "Lake Agassiz" stage (Ringrose, 1975). Further work will establish the synchronicity of glacial events in the two basins, given further C-14 dates and isostatic uplift data.

Shoreline sediments were washed from the main esker margins and deposited over lacustrine silt and clay as a result of the overall drop in lake level from about 335 m to 262 m above sea level. Continued retreat of both Labradorian and Keewatin ice along the Churchill axis may eventually have led to ice stagnation in the basin and the flow of lake water into the Tyrrell Sea between 8500 and 8000 years B.P.

As lake waters receded from the area and prior to the establishment of vegetation, wind-blown sand derived predominantly from the shore sand facies was blown onto esker crests and deposited along the esker margins.

Post-glacial activity includes also the development of peat bogs, floating swamps in poorly drained areas, and the deposition of minor amounts of alluvium.

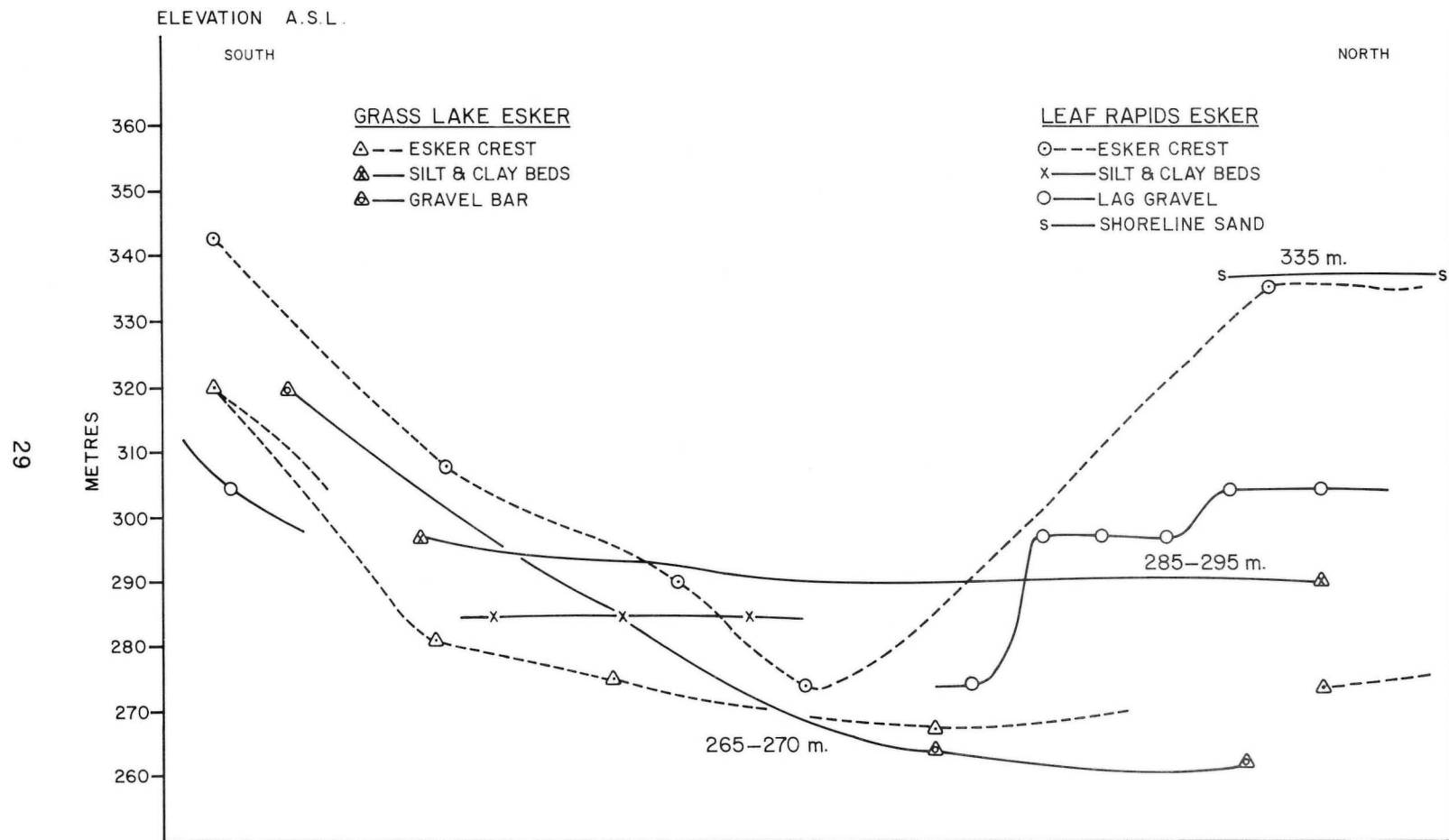


Figure 13: Elevations of glacial Lake Churchill

ECONOMIC EVALUATION OF SURFICIAL DEPOSITS

The surficial deposits of possible economic value in the Leaf Rapids Local Government District include quantities of sand and gravel, clay and peat.

LOCATION AND STATUS OF PRESENT PITS

Sand, gravel, clay and peat pits are found at roadside locations along Highway 391 and by the South Bay Road. The pit locations are shown on Map B, which when cross-referenced with Appendix 4, gives a clearer indication of the type of material present. The appendix lists the size of the area cleared to allow mineral extraction to take place, the average depth of excavation and the amount of material removed, as inferred from the size of the excavation. Generally, the depth of extraction is limited to the interception of either the bedrock surface or water table.

Along Highway 391, 28 sand and gravel pits, 30 sand pits and 16 clay pits have been opened up, comprising an approximate total area of 334 000, 194 000 and 107 000 square metres, respectively. The sand and gravel pits range in depth from 0.25 to 8.4 m. The total amount of material removed is estimated to be 805 000 cubic metres of sand and gravel, 128 000 cubic metres of sand and 76 500 cubic metres of clay.

Along PR 391, within the Local Government District, 74 pits in total have been opened up, an average of 2.3 pits per km. The high pit density has resulted mainly from the construction of Highway 391 as the sand and clay were required for borrow material. Most of the clay and sand pits could now be rehabilitated as they will unlikely be used again for mineral extraction. The disused pits have tended to become garbage and waste disposal sites (Plate 15A) so considerable improvement work will be involved before such sites can be reclaimed for recreation or alternative land uses. Most of the sand and gravel along Highway 391 will be required on a continuous basis. Pits such as B36W, B42E, B44E and B47W could be rehabilitated and the land put to alternative uses as they either occur within depleted deposits or are such that continued excavation would be impeded by highways, utility lines or existing recreation areas.

Between the Leaf Rapids townsite and Ruttan Lake mine (along the South Bay Road) one sand pit and 56 clay pits have been excavated. The sand pit area has been cleared (1 639 square metres) but little or no material removed. About 492 000 square metres have been cleared for clay extraction, to a depth of between 0.25 to 2.0 m, and approximately 224 000 cubic metres of clay removed. Along the 20 km stretch of road are 57 pits averaging 2.8 pits per km. In addition, there are two recently excavated peat pits. Most of the clay pits could be rehabilitated (for example B32N, Plate 15B) as there is little continuing demand for fill. One or two should remain open to provide clay binder for road maintenance. The sand pit (B1N) is very close to the townsite and should remain open as a source of fill.

Along the South Bay Road, between Ruttan Lake Mine and the north-eastern limits of the Local Government District, there are four sand and gravel pits, two sand pits, 15 clay pits, with cleared areas of 74 000 square metres, 29 000 square metres and 264 000 square metres, respectively. The sand and gravel pits range in depth from about 0.25 to 5.0 m, the sand pits between 0.25 and 3.0 m and the clay pits, average 0.5 m. Along this 20 km stretch of highway are 21 pits, or 1.0 pit per km. The sand pits should remain open as this material may prove useful for backfill in Ruttan Lake mine. The sand and gravel pits have not been used intensively since the road was constructed but should remain open for future use. B61N, a till deposit, could be rehabilitated immediately, whereas B60S could remain open as a source of coarse granular fill.

ECONOMIC USE OF MATERIALS

Gravel, Sand and Clay: Gravel, sand and clay deposits in the Local Government District are being used in the construction industry. Approximately 70% of the excavated aggregate and fill was used in highway construction and 30% in the construction of the mine, townsite and airstrip.

Different types of material have been used in highway construction. Ditch excavation complements the build-up of the sub-base grade which is usually composed of local materials through which the route runs. Additional clay pits are opened up by the roadside to provide borrow materials where local clay is deficient, and to provide a clay binder used in conjunction with aggregate. The clay is used largely as fill, to in-fill depressions, to provide minor causeways and fill areas resulting from blasting of bedrock knolls. Once the sub-base has been constructed, surface material is added directly. A "C" base of sand, granules and fine pebbles may be added to a clay-silt sub-base, as within the clay portions of Highway 391 and the South Bay Road. Between the townsite and Ruttan Lake reject material from the mine (crushed rock) was used and combined with clay to provide a stable base.

Pits B6W, B17W, B44E, B45W2, B59W and B69E have been used as gravel sources during the period of highway construction. Considerable quantities of gravel from within the Local Government District have been used also for highway construction beyond the Local Government District. Pit B45W2 is the most constantly used source for Department of Highways contracts (see Plate 16A and 16B). Similarly, along the South Bay Road, sand and till from B61N, B60S and B65S(ii) have been used as base course and surface material. Large quantities of crushable cobble-size gravel have been removed from B65AN and probably used to surface the South Bay Road.

The second largest user of aggregate has been the Leaf Rapids Corporation. Over 300 000 cubic metres of aggregate has been taken from the locally designated Leaf Rapids Corporation Pit, B49W (see Plate 17A).

Department of Highways' contractors and Transport Canada also may have used this source, in the latter case for airstrip construction. Pits B42E, B44E, B45W1 and B49W have been used in the development of the townsite. B45W is still being used. Most of the gravel has undergone crushing and screening. It is used as concrete in the construction of service roads, sewer and water systems and basements. It is used also as fill for driveways and parking lots and as a component of asphalt in paved parking areas. Ready-Mix concrete is manufactured locally by Galleli Sand and Gravel, part of Canada Concrete Ltd.* Use is being made of pit B55E (Plate 17B) for concrete manufacture.

Quantities of gravel were used by Sheritt-Gordon Mines Limited in the development of Ruttan Lake mine. Again early uses included concrete for foundations of buildings comprising the mine plant and pit-run for driveways, although mine waste has been used for these purposes. Shot-crete is currently being manufactured by Galleli Sand and Gravel for use as a stabilizer in mining operations.

No use to date (1974) has been made for the glaciolacustrine clay in the area for brick and tile manufacture.

Peat: The peat deposits along the South Bay Road have been excavated at two locations close to the highway (see Plate 18A). In both cases, approximately 1500 — 2000 cubic metres of peat have been removed. This is used as topsoil in the otherwise predominantly sandy yards and gardens of residences in the Leaf Rapids townsite.

* Since fieldwork took place J.C. Wilson has become the local producer of concrete products

EVALUATION OF SAND AND GRAVEL DEPOSITS

Gravel deposits can be assessed in terms of intrinsic geological qualities or physical factors pertaining to the site or access. Whether or not a given deposit is in demand is also an important contributory factor particularly in the analysis of northern granular sources.

As part of the pilot report to provide data to aid in the optimal use of granular resources within an area, an evaluation of the sand and gravel deposits of the Leaf Rapids Local Government District, in light of geological, physical and basic economic circumstances is presented.

Previous Work: Published methods of sand and gravel deposit evaluation emanate mainly from government agencies. The United States Bureau of Reclamation's Concrete Manual (1966) enumerates A.S.T.M. tests, such as: physical petrographic examinations, alkali-aggregate reactivity and freezing-thawing durability in concrete, which are used to determine the suitability of sand and gravel used in concrete manufacture. The Manual indicates how an evaluation of test results aids the construction industry (p. 178). The Bureau* emphasizes that:

"It is difficult to provide a definitive assessment of the relative significance of individual quality evaluation tests that are performed on aggregate materials which would be applicable in all cases. Generally most practical quality test methods are compromises that may not always measure with reliable accuracy the properties essential to adequate performance of the material in the end products. Although in certain special useages of aggregate material a single specific aggregate property might have primary importance, quality evaluations based upon the results of any single test would certainly be misleading"

The Institute of Geological Sciences in Britain, as part of its mineral evaluation program, maps aggregate including sand and gravel in 10 square kilometre resources blocks. Reserve estimates quoted in the survey (for example, Allender and Hollyer's work, 1973) are at the "indicated" level, since the test sites available are too "inappropriately spaced" to allow granular deposits to be outlined completely or the particle size distribution established throughout the deposit. The primary objective of the survey is therefore not accurate measurement but an appreciation of magnitude (and quality). Proving of reserves remains the responsibility of the mineral industry.

The assessment of deposits by the British Institute is defined in terms of limiting criteria by which potentially workable deposits may be recognized. They must be not less than 1 m thick, contain no more than 40% by mass of fines and have a ratio of overburden to sand and gravel not higher than 3:1. The potentially workable deposits are those which can be designated 'minerals'. Only "physical testing meaningful in the regional context should be attempted and, as with reserve assessment, detailed physical evaluation of commercial prospects might more appropriately be the responsibility of operators, consultants or contractors in the private sector"†. The Division considers that sieve analysis determines the most fundamental characteristics of granular deposits. Other useful tests listed in the context of resource assessment are: (a) specific gravity, (b) water absorption, (c) 10% fines value and (d) full petrographic analysis (including pebble counts) to identify deleterious minerals.

* Written communication on behalf of Howard J. Cohen, Chief, Division of General Research, U.S. Bureau of Reclamation

† Written communication R.A. Thurrell, Head, Mineral Assessment Unit, Mineral Resources Division, British Geological Institute.

In Canada, Dr. L. Dolar-Mantuani has developed the use of petrographic analysis of aggregate to reduce the need for further testing, and specify which detailed tests might most suitably be applied. Examination of the coarse or fine fraction of an aggregate sample reveals the presence of deleterious substances such as alkali-silica reactive rocks, weathered crystalline rocks, calcareous or iron-oxide incrustations (Dolar-Mantuani, 1969, 1972).

Aggregate resource assessment is being developed by the Ontario Division of Mines (Proctor and Redfern, 1974) as a basis for land-use planning. This work was prompted by increasing urban development in southern Ontario and the tendency to inadvertently sterilize aggregate reserve areas. Increasing awareness of the problem (see Leggett, 1973) has induced a nationwide requirement to define the aggregate resource base of an area, as part of the planning stage of development (for example, Holter's work in Red Deer, Alberta, 1975). In response to the demand in Ontario, McLellan and Bryant (1975) have suggested a relatively straight-forward aggregate rating or evaluation classification, which includes a combination of volume, quality (defined in terms of per cent stone) and physical constraints.

Analysis of Aggregate Deposits:

As indicated in the literature and considering local circumstances, the major factors which affect the overall value of a sand and gravel deposit include quality of deposit, quantity of available material, and distance of haulage. Thickness of overburden is not considered to be a major factor in sand and gravel evaluation in the Leaf Rapids area. The exploitability of the deposit also hinges on the presence of a market.

Quality of Sand and Gravel: Samples from each deposit were tested to give an indication of the type of material present and its quality. Laboratory tests include grading, per cent fines, organic content and a calculation of fineness modulus, the results of which are listed in Appendix 7. Data obtained from these tests were compared with standard specifications for industrial uses as set out by the American Society for Testing and Materials, the Canadian Standards Association, the Province of Manitoba, Portland Cement Association, U.S. Bureau of Reclamation, and Underwood McLellan and Associates (suggested specifications for septic fields in Manitoba). Results are given on Table 1.

Two categories of relative suitability become apparent: those materials which meet specifications exactly (indicated by X on Table 1) or which require minimal screening or addition of some size fractions (indicated by O); and those which are not readily useable in terms of the specifications (indicated by no symbol on the table). Based on the number of industrial uses for which a sample proved suitable, an overall assessment of quality was determined as indicated in the final column of the table. High quality deposits are arbitrarily ruled as those which meet 60% or more of the specifications for industrial uses considered in the evaluation (having between 18 and 30 industrial uses), and low quality deposits meet less than 60% of the specifications (having between 3 and 17 industrial uses). Large size material available for crushing and the presence of an excess of organic impurities in certain samples are indicated.

Direct comparison between deposit areas, sample locations and test results verifies that Unit 3 glaciofluvial gravel, some of 5a, and the underlying gravel of 4b constitutes most of the area defined as high quality gravel. Most of 4a and Unit 6 represent lower quality sand and pebbles. This is verified in a number of instances as illustrated by Figure 14, which shows the size range of all the channel samples. Relevant pebble lithology data (Appendix 3) show that

X — Material meets specifications exactly.
O — Some (minimal) processing required to meet specifications.
≠ — Presence of crushable material or high organic content indicated.

