MANITOBA
DEPARTMENT OF ENERGY AND MINES

MINERAL RESOURCES DIVISION

GEOLOGICAL REPORT
GR82-5

AGGREGATE RESOURCE INVENTORY OF THE CHURCHILL AREA

by
R.V. Young

1982

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DEPARTMENT OF ENERGY AND MINES

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ABSTRACT

Detailed Quaternary geological investigations were carried out in northeast Manitoba including an inventory and evaluation of sand and gravel deposits in the Churchill area. Aerial photographs were used to delineate each deposit. Field investigations included deposit sampling from both ground and helicopter reconnaissance. Sample analyses included grain size distribution, clast lithology and clast roundness. Reserves for each deposit were calculated and the quality of each deposit was estimated based upon grain size distribution and potential industrial usage. Abandoned Tyrrell Sea beaches and littoral deposits are the only economic source of sand and gravel. There are 34 million cubic metres of sand and gravel of which 3 million cubic metres are high quality. Accessible reserves are sufficient to supply the sand and gravel requirements for the Churchill area for at least 250 years. Engineering tests on selected bedrock samples show the local bedrock outcrops are suitable for crushed stone, a potential source of aggregate.

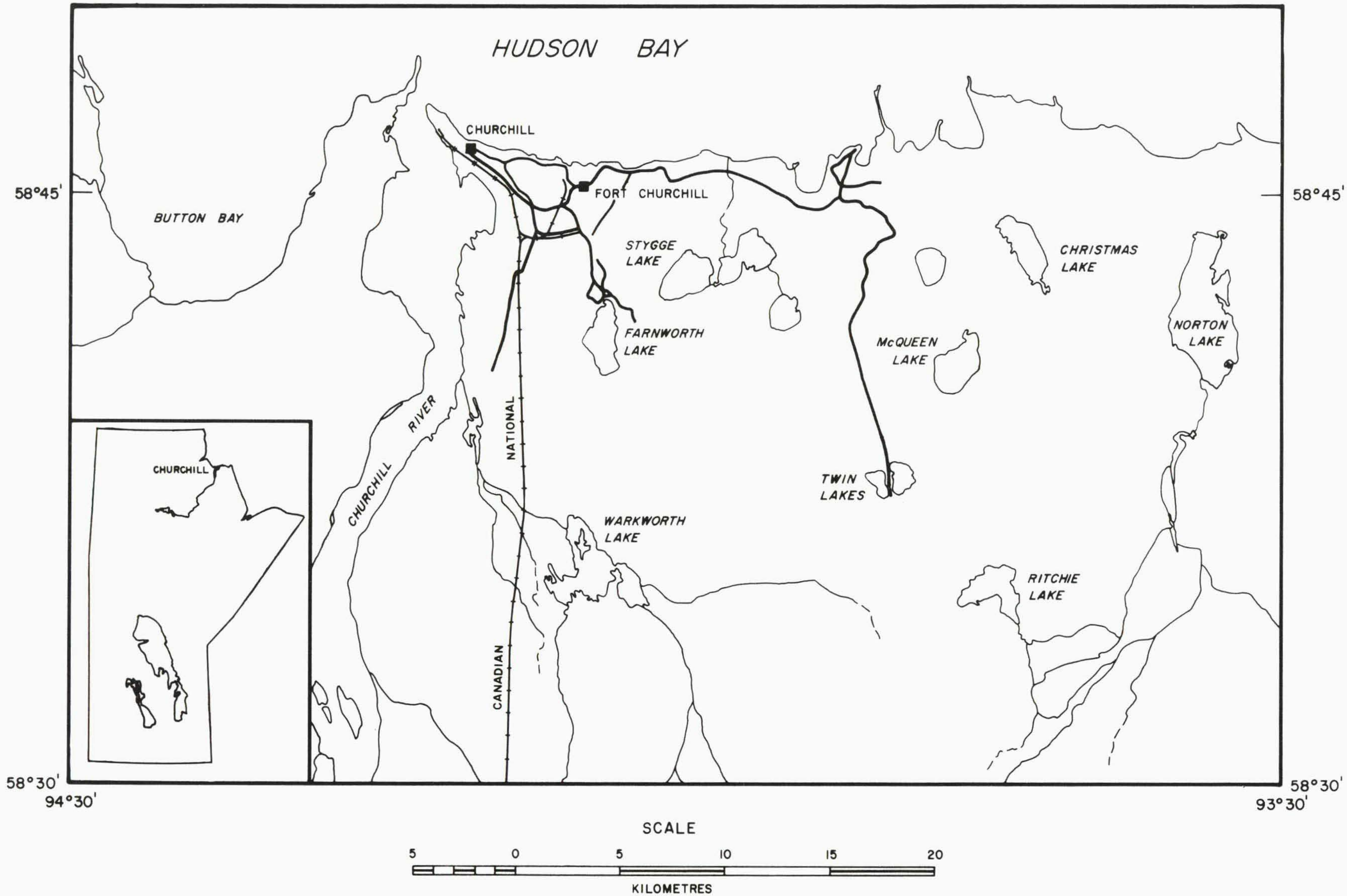

FIGURE 1. *Location of Churchill study area.*

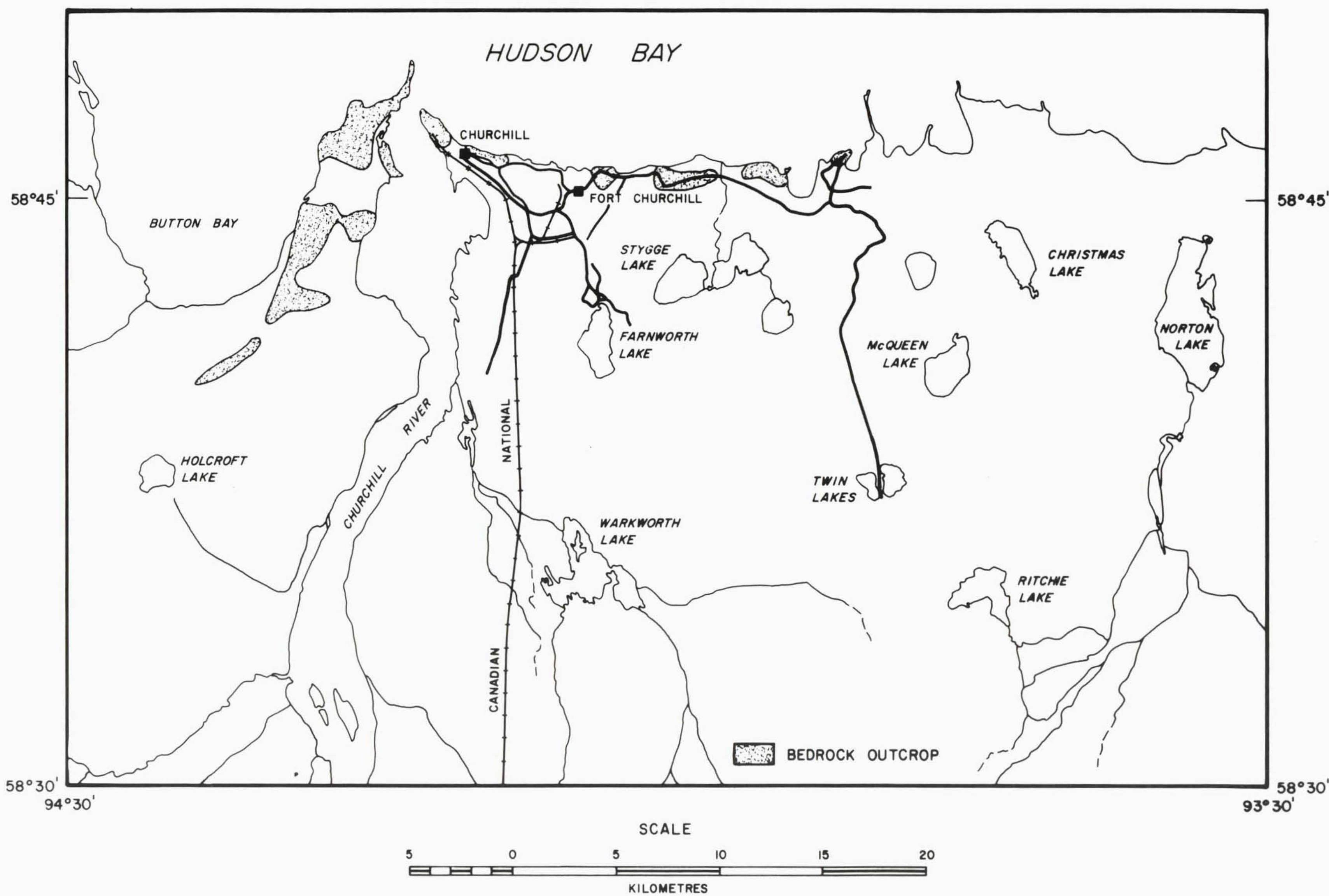

FIGURE 2. Bedrock outcrops within the Churchill area.

