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Sand and Gravel Resources of the Lethbridge Area

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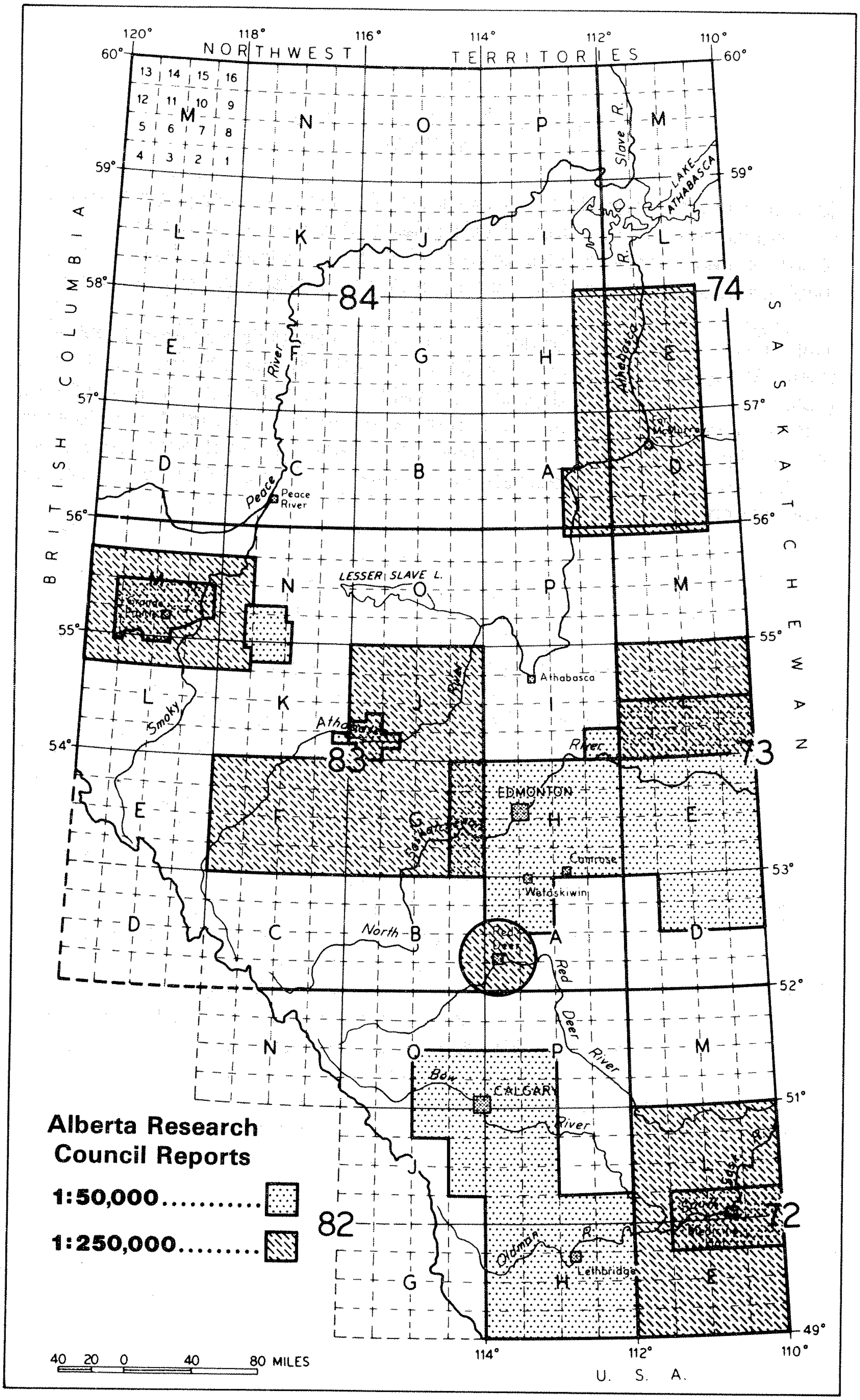
PREFACE

Sand and gravel production is often beset with land-use conflicts and environmental problems. The purpose of this series of reports is to provide information about sand and gravel deposits which can help planners make intelligent decisions involving land use and provide a starting point for detailed exploration programs.

This survey concentrates not only on currently exploitable resources, but also on many "untapped" deposits with a foreseeable use. The maps of the deposits have a scale of 1:50 000. The deposits, themselves, have a thickness of at least 1 m, and have a ratio of overburden to sand and gravel of no more than 1:1. Volume or tonnage figures are based on a broad geological knowledge of the deposits and not on detailed sampling or subsurface data. These figures should be used as general estimates only.



Location of the Lethbridge area and the other project study areas.

ABSTRACT

The most important sources of gravel and sand in the Lethbridge area are high and low level alluvial terraces associated with the Oldman River valley. These terraces contain gravel and gravelly sand, exposed at the surface in the case of the high terraces. The low terraces commonly have up to 3 m of fine sand and silt overlying the sand and gravel. The largest of the alluvial deposits, in the vicinity of Fort MacLeod, covers approximately 40 km^2 and is composed of coarse gravel with a consistent thickness of 3.0 to 3.5 m.

Extensive gravel deposits of preglacial age are located in upland areas south of Fort MacLeod, south of Magrath, and in the Del Bonita area. In the vicinity of Del Bonita, 45 km south of Lethbridge, preglacial gravel covers an area of approximately 50 km^2. The material varies in thickness from 3 to 5 m and generally has less than 3 m of overburden. These preglacial deposits are not being widely utilized at present but may become an important source of granular material in the future.

Good sources of coarse and medium sand are found in the kame deposits within hummocky moraine zones along the Rocky Mountain Foothills, in the southwest quarter of the area.

INTRODUCTION

LOCATION

The study area is situated in southern Alberta between 112°00′ and 114°00′ west longitude and 49°00′ and 50°15′ north latitude. It covers Tp 1 to 15 and R 16 to 30, W4th Mer, has a total area of about 18 000 km^2 and includes the counties of Lethbridge and Cardston, and most of the counties of Willow Creek, Taber, Pincher Creek, and Warner. The study area also encompasses part of Waterton Lakes National Park. The study did not include the Blood and Peigan Indian Reserves which are located within the area outlined.

Lethbridge, with a population of about 40 000 is the only city within the study area. The following incorporated towns with populations between 1000 and 5000 are located in the area: Cardston, Claresholm, Fort MacLeod, Granum, Magrath, Milk River, Picture Butte, Pincher Creek, and Taber. With the exception of the southwestern corner, an excellent network of highways and paved and gravelled roads cross the area.

The area divides into three major physiographic units: the Rocky Mountains, in the southwestern corner; the Foothills, bordering the mountains on the southwest; and the Great Plains, which includes most of the area. The general slope of the land surface is towards the northeast. The Oldman River and its tributaries, the St. Mary, Belly, Waterton, and Little Bow Rivers, drain the area, except for the southeastern part which is drained by the Milk River. These rivers flow in valleys 50 to 100 m deep.

PREVIOUS WORK

The surficial geology of the area has been mapped at a scale of 1:250 000 (Stalker, 1957, 1958, 1962, 1965). Hydrogeological surveys have been conducted at a scale of 1:250 000 (Tokarsky, 1974; Ozoray and Lytviak, 1974) and a soil survey at a scale of 1:126 720 (Kocaoglu, 1977). Comprehensive investigations of the sand and gravel resources of the study area had not been undertaken before this study.

PRESENT STUDY

This study was undertaken to determine the distribution, thickness, composition, quality, and reserves of gravel and sand and to provide maps that will aid future development of these resources. The gravel deposits of the entire region were mapped at a scale of 1:125 000 and the main areas of sand and gravel were mapped at a scale of 1:50 000. The results are presented on maps at scale of 1:250 000 (Fig. 1, 2) and 1:50 000 (Fig. 3, 4, 5).

During the winter of 1976–1977 existing information on gravel and sand deposits in the area was synthesized. Data were collected from the following sources: maps of surficial geology, soils, and hydrogeology; water-well logs, seismic shothole logs, and logs of shallow drillholes obtained from Alberta Environment. Airphotos of the entire area were studied.

Fieldwork, in the summer of 1977, included checking geological boundaries delineated on airphotos and surficial maps, and detailed geologic mapping of those areas considered favorable for gravel and sand deposits. Other work included a study of outcrop exposures of alluvial terraces in the Oldman River valley, describing and sampling of 185 pits, and the dry auger drilling of 330 testholes.

A resistivity survey was undertaken to test the efficiency of this method as an aid in prospecting for gravel and sand. The resistivity measurements showed good correlation with drilling data and proved that gravel and sand could be distinguished from other sediments by their electrical properties. The success of the resistivity method depended on the geological setting of the area studied. Gravel-bearing deposits could be located and delineated readily by resistivity measurements alone where they were in contact with till or bedrock. Complementary drilling information was required if gravel lenses were to be traced within areas composed of fine-grained sand. Electrical measurements could not distinguish gravel from pure, medium- to coarse-grained sand because of similar resistivity values. The most cost efficient method of searching for gravel and sand was to combine a resistivity survey with a limited number of drillholes.

Sieve analysis of 172 samples provided the grain-size information on the gravel and sand deposits. The maps and the reports were prepared in the winter and the spring of 1978.

THE MAPS: CONTENTS AND TERMINOLOGY

This report is written to accompany the maps which present the main results of the survey. Below is a description of the contents of the maps and sources of the data that were used to compile the maps.

SURFICIAL GEOLOGY MAP (Figure 1)

Figure 1 (scale: 1:250 000) provides a general picture of the distribution of surficial deposits. Map units are differentiated on the basis of genesis and lithology. Types shown on the map are those that predominate within the areas delineated.

The map was compiled from maps of surficial geology at a scale of 1:250 000 by Stalker (1957, 1958, 1962, 1965). The distribution and areal extent of sand and gravel have been modified from Stalker's maps as have interpretations of the origin of some surficial deposits.

The terminology for genetic types of glacial deposits (glacial drift) is currently not clearly defined. In this report, the terms proposed by R.F. Flint (1957), by C.P. Gravenor and W.O. Kupsch (1959), and by C. Embleton and C. King (1968) are used (Appendix A).

MAP OF DISTRIBUTION OF GRAVEL AND SAND DEPOSITS (Figure 2)

This map, at a scale of 1:250 000, shows all occurrences of gravel and sand observed in the area regardless of quality, extent, and economic importance.

The figure is accompanied by a list of the deposits (Appendix C) which provides information about thickness and areal extent of gravel and sand, thickness of overburden, lithologic and petrographic composition, and a rough estimation of reserves. The gravel and sand deposits on the map are numbered and are classified into seven groups according to their origin.

DETAILED MAPS OF GRAVEL AND SAND DEPOSITS (Figures 3, 4, 5)

These maps, at a scale of 1:50 000, provide detailed information about the distribution, lithology, and thickness of gravel and sand within the "Lethbridge," "Fort MacLeod," and "Del Bonita" areas. The maps are accompanied by eight geological profiles to show the composition of gravel and sand deposits and their relationship with adjacent beds.

The classification of gravel and sand used on the maps and in the report follows the industrial classification of the American Society for Testing and Materials (ASTM) (Appendix B).

Possible gravel and sand deposits shown on the maps are those that have not been defined by drilling or outcrop study because of inaccessibility. The presence of gravel was assumed on the basis of airphoto interpretation.

RELATIONS BETWEEN GRAVEL AND SAND DEPOSITS AND GLACIAL HISTORY

Gravel and sand deposits in the area are abundant and variable. Their composition and origin vary widely, and they are unevenly distributed. Numerous deposits of gravel and sand, some very extensive, occur in the western part of the region and along the Oldman River valley. Only scattered small bodies of gravel, however, have been identified in the eastern part of the area, on the uplands between the Bow and Oldman Rivers, and between the Oldman and the Milk Rivers.

The mantle of unconsolidated sediment that covers the area was deposited during Late Tertiary, Pleistocene, and Holocene time. Gravel and sand were accumulated intermittently during this period, but the rate of the accumulation and the character of the deposits changed repeatedly in response to changes in the source area of coarse material, the direction and type of drainage systems, and the regimen of streams.

Field examination of the lithologic composition of coarse gravel and pebbles has shown that most of the stones originated in the Rocky Mountains. They consist of durable rocks of Late Precambrian and Paleozoic age: limestone and dolomite, quartzite, hard sandstone, and argillite. Some of the coarse fragments were derived from the Precambrian Shield and brought into the area by glacial ice. They consist of igneous and metamorphic rocks, which are mainly granite, diorite, gneiss, and schist. About half the stones derived from the Canadian Shield are weathered and friable. The main source of deleterious material in the coarse fraction of the gravel and sand was local bedrock (late Cretaceous and early Tertiary), consisting of sandstone, siltstone, and shale containing thin coal layers and calcareous concretions.

The pattern of drainage throughout the Quaternary was controlled by large-scale features in the preexisting bedrock surface formed in the Tertiary. The deposits and temporary drainage modifications by glaciation did little to alter this pattern. The bedrock surface rises generally from the northeast to the southwest towards the Rocky Mountains, from elevations of 700 m above sea level to 2500 m above sea level. On the plains, the altitudes increase from 700 m to 1100 m above sea level, with the average gradient 2.5 m/km. The surface of the plains consists of successively higher, flat terraces, separated by gentle slopes. Within the Foothills the altitudes are from 1100 m to 1500 m above sea level, and the average gradient is 15 m/km. In the Rocky Mountains, the average gradient is as much as 80 m/km.

The bedrock surface was cut by valleys which are almost completely buried under the Quaternary deposits and are considered to be of preglacial age (Stalker, 1963). These valleys are as much as 50 to 75 m deep and up to 10 km wide. They extend across the area in a northeastern to eastern direction along the courses of the present Oldman, St. Mary, Belly, Waterton, and Milk Rivers (Geiger, 1965). In some places, the bedrock uplands between the valleys are summits, similar to plateaus, such as Del Bonita Upland and Milk River Ridge in the southern part of the area.