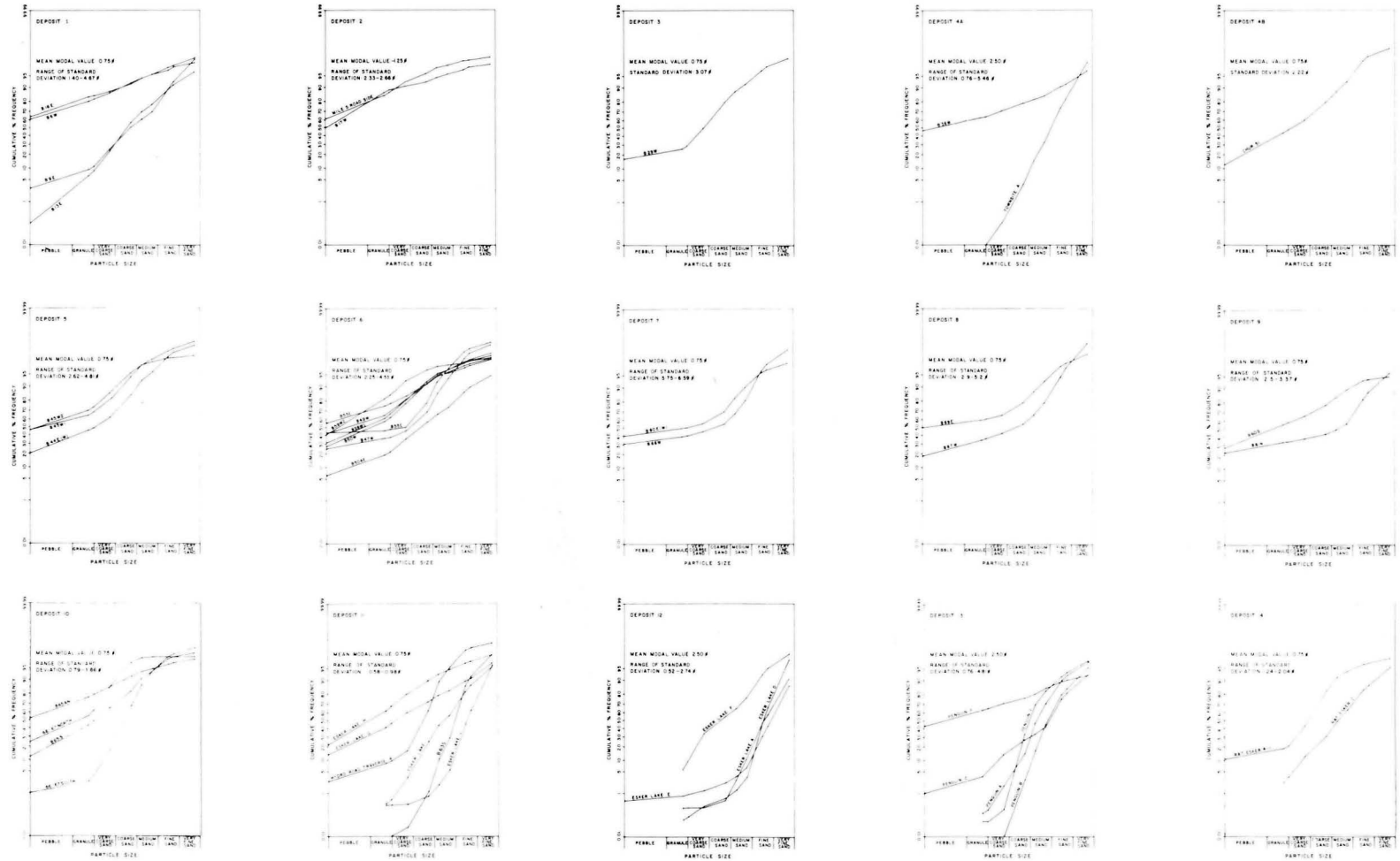


Figure 14: Particle size curves — channel samples

in most of the sample, deleterious substances are absent. The most common rock type is fragmented crystalline material, with very little detrital carbonate. In Deposits 1 to 7 and 10, pebbles with carbonate incrustations were noted. Deposit 1 shows evidence of iron-oxide weakly cementing pebble agglomerations and rapidly disintegrating weathered schists (Plate 18B). In Penguin F (Deposit 13) the surface cobbles are severely weathered; greater soundness is assumed at depth.

Quantity of Sand and Gravel: Granular deposits in the Leaf Rapids Local Government District were divided into 14 deposit areas as indicated on Map B. The estimated reserves of sand and gravel per deposit were determined by the areal extent of Units 3, 5a and 6 (planimetered at 1:50 000) multiplied by the average thickness of each deposit. Depth determinations have largely been interpreted from ground resistivity survey results. Resistivity profile locations are shown on Map B and an outline of techniques used given in Appendix 5.

The quantities of material available are reported in Table 2. In total, there are approximately 51 million cubic metres (67 million cubic yards) of Unit 3 (higher quality gravel) in the area, and close to 180 million cubic metres (235 million cubic yards) of lower quality sand with some pebbles. The proportion sterilized refers to both categories of material, although in most cases it is the higher quality Unit 3 material which is or has been made unavailable. In total there are about 164 million cubic metres (214 million cubic yards) of granular material available for use in the Local Government District.

Distance of Haulage: Distance of haulage from the closest point of a given deposit to the nearest market (Leaf Rapids or Ruttan Lake Mine) is given in Table 2. Most of the opened deposits are within 16 kilometres of the static markets. Greater haulage distances may be required for highway construction contracts and park development. Most of Deposits 11, 12, 13 and 14 do not have direct all weather road access, which reduces their significance in terms of total market availability.

Demand for Gravel Deposits: The future demand for aggregate has been estimated from correspondence with government agencies and projections based on past use. Past use figures are taken from data on file in the Mining Recording Office, Mineral Resources Division. The entire Local Government District has been "withdrawn from staking", hence leases and permits for aggregate extraction are not available (1974).

A statement of anticipated usage of sand and gravel was requested from the Parks Branch, Sherritt-Gordon Mines, and Department of Highways, and estimates, based on past 'permission to remove' data, were made for the Leaf Rapids Corporation and Galleli Sand and Gravel. The estimated future demand is noted in Table 3, as are indications of the quality of gravel required.

Parks Branch will require 440 000 cubic metres of material, most of which can be obtained by enlarging pits B30AW, B30W and B31W. If higher quality gravel is required, the nearest source is pit B17W in Deposit 2. The projected requirement for Ruttan Lake Mine is in the order of 750 000 cubic metres for mine back-fill. The closest source is Deposit 11, which contains over 26 million cubic metres of suitable material. Much of this could be extracted from the roadside in the vicinity of pit B63S. Access to the deposit could also be made via the winter road (dashed line, Map B). The possibility of opening up the southern portion of Deposit 11, following construction of an all-weather road from the eastern end of the mine complex to the vicinity of Esker H, could be considered.

The Department of Highways has projected gravel requirements for road maintenance and the surfacing of PR 391. This material can be obtained from a

TABLE 2 — SAND AND GRAVEL RESOURCES

DEPOSIT	ACCESS		AREA (hectares)		AVERAGE THICKNESS (metres) r = resistivity e = estimate		ESTIMATED VOLUME (000 Cubic metres)			AMOUNT STERILIZED AND REASONS	PRESENT STATUS	AVAILABLE MATERIAL (000 Cubic metres)
	Distance L = Leaf Rapids R = Ruttan Lake	Road	Unit 3	Units 5a and 6	Unit 3	Units 5a and 6	Unit 3	Units 5a and 6	Total			
1	13 km (L)	Highway 391	168	82	8.5 m (r)	7.0 m (e)	14 280	5740	20 020	30 highway garbage dump	Partially cleared 5 pits	14 014
2	11 km (L)	Highway 391	26	116	9.0 m (r)	7.0 m (r)	2340	8120	10 460	60 highway 20 available no access	Partially cleared 1 pit	4184
3	5 km (L)	Highway 391	5	98	3.0 m (e)	5.0 m (e)	150	4900	5050	1.00 recreation	Cleared recreation area	4900
4A	0 km (L)	Highway 391	49	405	5.0 m (e)	4.0 m (e)	2450	16 200	18 650	91 townsite	Partially cleared 1 pit	1865
4B	3 km (L)	Pump House	7	0	6.0 m (e)	—	420	0	420	0.0 no direct access	No clearing no excavation	420
5	0 km (L)	Highway 391	70	127	8.0 m (e + r)	3.5 m (r)	5600	4445	10 045	80 highway power line depletion	Partially cleared 5 pits	2009
6	4 km (L)	Highway 391	168	664	8.5 m (r)	4.5 m (r)	14 280	29 880	44 160	30 highway airfield dump	Partially cleared 10 pits	30 912
7	9 km (L)	Highway 391	44	397	8.5 m (r)	4.5 m (r)	3740	17 865	21 605	30 highway	Partially cleared 8 pits	15 124
8	16 km (L)	Highway 391	10	227	7.0 m (r)	3.5 m (r)	700	7945	8645	0.0	Partially cleared 2 pits	8645
9	6 km (R)	South Bay	0	38	—	Unit 2 1.0 m (e)	0	380	380	0.9 highway depletion	Partially cleared 2 pits	38
10	14 km (R)	South Bay	3	124	6.0 m (r)	2.0 m (e)	180	2480	2660	60 highway overburden	Partially cleared 1 pit	1064
11	11 km (R)	Winter road from South Bay Road	47	522	8.0 m (e)	5.0 m (r)	3760	26 100	29 860	0.0	Partially cleared 2 pits	29 860
12	13 km (R)	None	0	668	—	5.0 m (e)	0	33 400	33 400	0.0 no access	No clearing no excavation	33 400
13	18 km (R)	Winter road from South Bay Road	38	179	8.0 m (e)	5.0 m (e)	3040	8950	11 990	0.0	No clearing no excavation	11 990
14	25 km (R)	None	11	264	8.0 m (e)	5.0 m (e)	880	13 200	14 080	60 flooded	No clearing no excavation	5632
TOTALS			646	3911			51 820	179 605	231 425	Estimated 45% high quality gravel sterilized		164 057

number of gravel pits along the roadside. Frequently used sources include Deposit 8 (B69E), which is becoming depleted of higher quality material (700 000 cubic metres remaining), Deposit 5, B45W1, B45W2 (about 2 million cubic metres remaining), Deposit 2, B17W (about 4 million cubic metres remaining), and Deposit 1 (over 14 million cubic metres remaining).

Maintenance of the South Bay Road is relatively difficult because of the absence of roadside gravel. Deposits 9 and 10 provide the most readily accessible sources. In Deposit 9 there is little good quality material above the static water level, although an estimated 38 000 cubic metres remains in the entire deposit. Deposit 10 contains about 180 000 cubic metres of good quality gravel, much of which is under 3 to 4 metres of silt. The 10 000 cubic metres of available gravel at pit B65AN would have to be crushed for road maintenance. Eventually, Deposit 11 (Unit 3) will have to be opened up to provide aggregate for continued road maintenance or renewed construction.

Estimates of gravel demand in the Local Government District total one million cubic metres to 1999. The Leaf Rapids Corporation has habitually used Deposit 6 immediately east of the airstrip. Ten million cubic metres of good quality gravel remain in Deposit 6, and abundant lower quality material for street and parking lot maintenance. Future requirements for Galleli Sand and Gravel, based on past demands, could probably continue to be met from Deposits 5 and 6. These deposits are also being used by the Department of Highways' contractors but there are adequate available reserves.

Given that there are about 51.8 million cubic metres of good quality gravel in the Leaf Rapids Local Government District, (and 179.6 million cubic metres of poorer quality sand and gravel), and that about 45% of mainly the higher quality material is sterilized by cultural features, there remains at least 25 million cubic metres (of high quality gravel) available for use. Approximately 50% of this is accessible along Highway 391. Therefore, approximately 12.5 million cubic metres of high quality gravel will be available (and accessible) and over 100 million cubic metres of lower quality material available to meet demands until 1999.

TABLE 3 — ESTIMATED FUTURE DEMAND FOR SAND AND GRAVEL

A. Demand for high quality aggregate ('000 cubic metres):

	<u>1975-79</u>	<u>1980-89</u>	<u>1990-99</u>	<u>TOTALS</u>
Dept. of Highways	150	300	300	750
Galleli/Wilson	100	200	200	500
Leaf Rapids Corp.	100	200	200	500
	<u>350</u>	<u>700</u>	<u>700</u>	<u>1 750</u>

B. Demand for low quality aggregate ('000 cubic metres):

	<u>1975-79</u>	<u>1980-89</u>	<u>1990-99</u>	<u>TOTALS</u>
Dept. of Highways	150	300	300	750
Sherritt Gordon	150	300	300	750
Leaf Rapids Corp.	100	200	200	500
Parks Branch	200	200	40	440
	<u>600</u>	<u>1 000</u>	<u>840</u>	<u>2 440</u>

TOTAL DEMAND to 2000 A.D. 4 190 000 cubic metres

EVALUATION OF CLAY AND PEAT DEPOSITS

Clay Potential for Brick and Tile Manufacture: Glacial clays from northern Manitoba have been subjected to temperature gradient tests to assess their firing and shrinkage properties (Bannatyne, 1970). These clays appear to have good firing properties and are superior in quality to those in the Leaf Rapids area.

Results of a temperature gradient test* on Leaf Rapids glaciolacustrine clay (Unit 4) from pit B21BS are shown in Figure 15. Air drying shrinkage is 9% and the firing shrinkage at 1038° C (1900° F) is 5%. The clay has a high water of plasticity. It fires steel hard at 1025° C to a reddish-brown colour. The combined air drying and firing shrinkage should generally be less than 12% to prevent problems in brick manufacture. Although only one sample was tested the lacustrine clay appears unsuitable for brick and tile manufacture because of its high shrinkage. The poor firing properties are a consequence of the abundance of montmorillonite in the clay.

Peat: Peat is currently being exploited in the Leaf Rapids area for top-soil formation. The organic areas mapped as Unit 7 contain some sphagnum which may be of value as a soil conditioner at a future date.

GEOLOGICAL DATA FOR LAND-USE PLANNING

Surficial geology maps may be used in land-use planning. However, limitations stem from the fact that much of the geology has been interpreted from aerial photographs and would consequently be very generalized. The broader patterns of material distribution provide a basis for initial land-use planning. More detailed redefinition of boundaries and geological units is normally required before detailed land-use plans can be adequately formulated, as exemplified in the planning of the Leaf Rapids townsite (Ripley, Klohn and Leonoff, 1971).

Basic land-use units are associated with the distribution of surface materials, as indicated by Map A. These units are delineated on the basis of major lithologies and include:

Major Lithology	Map Unit
Bedrock, with weathered drift	1
Sand and Gravel; esker deposits	3
Clay overlying bedrock	4a
Clay overlying sand and gravel	4b
Sand overlying sand and gravel and clay	5a and 6
Fine sand or silt overlying clay	5b
Organic deposits	7
Open swamp areas	8

* Test performed by B. Bannatyne, Mineral Resources Division

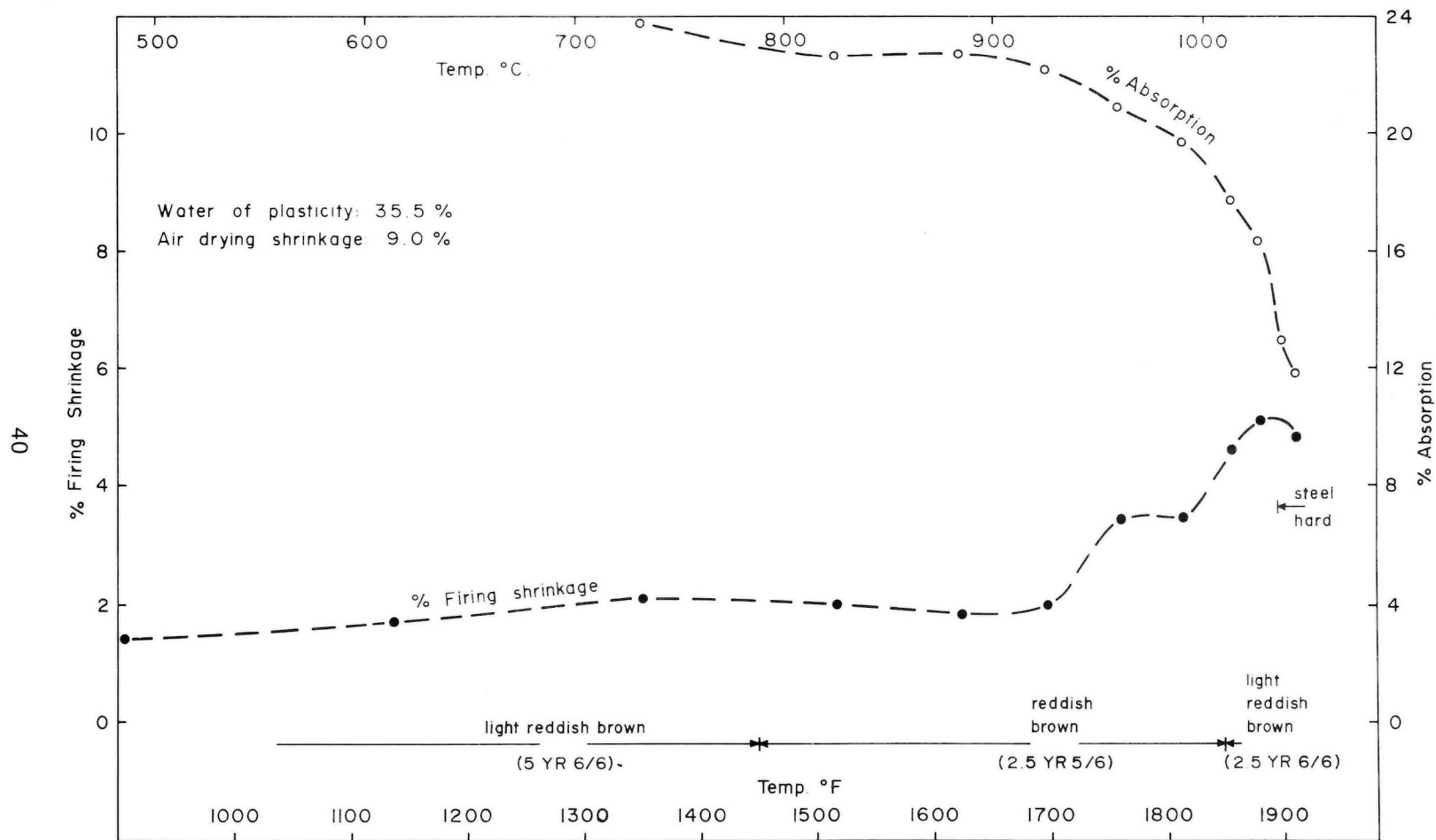


Figure 15: Temperature gradient furnace test — lacustrine clay

Little information is available on ground water resources, an important aspect of land-use planning activities. In the area, there is an abundance of surface water, with some evidence of a discontinuous permafrost table or frozen layer, 2 to 10 metres below the ground surface. In general, permafrost or frozen ground may be spasmodically encountered in areas underlain by sand and gravel deposits, and commonly encountered in finer silts, but it is not necessarily restricted to any sediment type or micro-environment. In organic terrain, permafrost is commonly encountered within 30 to 50 cm of the ground surface.