INTRODUCTION

OBJECTIVES

An aggregate resource inventory of the Churchill area was conducted with the following objectives:

1. To map the distribution of sand and gravel deposits at a scale of 1:50 000;
2. To determine the quality and reserves of available deposits; and
3. Evaluate bedrock outcrops as a potential source of crushed stone.

ACKNOWLEDGEMENTS

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LOCATION AND ACCESS

The Churchill study area comprises 1678 km^2 in northern Manitoba between 58° 30′ and 59° 00′ north latitude and between 93° 30′ and 94° 30′ west longitude (Fig. 1). Four map sheets at a scale of 1:50 000 define the study area; 54L/9, 54K/12 and the southern portion of map sheets 54L/16 and 54K/13. The only townsite within the study area is the Town of Churchill which is accessible by air, sea, or Canadian National Railway. There are 36 km of roads of which 14 km are restricted as they pass through the National Research Council space research and rocket range facilities.

PREVIOUS WORK

The first geological exploration in the area was by Bell (1881) who examined bedrock outcrops along Churchill River. Bell examined subgreywacke, quartzite and conglomerate outcrops in the vicinity of Churchill and termed the outcrops 'Churchill Quartzites'. Tyrrell (1896) described ripple-marks and cross-bedding of the Churchill Quartzites. Bedrock exposures were observed along the lower Churchill River by Alcock (1916) reporting both Precambrian and Paleozoic bedrock. From a study of the Quaternary drift, Williams (1948), suggested that Silurian bedrock underlies the immediate Churchill area. At Churchill, the Precambrian-Paleozoic contact is described by Bostock (1969). Schledewitz,(1977),mapped the bedrock geology and described the mineralogy of bedrock exposures along Churchill River.

Successive glaciations at Fort Churchill were first described by Tyrrell (1896). Examination of striated and grooved bedrock showed three distinct glacial advances with the last glaciation originating north of Churchill. Antevs (1931) described, in detail, the location and successive culmination of ice centres in northern Manitoba. Barnett (1966) and Craig (1968) calculated rates of isostatic rebound in the Churchill area. The surficial deposits and geomorphology of the Churchill area was mapped and described by Paradis (1980), and this data incorporated by Dredge and Nixon (1980a) into a surficial geology map of the Churchill area. The nature and distribution of esker, kame, moraine and beach ridges for northeastern Manitoba are described by Dredge and Nixon (1980b). The stratigraphy and a preliminary correlation of Quaternary deposits along Churchill River are described by Nielsen and Young (1981).

PHYSIOGRAPHY AND DRAINAGE

Between Cape Merry and Halfway Point along the shore of Hudson Bay are found a series of bedrock ridges ranging in elevation between sea level and 30.4 m a.s.l. (Fig. 2). A second series of bedrock ridges at similar elevations are found east of Churchill River and trend southwest from Eskimo Point for a distance of 14.4 km (Fig. 3).

Inland from these bedrock ridges, the terrain is a relatively flat plateau but occasionally interrrupted by small streams and

FIGURE 3. Bedrock outcrop at site C5 southwest of Eskimo Point.

abandoned sand and gravel ridges. Twin Lake Hill, a wave-washed sand and gravel deposit, rises 11.5 m above the surrounding flat terrain. A large portion of this plateau is composed of sedge swamps and lakes of varying sizes.

Beckel (1957) describes the vegetation at Churchill as consisting of boreal forest with frequent representatives of tundra vegetation. Scattered spruce up to 10 m high are found along the bedrock ridges. Inland from Hudson Bay, the forest begins to dominate with stunted tamarack and spruce.

Churchill River is the main drainage system for the area. The river is 2.5 km wide where it enters Hudson Bay at Port Churchill. Churchill River drains the southwest via Herriot Creek entering Churchill River at Thibaudeau Island. The central portion is drained by Warkworth and Goose Creek which enters Churchill River south of Beech Bay. Several small unnamed creeks drain the inland swamps directly into Hudson Bay.

The mean annual precipitation recorded at Churchill is 54.9 cm with a mean annual temperature of -11° C (Beckel, 1957). There is no developed soil in the Churchill area, rather a layer of peat up to 0.6 m deep is found above the subsurface gravel, sands, or clay. Permafrost is present and average thickness of the active layer ranges from 2.5 to 3.7 m for sandy soils, and 0.9 to 2.5 m for clay, clay-sand, or clay-gravel soils topped by a 15-30 cm layer of peat (Beckel, 1957).

METHODOLOGY

Geological investigations were carried out during June of 1981. Aerial photographs, at a scale of 1:60 000, were used to delineate potential sources of sand and gravel. Field investigations included road and helicopter traverses. Available natural exposures, road cuts and gravel pits were examined. Hand dug test pits were used to sample remote deposits. A total of 16 sites were examined and 12 samples analyzed. The locations of all ground observation sites are shown on Map GR82-5 accompanying this report. Selected engineering tests to simulate weathering were performed on bedrock samples to determine the suitability of the bedrock for crushed stone.

Permission to land within portions of the space and rocket research centre controlled air space was not granted by the National Research Council. Consequently, some identified sand and gravel deposits were not examined.

GEOLOGY

BEDROCK GEOLOGY

Bedrock outcrops in the Churchill area are located west of Churchill River and along the shore of Hudson Bay. Along Hudson Bay coastline at Churchill, Bostock (1969) observed steeply dipping Precambrian subgreywackes, outcropping through horizontal to gently dipping Paleozoic Severn River Formation dolomitic limestone. Inland from Hudson Bay, the Paleozoic bedrock is comprised of the Silurian Severn River Formation and the Upper Ordovician Churchill River Group, the contact being east of Churchill River.

The most recent geological investigation was conducted by Schledewitz (1977) west and east of Churchill River. The Paleozoic Severn River Formation was not observed in outcrop and not mapped by Schledewitz. The mineralogy of the bedrock as reported by Schledewitz did not correspond to that as described by Bostock. Schledewitz interpreted the subgreywacke as a series of interlayered protoquartzites and orthoquartzites, termed the Churchill Quartzite.

QUATERNARY GEOLOGY

Quaternary studies have been concentrated in north-central Manitoba and the Hudson Bay Lowlands. McDonald (1969) presented a stratigraphic correlation of the Hudson Bay Lowlands, including a section along the Hayes River where a nonglacial sub-till interval (clay, silt and pebbly sand) was recorded. No age of the interval is presented, although the author infers a tentative correlation to the Missinaibi beds as described by Terasamae and Hughes (1960) for the James Bay area. Klassen and Netterville (1973) reported at least three and probably four tills exposed along the banks of Gods River. Nielsen and Young (1981) describe the stratigraphy and presented a preliminary correlation of Quaternary deposits along Churchill River. The stratigraphy shows at least two till units overlying pre-Wisconsinan sand and gravel. Within the Tyrrell Sea marine limit, the tills are overlain by marine sediments. Nielsen and Dredge (1982) describe the sequence of Quaternary events along the lower Nelson River. They describe two pre-Wisconsinan grey tills underlying organic rich Missinaibi Formation silt and clays. The Missinaibi Formation is overlain by an upper grey Early Wisconsinan till which in turn is overlain by one and possibly two brown clayey tills. This sequence is overlain by glaciofluvial gravel and a sandy diamicton. The stratigraphic sequence continues with Lake Agassiz varved silts and clays overlain by Tyrrell Sea clay, silt and sand and gravel.

