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MINERAL RESOURCES DIVISION

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MINERAL AGGREGATE STUDY OF THE SOUTHERN INTERLAKE REGION
VOLUME 1

This study was carried out under contract by

JAMES F. MacLAREN LIMITED
CONSULTING ENGINEERS, PLANNERS AND SCIENTISTS

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Mineral Resources Division
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Winnipeg, Manitoba R3H 0W4

Mineral Aggregate Study of the Southern Interlake Region

Dear Mr. Bardswich:

We are pleased to submit our report on the Mineral Aggregate Study of the Southern Interlake Region of Manitoba.

This report consists of two volumes. Volume 1 is the written report in which the geological evaluation of the landscape in Quaternary Times is described in detail. The total sand and gravel reserves are summarized and areas of potential bedrock aggregate identified.

Volume 2 is a folio of 21 maps. Additional items, including aerial photographs and field inventory forms are submitted with the report and constitute supplementary technical data.

We trust that the information presented in this report will serve as a basis for the further development of aggregate resources in the Region and that it will also contribute significantly to the understanding of the Quaternary geology.

In conclusion, we wish to express the appreciation of the study team for the opportunity of working on this interesting project.

Yours very truly,

JAMES F. MacLAREN LIMITED

David L. Charlesworth, Ph.D.
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STUDY TEAM

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We also gratefully acknowledge the assistance given throughout this project by Dr. B.B. Bannatyne, Dr. S. Ringrose and Ms. P. Large of the Mineral Resources Division, Manitoba Department of Energy and Mines.

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LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
ft	feet
Ha	Hectare
in	inch
km	kilometre
L.G.D.	Local Government District
m^3	cubic metres
m	metre
mm	millimetre
MCM	million cubic metres
Sq	square
Ωm	ohm metre

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

This report summarizes the results of an aggregate inventory of the Southern Interlake Region, carried out by James F. MacLaren Limited for the Mineral Resources Division of the Manitoba Department of Energy and Mines.

The purpose of the study was to determine the quantity, quality and distribution of mineral aggregate (sand, gravel and near-surface dolomite) in the rural municipalities of Rockwood, St. Laurent, Woodlands, Coldwell, Eriksdale, Siglunes, Gimli and the L.G.D. of Armstrong; and to describe the Quaternary stratigraphy and geological evolution of the surficial deposits.

The Southern Interlake study area is situated northwest of Winnipeg, between Lakes Winnipeg and Manitoba, and covers an area of approximately 8200 square kilometres (Figure 1-1).

Eskers and kames, normally sources of aggregate in glaciated areas are absent and the extensive till is too clay rich to be used as aggregate. Large areas are covered with fine silty or clayey sediments and only the lacustrine beaches of glacial Lake Agassiz, (and associated glacio-fluvial features) provide sources of sand or gravel.

Crushable stone may be obtained from shallow or outcropping dolomite and related sedimentary rocks, but in many places the depth of the overburden is too great for economical exploitation.

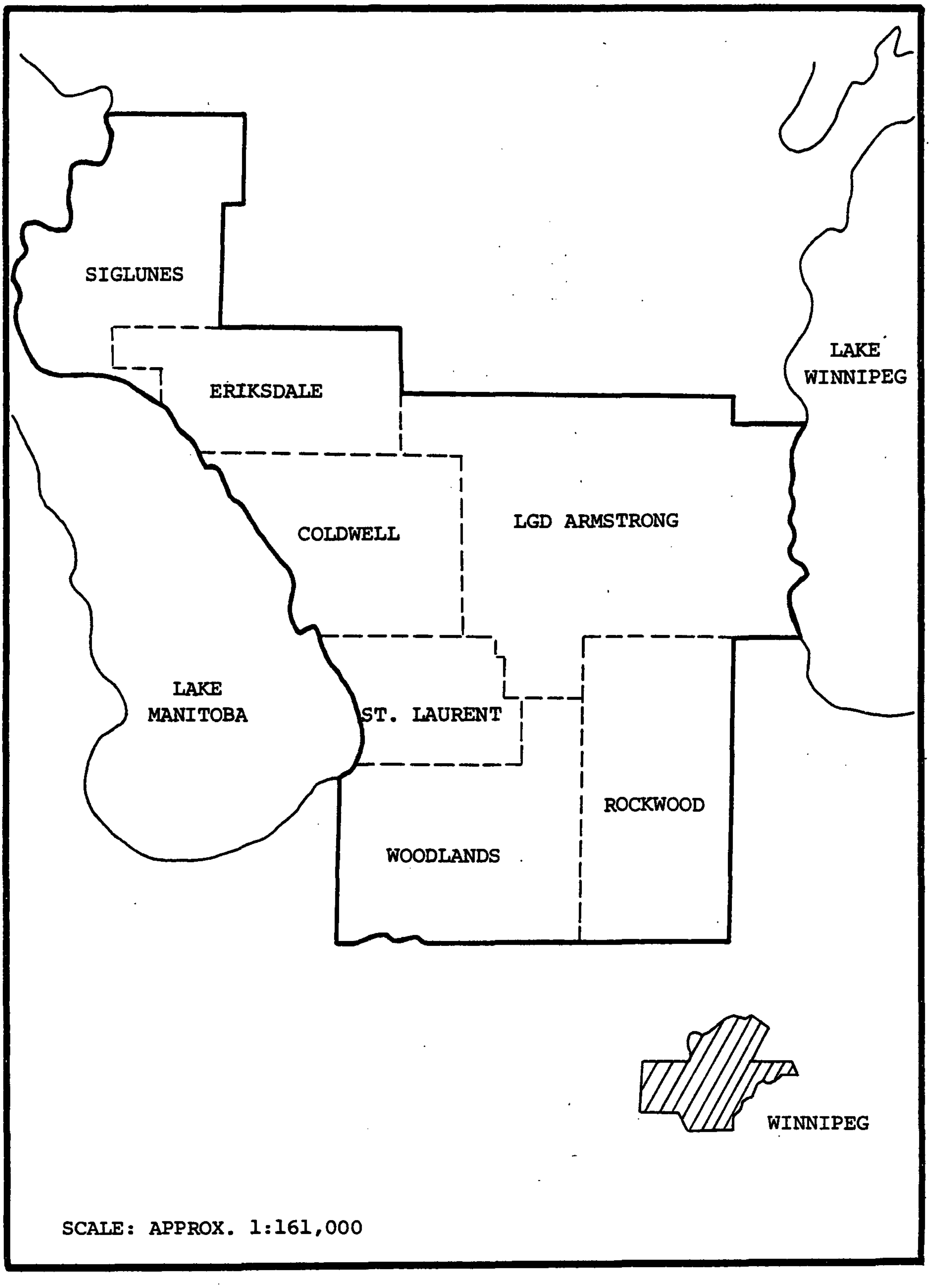

FIG. 1-1 LOCATION MAP OF STUDY AREA

CHAPTER 2
METHODOLOGY

2. METHODOLOGY

At the outset of the study existing maps and reports relating to the geology and aggregate resources of the area were collected and reviewed in order to obtain a preliminary understanding of the occurrence and distribution of the surficial deposits. Of particular value at this stage were 1:50 000 Quaternary geology maps, issued by the Department of Energy and Mines, and Manitoba - Canada Soil Survey maps at the scale of 1:125 000. A preliminary interpretation of panchromatic photography was carried out using stereoscopic pairs at scales ranging from 1:40 000 to 1:60 000 (Appendix 7). Aggregate-bearing landforms and geological boundaries were identified and delineated through the application of photo-interpretation criteria.

Field work included the identification of deposits on the ground. Channel samples were collected by hand and back-hoe pits were dug in order to assist in determining the thickness and quality of the deposits.

In the case of the assessment of near-surface limestone deposits preliminary maps, prepared from water well reports by the Water Resources Division, were updated using recent well logs and, in the case of the L.G.D. of Armstrong, by a programme of exploratory drilling and back-hoeing. Depth to bedrock maps were subsequently prepared at the scales of 1:50 000 and 1:250 000 showing the depth to bedrock and the bedrock formations.

Samples of both the surficial deposits and the limestone bedrock were subsequently tested in the laboratory using established procedures of the Mineral Resources Division.

Final maps were prepared at the scale of 1:50 000. These maps show the main stratigraphical and geological boundaries and the extent of all sand and gravel deposits. The granular deposits were numbered and classified according to quality, and existing gravel pits and quarries shown on the maps.

Twenty-one maps were produced at two different scales: 1:50 000 and 1:250 000. The location, thickness and quality of surficial aggregate desposits, the location of gravel pits and the Quaternary geology are presented on 16 maps at a scale of 1:50 000 corresponding to the following NTS map areas: 62O/2, 62O/1, 62J/15, 62J/16, 62I/13, 62I/14, 62I/15, 62J/9, 62I/12, 62I/11, 62I/10, 62J/8, 62J/1, 62I/5, 62I/6, 62I/4 and 62I/3.

The depth to bedrock and bedrock geology information is presented on two maps at a scale of 1:50 000 covering the Rural Municipality of Rockwood (Map Sheets 62I/3, 62I/6) and in two 1:250 000 maps included in the NTS map areas 62O, 62J, and 62I. The first includes the bedrock geology and depth to bedrock contours, and the second the depth to bedrock data points.

An additional 1:250 000 map of the study area integrating stratigraphic and historical geology information is also presented.

Information on the ownership of the deposits was determined and transferred to the computerized data input forms of the Mineral Resources Division.

CHAPTER 3
PREVIOUS WORK

3. PREVIOUS WORK

The present study is one of a series to investigate aggregate resources in Manitoba. Regions previously studied include Winnipeg (Underwood McLellan and Associates Ltd. 1976), Brandon (UMA, 1977) and the Dauphin Region (Gartner Lee Associates Ltd, 1978). The Winnipeg study, undertaken at a smaller scale overlaps partially with the present project area. Unpublished aggregate inventories (Block Files) compiled by the Manitoba Department of Highways and Transportation were used extensively during this study.

Upham (1895) was the first to achieve a complete and detailed monograph of the glacial Lake Agassiz basin. In his work the successive lake levels were defined, their relationship with the ice sheet and a palaeo-geographical evolution scheme for the whole area was proposed. Tyrrell produced several papers which included extensive bibliographies, especially in the field of glacial features (1901), glacial evolution (1898) and lacustrine genesis (1896). Johnston, during the period 1915 to 1946, dealt with the mode and extent of uplift of beach layers in the Agassiz basin. Leverett (1913, 1914, 1932) produced several papers on the geomorphological evolution and earth movements of the area, mainly in the Minnesota portion of the Lake Agassiz basin and, to a lesser extent, in the states of Wisconsin, Iowa, and North and South Dakota. Antevs (1931) produced a detailed correlation between ice recession and lacustrine palaeo-geography giving quantitative estimates of the rates of ice retreat in different areas of the country.

Laird (1943, 1964) and Nikiforoff (1947) studied the Lake Agassiz geology and, in 1967, an updated revision of facts and interpretations was prepared by Elson. This paper "Geology of Glacial Lake Agassiz", summarizes the available information on the evolution of the lake and provides interpretations of the lake history, relative to glacial recession.

Other authors have studied specific features of the lake such as intersecting minor ridges (Horberg, 1951; Clayton, et al, 1965); stratigraphy (Clayton, 1966); deglaciation in Saskatchewan (Christiansen, 1979); western strandlines (Elson, 1965) and palaeontology (Tuthill et al., 1962, Tuthill, 1963, 1964, and 1967). In recent years, Klassen studied the chronostratigraphy of southwestern Manitoba (1969), the Quaternary geology and geomorphology of the Assiniboine and Qu'Appelle Valleys (1975) and the Pleistocene geology and geomorphology of the Riding and Duck Mountain areas (1979). In addition studies have been carried out by the Mineral Resources Division and several Pleistocene geology maps of portions of the Province have been produced (Ringrose, 1975 to 1979 and Ringrose et al., 1977).

The limestone and related carbonate rocks had been previously studied by several authors but the Mineral Resources Division's publication of "High-Calcium Limestone Deposits of Manitoba" (Bannatyne, 1975) was the main source of background information for the present study.

CHAPTER 4
PHYSIOGRAPHY

4. PHYSIOGRAPHY

The study area covers the Rural Municipalities of Siglunes, Eriksdale, Coldwell, Rockwood, Gimli, Woodlands, St. Laruent and the Local Government District of Armstrong in the southern interlake region of the province of Manitoba. It lies approximately between latitudes 50° 04'N and 51° 15'N and longitudes 96° 57'W and 98° 48'W.

The climate may be classified as DFb region of Köppen, with a large annual temperature range and a definite summer maximum precipitation. In Gimli the mean annual precipitation for the period 1944-1959 was 537 mm (21.14 in) with a mean annual temperature of +1.4°C. The minimum and maximum mean monthly temperatures of -19°C and +18°C occur in January and August respectively, indicating a continental subhumid climate. The area is relatively flat with the highest point at slightly above 282 m (925 ft) in the north of the study area and the lowest at 217 m (713 ft) corresponding to the level of Lake Winnipeg. Regional slopes may reach 0.2% in an east-west direction and less than 0.05% in a north-south direction. Locally, slopes may show higher values (as for example, in the Woodlands area) but they never exceed 0.6% in any place.

Physiographically the area is composed of the Lake Winnipeg-Red River basin, which trends north-south, and the considerably higher Lake Manitoba depression connected by a slightly depressed zone located west of Woodlands and south of Lake Francis. Between, and north of these lowlands, the high plains of the Interlake region are found. These are flat, often swampy areas, covered in places with dense bush or forest, where a limited volume of crops are grown and some range land activities are carried out. Lakes are widespread in the study area.

CHAPTER 5
BEDROCK GEOLOGY

5. BEDROCK GEOLOGY

5.1 Regional Geology

Precambrian granites of Archean age underlie a succession of sedimentary formations which occur in the interlake region of Manitoba. These sedimentary formations trend approximately in a north-south direction in the southern part of the study area, changing to a north-northwesterly direction towards the north. Sandstone and shale of the Ordovician Winnipeg Formation overlie the Precambrian rocks which in turn are overlain by the Ordovician Red River Formation consisting of dolomite, dolomitic limestone and limestone.

The Stony Mountain Formation of Ordovician age overlies the Red River Formation and consists of dolomite, shale and some limestone. Dolomite of the Stonewall Formation, of Ordovician and Silurian age, overlies the Stony Mountain Formation. It in turn is overlain by dolomite of the Silurian Interlake Group. Carbonate strata of the Devonian Elk Point and Manitoba Groups overlie the Silurian rocks along the western edge of the map area. Shale, sandstone and gypsum of the Jurassic Amaranth Formation uncomformably overlie part of the palaeozoic rocks.

5.2 Depositional History of the Palaeozoic Strata of the Interlake Region

Sedimentation of the Winnipeg Formation occurred during the late Ordovician. Interbedded sand and clay were deposited in a shallow marine environment. At the end of this period, further subsidence occurred which caused submergence of the clastic sediment source area and consequent deposition of the finer grained Red River Formation.

Deposition of the Dog Head, Cat Head and Selkirk Members of the Red River Formation occurred in approximately the same environment throughout most of the Southern Interlake Region. A shallow water marine environment existed during that time and a significant amount of sedimentation probably occurred in a low energy infratidal environment. Regression of the sea occurred after the deposition of the Selkirk Member and this resulted in an alternating intertidal and supratidal environment. Subsequently, interbedded massive and laminar bedded carbonates of the Fort Garry Member were deposited.

In the latter portion of Fort Garry times, the sea began to transgress resulting in deposition of a biomicrite in a shallow marine environment. The limestone zones occurring within the Red River Formation were associated with periods of regression or transgression of the existing seas.

A sudden influx of terrigenous detritus occurred later, and the Gunn and Penitentiary Members of the Stony Mountain Formation were deposited (Cowan, 1971), followed later still by carbonates of the Gunton and Williams Members of the Stony Mountain Formation.

The accumulation of carbonates of the Stonewall Formation occurred during Ordovician and early Silurian times and carbonates of the Interlake Group were subsequently deposited in the Silurian in an extremely shallow water marine environment (Baillie, 1951). A regression of Silurian seas then occurred resulting in a period of erosion until late Lower or Middle Devonian time. Subsidence occurred in association with the development of the Elk Point Basin.

Sedimentation of the Ashern Formation of the Devonian Elk Point Group occurred on the eroded Silurian surface. The Ashern was overlain by carbonates of the Winnipegosis Formation consisting of reef, inter-reef, fringing bank, and shelf carbonates most of which are completely dolomitized.

In an area between Oak Point and Waterhen Lake a partially dolomitized to high calcium limestone of the Elm Point Formation is found at the base of the Winnipegosis Formation.

Deposits of halites, anhydrite, dolomite and potash salts of the Prairie Deposit were formed in the deeper parts of the Elk Point Basin. This occurred during or following reef development. Marine transgression occurred after the accumulation of the Prairie Evaporite and resulted in deposition of the Second Red Bed during the early stages of the transgression. The Second Red Bed may represent both a residual shale and an increase in clastic detritus caused by slight positive tectonic movements at the basin margins. Shelf carbonates and associated biostromal and apparent reef deposits overlie the Second Red Bed. The Dawson Bay strata consist of a cyclic sequence of lithologies reflecting a change in environment from subaerial to shallow marine, then deep marine followed by a gradual shallowing and restriction of circulation until evaporitic conditions existed (Bannatyne, 1975).

5.3 Stratigraphy and Petrography

The Winnipeg Formation, of Ordovician age, consists of poorly consolidated kaolinitic shale and quartzose sandstone. It is overlain by the Red River Formation which contains four members.