The bedrock terraces and plateaus are believed to represent remnants of old erosional surfaces formed by the action of rivers between Oligocene and late Pliocene time (Cope, 1891; Collier and Thom, 1918; Alden, 1924). Fluvial sedimentation has left a cover of gravel and sand over bedrock on some of these erosional surfaces. There is evidence for at least three stages of gravel and sand deposition during the late Tertiary. The oldest gravel, covering the flat surface of the Del Bonita Upland, at elevations between 1300 and 1400 m above sea level, could correspond to the Cypress Hills Formation of presumably Oligocene age (Westgate, 1968). Gravel and sand deposits on bedrock terrraces, with elevations between 1080 and 1150 m above sea level, south of Magrath and Fort MacLeod, may be correlated with the Flaxville gravels in Montana and in southeastern Alberta (Collier and Thom, 1918; Westgate, 1968), dated as Miocene to early Pliocene. The youngest preglacial alluvial deposits are known as "Saskatchewan gravel and sand." They fill the bottoms of preglacial channels and are thought to be of late Pliocene to early Pleistocene age (Stalker, 1963). These deposits, which are overlain by drift as much as 80 m thick, are exposed only along the banks of the Belly, St. Mary, and Oldman Rivers, wherever bottoms of the present valleys intersect floors of the ancient streams.

The area was glaciated several times during the Pleistocene (Stalker, 1963; Stalker and Harrison, 1977), but little is known of the details of the pre-Wisconsinan glacial history. During the Wisconsinan most of the region, with the exception of the Del Bonita Upland and the Rocky Mountains, was covered by the Laurentide ice advancing from the northeast and north.

The extent of the final "Classical" Wisconsinan glacier in the area remains controversial. The outer limit of this glaciation, as shown on the map by Westgate (1968), is marked by the well-developed hummocky moraine surrounding the Del Bonita Upland and the Rocky Mountains. Stalker (1977) sets the margin of the Classical Wisconsinan glacier 40 km north of Westgate's boundary, along the southern edge of the hummocky moraine belt that parallels Etzikom Coulee west to Lethbridge and then continues north toward the Traverse Reservoir. Direct evidence does not exist to confirm either of the boundaries, but the morphology of the relief makes the southern boundary appear more likely to represent the extreme maximum of the Classical Wisconsinan ice-sheet. No morphologic differences in the appearance of the hummocky moraines or the river valleys indicate that the relief south of the north boundary is more mature than within it. Thus, it seems logical to assume that the surficial deposits and the landforms of the area were formed during one continuous deglaciation rather than during two deglaciations and one major readvance of ice.

Most of the gravel in the area was deposited in meltwater streams draining the retreating glacier. The glacial drainage systems changed continuously, both in type and direction, as deglaciation proceeded (Fig. 6). Different types of gravel deposits were associated with each of the stages of ice retreat, as illustrated by Figures 6-I, 6-II, 6-III. The glaciofluvial processes also produced different effects southeast and northwest of the line that follows the St. Mary and Oldman Rivers. These differences and the factors involved are discussed below.

The first stage of deglaciation was characterized by a gradual lowering of the ice surface, as a result of a general increase in temperature and conversion of the economy of the ice sheet from positive to negative. At that time the accumulation of gravel and sand took place all along the Foothills belt where at higher elevations the generally thin ice stagnated quickly (Fig. 6-I).

The conditions of drainage differed considerably in the western and eastern parts of the Foothills. West of the St. Mary River, the strongly differentiated bedrock slope was towards the glacier. Meltwater streams, therefore, formed intermittent superglacial and englacial drainage systems. The south, and southwestern, directions of the flow corresponded to the slope of the glacier. The Foothills ridges soon protruded through the downwasting ice and became the sites of numerous small ponds that formed between the ice and the exposed land. These openings on the ice surface presented natural traps for material transported by meltwater flow. The deposits of kame-type origin are widespread within the western part of the Foothills. They are small in area and are generally of a two-storey composition: the lower layers consist of fine, well-sorted sand and silt formed by the initial low velocity flow; the upper layers are composed of coarse, poorly sorted gravel and sand brought in by the later, more rapidly flowing meltwater streams.

East of St. Mary River, meltwater could escape along the slopes of the bedrock uplands, first to the south through a series of marginal and proglacial channels, and later to the east through the pre-existing Milk River valley and its tributaries. Kame deposits are rare in this part of the Foothills, and the main type of glaciofluvial accumulations are meltwater stream deposits, consisting chiefly of fine sands and silt or, more rarely, of unsorted gravel and sand.

Progressive thinning of the ice caused disintegration of the wide marginal part of the ice sheet into fields of dead ice. The glacier terminus was separated into two lobes. One retreated to the northeast, along the Oldman River valley, the other, to the north along the slope of the Foothills.

Southeast of the St. Mary and Oldman Rivers, the glacier terminated at the relatively undifferentiated and steep bedrock slope dipping towards the ice. There the meltwater drained along the slope to the east and southeast carving a series of marginal and submarginal channels. As the melting ice exposed new portions of the slope, successively lower channels were formed. It appears the meltwater streams carried most of their sediment outside the area, since most of the channel terraces are erosional. Only a few terraces contain discontinuous and relatively thin veneers of poorly sorted sand and coarse gravel, largely composed of the rocks derived from the Canadian Shield and the local bedrock.

The conditions of drainage were entirely different in the rest of the area. The ice terminated on the broad lowlands, stretching along the preglacial Oldman, Belly, and St. Mary River valleys, or on the gentle bedrock slopes inclining away, as well as towards, the ice. Here the meltwater streams formed internal drainage systems. These systems were centered in shallow lakes, ponded in the lowlands, in front of the glacier terminus or dead-ice blocks. An absence of shoreline features suggests the lakes did not last long and fluctuated greatly. They drained primarily eastward through the systems of the ice-marginal channels developed in the southeastern part of the area. Part of the sediment the meltwater streams carried into the lakes accumulated as outwash plains, between the ice and the lakes, or between the dead-ice blocks. Fine-grained, well sorted sand is the dominant material in the outwash plains of the area. In some places, however, at the margins of the outwash plains gravel is present. These isolated, relatively small areas of gravel formed where meltwater streams emerging from ice slopes slowed down upon entering the plains. The outwash gravel largely consists of rocks derived from the Rocky Mountains and the Canadian Shield. The local bedrock component is insignificant.

When ice finally disappeared from the area, all the earlier, intermittent drainage systems transformed into the two major drainage basins that exist today, the Oldman River system and the Milk River system. Since that transformation, accumulation of gravel and sand has continued only in the river valleys. Evidence from the Oldman River system indicates there were three different stages of valley development: the initial stage; the late-glacial downcutting; and the period of predominant aggradation, presumably of post-glacial time. The Milk River system is not discussed here, because only a short section of the Milk River valley is within the study area.

Meltwater streams from the Rocky Mountain glaciers formed the Oldman, Waterton, Belly, and St. Mary River valleys and some of their tributary valleys. During early deglaciation, mountain streams merged with the meltwater streams that were draining the glacier on the plains to contribute to glaciofluvial accumulation. They incised deep channels on the steep slopes of the Foothills but made little impression on the Plains where there were low surface gradients and high local base levels controlled by the glacial lakes. As the glacier terminus retreated farther downslope, the meltwater streams from the mountains started to deepen their courses. The rates of downcutting remained low, and the depth of the newly formed valleys did not exceed 15 to 20 m, since the high terraces, all along the valleys, lie at the level of the surrounding plains, or just below it (Fig. 19, Profile R-S). It was the surrounding topography, not changes of the base levels in the lower parts of the valleys, that controlled river accumulation in the area. The stepped, longitudinal profiles of the streams reflected the alternation of the flat surfaces and gentle slopes in the late-glacial topography inherited from the preglacial landscape. The high river terraces have a thick cover of gravel and sand where the streams passed from the slopes to the flat surfaces (Fig. 7). Within the slopes,

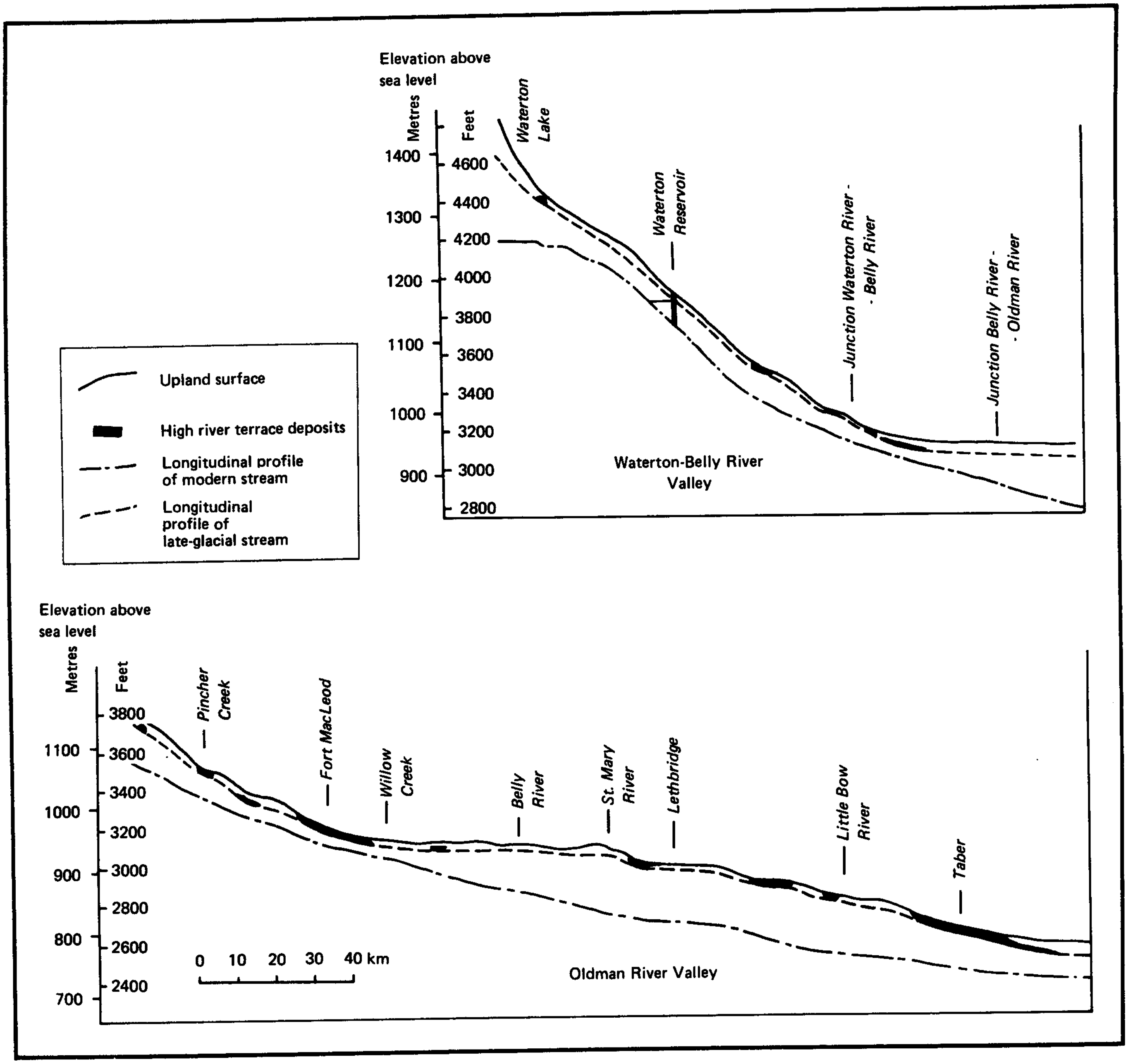


FIGURE 7. Relationship between high river terrace deposits and upland surface of the area.

however, the terraces are absent or are erosional with a thin veneer of lag-gravel over till. The gravel consists largely of rocks derived from the Rocky Mountains. The content of Shield stones in upstream sections of the valleys is relatively low, but increases downstream, with distance away from the mountains. Local bedrock material is usually absent.

The downcutting of valleys in the area took place later in the Pleistocene and, possibly, during the early Holocene. Since the present river valleys are incised into glacial drift and bedrock as much as 100 m deep (Fig. 19, Profile R-S), the erosion rates must have been very high. The valley slopes are mostly steep and non-terraced. Small sites of erosional terraces are found only in some places along the Oldman River valley. Whatever caused the downcutting had to have been of regional character, such as a substantial drop in the base level of the drainage system, a continuous uplift in the upper part of the system, or both. The increased melting of the valley glaciers in the Rocky Mountains intensified the erosional process.