Petrology of tills and striation directions were used by Shilts (1980) to define the ice flow directions along the Hudson Bay Lowland. At Churchill, Nielsen and Young (1981) found glacial grooves along the shoreline of Hudson Bay recording ice flow towards 160°. Ice flow dispersal patterns presented by Shilts (op. cit.) indicate ice originating from the Keewatin ice centre flowed southeast along the shore of Hudson Bay. The Keewatin ice coalesced with westward flowing Labradorean ice and was deflected towards the southwest along Nelson River, although the contact zone may have been as far north as Seal River.

As the Keewatin and Labradorean ice retreated north and northeast, proglacial Lake Agassiz formed adjacent to the retreating ice masses. The disappearance of ice in northeastern Manitoba resulted in the final drainage of Lake Agassiz through spillways along Nelson River and possibly Churchill and Gods Rivers (Manitoba Mineral Resources Division, 1981).

During the glaciation, the land surface was lowered by the weight of the ice mass depressing the Hudson Bay Lowlands relative to sea level. An inland transgression of the sea, termed the Tyrrell Sea advanced up to 200 km inland from the present shore of Hudson Bay. Marine limits of the Tyrrell Sea are found at elevations of 183 m along the Manitoba/District of Keewatin boundary, and at 122 m along Nelson River (Manitoba Mineral Resources Division, 1981).

As the ice retreated from Manitoba, the crust isostatically compensated the weight of the ice mass by slowly rebounding. Craig (1969) postulated that the Churchill area became ice free 7300 years B.P. based on radiocarbon dates on marine shells. Tyrrell Sea marine pelecypod shells *Mytilus eduilis* from several locations at Churchill were dated by Craig (op. cit.). He calculated that from the period 3000-1000 years ago isostatic rebound was 1.5 m per century. Barnett (1966) re-evaluated tidal gauge data from Churchill and concluded isostatic rebound is continuing at a rate of 0.6 m per century.

SURFICIAL GEOLOGY

The surficial deposits are the result of the Tyrrell Sea regression and nonglacial fluvial processes. Along the shoreline of Hudson Bay, stony marine silts and littoral sand and gravel predominate (Fig. 4 and 5). The stony marine deposits (Fig. 6) are 2-6 m thick with the littoral sands occurring as a blanket up to 3 m thick (Department of Public Works, 1961, unpublished). Inland from Hudson Bay, fen peat deposits up to 2 m thick predominate. Along Churchill River and tributary streams alluvium consisting of 3 m of sand, gravel and silty sand overlie 4 m of silty clayey till which in turn overlies limestone bedrock (Manitoba Hydro, 1976, unpublished). Geotechnical foundation investigations conducted by Manitoba Hydro adjacent to Churchill River recorded permafrost at 3.3 m depth.

Prominent bedrock ridges are located along Eskimo Point (highest elevation 34.7 m a.s.l.) and along Cape Merry to Bird Cove (highest elevation 31.6 m a.s.l.). Tyrrell (1896) first reported that the gravel terraces along the bedrock ridges mark former shorelines indicating a gradual rise of the land surface since the last glaciation.

Along the shoreline of Hudson Bay east of Halfway Point are a series of active transverse bars (Fig. 7) comprised of sand and gravel. Physical factors contributing to the formation and revegetation of these bars are described by Moir (1954). Inland from Hudson Bay are numerous and well developed abandoned Tyrrell Sea beaches (Fig. 8).

FIGURE 4. Beach deposit overlying a bedrock exposure at Cape Merry. The proximity of the bedrock and large boulders within the gravel makes mining uneconomical.

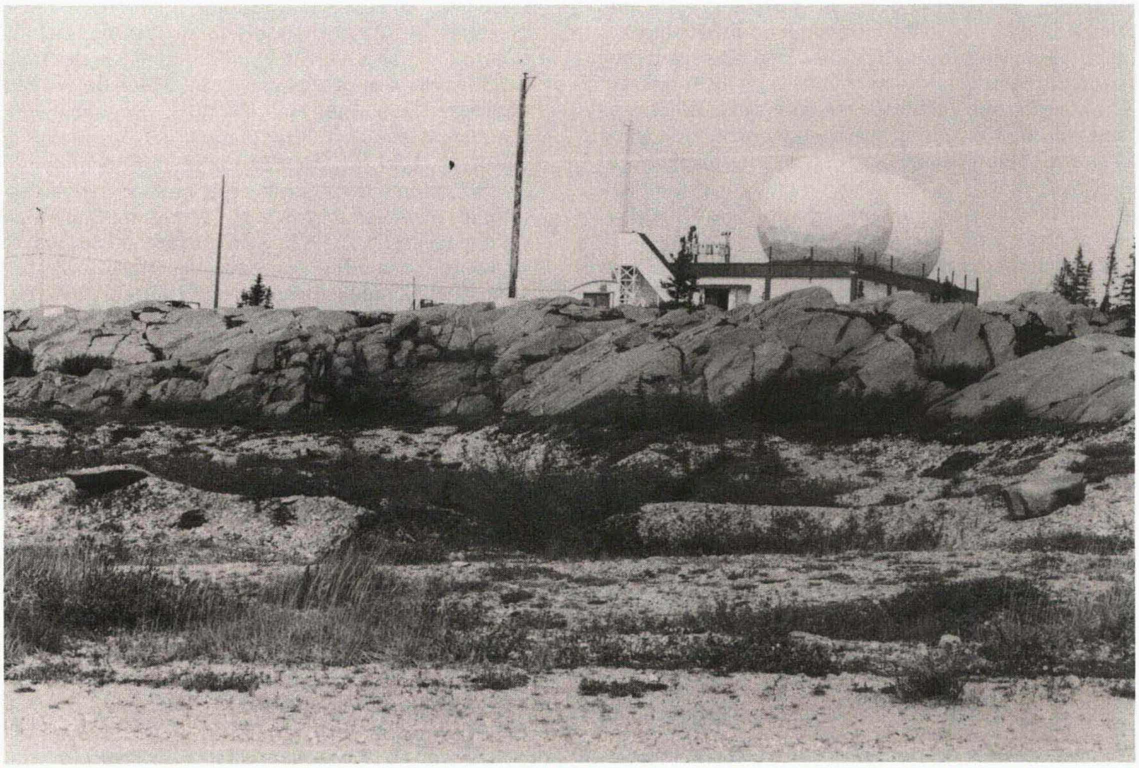

FIGURE 5. Sandy fine pebble beach alongside a bedrock exposure at site C4.

FIGURE 6. Littoral sand of deposit 32074, site C12. The deposit is a pebbly sand with average depth of 0.5 m.