General Construction Conditions: Earth materials have physical conditions that affect their suitability as foundations (see Appendix 6). Sand and gravel can be expected to provide a more stable foundation than clay, which in turn, is more stable than organic terrain. Data applicable for consideration for future construction are outlined in Appendix 6, and are general in character. The properties of earth materials considered important include water content, strength, sensitivity, ease of extraction and slope (after Larson, 1973).

Although no geotechnical tests were made, areas considered good for most construction are those underlain by sand or gravel (Units 3 and 5a), particularly where no clay is encountered. These sediments are characterized by high strength and low compressibility, and high permeability which minimizes problems associated with water table conditions (except in lowlying areas of Unit 5). Frozen ground is rarely intercepted in these areas. Problems include large boulders which, when encountered, are difficult to excavate, and clay lenses which encroach onto the margins of eskers.

Component lithologies comprising Units 4a, 4b, and 5b may be rated good to moderate for construction purposes. These areas have a moderately high inherent strength with a low permeability. In better drained clay areas problem water table conditions are minor because of high elevation. The presence of scattered boulders throughout the deposit may cause problems during excavation but to a relatively minor extent.

More drilling would be required at specific sites (for example, adjacent to the Leaf Rapids townsite) to ascertain the thickness of the clay wedge (c.f. Figure 5) and its effect on the ground water or permafrost conditions along the eskers. Lowlying silt and clay is saturated and therefore provides an unstable foundation base.

The areas rated lowest for general construction are the peat and swamp areas and immediately adjacent clay areas. The silt and clay has generally low bearing strength, high water content and a high plasticity. Permeability is very low and generally saturated conditions persist.

Waste Disposal: The base of a solid waste disposal area should be sufficiently impermeable that fluids moving down through a landfill or mound will not seep out. Cover material of sufficiently low permeability should be available. If possible, the base of the garbage should be well above the water table so that pollution of the water is minimized. There are relatively few areas in the Leaf Rapids Local Government District which can be described as ideal potential sanitary landfill sites, since dominant earth materials are highly permeable sand or sand and gravel, or clay which is impermeable and unstable. Perhaps the most favourable areas are those designated as 4a, 5a and 6. Use could have been made of pre-existing silt or clay pits where these have sufficient relief and are above the ground water table. A mixture of sand, silt and clay could be used as cover material.

Moderate to poor areas for sanitary landfill disposal are those underlain by

lowlying fine sand or silt deposits overlying clay (5b), and organic accumulations or swamp (7 and 8). These areas are generally saturated; therefore, ground water contamination is inevitable. There is also inadequate cover material.

Areas of poor suitability are underlain by sand and gravel (3) and bedrock (1). The former is highly permeable and provides poor cover material, in addition to which, the aggregate has practical value in the construction industry and as such sterilization of deposits should be avoided.

A sewage lagoon must be located in an area of low permeability and low relief to minimize leakage. It should not intercept the water table and should be away from an area of potential flooding to avoid contamination of surface and ground water. A lagoon in organic material (Unit 7) would suffer from leakage due to high permeability (above the ground water or permafrost table). The presence of organic matter may also inhibit the desired biological action in the lagoon.

The permeability of material is the major property determining the suitability of sewage lagoon locations. Good areas are those underlain by clay (4a) where the permeability is very low and the slope is gentle. Areas of high water table (Units 5a and 7) should be avoided. Areas where clay overlies sand (4b) should be discounted, particularly where they are lowlying because the sand may become saturated during construction, or it may cause seepage from the lagoon causing ground water pollution.

Areas which provide poor sites for sewage lagoons include those underlain by sand, gravel and peat (Units 3, 5a and 7). This is because of high permeability in sand and gravel and the problems of leakage and biological decay in peat.

Septic fields may be the principal method of sewage disposal in non-townsite residences, vacation cottages and trailer parks. The septic tank acts as an area of neutralization of harmful components by biological decay. The remaining solution is then passed through a dispersal field composed of sand and gravel through which the waste is filtered. In evaluating the suitability of foundation earth materials for a septic system, the permeability of the sediment is of major importance. If the permeability is too low this may lead to inadequate filtration and cause the liquid to back-up through the system. If the permeability is too high rapid and improper filtration will ensue. High permeability would also increase the danger of ground water pollution.

In the Local Government District of Leaf Rapids moderately poor areas for septic systems are those underlain by clay of low permeability (Units 4a, 4c and 5b), although the septic field can be lined with thicknesses of gravel to ensure efficient filtration in conjunction with large drain-tiles. Areas of organic deposits (Unit 7) are poor for septic systems because of their lack of cohesion and high ground water or permafrost table.

Areas where sand or silt underlies clay (4b) are suitable, if drainage takes place directly into sand. The required permeability may be effected through a drain-tile field where the water table is low enough to allow the proper operation of the system. Slope should also be considered; level areas being generally preferred to the steeply sloping esker sides where 4b clay occur.

Areas underlain by sand and gravel (Units 3, 5a) provide an adequate filtration base for septic systems. Such conditions prevail on the flanks of eskers which are underlain by sediment in the sand to pebble size ranges. Where the gravel is too coarse (cobble size) along portions of the esker crest (Unit 3), filtration may be too rapid to be effective.

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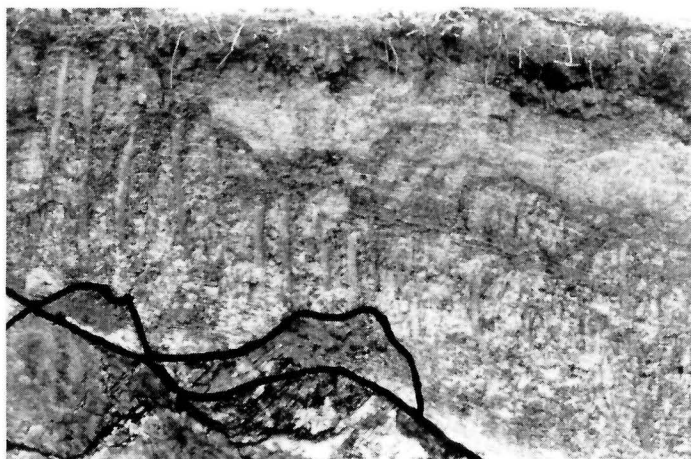
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APPENDIX 1
PHOTOGRAPHS



PLATE 1A: Cresscentic fractures at South Bay Road near benchmark 209. Ice direction from left to right. Knife 22 cm.



*PLATE 1B: Section of Notigi Till (between lines), directly above bedrock, covered by 3 to 4 m of lacustrine clay.
Location: Highway 391 at Notigi Control Structure.
Section: 5.0 m.*



PLATE 2A: Lag cobbles on crest of Leaf Rapids esker — Deposit 1 (B9E).



*PLATE 2B: Massive cobbles in sand matrix (subfacies 3a) — Leaf Rapids esker.
Location: B45W2
Person: 1.60 m.*



*PLATE 3A: Glaciofluvial gravel exposed at the southernmost limit of Leaf Rapids esker at B6W.
Hammer: 25 cm.*

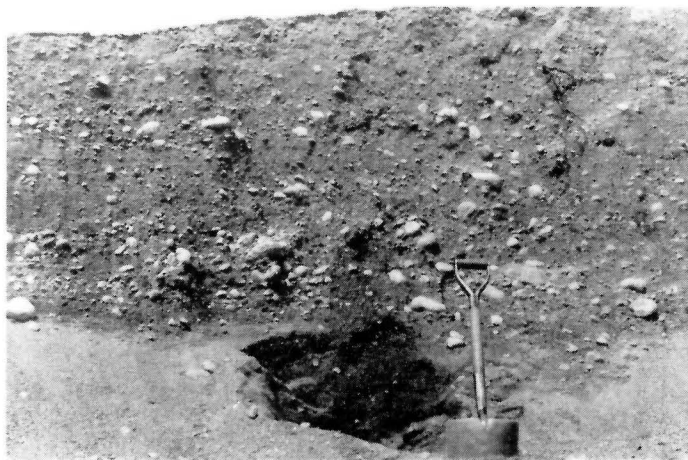


PLATE 3B: Coarse pebbles, granules and sand, with some indication of parallel horizontal bedding, at B45W1. Section is 2.0 m.



PLATE 4A: *Horizontally bedded pebbles and sand at Leaf Rapids esker crest (subfacies 3b) B47W. Exposed section is 1.0 m.*



PLATE 4B: *Beds of coarse to medium sand and pebbles dipping at 10° eastwards on east side of Leaf Rapids esker — B55E. Section is 14 m high.*



PLATE 5A: Details of normal faults in horizontally bedded sand and pebble units 5 to 8 cm thick in B55E, southwest wall. Exposed section 1.5 m.



PLATE 5B: Eastern margin of Leaf Rapids esker showing upward warping of sand-silt unit, with high angle reverse fault — Mine Road Cut 1.

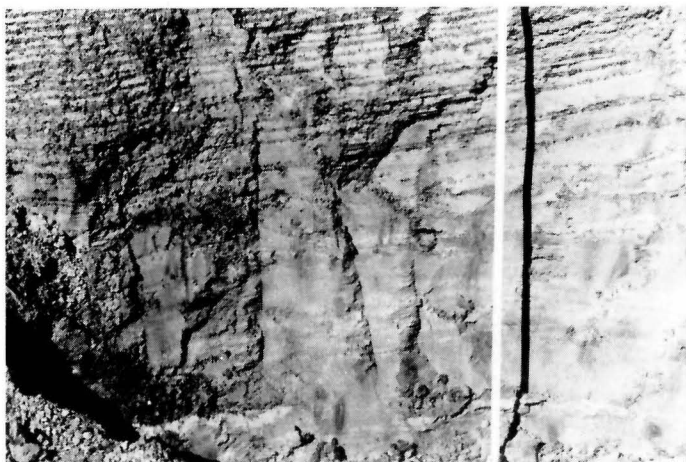


PLATE 6A: Massive silt grading upwards into varve-like couplets of silt and clay in ditch section east of B29W. Section 2.0 m.

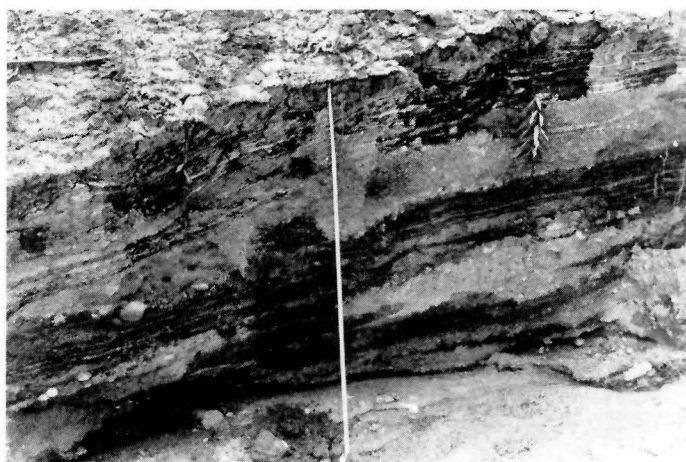


PLATE 6B: Convoluted silt and clay couplets with intercalated glaciofluvial sediments at B46E. Section is 2.0 m.

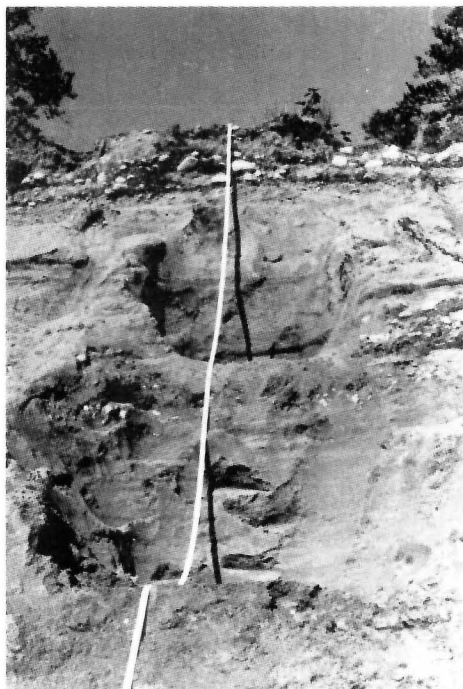


PLATE 7A: Lag gravel overlying parallel-bedded sand at B47W, west side.
Section is 5.0 m.

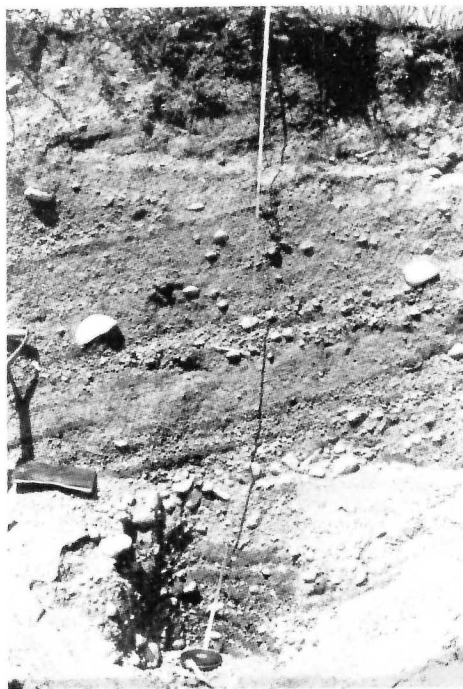


PLATE 7B: Detail of foreshore stratification, showing graded beds and fragmented pebbles. Glaciofluvial pebbles and granules at base of section.
Location: B58W1
Section: 3.0 m.



PLATE 8A: *Parallel laminated and accretionary foreshore sand overlying coarse glaciofluvial sediments. Note wave-cut notch at contact at B49W. Measured section 1.0 m.*

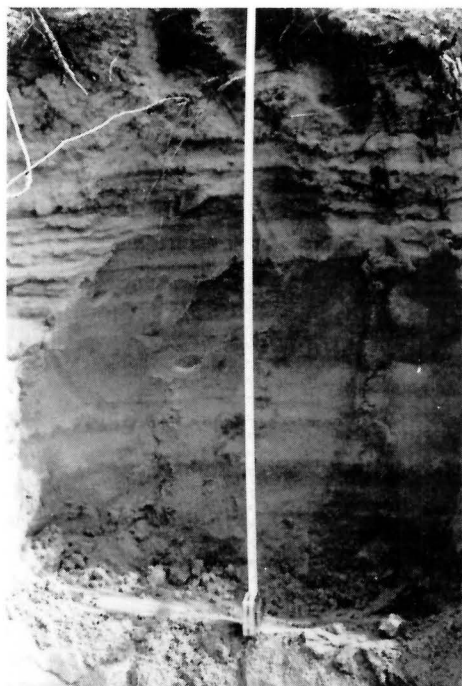


PLATE 8B: *Detail of dune sand, on crest of Leaf Rapids esker, showing horizontal laminations of medium to fine sand at 391 Townsite A. Section — 1.3 m.*



PLATE 9A: Section of rounded cobbles, pebbles and coarse sand (Unit 3a) of Grass Lake esker at B65AN. Pebbles (circled) show evidence of imbrication. Person: 1.55 m.