The lower Dog Head Member of the Ordovician Red River Formation consists of mottled dolomitic limestone. The mottles consist of brown to grey finely crystalline dolomite which occur in a light buff biomicrite limestone. Dolomite to dolomitic limestone make up the Cat Head Member which is dolomitized to a greater extent than either the Dog Head or Selkirk Members. The latter overlies the Cat Head Member and consists of mottled dark brown and buff fossiliferous dolomitic limestone. An upper limestone layer contains abundant chert nodules. The Selkirk Member is a source of the well known Tyndall building stone. The Fort Garry Member overlies the Selkirk Member and consists predominantly of dolomite. A marker bed of red argillaceous intraformational breccia occurs at the top of the lower sub-unit. An upper sub-unit contains limestone beds of variable thickness near the base and at the top.

The Red River Formation is overlain by the Stony Mountain Formation which also contains four members. The lower Gunn Member consists of red and purple fossiliferous calcareous shale which contains thin limestone interbeds. It is overlain by fossiliferous, argillaceous dolomite of the Penitentiary Member which in turn is overlain by mottled buff and grey dolomite of the Gunton Member. The Williams Member is the upper member of the Stony Mountain Formation and it consists of arenaceous and argillaceous dolomite.

Finely crystalline to aphanitic dolomite of the Stonewall Formation overlies the Stony Mountain Formation. The Stonewall Formation is of Ordovician and Silurian age. It contains an arenaceous and argillaceous marker bed near the middle.

The overlying Interlake Group, of Silurian Age, consists of the Strathclair, Brandon and Cedar Lake Formations. They are composed of fossiliferous dolomites which contain thin argillaceous and arenaceous marker beds.

The Elk Point Group of Devonian age consists of the Ashern, Elm Point and Winnipegosis Formations. Red dolomitic shale and local basal breccia beds comprise the Ashern Formation. It is overlain by the Elm Point Formation which is composed primarily of mottled high-calcium limestone. It is an eastern facies of the basal part of the Winnipegosis Formation. The latter consists primarily of dolomite and contains magnesian and high - calcium limestone.

The Middle Devonian Dawson Bay Formation consists of four units and comprises the lower unit of the Manitoba Group. A basal red dolomitic shale known as the "Second Red Bed" unconformably overlies the Winnipegosis Formation. It is overlain by a unit consisting of dolomite, dolomitic limestone and high - calcium limestone which in turn is overlain by a middle calcareous shale unit containing interbeds of argillaceous limestone. These units are overlain by an upper carbonate unit consisting of dolomite which in turn is overlain by a high - calcium limestone. Some Jurassic rocks occur in the southwest corner of the study area, to the south of Lake Manitoba.

CHAPTER 6
QUATERNARY GEOLOGY

6. QUATERNARY GEOLOGY

6.1 Introduction

This chapter presents an interpretation of the Quaternary geology of the study area with sections grouped according to the following format:

Sediments:

A brief description of the sediments found in the study area and a discussion of their depositional environment is presented.

Landforms:

The main geomorphological features are described.

Stratigraphy and Historical Geology:

The information gathered together in the preceeding sections are integrated in this final section to give an evolutive concept of the Quaternary geology of the Southern Interlake Region.

6.2 Sediments

The surficial deposits of the study area consist mainly of:

a) Glacial sediments (till)
b) Fluvial and fluvio-glacial sediments (undifferentiated on the aggregate maps, usually consisting of sand and gravel)
c) Lacustrine and glacio-lacustrine sediments (including beaches, near-shore and off-shore deposits with variable grain size characteristics).

d) Palustrine sediments (fine or very fine detritic deposits with abundant organic matter, and peat).

6.2.1 Glacial Sediments

Glacial sediments are composed of a wide range of unsorted material, genetically identified in the literature as ground moraine till (Christiansen, 1960) or irregular recessional moraine till (Klassen, 1975).

The typical tills in the area are usually silty (the silt content varies between approximately 30% and 50%), moderately clayey or clayey (clay content between 20% and 45%) and moderately sandy (sand content may vary from 20% to 35%) (Ehrlich et al, 1953, Pratt et al, 1961). Field descriptions show less typical grain size distributions in the Narrows area where less clay and higher sand contents are observed. Tills in the region are almost always stony with fragments ranging from gravel to boulder size.

The petrographic composition of pebbles and boulders varies both horizontally and vertically, according to the proximity of the bedrock. Normally clast content comprises 80% calcareous and 20% granitic rock types. In some areas where the bedrock is observed close to the surface, calcareous gravels and boulders make up more than 90% of the whole coarse detritic population and, in a few cases, no granitic material is found.

The thickness of the till varies from zero where outcropping bedrock is present, to more than 30 m in the deepest part of the basins. The average thickness was estimated at around 12-15 m.

6.2.2 Fluvial and Fluvio-Glacial Sediments

Fluvial and fluvio-glacial sediments were not differentiated during the present study, but there is evidence to believe that most of the deposits are fluvial and not related with glacial processes. They are usually associated with ridges intersecting the palaeo-shores of Lake Agassiz in times when the ice front was far to the north of the study area (see Section 6.3). Some fluvio-glacial sediments associated with the receeding ice sheet may exist but they were not differentiated on the aggregrate maps and are discussed here under the heading 'Fluvial and Fluvio-Glacial'. In the exposures, heterogeneous, poorly sorted, coarse materials with a few fine-grained lenses (fine sand, silt, clay) were observed.

The thickness of these sediments is quite variable, seldom exceeding 3 m and more often being in the order of 1 to 2 m.

6.2.3 Lacustrine and Glacio-Lacustrine Near-Shore Sediments

These deposits are heterogeneous, ranging from fine sediments (silt, fine sand, sometimes clay) to medium and coarse materials (medium and coarse sand, gravel). Their lacustrine origin and near-shore depositional environment have been widely stated in the literature (Upham, 1895; Johnston, 1946; Laird, 1964; Elson, 1967).

These sediments were accumulated in shallow open waters, in beaches and associated dunes, and in coastal swamps along the shorelines of glacial Lake Agassiz.

Due to the changing levels of the lake, especially during recessions, many related shoreline deposits can be observed. In some cases, the lake remained stable during a relatively long period of time and thicker deposits are found; in other cases, the lake dropped steadily and only thin scattered layers are present.

In some places, (particularly along shorelines B_{1-8} on the aggregate maps) the till has been washed and the finer elements (clay, silt and fine sand) removed, leaving only boulders, gravels and coarse sand which have undergone very little or no transport at all.

The thicker deposits are normally associated with relatively steep sloping beaches, as seen near Woodlands. In these cases, sediments are mainly sandy or gravelly with a medium degree of sorting. Thicknesses reach 5 to 7 m. In low angle slopes, the beach sediments are finer, and medium or fine sand layers predominate.

Shallow open water sediments are composed of fine sand or silt following the main beach systems and occurring as narrow strips along the shoreline. These sediments are thin, seldom exceeding 1 m.

The swamp deposits are also thin and are located behind the sand bars, in isolated or semi-isolated depressions. These sediments are fine-grained (mainly silt and clay) with a variable amount of organic matter.

6.2.4 Lacustrine and Glacio-Lacustrine Off-Shore Sediments

Lacustrine off-shore sediments were deposited in the deeper areas of the lake. Considering the sedimentological composition of the materials (clay and silt), and the fetch of the lake, a minimum depth of 3-5 m may be estimated. In some areas, (e.g. near Lake Winnipeg) during the Narcisse stage (see Section 6.3) the depth of the water would have reached 70 or 80 m. The thickness of these deposits may vary from zero to several metres in the deepest zones of the basin.

6.2.5 Palustrine Sediments

Isolated organic deposits were formed unrelated to contemporary shorelines. This happened with the swamps near Eriksdale, where organic sediments formed in depressions probably corresponding to the last stages of the glacial lakes. Sediments in the swamps are usually fine grained with variable organic content. In some cases, organic matter is predominant and the sediment can be considered a true peat. In most cases, accumulations are thin, with increasing detritic composition towards the edges of the basin.

6.3 Landforms

The geomorphology of the study area is relatively simple being comprised of till plains which are now partially covered by beaches and lacustrine deposits formed during the various recessions of the glacial lakes.

Lacustrine sediments predictably tend to be thicker in the deeper portions of the basin (areas where submergence lasted longer) as is seen in the south-eastern zone of the Rural Municipality of Rockwood. In these cases, till plains occur only as sub-surface features and, as such, are not shown on the surficial geology maps.

6.3.1 Till Plains

The till plains are gently undulating areas developed in strongly calcareous ground moraine sediments.

Alternating low ridges and elongated shallow depressions are scattered all over the plains, usually with the main axis oriented in a northwest direction. The drainage of the depressions varies from poor to very poor and from 0.1-0.4 m of silty sediments may be found overlying the till. The ridges are seldom more than 1 m high and are composed of slightly reworked till overlying an undisturbed strongly calcareous till. For mapping purposes, the till plains were divided into seven different units according to their order of emergence.

Till plain TP1 (Map 21) was the first till plain uncovered by the receeding lake. Several small islands appeared in the present Narcisse and Sandridge areas delineated by a discontinuous belt of narrow beaches. In subsequent stages, with a lower lake level, new till plains emerged. In some cases, when the till plains were water-free, lacustrine sediments remained deposited in a thin mantle. The last till plains to emerge are usually covered by a thick layer of fine sediments and are shown on the maps as "lacustrine plains".

6.3.2 Fluvial and Fluvio-Glacial Ridges

In some places in the study area, particularly near Teulon, low ridges intersect the topographic contours and beach ridges almost at right angles. They are usually of low relief and cannot be classified as typical "eskers". More probably, they were derived from very short streams coming from the slightly higher terrains of recently emerged islands while the ice sheet was far to the north. The sorting action was considerably reduced due to the small basins, a short time (because of the limited frost-free period) and the small distances of transport. Thus, the sediments themselves are often poorly sorted. Nevertheless, some well sorted layers may also be found occasionally exhibiting cross-bedding structures. The presence of some fluvio-glacial ridges are not excluded, but in this study they are not differentiated from the fluvial ones.

6.3.3 Beaches

Lacustrine beaches are perhaps one of the more characteristic geomorphic features of the study area. They appear as narrow, long, low ridges, and closely follow the topographic contours. A typical ridge may be anywhere from 10-100 m wide, 0.5-2 m high and several kilometres long. They are usually composed of well layered intercalated sand and gravel which dip at a low angle towards the lake. The thickness of these deposits is variable but seldom exceeds 5 m with the average thickness being between 1.0-2.0 m in the major deposits.

In at least some cases, the presence of thick beach deposits is related to significant pre-existing slopes in the till, which resulted in only small horizontal movements of the lake shore over long periods of time.

It seems likely that in the Woodlands area an underlying moraine may have caused beaches related to several lake levels to be super-imposed. This is thought likely because relatively steep slopes are found in the till along the palaeo-shorelines, and the orientation of this buried scarp follows the east-west orientation of other front moraines.

In many other places, the flatness of the landscape and the regional configuration of the lakes did not allow the formation of any coarse-grained beaches along the old lake shores and no ridges are observed.

6.3.4 Lacustrine Plains

In the lowest areas of the basin, where the till was covered by lacustrine sediments beyond the youngest beaches, the typical ridge-depression association of the till plains is masked by a fine sedimentary mantle. Their very flat surfaces slope gently toward the lakes. Very low intersecting lineations were observed on aerial photographs in the flattest part of the plain. These features are seldom noticeable in the field, and are thought to be the result of floating lake ice (Clayton et al., 1963), frozen ground structures, or fracture fillings in lake ice (Horberg, 1951).

6.4 Stratigraphy and Historical Geology

6.4.1 Pre-Lake Agassiz Deposits

Ground moraine till was deposited during the Wisconsin Glaciation that covered the whole province with an ice mantle several hundred metres thick (see 6.2.1).

During the late glacial period the ice receded northward leaving frontal moraines and till plains. Deglaciation first occurred to the south in the U.S.A., 11 700 years B.P. (Wright and Watts, 1979). Approximately 2000 years later the ice margin was located near Woodlands (sometime before Phase II of Klassen, 1975) and it is likely that the relatively steep slopes of the till in this area, later covered with lacustrine sediments, are related to a poorly defined moraine of this age. The retreat subsequently continued and it is estimated that the ice margin was located in the vicinity of the Narrows (north-west of the study area) about 11 000 years ago. The narrow channels both in Lake Winnipeg (Hecla and Black Island, etc.) and Lake Manitoba (The Narrows) suggest the presence of another poorly defined front moraine parallel to the Woodlands moraine and 'The Pas' moraine. The "The Narrows" moraine may possibly be correlated with the Phase II glacier margin of Klassen (1975).

The well defined late glacial moraine, known as "The Pas Moraine", which divides Cedar Lake from Lake Winnipegosis is approximately 10 800 years old. The ice disappeared from the northern part of Manitoba approximately 8300 years ago.

6.4.2 Lake Agassiz

Pre-Narcisse

The presence of the Laurentide continental ice-sheet acted as a dam for the mainly north sloping drainage in Manitoba and the neighbouring region of the U.S.A. As a consequence of this interference, a body of water of variable size appeared and remained during most of late glacial times, reaching an area in excess of 260 000 sq. km.

The first stages of the evolution of the lake occurred when the ice margin was south of the present international border, shortly after the "Des Moines" lobe started to retreat. At this time a relatively small lake draining south (Lake Milnor) existed in the area of south-eastern North Dakota, north-eastern South Dakota and western Minnesota (Clayton, 1966). Later a larger lake with a southern outlet appeared on both sides of the retreating glacial lake (Lake Agassiz I). The Herman and Upper Campbell beaches were probably formed during this stage (Laird, 1964). During the Holt-Edinburg moraine stage the lake continued to discharge southwards, and some deltas were formed in North Dakota.

Subsequently, the ice front continued to retreat and clays accumulated in the bottom of the basin. At a later stage the ice front retreated north of Winnipeg and an eastern outlet was opened which certainly lowered the level of the lake and possibly drained it completely.

Laird (1964) suggests that a new blockage of the eastern outlet was the cause of a new rise of lake levels in the Lake Agassiz II period. A southern discharge was re-established and the Lower Campbell beaches were formed. At this time the ice margin was located not far from the northern edge of present Lake Winnipeg.

Later, the lake level dropped steadily, perhaps because an eastern outlet again started to discharge the water of the lake in that direction, and the first small islands appeared in the Narcisse area.

Deposits in the Southern Interlake Region throughout all of the Pre-Narcisse lacustrine period, were mainly off-shore fine-grained sediments and stratigraphical identification is limited to rough palaeogeographical interpretations. They remain as a thin mantle covering the till and are usually buried under younger lacustrine sediments in the lacustrine plains.

Narcisse Stage (B1A, B2A)

The first small islands in the Southern Interlake Region appeared near Narcisse.

Two systems of beaches (B1A and B2A) were identified. The first one, and the highest, is located north-east of Narcisse and in two ridges near Sandridge which are now almost completely excavated. Its elevation reaches 282 m (925 ft) in the north and 280 m (920 ft) in the south.

B2A is found surrounding the village of Narcisse, with sand and gravel beaches on the western side. Some smaller islands, also related with B2A, existed west of Teulon and west of Woodlands. The average elevation of this shoreline is slightly less than 274 m (900 ft), (274-277 m (900-910 ft) in the North, and 271-274 m (890-900 ft) in the South).

Correlation of these beaches with identified shorelines West of Lakes Manitoba and Dauphin is not always clear. If elevations and Johnston's uplift curves (1946) are considered, the Narcisse stage would be clearly younger than the Lowest Campbell beaches and perhaps slightly older than the Gladstone level, as defined by Johnston (1946). If the ages proposed by Johnston (1946), and Elson (1967), are accepted then these beaches would be approximately 9000 years old, with an interval of a few hundred years between B1A and B2A.

At this time the ice margin was probably north of the northern edge of present Lake Winnipeg lying somewhere to the south of Thompson.

Lake Francis Stage (B3A)

During the Lake Francis stage the level of the lake dropped about 8 m below the B2A level. All the small islands following the axis of the Southern Interlake Region merged into a long central island with a north-westerly orientation.

Another relatively large island existed south-west of the Shoal Lakes depression, near Lake Francis where a well defined beach system is found. The elevation of this shoreline varies from 264-265 m (865-870 ft) in the south to 267-268 m (875-880 ft) in the north. This stage may be correlated with the Burnside beaches west of Lake Manitoba (Johnston, 1946). Correlations with Burnside levels east of the Red River seem less conclusive because of the significant difference of elevation between both beach systems. During this stage an ice free seasonal period was enough to allow surface flow, and streams appeared. Several fluvial ridges are found intersecting the B3A beaches at right angles, south-west of Teulon. These are not eskers because the ice was far to the north at that time. They are most likely small drainage channels related with summer runoff (see Section 6.3.2).

6.4.3 Transitional Period

Lundar Stage (B4A)

The lake level continued dropping until a large island was uncovered surrounded by shallow waters and with few beaches.

Most of the coarse grained shorelines are located along the south-eastern side. Several beaches are also found in the western shore, near Lundar, showing that a relatively large body of water existed in the Lake Manitoba depression.

Communication between western and eastern Lake Agassiz was probably limited to some shallow and swampy areas south of present Lake Manitoba, through the Assiniboine basin. Elevation of the beaches varies from 265 m (840 ft) in the south to 262 m (860 ft) in the north and they may be correlated with the Stonewall beaches proposed by Johnston (1946), and the Stonewall Phase described by Elton (1967).

From the present study it has become apparent that the name "Stonewall" is misleading as the main beaches associated with this level (as shown in Figure 5, Johnston, 1946) are far from the town of Stonewall. In addition the beaches that actually do occur near Stonewall are related with the lower B5W and B6W levels of the eastern Lake (Map 21).

During this period the Shoal Lake depression was isolated at a higher elevation from the main bodies of water. This depression was probably briefly linked to the main lake by swampy areas in the northwest and in the southeast, allowing some minimal communication, though this link disappeared by the end of the stage. At this time, one shallow large lake occupied the whole Shoal Lakes area (shoreline B7Sh).

6.4.4 Protolakes

Teulon-St. Laurent Stage (B5W, B5M, B6W)

At the start of this stage lake levels dropped to a lower level and communication between the eastern and western depressions became less important.