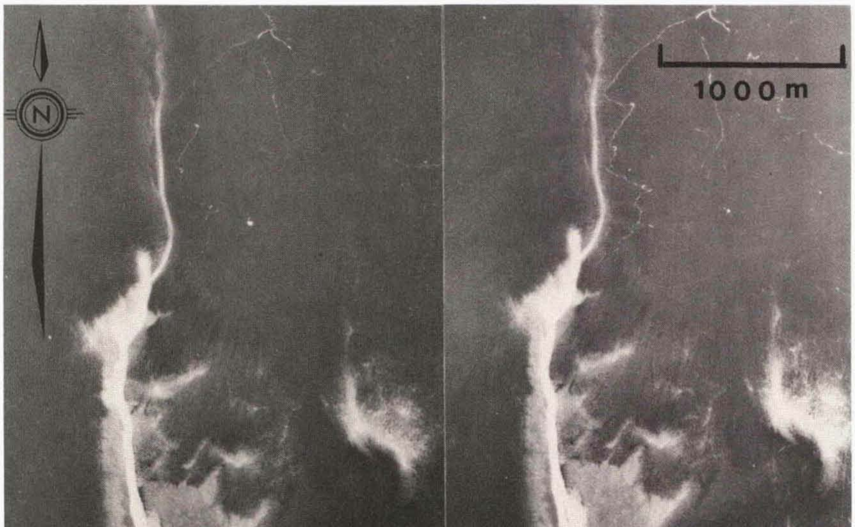

FIGURE 7. Stereopair (A22955-42, 43) illustrating an active transverse bar on Hudson Bay 2 km east of Halfway Point.

FIGURE 8. Abandoned Tyrrell Sea beach, deposit 32065, along the coast of Hudson Bay.

SAND AND GRAVEL RESOURCES

ANALYSES OF SAND AND GRAVEL

A total of 54 sand and gravel deposits were identified; of these, 40 deposits are situated east of Churchill River and 14 deposits situated west of the river. The majority of these deposits are within 8 km of the Hudson Bay coastline. The distribution of sand and gravel resources are shown on Map GR82-5 in the back pocket.

Sand and gravel deposits are either beach ridge or regressive shoreline deposits. The shoreline deposits are found as a discontinuous blanket over much of the area. The beach ridge deposits are either former Tyrrell Sea beaches or active transverse beaches, 1 to 3 m high, 50 to 150 m wide, and often extend up to 6 km in length. The tops of the ridges are generally flat with minor wave-cut terraces along the sides of the ridges (Fig. 9).

The textural composition of the sand and gravel varies from fine sand to cobbly coarse pebble gravel. The structures are variable ranging from massive to horizontal bedding. The 4 to 16 mm clasts are predominantly subrounded. Pebble lithologies are predominantly carbonate with secondary Precambrian crystallines. The percentage of carbonate pebble clasts increases eastward from Churchill (Fig. 10).

QUALITY OF SAND AND GRAVEL

The quality of each sampled deposit is based on the number of potential industrial uses and gravel content (sizes greater than 2.0 mm). The quality of deposits not sampled was estimated based upon the location, morphology and airphoto signature.

Each sand and gravel sample was sieved and the grain size distribution between 101.6 to 0.074 mm recorded. Grain sizes less than 0.74 mm were recorded as combined per cent silt and clay. The 4-16 mm pebble clasts were retained to determine pebble lithologies.

The type of industrial uses for which the sample is suited is related to the grain size distribution. Although processing methods can modify the sediment to accommodate a variety of potential uses, the industrial uses are based on the natural (unprocessed) characteristics of the deposit. A computer program developed by the Aggregate Resources Section of the Manitoba Mineral Resources Division correlates specification requirements (grain size distribution) of 48 different industrial uses with the grain size distribution data derived from laboratory testing of each sample. The computed results include individual ratings (suitable, marginal, or not suitable) for each correlation, and a positive or negative indication of whether screening is required; whether it is necessary to remove silt or clay from the deposit; whether crushable material is available on site; or whether it is necessary to add fines to meet the specifications for a particular use.

In Appendix I, the grain size distribution for each sample is shown as Table 1. Table 2 summarizes the potential uses of each sampled deposit, and the industrial usage laboratory specifications for each of the 48 industrial uses are shown in Table 3. From Table 2, three categories are indicated:

i) Those materials which meet specifications exactly (indicated by an X);
ii) Those materials which require minimal processing, screening or addition of some size fractions (indicated by an O), and
iii) Those requiring crushing to meet specifications and crushable material is available on site (indicated by a —).

The industrial usage assessment shows that except for coarse aggregate for highways and concrete, most sampled deposits are suited for a variety of industrial uses.

Grain size distributions greater than 30 per cent outside the limits of the industrial usage specifications are considered not suitable for that particular industrial use, even though the deposit

FIGURE 9. Abandoned Tyrrell Sea beach deposit 32072, site C1, inland from Hudson Bay. Note successive strandlines in background and boulders in foreground.

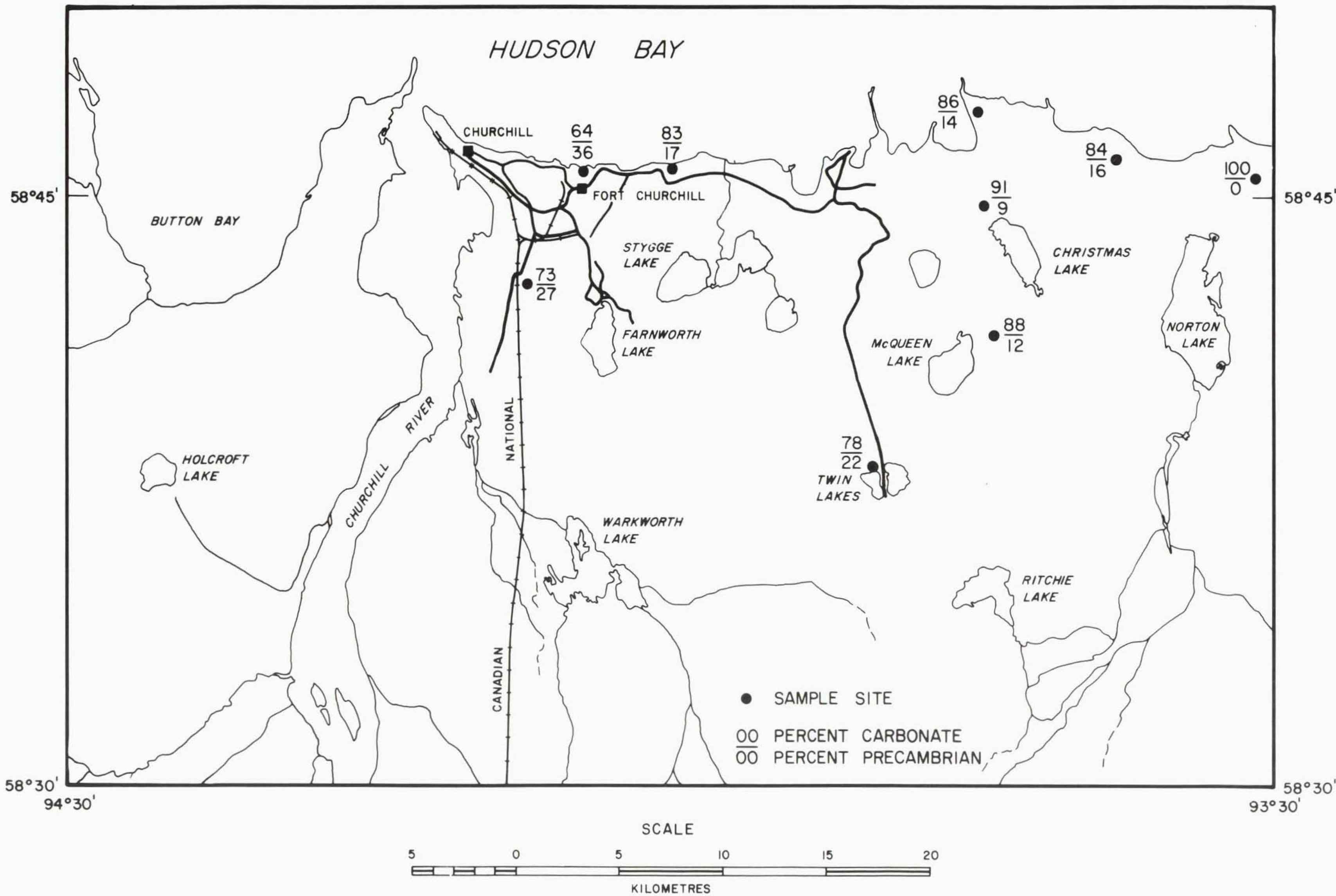

FIGURE 10. Carbonate and Precambrian pebble lithologies.