PLATE 9B: Coarse gravel deposits capped by massive silt, which merges laterally into clay (under trees in background) at B65S. Silt and gravel — 3.0 m high.



PLATE 10A: Unit 3 glaciofluvial gravel exposed at base of thick laminated silt and clay section (Unit 4).

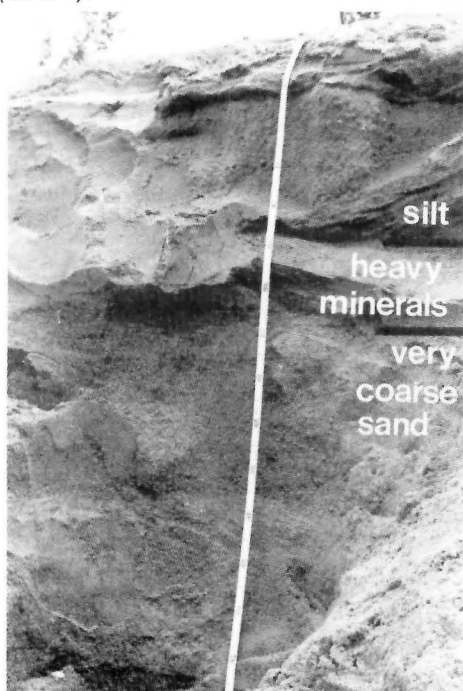


PLATE 10B: Subfacies 3c of northern bead of Grass Lake esker: very coarse sand, with medium-scale cross-stratification, grading upwards to fine silty sand. Heavy mineral laminae at contact. Current direction from left to right.

Location: B65S Section: 1.5 m.

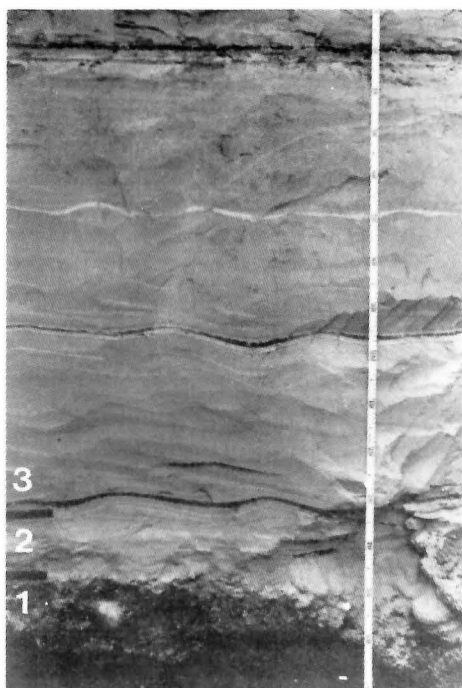


PLATE 11A: *Glaciofluvial gravel (1) capped by silt (3) with rippled subfacies 3c sand at contact (2).*

Location: 66-67 north.

Measured Exposure: 1.50 m.



PLATE 11B: *Climbing ripple drift cross-stratified sand merging into interfering ripple drift cross-stratification (at shovel handle).*

Location: Grass Lake Shovel: 1.0 m.



PLATE 12A: Climbing ripple drift cross-stratification, showing toeset development. Flow direction from left to right. Location: Grass Lake esker north of B63S. Knife blade — 11 cm.

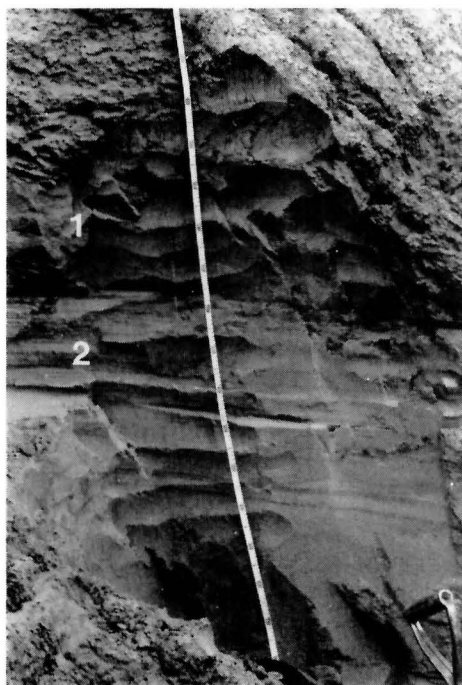


PLATE 12B: (1) Massive grey silt and sandy silt (facies 4c) overlying (2) parallel-laminated and ripple drift cross-stratified sand (facies 3c) — note preserved sand ripples at contact. Location: northern portion Grass Lake esker, south of B65S. Section: 1.8 m.



PLATE 13A: *Detail of contact between silt and glaciofluvial sand and gravel towards base of section 66-67 north. Paleoflow direction in medium-fine ripple drift cross-stratified sand indicates current from right to left in photo (from northeast to southwest). Scale in centimetres.*



PLATE 13B: *Detail of Penguin Lake B: lower cross-bedded sand, small scale cross-stratification in truncated sets. Current direction from right to left (east to west).*

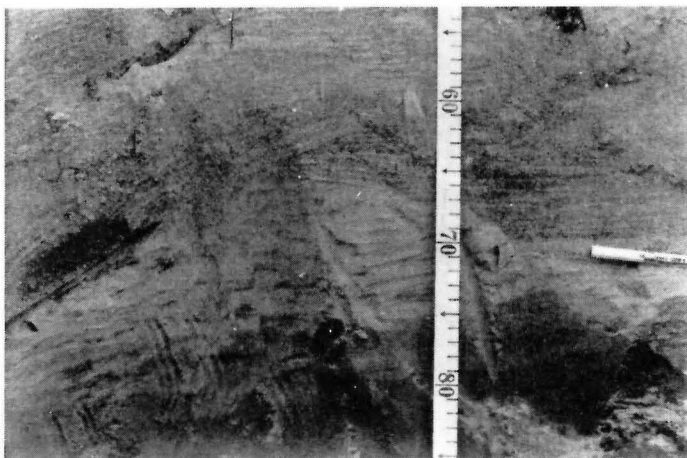


PLATE 14A: Faulted contact between upper cross-bedded sand and underlying silt on crest of esker. Location: Penguin Lake B. Scale in centimetres.



PLATE 14B: Coarse rounded gravel of the Rat River esker, exposed on peninsula. Shovel is 67 cm.



PLATE 15A: Disused garbage area on esker margin — B53E.



PLATE 15B: Disused clay borrow pit — B32N.



PLATE 16A: Equipment excavating gravel from B45W2 for Department of Highways contract.



PLATE 16B: Crushing and screening of gravel from B45W2 for Department of Highways contract.



PLATE 17A: Leaf Rapids Corporation pit: overlooking Churchill River; remnants of stockpile in middleground.



PLATE 17B: Gravel extraction for concrete manufacture — B55E.



PLATE 18A: Peat excavation along South Bay Road for use as topsoil in Leaf Rapids residences.



PLATE 18B: Disintegrating pebbles from B6W.



PLATE 19A: Equipment used in resistivity profile work: meter, coils, 30 m tape and electrodes spaced according to the Wenner configuration. Location: eastern margin of Leaf Rapids esker.

APPENDIX 2 — LOG OF PITS AND SECTIONS

LEAF RAPIDS ESKER

B69E

0.0	— 1.0 m	Pebbles, cobbles and granules, unsorted in fine silty sand matrix
1.0	— 1.65 m	Pebbles, cobbles and granules in coarse sand matrix
1.65	— 2.10 m	Medium to fine sand, occasional pebbles, horizontal bedding
2.10	— 4.60 m	Area obscured, mainly boulders cobbles and pebbles in medium and coarse sand
4.60	— 5.50 m	Medium sand, occasional pebbles
5.50	— 5.60 m	Pebble and granule layer
5.60	— 6.10 m	Medium to coarse sand, horizontal bedding

Micaceous, channel sample not representative — coarser cobbles not sampled, pebbles mainly angular

B67W

0.0	— 0.10 m	Cobble, pebble, granule layer
0.10	— 0.45 m	Medium to fine sand, no distinct bedding
0.45	— 1.15 m	Granules and pebbles, with sand layers, horizontally bedded
1.15	— 1.50 m	Fine sand, horizontally bedded (small sample)

sample: well sorted, some fragments and coarse sand, few micas, 10YR 6/4 light yellowish brown, non-calcareous, pebbles mainly rounded

B66W (east face)

0.0	— 1.0 m	Pebbles, some cobbles in matrix of granules and silty sand
1.0	— 1.50 m	Very coarse and medium sand with occasional pebbles, horizontally bedded
1.50	— 1.70 m	Medium sand layer
1.70	— 2.0 m	Very coarse granules and pebbles, with medium to coarse sand
2.0	— 4.50 m	Fine sand, heavy mineral laminae, horizontally bedded

Sand colour between 10YR 6/4, light yellowish brown and 10YR 6/6 brownish yellow, some micas, pebbles mainly sub-angular

Mile 19 by Loop Road, opp. B60E

0.0	— 1.50 m	Cobbles and pebbles, in matrix of silty sand
1.50	— 4.30 m	Cobbles and pebbles, in matrix of very coarse to medium sand
4.3	— 7.00 m	Medium sand — some coarse sand in horizontal laminations, very compact, grey

pebbles mainly angular

B59W2

Pit surface cleared to unknown depth

0.0	—	1.0 m	Cobbles, pebbles, granules and coarse sand in silty sand matrix, coarse debris dipping 20° to west
1.0	—	1.80 m	Coarse pebbles, granules, very coarse sand, horizontal bedding
1.80	—	2.50 m	Fine pebbles, granules, very coarse sand, no distinct bedding

Some iron staining, some small micas, sample taken not representative of larger cobble sizes between 11.5 cm — 20.5 cm, some frost-shattered fragments, pebbles and cobbles mainly sub-angular

B59W1

0.0	—	0.20 m	Sand and granules, unsorted
0.20	—	2.0 m	Very coarse sand and granules, interbedded with pebbles and granules, graded layers, with irregular cobbles, medium scale cross-trough stratification
2.0	—	3.0 m	Pebbles, granules and fine cobbles, horizontal bedding
3.0	—	6.0 m	Talus slope

Micaceous, pebbles mainly sub-rounded

B55E

0.0	—	0.50 m	Surface cobble layer — in matrix of medium to fine sand
0.50	—	14.0 m	Coarse to medium sand, with occasional pebbles — in laminae 5 to 8 cms thick, beds dipping to east 10°, and faulted in series of minor normal faults to eastern margin, very micaceous

Weathered cobbles on surface, some iron staining, pebbles mainly sub-angular

B53E

0.0	—	0.20 m	Silty sand, occasional pebbles
0.20	—	2.30 m	Cobbles, in matrix of pebbles, granules and sand; boulders in pit

B50AE

0.0	—	1.10 m	Coarse to medium sand, unsorted and unbedded
1.10	—	1.30 m	Coarse sand and pebbles, horizontal laminae
1.30	—	1.40 m	Clay horizon, with coarse granule laminae above and below
1.40	—	2.70 m	Coarse sand, occasional granules, indistinct horizontal bedding
		2.15 m	Very fine sand — silt horizon — associated with granule laminae above
		2.70 m	Clay horizon — with micaceous fragments (small sample), linear fissility defined by fine sand lenticles, some micas, 10YR 5/3 brown, non-calcareous

B50W — Airport

0.0	—	1.0 m	Pebbles and coarse granules (occasional cobbles) in matrix of very coarse and fine silty sand
1.0	—	2.0 m	Very coarse, coarse and medium sand, and granules, dense pebble concentrates at distinct horizons, horizontal bedding

Iron staining, some incrustations on undersides of pebbles and cobbles — which are mainly sub-rounded

B49W — North Wall (Leaf Rapids Corporation Pit)

0.0	—	2.0 m	Fine cobbles, granules and coarse sand, horizontally bedded
2.0	—	10.0 m	Coarse pebbles, with long axes parallel in matrix of granules and very coarse sand, some finer granule laminae, no calcareous constituents, few micas, matrix: 10YR 6/3 damp, pale brown

Coarse cobble fraction not sampled, between 11.5 — 64.0 cm, pebbles and cobbles mainly angular

B47W

0.0	—	0.20 m	Fine silty sand with granules, unsorted
0.20	—	0.55 m	Pebbles and granules, horizontal bedding
0.55	—	0.60 m	Granules, pebbles and fine silty sand
0.60	—	1.10 m	Coarse and medium sand, horizontal bedding, laminae 2 mm thick, graded, low mica content, no calcareous fragments (small sample)
		1.10 m	Very coarse sand, fine granule laminae, with medium sand layer below
1.10	—	1.35 m	Coarse to medium sand, trough cross-stratification, graded
		1.35 m	Coarse sand and granules, horizontally bedded
1.35	—	1.45 m	Medium sand, horizontally bedded, with some ripple drift cross-stratification, concentration of heavy minerals at base
1.45	—	1.90 m	Coarse to medium sand, occasional pebbles, horizontally bedded
1.90	—	2.10 m	Pebbles, coarse granules, some sand
2.10	—	3.40 m	Coarse to medium sand, some granules, discontinuous sand lenses, no calcareous constituents, few micas, 10YR 6/3 pale brown (small sample)
3.40	—	4.00 m	Pebbles, granules, some sand

B46E — Pit, mainly clay (see notes)

B45W2

0.0	—	2.0 m	Pebbles and cobbles in sand matrix
2.0	—	10.0 m	Cobbles and coarse pebbles, some in matrix of angular granules, fine pebbles, coarse to medium sand, open

B45W2 (cont)

work gravel, unbedded above, some horizontal bedding below, reverse grading, some micas

Cobbles too coarse to take representative sample — sizes between 14 cm — 64 cm unsampled

B45W1

0.0	—	1.0 m	Pebbles in silty sand matrix
1.0	—	2.0 m	Pebbles and coarse sand, no distinct bedding
2.0	—	4.50 m	Pebbles, very coarse to medium sand and granules, horizontal bedding, micas evident, section faulted on eastern margin

Pebbles mainly sub-rounded

B44E

0.0	—	1.20 m	Coarse to fine pebbles (unbedded) in medium to fine sand matrix
1.20	—	1.25 m	Medium to fine sand, horizontally bedded
1.25	—	1.30 m	Pebble and granule horizon
1.30	—	1.60 m	Medium to coarse sand, horizontally bedded
		1.60 m	Pebble and granule horizon
1.60	—	1.80 m	Medium to coarse sand, horizontally bedded
1.80	—	2.30 m	Unsorted pebbles, granules and coarse sand
2.30	—	2.60 m	Very coarse sand, some granules, horizontally bedded
2.60	—	3.00 m	Pebbles, granules and coarse sand, no distinct bedding

Pebbles mainly sub-rounded

391 Townsite A

0.0	—	0.58 m	Very fine sand and root material
0.58	—	5.00 m	Medium to fine sand, horizontal laminations, medium sand laminae < 1 cm at top of section, 2 cm at 1.20 m, associated with heavy mineral concentrations, high in micas, high in magnetite, 10YR 6/4 light yellowish brown, non-calcareous

detail:

1.15 m	Heavy mineral laminae, medium to fine sand, reverse grading
1.24 m	Heavy mineral laminae

B36W (east face)

0.0	—	1.16 m	Silty sand, with boulders on surface
1.16	—	2.00 m	Fine sand and cobbles, no bedding
2.00	—	3.00 m	Granules and very coarse sand, occasional pebbles, no distinct bedding auger refusal

No micas, matrix approx. 10YR 6/4 light yellowish brown to 6/6 brownish yellow, iron staining

B29W (north end of Turnbull Lake)

0.0	—	0.30 m	Angular boulders
0.30	—	0.50 m	Coarse sand, dipping northwards
0.50	—	2.10 m	Coarse sand and granules, horizontally bedded
2.10	—	2.80 m	Coarse sand, with pebbles and granules, horizontally bedded, some silt lumps found in section

No micas, some iron staining, pebbles mainly angular

Section — Mile 5 (east of roadside)

0.0	—	0.50 m	Pebbles and cobbles, in silty sand matrix, unsorted
0.50	—	2.30 m	Pebbles and cobbles in coarse sand matrix, unsorted, unbedded indistinct evidence of granule lenses