The channel erosion cycle was ended later in the Holocene, by a period of accumulation during which the alluvial fills of the valley bottoms were deposited (Fig. 8; Fig. 19, Profiles K-L, M-N, O-P). Two depositional terraces, at 2.0 to 3.5 m and 5.0 to 7.5 m above river level, can be traced in the major river valleys and in most of the tributary valleys of the area. Remnants of a higher depositional terrace, at 12 to 16 m above stream level, are present only in the Oldman River valley. Each later fill is successively inset in the trench cut in the earlier fill (Fig. 8). The lowest terrace is composed of gravel and sand, fine-grained sand, and silt mixed in variable proportions. The best gravel appears to constitute the lower parts of the fill lying below river level. In the Oldman River valley, downstream from its junction with the St. Mary River valley, this terrace generally has a cover of floodplain deposits which are fine-grained sand and silt, as much as 4.5 m thick. The two upper terraces are composed mainly of floodplain sand and silt. Layers of gravel are near the bottoms of the terraces, although in some places thick lenses of gravel have also been found within these terraces close to the surface. Alluvial gravel consists predominantly of clasts derived from the Rocky

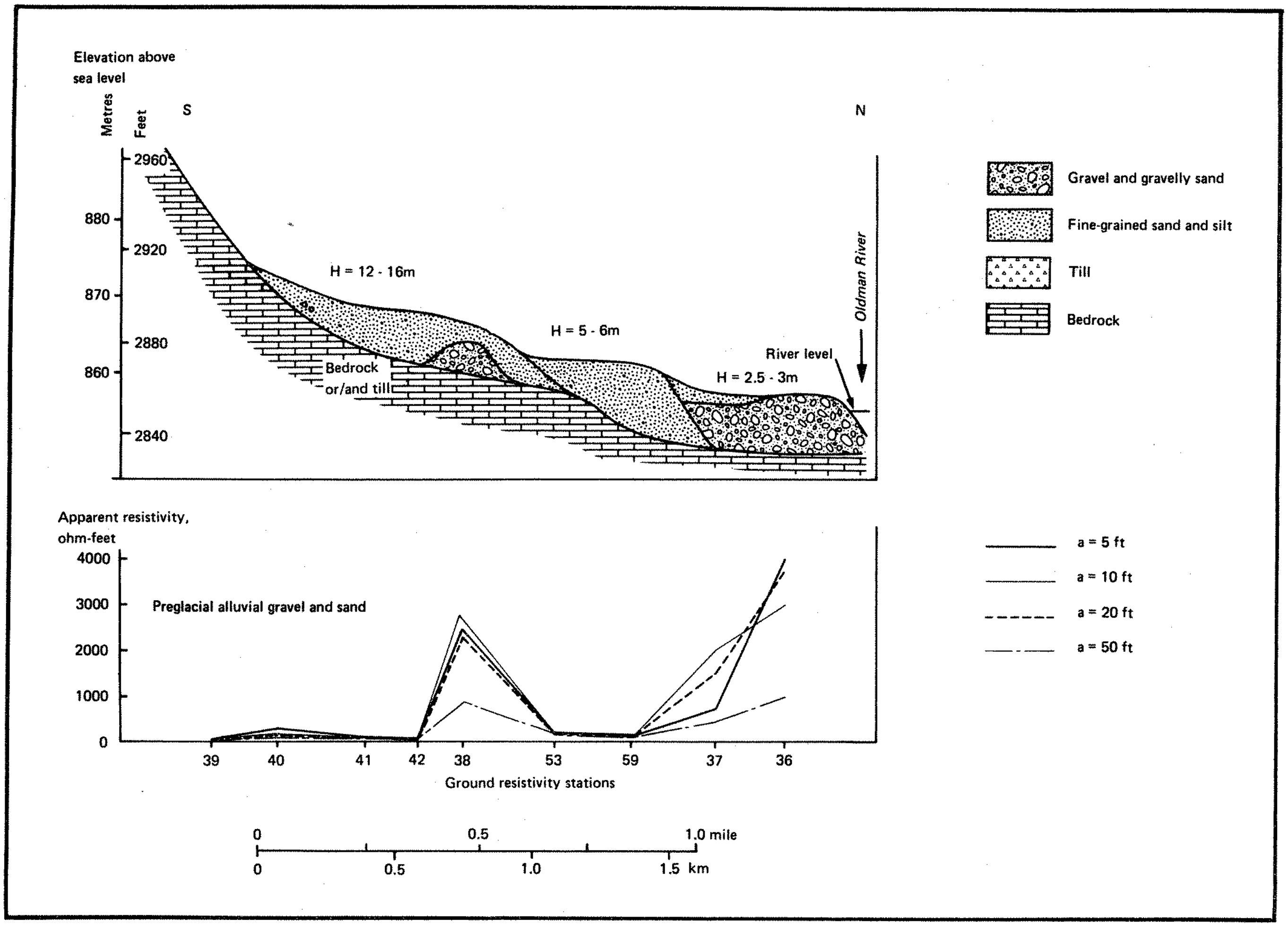


FIGURE 8. Composition of recent alluvial terraces in the Oldman River Valley (Kipp Section).

Mountains. The proportion of Shield and local bedrock material does not exceed 20 percent.

SAND AND GRAVEL DEPOSITS

The gravel-bearing deposits are classified, on the basis of origin, into the seven types listed below:

1. preglacial alluvial deposits;
2. kame deposits;
3. esker deposits;
4. outwash deposits;
5. marginal stream deposits;
6. valley train (high river terrace) deposits;
7. recent alluvial (low river terrace) deposits.

The general characteristics of each type of gravel, and the major deposits within each group, are described in this section. All gravel-bearing deposits found in the area are listed in Appendix C. The bracketed numbers for the deposits refer to the location number given in Figure 2 and Appendix C.

PREGLACIAL ALLUVIAL DEPOSITS

Preglacial gravel and sand constitutes the most extensive aggregate deposit in the area (Deposit 6). It is situated in the southern part of the region near Del Bonita, 70 km south of Lethbridge (see Fig. 5). Approximately 50 km^2 of gravel and sand covers the flat surface of the Del Bonita Upland, between elevations 1300 and 1400 m above sea level. An overburden of silt, interbedded with fine sand, is generally present, but exceeds 2 m in thickness only in a few places. The deposit consists of a fine to coarse, poorly to moderately well-sorted sandy gravel, with layers of fine sand and silt, mainly near the bottom of the deposit. The well-rounded to rounded cobbles and coarse fraction of gravel consist dominantly of quartzite and limestone with a minor amount of arkose and volcanic rocks. The thickness of gravel and sand varies between 1.5 and 15 m. Maximum thickness from 9 to 15 m was recorded in the central part of the upland (Fig. 19, Profile A-B). A minimum estimate of the gravel reserves on the Del Bonita Upland is 2.3×10^8 m^3.

Three preglacial gravel and sand deposits, of areas between 2.5 and 4 km^2, have been found on the lower bedrock terraces (Fig. 4) at elevations between 1080 and 1140 m above sea level, 16 and 10 km south of Fort MacLeod (Deposits 81 and 82) and 40 km south of Lethbridge (Deposit 54). The sand and gravel is overlain by stony sandy till. Although the overburden varies greatly in thickness, between 0.6 and 6 m, it is generally less than 2 m. The average thickness of the deposits is between 4.5 and 7.5 m (Fig. 19, Profile H-I). The minimum estimated reserves are 2.3×10^7 m^3 (Deposit 81), 1.9×10^7 m^3 (Deposit 82), and 5.3×10^7 m^3 (Deposit 54).

The Del Bonita deposit and other deposits of preglacial age consist of sandy gravel with the proportion of gravel varying between 55 and 75 percent. The matrix is composed predominantly of fine-grained sand (Fig. 9). The deposits are classified as clean to dirty. The gravel fraction consists of durable rocks derived from the Rocky Mountains. The amount of weak, locally derived, stones does not exceed five percent.

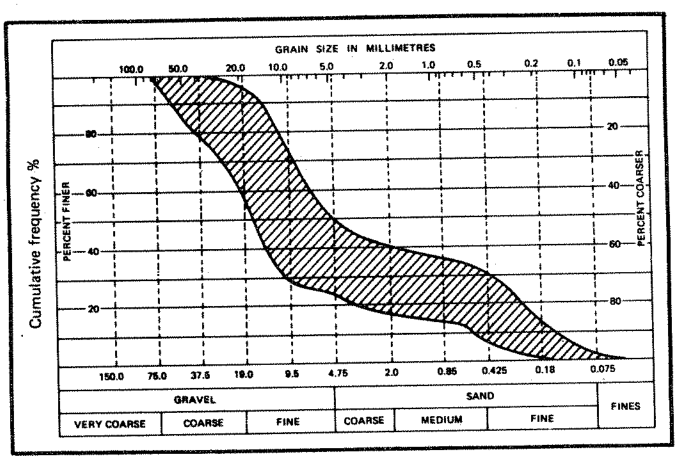


FIGURE 9. Range in grain-size distribution of the preglacial alluvial deposits (8 samples).

The gravel is suitable for most industrial purposes, including concrete and asphalt aggregate, but would require crushing because of its generally coarse nature. At present, a few small pits are contributing to the maintenance of local roads. One pit, 16 km south of Fort MacLeod, is used for asphalt aggregate.

KAME DEPOSITS

Gravel and sand deposits of this origin are scattered throughout the southwestern part of the region, within the Foothills belt. Twenty-two deposits, of areas 1.5 to 50 ha have been recorded in this area. The gravel and sand form mounds, or irregular hills, that stand isolated or in groups. They are situated in low places, between high hills or ridges of bedrock or till. The thickness of the deposits varies within wide limits between 1.5 and 18 m but is generally between 3 and 6 m.

In the northwest portion of the study area, 8 and 16 km to the west of Granum, deposits of this type are also present (Deposits 88, 89, 90). Here they form kame terraces with gently rolling or undulating surfaces. The thicknesses of gravel and sand are up to 17 to 18 m and the areas 26 to 240 ha .

East of the St. Mary River only five gravel-bearing deposits of kame type were found (Deposits 10, 50, 51, 52, 53). Their thicknesses are usually less than 3 m and the areas do not exceed 1.5 ha. The exceptions are the relatively extensive deposits 13 km north of Del Bonita (Deposit 10), and 22 km south of Raymond (Deposit 53), which cover 55 and 50 ha respectively.

The kame gravel and sand deposits are exposed at the surface or have an overburden of silt, fine sand and, in places, till, with thicknesses between 0.3 and 2.4 m. In the western part of the Foothills, the deposits usually consist of two layers. The upper part of the deposits with thicknesses from 1 to 3 m are composed of poorly sorted gravel and sand (Fig. 10), with the content of gravel ranging between 50 and 75 percent (Fig. 11, A). The lower part consists of coarse- and medium-grained clean sand, grading down section into fine-grained sand and silt; proportions of gravel range from 5 to 25 percent (Fig. 11, B). Sand and gravel are horizontally bedded and cross-bedded with a general dip to the south. Lenses and layers of charcoal, up to 5 cm thick, are present in places near the contact between gravel and sand, but generally the amount of

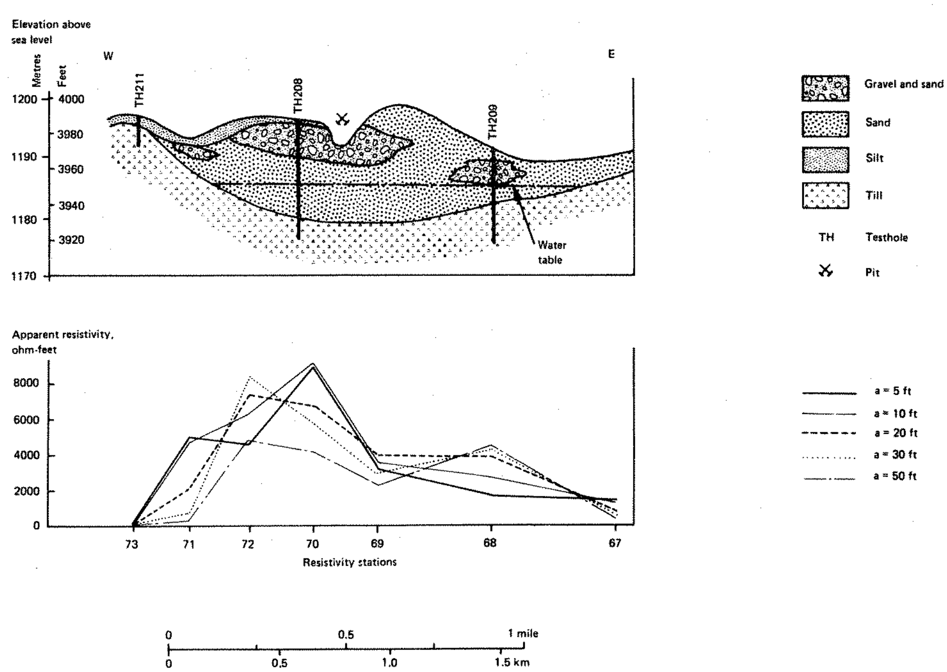


FIGURE 10. Composition of kame, 4 km south-west of Hill Springs (Deposit No. 44).

organic impurities is insignificant and never exceeds 0.1 percent of the volume of the deposit. The deposits in the eastern part of the Foothills are composed of poorly sorted fine- to coarse-grained gravelly sand, with a gravel content of usually 20 to 35 percent. Figures 11 and 12 illustrate the difference in composition and sorting of sand in kame deposits of the southeastern and southwestern parts of the region.

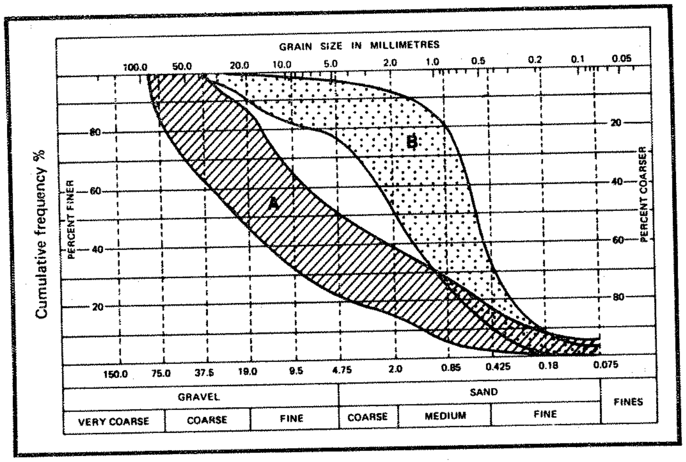


FIGURE 11. Range in grain-size distribution of the kame deposits in the western part of the Foothills:
A - upper gravel and gravelly sand (14 samples)
B - lower sand (9 samples).

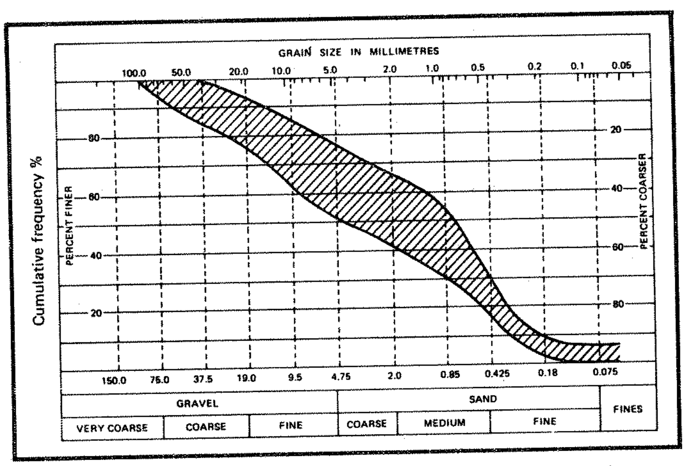


FIGURE 12. Range in grain-size distribution of the kame deposits in the eastern part of the Foothills (5 samples).

The gravel of kame origin consists predominantly (60 to 100 percent) of durable clasts from the Mountains. Deleterious local material generally is absent, or is present in amounts of less than 10 percent, but in places it increases to 20 percent. The content of the rocks derived from the Canadian Shield is small in the west (0 to 12 percent) but is significant in the east (as much as 30 percent).