FIGURE 11. Cobbly coarse pebble gravel of deposit 32042, ground observation site C6. Shovel 1.0 m high. Lithology is predominantly limestone with minor Precambrian crystallines.

FIGURE 12. Beach deposit 32042, ground observation site C6. The water table is 1.0 m below the beach surface.

may contain coarse size fractions. Size fractions greater than 8 mm were normally not included within the deposit sample. Size fractions greater than 15 cm are recorded in the field and referred to as crushable material. Deposits which contain material greater than 15 cm and which may meet coarse aggregate specifications include the following deposits: 32031, 32042, 32058, 32063, 32064, 32069 and 32075. Deposit 32042 was not sampled but the sediment type was recorded and is shown in Figures 11 and 12.

RESERVES OF SAND AND GRAVEL

Total reserves are estimated at 34.0 million cubic metres and a summary of reserves by quality is shown in Table 1. Of the 34.0 million cubic metres of available reserves, 3.0 million cubic metres are estimated to be high quality (80 to 100 per cent gravel). Although the reserves would appear adequate, accessibility to deposits is restricted by Churchill River, small lakes and swampy terrain (Fig. 13). An estimate of reserves based upon accessibility is shown in Table 2. Reserves within 1.0 km of an existing roadway total 15.8 million cubic metres of which 156 000 cubic metres are of high quality. A summary of sand and gravel resource data including deposit reserve estimates and quality is shown in Table 4 of Appendix I.

Within close proximity of the Churchill townsite, deposit 32030 is 95 per cent depleted, and the remaining 3100 cubic metres are sterlized by a garbage dump. Deposit 32034 (Fig. 14) is currently being mined but extraction is limited to mining above the water table. Viable and accessible alternative deposits include the 1.6 million cubic metres of medium quality sand and gravel within deposit 32031, and an estimated 826 thousand cubic metres of medium to high quality gravel along the west portion of deposit 32075.

Other accessible medium to high quality reserves include deposit 32041 and 32042, with combined reserves of 362.0 thousand cubic metres. The largest single accessible deposit within the study area is deposit 32063 with estimated reserves of 9.7 million cubic metres of medium to high quality sand and gravel. Access to this deposit may be restricted as it is located within the space and rocket research centre.

TABLE 1. ESTIMATED RESERVES OF SAND AND GRAVEL BY QUALITY ('000 cubic metres)

QUALITY	ESTIMATED RESERVES
Low	9,861.2
Medium Low	3,366.4
Medium	6,679.9
Medium High	10,917.6
High	3,026.1
TOTAL	34,026.1

TABLE 2. ESTIMATED RESERVES OF ACCESSIBLE SAND AND GRAVEL BY QUALITY ('000 cubic metres accessible within 1.0 km of an existing roadway)

QUALITY	ESTIMATED RESERVES
Low	981.0
Medium Low	112.6
Medium	3,810.9
Medium High	10,821.6
High	156.0
TOTAL	15,882.1

DEMAND FOR SAND AND GRAVEL

The demand for sand and gravel within the study area was based upon a review of applications for mineral dispositions and reported quarry returns on file with the Manitoba Mineral Resources Division for a five-year period, 1976-1980 inclusive. This data is presented as Table 3 and shows the annual demand to be 54 900 cubic metres. The largest demand is for fill, 28 200 cubic metres annually, with only 1500 cubic metres required annually for concrete.

Given that there is an estimated 15.8 million cubic metres of accessible reserves, including 156 000 cubic metres of high quality sand and gravel, there is an adequate supply of aggregate for 289 years, assuming consumption remains constant and there are no major fluctuations of the water table.

TABLE 3. ESTIMATED ANNUAL DEMAND FOR SAND AND GRAVEL ('000 cubic metres)

USE	ANNUAL DEMAND
Fill	28.2
Road Maintenance	16.0
Dyke Maintenance	2.5
Concrete	1.5
Other	6.6
TOTAL	54.9

FIGURE 13. Stereopair (A22955-12, 13) showing abandoned beach deposits south of Gordon Point. Shoreline of Hudson Bay at top of photographs. Numerous swamps on both sides of the beach ridge restrict access to the deposit.

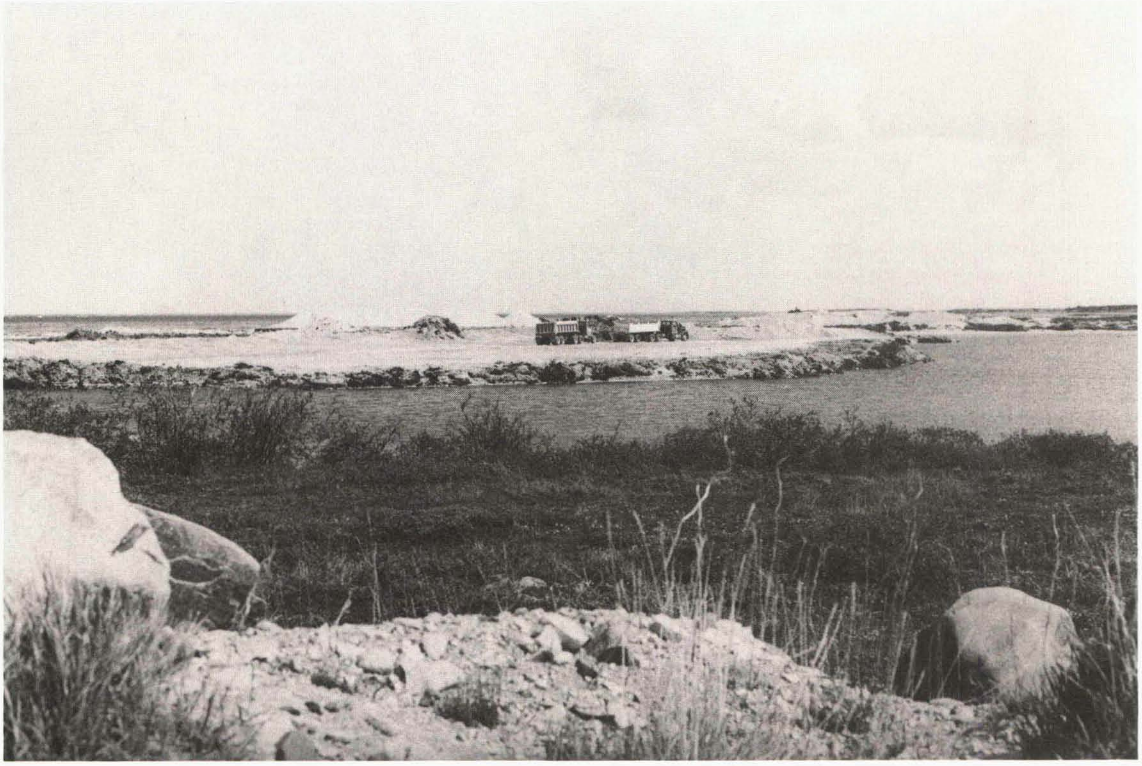

FIGURE 14. Sand and gravel removal from deposit 32034. Hudson Bay in background. Economic thickness of deposit and depth to water table is 1.0 m.

BEDROCK AS AN AGGREGATE SOURCE

INTRODUCTION

The Churchill quartzite bedrock was evaluated as an alternate source of aggregate derived from crushed stone. Specific engineering tests were performed on selected bedrock samples to determine the physical and weathering characteristics as indicators of the suitability of the bedrock for crushed stone. Test results were previously reported by Young (1982).