Sample very dusty because of proximity to surface, pebbles mainly sub-rounded

B17W

0.0	—	1.10 m	Cobbles and pebbles in fine silty sand matrix, unbedded, unsorted
1.10	—	3.20 m	Alternating granule and pebble layers, in matrix of medium sand, dipping downwards to north
3.20	—	3.40 m	Medium sand with coarse granules, no distinct bedding
3.40	—	3.70 m	Granules and pebble layer, alternately bedded in matrix of medium sand

Some micas, pebbles mainly sub-rounded

B16E

Surface area disturbed

0.0	—	2.20 m	Pebbles and granules, with occasional cobbles, compacted, in a silty sand and granule matrix, more cobbles below, unsorted, no bedding
2.20	—	3.00 m	Coarse and fine granule layers, 10 cm wide, with occasional cobbles and pebbles, layers dipping southwards, approx. 5°
		3.00 m	Auger refusal

Some mica, pebbles mainly sub-rounded

B13E

0.0	—	0.70 m	Fine sand, some indistinct laminations, non-calcareous, yellowish brown
0.70	—	1.00 m	Medium sand, horizontally bedded, greyish, some iron staining
1.00	—	1.30 m	Coarse and fine granules, some pebbles, unsorted
1.30	—	2.00 m	Fine granules and very coarse sand, horizontally bedded
		2.00 m	Bedrock

Some mica, general colour 10YR 5/4 — 5/6 yellowish brown

B9E

0.0	—	0.20 m	Soil, intermixed with granules, sand and organic debris, some iron staining
0.20	—	0.40 m	Coarse sand and granules, horizontally bedded
0.40	—	0.43 m	Pebble layer
0.43	—	0.85 m	Very coarse sand and granules, trough cross-stratification dipping down to east at 25°, truncated above by pebble layer, 7.5YR 6/5, wet, strong brown, non-calcareous, no micas
0.85	—	1.70 m	Very coarse sand and coarse granules, trough cross-stratification, dipping down to east at 14°, 10YR 5/4 yellowish brown, non-calcareous
1.70	—	3.50 m	Sand
3.50	—	3.60 m	Very coarse granules
		3.60 m	Pebbles and very coarse granules
			Auger refusal

Sub-rounded to sub-angular pebbles

B6W

Cobbles forming part of beach ridge accumulations

Surface cleared

0.0	—	1.0 m	Unsorted cobbles and pebbles, in a fine sand, silt and granule matrix
1.0	—	3.0 m	Pebbles, with granules, 8 — 10 cm granule layers, matrix of very coarse sand with finer granules
3.0	—	4.0 m	Unsorted cobbles and pebbles in matrix of granules and coarse sand

Non-calcareous concretions on underside of pebbles, some spheroidal weathering — iron oxidation, sample biased towards finer cobble sizes, true size of very coarse fraction between 15 cm — 75 cm, averaging 28 cm — 38 cm

CHURCHILL RIVER

Chur 51

0.0	—	0.10 m	Medium to fine sand, dirty
0.10	—	0.20 m	Granules and pebbles in fine silty sand
0.20	—	0.65 m	Pebbles, granules and coarse sand, some iron staining, 10YR 5/6 damp, yellowish brown, horizontal bedding demarked by pebble layers
0.65	—	1.10 m	Coarse sand and granules, with irregular pebbles

GRASS LAKE ESKER — NORTH

66-67, north

0.0	—	0.30 m	Peat, overlying silt and humus	
0.30	—	0.40 m	Silt layer	
		0.40 m	Clay layer	
0.40	—	0.90 m	Silt layer	
		0.90 m	Clay layer	Clay layers — micro laminations of
0.90	—	1.10 m	Silt layer	very fine silt, 2.5Y 4/2 dark grayish
		1.10 m	Clay layer	brown, moderately calcareous, carbo-
1.10	—	1.28 m	Silt layer	naceous material at base of clay, silt
		1.28 m	Clay layer	layers — unbedded, homogeneous,
1.28	—	1.53 m	Silt layer	strongly calcareous, 2.5Y 7/2 light grey
		1.53 m	Clay layer	
1.53	—	1.75 m	Silt layer	
1.75	—	2.30 m	Silt layer, with sand lenses	
		2.30 m	Clay layer	
2.30	—	2.33 m	Silt layer	
2.33	—	2.37 m	Sand layer	
2.37	—	2.69 m	Silt layer (small sample)	
2.69	—	2.71 m	Sand layer — undulating	
2.71	—	2.96 m	Silt layer (small sample)	
		2.96 m	Clay layer, silt above	
2.96	—	3.32 m	Silt layer	
3.32	—	3.34 m	Clay layer	
3.34	—	3.40 m	Silt layer	
3.40	—	3.52 m	Medium to fine sand, ripple drift cross-stratification, high mica content, moderately well-sorted, contains elongated silt inclusions, some angular granules, strongly calcareous, 10YR 7/3 very pale brown (small sample)	
			irregular contact	
		3.52 m	Pebble layer	
3.52	—	below	Pebbles, granules and very coarse sand, rounded and faceted fragments, contains carbonate fragments, some calcareous incrustation on base of fragments (small sample)	

66-67, south

0.0	—	0.30 m	Coarse sand, intermixed with soil
0.30	—	1.00 m	Medium to coarse sand, horizontally bedded slightly dipping towards south
1.00	—	2.00 m	Coarse sand and granules, cross-stratified sets, flow direction to SW
2.00	—	2.50 m	Coarse sand, granules and few pebbles

Hydro Road — traverse 4

0.0	—	0.20 m	Disturbed sandy material
0.20	—	0.50 m	Medium to fine sand and granules
		0.50 m	Interdigitating of beds
0.50	—	0.70 m	Very coarse sand and granules, some pebbles, indistinct horizontal laminations
0.70	—	1.50 m	Coarse sand, some granules and pebbles

B65AN

0.0	—	1.0 m	Medium cobbles and silty sand
1.0	—	9.0 m	Cobbles, pebbles, granules and very coarse sand, calcareous concretions, some iron staining

B65S

0.0	—	0.40 m	Silt layer
0.40	—	0.85 m	Very fine sand, some granules, dense, heavy mineral concentrations irregular contact
0.85	—	1.34 m	Very coarse sand, graded into granules below, calcareous rock fragments (small sample) irregular contact
1.34	—	1.50 m	Sand, medium scale cross-stratification
1.50	—	2.00 m	Very coarse sand, horizontally bedded 4.5 m of very coarse sand (obscured)
6.50	—	8.00 m	Pebbles and granules
		8.00 m	Very coarse pebbles

Section south of B65S

0.0	—	0.55 m	Grey silt
0.55	—	0.90 m	Sandy silt undulating contact
0.90	—	1.00 m	Fine sand, ripple drift cross-stratification, heavy mineral concentrations
1.00	—	2.00 m	Fine sand, horizontally bedded, heavy mineral concentrations, large micas, strongly calcareous, 10YR 7/3 very pale brown (small sample)

Section north of B63S

0.0	—	0.90 m	Very fine sand
0.90	—	1.00 m	Silt, calcareous
1.00	—	2.10 m	Fine sand, ripple drift cross-stratification
2.10	—	2.30 m	Silt, calcareous
		2.30 m	Very fine sand

B63S

0.0	—	1.30 m	Silt
1.30	—	1.50 m	Sand horizon in dipping bed
1.50	—	1.85 m	Fine sand, with irregular silt lenses
		1.85 m	Sand, indistinctive horizontal bedding

GRASS LAKE ESKER — SOUTH

Esker Lake A

0.0	—	0.50 m	Sand, occasional boulder (pebble sample)
0.50	—	1.50 m	Fine sand, some medium sand, very micaceous, faint horizontal laminations, shown up by heavy mineral concentrations — 0.5 cm thick, non-calcareous, 2.5Y 6/4 light yellowish brown
1.50	—	2.00 m	Medium to fine sand, auger refusal on hard surface

Esker Lake D

0.0	—	0.10 m	Soil horizon
0.10	—	0.50 m	Soil horizon — iron stained
0.50	—	0.80 m	Fine sand, indistinct bedding, non-calcareous, 10YR 6/3 pale brown
0.80	—	1.80 m	Fine sand, some silty lenses, very micaceous, non-calcareous, 10YR 7/3 very pale brown

Auger hole sloughed due to infilling by water

Esker Lake E

0.0	—	0.50 m	Iron stained, soil horizon, surface layer of pebbles and granules
0.50	—	0.90 m	Fine sand, non-calcareous, 10YR 6/3 pale brown
0.90	—	1.0 m	Granules overlying a frozen silt layer, concentration of very heavy minerals
1.0	—	2.80 m	Fine sand, very indistinct horizontal laminae, non-calcareous, 10YR 7/3 very pale brown (small sample)

Esker Lake F

0.0	—	0.20 m	Soil horizon
0.20	—	0.40 m	Sand, iron stained with pebble horizon (pebble sample)
0.40	—	0.95 m	Medium to fine sand, some coarse sand and rock fragments, very micaceous, no iron staining, non-calcareous, 10YR 7/4 dry, very pale brown (small sample)
0.95	—	1.0 m	Coarse pebble and granule layer, mainly crystalline rock fragments, one small limestone (pebble sample)
1.0	—	2.0 m	Very coarse sand, some medium sand and granules, medium scale cross-stratification evident dipping 22° southwards, calcareous constituents present as fragments and concretions (small sample)

Esker Lake G

0.0	—	0.50 m	Medium sand, unsorted, no obvious bedding
0.50	—	0.75 m	Granules and very coarse sand, some pebbles — well sorted (pebble sample)
0.75	—	1.0 m	Medium sand, some granules and rounded pebbles, few micas, non-calcareous, some iron staining Appears to be gravel below

Esker Lake H

0.0	—	1.0 m	Granules, pebbles and cobbles, very little sand, some calcareous concretions, fine cobbles concentrated at surface, silty matrix iron stained, 7.5YR 5/6 strong brown, no bedding
		1.0 m	Cobbles

Esker Lake I

0.0	—	0.30 m	Soil horizon, platy pebbles on surface
0.30	—	0.75 m	Very fine sand, iron stained, no bedding

Esker Lake I (cont)

0.75	—	2.50 m	Fine and medium sand, laminated, some heavy mineral horizons (small sample), few rock fragments, large mica flakes, iron staining particularly in coarser laminations, non-calcareous 10YR 5/6 yellowish brown, frozen horizon at 1.35 m
2.50	—	3.00 m	Medium to very coarse sand, very unsorted, non-calcareous 10YR 4/4 damp, dark yellowish brown

PENGUIN LAKE ESKER

Penguin Lake A

0.0	—	0.20 m	Soil horizon
0.20	—	1.80 m	Medium sand, some coarse fragments, few large micas, unsorted, some pebbles and granules, iron stained above, 10YR 5/6 wet, yellowish brown, non-calcareous (2 small samples — above & below)
1.80	—	4.0 m	Medium sand, graded at 4.0 m, clay bed inclusions — 0.5 — 2 cm diameter, highly calcareous clay

Penguin Lake B

0.0	—	0.30 m	Soil horizon
0.30	—	0.70 m	Fine sand, current bedded, some micas, iron stained, many calcareous fragments, 10YR 6/4 light yellowish brown (small sample — upper)
0.70	—	0.90 m	Clay, faint laminations, very calcareous 2.5YR 6/2 light brownish grey
0.90	—	1.00 m	Very fine sand, with silt aggregates, well sorted, strongly calcareous 5Y 7/2 light grey (small sample — middle)
1.00	—	1.30 m	Clay, massive
1.30	—	2.50 m	Fine sand, well sorted, many micas, strongly calcareous with carbonate fragments, 7.5YR 7/2 pinkish grey (small sample — lower)
2.50	—	4.75 m	Medium sand, some bedding

Pit augered from 2.50 m

Penguin Lake C

0.0	—	0.05 m	Pebble horizon (small sample)
0.05	—	0.90 m	Medium to fine sand, massive, non-calcareous 10YR 7/4 very pale brown
0.90	—	1.50 m	Fine granules and very coarse sand
1.50	—	1.70 m	Fine silt, non-calcareous 10YR 5/2 greyish brown
		1.70 m	Gravel (auger refusal)

Penguin Lake E

0.0	—	0.50 m	Soil horizon
0.50	—	1.50 m	Medium sand, indistinct bedding, non-calcareous, 10YR 5/4 yellowish brown
1.50	—	1.70 m	Clay layer (frozen)
1.70	—	3.70 m	Medium sand

Penguin Lake F

0.0	—	0.2 m	Medium to fine sand, some cobbles
		0.2 m	Cobbles, granules and sand (pebble sample)

RAT RIVER ESKER

Rat River 2-3 (pebble sample)

0.0	—	2.30 m	Clay, massive, non-calcareous 10YR 3/3 dark brown
2.30	—	2.35 m	Organic rich horizon, few pebbles
2.35	—	2.60 m	Sand and organic debris, few pebbles irregular contact
2.60	—	3.30 m	Fine sand, non-calcareous, few mica flakes, 10YR 7/6 yellow (small sample)
3.30	—	5.0 m	Fine silty sand, moderately calcareous, few micas, 2.5Y 7/2 light grey, interspersed with irregular clay lenses, comprising non-calcareous dark brown clay (small sample)

Rat River 3D

0.0	—	0.20 m	Soil horizon
0.20	—	0.50 m	Pebbles and granules, iron stained, non-calcareous (pebble sample)
0.50	—	1.0 m	Silty sand, well-sorted, non-calcareous, dark minerals evident, 10YR 6/3 damp, pale brown (small sample)
1.0	—	1.1 m	Clay horizon
1.1	—	1.5 m	Medium to fine sand, some coarser fragments, many micas, one granitic rock fragment, some fine silt aggre- gates, general colour 10YR 6/3 pale brown, moderately calcareous, especially in silt aggregates (small sample)
1.5	—	1.6 m	Clay horizon, weakly calcareous 10YR 6/3 light brownish grey
1.6	—	3.4 m	Coarse sand, non-calcareous, 10YR 4/4 dark yellowish brown

Rat River 4-1

0.0	—	0.20 m	Soil horizon
0.20	—	0.70 m	Pebble and cobble horizon
0.70	—	2.0 m	Very coarse sand, and irregular pebbles, unsorted. Indistinct laminations of coarser and finer sand, non- calcareous, 10YR 5/4 damp, yellowish brown
2.0	—	3.10 m	Very coarse sand, and gravel, colour becoming greyer with depth, auger refused in gravel

APPENDIX 3 — DRIFT LITHOLOGIES (a)

	Amphibolite	Amphibolite — Gneiss	Gneiss	Granodiorite	Pegmatite	Quartz Monzonite	Granite	Basalt	Chlorite Schist	Hornblende — Biotite Schist	Schist	Syenite	Diorite	Arkose	Greywacke	Chert	Quartz	Siliceous volcanic
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LEAF RAPIDS ESKER

B69E	6*	-	9	7	2	-	12	-	-	-	7	-	-	-	-	1	1	1
B67W	2	-	4	1	2	-	12	-	-	-	-	-	2	-	-	-	2	-
B66W	2	-	5	2	4	-	7	-	-	-	1	1	-	-	-	-	2	-
B60E	4	7	-	-	3	-	12	-	-	-	5	-	-	-	2	1	1	-
B59W2	4	-	5	-	3	-	9	-	1	-	-	-	1	-	2	-	-	-
B59W1	1	-	4	3	4	-	7	-	-	-	2	1	3	-	-	-	-	-
B55E	-	-	4	11	6	-	39	-	-	-	4	1	12	1	1	-	1	-
B53E	7	1	5	-	2	-	12	-	-	-	-	-	-	-	-	-	-	-
B50W	2	1	-	-	-	-	4	-	-	-	-	-	1	-	-	-	-	-
B49W	14	2	11	-	4	-	16	-	3	-	-	-	1	-	-	-	-	-
B45W2	8	-	-	1	2	-	15	-	-	-	3	2	-	-	-	-	-	-
B45W1	17	-	4	1	1	-	16	-	-	-	2	-	1	-	-	-	1	-
B44W	11	-	2	1	4	2	16	-	-	-	3	-	-	-	-	-	-	-
B29W	9	1	2	4	-	3	16	-	-	-	3	1	1	-	-	-	1	-
B17W	14	-	10	-	5	3	22	-	-	-	4	4	-	-	-	-	-	-
Mile 5	11	-	6	3	5	2	11	-	-	-	2	-	-	-	-	-	1	-
B16E	26	-	4	21	5	7	23	-	-	1	1	-	-	-	-	-	-	-
B9E	14	1	2	25	5	4	3	1	1	1	-	-	-	-	-	-	-	-
B6W	30	5	4	18	2	1	-	-	-	-	-	-	-	-	-	-	-	-

* numbers represent pebble count of each lithology within sample

APPENDIX 3 — DRIFT LITHOLOGIES (b)

	Amphibolite	Quartzite	Gneiss	Granodiorite	Pegmatite	Quartz Monzonite	Granite	Basalt, volcanic	Chlorite Schist	Hornblende Schist	Schist, Biotite Schist	Syenite	Diorite	Arkose	Greywacke	Granite-gneiss	Quartz	Metasediments
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Grass Lake — North