At the end of this period two relatively isolated bodies of water remained on either side of the Interlake highlands: Proto-Lake Manitoba, with an area slightly bigger than the present one; and Proto-Lake Winnipeg, extending south and south-west through large and shallow bays, along the basins of the present Red and Assiniboine rivers.

Beaches on the western side are found near St. Laurent at 256-259 m (840-850 ft) above sea level (B5M), and, on the Eastern shore, coarse grained deposits can be seen north-east of Teulon at elevations from 250-259 m (820-850 ft) (B5W and B6W).

The B5W shorelines extended towards the southwest along the Assiniboine river valley forming an entrance of shallow water which in the next phase (B6W), disappeared almost completely.

The Stonewall and Stony Mountain hills were small rocky islands surrounded by beaches during the B5W stage and gradually, as the Lake receeded, joined with the Interlake mainland (during B6W). These shorelines seem to be intermediate between the Stonewall and Gimli beaches (Johnston, 1946).

According to Elson (1967), this period may be dated between 8300 and 8000 years; and, at this time, an eastern outlet was still discharging water from the basin.

6.4.5 Present Lakes

Gimli-Oak Point Stage (B7A, B7M)

During this stage the Lake Winnipeg depression was isolated from Lake Manitoba and the water levels dropped a few metres to B6M in the Narrows area and, later, to B7M in the whole basin.

In the Lake Winnipeg basin a system of beaches (B7W) can be recognized near Gimli Airport following a low shoreline at an elevation of 236-241 m (775-790 ft). This correlates with the "Gimli" beach of Johnston (1946), and the "Gimli" phase of Elson (1967).

Correlations between the Lake Manitoba and Lake Winnipeg shorelines remain uncertain during this period because of the isolation of both basins. Elson (1967) proposed during this phase a large body of water covering the whole Lake Winnipeg, northern Lake Manitoba, Lake Winnipegosis and Cedar Lake areas. Because of its higher elevation, the Lake Manitoba southern basin may have been completely drained during this period. However, the presence of a system of beaches at B6M on both sides of The Narrows with an elevation of 251 m (825 ft) seems to show that Lake Manitoba had a separate evolution and most likely was never completely dry.

Present Shorelines (B8W, B8M, B8Sh, B8D)

Shorelines of the lakes gradually approached the present ones. When Lake Manitoba dropped from B7M to B8M, Dog Lake was isolated as a separate body of water. Some beaches were formed during its first and deeper phase (B7D) before receeding to the present level (B8D).

The Shoal Lake was separated from the main lakes with the Lundar Stage being reduced to three smaller isolated lakes (West, East and North Shoal Lakes). Very few beaches (none of them coarse grained) are found in the receeding shorelines. The main shoreline during the first phase, before the lake receeded to the present level is named B7Sh on the 1:50 000 maps accompanying this report.

The present Lake Winnipeg is the lowest lake in the area with an elevation of 217 m (712 ft) above sea level. Lake Manitoba's present shorelines (B8M) are nearly 30 m higher at 248 m (813 ft) and the Dog Lake level is approximately the same at 247 m (811 ft).

The Shoal lakes are the highest bodies of water (almost 12 m higher than Lake Manitoba) with an average level of approximately 259 m (850 ft).

CHAPTER 7
ECONOMIC EVALUATION OF MINERAL AGGREGATES

7. ECONOMIC EVALUATION OF MINERAL AGGREGATES

7.1 Bedrock Aggregates

7.1.1 Previous Work

Quarry operations and chemical analyses of carbonate rocks in Manitoba are outlined in a report by Goudge (1944). The geology of Silurian formations of the Interlake area, Manitoba and Devonian geology of the Lake Manitoba-Lake Winnipegosis area was reported by Baillie in 1951. Ordovician geology of the Lake Winnipeg and adjacent areas was also outlined by Baillie in 1952. High-calcium limestone beds near Lake St. Martin were reported by McCabe and Bannatyne in 1970. A comprehensive study of the distribution, quality and stratigraphic position of high-calcium limestone deposits primarily in the southwestern part of Manitoba was also published by Bannatyne in 1975, who reported that high-calcium limestone occurs in two thin beds within the Ordovician Red River Formation and in at least six zones within Devonian formations. Preliminary maps outlining the overburden thickness, geology and bedrock topography in the areas of Stonewall and Teulon were published by Bannatyne and Jones in 1979.

7.1.2 Present Investigation

The purpose of the present investigation was to determine the depth to bedrock throughout the southern interlake region of Manitoba. Water well data were utilized and additional field studies were undertaken in order to obtain more information. Sixty test pits were dug in the areas around Stonewall and Teulon using a backhoe. Twenty-three test holes were also drilled in the same areas to determine depth to bedrock where the overburden is too thick for backhoe excavation. The locations of these sites are shown on Maps 19 and 20 and the data tabulated in Appendix 1.

A contour map of the depth to bedrock in the study area was completed at a scale of 1:250 000 as shown on Map 17. The data points used in compiling this map are included as Map 18. Shading is used to denote those areas where the depth to bedrock is less than 3.0 m below the ground surface. In addition, the geology of the area is shown in order that both depth to bedrock and type of bedrock could be evaluated simultaneously.

Contour maps of the depth to bedrock in the areas of Stonewall and Teulon were completed at a scale of 1:50 000 as shown on Maps 19 and 20. Areas where the depth to bedrock is less than 3 m are highlighted and the geology is also indicated.

7.1.3 Distribution and Depth to Bedrock

The depth to bedrock at a scale of 1:250 000 is shown on Map 17 excluding the areas of Stonewall and Teulon. These areas are shown in greater detail on Maps 19 and 20 at a scale of 1:50 000

a) Southern Interlake Region (excluding the Rural Municipality of Rockwood)

There are no significant areas in the northeast part of the study area where the bedrock occurs within 3 m of the ground surface. However, bedrock occurs within 8 m of the ground surface in two areas and within 3 m in one of these areas. The latter area occurs in the vicinity of Komarno situated north of Teulon. It occurs within the Gunn, Penitentiary and Gunton members of the Ordovician Stony Mountain Formation which consist of shale and dolomite. Dolomite of the Ordovician Penitentiary Member has been used as a decorative building stone in the past and similarly dolomite of the Gunton Member has been quarried. The other area occurs west of Winnipeg Beach within the Selkirk Member of the Red River Formation. Dolomitic limestone known as "Tyndall Stone" has been quarried for building stone from beds below the middle of the Selkirk Member at Garson which is situated south of Lake Winnipeg (Bannatyne, 1975). High-calcium to magnesian limestone occurs at or near the top of the Selkirk Member in some areas. However, the upper Selkirk limestone zone is thin or absent in the Southern Interlake Region.

Several large areas occur where the depth to bedrock is less than 3 m below ground surface and where the bedrock outcrops. Two areas occur northeast and east of North Shoal Lake. The latter area is situated in the vicinity of Inwood where several quarries are located. Other areas occur north of Narcisse and in the vicinity of Poplarfield. All of the above areas are situated within the Silurian Interlake Group which generally consists of dolomite. Two other large areas occur northeast and east of Lundar within the Interlake Group. Smaller areas where the bedrock is at a depth less than 3 m below the ground surface are shown on Map 17.

A long, narrow area of bedrock within 3 m of the surface occurs northeast of Dog Lake within the Devonian Ashern Formation of the Elk Point Group. The Ashern Formation generally consists of red dolomitic shale which would not be suitable as a source of crushed rock. However, in some places the Ashern Formation is a hard red argillaceous dolomite that has been use for crushed stone, e.g. at a quarry south of Provincial Road 235, 8 km west of Mulvihill.

Several large areas where the depth to bedrock occurs within 3 m of the ground surface exist within the Devonian Elm Point Formation of the Elk Point Group. The Elm Point Formation generally consists of high-calcium limestone. One area occurs in the vicinity of Lily Bay near eastern Lake Manitoba and is underlain by 3.7-17.1 m of Elm Point Formation limestone of varying quality. Several quarries occur in this area. Other areas of Elm Point limestone which are overlain by thin surficial deposits occur south-east and north of Dog Lake. In the map area, the Elm Point Formation has a variable magnesium content.

Several areas occur west of Dog Lake which are underlain primarily by dolomite of the Devonian Winnipegosis Formation. This formation also contains known occurrences of magnesian and high-calcium limestone. However, the existing occurrences of high-calcium limestone are very thin or occur at depth.

The Middle Devonian Dawson Bay Formation of the Manitoba Group occurs west and southwest of Dog Lake. Several areas are underlain by surficial deposits less than 3 m thick. The Narrows area located between Nina Lake and Wapah contains about 2.7 m of high-calcium limestone which occurs at the top of the formation. Other known occurrences of high-calcium limestone exist outside of the study area.

b) <u>Rockwood Area</u>

The depth to bedrock in the Stonewall and Teulon areas is shown on Maps 19 and 20. A large area of bedrock outcrop occurs at Stony Mountain which contains quarries still in use. It consists of dolomite of the Gunton Member of the Ordovician Stony Mountain Formation. Dolomite of the Penitentiary Member and shale of the Gunn Member also occur where the surficial deposits are less than 3 m thick.

Two large areas of shallow bedrock containing some outcrop occur within areas of dolomite of the Gunton Member. One area occurs in the vicinity of Gunton and another much larger area is situated northeast of Stonewall. Both of these areas contain quarries which have been used for crushed stone. Several other smaller areas within the Gunton Member occur southeast of Stonewall.

An area of bedrock outcrop and surficial deposits less than 3 m thick occurs in the northeast part of Stonewall. This area lies essentially within dolomite of the Gunton Formation. Several quarries exist which were in operation until 1965. The eastern edge of the area lies within dolomite of the Williams Member of the Ordovician Stony Mountain Formation. Other smaller areas within dolomite of the Stonewall Formation occur southwest of Stonewall.

7.1.4 Analysis of Selected Samples

The use of bedrock material as aggregate is dependent upon a number of factors such as resistance to abrasion, soundness in freeze/thaw and wetting/drying conditions and percentage of insoluble material. Seven bedrock samples were analyzed at The National Testing Laboratories Limited in Winnipeg, Manitoba in order to determine the above factors. The locations of samples X^{I}, X^{II}, X^{V}, and X^{VI} are shown on Map 19 and samples X^{III}, X^{IV} and X^{VII} on Map 17. A summary of the laboratory results is shown in Table 7.1

Resistance to Abrasion

The resistance of the samples to abrasion was determined by the Los Angeles Abrasion Test. A specified quantity of sample was placed with a number of steel balls into a steel drum that has a shelf running across its width. The drum is rotated a specific number of times at a certain speed and the percentage of material worn away is subsequently measured. Thus the greater the percent loss the smaller the resistance to abrasion. Both ASTM C535, grade 2 and ASTM C131, Grade D test methods were used in testing for percentage of wear. Sample X^{III} was tested using ASTM C131 due to the fine gradation of the sample after crushing.

The percent loss of material for the analyzed samples varied from 23.8% to 44.6%. All of the results except that for

TABLE 7.1

LABORATORY TEST RESULTS OF SELECTED BEDROCK SAMPLES

Sample No.	Los Angeles Abrasion (% Loss)	Sodium Sulphate Soundness Fine Aggregate (% Loss)	Sodium Sulphate Soundness Coarse Aggregate (% Loss)	Insoluble (%)
X^{I}	28.8	1.8	12.7	15.4
X^{II}	44.6	6.0	41.5	5.9
X^{III}	31.8	17.7	-	0.6
X^{IV}	33.0	1.9	20.6	1.3
X^{V}	27.7	2.1	15.6	3.9
X^{VI}	29.2	3.4	30.3	0.6
X^{VII}	23.8	0.3	5.4	2.1

sample X^{II} were within the allowable limits for those uses outlined in Table 7.2. Sample X^{II} would only be suitable for use as Base Course Class A material based on the Ontario Ministry of Transportation and Communications specifications (1979, 1980).

Soundness in Freeze/Thaw and Wetting/Drying Conditions

The soundness of the bedrock samples in freeze/thaw and wetting/drying conditions was determined by the Sodium Sulphate Soundness Test. It is a measure of the resistance of a sample to disintegration by the destructive forces produced by weathering. The test was carried out in accordance with ASTM C88 on fine and coarse crushed stone aggregates to be used in bituminous and concrete applications.

The two sizes tested on the coarse fraction ranged from 38.1-19.1 mm and 19.1-9.5 mm. Material passing 9.5 mm and retained on a No. 8 sieve was tested as the fine fraction of the sample. Only the fine fractions could be tested for sample X^{III} and thus material less than 9.5 mm, but that retained on a No. 50 sieve was analyzed.

The test consists of immersing the sample in a sodium sulphate solution for sixteen hours. This serves to create a pressure due to salt crystals growing in pores producing an effect similar to that of freezing water. The sample is subsequently dried in an oven for eight hours. This cycle is repeated five times and the percentage weight loss is determined.

For the fine fraction, the percentages of material lost varied from 0.3% to 17.7%. The percent lost for the coarse fraction ranged from 5.4% to 41.5%. This figure was not determined for sample X^{III}. The results for the fine fraction are within the allowable limits for concrete with the exception of sample X^{III}. Only the result for sample X^{VII}

TABLE 7.2

PHYSICAL REQUIREMENTS OF BEDROCK FOR VARIOUS AGGREGATE USES

TEST	SPECIFICATION: Base Course Class A	Traffic Type A	Bituminous Class A	Concrete Fine	Concrete Coarse I
Los Angeles Abrasion (% Loss)	60[(a)]	35	35	-	40
Sodium Sulphate Soundness (% Loss)	-	-	-	16	12

Except where noted all of above maximum limits based on Manitoba Department of Highways and Transportation specifications.

(a) Ontario Ministry of Transportation and Communications, 1979, 1980.

was within the allowable limits for coarse aggregate to be used for concrete.

In addition, the percent splitting, crumbling, cracking and flaking was determined for those particles exhibiting distress after the Sodium Sulphate Soundness Test for the coarse aggregate. The results are shown in Table 7.3. Samples No. X^{IV} and X^{VII} were most resistant whereas samples X^{II} and X^{V} were least resistant.

Percentage of Insoluble Material

Percentages of silica and insolubles were determined by digesting the samples in perchloric acid and subsequently filtering and weighing them. The results are outlined in Table 7.3. Sample X^{I} contained 15.4% insoluble material which was the highest percentage. The remaining samples varied from 0.6% to 5.9% insoluble material.

7.1.5 Summary and Conclusions

Several areas where the surficial deposits are less than 3 m thick occur in the study area. In particular, a large area consisting of Gunton dolomite occurs northeast of Stonewall. A bedrock sample which was obtained from one of the quarries in the southeast part of that area was analysed. The results seem to indicate that this bedrock could be used for all of the uses outlined in Table 7.2 with the exception of coarse aggregate for concrete. An immense area still remains available for extraction of rock. Other smaller potential areas occur south of this location. South of Gunton a large quarry (where the type section of the Gunton formation is defined) is now in disuse, though the surrounding area is only covered by shallow overburden and could potentially be quarried. The majority of exposed Gunton dolomite in the Stony Mountain area has already been removed. As much of this rock was suitable for concrete aggregate

TABLE 7.3

LABORATORY TEST RESULTS OF PARTICLES EXHIBITING DISTRESS AFTER SODIUM SULPHATE SOUNDNESS TEST ON COARSE AGGREGATE

Sample No.	Splitting (%)	Crumbling (%)	Cracking (%)	Flaking (%)	Percent Affected
X^{I}	0	0	11.9	4.8	16.7
X^{II}	4.7	0	30.2	11.6	46.5
X^{III}	NT	NT	NT	NT	NT
X^{IV}	7.8	0	2.0	0	9.8
X^{V}	4.6	0	41.8	11.7	58.1
X^{VI}	5.5	0	21.8	0	27.3
X^{VII}	0	0	4.8	2.5	7.3

NT = Not Tested

(Goudge, 1944), it is possible that more detailed testing in the area northeast of Stonewall could outline similar high quality dolomite.

Quarries occur in the northeast part of Stonewall but the majority of dolomite from the Stonewall Formation has either been quarried or it cannot be extracted due to its proximity to the towns. However, several other potential areas occur southeast of Stonewall.

Quarries located in the Inwood area could be expanded due to the large area of relatively thin surficial deposits. Two samples were collected from these quarries and analysed for resistance to abrasion. The results indicate that the rock could be used for all of the uses outlined in Table 7.2. Results of the Sodium Sulphate Soundness Test indicate that one of the samples would be marginally unsuitable as fine aggregate in concrete and the other would be unsuitable as coarse aggregate in concrete. However, these results are not conclusive because they are only based on one sample. Two other large potential areas containing bedrock outcrops occur north of Narcisse and in the vicinity of Poplarfield. Laboratory testing of outcrop samples would be required to determine the suitability of these areas.

Two large areas occur northeast and east of Lundar. Results of testing of a sample collected from a quarry northeast of Lundar indicate that the dolomite is suitable for all of the uses outlined in Table 7.2. This sample exhibited the best results as compared to the other rock samples that were analysed. The potential for expansion of quarrying in this area is relatively high. In addition, further investigations should be carried out to determine the quality of the bedrock in the area to the east. This area of bedrock overlain by surficial deposits less than 3 m thick is larger than that area containing quarries to the west. Two other potential areas within the Interlake Group occur northeast of Dog Lake, one of which contains bedrock outcrops.

The area in the vicinity of Lily Bay generally consists of high-calcium limestone of the Devonian Elm Point Formation. Several quarries occur in this area due to the presence of shallow surficial deposits. This area should continue to be used until the thickness of the surficial deposits becomes too great to economically allow further extraction of the rock. Other potential areas occur southeast and north of Dog Lake.

Areas of shallow bedrock occur within the Devonian Ashern and Winnipegosis Formations, but much of the Ashern consists of bedrock unsuitable for building purposes. Occurrences of high-calcium limestone within the Winnipegosis Formation are very thin or at depths too great to quarry economically. Dolomite from the Winnipegosis area has been quarried extensively around The Narrows of Lake Manitoba.