TESTING PROCEDURES

A total of five bedrock samples (Fig. 15) were tested. Tests selected were based on specifications from the American Society for Testing and Materials (A.S.T.M.), the Canadian Standards Association (C.S.A.), and from data supplied by local contractors and engineering firms. Specific tests included:

1. Los Angeles abrasion, which is a measure of the abrasive resistance of the bedrock.
2. Sodium sulphate soundness which is designed to measure a sample's resistance to disintegration.
3. Absorption which is a measure of the increase in weight of a porous solid body resulting from penetration of a liquid into the rock's permeable pores.

Table 4 summarizes some of the engineering specifications for various end uses of crushed stone. Included within the table is the percentage shale which is the allowable percentage deleterious material, and fineness modules which is an empirical factor of coarseness or fineness of aggregate relating the amount of water and cement that must be used in producing a workable mixture of concrete.

TEST RESULTS

Test results are summarized in Table 5. Samples 82-1, 82-2, 82-3 and 82-5 are very consistent and indicative of a sound durable rock. The samples crushed into fairly equiangular pieces indicating that these rock units are quite massive. Visually, these four samples appear durable and competent. The bedrock outcrops represented by these four samples would be acceptable sources of crushed rock for all applications including base coarse, traffic, bituminous, concrete, ballast and terrazo aggregate.

Sample 82-4 has nearly twice the abrasion loss, absorption, porosity and soundness loss of the other samples. It also has a lower bulk specific gravity and produces more flaky particles when crushed. Visually, the sample appears to be less well indurated than the other samples, and this is primarily responsible for the higher abrasion loss. Even though this sample's performance is poorer than the other samples, it could be acceptable for all end uses, although the high abrasion loss may be a concern for some of these applications. It would not likely be considered for use as ballast.

TABLE 4. MAXIMUM VALUE ENGINEERING TEST REQUIREMENTS OF AGGREGATE DERIVED FROM CRUSHED BEDROCK

TEST	BASE COURSE CLASS A	BASE COURSE CLASS B	TRAFFIC TYPE A	BITUMINOUS CLASS A	CONCRETE FINE	CONCRETE COARSE	BALLAST	TERRAZO AGGREGATE
Los Angeles Abrasion % Loss	60		35	35		50 40 35[1]	40	25
Sodium Sulphate Soundness % Loss				12	16	12	10	6
Absorption - %				1-2	1-2		0.5-1.0	
Shale - %	15	5	15					
Fineness Modules					2.3 to 3.1			

[1] The abrasion loss shall not be greater than 35 per cent when aggregate is used in concrete paving or for other concrete surface subject to significant wear.

TABLE 5

TEST	SAMPLE NUMBER				
	82-1	82-2	82-3	82-4	82-5
Los Angeles Abrasion Loss	26.8%	22.7%	23.6%	41.6%	27%
Bulk Specific Gravity	2.690	2.694	2.681	2.660	2.686
Bulk Specific Gravity (Saturated Surface Dry Basis)	2.698	2.703	2.691	2.679	2.697
Apparent Specific Gravity	2.771	2.718	2.708	2.713	1.716
Absorption	0.3%	0.3%	0.4%	0.7%	0.4%
Porosity	0.8%	0.9%	1.0%	1.96%	1.1%
Soundness Loss	0.2%	0%	0%	0.6%	0.1%/0.4%

CONCLUSIONS

Bedrock outcrops, stony marine silt and littoral sand and gravel are predominate surficial materials along the shoreline of the Hudson Bay. Numerous well developed abandoned Tyrrell Sea beaches are located along the shoreline and extend inland for several kilometres. The shoreline and beach ridge deposits are the only source of sand and gravel.

A total of 54 sand and gravel deposits have been identified with total reserves estimated at 34 million cubic metres of which 3.0 million cubic metres are of high quality. Accessible reserves are estimated at 15 million cubic metres of which 150 000 cubic metres are high quality. A secondary source of sand and gravel may be derived from crushed stone. Selected engineering tests on bedrock samples show the Churchill quartzites to be suitable as a source of crushed stone.

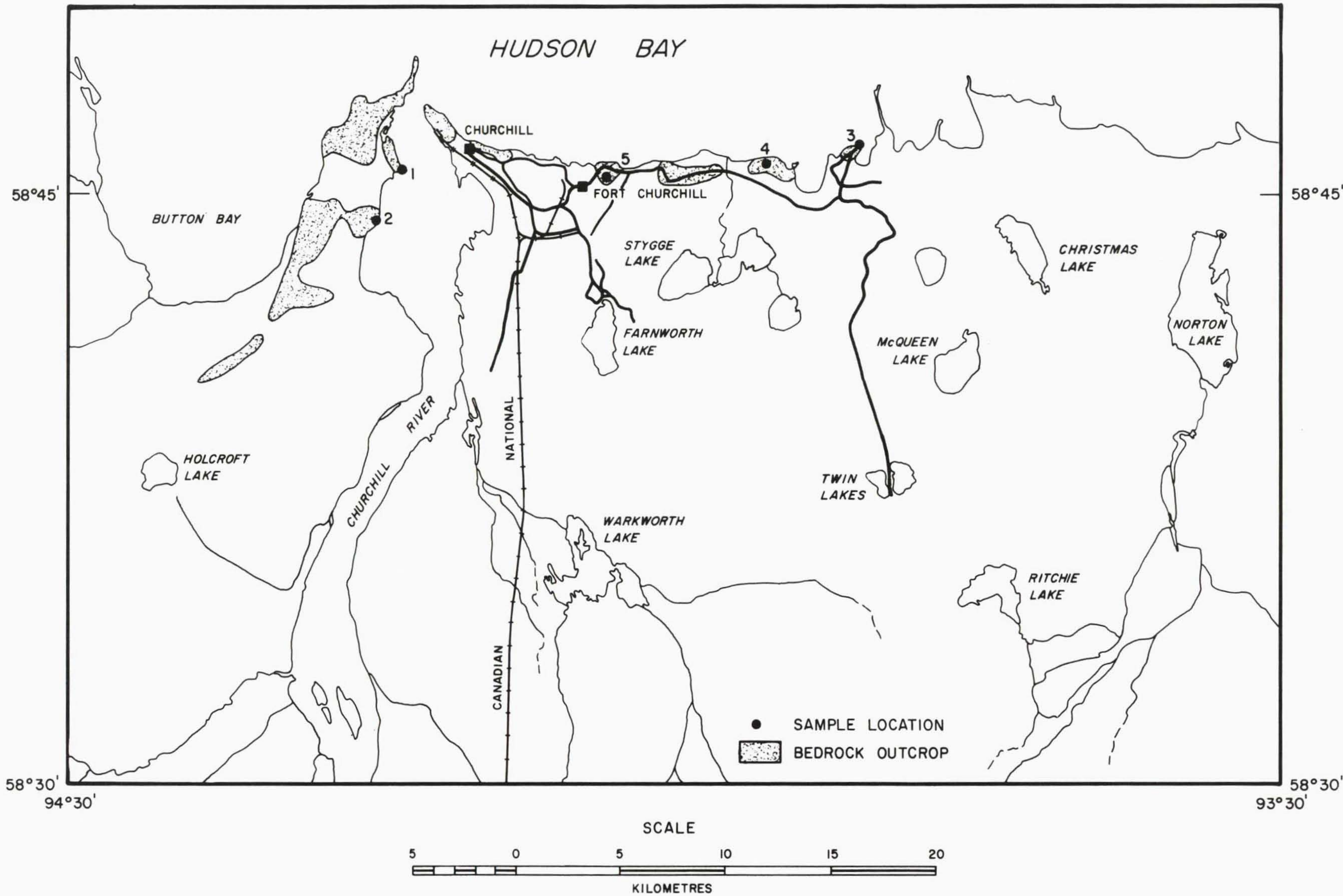

FIGURE 15. Bedrock sample locations.