Minimum estimated reserves of gravel and sand in the individual deposits vary between wide limits, from 7.5 to 10^3 m^3 to $1.1 \times 10^7 m^3$ but generally do not exceed 7.5×10^5 m^3. In spite of their relatively small sizes, these deposits are an important source of aggregate material which is being intensively used at present for various purposes: for concrete and asphalt aggregate, for maintenance of gravel roads, and as fill material. The kame deposits are also a good source of clean, coarse- and medium-grained sands that are generally rare in the area.

ESKER DEPOSITS

Only three esker deposits were found within the study area, these are located 9.5 km northeast of Del Bonita, 21 km east of Claresholm, and 11 km east of Parkland.

The deposit near Del Bonita (Deposit 7) forms a short ridge, approximately 2.5 km long and 30 m wide, with a height of 1.5 m. The deposit consists of coarse gravel and cobbles, with a small amount of coarse sand. Dry auger drilling failed to penetrate the gravel below a depth of 1.5 m. The approximate areal extent of the deposit is 28 ha and minimum estimated reserves are 3.8×10^5 m^3.

In the northeastern part of the area, esker deposits (Deposits 128, 129) form long narrow ridges as much as 6.5 km long, trending in a southwesterly direction. The heights of the ridges range between 3 and 7.5 m and the widths do not exceed 45 m. The ridges are composed mainly of clean, fine-grained sand, but in places, discontinuous lenses of gravel and poorly sorted fine-, medium-, and coarse-grained sand are present. Their thicknesses vary from 2 to 6 m. The content of gravel in the lenses is between 40 and 55 percent. The coarse fraction of the deposits consists of the rocks derived from the Rocky Mountains (65 to 80 percent) and from the Canadian Shield (20 to 35 percent).

The gravel lenses are scattered within the fine-grained sand deposits and generally are too small to be economically exploited. Thus, the esker deposits, although of good quality, have little use other than for local needs.

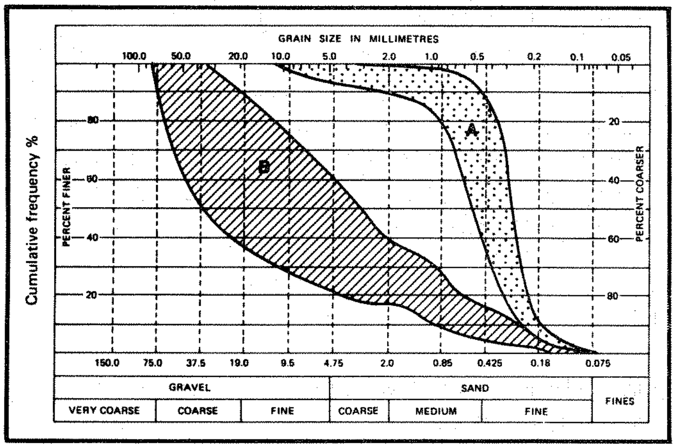


FIGURE 13. Range in grain-size distribution of the outwash deposits:
A - sand (3 samples)
B - gravel and gravelly sand (12 samples).

OUTWASH DEPOSITS

The outwash occurs as sheets composed largely of fine-grained, well-sorted sand with less than 5 percent gravel (Fig. 13, A), which is scattered in the top layers of the sand deposits.

Isolated bodies of sandy gravel and gravelly sand are present in places within ice-contact margins of the outwash plains, where they form low hills or groups of hills of irregular shape (Fig. 19, Profile F-G). Nine gravel-bearing deposits of outwash origin are known in the area. All of them are located within the lowlands extending along the Oldman River and the Little Bow River valleys (Deposits 83, 86, 93, 110, 111, 112, 114, 123, 130).

These deposits are exposed at the surface or buried under silt and fine sand, as much as 1.5 m thick. The thickness of gravel and sand varies from 1.5 to 10.5 m but is mainly between 2 and 4.5 m. The outwash deposits range from clean gravelly sand to sandy gravel, with gravel contents between 30 and 75 percent. The material is generally poorly sorted (Fig. 13, B), and the sorting becomes poorer from the base to the top of the sections. Near the top of the deposits, coarse and unsorted gravel, as much as 1.2 m thick, is generally cemented by calcium carbonate. Sand is mainly medium- and fine-grained although in some deposits coarse-grained sand predominates (Deposits 93, 110).

In the western part of the area (Deposits 86, 93, 130), the gravel largely consists of clasts from the Rocky Mountains (from 70 to 95 percent). The content of stones from the Shield does not exceed 20 percent. Deleterious material derived from local bedrock forms as much as 10 percent of the deposits. In the east, Mountain and Shield rocks are mixed almost in equal proportions: gravel from the Rocky Mountains constitutes from 45 to 65 percent; the Canadian Shield stones, from 35 to 55 percent. The percentages of local bedrock fragments is less than 5 percent.

Deposit areas vary widely between 4 and 97 ha. Their reserves range from 3.0×10^5 m^3 to 2.5×10^6 m^3.

The outwash gravel and sand is being used mainly for maintenance of gravel roads. They are suitable generally for production of asphalt aggregate, but at present only one deposit located in the western part of the area, 8 km west of Brocket, (Deposit 86) is being used for this purpose.

MARGINAL STREAM DEPOSITS

Gravel and sand deposits of this origin are confirmed to the southeastern quarter of the region, where they form discontinuous terraces on the upper part of the slopes of the ice-marginal channels or, more rarely, are present as channel floor deposits.

Gravel and sand are mostly exposed at the surface; in places, silt overburden is present, up to 1.5 m thick. The thickness of the deposits varies between 1 and 4 m but generally does not exceed 2 m.

The marginal stream deposits are composed mainly of moderately clean gravelly sand or sandy gravel, with a gravel content of 45 to 64 percent. The material is poorly sorted (Fig. 14, A). The gravel is coarse, mainly subangular, and in places roughly horizontally bedded. The content of the Mountain clasts varies between 35 and 55 percent. The content of Shield stones is generally large in these deposits, ranging between 20 and 50 percent. Local bedrock material in places makes up as much as 18 percent of the deposit. Some of the deposits contain lenses and beds composed of angular fragments of shale and sandstone, with a fine sand matrix. Boulders of weathered granite or gneiss are abundant on the surface of the deposits.

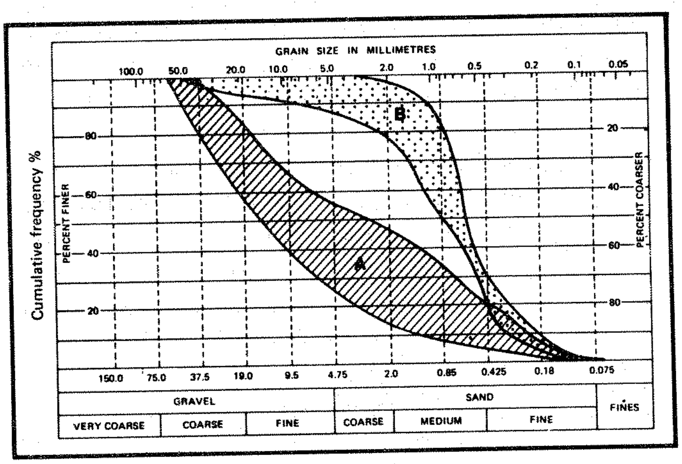


FIGURE 14. Range in grain-size distribution of the marginal stream deposits:
A - gravel and sand (7 samples)
B - sand (2 samples).

A deposit (62) in the western part of the Chin Lake Channel, 25 km east of Lethbridge, differs considerably from the other deposits of this type. Here a small depression on the surface of the generally erosional terrace is filled by well-sorted sand, with a thickness of more than 6 m. The sand is mainly medium-grained (Fig. 14, B), with horizontal layers and lenses of coarse and fine-grained sand, as much as 1 m thick.

The areal extents of the marginal stream deposits vary between 2.5 and 32 ha. The reserves range between 1.9×10^5 m^3 and 3.8×10^5 m^3.

The gravel and sand of this type are used only for road foundation purposes because of the coarseness of the material and the abundance of deleterious clasts.

VALLEY TRAIN (HIGH RIVER TERRACE) DEPOSITS

The gravel and sand deposits of this origin are the most widespread and variable in composition of all the gravel-bearing deposits.

Forty-one valley train gravel and sand deposits have been reported in the area, varying from minor bodies of area no more than 1.2 ha to extensive mantles covering a few square kilometres.

The deposits are classified into two major subgroups on the basis of their distribution: the deposits of the Oldman River basin, in the western and northern parts of the area; and the deposits of the Milk River basin, confined to the extreme southern part of the region. Vast areas of the divide between the Oldman and Milk Rivers are devoid of gravel and sand of this type.

Deposits of the Oldman River Basin

The valley train terraces have different compositions in the upstream and downstream sections of the basin. The upstream section includes the Waterton and Belly Rivers, Willow Creek, and the upper part of the Oldman River, to its junction with the St. Mary River valley. The downstream section includes the remaining part of the Oldman River and the Little Bow River.

The most extensive upstream deposit is located near Fort MacLeod (Deposit 84) and covers approximately 50 km^2 (Fig. 4). It has an irregular, elongated shape and extends along the Oldman

River for a distance of 16 km. The width of the terrace varies between 2.5 and 4 km. Gravel and sand are exposed at the surface. The deposit has a rather uniform thickness of 3.0 to 3.7 m, increasing in some places near the river to 7.5 m (Fig. 19, Profile C-D).

The material consists of clean gravel and sandy gravel. Fifty-five to 75 percent of the gravel is coarser than 4.6 mm. It ranges from well- to poorly sorted, unbedded or cross-bedded, with bedding dipping to the northeast. The matrix consists of fine and medium sand. In places, the gravel contains lenses of coarse-grained sand. The coarse fraction of the deposit is composed largely of durable rocks derived from the Rocky Mountains (from 20 to 96 percent).

The deposit has four pits in operation for production of asphalt aggregate, road foundation, and fill material. The minimum estimated reserves are approximately 1.5×10^8 m^3.

Similar deposits, which cover smaller areas, are also present: in the Willow Creek valley, 3 km west of Claresholm (Deposits 133, 134); the Oldman River valley, 3 km west of Brocket (Deposit 85); and the Waterton and Belly River valleys (Deposits 45, 78, 79, 80). The gravel-bearing material is exposed at the surface or buried under 0.3 to 1.2 m of silt. Gravel content varies between 55 and 75 percent, but is mainly between 60 and 70 percent; the amount of fines does not exceed 3 percent (Fig. 15). The sand matrix is fine- to medium-grained, and more rarely, is coarse- to medium-grained. The gravel is composed mostly of rocks derived from the Rocky Mountains. The thicknesses of the deposits range between 1 and 6 m but mainly between 2 and 4 m. The minimum estimated reserves of the deposits vary between 0.8×10^6 m^3 and 2.3×10^6 m^3.

The downstream valley train deposits are found along two sections of the Oldman River valley, 16 km north of Lethbridge (Deposits 103 to 108) and in the neighborhood of Taber (Deposits 113, 115 to 121). Four deposits are located in the Little Bow River valley, near the Traverse Reservoir (Deposits 124, 125) and 25 km east of Stavely (Deposits 126, 127). The valley train deposits form elongated, mainly narrow, fill terraces, from 6 to 15 m below the surrounding plain and from 65 to 90 m above the river level.

In the Lethbridge section of the Oldman River, the gravel and sand deposits have an overburden cover of silt, from 0.3 to 1.0 m thick (Fig. 19,

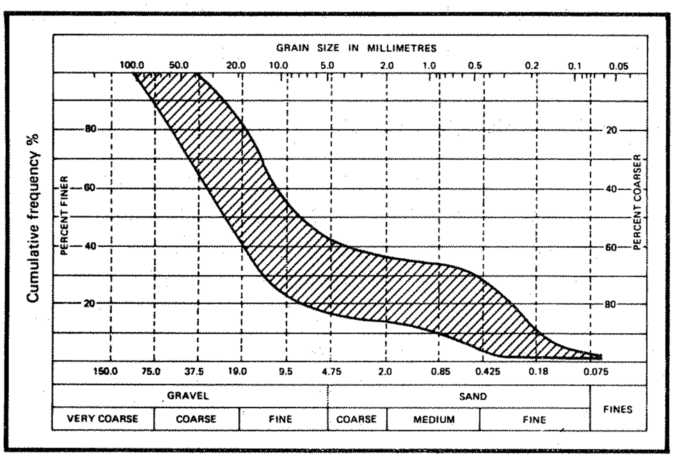


FIGURE 15. Range in grain-size distribution of the valley train (high river terrace) deposits in the Oldman River Basin, upstream sections (16 samples).

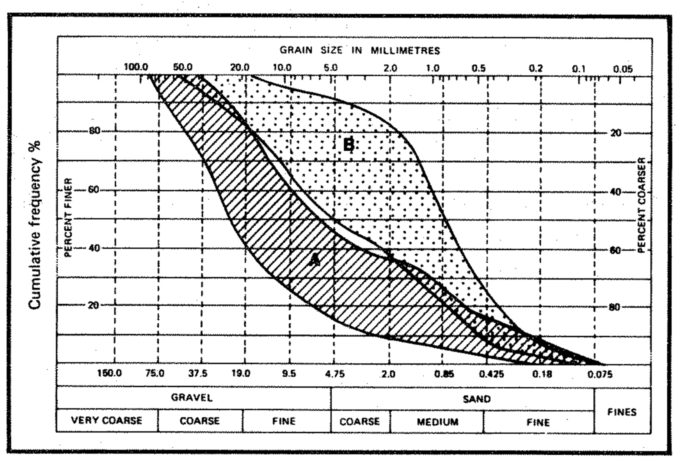


FIGURE 16. Range in grain-size distribution of the valley train (high river terrace) deposits in the Oldman River Basin, downstream sections:
A - Upper gravel (21 samples)
B - Lower sand and gravelly sand (13 samples).

Profile R-S). The thickness of the deposits here varies from 2.5 to 7.5 m. In the Little Bow River valley gravel-bearing material is exposed at the surface and has a thickness between 1.8 and 6 m. In both valleys the deposits generally have a two-layer composition: the top layer, 1.0 to 1.5 m thick, is composed of poorly sorted, clean, coarse and fine gravel, slightly cemented by calcium carbonate (Fig. 16, A); the lower layer consists of moderately to well-sorted, medium to coarse-grained clean sand, (Fig. 16, B) with thin lenses of fine sand and, in places, lenses of soft charcoal. In deposit 105, sand is interbedded with layers of well-rounded, clay and till balls, with diameters between 5 and 15 cm.