B65S	-	3*	1	6	-	-	10	-	-	-	-	-	-	-	-	1	-	-
B65AN	-	3	-	36	2	-	19	-	-	-	2	-	-	-	-	-	-	-
// 66-67 north	-	-	3	27	8	-	13	2	-	-	-	-	2	-	-	-	-	-
// 66-67 south	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Traverse #4	-	1	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Grass Lake — South

Esker Lake A	-	-	1	-	-	-	7	-	-	-	1	-	-	-	-	-	-	-
Esker Lake F	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Esker Lake G	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-	2	-
Esker Lake H	-	-	-	-	-	-	11	-	-	-	-	1	-	-	-	-	-	-

Penguin Lake Esker

Pit A	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-	-	-
Pit C	1	-	4	-	-	5	-	2	-	-	1	-	-	-	-	-	-	-
Pit F	-	-	2	18	1	-	-	6	3	2	6	-	-	-	-	-	-	1

Rat River Esker

Traverse I	-	-	9	42	4	3	-	1	-	-	-	-	-	-	-	-	1	-
Traverse II	-	-	-	27	9	-	28	10	-	-	-	-	-	-	3	-	1	-
Traverse III	3	-	-	22	15	10	4	-	-	-	-	-	-	6	-	-	-	-
B63S	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Karsak 101	-	-	-	-	-	-	3	9	-	-	-	-	-	-	-	-	-	-
Karsak 102	-	-	1	-	-	-	6	3	-	-	1	-	-	-	-	-	-	-
Hydro Road to Karsak	-	-	1	1	-	-	2	-	-	-	-	-	1	-	-	-	-	-
B60S	-	-	1	1	-	-	9	6	-	-	2	-	-	-	-	-	-	-

* numbers represent pebble count of each lithology within sample

APPENDIX 4 — HIGHWAY PIT DATA

A HIGHWAY 391

Pit Code	Composition	Cleared area	Average depth of excavation		Material removed	Additional information
B6W	Sand and gravel	28 637 m ²	1.0 m	x 24 979	35 954 m ³	Channel sample +
			3.0	x 3 658		
B7E	Sand and gravel	11 073	1.0		11 073	Stock pile
B8W	Sand and gravel	3 689	.5	(wt)*	1 844	
B9E	Sand and gravel	8 398	.5	x 5 984	8 883	Channel sample
			2.5	x 2 414		
B10W	Fine sand	4 547	.5		2 273	
B10AE	Fine sand; some pebbles					
	occasional boulder	9 994	±		—	
B10BW	Sand over clay; some boulders	1 749	.5		875	
B11E	Fine sand	11 755	2.0	(bd)*	23 510	
B12E	Fine sand; granules, pebbles	13 765	1.5	(wt)	20 647	
B13E	Sand; some pebbles	11 185	.5	(wt)	5 593	Channel sample
B14W	Fine sand; occasional granules and pebbles	8 166	.5		4 083	
B14AW	Silt over sand	5 990	.5		2 995	
B15W	Sand and silt	12 282	.5	(wt)	6 141	
B16E	Sand and gravel	4 658	.5	x 3 346	3 641	Channel sample
			2.5	x 525		
B17W	Sand and gravel	34 344	.5	x 33 556	19 691	Channel sample
			3.7	x 787		
B18E	Clay	5 695	.5	(wt)	2 847	
B19E	Clay	7 730	.5	(wt)	3 865	
B20W	Clay	12 054	.5		6 027	
B21E	Clay; varved, occasional pebbles, cobble, boulder	9 120	1.0	(wt)	9 120	
B22E	Clay; capping of sand & gravel	3 429	.5		1 714	
B23W	Clay; some fine sand	5 527	.5	(wt)	2 763	
B24E	Clay; varved, some pebbles and cobbles	12 849	1.5	(wt)	19 274	
B24AE	Clay; occasional boulder	1 732	.25	(wt)	433	
B25E	Clay; varved	9 017	.5	(wt)	4 509	
B25AW	Clay	2 829	.5	(wt)	1 415	
B26E	Clay; varved	8 116	.5	x 7 197 (wt)	3 599	
B27W	Silt and clay; varved	6 957	1.5		10 436	
B28E	Silt and clay; varved	9 448	.5	(wt)	4 724	
B29W	Sand and gravel	525	.6		320	Channel sample larger area cleared for recreation
B29AE	Sand; fine	8 655	.5		4 328	
B30W	Sand; fine, some cobbles	4 519	.5		2 260	
B30AW	Sand; fine	478	.5		239	
B31W	Sand and silt; some cobbles and boulders	8 456	.5		4 228	
B32E	Sand; fine	11 705	.5		5 852	
B34E	Sand; surface granules	16 271	—		—	
B36W	Sand and gravel	21 605	—		—	Channel sample
B42E	Sand and gravel	28 265	3.0		86 208	
B44E	Sand and gravel	13 826	5.2		71 688	Channel sample
B45W	Sand and gravel	39 366	3.3		19 852	2 Channel samples +
B46E	Clay over sand and gravel	3 569	.5	(wt)	1 785	
B46AE	Sand and gravel; some clay	19 539	.5	(wt)	9 769	
B47W	Sand and gravel	15 996	6.1		97 574	Channel sample
B47AW	Sand and gravel	6 404	2.0	x 5 459	10 918	
B48E	Sand; occasional cobbles	5 970	—		—	Camp
B49W	Sand and gravel	46 885	8.4	x 41 741	350 103	Channel sample + Leaf Rapids Corp. pit

+ , cobbles > 15 cm not samples

* (wt) , excavated to water table

(bd) , excavated to bedrock

+ — , cleared but not excavated

Pit Code	Composition	Cleared area	Average depth of excavation		Material removed	Additional information
B50W	Sand and gravel	7 086	5 m	x 6 829	3 963	Channel sample
B50AE	Sand; pebbles, clay	6 220	2.0		12 440	Channel sample
B51AE	Sand; surface boulders	2 446	—		—	
B52W	Sand and gravel	3 301	1.0		3 301	
B53E	Sand and gravel	2 459	1.5		3 750	Channel sample +
B54E	Sand; surface pebbles	6 354	.5		3 177	
B55E	Sand and gravel	5 304	8.0	x 1 024	8 188	Channel sample
B56AE	Clay	4 593	—		—	
B57E	Clay	4 080	1.0	(wt)	4 080	Stock pile
B57AE	Sand; surface boulders	1 450	.25	(wt)	362	
B58E	Sand; surface pebbles	1 590	2.0		3 181	Garbage dump
B59W	Sand and gravel	10 162	2.5		25 164	2 Channel samples +
B60E	Sand; cobbles and pebbles	3 078	.5		1 539	Channel sample
B60AE	Sand; cobbles, pebbles, granules	3 937	—		—	
B61E	Sand; surface cobbles	5 310	1.0		5 310	
B61AE	Sand; some cobbles, granules	5 686	1.5		8 530	
B62W	Sand; surface granules	3 107	.5		1 554	
B62AE	Sand and gravel	1 753	.25		438	
B62BW	Sand and gravel	1 457	—		—	
B63W	Sand; surface pebbles	4 881	.5		2 441	
B64W	Sand and gravel	4 064	—		—	
B65W	Sand and gravel	3 590	1.0		3 590	
B66W	Sand and gravel	5 014	2.6		12 999	Channel sample
B66AW	Sand; surface gravel	1 695	—		—	
B67W	Sand; pebbles and surface gravel	5 696	.5		2 848	Channel sample
B68E	Sand; surface gravel	7 062	.5		3 531	
B69E	Sand and gravel	6 539	4.3	x 3 793	16 196	Channel sample +

B RUTTAN LAKE MINE ROAD AND SOUTH BAY (HYDRO) ROAD

Pit Code	Composition	Cleared area	Average depth of excavation		Material removed	Additional information
B1N	Fine sand; some gravel	1 639 m ²	— m		— m ³	
B2N	Clay; varved, occasional boulder	10 747	.25	(bd)	2 687	
B3S	Clay; occasional boulder	9 842	.5	(wt)	4 921	
B3AS	Clay	6 102	1.0	(wt)	6 102	
B4S	Clay; occasional pebbles	17 721	.25	(wt)	4 430	
B4AS	Clay; rock rubble	3 941	—	(bd)	—	
B5N	Clay	5 536	.25	(wt)	1 384	
B6S	Clay; rock fragments occasional pebble	17 207	.5	x 14 447 (wt)	7 239	
B7N	Clay	13 543	.5		6 772	
B8S	Clay; some pebbles	8 693	.5	(wt)	4 347	
B9N	Clay; some cobbles	4 758	.25	(bd)	1 190	
B10N	Clay; rock fragments	5 102	.25	(bd)	1 275	
B11S	Clay; few granule-size stones	5 968	1.0	x 1 890 (wt)		
		14 216	.25	x 4 078	2 909	
B12N	Clay	14 216	.5	(wt)	7 108	
B13N	Clay; few pebbles	5 629	1.0	(wt)	5 629	
B14N	Clay; one boulder	1 298	.25	(wt)	324	
B15S	Clay; few boulders	7 819	.5	(wt)	3 910	
B16S	Clay; occasional pebble	5 897	.5		2 949	
B17N	Clay; some pebbles	4 841	.5		2 420	
B18N	Clay; varved, some pebbles	3 429	.5	(bd)	1 714	
B18AN	Clay; varved, surface pebbles	3 057	.5		1 529	
B19N	Clay; varved, pebbles, till, rubble	4 068	.5		2 034	
B19AN	Clay, some boulders, rubble	8 995	.25	(bd)	2 249	
B21S	Clay; boulders	4 435	.25	(wt)	1 109	
B21AS	Clay; varved, pebbles, boulders, rubble	5 220	.5	(bd)	2 610	
B21BS	Clay; boulders	3 602	.5	(wt)	1 801	Channel sample

Pit Code	Composition	Cleared area	Average depth of excavation		Material removed	Additional information
B22N	Clay; boulders, rubble	4 024 m ²	.5 m		2 012 m ³	
B23N	Clay; granule-size rubble	6 968	.5	(wt, bd)	2 959	
B23AN	Clay; boulders, rubble	7 777	.5	(wt)	3 888	
B24S	Clay; many boulders, much rubble	3 767	.25	x 2 717	679	
B25S	Clay; boulders	5 956	1.0	(wt)	5 956	
B26N	Clay; boulders	7 485	.25		1 871	
B27S	Clay; boulders	8 227	.25	(wt, bd)	2 057	
B29N	Clay; boulders, rubble	29 249	1.0	x 27 937 (wt)	27 937	
B30S	Clay; some rubble	12 707	.5	x 11 657 (wt)	5 829	
B31N	Clay; some boulders	2 395	1.0		2 395	
B32N	Clay over bedrock; drift cobbles, pebbles, granules	12 491	1.0	(bd)	12 491	
B33N	Clay; boulders, rubble	5 328	.5	x 3 182 (wt, bd)	1 591	
B33AN	Clay; boulders, some granules	16 980	.25	x 3 858	964	
B34AN	Clay	3 149	.5	(wt)	1 575	
B35S	Clay; much rubble	5 186	.25	(wt)	1 296	
B36N	Clay; some granules, pebbles, boulders	28 124	.25	(wt, bd)	7 031	
B37S	Clay; boulders, pebbles, sand, rubble	6 745	.5	x 6 679 (wt)	3 340	
B38N	Clay; boulders, rubble, some sand	12 845	.5	x 10 483	5 242	
B39N	Clay; pebbles, granules, some rubble	22 836	.25	x 19 476 (wt)		
B40S	Clay; rubble	3 316	.5	x 1 260 (wt)	5 499	
B41S	Clay; pebbles, granules, rubble	16 561	.25	(bd)	829	
B42N	Clay; some rubble	11 033	.5	(wt)	4 140	
B43S	Clay; boulders	3 281	1.0	(bd)	5 516	
B44S	Clay; occasional boulder	9 776	.25	(wt)	3 281	
B45S	Clay; little sand and gravel	23 626	.25	x 3 281 (wt)	2 444	
			.5	x 14 992 (wt)	19 024	
			2.0	x 5 354 (wt)		
B46S	Clay; varved, occasional boulder	6 072	.25	(wt)	1 518	
B46AN	Clay; boulders	7 842	1.0	(wt)	7 842	
B46BS	Clay	2 375	.25	(wt)	594	
B47N	Clay; some granules, fine sand	4 759	1.0	x 4 199 (wt)	4 199	
B52N	Clay	13 122	—		—	
B55N	Clay	32 149	1.0	(wt)	32 149	
B55AN	Clay; boulders	13 471	.5		6 736	
B56N	Clay; some pebbles, granules	18 305	1.0		18 305	
B57N	Clay; some boulders, pebbles	22 747	.5	(wt, bd)	11 373	
B58N	Clay; occasional pebbles	25 850	.5	(wt)	12 925	
B59N	Clay; some pebbles	14 205	.5		7 102	
B60S	Sand and gravel	19 377	.25	x 2 812 (bd)		
			.5	x 16 565 (wt, bd)	8 986	Channel sample
B61N	Sand and gravel	19 972	.5	x 16 298 (bd)		
			1.0	x 3 674 (wt)	11 823	Channel sample
B62N	Clay; boulders	78 732	1.0	(bd)	78 732	
B62AN	Fine sand	2 593	.25	(wt)	648	
B63S	Silt and fine sand	26 722	3.0	x 20 423	61 269	Channel sample
B63AN	Clay	1 096	.75	(wt)	822	
B65S(i)	Clay	13 794	.25	(wt)	3 448	
B65S(ii)	Silt over sand over gravel	3 464	5.0		17 321	Channel sample
B65AN	Sand and gravel	30 915	1.0		30 915	Channel sample +
B66S	Clay	9 613	—		—	Stock pile
B66AS	Clay	3 013	1.0	(wt)	3 013	
B67N	Clay; few pebbles	3 385	.25		846	
B67AN	Clay	12 197	1.5	x 10 360 (wt)	15 540	
B67BS	Clay, few pebbles	10 944	.5		5 472	
B68S	Clay; varved	4 724	1.0		4 724	

APPENDIX 5 — RESISTIVITY SURVEY

Prospecting for sand and gravel deposits using resistivity methods is based on electrical potential theory. The current, derived from a point source, is impressed artificially into the ground and the effects of this current on or within the ground are obtained by measurement of potential, difference of potential, ratios of potential differences or some parameter directly related to these variables. The difference in the alternative methods of direct current prospecting lies in the number and spacing of the current and potential electrodes employed and the variable electric quantity determined (Van Nostrand and Cook, 1966, p. 27).

Resistivity is a fundamental property of material (similar to density), is independent of material shape or size and is represented by:

$$\rho = RA/L \text{ where } \begin{array}{l} R = \text{resistance} \\ A = \text{cross-sectional area} \\ L = \text{length} \end{array}$$

The reciprocal of resistivity, $1/\rho$ = conductivity.

This is considerably influenced by the presence of mineralized water in pores and fissures.

Apparent resistivity measurements are obtained, because of unknown influences. The apparent resistivity of a 4 electrode configuration C1, C2, P1 and P2 as applied to the Wenner configuration is:

$$\rho_a = 2\pi \frac{V}{I} \cdot \frac{1}{\frac{1}{r_1} + \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}}$$

Where ρ_a = apparent resistivity, r_1 = difference between C₁ and P₁
 r_2 = difference between C₂ and P₁
 r_3 = difference between C₁ and P₂
 r_4 = difference between C₂ and P₂
 V = voltage
 I = current

A portable Bison 2035A instrument was used with electrode spacing forming the Wenner configuration. This configuration has proven most popular for shallow work in North America and it has been found to be the most useful configuration when testing for gravel deposits.

In this study, a resistivity system was used to determine the apparent depth of gravel in granular deposits and apparent water table and/or frost level.

Readings were taken over clay to determine the depth and nature of underlying sediment. The results are listed in the accompanying table.

A Wenner configuration was used, employing a 1.5 metre outer electrode spacing, and apparent resistivity determinations were obtained to an assumed depth of approximately 20 metres. Plate 19A shows the equipment used and the type of material involved. Dry, hot sunny conditions were typical of the weather encountered during the survey. The dryness and coarseness of material account for excessively high readings in a number of cases.