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APPENDIX I

TABLE 1. GRAIN SIZE DISTRIBUTION

DEPOSIT	32024		32031		32034		32057		32058		32063	
SAMPLE	C 4		C 3		C 13		C 10		C 9		C 2	
SIEVE SIZE	PERCENT PASSING	PERCENT RETAINED	PERCENT PASSING	PERCENT RETAINED	PERCENT PASSING	PERCENT RETAINED	PERCENT PASSING	PERCENT RETAINED	PERCENT PASSING	PERCENT RETAINED	PERCENT PASSING	PERCENT RETAINED
4 IN	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0
3½ IN	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0
3 IN	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0
2½ IN	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0
2 IN	100.00	0.0	96.59	3.41	100.00	0.0	87.56	12.44	100.00	0.0	91.86	8.14
1½ IN	100.00	0.0	90.99	9.01	100.00	0.0	84.11	15.89	95.21	4.79	87.48	12.52
1 IN	100.00	0.0	86.33	13.67	94.66	5.34	81.22	18.78	94.04	5.96	78.45	21.55
¾ IN	100.00	0.0	82.48	17.52	93.08	6.92	78.59	21.41	91.19	8.81	73.03	26.97
⅝ IN	100.00	0.0	80.34	19.66	93.08	6.92	78.59	21.41	87.17	12.83	64.72	35.28
½ IN	100.00	0.0	77.58	22.42	91.87	8.13	78.59	21.41	80.85	19.15	62.79	37.21
⅜ IN	100.00	0.0	73.28	26.72	87.11	12.89	77.11	22.89	71.94	28.06	57.44	42.56
¼ IN	99.92	0.08	66.06	33.94	80.79	19.21	75.45	24.55	65.91	34.09	47.12	52.88
# 4	99.87	0.13	61.19	38.81	74.49	25.51	74.27	25.73	62.26	37.74	38.63	61.37
# 8	99.73	0.27	51.19	48.81	59.98	40.02	69.68	30.32	54.20	45.80	26.53	73.47
# 10	99.48	0.52	47.37	52.63	54.49	45.51	66.46	33.54	51.29	48.71	22.32	77.68
# 16	98.53	1.47	40.12	59.88	41.41	58.59	54.23	45.77	42.81	57.19	13.87	86.13
# 30	81.22	18.78	27.66	72.34	22.75	77.25	15.67	84.33	25.25	74.75	3.18	96.82
# 40	41.58	58.42	18.48	81.52	12.42	87.58	3.84	96.16	12.73	87.27	1.07	98.93
# 50	11.29	88.71	12.77	87.23	3.37	96.63	1.36	98.64	4.96	95.04	0.64	99.36
# 80	1.37	98.63	8.22	91.78	0.85	99.15	0.93	99.07	1.93	98.07	0.44	99.56
# 100	1.08	98.92	7.14	92.86	0.72	99.28	0.88	99.12	1.79	98.21	0.41	99.59
# 200	0.60	99.40	4.44	95.56	0.39	99.61	0.62	99.38	1.24	98.76	0.29	99.71
< 200	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00
% Cobbles	0.0		0.0		0.0		0.0		0.0		0.0	
% Pebbles	0.13		38.81		25.51		25.73		37.74		61.37	
% Granules	0.39		13.82		20.00		7.82		10.97		16.31	
% Sand	98.88		42.93		54.10		65.84		50.05		22.04	
% Silt/Clay	0.60		4.44		0.39		0.62		1.24		0.29	
Fineness Modulus	2.08		4.53		4.17		4.44		4.50		5.99	

TABLE 1. GRAIN SIZE DISTRIBUTION (Cont'd)

DEPOSIT	32064		32069		32072		32074		32075	
SAMPLE	C 7		C 8		C 1		C 12		C 11	
SIEVE SIZE	PERCENT PASSING	PERCENT RETAINED	PERCENT PASSING	PERCENT RETAINED	PERCENT PASSING	PERCENT RETAINED	PERCENT PASSING	PERCENT RETAINED	PERCENT PASSING	PERCENT RETAINED
4 IN	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0
3½ IN	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0
3 IN	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0
2½ IN	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0
2 IN	92.36	7.64	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0
1½ IN	88.38	11.62	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0
1 IN	77.42	22.58	98.82	1.18	99.36	0.64	100.00	0.0	88.18	11.82
¾ IN	64.47	35.53	94.49	5.51	99.36	0.64	97.34	2.66	71.82	28.18
⅝ IN	61.07	38.93	91.77	8.23	99.36	0.64	97.34	2.66	63.25	36.75
½ IN	52.64	47.36	86.80	13.20	99.00	1.00	97.34	2.66	51.30	48.70
⅜ IN	43.14	56.86	76.28	23.72	98.29	1.71	97.15	2.85	42.01	57.99
¼ IN	32.41	67.59	54.99	45.01	98.19	1.81	96.51	3.49	37.72	62.28
# 4	25.83	74.17	41.43	58.57	97.98	2.02	96.19	3.81	35.99	64.01
# 8	17.84	82.16	25.23	74.77	97.51	2.49	95.96	4.04	32.81	67.19
# 10	16.39	83.61	19.67	80.33	96.85	3.15	95.93	4.07	31.35	68.65
# 16	13.75	86.25	6.28	93.72	93.93	6.07	95.83	4.17	26.98	73.02
# 30	6.65	93.35	2.45	97.55	65.46	34.54	94.25	5.75	13.65	86.35
# 40	2.65	97.35	1.39	98.61	23.10	76.90	90.32	9.68	3.28	96.72
# 50	1.25	98.75	0.80	99.20	5.49	94.51	65.27	34.73	1.61	98.39
# 80	0.83	99.17	0.55	99.45	0.96	99.04	7.01	92.99	1.10	98.90
# 100	0.77	99.23	0.52	99.48	0.85	99.15	2.41	97.59	1.01	98.99
# 200	0.42	99.58	0.38	99.62	0.52	99.48	0.35	99.65	0.68	99.32
< 200	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00	0.0	100.00
% Cobbles	0.0		0.0		0.0		0.0		0.0	
% Pebbles	74.17		58.57		2.02		3.81		64.01	
% Granules	9.43		21.76		1.13		0.26		4.64	
% Sand	15.97		19.29		96.33		95.58		30.66	
% Silt/Clay	0.42		0.38		0.52		0.35		0.68	
Fineness Modulus	6.38		5.53		2.41		1.56		5.74	

TABLE 2. INDUSTRIAL USAGE ASSESSMENT*

Deposit	Sample	Asphalt			Base Course			Sub-Base, Base and Surface Course						Traffic Gravel				Seal Coat		
		A	B	C	A	B	C	A	B	C	D	E	F	A	B	C	D	A	B	C
32024	C 4						O					O	O							O
32031	C 3	—	O		—	X	X	—	—	—	O	O	O		—	—	—		—	O
32034	C 13	—	—		—	O	O				O	O	O		—	—	—		—	X
32057	C 10						—					O					—		—	X
32058	C 9	O	O		O	O	O	—	—	—	O	O	O	—	O	X	X		—	X
32063	C 2	O	O		O	O	O	O	O	O				O	O	O	O		X	X
32064	C 7		O		O	O	O	O	O	O				O	O	O	O		X	X
32069	C 8				O	O	O	—	—	O				—	—	O	O	—	X	X
32072	C 1						O					O	O							X
32074	C 12		O				O						O							
32075	C 11	O	O		O	O	O	O	O	O				O	O		O		—	X

Deposit	Sample	Standard Sizes Coarse Aggregate (for highways and concrete)																			Fine Concrete Aggregate			Mortar	Portland Cement	Built-up Roofs	Airfield Runways	Pit Run	Septic Fields	Shoulders
		1	2	24	3	357	4	467	5	56	57	6	67	68	7	78	8	89	9	10	A	I	II							
32024	C 4																			O	O		O	X				O	O	O
32031	C 3																			O	O	O	O	O	O		—	X	—	X
32034	C 13																			O	O			O	O		—	X	O	O
32057	C 10																			O	O	O	O	O	O			—	—	—
32058	C 9																			O	O	O	O	O	O		O	X	—	X
32063	C 2																			O				O			O	X	—	X
32064	C 7																	O						O			O	X	—	X
32069	C 8																	O									O	X	—	X
32072	C 1																			O	O	O	O	X				O	O	O
32074	C 12																			O				X				O	O	O
32075	C 11																			O	O	O	O	O	O		O	X	—	X

X Material meets specifications exactly.
O Some (minimal) processing required to meet specifications.
— Crushing required and material on site.