A relatively large area also in the vicinity of The Narrows contains high-calcium limestone. About 2.7 m was intersected at the top of the Middle Devonian Dawson Bay Formation in a hole drilled by the Mineral Resources Division. Further drilling would be required to determine the thickness of this deposit. Other potential areas occur west of Dog Lake.

7.2 Sand and Gravel Aggregates

7.2.1 Introduction

An assessment of the distribution and volume of sand and gravel deposits in the study area was based on the interpretation of aerial photography, existing soil survey and Quaternary geology maps, field observations and an inventory of sand and gravel resources conducted by the Manitoba Department of Highways.

Field work was carried out in September 1979 and involved visiting deposits identified on aerial photographs located on the 1:50 000 scale topographical maps to: (a) confirm that the air photographs, soils and geology maps had correctly identified the deposit; (b) more accurately delimit the boundary of the deposit; (c) record the existence of pits; and (d) where accessible, record a typical geological log of the deposit and obtain a representative sample either from the face of an existing pit or by use of a backhoe.

Sand and gravel inventory Forms 2 and 3 (included in Appendix 2) provided by the Mineral Resources Division were completed for each exposure visited. For the purpose of this study an exposure was considered either as a dug backhoe pit or a section of an existing pit face. A brief description of each exposure is given in Appendix 3.

Each sand and gravel deposit was numbered according to a system devised by the Mineral Resources Division. Thus, deposits in the Rural Municipalities of Woodlands, St. Laurent and Rockwood were given a number between 4500 and 4588, whilst the remaining disposits to the north were numbered from 34001 to 34069 inclusive. In the present study a total of 153 deposits were identified. Deposit numbers 4517, 4523, 4566, 34007 and 34031 were not used.

Volumes for each deposit were calculated by estimating the area, average depth and the percentage of the deposit already depleted inside a quarter section on the 1:50 000 scale topographical maps. Areas were estimated using a square grid with each square approximately 1 Ha in area and those figures verified by planimetry. This data was recorded on Form 1 (Appendix 2) and applied to a computer programme at the Mineral Resources Division to produce the volumes quoted in Appendix 4. The volumes are further summarized by Municipality in Table 7.4.

TABLE 7.4

TOTAL QUANTITY ESTIMATES OF SAND AND GRAVEL BY MUNICIPALITIES

Municipality	Estimated Total Original Volume tonnes	Estimated Volume of Reserves tonnes
Woodlands	54 555 480	19 373 044
Rockwood	47 175 840	33 185 628
St. Laurent	23 118 840	20 913 210
Coldwell	16 245 900	11 679 480
Eriksdale	291 240	256 248
Siglunes	4 879 890	4 027 725
Gimli	25 489 980	16 264 395
Armstrong L.G.D.	39 150 360	33 122 457
Deposit 34055*	954 000	851 000
TOTALS	211 861 530	139 673 587

*Deposit 34055 is outside the study area but is included in Appendix 4 and therefore included here to make up the final total.

The quality of sand and gravel was determined from grain size analyses of samples collected in the field (Appendix 5) and similar analyses provided by the Department of Highways in their aggregate inventory block files. These data were run through the Mineral Resources Division's Industrial Usage Assessment Program to evaluate the quality of each sand and gravel sample. Each sample is rated on a scale from 1 to 9 according to its potential usage and the number of treatment processes required to produce the final product. This rating was translated into 'High' (1-3), 'Medium' (4-6) and 'Low' (7-9) quality material and symbolized on the final aggregate maps. Appendix 4 lists the quality of aggregate for each deposit. Where no sample was obtained, the quality was estimated based on its similarity to other deposits.

Each deposit is classified in one of three groups and symbolized on the aggregate maps as sand, sand and gravel or gravel. These are purposely left undefined and are used merely to draw attention to the general nature of the deposit as observed in the field or demonstrated by grain size analyses.

Surface resistivity profiles were obtained in selected areas where the thickness of the deposits exceeded the depth capability of the backhoe. The results of this survey are given in Appendix 6.

7.2.2 Sand and Gravel Resources of the Southern Interlake Region

The present study has compiled data from several sources to produce an estimate of sand and gravel reserves available in the Southern Interlake Region. Particularly invaluable in this respect was the inventory carried out by the Manitoba Department of Highways and Transportation. This source provided a comprehensive inventory of pits in the Rockwood and Woodlands municipalities, but gave only sparse coverage of the remaining areas.

An aggregate study conducted in 1976 by Underwood, McLellan and Associates Ltd., included an assessment of deposits in the 'Southern Interlake Region', roughly corresponding to the area covered by the Municipalities of Rockwood and Woodlands. The UMA Group estimated original reserves of 161.1 million tonnes before depletion and 134.5 million tonnes of remaining reserves (see page 36 of the UMA report). This compares to the lower values of 101.7 million tonnes and 52.6 million tonnes estimated in this study. The differences in reserve estimates may be accounted for by different scales of mapping, therefore there is greater precision in the present study.

The following sections provide a discussion of the sand and gravel resources in each municipality. No attempt is made to discuss deposits one by one but rather to provide an overview of aggregate potential in each area and to highlight the existing areas of exploitation.

7.2.3 Sand and Gravel Resources in the Rural Municipality of Woodlands

The Rural Municipality of Woodlands is covered by Maps 13, 14, 15, 16 and 17 with the principal deposits located in the northern half of the Woodlands map sheet (Map 15) and along Highway 6 shown on the St. Laurent map sheet (Map 13).

A total of 30 deposits were identified (Deposits 4500-4516, 4528, 4529, 4568-4578) with an estimated volume before depletion of 54.5 million tonnes. However, widespread excavation of sand and gravel has occurred leaving the present reserves at around 19.4 million tonnes (Table 7.4).

Three dominant lines of deposits can be observed: the first is a 30 km long sand and gravel ridge which runs parallel to Highway 227 in the south-west of the area and turns northwards along Highway 248 where it ends 2 km south of Highway 411; the second is an apparent offshoot of the first starting west of the junction of Highways 248 and 323, and passing north of Woodlands where the westward extension becomes disjointed with only low quality shallow deposits completing the line; and the third is a north-south trending line starting 1 km west of the community of Lake Francis extending 20 km south and ending in Deposit 4514, 4 km west of Highway 248. A fourth, shorter and less pronounced, ridge is formed by Deposits 4576 to 4578, extending into the St. Laurent Municipality.

The first of these ridges has been comprehensively exploited along its entire length. Many of the pits, particularly in Deposit 4500 have been poorly managed and subsequently abandoned, leaving large volumes of usable material covered with overburden stripped from the excavated areas. Several large pits are still used, notably those in the central part of Deposit 4502, though the only pit along this ridge in continuous production at the time of fieldwork (September 1979) was located 5 km west of Woodlands in the northern half of Section 24, Township 14, Range 3W. The thickness and stratigraphy of sand and gravel varies considerably between exposures. Horizontally bedded layers of variable composition are typical on 3 to 4 m thick sections which were observed in deposits 4503 and 4504 whilst thinner sections appeared further to the west.

The second line of deposits is generally thinner, finer grained and exploited by fewer pits. The largest pit observed is in Deposit 4510, 8 km due north of Warren. Similar size pits were reported in Deposits 4507, 4508 and 4509. All of these were only in sporadic use, primarily by local farmers.

The third north-south ridge constitutes Deposit 4569 which is one of few with a high quality grading. A municipal supply pit is located in the southern end of this deposit with convenient access to Highway 6. Except for Deposit 4515, which is a relatively shallow and sandy deposit, this entire ridge once contained good quality gravel that has now been largely exploited. A cobbly layer was observed in the top 1-2 m of the exposures underlain either by a clayey till or sand with a water table at approximately 3 m below the normal ground level. Deposits 4570 and 4571 are almost completely depleted though stockpiles have accumulated alongside several of the pits dug into these ridges

The ridge formed by Deposits 4576-4578 is less than 20 m wide and of little commercial value. Deposit 4576 was exploited years ago and is now marked by a line of well established trees.

The remaining deposits are small and isolated . However, the entire municipality has apparently been well explored in previous years in search of sand and gravel supplies, as the main reserves seem to have been already located and exploited. Possibly the only deposit remaining which offers significant quantity of material is Deposit 4573. If this is part of the Lake Francis north-south ridge it could prove to contain significant reserves of good quality aggregate.

7.2.4 Sand and Gravel Resources in the Rural Municipality of Rockwood

The Rural Municipality of Rockwood is covered by Maps 9, 10, 13, 14 and 16 with the main deposits located within the Teulon and Stonewall map sheet areas (Maps 14 and 16).

A total of 48 deposits were identified (Deposits 4518-4522, 4524-4565, 4567) with an estimated volume before depletion of 47.2 million tonnes and reserves of 33.1 million tonnes.

The southern part of the municipality, defined as the area covered by the Stonewall map sheet (Map 16), contains a number of isolated deposits which are among the most exploited in the entire study area. Deposit 4520 is a 7 km long ridge 3 km south-west of Stony Mountain. In places over 6 m of sand and gravel were observed, although, except for an area in Section 5, Township 13, Range 2E, over 90 percent of this material has been removed, whilst excavation of the remaining deposit continues.

Other large pits were observed in Deposits 4526, 4527 and 4518. All of these are characteristically overlain by a 1 to 2 m thick layer of silty, stony, clay till. A small pit on the south side of the Ekhart Road, a few hundred metres west of Highway 322 in Deposit 4518, demonstrates this relationship, where till overlays a cross-bedded silty sand of probable alluvial origin. A railway cutting at the next mile road north is the location of an old gravel pit excavated to a depth of 6 m. At the continuation of the ridge on the next mile road to the north, a new pit was only recently opened. Over 6 m of gravelly sand was observed in the pit face below 1 m of till. A few small pockets of sand and gravel were observed 3 km east of Stonewall in some private pits showing typically that only 1 m of sand and gravel is present.

The northern part of the municipality, defined as the area covered by the Teulon map sheet (Map 14), contains two principal trends of deposits. One group is orientated south-west to north-east and the second lies perpendicular to this on a north-westerly axis. In terms of their origin, the first group represents a series of beach lines, and the second are most likely derived from high energy streams probably in a pro-glacial or extra-glacial environment.

Despite the numerous deposits in the Teulon map sheet area (Map 14), very few of these are considered commercially viable for the extraction of sand and gravel. Except for Deposit 4530, all deposits in the Rural Municipality of

Rockwood east of a north-south line drawn through Balmoral are no more than 1 m in thickness. Backhoe pits dug into Deposit 4548, 5 km north-east of Teulon, proved nearly 2 m of material in the centre of a 25 m wide ridge, but the material is sandy (graded as 'medium' from a sample at Exposure 104). Similar material is found in Deposit 4554, 7 km north of Teulon, to a maximum depth of 1.2 m. The remaining deposits in this eastern area are much shallower (less than 1 m) and contain occasional pits which serve local uses but appear to be of no commercial value.

The most dominant feature on the Teulon map sheet is the long beach ridge of Deposit 4530 with the accompanying deposits that lie perpendicular to the ridge and terminate along its western edge. The beach ridge is composed of primarily sand which in places is over 5 m deep. Consequently very little exploitation has occurred along the ridge except for an occasional sand pit (for example, Exposure 62). The ridge is noticeably coarser grained in the top 1 m of the deposit. The northern tip of the deposit, 5 km west of Teulon, is excavated but only to a depth of 1 m. Similar excavation has occurred at the southern extremity, 8 km west of Balmoral.

The quality and thickness of the fluvial deposits perpendicular to the beach ridge are highly variable. The northern end of Deposit 4533 is being excavated down to the water table at 1.5 m depth though the actual depth of deposit here is at least 3 m. The southern extremity, 1.5 km south of Highway 415 is yet unexploited, and contains over 2.5 m of sand and coarse pebble gravel in a 45 m wide ridge.

Pits are also located at the northern ends of Deposits 4531, 4532 and 4567, all of which appear to be in occasional use though none of these is deeper than 2 m before encountering till. Deposits 4535 and 4536 are narrow, 50 m wide ridges containing sandy material to a maximum depth of less than 2 m.

The remaining deposits in the north-west around Norris Lake are all shallow, sandy features less than 1 m in thickness.

7.2.5 Sand and Gravel Resources in the Rural Municipality of St. Laurent

The Rural Municipality of St. Laurent is covered mainly by Map 13, with a small overlap onto Map 9. All the sand and gravel deposits are located within 8 km of the Lake Manitoba shoreline and except for Deposit 4588 are centred on Highway 6.

A total of 10 deposits were identified (Deposits 4579-4588) with an estimated volume before depletion of 23.0 million tonnes and total resources of 20.9 million tonnes.

By far the largest feature of the area is Deposit 4588 in the north of the municipality. Several small, 2 m deep pits owned by the municipality were in operation at the time of this study in the southern part of this deposit, but no large scale excavations had been started. The northern extension of this deposit in the Rural Municipality of Coldwell (where it is renumbered as Deposit 34001) was well excavated and in the process of expansion in 1979. Deposit 4587 contains the single largest working pit in the St. Laurent area located 5 km east of St. Laurent in the northwest quarter of Section 6, Township 17, Range 3W. Sand and gravel was excavated by a dragline to allow removal of material from below the water table. Over 4 m of sand and gravel was noted with the water table at 2 m below the normal ground level.

An old gravel pit located at the north-east corner of St. Laurent Parish (Deposit 4586) was dug out to a depth of 3 m years ago and is now abandoned. Excavation of this area apparently stopped at the water table. There is potential for further excavation in the old pit. The eastern limb of this circular deposit contains 2 to 3 m of sand and gravel.

A new pit was in the process of being developed by the owner in Deposit 4580 in the south-west of the municipality. However, an existing pit contains sandy material and the water table is encountered at 2 m, preventing further excavation by a front-end loader. Deposit 4581 is presently inaccessible. The land is very wet and marshy and could prove to contain significant reserves. The estimate of 2.0 million tonnes for this deposit is based on an average depth of 1 m throughout and could easily be an underestimate of the actual quantity.

Deposit 4579 is excavated along its northern edges to a depth of 2 m. A sample from the pit tested as high quality aggregate.

7.2.6 Sand and Gravel Resources in the Rural Municipality of Coldwell

The Rural Municipality of Coldwell is covered by Maps 4, 5, 8 and 9 with all but one deposit (Deposit 34008) located on the western half of the Narcisse map sheet (Map 9).

A total of 7 deposits were identified (Deposits 34001-34006, 34008) with an estimated volume before depletion of 16.2 million tonnes and total remaining reserves of 11.7 million tonnes.

All of these deposits are part of the same beach line and except for Deposit 34001, are composed primarily of sandy material which is often less than 1 m thick. A few small privately used pits were found in areas that proved to contain a thin layer of coarser aggregate above the sand. Deposit 34008 located 5 km east of Highway 418 in the north of the municipality contains several old excavations from which between 1 and 1.5 m of medium grade aggregate has been removed. A clay till forms the base in this area such that the land is now damp and occasionally flooded, and only usable for pasture.

Deposit 34001 located 8 km south of Highway 229 in the south of the municipality is the northward extension of Deposit 4588 in the Rural Municipality of St. Laurent. This deposit is extensively worked to a depth of over 3 m, although the main pit area is largely disused and infilled with water at approximately 2 m below the surface. The material consists of a coarse, cobbly 1 m thick layer and other horizontally bedded layers mixed with a high proportion of sand. New shallow exploratory excavations were observed in the south end of the property which show promising coarse grade material 1 m below surface.

7.2.7 Sand and Gravel Resources in the Rural Municipality of Eriksdale

The Rural municipality of Eriksdale is covered by Maps 3, 4 and 5 and contains an insignificant quantity of sand and gravel reserves, mainly located on the Eriksdale map sheet (Map 4).

A total of 4 deposits were identified (Deposits 34051-34054) with an estimated volume before depletion of 0.29 million tonnes and reserves of 0.25 million tonnes. The volume estimate for Deposit 34055 (Appendix 4) is based on a large area lying inside the Rural Municipality of Grahamdale and therefore not included in the above total. The actual area of Deposit 34055 within Eriksdale is negligible.

A small 0.5 m deep pit was observed in Deposit 34054 5 km west of Eriksdale, otherwise the deposits are unexploited, due to the sandy nature, small size and relatively isolated locations of the deposits.

7.2.8 Sand and Gravel Resources in the Rural Municipality of Siglunes

The Rural Municipality of Siglunes is covered by Maps 1, 2, 3 and 4 with the main deposits located in the south-east quarter of the Ebb and Flow Lake map sheet (Map 1) and in the north-west corner of the Eriksdale map sheet (Map 4).

A total of 14 deposits were identified (Deposits 34056-34069) with an estimated volume before depletion of 4.9 million tonnes and reserves of 4.0 million tonnes.

The deposits are either small isolated beach features lying above an elevation of 251 m (825 ft) (Deposits 34059-34065), or relatively younger beaches associated with the margins of Dog Lake (Deposits 34056-34058, 34066-34068). Deposit 34069 is an isolated beach remnant at an elevation of 282 m (925 ft).

All of the deposits above elevation 251 m (825 ft) contain small gravel pits (except Deposit 34065 which is insignificant in size). None of these pits contain greater than a 1 m thick layer of material which is characteristically a coarse sand with occasional pebbles. The only pit apparently in use in 1979 was that in Deposit 34064 located 6 km north of Highway 235 on Highway 325.

Of the deposits associated with Dog Lake, pits were observed only in Deposit 34058 at the south end of the Lake along Highway 514. These contain a coarse, unsorted, cobbly material to a depth of 1.5 m. The remaining deposits are inaccessible but are expected to be of similar composition and thicknesses.

7.2.9 Sand and Gravel Resources in the Rural Municipality of Gimli

The Rural Municipality of Gimli is covered by Maps 10 and 11 with all the deposits located in the eastern half of the Fraserwood map sheet (Map 10).