In the Taber section gravel-bearing material is exposed at the surface, its thickness varies between 2 and 10 m but averages less than 3 m. The deposits are composed largely of sandy gravel or gravelly sand, from poorly to well-sorted, with gravel content varying widely from 20 to 75 percent.

In the downstream valley train deposits the content of rocks derived from the Canadian Shield is much greater than in the upstream deposits, and constitutes from 10 to 50 percent of the coarse clasts; the content of local bedrock is in most places insignificant, but in some places reaches as much as 15 percent.

The deposits of this type range in area from 1 to 80 ha but are mainly between 20 and 40 ha. The minimum estimated reserves vary from 1.5 x 10^5 m^3 to 5.3 x 10^5 m^3.

Deposits of the Milk River Basin

The valley train deposits of the Milk River valley are confined to the section of the river near the Del Bonita Upland (Deposits 8, 9, 12, 13). Only one deposit (4) was found downstream from the Del Bonita area, 5 km west of Milk River. The gravel and sand deposits are exposed at the surface or have an overburden cover of silt from 0.3 to 1 m thick. Thickness of gravel-bearing material is mainly between 3.0 and 3.5 m.

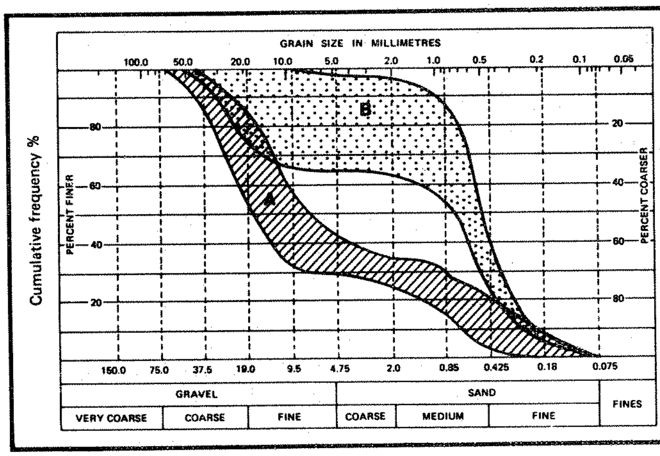


FIGURE 17. Range in grain-size distribution of the valley train (high river terrace) deposits in the Milk River Basin:
A - upstream section - gravel and sand (8 samples)
B - downstream section - mainly sand (2 samples).

The upstream deposits are composed of coarse and fine gravel (60 to 85 percent) and medium- and fine-grained, poorly sorted, clean sand. The downstream deposit (4) has a composition similar to that of the downstream valley train deposits in the Oldman River valley. The upper 1.5 m of the deposit is composed of poorly sorted, slightly cemented gravel (Figure 17, A); the lower layers (4 m) consist of medium-grained sand, with beds of coarse-grained sand and fine gravel (Fig. 17, B).

The gravel consists predominantly of clasts derived from the Mountains (85 to 95 percent) with some Shield-derived stones (5 to 15 percent).

The deposits of the Milk River basin cover from 40 to 120 ha and have reserves between 0.5 x 10^6 m^3 and 2.0 x 10^6 m^3.

The valley train deposits represent one of the best sources of sand and gravel for industry. They are easily accessible and can be readily developed. Coarse material in the upstream river sections is being used at present, after crushing, for asphalt aggregate and for road foundation. Sand from a few of the downstream deposits supplies washed sand for concrete. The operations include screening and washing; the clayey lumps in the sand of deposit 105 have to be removed manually. The gravel material of the downstream sections is being taken from some pits for use as concrete aggregate after screening, crushing, and washing. However, this material is exploited primarily for asphalt aggregate and road foundation, and only crushing is required.

RECENT ALLUVIAL (LOW RIVER TERRACE) DEPOSITS

Gravel-bearing alluvial deposits are believed to be present in most of the depositional terraces in the major river valleys. Generally the gravel is only partly exposed at the surface, and in many areas the gravel and sand deposits are buried under thick covers of floodplain silt and fine sand. Gravel and sand also make up alluvial fans in the Balkiston, Galway, Dunvegan, and Blood Canyon Creek valleys, along the foot of the Rocky Mountains. The composition between upstream and downstream alluvium is not significantly different as was observed for the valley train deposits.

The most extensive deposit of recent alluvial gravel and sand is located near the junction of the Waterton and Belly Rivers, 27 km south of Fort MacLeod (Deposit 49), where the deposit forms a broad terrace with a flat braided surface, 2 to 3 m above the river level, with an areal extent of 14 km^2 (Fig. 4). Gravel and sand are exposed at the surface or, in some places, are buried under fine sand as much as 1.8 m thick. The thickness of the deposit ranges from 1.8 to 4.0 m but is mainly 2.5 m thick. The deposit is composed of poorly sorted, clean, sandy gravel, with 50 to 65 percent of the material greater than 4.6 mm in diameter. It is estimated to contain about 3.0×10^7 m^3 of undeveloped gravel and sand.

Deposits similar in composition are present along the St. Mary, Belly, and Waterton River valleys, (Deposits 16, 17, 28, 32, 33, 37, 47, 48). The gravel generally is poorly sorted, with a considerable amount of coarse material; the matrix consists of fine, medium, and coarse sand. Resistant stones from the Rocky Mountains are predominant (75 to 100 percent); rocks derived from the Canadian Shield compose the remainder of the coarse-grained component; deleterious bedrock material is usually absent. The thickness of the gravel and sand ranges between 1 and 3 m the reserves of the deposits are estimated to vary between 0.5×10^6 m^3 and 2.5×10^6 m.

The alluvial terraces of the Oldman River valley have been best studied along a 55 km section of the river, between Monarch and Diamond City (Fig. 3). Downstream from this section to the eastern boundary of the area the alluvium is composed mainly of silt and fine sand.

Three fill terraces form the bottom of the valley. The highest terrace, with heights between 12 and 16 m above river level, is found only in the upper part of this river section, between Monarch and Kipp. The terrace is generally composed of silt and fine sand, but, in some places, it consists of coarse gravel. The most extensive gravel-bearing deposit within this terrace is located on the south bank of the river, 3 km south of Monarch (Deposit 97). Gravel and sand is exposed at the surface and has a thickness of up to 8 m. The deposit consists of poorly sorted coarse and fine gravel (70 percent) and mainly fine-grained sand. The areal extent is 60 ha; the minimum estimated reserves are about 1.8×10^6 m^3; the deposit has not been developed. Gravel-bearing deposits of the highest fill terrace are being exploited in two pits, No. 33 and No. 37, 3 km west of Kipp (Deposit 99). The resistivity measurements show that the gravel and sand does not extend far beyond these pits.

An intermediate fill terrace was observed in many places along the section described. It has heights between 5.0 and 7.5 m above river level. The terrace is composed mainly of silt and fine sand (Fig. 19; Profiles K-L, M-N, O-P). The gravel-bearing deposits have been recorded in testholes at depths of between 5 and 7 m below surface. The thickness of gravel ranges between 1 and 3 m. These deposits are neither close enough to the surface nor thick enough to be utilized. In places, lenses are present within the upper silt and fine sand deposits. Such lenses are being exploited at present in pits No. 34 and No. 38, about 5 km west of Kipp (Deposit 99). The gravel is exposed at the surface or is buried under silt as much as 3 m thick. The thickness of the deposits varies between 2 and 3 m. The proportion of gravel is about 60 percent. The deposits have a composition similar to the gravel-bearing material of the highest terrace.

The lowest terrace extends along the section described, from Monarch to Diamond City. Its height above the river varies between 2.5 and 3.5 m. The terrace consists of sections built entirely of gravel and sand (Fig. 19, Profiles K-L, M-N) and sections where gravel is covered by fine silty sand and silt (Fig. 19, Profile R-S).

Terraces composed of gravel and gravelly sand prevail in the segment of the valley between Monarch and the junction of the Oldman and St. Mary Rivers. Here the gravel deposits usually are exposed at the surface, or more rarely, have an overburden cover of fine sand, as much as 1.5 m thick (Deposits 73, 75, 76, 95, 96, 97, 99). The gravel is coarse and fine, poorly sorted and clean; the matrix consists mainly of fine and medium sand (Fig. 18). The proportion of gravel varies between 50 and 60 percent, increasing in places to 80 percent. Areal extents range from 20 to 100 ha and the minimum reserves of the deposits

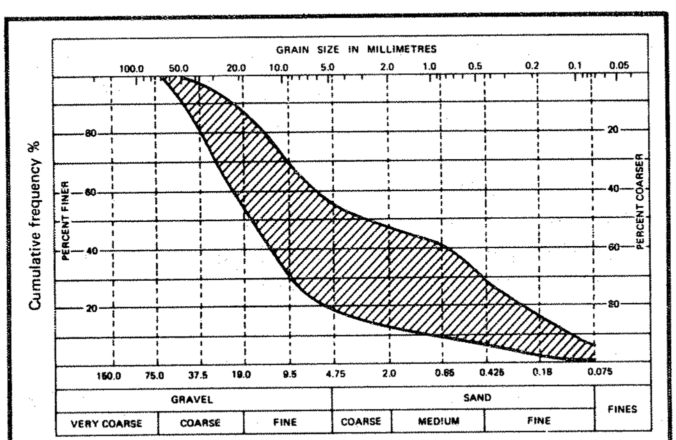


FIGURE 18. Range in grain-size distribution of the recent alluvial deposits (25 samples).

are estimated to be between 0.4×10^6 m^3 and 3×10^6 m^3.

Alluvium with a two-layer composition is present in places in this portion of the river, but it predominates downstream of the junction of the Oldman and St. Mary Rivers. Here the upper part of the lowest terrace is composed of fine-grained sand with scattered lenses of gravel-bearing material. These lenses, varying greatly in extent and thickness, are exploited by a few pits near Lethbridge (Deposits 69, 70, 71, 72, 100). The gravel content in most of the deposits usually does not exceed 25 percent, although the proportion of gravel in some layers may reach as much as 70 percent. The gravel within the lenses is interbedded with fine sand.

The lower beds of the alluvium, generally below the water level, or only a little above, are composed of uniform, coarse and fine, poorly sorted gravel (up to 70 percent) with some fine-grained sand. Beds of gravel have been recorded in the testholes, well logs, and seismic shotholes at depths below surface ranging from 3.0 to 4.5 m. This gravel is believed to extend along the entire river section described. Its thickness varies between 4.5 and 7.5 m. Exploitation of the deposit is complicated, because in large part, it is saturated with water. At present, this gravel is being extracted in two pits, No. 42, 7 km north of Lethbridge, and No. 32, 2.5 km northwest of Kipp. Generally these pits are operated after the high water conditions of spring and early summer have subsided; pumping is used to dewater the pits.

The alluvial gravel consists predominantly of durable rocks derived from the Rocky Mountains (75 to 95 percent). Deleterious materials, such as local bedrock fragments and weathered stones from the Canadian Shield, are practically absent in this type of deposit.

The alluvial deposits are being used for concrete and asphalt aggregate, road-base, and as fill material. The gravel is generally coarse and, for most uses, require crushing and screening.

CONCLUSIONS

The three major groups of gravel and sand deposits in the area are valley train deposits, preglacial deposits, and recent alluvial deposits. Their total reserves are estimated to be hundreds of millions of cubic metres. Most of these deposits are suitable for production of crushed gravel for asphalt aggregate, washed and screened gravel for concrete, crushed gravel for road-base, and gravel for railway ballast. Some of the valley train and recent alluvial deposits supply washed sand for concrete aggregate.

The total reserves of kame, outwash, and marginal stream deposits in the area are estimated to be millions of cubic metres. The outwash and kame gravels are suitable for producing crushed gravel for aggregate and road-base. The marginal stream deposits can serve as a source of crushed gravel for asphalt aggregate and road maintenance.

The esker deposits contain the smallest reserves, estimated to be hundreds of thousands of cubic metres. They can be used as pit-run gravel and sand for local roads. Generally the study area is well provided with gravel for many purposes, but has a shortage of sand of good quality.

Most of the gravel-bearing deposits in the area are now being exploited. Those with limited reserves that will be exhausted within a few years, include: (1) the valley train deposits west and north of Taber; (2) the valley train deposits north of Lethbridge and lenses of alluvial gravel in the vicinity of Lethbridge; (3) the valley train deposit, west of Milk River; (4) most of the kame deposits in Cardston County.

Some of the major deposits which may form the future supplies of gravel in the area are listed below. Some of these deposits are being intensively exploited at present, but have vast reserves, such as the Fort MacLeod deposits. The others are not being utilized because they are located too far from the settlements or are generally unknown.

1. The Fort MacLeod valley train deposit (84): A few pits are being operated at present in the eastern part of the deposit, around Fort MacLeod (Fig. 4): The western part is practically undeveloped.

2. The recent alluvial deposits at Monarch (Deposits 96, 97), 32 km west of Lethbridge (Fig. 3): The deposit has not been developed.

3. The water-bearing alluvial gravel, filling the bottom of the Oldman River valley, between its junctions with the Belly and St. Mary Rivers and near Lethbridge (Fig. 3): It is being extracted at present in two pits.

4. The preglacial alluvial deposit (82), 16 km south of Fort MacLeod (Fig. 4): The deposit has not been developed.

5. The preglacial alluvial deposit (81), 22 km south of Fort MacLeod (Fig. 4): The material is being exploited in two minor pits.

6. The recent alluvial deposit (49), near the junction of the Waterton and Belly Rivers (49), 27 km south of Fort MacLeod (Fig. 4): The deposit has not been developed.

7. The preglacial alluvial deposit (54), 8 km south of Magrath: The deposit has not been developed.

8. The preglacial alluvial deposit at Del Bonita (6), (Fig. 5): Gravel and sand are being exploited in a few minor pits.

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REFERENCES

Alden, W.C. (1924): Physiographic development of the Northern Great Plains; Bulletin of the Geological Society of America, Vol. 35, p. 385-424.

Collier, A.J., and Thom, W.T. (1918): The Flaxville gravel and its relation to other terrace gravels of the Northern Great Plains; U.S. Geological Survey Professional Paper 108-J, p. 1978-184.