*Refer to Table 3, Appendix I for Industrial Use Specifications.

TABLE 3. INDUSTRIAL USE — LABORATORY TESTS

ASPHALT A (P. OF M.)
ASPHALT B (P. OF M.)
ASPHALT C (P. OF M.)
BASE COURSE A (P. OF M.)
BASE COURSE B (P. OF M.)
BASE COURSE C (P. OF M.)
SUB-BASE/BASE COURSE A (ASTM) D1241)
SUB-BASE/BASE COURSE B (ASTM) D1241)
SUB-BASE/BASE/SURFACE COURSE C (ASTM) D1241)
SUB-BASE/BASE/SURFACE COURSE D (ASTM) D1241)
SUB-BASE/BASE/SURFACE COURSE E (ASTM) D1241)
SUB-BASE/BASE/SURFACE COURSE F (ASTM) D1241)
TRAFFIC GRAVEL A (P. OF M.)
TRAFFIC GRAVEL B (P. OF M.)
TRAFFIC GRAVEL C (P. OF M.)
TRAFFIC GRAVEL D (P. OF M.)
SEAL COAT A (P. OF M.)
SEAL COAT B (P. OF M.)
SEAL COAT C (P. OF M.)
COARSE AGGREGATE 1 (ASTM C33,D448)
COARSE AGGREGATE 2 (ASTM C33,D448)
COARSE AGGREGATE 24 (ASTM C33,D448)
COARSE AGGREGATE 3 (ASTM C33,D448)
COARSE AGGREGATE 357 (ASTM C33,D448)
COARSE AGGREGATE 4 (ASTM C33,D448)
COARSE AGGREGATE 467 (ASTM C33,D448)
COARSE AGGREGATE 5 (ASTM C33,D448)
COARSE AGGREGATE 56 (ASTM C33,D448)
COARSE AGGREGATE 57 (ASTM C33,D448)
COARSE AGGREGATE 6 (ASTM C33,D448)
COARSE AGGREGATE 67 (ASTM C33,D448)
COARSE AGGREGATE 68 (ASTM C33,D448)
COARSE AGGREGATE 7 (ASTM C33,D448)
COARSE AGGREGATE 78 (ASTM C33,D448)
COARSE AGGREGATE 8 (ASTM C33,D448)
COARSE AGGREGATE 89 (ASTM C33,D448)
COARSE AGGREGATE 9 (ASTM C33,D448)
COARSE AGGREGATE 10 (ASTM C33,D448)
FINE CONCRETE AGGREGATE A (P. OF M.)
FINE CONCRETE AGGREGATE I (ASTM C33, C404)
FINE CONCRETE AGGREGATE II (ASTM C33, C404)
MORTAR (ASTM C144)
PORTLAND CEMENT (P.C.A.)
BUILT-UP ROOFS (ASTM D1863)
AIRFIELD RUNWAYS (P. OF M.)
PIT RUN (P. OF M.)
SEPTIC FIELDS (U.M.A.)
SHOULDERS (P. OF M.)

P. OF M.	MANITOBA DEPARTMENT OF HIGHWAYS AND TRANSPORTATION SPECIFICATIONS
ASTM	AMERICAN SOCIETY FOR TESTING AND MATERIALS
P.C.A.	PORTLAND CEMENT ASSOCIATION
U.M.A.	UNDERWOOD McLELLAN AND ASSOCIATES

TABLE 4. SAND AND GRAVEL RESOURCES

Deposit	Sample	Area (hectares)	Average Depth (metres)	Lithology % Precambrian Crystallines	% Carbonate	Roundness[1]	Available Aggregate ('000 cubic metres)	Estimated[2 3] Quality
32021		41.1	0.5				205.5	Low
32022		12.4	0.5				62.0	Low
32023		14.0	1.0				40.0	Medium Low
32024	C 4	67.2	3.0				2,016.0	Low
32025		41.2	0.5				206.0	Medium Low
32026		80.5	1.0				805.0	Medium
32027		4.4	1.0				44.0	Medium Low
32028		3.5	1.0				19.0	Medium Low
32029		5.4	1.0				17.0	Medium Low
32030		19.1	0.5				4.7	Medium
32031	C 3	83.3	2.0	27	73	3-4	1,666.0	Medium
32032		31.4	1.0				3.1	Medium Low
32033		16.1	1.0				161.0	Medium
32034	C 13	40.9	1.0	17	83	4	102.2	Medium
32035		10.3	1.0				103.0	Medium
32036		18.3	0.3				54.9	Low
32037		132.8	0.3				394.1	Low
32038		21.3	0.5				106.5	Medium Low
32039		6.5	0.7				45.5	Low
32040		10.4	0.5				5.2	Low
32041		20.6	1.0				206.0	Medium High
32042	C 6	15.6	1.0				156.0	High
32043		11.3	1.0				5.6	Low
32044		5.7	1.0				57.0	Medium High
32045		4.9	1.0				39.0	Medium High
32046		5.6	1.5				84.0	Medium Low
32047		6.4	1.0				64.0	Low
32048		15.4	1.0				3.0	Medium Low
32049		32.5	0.5				162.5	Low
32050		88.7	2.0				1,774.0	Medium
32051		7.8	1.0				78.0	Medium Low
32052		2.9	1.0				29.0	Medium Low
32053		20.2	1.0				102.0	Medium Low
32054		12.4	0.5				62.0	Low
32055		7.0	0.5				35.0	Low
32056		8.0	1.0				80.0	Low
32057	C 10	102.8	2.0	9	91	3-4	2,056.0	Medium Low
32058	C 9	45.3	2.0	12	88	4-5	906.0	Medium
32059		57.9	2.0				1,158.0	Medium
32060		9.2	0.5				46.0	Medium Low
32061		9.9	0.5				49.5	Medium Low
32062		10.6	0.5				53.0	Medium Low
32063	C 2	492.5	2.2	22	78	4	9,789.6	Medium High
32064	C 7	18.1	1.5	14	86	3-4	271.5	High
32065		130.1	1.5				1,951.5	High
32066		33.0	1.0				330.0	Medium Low
32067		12.6	0.5				63.0	Low
32068		21.3	0.5				106.5	Low
32069	C 8	54.8	1.5	16	84	4	822.0	High
32070		7.4	0.7				51.8	Low

TABLE 4. SAND AND GRAVEL RESOURCES (Cont'd)

Deposit	Sample	Area (hectares)	Average Depth (metres)	Lithology % Precambrian Crystallines	Lithology % Carbonate	Roundness[1]	Available Aggregate ('000 cubic metres)	Estimated[2,3] Quality
32071		45.9	5.0				2,295.0	Low
32072	C 1	74.0	5.0	0	100	3-4	3,700.0	Low
32073		16.9	0.5				84.5	Low
32074	C 12	176.8	1.0				368.1	Low
32075	C 11	29.5	3.5	36	64	4-5	826.0	Medium High
TOTAL							34,026.1	

1. Roundness Scale (Powers, 1953)
   1. Very Angular
   2. Angular
   3. Subangular
   4. Subrounded
   5. Rounded
   6. Well Rounded

2. Estimated Quality — Percent Gravel
   - 80-100 High
   - 60-80 Medium High
   - 40-60 Medium
   - 20-40 Medium Low
   - 0-20 Low

3. Industrial Usage Assessment