A total of five deposits were identified (Deposits 34028-34030, 34032 and part of 34033) with an estimated volume before depletion of 25.6 million tonnes and reserves of 16.2 million tonnes.

Except for Deposit 34028 which is a higher elevation beach-ridge, the remaining deposits in the Municipality form an almost continuous ridge running some 35 km from north to south. The main excavations in the area are found 3 km northwest of Camp Morton in Deposit 34033 where pits over 6 m deep have been worked. A 3 km strip along the ridge is almost completely removed and new workings were being opened up southwards. Gravel pits are established at the north and south ends of Deposit 34032 to depths of 2 m though no workings at all were found in the central length of the deposit. Further south the ridge becomes narrower with few excavations still in operation. Large tracts of Deposits 34029 and 34030 were completely removed in the past, typically to depths of 2 m.

Deposit 34028 contains two small privately operated pits which proved between 1.5 and 2 m of sand and gravel.

7.2.10 Sand and Gravel Resources in the Local Government District of Armstrong

The Local Government District of Armstrong is covered by Maps 5, 6, 9 and 10 with the main deposits located on the Fraserwood map sheet (Map 10) and significant deposits on the Arborg and Poplarfield sheets (Maps 5 and 6).

A total of 37 deposits were identified (Deposits 34009-34027, 34034-34050 and part of Deposit 34033) with an estimated volume before depletion of 39.2 million tonnes and reserves of 33.1 million tonnes.

A scattered distribution of northwest to southeast trending deposits dominates the southern part of the area. In the northeast a 15 km long ridge, starting 2 km west of Highway 7, runs southeastwards and forms the northernmost extension of the beach ridge running the entire length of the Rural Municipality of Gimli. A final group of deposits forms a semi-circular distribution starting at Highway 16 and terminating in Chatfield.

The smaller, northwest to southeast trending deposits contain numerous small pits which are used privately or have been abandoned. Few of these deposits contained over 1 m in thickness of sand and gravel. Deposit 34022 (exposure 154) contains over 2 m of a coarse pebble gravel. However this is not consistant throughout the deposit. A sample which tested as high quality was obtained from an abandoned pit in Deposit 34009, 2 km north of Narcisse. The area is largely worked out and is designated as a wildlife management area.

Deposit 34033 is a long, narrow ridge, the northern extent of which is 2.5 km north of Rembrandt at Highway 7. 5 km east of Rembrandt Highway 324 follows the top of the ridge for 10 km into the Rural Municipality of Gimli. Gravel pits are found at sporadic intervals along the part of the ridge located in the Local Government District of Armstrong. The north-west had been dug out for a continuous distance of nearly 3 km although at no point are excavations deeper than 2 m despite the total depth of the deposit being over 3 m. Several 5 m deep disused pits were found 1 km northwest of the junction of the ridge with Highway 324, some with stockpiles of gravel indicating some temporary use of the material. Where Highway 324 follows the top of the ridge few pits were observed.

The semi-circular beach ridge between Chatfield and Highway 16 contains several pits concentrated in Deposits 34048 and 34046. Some shallow 1-2 m deep pits were observed in Deposit 34048 around Highway 18 but larger excavations are known to occur 0.5 km east of the road. This whole area is a designated wildlife management area. At a farm in Section 31, Township 19, Range 1E, 0.6 m of a coarse, cobbly layer of gravel was observed overlying sand. This upper layer is excavated for private usage. The whole ridge is composed mainly of medium sand with coarser sand lenses and smaller lenses of pebbles and cobbles.

Two ridges at higher elevations (Deposits 34044 and 34045) are located within the arms of the semi-circular beach ridge.

CHAPTER 8
SUMMARY AND GENERAL CONCLUSIONS

8. SUMMARY AND GENERAL CONCLUSIONS

The Southern Interlake Region is an area of low relief consisting of the western rim of the Lake Winnipeg-Red River depression, and the eastern rim of the Lake Manitoba depression. These rims are linked in the north by the high till plains of the Interlake and in the south by the Shoal Lake depression.

The existing landforms reflect a series of events during the Quaternary period closely related to the recession of glacial Lake Agassiz. A series of lacustrine and till plains are observed with superimposed fluvial and beach ridges corresponding to successive levels of Lake Agassiz.

Between Ordovician and Jurassic times the area was part of a large, generally shallow and warm marine depositional basin. A series of carbonate-based sediments were lain down during this period consisting of calcareous shales and argillaceous and crystalline limestones, many of which were subsequently dolomitized to varying degrees.

Areas where bedrock is less than 3 m below the surface are identified on Maps 17, 19 and 20. The main quarrying in the region has concentrated on the exploitation of the most accessible rock. Thus, the dolomites of the Gunton and Penitentiary Members of the Stony Mountain Formation and the Stonewall Formation have been extensively quarried from their type areas around Stonewall, Gunton and Stony Mountain. Presently the principal quarrying is from the Gunton Formation in quarries two to three miles north-west of Stonewall. High-calcium limestones are perhaps better grade rocks for aggregate but these are mainly found near the surface in the north-west of the study area (taken from the Dawson Bay Formation and the Elm Point Member of the Elk Point Formation) and are therefore presently at an uneconomical distance from the main consuming areas.

Assuming a density for dry dolomite as 2.30 tonnes/m^3 and considering a vertical extent of bedrock of 5 m, then in 1 square kilometre, there is the potential to quarry 11.5 million tonnes of rock. In the area, northeast of Stonewall for example (an area of approximately 20 km^2) a total of 230 million tonnes of bedrock could conceivably be quarried.

The sand and gravel reserves are estimated at 139.7 million tonnes and are summarized by municipality in Table 7.4. Individual deposits are indicated on the 1:50 000 scale aggregate resource maps covering the area (Maps 1 to 16). Most of the sand and gravel is concentrated in ancient beach ridges and associated with the regression of glacial Lake Agassiz and along lines of old river channels. Much of the good quality coarse grade sand and gravel has already been extracted whilst throughout the entire area there are relatively few deposits that do not contain pits. In many areas, notably in the Rural Municipality of Woodlands and in the north-east of the Local Government District of Armstrong there are numerous pits that have in the past been poorly managed and which may allow future reworking of the sites.

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APPENDIX 1
DEPTH TO BEDROCK INFORMATION

APPENDIX 1

DEPTH TO BEDROCK INFORMATION

Location Number	U.T.M. Easting	U.T.M. Northing	Source	Depth to Bedrock	Comments
272	6227	55798	B	>3.4	
273	6243	55798	B	>4.1	
274	6227	55782	B	>4.3	
275	6228	55766	B	>4.7	
276	6195	55747	B	>3.5	
277	6211	55749	B	>3.8	
278	6227	55749	B	>4.3	
279	6221	55732	B	3.7	Dolostone
280	6228	55732	B	>4.0	
281	6229	55716	B	3.0	Massive dolostone
282	6228	55700	B	>3.8	
283	6245	55700	B	>4.1	
284	6229	55683	B	3.5	Blocky dolostone
285	6246	55683	B	>3.7	
286	6198	55649	B	>3.7	
287	6197	55633	B	3.2	Slightly weathered pale orange dolostone
288	6181	55616	B	>5.5	
289	6198	55617	B	>4.3	
290	6214	55616	B	4.4	Dolostone
291	6214	55608	B	0	Pale orange dolostone
292	6199	55600	B	3.8	Blocky fine crystalline dolostone
293	6214	55600	B	3.8	Massive dolostone
294	6231	55600	B	1.5	Massive dolostone
295	6182	55583	B	>4.4	
296	6199	55583	B	>4.7	
297	6216	55583	B	3.5	Fine crystalline dolostone
298	6231	55584	B	2.4	Massive pale orange fine crystalline dolostone
299	6200	55567	B	3.2	Buff fine crystalline dolostone
300	6215	55567	B	2.1	Slightly vuggy and fractured dolostone
301	6232	55568	B	2.1	Dolostone
302	6166	55549	B	>4.6	

APPENDIX 1

DEPTH TO BEDROCK INFORMATION (Cont'd)

Location Number	U.T.M. Easting	U.T.M. Northing	Source	Depth to Bedrock	Comments
303	6151	55534	B	>4.6	
304	6168	55534	B	>4.3	
305	6184	55534	B	>3.8	
306	6151	55517	B	>5.3	
307	6168	55517	B	4.3	Massive bedrock
308	6184	55517	B	2.7	Dolostone
309	6152	55501	B	>3.8	
310	6169	55500	B	3.8	
311	6184	55501	B	3.8	
312	6136	55483	B	>4.3	
313	6151	55484	B	3.5	Blocky white dolostone
314	6169	55485	B	3.4	Massive bedrock
315	6185	55485	B	>4.0	
316	6225	55519	B	>4.1	
317	6217	55510	B	>4.4	
318	6234	55511	B	>4.4	
319	6218	55502	B	2.1	Buff dolostone
320	6226	55502	B	3.5	Massive dolostone
321	6218	55495	B	3.5	Fractured dolostone
322	6234	55494	B	3.4	Dolostone
323	6218	55486	B	2.1	Buff dolostone
324	6226	55486	B	3.7	
325	6234	55486	B	2.9	Dolostone
326	6281	55552	B	>4.6	
327	6315	55554	B	>4.6	
328	6265	55536	B	>5.5	
329	6282	55537	B	>4.4	
331	6298	55537	B	>4.3	
332	6316	55520	B	3.8	
333	6195	55759	D	6.1	Drilled alternating 10.2 m thick hard and soft layers in bedrock. Difficult to determine exactly where bedrock was reached.

APPENDIX 1

DEPTH TO BEDROCK INFORMATION (Cont'd)

Location Number	U.T.M. Easting	U.T.M. Northing	Source	Depth to Bedrock	Comments
334	6203	55748	D	4.3	
335	6218	55712	D	4.9	Drilled into alternating hard and soft layer in bedrock. Exact depth to bedrock difficult to determine.
336	6229	55691	D	3.4	
337	6198	55641	D	5.2	
338	6198	55625	D	2.6	
339	6214	55624	D	5.8	
340	6224	55617	D	4.9	
341	6198	55610	D	5.9	
342	6190	55600	D	>7.9	
343	6121	55583	D	4.9	
344	6208	55583	D	2.6	
345	6167	55575	D	6.2	
346	6159	55566	D	4.3	
347	6147	55566	D	>7.8	From 7.1 to 7.8 m boulders were drilled. Possibly fractured top of bedrock.
348	6160	55550	D	6.0	
349	6176	55533	D	4.1	Large circulation loss during drilling in top of bedrock - strongly fractured?
350	6192	55518	D	2.9	
351	6201	55480	D	5.8	
352	6281	55565	D	>8.1	
353	6268	55536	D	>8.2	
354	6331	55540	D	8.4	Large circulation loss during drilling in top of bedrock - strongly fractured?
355	6300	55499	D	7.9	

APPENDIX 2

MINERAL RESOURCES DIVISION SAND AND GRAVEL DATA FORMS

FORM 1

SAND & GRAVEL INVENTORY

DEPOSIT STATUS

DEPOSIT NO: ________ __ SUB

LANDFORM __ (if Z specify ______________________)

COMPLETELY DEFINED __ (Y, N)

OWNERSHIP & RESERVES

LOCATION							OWNERSHIP				
TWP	RNG	SCT	¼ SCT	APPROXIMATE AREA (HA.)	AVERAGE DEPTH (m.)	% DEPLETED NOT AVAILABLE					

FORM 2

SAND AND GRAVEL INVENTORY

EXPOSURE-STRATIGRAPHIC SECTION DATA

DEPOSIT NO. SUB

TOWNSHIP RANGE SECTION 1/4 SECTION

EXPOSURE NO.

EXPOSURE TYPE | MATERIAL USE | LAND USE | THICKNESS OF ECONOMIC UNIT (m.) | VISUAL QUALITY | Y M D DATE EXAMINED

MATERIAL DESCRIPTION

COMMENTS

STRATIGRAPHIC SECTION

GEOLOGIST | HEIGHT OF SECTION | HEIGHT EXAMINED (m.) | DEPTH TO WATER TABLE (m.)

MATERIAL AT BASE OF SECTION

% LITHOLOGY (PRIMARY) | % LITHOLOGY (SECONDARY) — GROSS LITHOLOGY

PRIMARY | SECONDARY — DELETERIOUS SUBSTANCES

CHANNEL SAMPLE (Y,N)

CHECK: MATERIAL LARGER THAN 15CM AVAILABLE BUT NOT SAMPLED

STRATIGRAPHIC SECTION

GEOLOGIST | HEIGHT OF SECTION | HEIGHT EXAMINED (m.) | DEPTH TO WATER TABLE (m.)

MATERIAL AT BASE OF SECTION

% LITHOLOGY (PRIMARY) | % LITHOLOGY (SECONDARY) — GROSS LITHOLOGY

PRIMARY | SECONDARY — DELETERIOUS SUBSTANCES

CHANNEL SAMPLE (Y,N)

CHECK: MATERIAL LARGER THAN 15CM AVAILABLE BUT NOT SAMPLED

SAND AND GRAVEL INVENTORY

FORM 3

QUATERNARY GEOLOGY (SUB-UNIT DATA

DEPOSIT	SUB	TOWNSHIP	RANGE	SECTION	1/4 SECTION	EXPOSURE	STRAT. SECTION

	TOP (m.)	BOTTOM (m.)	DELETERIOUS SUBSTANCES	LITHO-MORPHOLOGY				COHESION	ACID REACTION (N,W,S)	SEDIMENT TYPE	SEDIMENTARY STRUCTURE	NATURE OF DEPOSITIONAL INTERFACE	POST-DEPOSITIONAL STRUCTURE/WEATHERING	PALEOFLOW DIRECTION	DIP		NO. OF STRAT. SAMPLES
				%	LITHOLOGY	ROUNDNESS	CLAST SHAPE								DEGREES	DIRECTION	
1.																	
2.																	
3.																	
4.																	
5.																	
6.																	
7.																	
8.																	
9.																	
10.																	

FORM 4

SIEVE ANALYSIS

	DEPOSIT NO.	SUB	TWP.	RNG.	SCT.	¼ SCT.	EXPOSURE	STRAT SCT.
SAMPLE NO.								

NAME ______________________________

CRUSHABLE MATERIAL ☐ (Y,N) (1,0)

WEIGHT OF SAND ______________ GMS.

WEIGHT BEFORE WASHING ______________ GMS. WEIGHT AFTER WASHING ______________ GMS.

Screen	mm	phi units	Weight on Sieve (Gms.)
4"	101.6	-6.65	
3½"	88.9	-6.47	
3"	76.2	-6.25	
2½"	63.5	-6.00	
2"	50.8	-5.67	
1½"	38.1	-5.25	
1"	25.4	-4.67	
3/4"	19.1	-4.25	
5/8"	15.9	-4.00	
1/2"	12.7	-3.67	
3/8"	9.5	-3.25	
1/4"	6.35	-2.67	
#4	4.76	-2.25	
#8	2.38	-1.25	
#10	2.00	-1.00	
#16	1.19	-0.25	
#30	0.59	+0.75	
#40	0.42	+1.25	
#50	0.30	+1.75	
#80	0.177	+2.50	
#100	0.149	+2.75	
#200	0.074	+3.75	
< 200			

COARSE FRACTION (4" through 3/4")

FINE FRACTION (5/8" through < 200)

DESCRIPTION OF HEADINGS

Exposure Type

B	Backhoe pit section
P	Sand and gravel pit section
BP	Backhoe pit section dug in sand and gravel pit
O	Other - road section

Lithology

The dominant constituent in all the sand and gravel throughout the area is limestone (or dolostone). This is indicated by the letter J. The preceeding figure (e.g. 80) indicates the approximate proportion of the material comprised of limestone. Only the dominant constituent is given. In general the remaining proportion is made up of crystalline derived material from Precambrian rocks of the region.

Degree of Sorting

W	Well sorted. Exposure exhibits uniformity of grain size
W (G)	Where several uniform layers of varying grain size exist this classification is used to indicate the several grades
P	Poorly sorted. Exposure exhibits wide range of grain sizes mixed together

Roundness

A	Rounded
B	Sub-rounded
C	Sub-angular

Depth to Water

Measured below normal ground level. Where no water was observed the greatest depth of the section is indicated (e.g. >0.9 m).

N.S. - near surface (usually refers to old waterlogged pits observed from a distance, i.e. the water level was not measured).