Cope, E.D. (1891): On vertebrata from the Tertiary and Cretaceous rocks of the Northwest Territories. 1. The species from the Oligocene or Lower Miocene of the Cypress Hills; Geological Survey of Canada; Contributions to Canadian Paleontology, Vol. 3, pt. 1, 25 pp.

Embleton, C., and King, C.A.M. (1968): Glacial and Preglacial Geomorphology, Edward Arnold, 608 pp.

Flint, R.F. (1957): Glacial and Pleistocene geology; John Wiley, 553 pp.

Geiger, K.W. (1965): Bedrock topography, southwestern Alberta. Scale 1 in = 4 m Accompanies Research Council of Alberta Report 65-1.

Gravenor, C.P. and Kupsch, W.O. (1959): Ice-disintegration features in western Canada; Journal of Geology, Vol. 67, p. 48-64.

Hewitt, D.F., and Karrow, P.F. (1963): Sand and gravel in southern Ontario. Department of Mines, Industrial Minerals Report No. 11, 5 maps, 151 pp.

Kocaoglu, S.S. (1977): Soils of the Lethbridge area (NW 82 H), Alberta Institute of Pedology; Map M - 77-3 with marginal notes.

Ozoray, G.F., and Lytviak, A.T. (1974): Hydrogeology of the Gleichen area, Alberta; Research Council of Alberta Report 74-9, 1 map, 16 pp.

Stalker, A. MacS. (1957): Surficial geology, High River, Alberta; Geological Survey of Canada, Map 14, 1957, with marginal notes.

------(1958): Surficial geology, Fort MacLeod, Alberta; Geological Survey of Canada, Map 21, 1958, with marginal notes.

------(1962): Surficial geology, Lethbridge, Alberta; Geological Survey of Canada, Map 41, 1962.

------(1963): Surficial geology of Blood Indian Reserve, No. 148, Alberta, Geological Survey of Canada Paper 63-25, 1 map, 20 pp.

------(1965): Surficial geology, Bassano, Alberta; Geological Survey of Canada, Map 5, 1965.

------(1977): The probable extent of Classical Wisconsin ice in southern and central Alberta; Canadian Journal of Earth Sciences, V. 14, p. 2614-2619.

------and Harrison, J.E. (1977): Quaternary glaciation of the Waterton-Castle River region of Alberta; Bulletin of Canadian Petroleum Geology, Vol. 25. p. 882-906.

Tokarsky, O. (1974): Hydrogeology of the Lethbridge - Fernie area, Alberta; Research Council of Alberta Report 74-1, 2 maps, 18 pp.

Westgate, J.A. (1968): Surficial geology of the Foremost - Cypress Hills area, Alberta; Research Council of Alberta Bulletin 22, 8 maps, 121 pp.

APPENDIX A

GLOSSARY

alluvial: pertaining to material deposited by running water.

alluvial terrace: terrace composed of valley-fill sediments that were originally deposited by stream action and later cut through by the stream, leaving the former floodplain surface some distance above the bed of the present stream.

alluvium: material deposited during relatively recent geological time by running water; includes clay, silt, sand, or gravel in stream beds, floodplains, terraces, alluvial fans, etc.

bedrock: in-place pre-Quaternary material exposed at the surface or underlying the surficial material.

carbonate rocks: sedimentary rocks, mainly limestone and dolomite, consisting chiefly of carbonate minerals.

clast: an individual constituent, grain, or fragment produced by the physical disintegration of rock.

consequent stream: a stream that originates on a newly exposed or recently formed surface and that flows along a course determined entirely by the initial slope and configuration of that surface.

deposit: an accumulation of sediments left in a new location by a natural transportative agent such as water, wind, ice, or gravity.

durable rock: a rock fragment which is hard and inert and can be used as aggregate without breaking, crumbling or reacting with the cementing material.

eolian: pertaining to wind action.

esker: a narrow ridge, often long and sinuous, composed of sand and/or gravel deposited by a meltwater stream flowing in or on glacier ice.

fluvial: pertaining to rivers or streams.

glacial drift: a general term for material moved and deposited by glaciers and by the action of meltwater streams and glacial lakes associated with them.

glaciofluvial deposits: material deposited by streams flowing from, on, or within melting glacier ice, generally composed of sorted, stratified sand and gravel; includes outwash, kame, esker, etc.

glaciolacustrine deposits: material deposited in lakes affected by glacier ice or by meltwater flowing directly from glaciers; composed of well-sorted clay, silt, or sand.

ground moraine: a deposit of till with a flat or undulating surface.

hummocky: an irregular or knob and kettle surface.

hummocky moraine: a deposit of till with a hummocky surface.

ice-contact deposit: material deposited in contact with glacier ice by meltwater; includes kames, eskers, kame terraces, etc.

kame: a round or irregular hill, formed in contact with glacier ice by meltwater; composed of sand and gravel and occasional till blocks.

kame terrace: a terrace formed by the deposition of material from flowing meltwater confined between ice and adjacent high land; usually composed of sorted and stratified sand and gravel.

lacustrine deposit: material deposited in a lake.

marginal stream deposit: discontinuous, narrow body of stratified drift deposited by meltwater streams flowing along the edges of glacial ice.

outwash: a glaciofluvial deposit formed in front of the margin of glacier ice.

plain: a flat to gently undulating surface.

post glacial: pertaining to the time interval since the final disappearance of continental glaciers.

preglacial: pertaining to the time interval prior to the onset of extensive glaciation.

proglacial: the area immediately in front of or beyond the limits of the glacier; proglacial deposits include outwash, glaciolacustrine deposits, etc.

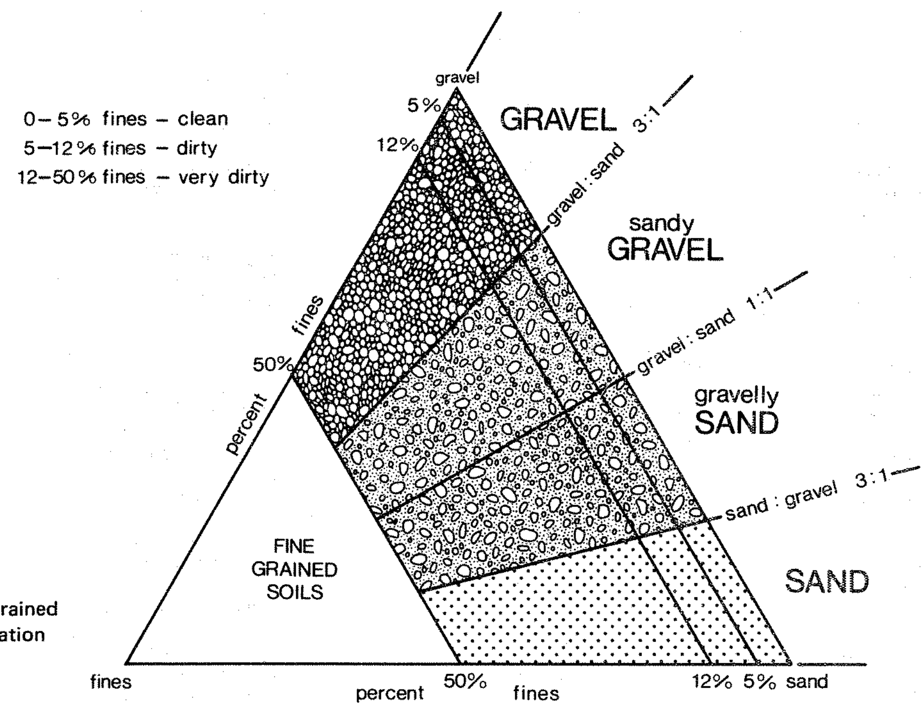
terrace: a relatively flat, stair-stepped, depositional or erosional surface bounded by an ascending slope on one side and a descending slope on the other.

till: unsorted and unstratified sediment deposited directly by glacier ice.

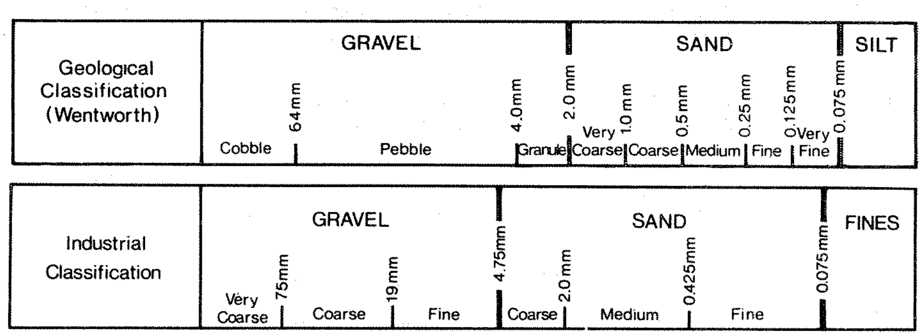
valley train: outwash confined within a valley.

APPENDIX B

CLASSIFICATION OF SEDIMENTS



Classification of unconsolidated, coarse-grained sediments (after the United Soil Classification System).



Geological and Industrial grain-size classification.

APPENDIX C: GRAVEL AND SAND DEPOSITS

Origin	Number on Figure 2	Location (West of 4th Meridian)	Brief Description	Thickness in metres	
				Gravel and Sand	Overburden
Preglacial alluvial deposits	6	**Tp 1, R 21, Secs 3 to 10, 14 to 25, 28 to 31; Tp 1, R 22, Secs 1 to 3, 9 to 16, 21 to 27**	Gravel fine and coarse; sand fine- and medium-grained, clean and moderately clean	1.5 to 15 Avg 4.5	0 to 3 Avg 1.5
Preglacial alluvial deposits	6a	Tp 1, R 23, Sec 36; Tp 2, R 22, Sec 6; Tp 2, R 23, Sec 1	Gravel mainly coarse with some fine, moderately clean; sand fine- and medium-grained	More than 1.5	0.9 to 1.5
Preglacial alluvial deposits	11	TP 3, R 21, Sec 17	Gravel coarse; sand fine- and medium-grained, clean	More than 1.8	2.0
Preglacial alluvial deposits	14	**Tp 2, R 23, Sec 3**	Gravel coarse and fine; sand fine- and medium-grained, clean	More than 1.5	1.2
Preglacial alluvial deposits	54	Tp 5, R 21, Secs 6 to 8; Tp 5, R 22, Sec 1	Gravel fine with some coarse; sand fine-grained, clean	3 to 6 Avg 4.5	0.8 to 4.2 Avg 2.1
Preglacial alluvial deposits	66	Tp 9, R 22, Sec 1	Gravel coarse and fine; sand fine-grained, silty, moderately clean	3 to 6	0 to 3
Preglacial alluvial deposits	67	Tp 9, R 22, Sec 13	Gravel coarse and fine; sand fine-grained, moderately clean	3 to 6	0 to 3
Preglacial alluvial deposits	81	Tp 7, R 26, Secs 4, 9, 10, 15	Gravel coarse; sand fine- and medium-grained, silty, moderately clean	5.5 to 9 Avg 7.5	0.6 to 6 Avg 1.5
Preglacial alluvial deposits	82	Tp 7, R 26, Secs 28, 32, 33, 34,	Gravel coarse and fine; sand fine- and medium-grained, silty, moderately clean	More than 7	1 to 2
Kame deposits	10	**Tp 2, R 21, Secs 8, 17**	Gravel coarse and fine; sand fine- to coarse-grained, clean	1.8 to 2.4	0.3 to 0.5
Kame deposits	15	Tp 1, R 24, Secs 9, 16	Sand fine- and medium-grained, clean with fine gravel	12	0.3 to 1.5
Kame deposits	18	Tp 2, R 25, Secs 22, 23	0 to 2.1 Gravel and sand moderately sorted, clean/ 2.1 to 3.7 Sand medium-grained, clean with some gravel	3	0.6
Kame deposits	19	Tp 2, R 25, Sec 33	Gravel mainly fine; sand fine- to coarse-grained, clean	1.5	

Size Distribution (percentage)			Source of Gravels and Cobbles			Approximate Area in hectares	Minimum Estimated Reserves in cubic metres	Reference Number	
>4.75 mm	0.075 mm to 4.75 mm	<0.075 mm	Rocky Mountains	Canadian Shield	Bedrock			Pits	Testholes
60.4 to 66.3	32.7 to 39.0	0.6 to 1.0	100	0	0	5 000	230 000 000	95 113	175 176 184 to 190 90
56.2	38.6	5.2	100	0	0	240	2 300 000	90	
76.6	22.4	1.0	100	0	0	4	30 000	92	
~70	~30	~0	100	0	0	4	30 000	91	
50.0	49.8	0.2	98	0	2	250	5 300 000		251 to 260
~70	~20	~10	100	0	0	0.2	3 000	16	
~65	~30	~5	100	0	0	0.2	3 000	41	
37 to 55	35 to 54	5 to 10	97	0	3	285	23 000 000	154	27 to 30 265 to 270
~55	~35	~10	95	0	5	365	19 000 000		271 272
75.2	23.2	1.6	92	8	0	55	500 000	93	179 180
7.6	91.3	1.1	60	28	12	35	2 000 000	89	196
53.3	Upper Layer 46.0	1.7	76	4	20	15	200 000	81	
11.2	Lower Layer 87.8	1.0							
65.1	33.4	1.6	92	0	8	7	60 000	80	