APPENDIX 5 — RESISTIVITY RESULTS (OHM-METRES)

DEPTH (METRES)	PROFILES																			
	1a	1b	1c	2a	2b	3a	3b	4a	5a	5b	5c	6a	6b	6c	6d	6e	7a	7b(i)	7b(ii)	7c
1	-	4818	-	8963	-	-	-	-	-	10000	-	-	-	-	48.4	23.9	5980	24.1	22.6	-
2	-	2620	-	12160	-	15800	-	18220	12580	19350	18600	11100	-	-	112.2	58.2	12060	35.6	36.8	-
3	-	1068	-	11901	21180	13890	-	19410	19020	3660	13560	7650	-	22080	207.0	55.2	14550	47.1	50.1	12300
4	7200	652	31816	11360	16440	15680	39120	36900	20000	-	13080	4440	32840	21200	298.4	72.0	12200	64.0	63.2	12640
5	3800	2060	32000	10000	13100	16500	34650	34800	30000	10650	9750	3135	31375	15750	414.5	87.5	10100	79.0	80.5	12850
6	1872	1800	27720	7800	10800	15420	28500	28920	14200	3324	6480	2634	29700	12180	543.0	105.60	10020	99.0	100.2	10080
7	1099	2534	25200	7140	9100	11760	21210	29260	14995	3500	2534	2660	32200	12320	679.7	123.55	10150	121.0	125.3	7630
8	4928	120.80	26680	6888	8720	12000	14560	32080	17680	21680	4240	2376	30720	10000	836.0	144.00	10800	142.4	143.2	6320
9	4248	1035.00	22356	5004	6678	10890	13320	28980	16200	18000	3060	2025	28575	7470	990.0	166.05	10710	171.0	168.3	6894
10	296	351.00	25650	4140	7500	8700	12600	28800	18000	10000	2980	2250	22500	6250	1140.0	190.00	9200	205.0	190.0	6750
11	150.70	607.20	24794	4510	10175	2596	10032	25520	18700	979	4268	2332	21780	4708	1309.0	213.40	9900	233.2	215.6	6468
12	45.12	1260.00	19356	3396	8352	6444	6360	22320	19200	114	2952	2268	18240	3936	1452.0	237.6	9516	252.0	240.0	5856
13	94.90	715.00	18421	3796	7371	4992	7124	18200	22360	2743	3718	2145	20670	3341	1652.0	257.4	8853	245.7	269.1	3146
14	225.40	1370.60	21000	2912	7840	3612	6916	14420	21700	6342	2786	2688	22200	3262	1771.0	281.4	10612	161.8	299.6	6272
15	181.50	431.25	16200	2790	6960	3150	5010	12495	21000	6150	4995	2445	20850	3825	1897.5	307.5	9180	274.5	327.0	4500
16	63.68	1140.80	17280.0	2080	6240	3360	3456	16480	20000	2080	4640	2832	19520	3488.0	1064.0	328.0	9248	284.8	353.6	4432
17	64.00	-	16340.4	1938	6630	1620	2975	17510	16286	3655	-	2890	18530	955.4	2210.0	355.3	8483	-	377.4	4981
18	54.00	-	15462.0	3870	3024	1200.0	-	11520	16290	5310	-	2610	17820	1150.2	2358.0	378.0	8694	311.4	405.0	3006
19	283.10	-	15830.8	3705	6688	366.7	-	12179	18570	6745	-	3040	17575	-	2489.0	372.4	9017	336.3	438.9	2850
20	316.00	-	12300.0	3400	-	1418.0	-	10860	20000	7260	-	2740	16420	1260.0	2560.0	386.0	9660	340.0	-	-

APPENDIX 5 — RESISTIVITY RESULTS (OHM-METRES) — (Cont.)

DEPTH (METRES)	PROFILES																			
	7d	7e	9a	9b	9c	9d	10a	10b	11a	12a	12b	12c	13a	14a	15a	15b	16a	17a	17b	18a
1	6430	-	-	250.0	-	-	1660.0	-	-	10000	-	-	2.66	6270	-	-	531	3960	3350	33.8
2	14200	-	13960	598.0	18430	20000	61.4	-	13140	7080	-	15400	13.52	8240	-	6080	1040	4000	4080	29.2
3	12390	17790	14910	755.4	20340	23100	91.2	26010	15840	8340	-	7350	9.00	20550	-	3750	1545	4560	2052	40.8
4	12160	15960	12960	920.0	18920	24640	117.2	29280	17040	7680	24680	14800	16.00	7240	16200	4000	1988	3352	3340	58.4
5	8250	16000	14575	970.0	20150	21950	120.0	30650	18350	7550	25050	5450	27.50	8200	12700	4325	2495	4315	4365	76.5
6	6480	17820	14460	1020	18600	19040	170.4	26280	21420	2196	24840	18180	168.00	3228	4728	5280	3054	3870	3852	96.0
7	5992	12180	12320	1050	18550	17570	250.6	29120	21490	4522	18060	8540	140.00	7000	7910	5215	3745	4417	4151	118.3
8	2776	11200	12000	1088	17200	15200	265.6	28320	19520	3088	14320	14480	176.00	6240	9040	5520	4280	3040	4056	141.6
9	1494	11340	11700	1134	15930	10530	298.5	25650	18630	2313	13320	10260	40.5	7803	8163	6291	4797	2592	3348	167.4
10	4440	7290	11900	1120.0	14300	10000	334.0	22500	20000	2570	12200	15500	58.0	7160	5920	6320	5260	2420	2800	187.0
11	5225	7711	11550	1138.5	13090	11550	335.5	20400	22440	20460	13040	8690	-	8030	6094	6160	5511	2310	2871	204.6
12	4140	5832	10800	1147.2	12480	9600	350.4	21120	24600	9168	13680	9696	-	8400	16080	6204	5952	2784	2484	228.0
13	3146	5798	10270	1099.8	10504	9074	445.9	20800	27170	299	17680	9126	-	8216	7462	5837	6227	2171	2080	248.3
14	3752	5586	9828	1104.6	11368	7672	434.8	17360	13552	-	17640	5124	161.00	7308	5978	7574	6566	217.0	1890	273.0
15	2025.0	4755	8475	1183.5	11160	6406	406.5	20250	1130	-	12510	8805	300.00	7650	2190	7800	6960	349.5	3045	291.0
16	1107.2	4880	8272	1132.8	9648	6336	336.0	16480	13968	-	9632	5456	448.00	8480	1824	8512	7168	1632.0	2460	313.6
17	3791.0	3927	8279	1094.8	9265	5446	528.7	17680	13039	8075	8041	8330	374.0	8126	4182	8772	7463	1853.0	3094	334.9
18	-	2844	7776	1049.4	-	5264	469.8	19620	10404	6660	13320	8406	45.0	7596	3348	7920	7596	1423.8	2808	363.6
19	-	3857	7790	912.0	8056	5246	475.0	14250	10710	5700	13585	12920	85.5	7106	4560	7904	7657	1153.3	3363	366.7
20	-	3260	7640	872.0	5300	4626	490.0	16340	12400	4880	10420	9040	44.0	8560	2920	8900	7640	1504.0	2680	390.0

Interpretation of Results:

A basic assumption underlying the interpretation of most electrical earth resistivity surveys is that subsurface layers are nearly horizontal. This may apply also to dipping or contorted gravel located above the local water table, such as frequently occur in glaciofluvial deposits as these deposits have similar moisture contents for the different layers and thus exhibit similar resistivity, irrespective of their non-horizontal nature.

The interpretation of resistivity data in this area is based on assumed 1 — layer and 2 — layer models. The 2-layer model requires dry granular material over moist sand, clay or clay-rich till with a recognizable water table. The 1-layer model requires a homogeneous clay or clay-silt bed.

At Resistivity Station 1 (RS1 on Map B) two of these determinations show close correspondence with the layer models. At this location, sand and fine granules were known to overlie lacustrine clay and the static water level was noted in nearby pits. The results of profiles 1a and 1b may be interpreted generally as:

0 — 5.0 m	sand with granules
at 5.0 m	water table
5.0 — 20.0 m	saturated sand or clay

Determinations from Section 1c were excessively high, possibly due to the coarseness and dryness of underlying material.

Very high readings were also obtained at Station RS2 (Deposit 8), a high gravel ridge. The determinations indicate granular material to approximately 20 m with water level 5.0 — 7.0 m below ground surface. Fluctuations in the readings are thought to result from poor electrode contacts, a difficulty encountered when inserting the electrodes through surface cobbles.

At RS3 (Deposit 7) lower apparent resistivity results were obtained from a series of gravel ridges. The material is assumed to consist of interbedded sand and gravel, with water between 8 and 14.0 m below ground surface.

Station 5 comprises three sets of results taken on the eastern Leaf Rapids esker margin, in Deposit 6. The following generalized profile was interpreted from two of the three readings.

0 — 6.0 m	sand and gravel
at 6.0 m	water level
8.0 m — 20.0 m	frozen or water logged clay

At Station RS6, a series of resistivity profiles were taken from the Churchill River to the Leaf Rapids airstrip, in Deposit 6. At 6a, 3 m of coarse material (gravel) is interpreted as overlying clay on the eastern edge of the esker. The results of profile 6b were excessively high reflecting, if anything, the coarseness of material at this location. Profile 6c indicates coarse, granular material present to about 5.0 m with gradually decreased grain size and/or an increased moisture content at depth. There is some indication of additional coarser material at between 15 and 16 m below ground surface. Profiles 6c and 6d show gradual increases in resistivity with depth. On the surface, the material is predominantly clay, and the readings, between 250 — 2500 ohm metres are regarded as being extremely low. The curves are interpreted as representing a uniform clay bed, with no indication of the bedrock clay contact. The increase in resistivity readings with depth may indicate a lack of moisture or suggest a high degree of clay compaction with increasing depth.

RS7 refers to a similar series of transverse profiles taken across the esker in Deposit 5. Profile 7a was recorded by the highway and the results indicate 2 to 3 m of coarse granular material overlying finer material, possibly sand or clay. This is illustrative of the beach-ridge type stratigraphic configuration, where surface gravel overlies thicknesses of bedded sand containing intermittent pebbles. Profile 7b is off the esker, and the results suggest a typical 1-layer clay profile. Readings 7d and 7e were taken in pit B44E towards the edge of Deposit 5. The results indicate that coarse granular material may extend between 3.0 and 5.5 m below the ground surface. The water table is evident at 8.0 m, with additional granular material at depth between 9.5 and 13.5 m.

Resistivity readings were taken around Turnbull Lake (RS9), as the Leaf Rapids esker intersects the lake from north to south. On the southern peninsula (9a, 9c and 9d) sand was encountered to an assumed depth of 9.0 m with moist or finer material becoming prevalent below 9.0 m. The depth of the static water level is assumed to be between 9.0 and 10.0 m. At 9b on the western margins of the lake, initial low readings suggest up to 3.0 m of clay, overlying coarser sand and possibly till. The very low readings suggest moist conditions.

Resistivity profile 10a was taken on the southern edge of B17W in Deposit 2 and is interpreted as containing 2.0 m gravel, a water table at 2.0 m and possibly clay or till below. Station 10b was at Mile 5 on the crest of the esker. The initially high readings indicate up to 9.0 m of gravel at this location. The water table appears at 10.0 m, below which is an indication of finer sediment with depth.

Profile 11a in Deposit 1 (B16W) is on the crest of the Leaf Rapids esker. The results suggest up to 10.0 m of gravel, with an assumed water table at 14.0 m below which is finer material, possibly clay or clay-rich till.

A series of three readings were derived from Deposit 1 at RS12, through the most significant esker-delta complex in the area. However, profiles 12a and 12c were too erratic to interpret due to extreme dryness and coarseness of the sediment and the cobble/electrode contacts. 12b suggests up to 7.0 m of coarse, granular material may be present with evidence of the water table at 10.0 m. Below the water level are possibly two more coarse granular beds, between 13 — 15.0 m, and 18 — 19.0 m. Hence there appears to be a total of about 12.0 m of coarse gravel in this deposit.

Other readings were taken, mainly on gravel deposits, along the South Bay Road. Station 14 was an attempt to indicate the thickness of sandy till (at B61N) over bedrock. The results were generally too erratic to interpret. Bedrock features in the vicinity suggest the proximity to surface of the drift/bedrock contact, and one exceptionally low reading (3228 ohm — metres, whereas the majority of readings fall between 7000 — 9000 ohm — metres) may suggest that the contact is around 6.0 m (Deposit 9).

Profile 15a was taken on the eastern edge of pit B63S, in Deposit 11. Results suggest the exposed interbedded sand and silt persists to a depth of 5.0 m. The water table may be found at 6.0 m below ground surface. Below the water level the readings indicate fine sand continuing to 14.0 metres beyond which silt or clay may be prevalent.

Station 16a was on the high silt banks of Deposit 10. The resistivity readings increase with depth. The lower values correspond with surface silts to a depth of 6.0 to 7.0 m, below which coarser sand (or sand and gravel) is assumed to be prevalent, judging by the stratigraphy in similar exposed sites in the vicinity.

The readings of RS17 were taken along the South Bay Road on the crest of the Grass Lake esker (Deposit 10). Profile 17b suggests there may be up to 1.5 m of coarse granular material above the water table which is at 4.0 m. There may be an additional 3.5 m of coarse sediment below the water table.

RS18 was taken on a predominantly lacustrine clay area. The uniformly low readings suggest a uniform clay bed to 20.0 m.

Data derived from resistivity survey results have been used with depth of deposits as determined from exposures and drill log information to determine deposit depth and, therefore, quantity of gravel in any given deposit. (See Table 2 in evaluation section of this report.)

APPENDIX 6 — ENGINEERING CHARACTERISTICS OF SEDIMENTS

The engineering characteristics are considered necessary to determine the suitability of land for planning purposes. These are general properties, (following Larsen, 1973), pertinent to the different sediment types as described in the report. Engineering terms used in the accompanying table are described as:

Water Content:

Low	(less than 10% dry weight of sample)
Medium	(10% - 25% dry weight of sample)
High	(greater than 25% dry weight of sample)

U.S.C.S. Classification and Plasticity Index — See PCA Soil Primer, Portland Cement Association, Chicago, 1962, p. 27 or Larsen, 1973.

Strength:

	Unconfined Compression	Blow Count for 12" Penetration
Soft	0.25-0.5 tons/sq. foot	2-4
Stiff	1.0 -2.0 tons/sq. foot	8-15

Sensitivity:

	Ratio Natural Strength/Remoulded Strength
Insensitive	1
Slightly sensitive	1-2
Very sensitive	4-8

Permeability:

	cm/sec	(Gallons/Day/ Square Foot)
Good	Gravel $10^{-2} - 10^{-3}$	$10^2 - 10$
	Sand $1.0 - 10^{-2}$	$10^4 - 10^2$
Poor	$10^{-3} - 10^{-6}$	$10 - 10^{-2}$
Practically impermeable	$10^{-6} - 10^{-8}$	$10^{-2} - 10^{-4}$

Frost Susceptibility: tendency to heave or swell from formation of ice

F1 — Negligible to low

F4 — Very high

Compressibility: tendency to settle under increased load

Low compressibility — greatest expected settlement
measured in fractions of an inch

High compressibility — greatest expected settlement
measured in inches

Erodability is classified as:

High erosion factor — much erosion by wind or water
anticipated on unvegetated slopes

Low erosion — little erosion anticipated in clay

The clay is susceptible to slumping at lakeshore locations and gulleying down non-vegetated slopes (e.g. in burrow pits).

Excavatability is related to the type of equipment required to handle material in construction. Most of the Leaf Rapids surficial deposits can be handled by common excavation methods. The kind of equipment necessary includes: scraper tractors, front-end loaders and backhoes.