APPENDIX 3

SUMMARY OF FIELD DATA

APPENDIX 3

SUMMARY OF FIELD DATA

Field Exposure No.	Deposit No.	Township	Range	Section	¼ Section	Exposure Type	Thickness of Sand and Gravel (m)	Lithology	Degree of Sorting	Roundness	Depth to Water (m)	Comments
1	4516	15	3W	2	SE	B	2.9	80J	P	B	>3.1	
2	4516	15	3W	2	SE	P	-	-	-	-	-	Pit in operation
3	4515	15	3W	2	SW	B	0.3	80J	W	B	>0.6	
4	4515	15	3W	2	SW	B	1.7	80J	W(G)	B	>1.9	
5	4515	15	3W	2	SW	B	0.0	-	-	-	-	Silty, clay, till
6	4514	14	3W	15	NW	B(P)	>2.4	80J	W(G)	B	2.4	
7	4514	14	3W	22	SW	B	0.5	80J	P	B	>0.5	
8	4514	14	3W	15	NW	B	0.0	-	-	-	-	Clay till
9	4514	14	3W	15	NW	B	0.0	-	-	-	-	Clay till
10	4500	13	4W	20	NW	P	-	-	-	-	-	Disused pit - garbage dump
11	4500	13	4W	27	NE	BP	0.6	85J	P	B	>0.9	
12	4500	13	4W	27	NE	B	0.5	80J	W(G)	B	>1.5	
13	4500	13	4W	27	NE	B	0.5	80J	P	B	>0.5	
14	4502	14	3W	31	SW	B	0.5	80J	P	B	>0.5	
15	4503	13	3W	33	SW	P	3.0	-	-	-	-	
16	4503	14	3W	11	NE	B	0.8	80J	P	B	>0.8	
17	4503	14	3W	12	NW	B	>2.4	85J	W(G)	B	>2.4	
18	4503	14	3W	13	NW	P	>4.5	80J	P	B	>4.5	
19	4504	14	3W	24	NW	P	-	-	-	-	N.S.	Old waterlogged pit
20	4504	14	3W	24	NE	P	>2.4	80J	W(G)	B	>2.7	
21	4504	14	3W	25	SE	B	>3.0	80J	W(G)	B	>3.0	
22	4505	14	3W	12	NW	B	1.8	80J	W	B	0.9	
23	4505	14	3W	13	SE	P	>1.0	80J	W	B	>1.0	
24	4505	14	3W	12	NW	B	0.8	80J	W	B	0.2	
25	4506	14	2W	29	SW	0	>1.5	80J	P	B	>1.5	
26	4506	14	2W	28	SW	B	0.0	-	-	-	-	
27	4506	14	2W	28	SW	B	0.7	80J	W(G)	B	>0.9	
28	4506	14	2W	28	SW	B	0.4	80J	W(G)	B	>0.6	
29	4506	14	2W	27	NW	B	0.0	-	-	-		Stony till
30	4506	14	2W	27	NW	B	0.2	80J	P	B	>0.2	

APPENDIX 3 (Cont'd)

Field Exposure No.	Deposit No.	Township	Range	Section	¼ Section	Exposure Type	Thickness of Sand and Gravel (m)	Lithology	Degree of Sorting	Roundness	Depth to Water (m)	Comments
31	4506	14	2W	27	NW	B	0.0	-	-	-	-	Till
32	4507	14	2W	27	NW	B	0.1	80J	P	B	>0.3	
33	4507	14	2W	27	NW	B	0.1	80J	P	B	>0.3	
34	4510	14	1W	20	NE	B(P)	1.5	80J	P	B	>1.5	
35	4510	14	1W	20	NE	B(P)	1.0	80J	P	B	>1.5	
36	4510	14	1W	20	NE	B(P)	1.3	80J	W(G)	B	>1.5	
37	4510	14	1W	20	NE	B(P)	1.4	80J	W(G)	B	>1.4	
38	4513	14	1W	33	SE	B	0.3	85J	P	B	>0.5	
39	4513	14	1W	33	SE	B	0.0	-	-	-	-	Till
40	4513	14	1W	33	SE	B	0.0	-	-	-	-	Till
41	-	13	3W	31	NW	O	0.0	-	-	-	-	Silty, clay till
42	-	14	3W	18	SW	O	0.0	-	-	-	-	Till
43	-	14	3W	30	SW	O	0.0	-	-	-	-	Till
44	4518	13	1E	31	NW	P	6.0	-	-	-	-	New pit
45	4518	13	1E	31	SE	P	>6.0	75J	W(G)	B	>6.0	Disused pit
46	4518	13	1E	30	SE	P	4.0	-	W	-	-	Sand pit
47	4518	13	1E	20	NW	O	-	-	-	-	-	Sand ridge in roadside
48	4520	13	2E	7	SW	P	6.0	80J	W(G)	B	>6.0	
49	4521	13	2E	21	NW	B	-	-	-	-	-	Stony, clay till
50	4521	13	2E	21	NW	B	0.1	80J	P	B	>0.3	
51	4522	13	2E	32	SE	O	~2.0	-	-	-	-	Sandy ridge in roadside
52	4526	14	2E	21	SW	P	>2.5	90J	W(G)	B	>3.0	
53	4526	14	2E	21	SW	P	-	-	-	-	-	1.2 m Silty, clay till overlying sand and gravel
54	4538	15	2E	5	NE	P	1.0	-	-	-	-	Disused pit - garbage dump
55	4539	15	2E	16	SW	P	0.7	85J	W(G)	B	>0.9	
56	4540	15	2E	28	SW	P	1.0	-	-	-	-	Disused pit - garbage dump
57	4567	15	1E	8	NE	P	-	-	-	-	-	Municipal supply pit
58	4530	15	1E	5	NW	P	>1.2	90J	W(G)	B	>1.2	
59	4530	15	1E	5	NE	P	2.1	85J	W(G)	B	>1.2	
60	4530	15	1E	14	NW	O	>0.1	-	-	-	-	

APPENDIX 3 (Cont'd)

Field Exposure No.	Deposit No.	Township	Range	Section	¼ Section	Exposure Type	Thickness of Sand and Gravel (m)	Lithology	Degree of Sorting	Roundness	Depth to Water (m)	Comments
61	4530	15	1E	23	SW	B	3.0	80J	W(G)	B	>3.0	
62	4530	16	1E	1	SW	B	>3.7	80J	W	A	>3.7	
63	4530	16	1E	1	SW	B	>3.0	80J	W	A	>3.0	
64	4530	16	1E	1	SW	B	>2.1	80J	W	A	>2.1	
65	4530	16	1E	25	SE	B	0.1	80J	W	B	>0.3	
66	4530	16	1E	25	SE	B	0.7	80J	W(G)	B	>0.9	
67	4530	16	1E	25	SE	B	0.1	80J	W	B	>0.3	
68	4530	16	2E	30	NW	P	>0.9	80J	W(G)	B	1.2	
69	4530	15	1E	27	SW	P	1.5	80J	P	B	>1.5	
70	4532	16	1E	15	SE	B(P)	-	-	-	-	-	Till
71	4532	16	1E	15	SE	B(P)	1.2	80J	P	B	1.1	
72	4532	16	1E	15	SE	B(P)	1.0	80J	W(G)	B	1.1	
73	4533	16	1E	14	SE	B	-	-	-	-	-	Bouldery till
74	4533	16	1E	14	SE	B	-	-	-	-	-	Bouldery till
75	4533	16	1E	14	SE	B	1.1	80J	P	H	1.4	
76	4533	16	1E	14	SE	B	>2.1	80J	P	C	1.2	
77	4533	16	1E	14	SE	B	>2.2	80J	P	C	1.3	
78	4533	16	1E	14	SE	B	>1.9	80J	W(G)	B	1.2	
79	4533	16	1E	23	SW	P	2.0	-	-	-	N.S.	Old waterlogged pits
80	4533	16	1E	27	SE	P	11.0?	-	-	-	-	Implied depth of gravel from old well log
81	4533	16	1E	27	SE	B(P)	-	-	-	-	-	Till
82	4533	16	1E	27	SE	B(P)	0.9	80J	P	C	1.1	
83	4533	16	1E	27	SE	P	1.4	80J	P	C	1.2	
84	4533	16	1E	27	SE	P	>2.4	80J	P	C	1.2	
85	4533	16	1E	27	SE	P	>2.4	80J	P	C	1.2	
86	4534	16	1E	23	NE	P	0.9	70J	P	C	>0.9	
87	4535	16	1E	25	SE	B	0.2	80J	W	B	>0.4	
88	4535	16	1E	25	SE	B	1.4	80J	W(G)	B	>1.7	
89	4535	16	1E	25	SE	B	0.9	80J	W(G)	B	>1.2	
90	4542	16	2E	32	NE	P	1.0	-	-	-	N.S.	Old waterlogged pit

APPENDIX 3 (Cont'd)

Field Exposure No.	Deposit No.	Township	Range	Section	¼ Section	Exposure Type	Thickness of Sand and Gravel (m)	Lithology	Degree of Sorting	Roundness	Depth to Water (m)	Comments
91	4554	17	2E	17	SE	B	0.7	80J	W	B	0.9	
92	4554	17	2E	17	SE	B	1.0	80J	W(G)	B	0.9	
93	4554	17	2E	17	SE	B	1.0	80J	W(G)	C	1.0	
94	4554	17	2E	17	SE	B	1.0	75J	W(G)	B	1.2	
95	4559	17	1E	21	SE	B	0.0	-	-	-	-	Till
96	4559	17	1E	21	SE	B	0.1	80J	P	B	>0.3	
97	4559	17	1E	21	SE	B	0.0	-	-	-	-	Till
98	4550	17	2E	13	SW	P	1.0	-	-	-	-	
99	4547	17	2E	2	NW	B	0.3	80J	P	B	>0.5	
100	4547	17	2E	2	NW	B	0.6	80J	W(G)	B	>0.9	
101	4547	17	2E	2	NW	-	-	-	-	-	-	Till
102	4548	17	2E	2	NE	B	0.4	80J	W	B	>0.6	
103	4548	17	2E	2	NE	B	1.0	80J	W(G)	B	>1.2	
104	4548	17	2E	2	NE	B	1.6	80J	W(G)	B	1.4	
105	4543	17	2E	3	SE	O	-	-	-	-	-	Low ridge
108	4548	16	2E	27	NE	P	>1.0	-	-	-	-	Disused pit
109	4548	16	2E	35	SW	P	1.0	-	-	-	-	Old waterlogged pit
110	4561	17	2E	25	SW	O	0.1	-	-	-	-	Road ditch observation
111	4551	17	2E	25	NW	P	1.0	-	-	-	-	
112	4540	16	2E	3	NW	P	1.0	-	-	-	-	Disused pit
113	4530	16	2E	6	SW	P	2.0	70J	P	-	-	
114	4587	17	3W	20	NW	P	>1.7	85J	W(G)	B	>1.7	
115	4588	17	3W	20	NW	P	2.0	-	-	-	-	
116	4586	17	4W	2	SW	P	3.0	-	-	-	-	Disused pits
117	4586	16	4W	35	NE	O	~3.0	-	-	-	-	Ridge
118	4580	16	3W	1	SE	P	>1.9	75J	W(G)	B	1.9	
119	4576	15	3W	29	SE	P	1.7	85J	W(G)	B	>1.7	
120	4570	15	3W	22	NE	P	>1.2	80J	P	B	>1.5	
121	4570	15	3W	23	SW	P	>2.0	-	-	-	-	
122	4569	15	3W	14	NW	O	0.8	80J	P	B	>1.1	
123	4579	16	3W	6	NW	P	2.0	-	-	-	-	

APPENDIX 3 (Cont'd)

Field Exposure No.	Deposit No.	Township	Range	Section	¼ Section	Exposure Type	Thickness of Sand and Gravel (m)	Lithology	Degree of Sorting	Roundness	Depth to Water (m)	Comments
124	4587	17	3W	6	NW	P	>4.0	60J	W(G)	B	2.3	
125	34021	18	2E	4	NW	B	0.0	-	-	-	-	Till
126	34021	18	2E	4	NW	B	1.3	80J	P	B	>1.5	
127	34021	18	2E	4	NW	B	0.3	80J	P	B	>0.5	
128	34021	18	2E	4	NW	B	0.0	-	-	-	-	Till
129	34021	18	2E	4	SW	O	>1.0	-	-	-	N.S.	Old waterlogged pit
130	34012	18	1E	16	SE	B	1.3	80J	P	B	>1.5	
131	34012	18	1E	16	SE	O	0.0	-	-	-	-	Bouldery, clay till
132	34012	18	1E	16	SE	O	0.0	-	-	-	-	Bouldery, clay till
133	34012	18	1E	16	SE	B	0.7	80J	P	B	>0.9	
134	34012	18	1E	16	SE	B	1.3	80J	W(G)	B	1.4	
135	34012	18	1E	16	SE	B	0.1	80J	W	B	>3.0	
136	34012	18	1E	16	SE	B	0.0	-	-	-	_	Clay - till?
137	34012	18	1E	16	SE	B	0.1	-	-	-	-	
138	34012	18	1E	16	SE	B	0.0	-	-	-	-	Sandy till
139	34012	18	1E	16	SE	B	0.6	80J	P	B	>0.8	
140	34012	18	1E	16	SE	B	1.0	80J	P	B	>1.1	
141	34012	18	1E	16	SE	B	0.0	-	-	-	-	Till
142	34017	18	1W	35	SE	O	1.0	-	-	-	-	Disused pits
143	34018	19	1E	6	SE	P	0.6	80J	P	B	>0.6	
144	34018	19	1E	7	SW	O	1.0	-	-	-	-	Disused pits
145	34041	19	1E	35	SW	B	0.3	80J	P	B	>0.5	
146	34041	19	1E	35	SW	B	0.6	80J	W(G)	B	>0.9	
147	34041	19	1E	35	SW	B	0.6	80J	P	B	>0.8	
148	34024	19	1E	2	SE	O	-	-	-	-	-	Shallow ridge
149	34023	18	1E	36	NE	P	<1.0	-	-	-	-	
150	34023	18	2E	31	SW	P	<1.0	-	-	-	N.S.	Old waterlogged pit
151	34022	18	2E	30	SW	B	1.4	80J	W(G)	B	1.2	
152	34022	18	2E	30	SE	B	1.0	80J	W(G)	B	>1.2	
153	34022	18	2E	30	SE	B	0.4	80J	P	B	>0.6	
154	34022	18	2E	30	SE	B	>2.2	80J	P	B	1.8	

APPENDIX 3 (Cont'd)

Field Exposure No.	Deposit No.	Township	Range	Section	¼ Section	Exposure Type	Thickness of Sand and Gravel (m)	Lithology	Degree of Sorting	Roundness	Depth to Water (m)	Comments
155	34022	18	2E	30	SE	B	1.5	80J	W(G)	B	1.2	
156	34022	18	2E	30	SE	B	0.3	80J	W	B	0.0	
157	34022	18	2E	30	SE	B	0.0	-	-	-	-	Clay
158	34025	18	2E	22	SE	P	1.5	-	-	-	-	Disused pit
159	34028	18	3E	3	NW	P	>1.5	80J	W(G)	B	>1.5	
160	34028	18	3E	15	SE	BP	1.3	80J	W(G)	B	>1.5	
161	34028	18	3E	15	SE	B	0.6	80J	P	B	>0.9	
162	34028	18	3E	15	SE	B	1.0	80J	W(G)	B	>1.2	
163	-	18	3E	21	NE	B	0.0	-	-	-	-	Till ridge
164	34029	18	3E	2	SW	P	2.0	-	-	-	N.S.	Old waterlogged pit
165	34029	18	3E	11	SW	P	2.0	-	-	-	-	Disused pits
166	34029	18	3E	11	NE	BP	0.9	80J	W(G)	C	>1.2	
167	34029	18	3E	11	NE	BP	0.9	80J	W(G)	B	>1.8	
168	34029	18	3E	23	NW	BP	0.3	80J	W	B	>0.5	
169	34029	18	3E	23	NW	BP	1.3	80J	W(G)	B	>1.8	
170	34029	18	3E	23	NW	BP	1.5	80J	P	B	>1.8	
171	34030	18	3E	34	NW	P	<1.0	-	-	-	-	
172	34030	19	3E	9	NE	B	0.0	-	-	-	-	Clay
173	34030	19	3E	9	NE	B	1.3	80J	W(G)	B	>1.5	
174	34030	19	3E	9	NE	B	0.7	80J	W(G)	B	>0.9	
175	34030	19	3E	9	NE	B	0.0	-	-	-	-	Clay till
176	34030	19	3E	16	SE	P	-	-	-	-	-	Disused pit - garbage dump and rifle range
177	34032	19	3E	34	NE	BP	1.1	80J	W	B	0.6	
178	34032	19	3E	34	NE	BP	2.6	80J	W(G)	B	2.5	
179	34032	19	3E	34	NE	BP	1.2	80J	W(G)	B	0.9	
180	34032	20	3E	24	SW	O	-	80J	W(G)	B	-	
181	34032	20	3E	23	SE	BP	0.6	80J	P	B	0.7	
182	34032	20	3E	23	SE	BP	3.0	80J	W(G)	B	2.5	
183	34032	20	3E	23	SE	BP	2.8	80J	W(G)	B	2.7	
184	34032	20	3E	24	NW	P	>10.0m	-	-	-	-	

APPENDIX 3 (Cont'd)

Field Exposure No.	Deposit No.	Township	Range	Section	¼ Section	Exposure Type	Thickness of Sand and Gravel (m)	Lithology	Degree of Sorting	Roundness	Depth to Water (m)	Comments
185	34037	20	2E	14	NW	B	1.0	80J	W(G)	B	1.2	
186	34037	20	2E	14	NW	B	1.2	80J	W(G)	B	1.3	
187	34037	20	2E	14	NW	B	1.3	85J	W(G)	B	1.2	
188	34027	20	2E	14	NW	B	0.5	80J	P	B	>0.8	
189	34037	20	2E	14	NW	B	2.2	80J	W(G)	B	1.5	
190	34037	20	2E	14	NW	B	0.9	80J	W(G)	B	1.2	
191	34037	20	2E	14	NW	B	0.5	80J	W	B	>0.8	
192	34042	20	1E	4	NE	BP	0.1	80J	P	B	>0.3	
193	34042	20	1E	4	NE	BP	1.2	80J	W(G)	B	1.2	
194	34042	20	1E	4	NE	BP	0.9	80J	P	B	>1.2	
195	34042	20	1E	4	NE	BP	0.3	80J	P	B	>0.5	
196	34042	20	1E	4	NE	BP	0.3	80J	P	B	>0.5	
197	34042	20	1E	4	NE	BP	0.3	80J	P	B	>0.5	
198	34043	19	1E	31	SW	P	>0.6	-	-	-	-	Private pit 0.6m pebbles over sand
199	34043	19	1E	32	NW	O	-	80J	W	-	-	Sandy ridge
200	34033	21	2E	23	SW	BP	3.7	80J	W(G)	B	3.0	
201	34033	21	2E	23	SW	BP	1.1	80J	W(G)	B	0.9	
202	34033	21	2E	23	SE	P	3.0	-	-	-	N.S.	Old water logged pits
203	34033	21	2E	13	NW	P	5.0	-	-	-	-	Disused pits
204	34033	21	3E	18	SW	P	3.0	-	-	-	-	
205	34033	21	3E	18	SE	P	>3.0	85J	W(G)	B	>3.0	
206	34033	21	3E	9	SW	B	3.0	80J	W(G)	B	2.8	
207	34033	21	3E	9	NW	B	2.4	80J	W(G)	B	1.8	
208	34033	21	3E	9	SW	B	1.2	80J	P	B	0.7	
209	34033	21	3E	10	SW	P	2.0	-	-	-	-	Disused pit
210	34033	21	3E	2	SW	P	2.0	-	-	-	-	Disused pit
211	34033	20	3E	35	SE	B	0.9	80J	P	B	>1.2	
212	34033	20	3E	35	SE	B	2.1	80J	W(G)	B	2.0	
213	34033	20	3E	35	SE	BP	2.3	80J	W(G)	B	1.8	
214	34033	20	3E	35	SE	P	2.0	-	-	-	-	