Origin	Number on Figure 2	Location (West of 4th Meridian)	Brief Description	Thickness in metres	
				Gravel and Sand	Overburden
Kame deposits	20	Tp 1, R 26, Secs 29, 33	Gravel coarse and fine; sand fine- and medium-grained, clean	2 to 5	1 to 1.5
Kame	21	Tp 2, R 26, Sec 18	0 to 1.2 Gravel coarse and fine; sand fine- to coarse-grained, clean/ 1.2 to 3.0 Interbedding of poorly sorted sand and gravel	3	0
Kame deposits	22	Tp 2, R 26, Sec 7	Gravel coarse and fine; sand fine- to coarse-grained, clean	1.5	0
Kame deposits	23	Tp 1, R 26, Sec 2	Sand medium-grained, well sorted, clean; gravel coarse and fine	1.8	0
Kame deposits	25	Tp 2, R 27 Sec 21, 22	Gravel coarse with some sand; sand medium-grained with layers of fine- and coarse-grained, clean	7.6 to 9.0	1.2 to 2.4
Kame deposits	26	Tp 2, R 27, Sec 17	Gravel fine with lenses of of coarse; sand fine- to coarse-grained, clean	2 to 5.5 Avg 3.7	1.2 to 2.4
Kame deposits	27	Tp 2, R 28, Secs 11, 12	Gravel coarse; sand coarse- and medium-grained	3	0
Kame deposits	30	Tp 2, R 29, Secs 17, 20	Gravel fine and coarse; sand coarse and medium-grained, clean	1.8	0
Kame deposits	31	Tp 2, R 29, Sec 29	Sand fine- to coarse; grained, clean; gravel coarse and fine	10.7	0
Kame deposits	34	Tp 4, R 30, Sec 9	Sand fine- and medium-grained, moderately clean; gravel coarse and fine	1.5 to 2.4	0
Kame deposits	35	Tp 4, R 29, Secs 17, 18, 20	Gravel coarse and fine; sand fine- to coarse-grained, clean	1.8	0
Kame deposits	36	Tp 4, R 29, Sec 21	Gravel coarse and fine; sand medium-grained, clean	3	0
Kame deposits	38	Tp 4, R 29, Secs 14, 15	Gravel fine with some coarse; sand coarse- and medium-grained; clean	4.6 to 9.0 Avg 6	0
Kame deposits	39	Tp 4, R 29, Sec 11	Gravel coarse with some fine; sand coarse- and medium-grained, clean	3 to 5 Avg 3.7	0
Kame deposits	40	Tp 5, R 30, Sec 10	Gravel coarse; sand fine- and medium-grained	1.2	0
Kame deposits	41	Tp 5, R 30, Sec 1	Gravel coarse and fine; sand coarse, clean	2.1 to 4.2 Avg 2.4	0

Size Distribution (percentage)			Source of Gravels and Cobbles			Approximate Area in hectares	Minimum Estimated Reserves in cubic metres	Reference Number	
>4.75 mm	0.075 mm to 4.75 mm	<0.075 mm	Rocky Mountains	Canadian Shield	Bedrock			Pits	Testholes
50.5 to 71.8	25.0 to 48.4	1.1 to 3.2	96	4	0	48	1 000 000	84	200 201
54.6	44.3	1.1	76 to 84	8 to 16	8	5	70 000	82	
~60	~38	~2	---	---	---	3	20 000	83	
~30	~70	--	100	0	0	12	100 000	85	
68.5 24.0	sandy gravel 30.4 sand 75.5	1.1 0.5	88	12	0	40	3 000 000	10	202 203
63.2 4.0	gravel 35.8 sand 95.2	1.0 0.8	80 to 95	0	5 to 20	23	380 000	7 8 9	
59.2	39.4	1.4	100	0	0	40	600 000	6	
21.6	78.1	0.3	100	0	0	4	40 000	2	
40.5 to 48.0	50.3 to 59.3	0.2 to 1.7	100	0	0	4	210 000	3	
~35	~55	~10	92	0	8	4	40 000	123	
~60	~40	~0	---	---	---	5	40 000	119	
~65	~35	---	68	20	12	20	300 000	124	
62.8	36.8	0.4	78	10	12	10	300 000	122	
74.1	25.5	0.4	90	10	0	7	130 000	118	
55.8	43.3	0.9	92	0	8	6	35 000	129	
52.1	46.4	1.5	---	---	---	15	330 000	128	214 215

Origin	Number on Figure 2	Location (West of 4th Meridian)	Brief Description	Thickness in metres	
				Gravel and Sand	Overburden
Kame deposits	42	Tp 5, R 29, Secs 5, 6	Gravel coarse and fine; sand fine- to coarse-grained, clean and moderately clean	2.7 to 3.7 Avg 3	0 to 0.6 (0 to 2)
Kame deposits	43	Tp 4, R 28, Secs 2, 3	Gravel fine with lenses of coarse; sand fine- to coarse-grained	2.1	0
Kame deposits	44	Tp 4, R 28, Sec 1	0 to 3 Gravel fine with some coarse; sand coarse and medium-sorted / 3 to 5.5 Sand medium-grained; gravel fine and coarse	4.6 to 5.5	0 to 1.5
Kame deposits	50	Tp 4, R 23, Secs 3, 4, 9	Sand fine- to coarse-grained; gravel coarse and fine	0.6 to 3 Avg 1.5	0
Kame deposits	51	Tp 4, R 23, Sec 2	Sand fine- to coarse-grained, clean; gravel coarse and fine	2.4	0.5
Kame deposits	52	Tp 4, R 22, Sec 6	Sand fine to coarse-grained, clean; gravel coarse and fine	4.6	0 to 1.5
Kame deposits	53	Tp 4, R 21, Secs 1, 12	Sand fine to coarse-grained, clean; gravel coarse	1.8 to 4.6 Avg 3	0
Kame deposits	56	Tp 6, R 20, Secs 19, 20, 29	Sand medium-grained, well sorted, clean	6	0
Kame deposits	88	Tp 11, R 28, Secs 10, 11, 14, 15	Gravel coarse and fine; sand fine- to coarse-grained, clean	6 to 17 Avg 9	0 to 1
Kame deposits	89	Tp 11, R 28, Sec 25; Tp 11, R 27, Sec 30	Gravel coarse; sand fine-grained, clean and moderately clean	1.2 to 2.7 Avg 1.8	0
Kame deposits	90	Tp 11, R 27, Secs 4, 5	Gravel fine and coarse; sand fine-grained, clean and moderately clean	Up to 18.6	0
Esker deposits	7	Tp 2, R 21, Secs 1, 2, 11, 12	Gravel coarse with pebbles and boulders	More than 1.5	0
Esker deposits	128	Tp 12, R 24, Sec 19, 30; Tp 12, R 25, Secs 25, 35, 36; Tp 13, R 25, Sec 1, 2	Sand fine- and medium-grained; gravel coarse and fine	3 to 10.7 Avg 7.6	0
Esker deposits	129	Tp 15, R 26, Secs 10, 11	Sand fine- and medium-grained; gravel fine and coarse	6	0
Outwash deposits	83	Tp 8, R 26, Secs 17, 18	Sand fine to coarse, clean; gravel mainly fine	10.7	0

Size Distribution (percentage)			Source of Gravels and Cobbles			Approximate Area in hectares	Minimum Estimated Reserves in cubic metres	Reference Number	
>4.75 mm	0.075 mm to 4.75 mm	<0.075 mm	Rocky Mountains	Canadian Shield	Bedrock			Pits	Testholes
41.7 to 76.2	22.9 to 52.3	0.3 to 5.5	88	8	4	35	750 000	125 126	212 213
~60	~39	~1	88	8	4	5	55 000	116	
69.3 45.4	Upper layer 29.9 Lower layer 52.7	0.8 1.9	76	16	8	38	850 000	115	208 to 211
~25	~73	~2	74	26	0	0.8	7 500	51 52	
21.5	77.7	0.8	65	30	5	0.8	9 000	53	
35.9	63.5	0.6	64	24	12	1.5	35 000	54	
31.5 to 58.7	40.8 to 64.9	0.5 to 3.6	60	36	4	50	750 000	183	123 124
0	100	0	---	---	---	32	1 000 000	55	
66.4	34.7	0.9	78	16	6	240	10 000 000	142 143	53 54
~70	~25	~5	---	---	---	26	200 000	141	
~50	~45	~5	72	20	8	80	7 500 000	144 145	51 52 277, 278
---	---	---	---	---	---	28	380 000		D.H. 177
38.6 to 55.6	42.8 to 60.4	1.0 to 1.6	65 to 80	20 to 35	0	12	300 000	171 172 173	
44.9	54.2	0.9	76	24	0	8	200 000	147	
~0	~30	~70	---	---	---	24	1 400 000		40

Origin	Number on Figure 2	Location (West of 4th Meridian)	Brief Description	Thickness in metres	
				Gravel and Sand	Overburden
Outwash deposits	86	Tp 7, R 29, Secs 9, 10, 16	Gravel coarse and fine; sand coarse- to fine-grained, clean	1.8 to 4.6 Avg 3	0 to 1.5
Outwash deposits	93	Tp 10, R 23, Secs 34; Tp 11, R 23, Sec 2	Gravel coarse; sand fine- to coarse-grained, clean	More than 1	0
Outwash deposits	110	Tp 12, R 20, Sec 10	0 to 1.2 Gravel coarse / 1.2 to 3.7 Sand and gravel; sand coarse and medium-grained, gravel coarse and fine	4 to 9 Avg 7.6	0
Outwash deposits	111	Tp 11, R 20, Secs 26, 35	Sand medium and fine-grained, clean and moderately clean; gravel fine and coarse	1.8	0
Outwash deposits	112	Tp 10, R 18, Secs 14, 23	Sand medium-grained, clean; gravel fine and coarse	2.1	0
Outwash deposits	114	Tp 10, R 17, Secs 9, 16	Gravel fine and coarse; sand fine- to coarse-grained, clean	1.8	0 to 0.6
Outwash deposits	123	Tp 12, R 19, Secs 19, 20, 21, 29, 30	Gravel fine and coarse; sand fine-to coarse-grained, clean grained, clean	1.8 to 6.7 Avg 3.7	0.5
Outwash deposits	130	Tp 15, R 26, Secs 10, 11	Gravel coarse and fine; sand medium-grained, clean	2.1 to 3.7 Avg 2.4	0
Marginal stream deposits	1	Tp 1, R 16, Secs 11, 12	Gravel fine and coarse; sand fine- and medium-grained, clean	1.2	0
Marginal stream deposits	2	Tp 1, R 16, Secs 17, 18	Sand fine-grained, clean; gravel coarse and fine	4	0
Marginal stream deposits	3	Tp 2, R 16, Secs 4, 5	Gravel coarse and fine; sand fine- to coarse-grained, clean	2	0
Marginal stream deposits	5	Tp 1, R 20, Secs 15, 16, 22, 27	Gravel coarse; sand from fine- to coarse-grained, clean	2.4 to 6.4 Avg 3.7	1.2 to 1.5

Size Distribution (percentage)			Source of Gravels and Cobbles			Approximate Area in hectares	Minimum Estimated Reserves in cubic metres	Reference Number	
>4.75 mm	0.075 mm to 4.75 mm	<0.075 mm	Rocky Mountains	Canadian Shield	Bedrock			Pits	Testholes
71.3	28.7	0.3	92	0	8	97	2 500 000	131 132 133 134	45 to 49
67.5	32.0	0.5	70	22	8	10	85 000	103	76
74.9	Upper layer 23.9	1.2	46	54	0	4	300 000	19	D.H. 1 D.H. 2. 87
38.8	Lower layer 59.9	1.3							
5	90	5	50	50	0	12	190 000	20 21	
34.0	65.5	0.5	60	36	4	28	290 000	62	
69.4	29.5	1.1	---	---	---	12	100 000	60	
65.0	34.2	0.8	64	36	0	80	2 500 000	46	85 86
60.2 to 77.2	22.3 to 38.1	0.5 to 1.7	84	16	0	14	350 000	146	
50.6	48.8	0.6	---	---	---	32	190 000	156	
~40	~60	~0	---	---	---	17	350 000	167	
64.0	35.4	0.6	56	26	18	25	230 000	157	
57.3	41.4	1.3	72	28	0	32	190 000	112	171 172

Origin	Number on Figure 2	Location (West of 4th Meridian)	Brief Description	Thickness in metres	
				Gravel and Sand	Overburden
Marginal stream deposits	57	Tp 5, R 19, Sec 36; Tp 5, R 18, Secs 31, 32	Gravel fine and coarse; sand fine- to coarse-grained, with lenses of silt	1.8 to 3	0
Marginal stream deposits	58	Tp 6, R 18, Sec 27	Gravel coarse and fine; sand fine- to coarse-grained, clean and moderately clean	1.2	0
Marginal stream deposits	59	Tp 4, R 17, Sec 35	Gravel coarse and fine; sand fine- and medium-grained	1.2 to 3.7 Avg 2.4	—
Marginal stream deposits	60	Tp 7, R 16, Sec 27, 28	Gravel coarse; sand fine- to coarse-grained, moderately clean	2.1	0.3
Marginal stream deposits	61	Tp 9, R 16, Secs 8, 17, 18	Gravel fine with some coarse; sand fine- to coarse-grained, clean	1.8 to 3 Avg 2.4	0.3
Marginal stream deposits	62	Tp 9, R 19, Sec 1	Sand medium-grained with lenses of fine and coarse sand and fine gravel, clean	More than 6	1
Marginal stream deposits	63	Tp 7, R 19, Sec 5	Gravel fine and coarse; sand fine and medium-grained, clean	1.5	—
Marginal stream deposits	132	Tp 14, R 26, Secs 7, 8	Gravel coarse and fine; sand medium- and coarse-grained, clean and moderately clean	2.1	—
Valley train deposits	4	Tp 2, R 17, Secs 25, 26, 27	0 to 1.5 Gravel fine and coarse with some sand/ 1.5 to 5.5 Sand medium-grained with some coarse sand and gravel	2.4 to 5.5 Avg 3.7	—
Valley train deposits	8	Tp 2, R 21, Secs 10, 11	Gravel fine and coarse; sand fine- to coarse-grained	3	—
Valley train deposits	9	Tp 2, R 21, Secs 5, 8, 9	Sand coarse and medium-grained with layers of organic material; gravel coarse and fine	1.5	1
Valley train deposits	12	Tp 1, R 22, Secs 19, 29, 30	Gravel coarse; sand fine- and medium-grained	3 to 5.2 Avg 3.7	0.3 to 1.2

Size Distribution (percentage)			Source of Gravels and Cobbles			Approximate Area in hectares	Minimum Estimated Reserves in cubic metres	Reference Number	
>4.75 mm	0.075 mm to 4.75 mm	<0.075 mm	Rocky Mountains	Canadian Shield	Bedrock			Pits	Testholes
56.3	43.0	0.7	78	18	4	24	300 000	77 78 79	126 127 128
~55	~40	~5	48	48	4	28	170 000	97 98	129 130
71.3	27.1	1.6	64	24	12	16	380 000	160	135
~50	~40	~10	64	36	0	32	350 000	96	136 137 138
43.7	54.0	2.3	80	20	0	24	290 000	73	
14.8	83.5	1.7	24	76	0	5	115 000	75	
70.8	27.6	1.6	56	44	0	2.5	19 000	76	
~60	~35	~5	72	20	8	32	350 000	136	217
~30	~70	~0	92	8	0	40	760 000	158 159	163 164
66.8	31.1	1.1	84	16	0	77	1 000 000	114	
~15	~85	~0	95	5	0	80	610 000		182 181
61.8 to 77.0	20.7 to 37.0	0.9 to 2.3	96	4	0	120	2 000 000	99	D.H. 192