Slope is a descriptive term denoting the vertical rise per 100 feet horizontal distance predominating in each unit as defined by the U.S. Department of Agriculture:

Slope	% Grade
Nearly Level	.5
Very gently sloping	.5 — 2
Gently sloping	2 — 4
Moderately sloping	4 — 7
Strongly sloping	7 — 12
Moderately steep	12 — 18

APPENDIX 6 — ENGINEERING CHARACTERISTICS OF SEDIMENTS

69

<u>Surface sediment type</u>	<u>Water content</u>	<u>U.S.C.S. Classifi- cation</u>	<u>Plasti- city Index</u>	<u>Strength</u>	<u>Sensi- tivity</u>	<u>Permea- bility</u>	<u>Frost suscepti- bility</u>	<u>Compress- ibility</u>	<u>Erod- ability</u>	<u>Excavata- bility</u>	<u>Slope (%)</u>
Sand and gravel (3)	Low	GW	—	—	Insensi- tive	Good	F1	Low	High	Common	12-18
Sand (5a, 5b)	Low	SW-SM	—	Soft	Slightly	Good	F1	Low	High	Common	2-4
Clay (4)	Medium — High	CH-OH	20-60	Stiff	Very sensitive	Practically imperme- able	F4	High	Low	Common	0.5-2
Organic Soils (7)	High	Pt.	—	Soft	—	Poor	—	—	—	Common	0.5

APPENDIX 7 — PHYSICAL ANALYSES — SAND AND GRAVEL

	B6W	B9E	B13E	B16E	Mile 5 Roadside	B17W	B29W	B38W	Townsite A	Chur 51	B44E(W)	B45W1	B45W2	B47W	B49W	B50W	B50AE	B53E	B55E	B59W1	B59W2	B60E(W)	B66W	B67W	B68E	B69S
SIEVE SIZE	WEIGHT RETAINED																									
4"	23.18	-	-	-	7.06	-	12.13	-	-	-	-	25.61	-	-	13.06	-	-	14.60	6.70	-	8.55	10.83	18.86	-	7.69	-
3 3/4"	-	-	-	18.43	4.81	-	-	-	-	-	-	-	-	-	-	-	-	9.23	4.44	-	-	5.10	-	-	14.70	-
3"	5.18	-	-	7.18	3.71	-	-	12.06	-	-	-	-	-	-	-	-	-	3.10	4.58	2.08	3.26	-	-	9.13	3.57	-
2 1/2"	3.94	-	-	5.79	9.46	4.95	-	7.98	-	-	-	2.32	8.24	-	8.24	2.78	-	7.30	4.44	4.76	7.60	3.64	-	-	1.82	8.95
2"	4.10	-	-	5.79	16.64	7.02	1.72	10.91	-	3.11	4.61	4.51	5.09	5.56	2.27	4.24	1.34	4.68	3.64	2.11	4.73	8.60	-	-	5.64	7.3
1 1/2"	4.75	1.29	-	7.05	5.73	3.78	.86	2.58	-	1.38	4.74	4.56	10.18	4.07	3.14	7.54	36	6.19	6.99	4.81	5.21	2.93	5.81	2.37	2.75	4.42
1"	12.70	1.28	-	8.97	7.92	5.98	1.30	5.43	-	2.42	6.81	7.28	6.92	12.13	4.00	8.06	66	6.58	8.66	10.21	4.63	4.66	2.84	4.50	6.51	3.20
3/4"	47	25	-	2.76	1.06	11.19	0.11	1.18	-	1.16	1.41	54	92	1.53	1.39	1.65	24	1.19	1.35	1.20	4.85	1.55	55	85	1.11	84
1/2"	4.70	.09	-	1.52	1.70	7.99	.18	1.00	-	54	40	1.21	40	1.51	.30	1.10	-	36	82	1.51	.75	.37	2.15	.92	.94	6.58
5/16"	1.87	-	-	5.05	2.42	8.10	-	4.57	-	3.02	1.40	1.04	4.66	.11	1.06	1.18	3.66	2.26	45	3.91	.76	1.16	.04	-	4.39	1.34
1/8"	2.29	-	-	4.48	2.17	6.90	.83	3.53	-	5.55	4.03	1.36	2.88	1.63	1.12	1.71	1.33	3.23	.15	3.82	5.59	1.90	1.77	1.09	2.01	1.69
3/16"	2.11	31	-	4.61	4.10	8.48	.43	1.70	-	3.11	2.69	.85	3.07	.34	2.26	2.33	1.17	2.25	27	2.52	4.54	1.96	1.58	3.37	2.29	5.85
1/4"	2.56	90	74	3.63	3.78	9.03	.88	3.05	-	5.88	5.03	3.02	4.96	2.56	2.99	5.84	1.17	3.07	41	4.08	8.43	1.45	1.11	3.99	2.02	7.03
#4	3.74	97	51	2.54	3.28	4.91	1.79	2.26	0.0	5.01	4.18	2.20	3.34	2.35	2.98	4.39	1.33	2.86	.52	4.35	6.60	1.38	1.38	2.24	1.10	4.78
#8	8.22	4.04	5.22	5.15	10.32	8.59	5.62	5.89	.002	12.21	9.80	9.40	10.73	4.70	14.00	16.27	7.13	8.17	2.09	15.77	15.92	3.08	2.72	6.12	2.99	10.11
#10	1.88	1.96	2.31	1.15	2.50	1.29	3.03	1.81	.002	3.33	3.25	3.59	3.57	1.50	4.53	4.88	2.88	2.15	.55	4.90	3.40	1.26	1.09	1.58	.98	2.14
#16	5.26	14.53	14.80	3.14	5.46	2.42	20.29	6.70	.131	12.58	13.46	14.15	12.46	7.77	12.16	14.88	13.72	6.97	3.50	14.34	7.79	4.68	4.68	6.32	4.92	7.49
#30	5.14	25.06	33.29	3.69	3.66	2.22	29.66	7.60	3.515	19.26	22.48	12.29	9.43	23.09	9.88	14.31	20.23	7.65	27.95	11.77	3.67	14.54	10.79	11.76	13.07	11.94
#40	2.03	10.31	12.47	2.52	1.26	1.60	8.73	3.41	10.69	8.53	8.37	3.16	2.04	17.27	3.22	3.71	10.49	2.55	14.61	3.04	.80	13.54	11.60	11.18	8.75	7.35
#50	1.15	8.82	7.43	1.44	.57	1.17	4.31	2.77	17.67	5.56	3.09	1.06	.62	7.66	1.33	1.50	7.62	1.17	4.54	1.30	.36	7.17	13.65	12.74	5.51	4.74
#80	1.52	19.12	11.91	1.71	.61	1.27	4.71	5.76	41.46	5.60	2.80	.87	50	4.63	1.41	1.49	13.27	1.41	2.36	1.42	.45	5.50	15.63	16.17	4.43	4.03
#100	35	3.75	2.39	38	13	27	.76	1.59	7.94	53	42	19	.08	.52	.32	.28	2.63	.36	.22	.31	.13	.80	1.54	2.64	.64	.47
#200	91	5.86	5.10	1.00	.34	.63	1.24	4.81	16.63	60	45	38	23	.55	.82	.63	5.46	.93	.30	.74	.45	1.79	1.48	2.57	1.09	1.30
▲ #200	1.95	1.46	3.83	1.39	1.31	2.21	1.42	3.41	1.96	62	58	41	1.37	.52	1.51	1.23	5.31	1.74	.46	1.05	1.53	2.11	.73	.46	1.08	5.02
% Gravel	71.59	5.09	1.25	78.43	84.16	78.33	20.23	56.25	0	31.18	35.30	54.50	58.97	31.79	50.82	40.82	11.26	66.90	43.42	45.36	65.50	45.53	36.09	28.46	56.54	45.41
% Sand	26.46	93.45	94.92	20.18	14.53	19.46	78.35	40.34	98.04	68.20	64.12	45.09	39.66	67.69	47.67	57.96	83.43	31.36	56.12	53.59	32.97	52.36	63.18	71.08	42.38	49.57
% Silt	1.95	1.46	3.83	1.39	1.31	2.21	1.42	3.41	1.96	62	58	41	1.37	.52	1.51	1.23	5.31	1.74	.46	1.05	1.53	2.11	.73	.46	1.08	5.02
Fineness Modulus	7.08	2.60	2.56	7.36	7.30	6.63	4.24	5.81	1.17	3.78	4.70	6.49	6.37	4.37	6.23	5.31	2.96	6.97	5.43	5.53	6.62	5.31	4.61	3.95	6.11	4.98
% Loss on Washing	3.46	.98	2.86	2.78	2.73	2.7	1.43	4.04	.95	.51	.61	.96	2.12	.61	2.05	1.42	4.75	3.28	.70	1.12	2.06	2.81	.86	1.01	1.55	5.39
Organic Impurities																										
Colour Value	5	2	3	4	5	4	3	4	2	4	1	4	1	3	1	3	2	5	1	3	5	5	4	4	5	5

APPENDIX 7 — PHYSICAL ANALYSES — SAND AND GRAVEL (Cont.)

	B6N	B6S	B65AN	66-67 North	66-67 South	B6S	Traverse #4	Esker A	Esker D	Esker E	Esker F	Esker G	Esker H	Esker I	Esker J	Penguin A	Penguin B	Penguin C	Penguin E	Penguin F	Rat #2	Rat #4-1
SIEVE SIZE	WEIGHT RETAINED																					
4"	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 1/2"	-	4.18	12.92	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3"	-	-	5.94	4.60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.13	-	5.76
2 1/2"	13.70	-	4.71	2.31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.27	-	-
2"	2.01	2.41	6.70	2.84	-	-	-	-	-	-	-	2.49	4.16	-	-	-	-	-	-	10.67	-	-
1 1/2"	2.05	1.33	7.43	4.72	-	-	1.04	-	-	-	-	3.08	12.78	-	-	-	-	-	-	6.92	-	-
1"	2.87	1.68	9.59	3.50	0.96	-	1.25	-	-	0.51	-	6.53	2.47	-	-	-	-	-	-	6.16	-	2.15
3/8"	0.44	0.52	0.71	1.00	-	-	0.16	-	-	-	-	0.71	0.45	-	-	-	-	-	-	1.12	-	0.37
3/4"	0.47	0.06	0.63	0.57	-	-	0.17	-	-	-	-	0.31	0.28	-	-	-	-	-	-	0.32	-	0.15
1/2"	-	2.53	3.13	4.77	-	-	-	-	-	-	-	1.51	-	-	-	-	-	-	-	2.90	-	2.02
1/4"	0.63	0.77	2.00	1.23	-	-	-	-	-	0.82	1.86	1.97	-	-	-	-	-	-	-	3.63	-	-
3/16"	1.15	2.10	2.30	3.96	-	-	0.24	-	-	0.41	1.38	3.87	-	-	-	-	-	-	-	3.17	-	0.32
1/8"	2.18	4.07	5.58	5.90	0.07	-	1.21	0.282	-	0.43	3.94	6.26	-	0.27	-	-	-	0.34	-	5.02	0.08	0.92
#4	1.97	4.72	4.05	4.22	0.04	0.0	0.63	-	-	0.09	0.43	4.27	6.86	0.60	-	-	-	0.63	-	2.63	0.46	1.39
#8	5.38	18.53	10.31	15.74	1.54	0.008	3.67	0.002	0.07	0.20	3.73	16.00	20.79	0.34	0.06	0.15	-	2.71	0.06	6.47	1.74	5.14
#10	0.96	5.15	2.56	6.47	1.14	0.002	1.18	0.002	0.04	0.10	3.61	5.04	5.31	0.19	0.01	0.08	-	1.41	-	1.66	1.27	2.29
#16	3.72	16.40	6.79	23.25	12.54	0.02	6.52	0.002	0.21	0.36	24.42	14.25	12.92	2.66	0.03	1.59	0.01	8.22	0.18	5.54	8.84	22.07
#30	5.40	17.41	6.14	11.41	50.86	1.15	49.95	0.282	0.37	0.94	21.11	11.82	9.52	20.87	0.38	12.45	2.90	13.32	32.55	5.66	17.71	40.42
#40	5.20	8.18	2.15	1.10	19.15	9.66	26.18	2.34	0.69	1.58	9.35	6.39	3.57	18.92	1.18	32.43	13.13	6.24	36.53	3.97	18.71	8.29
#50	8.70	3.58	1.10	0.16	7.25	27.25	7.26	7.58	2.11	2.96	11.84	4.78	1.83	12.78	3.53	23.67	28.42	8.86	13.38	5.15	14.29	2.73
#80	25.50	3.62	1.32	0.04	4.11	48.09	3.24	35.86	43.88	23.57	16.68	6.28	1.92	26.16	39.42	19.57	34.95	32.98	9.17	4.04	21.02	2.12
#100	4.85	0.49	0.32	0.002	0.44	5.29	0.29	11.04	18.58	11.99	2.23	1.70	0.45	4.72	17.04	2.57	4.79	5.68	1.58	0.64	3.32	0.41
#200	8.72	0.57	0.92	0.008	0.76	6.62	0.34	33.18	31.32	44.40	3.19	5.95	1.16	8.84	34.02	4.46	11.06	11.78	3.59	2.51	8.52	1.19
<#200	4.10	1.70	2.70	2.20	1.14	1.91	0.67	9.43	2.73	13.30	1.75	3.22	1.92	4.46	4.06	3.03	4.74	7.83	2.96	7.42	4.58	2.26
% Gravel	27.47	24.37	65.69	39.62	1.07	0	4.70	0.282	0	0.60	2.09	24.57	46.61	0.06	0.27	0	0	0.97	0	56.94	0.54	13.08
% Sand	68.43	73.93	31.61	58.18	97.79	98.09	94.63	90.288	97.27	86.10	96.16	72.21	57.47	95.48	95.67	96.97	95.26	91.20	97.04	35.64	94.88	84.66
% Silt	4.10	1.70	2.70	2.20	1.14	1.91	0.67	9.43	2.73	13.30	1.75	3.22	1.92	4.46	4.06	3.03	4.74	7.83	2.96	7.42	4.58	2.26
Fineness Modulus	3.47	4.43	6.71	5.40	2.81	1.31	2.92	0.69	0.71	0.55	2.69	4.05	5.27	1.70	6.91	1.79	1.32	1.67	2.09	5.73	1.95	3.78
% Loss on Washing	8.65	1.74	4.96	2.36	0.95	1.29	0.62	2.47	1.46	2.39	1.36	2.38	1.93	2.61	1.02	2.49	3.07	4.19	2.79	8.84	3.32	1.86
Organic Impurities Colour Value	4	1	1	1	3	3	3	3	1	1	1	3	5	4	1	3	1	1	1	5	1	3

APPENDIX 8 — TEMPERATURE GRADIENT FURNACE RESULTS

Sample No. B21BS, lacustrine clay

Sample: Surface clay, slightly calcareous
 Water of plasticity: $W-D/D = 35\%$
 Air Drying Shrinkage: $W-D/W = 9.0\%$
 Workability: Slightly leathery.

	Firing Shrinkage $\frac{D-F}{D}$	Temperature		Absorption $\frac{W-F}{F}$
		Dist.	Temp. °F.	
0				
1	0.1%	0.5"		
2	1.4	1.0	900	
3	1.7	1.5	1130	
4	2.1	2.0	1340	24.1%
5	2.0	2.48	1505	22.8
6	1.8	2.97	1610	22.8
7	1.9	3.46	1685	22.2
8	3.4	3.95	1745	21.0
9	3.4	4.45	1800	19.7
10	4.5	4.94	1840	17.7
11	5.0	5.42	1865	16.2
12	5.0	5.88	1883	12.8
13	4.7	6.34	1895°	11.8
14				
15				

Colour: 1100 — 1430 light reddish brown 5YR 6/6
 1430 — 1850 reddish brown 2.5YR 5/6
 1850 — 1900 light reddish brown 2.5YR 6/6

Hardness: Steel hard at 1890°F.

Remarks: Surficial clay, slightly calcareous, with a short firing range and a high combined shrinkage ($9.0 + 5.0\%$) in the temperature range of steel hardness.

Not suitable for face brick.

* Data supplied by Barry Bannatyne.

APPENDIX 9 — HEAVY MINERAL CONTENT

Sample	Particle Size	Bromoform Separation		Magnetic Separation	
		% Mafic	% Felsic	% Mafic	% Felsic
B6W	80 mesh	16.7	83.3	22.0	78.0
	100 mesh	17.0	83.0	22.9	77.1
B45W2	80	12.6	87.4	24.7	75.3
	100	17.5	82.5	29.8	70.8
391 Townsite A	80	3.3	96.7	8.2	91.8
	100	6.0	94.0	11.8	88.2
B47W	80	36.3	63.7	40.1	59.9
	100	33.1	66.2	36.6	63.4
B49W (Unit 5)	80	14.9	85.1	26.6	73.4
	100	14.0	86.0	30.8	69.2
B49W (Heavy Mineral)	80	92.9	7.1	93.9	6.1
	100	68.7	31.3	61.8	38.2
B49W (Unit 3)	80	13.9	86.1	27.5	72.5
	100	16.1	83.9	31.2	68.8
B50AE	80	6.1	93.9	12.2	87.8
	100	10.7	89.3	14.9	85.1
B59W2	80	11.4	88.6	22.7	77.3
	100	14.5	85.5	27.1	72.9
391-2-10A	80	6.7	93.3	14.1	85.9
	100	6.1	93.9	12.0	88.0
391-2-10B	80	6.7	93.3	11.0	89.0
	100	7.0	93.0	11.8	88.2
391-2-10C	80	9.8	90.2	15.0	85.0
	100	20.5	79.5	27.8	72.2
B69E	80	7.6	92.4	12.5	87.5
	100	13.4	86.6	20.0	80.0
Chur. 51	80	7.7	92.3	13.3	86.7
	100	23.6	76.4	26.0	74.0
Mine Road Cut (ripple drift)	80	2.9	97.1	9.6	90.4
	100	4.3	95.7	8.0	92.0
B60S	80	10.0	90.0	14.6	85.4
	100	21.1	78.9	36.2	63.8
B65S	80	4.8	95.2	8.1	91.9
	100	9.0	91.0	12.2	87.8
66-67, north	80	3.8	96.2	6.7	93.3
	100	6.8	93.2	9.5	90.5
Esker H	80	8.5	91.5	16.2	83.8
	100	8.8	91.2	28.3	71.7
Penguin F	80	9.5	90.5	20.4	79.6
	100	15.8	84.2	39.5	60.5
Rat River, 4-1	80	12.7	87.3	18.6	81.4
	100	15.5	84.5	28.5	71.5