APPENDIX 3 (Cont'd)

Field Exposure No.	Deposit No.	Township	Range	Section	¼ Section	Exposure Type	Thickness of Sand and Gravel (m)	Lithology	Degree of Sorting	Roundness	Depth to Water (m)	Comments
215	34035	20	3E	33	NW	P	<2.0	-	-	-	-	Disused pit
216	34035	20	3E	28	SW	P	2.0	-	-	-	-	
217	34035	20	3E	30	NE	P	<2.0	-	-	-	-	Disused pit
218	34049	21	1W	33	NE	B	0.5	80J	P	B	>0.8	
219	34049	21	1W	33	NE	B	0.1	80J	P	B	>0.3	
220	34049	21	1W	33	NE	B	0.0	-	-	-	-	Clay till
221	34049	21	1W	33	NE	B	0.0	-	-	-	-	Clay till
222	34048	21	1W	4	SW	P	2.0	-	-	-	-	Disused pit
223	34048	21	1W	4	SW	P	2.0	-	-	-	-	Disused pits
224	34048	20	1W	33	NE	P	1.0	-	-	-	-	Disused pits
225	34005	19	4W	12	NW	B	>2.0	80J	W(G)	B	>2.0	
226	34003	19	4W	1	SW	O	0.5	-	-	-	-	
227	34003	18	4W	36	NW	B	0.4	80J	P	B	>0.4	
228	-	18	4W	24	SE	O	0.0	-	-	-	-	Limestone boulders
229	-	18	4W	24	SW	O	0.0	-	-	-	-	Till
230	-	18	4W	13	NE	O	0.0	-	-	-	-	Silty brown till with boulders
231	-	18	4W	13	NE	O	0.0	-	-	-	-	Silty brown till with boulders
232	34002	18	3W	7	NE	P	1.8	85J	P	B	>1.8	
233	34001	18	3W	6	NE	BP	>3.0	80J	W(G)	B	3.0	
234	34001	18	3W	6	NE	P	>3.0	75J	W(G)	B	1.7	
235	34001	18	3W	6	SE	P	>1.0	-	-	-	-	New excavations
236	34009	20	1W	9	SE	P	>1.1	80J	P	B	1.1	
237	34063	24	10W	25	NW	P	0.2	95J	P	B	>0.2	
238	34060	24	10W	13	NE	P	0.2	85J	W	B	>0.2	
239	34062	24	9W	16	NW	P	0.6	80J	P	B	>0.6	
240	34064	24	9W	35	NW	P	0.6	80J	P	B	>0.6	
241	34064	24	9W	35	NW	O	0.0	-	-	-	-	Clay, silty, bouldery till
242	34066	25	8W	5	SE	O	>1.0	-	W	-	-	Sandy ridge

APPENDIX 3 (Cont'd)

Field Exposure No.	Deposit No.	Township	Range	Section	¼ Section	Exposure Type	Thickness of Sand and Gravel (m)	Lithology	Degree of Sorting	Roundness	Depth to Water (m)	Comments
243	-	25	8W	4	SE	O	0.0	-	-	-	-	Silty, clay till with pebbles
244	-	29	9W	1	SW	O	0.0	-	-	-	-	Sandy, silt till with boulders and pebbles
245	-	23	8W	4	SW	O	0.0	-	-	-	-	Sandy, silt till with boulders
246	34069	26	6W	7	NE	P	>1.8	80J	P	B	1.8	
247	34054	21	6W	35	SE	B	0.4	80J	P	B	>0.4	
248	34054	21	6W	36	SW	P	0.1	-	-	-	-	Disused pit
249	34008	20	6W	36	NE	B	0.3	80J	P	B	>0.3	
250	34008	20	6W	36	SE	P	0.6	80J	W	B	>0.6	
251	34057	23	7W	20	SW	B	>0.5	80J	W(G)	B	>0.5	
252	34058	23	7W	19	SW	P	1.5	80J	P	B	>1.5	
253	-	22	6W	35	NW	O	0.0	-	-	-	-	Silty till
254	-	22	6W	25	SW	O	0.0	-	-	-	-	Sandy, silt till
255	-	22	6W	24	NW	O	0.0	-	-	-	-	Sandy, silt till
256	-	22	5W	17	SW	O	0.0	-	-	-	-	Sandy till with boulders
257	-	22	6W	2	SW	O	0.0	-	-	-	-	Silty till with pebbles
258	-	21	7W	15	NW	O	0.0	-	-	-	-	Silty till
259	34053	21	6W	15	NW	O	1.5	-	P	-	-	
260	-	21	6W	14	NW	O	0.0	-	-	-	-	Stony till
261	-	21	5W	29	NE	O	0.0	-	-	-	-	Sandy till with pebbles
262	-	21	5W	3	NE	O	0.0	-	-	-	-	Limestone quarry
263	-	25	7W	12	NW	O	0.0	-	-	-	-	Limestone quarry
264	-	20	4W	7	SW	O	0.0	-	-	-	-	Limestone quarry
265	34050	21	1W	32	NW	O	0.2	-	-	-	-	Road cutting
266	-	19	4W	34	NE	O	0.0	-	-	-	-	Sandy, silt till
267	-	19	4W	34	NW	O	0.0	-	-	-	-	Limestone quarry
268	-	18	2E	8	NE	O	0.6	-	-	-	-	Small pit - till
269	-	18	1W	11	SW	O	0.0	-	-	-	-	Limestone quarry
270	-	14	3W	33	NE	O	0.0	-	-	-	-	Till - boulder and pebbles
271	-	17	2E	13	NE	O	0.0	-	-	-	-	Till

APPENDIX 3 (Cont'd)

Field Exposure No.	Deposit No.	Township	Range	Section	¼ Section	Exposure Type	Thickness of Sand and Gravel (m)	Lithology	Degree of Sorting	Roundness	Depth to Water (m)	Comments
356	-	21	4W	31	NW	O	0.0	-	-	-	-	Till
357	-	22	5W	31	NE	O	0.0	-	-	-	-	Till
358	3455	22	5W	31	NE	O	0.0	-	-	-	-	Shallow gravel over till
359	-	22	6W	31	NE	O	0.0	-	-	-	-	Limestone outcrop
360	-	22	8W	35	NE	O	0.0	-	-	-	-	Till
361	-	22	7W	6	SW	O	-	-	-	-	-	Medium sand in very thin deposit
362	-	20	4W	7	SW	O	0.0	-	-	-	-	Limestone quarry
363	-	19	5W	1	SW	O	0.0	-	-	-	-	Till
364	-	18	5W	2	SE	O	0.0	-	-	-	-	Fine sand on L.Manitoba shore
365	-	20	6W	5	SW	O	0.0	-	-	-	-	Silt
366	-	18	5W	24	SE	O	0.0	-	-	-	-	Till

APPENDIX 4

SAND AND GRAVEL POTENTIAL OF DEPOSITS IN THE SOUTHERN INTERLAKE REGION

APPENDIX 4

SAND AND GRAVEL POTENTIAL OF DEPOSITS IN THE SOUTHERN INTERLAKE REGION

Deposit Number	Location	Volume Before Depletion (tonnes)	Volume of Reserves (tonnes)	Quality	Samples Analysed	Principal Ownership
4500	W	9 504 360	1 926 817	M (4)	500, 501	P
4501	W	1 403 100	526 860	M (5)	502	P (G)
4502	W	4 645 440	1 527 181	M (4)	503	P (G)
4503	W	18 691 020	4 726 807	M (4)	17,405,505	P (G)
4504	W	5 625 000	2 576 520	M (4)	506	P (G)
4505	W	967 500	762 300	L (7)	22	P (G)
4506	W	1 141 200	907 200	M (6)	507	P (G)
4507	W	353 700	260 820	M (4)	508	P
4508	W	37 800	37 800	M (4)	509	P
4509	W	487 800	405 720	M (4)	510	P
4510	W	310 500	248 400	M	-	P
4511	W	77 580	77 580	M	-	P
4512	W	37 800	37 800	M	-	P
4513	W	18 900	18 900	L	-	P
4514	W	4 356 360	1 799 771	M (4)	6, 511	P (G)
4515	W	819 000	700 200	M (4)	4	P
4516	W	777 600	141 174	M (5)	1	P
4517	Does not exist	-	-	-	-	-
4518	R	3 276 000	1 657 350	M (6)	45	P
4519	R	172 800	17 100	L	-	P
4520	R	6 705 000	1 213 650	M (5)	513, 514	P
4521	R	93 600	45 900	L	-	P
4522	R	103 500	87 300	L	-	P
4523	Does not exist	-	-	-	-	-
4524	R	198 000	198 000	M	-	P
4525	R	139 680	139 680	M	-	-
4526	R	1 147 500	918 000	M (4)	52	P (G)
4527	R	1 174 500	548 100	M (4)	515	P
4528	W	109 800	109 800	M	-	P
4529	W	40 500	40 500	M	-	P
4530	R	14 264 100	12 343 860	M (5)	59, 62, 66	P (G)
4531	R	381 600	281 160	M (4)	69	P
4532	R	2 218 140	1 975 032	M (4)	71	P (G)

APPENDIX 4

SAND AND GRAVEL POTENTIAL OF DEPOSITS IN THE SOUTHERN INTERLAKE REGION

Deposit Number	Location	Volume Before Depletion (tonnes)	Volume of Reserves (tonnes)	Quality	Samples Analysed	Principal Ownership
4533	R	4 096 080	2 193 210	M (4)	77, 83	P
4534	R	835 020	769 500	M (4)	86	G
4535	R	951 300	951 300	M (5)	89	P
4536	R	676 800	676 800	M	-	P
4537	R	111 600	111 600	L	-	P
4538	R	83 700	8 370	L	-	P
4539	R	368 460	170 226	M	-	P
4540	R	3 202 200	2 778 840	L	-	P
4541	R	50 400	50 400	L	-	P, G
4542	R	94 500	20 250	M (6)	536	P (G)
4543	R	70 200	70 200	L	-	P
4544	R	16 200	16 200	L	-	P
4545	R	293 400	293 400	M	-	P
4546	R	32 940	32 940	L	-	P
4547	R	273 600	273 600	M (5)	100	P
4548	R	2 027 880	1 726 200	[a]M (4)	104	P
4549	R	270 000	270 000	L	-	P
4550	R	341 100	275 400	M	-	P
4551	R	146 700	133 200	L	-	P
4552	R	288 000	288 000	L	-	P
4553	R	198 000	198 000	L	-	P
4554	R	522 000	522 000	M (4)	94	P (G)
4555	R	116 640	116 640	L	-	P
4556	R	58 320	58 320	L	-	G
4557	R	44 640	44 640	L	-	P
4558	R	160 200	160 200	L	-	P
4559	R	5 400	5 400	L	-	P, G
4560	R	14 400	14 400	L	-	P
4561	R	7 200	7 200	L	-	P
4562	R	121 500	121 500	M	-	P, G
4563	R	10 800	10 800	L	-	P
4564	R	18 000	18 000	L	-	P
4565	R	207 000	207 000	L	-	P (G)

APPENDIX 4

SAND AND GRAVEL POTENTIAL OF DEPOSITS IN THE SOUTHERN INTERLAKE REGION

Deposit Number	Location	Volume Before Depletion (tonnes)	Volume of Reserves (tonnes)	Quality	Samples Analysed	Principal Ownership
4566	Does not exist	-	-	-	-	-
4567	R	1 371 600	1 166 400	M	-	P
4568	W	376 200	134 658	M	-	P, G
4569	W	1 262 520	689 990	H (3)	416	P, G
4570	W	1 280 160	529 812	M (4)	517	P (G)
4571	W	831 600	207 900	M (4)	518	P
4572	W	283 320	247 453	M (4)	519	P
4573	W	133 200	133 200	L	-	P
4574	W	24 840	24 840	L	-	P
4575	W	81 900	80 100	L	-	P
4576	W	576 180	298 539	M (4)	119	G (P)
4577	W	87 480	87 480	M	-	P
4578	W	105 480	105 120	M	-	P
4579	SL	904 500	803 700	H (3)	520	P
4580	SL	1 290 060	1 247 400	M (6)	118	P
4581	SL	1 942 200	1 942 200	L	-	P
4582	SL	831 600	831 600	M	-	P
4583	SL	153 900	171 900	M	-	P
4584	SL	205 380	205 380	M	-	P
4585	SL	48 600	48 600	M	-	P
4586	SL	4 950 000	3 964 680	M (5)	521	P
4587	SL	2 160 000	1 739 700	M (4)	124	P
4588	SL	10 632 600	9 976 050	M (4)	114	P (G)
34001	C	7 403 400	3 738 960	H (3)	528	P (G)
34002	C	1 080 000	823 500	M (5)	529	P (G)
34003	C	726 300	726 300	H (3)	227	P (G)
34004	C	68 400	68 400	L	-	G
34005	C	4 897 800	4 897 800	(a)M (4)	530	P (G)
34006	C	189 000	189 000	L	-	G (P)
34007	Does not exist	-	-	-	-	-
34008	C	1 881 000	1 235 520	M (5)	250	P (G)
34009	A	745 200	521 640	H (3)	236	P (G)

APPENDIX 4

SAND AND GRAVEL POTENTIAL OF DEPOSITS IN THE SOUTHERN INTERLAKE REGION

Deposit Number	Location	Volume Before Depletion (tonnes)	Volume of Reserves (tonnes)	Quality	Samples Analysed	Principal Ownership
34010	A	553 500	553 500	M	-	P
34011	A	49 500	49 500	L	-	P
34012	A	773 100	891 000	M (4)	130	P
34013	A	72 360	72 360	M	-	P
34014	A	58 320	58 320	M	-	G
34015	A	28 800	28 800	M	-	P
34016	A	27 000	5 400	M	-	G
34017	A	109 800	21 960	M	-	G
34018	A	747 720	644 040	M (4)	143	G (P)
34019	A	154 800	154 800	M	-	P
34020	A	243 000	243 000	M	-	P
34021	A	1 898 820	1 621 980	M (6)	126	P
34022	A	1 179 900	1 004 940	M	-	P (G)
34023	A	245 880	87 732	M (4)	525	P
34024	A	131 220	131 220	M	-	P, G
34025	A	1 666 800	971 820	M (4)	526	P (G)
34026	A	40 500	40 500	L	-	P
34027	A	39 600	39 600	M	-	P
34028	G	1 314 900	1 281 285	M (4)	159, 160	P
34029	G	3 065 580	945 180	M (5)	166, 522	P (G)
34030	G	1 989 000	1 469 790	M (4)	173, 523	P
34031	Does not exist	-	-	-	-	-
34032	G	6 266 700	3 825 900	M (4)	182	P (G)
34033	G, A	24 584 400	17 740 080	M (4)	206, 531, 524	P (G)
34034	A	223 200	223 200	M (4)	532	P, G
34035	A	2 313 000	2 086 200	M (4)	533, 534	P (G)
34036	A	315 900	315 900	M	-	P
34037	A	2 599 200	2 599 200	M (4)	185	P
34038	A	266 400	266 400	L	-	P
34039	A	322 200	293 040	M	-	C (P)
34040	A	40 500	40 500	M	-	P
34041	A	490 320	495 720	M (4)	146	G (P)
34042	A	1 467 900	1 367 910	M (4)	193	G

APPENDIX 4

SAND AND GRAVEL POTENTIAL OF DEPOSITS IN THE SOUTHERN INTERLAKE REGION

Deposit Number	Location	Volume Before Depletion (tonnes)	Volume of Reserves (tonnes)	Quality	Samples Analysed	Principal Ownership
34043	A	2 979 000	2 926 260	L (7)	199	G (P)
34044	A	585 000	585 000	M	-	G
34045	A	198 720	198 720	M	-	G
34046	A	1 627 200	1 533 420	M (4)	527	G
34047	A	63 000	63 000	L	-	P
34048	A	5 042 700	4 083 075	H (3)	535	G (P)
34049	A	103 500	20 700	(b)H (3)	537	P
34050	A	10 800	2 160	L	-	P (G)
34051	E	121 500	121 500	M	-	G
34052	E	27 000	27 000	L	-	P
34053	E	90 000	90 000	L (8)	259	P
34054	E	52 740	17 748	L	-	P
34055	E*	954 000	851 400	M	-	P
34056	S	558 000	558 000	M	-	G
34057	S	204 300	204 300	M (5)	251	P, G
34058	S	793 800	739 125	M (4)	252	P, G
34059	S	81 000	48 600	L	-	G
34060	S	174 240	150 624	M (4)	238	G
34061	S	157 680	102 816	L	-	G
34062	S	157 680	98 064	M (4)	239	G (P)
34063	S	254 520	203 616	L (4)	237	P, G
34064	S	653 760	438 120	(a)M (4)	240	G
34065	S	10 800	10 800	L	-	G
34066	S	44 910	44 910	M (5)	242	P (G)
34067	S	124 200	124 200	L	-	P
34068	S	204 300	204 300	L	-	G (P)
34069	S	1 460 700	1 100 250	M (4)	246	P
TOTALS:		211 861 530	139 673 587			

Notes:

(1) Location refers to Rural Municipality as follows: W-Woodlands; R-Rockwood; SL-St. Laurent; C-Coldwell; E-Eriksdale; S-Siglunes; G-Gimli; A-L.G.D. of Armstrong.

(2) Quality codes: H-High; M-Medium; L-Low. Figures in brackets indicate the grade of the analysed samples (see text).

(3) Ownership codes refer to sand and gravel rights: P-privately owned; G-government property. Bracketed letter indicates ownership of small areas of the deposit.

* Deposit 34005 is largely in the Rural Municipality of Grahamdale.

(a) Map incorrectly designates this deposit as L.

(b) Map incorrectly designates this deposit as M.

APPENDIX 5

RESULTS OF SIEVE ANALYSES OF SAND AND GRAVEL SAMPLES

APPENDIX 5

RESULTS OF SIEVE ANALYSES OF SAND AND GRAVEL SAMPLES

Deposit Number	Exposure Number	Sieve Analysis - Weight Retained (%)																							Sand and Gravel Fractions		
		4"	3½"	3"	2½"	2"	1½"	1"	3/4"	5/8"	1/2"	3/8"	1/4"	#4	#8	#10	#16	#30	#40	#50	#80	#100	#200	#<200	% Gravel	% Sand	% Silt
4503	17							16.33	13.37	13.28	13.28	13.28	8.00	8.00	3.64	3.64	1.52	2.11	0.59	0.95	1.16	0.21	0.25	0.39	92.82	6.80	0.39
4505	22														0.24	0.23	0.66	2.15	1.50	16.55	40.23	23.67	8.83	5.96	0.46	93.58	5.96
4514	6									2.29	2.29	2.29	12.97	12.97	14.77	14.77	8.82	14.28	5.46	3.43	4.21	0.78	0.21	0.49	62.33	37.58	0.49
4515	4							5.89	0.0	1.77	1.77	1.77	7.86	7.86	8.38	8.38	10.82	21.47	10.65	5.40	6.06	0.66	0.47	0.79	43.67	55.54	0.79
4516	1									2.58	2.58	2.58	8.75	8.75	15.34	15.34	13.90	20.60	6.70	0.91	1.04	0.13	0.26	0.54	55.92	43.54	0.54
4518	45						6.79	2.11	1.37	1.82	1.82	1.82	5.96	5.96	7.44	7.44	5.21	7.47	2.25	2.08	7.37	5.28	12.95	14.87	42.32	42.61	14.87
4526	52					15.09	20.34	5.68	11.36	5.27	5.27	5.27	2.00	2.00	2.77	2.77	4.92	8.19	3.28	1.10	1.37	0.28	0.46	2.61	77.80	19.59	2.61
4530	59		17.16	17.16	4.43	4.43	0.0	3.74	1.68	2.31	2.31	2.31	3.15	3.15	5.60	5.61	6.06	9.95	3.89	2.79	3.03	0.26	0.25	0.75	73.03	26.23	0.75
4530	62								5.49	0.86	0.86	0.86	0.55	0.54	1.34	1.33	1.86	4.19	2.36	6.40	22.23	15.83	28.24	7.04	11.86	81.11	7.04
4530	66									0.77	0.77	0.77	4.16	4.16	6.74	6.75	8.07	17.28	9.21	16.25	18.90	2.65	1.21	2.31	24.12	73.56	2.31
3431	69							7.43	7.10	4.27	4.27	4.27	6.58	6.58	8.11	8.11	7.67	12.95	5.28	4.93	7.82	2.89	1.00	0.72	56.76	42.52	0.72
4532	71							16.46	0.0	2.29	2.29	2.29	5.14	5.14	6.70	6.70	9.26	17.65	8.40	5.78	7.99	2.21	0.89	0.83	47.00	52.17	0.83
4533	77							3.61	5.00	2.56	2.56	2.56	5.55	5.55	6.54	6.54	6.04	13.71	7.67	12.56	15.00	2.44	0.72	1.39	40.47	58.14	1.39
4533	83					15.95	6.52	2.18	7.68	4.16	4.16	4.16	5.69	5.69	5.55	5.55	5.67	10.67	5.00	3.40	4.91	1.51	0.71	0.83	67.30	31.87	0.83
4534	86					19.78	21.76	12.30	9.89	3.36	3.36	3.36	2.84	2.84	2.61	2.61	2.56	4.83	2.27	1.89	2.34	0.45	0.38	0.59	84.69	14.72	0.59
4535	89									0.34	0.34	0.34	4.56	4.56	9.72	9.72	16.37	27.47	11.11	3.68	4.86	1.18	3.34	2.42	29.59	68.00	2.42
4547	100					33.61	0.0	0.0	0.0	2.51	1.61	1.82	2.98	1.62	6.32	2.49	6.40	10.31	5.34	6.39	12.83	2.58	2.29	0.90	52.96	46.14	0.90
4548	104							6.56	0.0	2.60	2.60	2.60	7.16	7.16	8.05	8.05	6.42	10.87	4.46	5.29	11.98	6.69	8.02	1.47	44.80	53.73	1.47
4554	94								1.86	1.38	1.76	5.14	13.05	6.23	17.75	5.06	15.67	20.40	2.37	0.51	1.22	0.99	3.26	3.32	52.25	44.43	3.32
4576	119										1.31	2.27	7.14	5.03	15.67	5.93	17.18	20.93	9.28	5.72	7.28	0.23	0.80	1.25	37.36	61.40	1.25
4580	118									0.46	0.46	0.46	1.07	1.07	1.66	1.64	9.40	21.64	12.24	9.80	17.53	7.73	7.44	7.38	6.84	85.78	7.38
4587	124					22.44	3.08	4.25	5.93	3.27	3.27	3.27	3.63	3.63	4.82	4.82	4.74	10.91	5.71	4.25	6.80	2.09	1.67	1.42	62.43	36.16	1.42
4588	114								4.15	0.85	0.85	0.85	10.07	10.07	10.53	10.53	10.12	18.28	8.17	6.06	7.23	1.17	0.43	0.63	47.92	51.46	0.63
34003	227						7.18	2.04	6.09	4.31	4.31	4.31	5.51	5.51	5.99	5.99	9.07	17.20	8.13	3.34	4.70	1.36	1.69	3.27	51.24	45.50	3.27
34008	250									0.54	0.54	0.54	3.72	3.72	10.24	10.24	12.82	21.28	8.46	4.72	6.73	2.00	2.74	11.71	29.54	58.75	11.71
34009	236							4.07	8.48	3.79	3.79	3.79	6.55	6.55	10.15	10.15	8.86	14.72	5.86	4.58	5.34	0.76	0.97	1.59	57.33	41.08	1.59
34012	130								1.09	2.55	2.55	2.55	6.55	6.55	8.29	8.29	7.88	15.62	7.74	11.54	13.83	2.30	1.17	1.52	38.41	60.07	1.52
34018	143						29.23	4.11	4.95	3.57	3.57	3.57	5.03	5.03	5.65	5.65	6.37	10.65	4.28	2.55	3.10	0.55	0.90	1.22	70.38	28.40	1.22
34021	126							7.52	2.89	3.27	1.40	4.08	4.44	2.40	6.53	2.11	5.22	9.99	6.05	6.41	11.71	3.61	7.64	14.71	34.65	50.64	14.71
34028	159								0.93	1.95	1.95	1.95	6.67	6.67	14.03	14.04	9.09	12.95	3.86	5.01	11.15	6.15	1.37	2.25	48.18	49.57	2.25
34028	160									2.27	2.27	2.26	12.15	12.15	13.59	13.59	10.24	16.45	6.22	2.72	3.43	0.71	0.55	1.42	58.27	40.31	1.42
34029	166									1.78	1.78	1.78	5.60	5.60	7.15	7.15	10.51	18.34	7.83	8.99	14.36	5.37	2.29	1.49	30.84	67.67	1.49

APPENDIX 5 (Cont'd)

RESULTS OF SIEVE ANALYSES OF SAND AND GRAVEL SAMPLES

Deposit Number	Exposure Number	Sieve Analysis - Weight Retained (%) 4"	3½"	3"	2½"	2"	1½"	1"	3/4"	5/8"	1/2"	3/8"	1/4"	#4	#8	#10	#16	#30	#40	#50	#80	#100	#200	#<200	Sand and Gravel Fractions % Gravel	% Sand	% Silt
34030	173						15.86	4.58	3.74	1.88	1.88	1.88	4.48	4.48	5.25	5.25	7.99	15.55	7.55	5.11	7.57	2.45	2.32	2.17	59.30	48.54	2.17
34032	182							4.53	8.14	5.21	5.21	5.21	5.67	5.67	9.57	9.57	10.52	12.56	2.04	4.83	7.18	2.36	0.98	0.74	58.79	40.46	0.74
34033	206						21.15	5.11	2.58	1.96	1.96	1.96	3.73	3.73	6.55	6.55	7.62	14.42	6.80	5.62	7.46	1.84	0.63	0.32	55.29	44.40	0.32
34037	185									2.97	2.97	2.97	6.05	6.05	12.82	12.82	11.15	15.97	4.82	4.03	6.88	2.86	2.58	5.07	46.64	48.29	5.07
34041	146						12.37	4.56	3.04	3.57	3.57	3.57	4.64	4.64	3.72	3.72	2.79	8.77	5.98	12.70	16.47	3.77	1.33	0.80	47.38	51.81	0.80
34042	193							0.51	5.49	4.70	4.70	4.70	6.10	6.10	6.78	6.78	5.93	10.82	4.90	7.06	12.79	5.73	5.33	1.57	45.85	52.57	1.57
34043	199							3.46	0.0	1.00	1.00	1.00	2.28	2.28	4.01	4.00	3.50	4.96	1.45	9.36	32.95	23.60	4.60	0.56	19.02	80.42	0.56
34053	259							0.46	0.33	0.78	1.04	1.42	1.50	0.66	2.12	0.55	1.44	2.03	1.03	1.09	2.81	1.12	8.54	73.08	8.86	18.07	73.08
34057	251									0.78	0.78	0.78	2.67	2.67	9.23	9.23	17.47	27.88	10.42	7.34	8.09	0.75	0.76	1.16	23.13	72.71	1.16
34058	252						11.71	5.08	1.30	2.99	2.99	2.99	4.40	4.40	6.50	6.50	9.42	16.95	7.53	5.13	7.99	2.86	1.12	0.12	48.86	51.01	0.12
34060	238							1.37	1.68	6.51	6.51	6.51	11.32	11.32	10.44	10.44	6.01	9.96	3.96	2.68	3.31	0.63	1.54	5.80	66.11	28.09	5.80
34062	239							17.54	5.96	5.49	5.49	5.49	5.84	5.84	6.59	6.58	6.12	10.92	4.80	4.91	6.04	1.13	0.61	0.66	64.81	34.53	0.66
34063	237								7.30	2.88	2.88	2.88	11.87	11.87	10.56	10.56	9.09	15.65	6.56	1.47	1.76	0.29	1.07	3.32	60.81	35.88	3.32
34064	240							12.61	3.84	6.15	6.15	6.15	11.01	11.01	6.54	6.54	3.41	8.57	5.16	4.08	5.37	1.29	0.84	1.30	69.98	28.72	1.30
34066	242									0.41	0.41	0.41	3.44	3.43	10.99	10.99	12.95	18.43	5.48	5.97	10.51	4.54	6.74	5.32	30.06	64.62	5.32
34069	246					8.79	7.28	12.72	7.50	3.83	3.83	3.84	5.43	5.43	4.97	4.97	4.96	8.61	3.65	4.53	6.16	1.63	0.72	1.13	68.61	30.26	1.13

APPENDIX 6

RESULTS OF SURFACE RESISTIVITY SURVEY

SURFACE RESISTIVITY SURVEY

Introduction

The resistivity of rocks and minerals ranges over a very wide spectrum. In most rocks, the electrical current is conducted through the interstitial fluid and the resistivity is mainly controlled by the porosity, water content, and water quality. In certain rocks, especially those containing clay minerals, electricity may also pass through the material itself. Resistivity values for sedimentary materials commonly range from less than 1 ohm-m for clay saturated with saline water, to several thousand ohm-m for dry sand and gravel. The resistivity of massive igneous and metamorphic rocks may be several orders of magnitude higher than this latter value. Measurement of the resistivity of earth materials represents a method of obtaining valuable sub-surface information. This information may be used to correlate between similar areas, to identify horizontal or vertical discontinuities, to locate the groundwater table, to identify the presence of saline water, and to obtain preliminary indications of the identity of the rock types.

Resistivity measurements are made by introducing a controlled electric current into the ground via two electrodes. The potential difference is then measured between a second pair of electrodes placed in the area of investigation. A full survey is carried out by repeating this operation several times using different electrode positions for each depth measurement.

A vertical electrical sounding survey is designed to investigate subsurface changes with depth below a fixed point. It is based upon the assumption that the greater the distance between the electrodes, the deeper the penetration of the electric field will be. The survey is carried out by fixing the electrodes in the ground over the area of investigations, and then increasing the spacing between the electrodes in a systematic fashion until the required depth of penetration is obtained. In actual practice, there are several alternative electrode arrangements which may be employed, each with certain advantages depending upon the context of the survey. For this study, the Schlumberger configuration was employed. Interpretation of the resistivity measurements involves a curve matching solution technique.

For optimum control, electrical resistivity surveys should be carried out in conjunction with a test drilling programme, permitting accurate calibration of the resistivity measurements. In this way, definite correlations can be made between the measured resistivity values and the actual identities of the sub-surface materials.

Surface Resistivity Survey

Four surface electrical resistivity profiles were performed and are indicated on the appropriate maps as profiles R1, R2 (Map 10), R3 (Map 14) and R4 (Map 15).

Each profile was run to a maximum current electrode separation of 140 m using the Schlumberger configuration. Three and four layer master-curves were then used to interpret the results in terms of resistivity and the corresponding thickness of each layer. Results of the interpretations are presented in Table A6.1.

Typically (Jones and Skibitzke, 1956; Astier, 1971) sand and gravel saturated with fresh water will have a resistivity of between 100 and 1000 ohm-m. Dry material (till and bedrock) may give much higher values. A brief description and possible interpretation of the profiles is presented in the following pages.

Resistivity Profiles R1, R2, R3 and R4

Electric resistivity profile R1 was carried out northwest of Gimli in a B7W deposit (Map 10).

The result of the survey at this location indicates the presence of a surface layer with a resistivity of 175 ohm-metre reaching a thickness of 2.8 m.

Underlying the surface layer a 5.6 m thick layer of 3500 ohm metre resistivity was found overlying a 17.5 ohm-metre layer with a thickness of 7.4 m. A resistive layer with resistivity value of over 3500 ohm-metre was encountered at 15.8 m depth. The surface layer can be interpreted as an unconsolidated coarse deposit (sand and gravel) overlying dry till.

Electric Resistivity Profile R2 was carried out west of Teulon (see Map 10). The resistivity survey at this location indicated the presence of three layers. A surface layer 2 m thick reached a resistivity value of 900 ohm-metre and overlies a resistive layer of 4500 ohm-metre which reaches a thickness of 30 m. A highly resistive layer with values above 18 000 ohm-metre represents the bottom layer at this location. The upper layer can be interpreted as a sand and gravel deposit overlying till and bedrock.

To the northeast of Narcisse a resistivity profile (R3) was also carried out on a B2A deposit (Map 10). Three layers were encountered; a surface layer with resistivity value of 500 ohm-metre reaching a thickness of 2 m overlying a middle layer with resistivity of 4000 ohm-metre and 3 m thick. The bottom layer exceeds 4000 ohm-metre. The upper layer is interpreted to be sand and gravel. The underlying second layer is probably till overlying bedrock.

Another profile was also carried out southwest of Woodlands on a B4A beach deposit (Map 15). Three layers were encountered; a surface layer with a resistivity value of 560 ohm-metre overlying a layer with a higher resistivity of 1120 ohm-metre and 8.5 m thick. A bottom layer with an undetermined value exceeding 1120 ohm-metre was also found.

The upper 1.4 m thick layer seems to represent the unconsolidated coarse deposits. High resistivity till overlying bedrock complete the lower part of the profile.

TABLE A6.1

RESULTS OF SURFACE RESISTIVITY PROFILES

Profile	Length of Profile m	NTS Coordinates Northing	NTS Coordinates Easting	Layer 1 Thick-ness m	Layer 1 Resis-tivity Ω-m	Layer 2 Thick-ness m	Layer 2 Resis-tivity Ω-m	Layer 3 Thick-ness m	Layer 3 Resis-tivity Ω-m	Layer 4 Thick-ness m	Layer 4 Resis-tivity Ω-m
R1	140	5 622 400	637 000	2.8	175	5.6	3500	7.4	17.5	-	∞
R2	140	5 615 500	610 700	2.0	900	30.0	4500	-	∞	-	-
R3	140	5 577 000	619 700	2.0	500	3.0	4000	-	∞	-	-
R4	140	5 559 300	588 500	1.7	560	8.5	1120	-	∞	-	-

APPENDIX 7

LIST OF AERIAL PHOTOGRAPHS COVERING THE SOUTHERN INTERLAKE REGION

APPENDIX 7

LIST OF AERIAL PHOTOGRAPHS COVERING THE SOUTHERN INTERLAKE REGION

Area Covered	Date of Photography	Orientation of Flight Lines	Scale (Approx.)	Identification Numbers I.D.	Photograph No.
Lake Manitoba Shoreline and Southern Parts of the Study Area	1968	east-west	1:65 000	A20663	14 - 17
					23 - 35
					44 - 56
				A20664	31 - 32
					34 - 37
					55 - 60
					115 - 124
					132 - 143
				A20665	26 - 44
					51 - 63
				A20666	155 - 172
"The Narrows" Area	1968	east-west	1:65 000	A21280	36 - 46
				A21281	34 - 44
Main Part of the Region except for the South and West	1978	north-south	1:50 000	A24923	1 - 18
					27 - 36
				A24966	72 - 91
					100 - 131
					139 - 154
					177 - 185
				A24700	83 - 90

All Photographs are available from the National Air Photo Library, Ottawa.