Origin	Number on Figure 2	Location (West of 4th Meridian)	Brief Description	Thickness in metres	
				Gravel and Sand	Overburden
Valley train deposits	13	Tp 1, R 23, Sec 14	Gravel coarse; sand coarse- to fine-grained, clean	6	1.2
Valley train deposits	24	Tp 2, R 27, Sec 11	Gravel coarse and fine; sand coarse- and medium-grained, clean	5.5	---
Valley train deposits	29	Tp 1, R 29, Sec 31	Gravel fine; sand coarse- and medium-grained, clean	2.7	0.3
Valley train deposits	45	Tp 5, R 27, Sec 35; Tp 6, R 27, Sec 2	Gravel coarse and fine; sand coarse- and medium-grained clean	1.2 to 2.7 Avg 8	---
Valley train deposits	46	Tp 5, R 27, Secs 25, 36; Tp 5, R 26, Secs 30, 31	Gravel coarse and fine; sand medium-grained	1.5 to 2.1	0 to 0.5
Valley train deposits	65	Tp 8, R 21, Secs 17, 20	Sand medium-grained; gravel coarse and fine	2.7 to 6 Avg 3.7	0 to 2.4
Valley train deposits	78	Tp 8, R 25, Secs 11, 14, 15, 23	Gravel coarse and fine with some sand, fine- and medium-grained, clean	1.5	---
Valley train deposits	79	Tp 7, R 25, Secs 23, 25, 26	Gravel coarse and fine; sand fine- and medium-grained, clean	1.8 to 3 Avg 2.1	---
Valley train deposits	80	Tp 6, R 25, Secs 29, 32, 33; Tp 7, R 25, Sec 3	Gravel coarse and fine; sand medium-grained	1 to 2.1 Avg 1.5	---
Valley train deposits	84	Tp 9, R 25, Secs 5 to 16, 17; Tp 9, R 26, Secs 1 to 18, 23, 24; Tp 9, R 27, Secs 1 to 4, 10 to 15	Gravel coarse and fine; sand coarse- to fine-grained, clean	1.5 to 7.6 Avg 3	0
Valley train deposits	85	Tp 7, R 29, Secs 12, 13	Gravel coarse and fine; sand coarse- and medium-grained clean	3 to 4.6 Avg 3.4	0 to 1
Valley train deposits	87	Tp 7, R 30, Secs 24, 25	Gravel coarse; sand coarse- and medium-grained, clean	2.1 to 3.7 Avg 2.4	---

Size Distribution (percentage)			Source of Gravels and Cobbles			Approximate Area in hectares	Minimum Estimated Reserves in cubic metres	Reference Number	
>4.75 mm	0.075 mm to 4.75 mm	<0.075 mm	Rocky Mountains	Canadian Shield	Bedrock			Pits	Testholes
87.4	11.2	1.4	84	16	0	12	350 000	100	
51.4	47.6	1.0	76	24	0	5	130 000	11	
76.0	23.4	0.6	---	---	---	49	610 000	1	
~60	~37	~3	96	4	0	120	1 000 000		68
51.8 to 75.2	24.0 to 47.0	0.8	88	8	4	60	1 000 000	177 178	70
20.3 to 47.5	51.9 to 79.2	0.5	58	40	2	20	380 000	12 13	107 to 110
~75	~25	~0	---	---	---	305	2 500 000		18 19
75.6	23.2	1.2	96	4	0	35	720 000	175 176	21
69.5	28.3	2.2	100	0	0	160	2 500 000	155	23
57.5 to 77.5	21.1 to 40.5	0.4 to 1.4	90 to 96	6 to 10	0	4,920	150 000 000	106 to 110, 152, 153, 163, 164, 167	1 to 15, 34
69.5 to 74.3	24.9 to 29.4	0.8 to 1.1	96	0	4	77	1 300 000	134 135	43
86.1	13.0	0.9	96	4	0	60	750 000	130	

Origin	Number on Figure 2	Location (West of 4th Meridian)	Brief Description	Thickness in metres	
				Gravel and Sand	Overburden
Valley train deposits	91	Tp 10, R 24, Sec 30	Gravel coarse; sand fine- to coarse-grained	1	0.3
Valley train deposits	92	Tp 10, R 24, Sec 16	Gravel coarse and fine; sand fine- to coarse-grained	2.1	---
Valley train deposits	103	Tp 10, R 21, Secs 15, 16	Gravel coarse and fine; sand fine- to coarse-grained	2.4	0.6
Valley train deposits	104	Tp 10, R 21, Sec 22	0 to 1.5 Gravel coarse; sand fine- to coarse- grained/ 1.5 to 5 Sand medium-grained with fine gravel	5.2	0.3 to 1.2
Valley train deposits	105	Tp 10, R 21, Sec 23	Sand medium-grained with lenses of fine gravel, coarse- and fine-grained sand	6	0.6 to 1.2
Valley train deposits	106	Tp 10, R 21, Secs 24, 25	0 to 1.5 Gravel coarse; sand coarse- to fine- grained/ 1.5 to 4.6 Sand medium-grained with lenses of fine gravel and coarse fine sand	4 to 7 Avg 4.6	0.3 to 1
Valley train deposits	107	Tp 10, R 20, Secs 19, 20	0 to 1.5 Gravel coarse and fine; sand fine- to coarse-grained / 1.5 to 5.8 Sand medium- and coarse-grained with fine gravel	1.2 to 5.8 Avg 4.6	0.3 to 1
Valley train deposits	108	Tp 10, R 20, Sec 26	Gravel fine and coarse; sand coarse- and medium-grained	2.7 to 3.7	0.3 to 0.5
Valley train deposits	109	Tp 10, R 19, Secs 28, 33	Gravel coarse and fine; sand medium-grained	5.6	--
Valley train deposits	113	Tp 10, R 18, Sec 24; Tp 10, R 17, Secs 18, 19	Gravel fine with some coarse; sand medium- and fine-grained	2.1	0 to 0.6
Valley train deposits	115	Tp 10, R 17, Secs 2, 10, 11, 12	Gravel coarse and fine; sand medium-grained	2.4	0 to 0.37
Valley train deposits	116	Tp 10, R 17, Sec 13	Gravel fine and coarse; sand fine- to coarse-grained	1.1	0.5
Valley train deposits	117	Tp 10, R 16, Sec 31; Tp 11, R 16, Sec 5	Gravel fine; sand coarse- and medium-grained	3	0.6

Size Distribution (percentage)			Source of Gravels and Cobbles			Approximate Area in hectares	Minimum Estimated Reserves in cubic metres	Reference Number	
>4.75 mm	0.075 mm to 4.75 mm	<0.075 mm	Rocky Mountains	Canadian Shield	Bedrock			Pits	Testholes
74.9	22.5	2.7	76	24	0	2	15 000	104	75
45.2 to 60.6	52.6 to 38.7	0.7 to 2.2	---	---	---	1.2	14 000	102	72
67.4 to 70.9	29.2 to 30.0	0.9 to 2.6	68	32	0	1.2	15 000	28	225 226
75.6 12.7	gravel 22.6 sand 86.2	1.8 1.1	70	30	0	4	100 000	27	
9.7	87.9	2.4	54	46	0	12	360 000	45	103 104 105
52.3 to 83.2 0 to 33.5	gravel 14.8 to 46.6 sand 65.9 to 10 0	1.1 to 2.1 0 to 0.6	64	36	0	26	600 000	23 24 25 26	90 90a 91 92 93 94
61.3 to 67.5	gravel 31.5 to 35.1	1.0 to 3.6	68	30	2	20	460 000	56	99 100
~65	~30	~5	68	32	---	20	380 000	22	95 96
87.8	11.7	0.5	---	---	---	8	270 000	65	20 21
~70	~30	~0	70	26	4	50	460 000	61	
55.7 to 63.7	34.5 to 43.0	1.3 to 1.8	52 to 54	30 to 48	6 to 16	24	290 000	56 57	
~50	~50	~0	68	32	0	4	19 000	58	
77.9	19.7	2.4	64	36	0	26	380 000	181	149

Origin	Number on Figure 2	Location (West of 4th Meridian)	Brief Description	Thickness in metres	
				Gravel and Sand	Overburden
Valley train deposits	118	Tp 10, R 17, Sec 36; Tp 11, R 16, Sec 6	Gravel fine and coarse; sand medium-grained	9.8	---
Valley train deposits	119	Tp 11, R 16, Secs 31, 32	Sand medium-grained with some gravel	4.6	---
Valley train deposits	120	Tp 12, R 16, Secs 2, 3	Gravel fine and coarse; sand fine- and medium-grained	1.8	0.6
Valley train deposits	121	Tp 11, R 16, Secs 26, 34, 35	Gravel fine and coarse; sand fine- to coarse-grained with lenses of well sorted coarse sand	1.8 to 6 Avg 4.2	0.2 to 0.5
Valley train deposits	122	Tp 15, R 16, Secs 1, 12	Sand fine- and medium-grained; gravel fine- and coarse-grained	2	0.2
Valley train deposits	124	Tp 14, R 20, Secs 17, 18	Gravel fine with some coarse; sand medium- and coarse-grained	4.6	---
Valley train deposits	125	Tp 14, R 20, Sec 4, 9	0 to 1.2 Gravel fine and coarse; sand fine- to coarse- grained/ 1.2 to 6 Sand coarse- and medium-grained with fine gravel	6	---
Valley train deposits	126	Tp 14, R 25, Secs 1, 11, 12, 13	0 to 1 Gravel fine and coarse; sand fine- to coarse- grained/ 1 to 4.6 Sand fine to coarse with fine gravel	2.1 to 4.6 Avg 3	---
Valley train deposits	127	Tp 14, R 25, Secs 23, 26, 27	Gravel coarse and fine; sand medium- and coarse-grained	1.8	---
Valley train deposits	131	Tp 15, R 26, Secs 3, 4, 9, 10	Gravel coarse and fine with lenses of sand, coarse- and medium-grained	2.1 to 3.7 Avg 2.4	---
Valley train deposits	133	Tp 12, R 28, Secs 13, 24	Gravel fine and coarse; sand medium- and coarse-grained	4.3	1.2
Valley train deposits	134	Tp 12, R 28, Secs 23, 26, 35	Gravel fine and coarse; sand medium- and coarse-grained	3.7 to 5.8 Avg 4.3	0.3 to 1

Size Distribution (percentage)			Source of Gravels and Cobbles			Approximate Area in hectares	Minimum Estimated Reserves in cubic metres	Reference Number	
>4.75 mm	0.075 mm to 4.75 mm	<0.075 mm	Rocky Mountains	Canadian Shield	Bedrock			Pits	Testholes
~30	~70	~0	---	---	---	6	290 000		142
~25	~75	~0	---	---	---	32	610 000		145
~25	~75	~0	64	36	0	49	380 000	70	146 147
70.3 to 78.2	20.5 to 29.0	0.3 to 1.3	76 to 92	8 to 24	0	80	1 700 000	67 68 69	
42.8	55.9	1.3	76	24	0	20	200 000	72	156 157
73.5	26.0	0.5	51	49	0	28	650 000	47	81 82
59.7 27.7	gravel 38.8 sand 71.7	1.5 0.6	74	26	0	20	610 000	48	84
72.5 23.3 to 45.6	gravel 25.8 sand 33.6 to 76.0	1.7 0.2 to 0.8	76 to 88	12 to 24	0	36	530 000	149 150 170	222 223
52.7	47.1	0.2	80	20	0	20	180 000	148	221
42.0 to 72.5	26.5 to 57.8	0.2 to 1.0	80	12	8	40	490 000	137	218
62.7	36.4	0.9	84	16	0	36	760 000	139	
52.7	47.1	0.2	96	0	4	60	1 300 000	140	58 216

Origin	Number on Figure 2	Location (West of 4th Meridian)	Brief Description	Thickness in metres	
				Gravel and Sand	Overburden
Recent alluvial deposits	16	Tp 1, R 25, Secs 25, 36; Tp 2, R 25, Sec 1	Sand fine- and medium-grained; gravel coarse and fine	2.1	0.6 to 0.9
Recent alluvial deposits	17	Tp 2, R 25, Secs 11, 12, 13	Sand fine- and medium-grained; gravel coarse and fine	1.8	0.3 to 0.6
Recent alluvial deposits	28	Tp 3, R 27, Secs 18, 19; Tp 3, R 28, Sec 13	Gravel coarse; sand fine- and medium-grained	1.8 to 3.0 Avg 2.4	---
Recent alluvial deposits	32	Tp 3, R 29, Sec 7; Tp 3, R 30, Secs 11, 12	Gravel coarse; sand fine- to coarse-grained	2.1 to 3.7 Avg 3	0.3 to 0.5
Recent alluvial deposits	33	Tp 3, R 30, Secs 21, 22	Gravel coarse; sand fine- to coarse-grained	0.9 to 1.8 Avg 1.5	—
Recent alluvial deposits	37	Tp 4, R 29, Secs 8, 9	Gravel coarse; sand fine- to coarse-grained	1.5	0.5
Recent alluvial deposits	47	Tp 5, R 27, Sec 36; Tp 5, R 26, Sec 31	Gravel coarse; sand fine-grained	2.1	---
Recent alluvial deposits	48	Tp 4, R 26, Secs 31, 32; Tp 5, R 26, Secs 5, 6	Gravel coarse; sand fine- to coarse-grained	2.1	0.9
Recent alluvial deposits	49	Tp 6, R 25, Secs 18 to 21, 27 to 29, 33, 34	Gravel coarse and fine; sand fine- to coarse-grained	1.8 to 4 Avg 2.4	0 to 1.8
Recent alluvial deposits	55	Tp 6, R 23, Secs 13, 14	Sand medium- and coarse-grained; gravel coarse and fine	1.5	---
Recent alluvial deposits	64	Tp 7, R 21, Secs 18, 19	Gravel coarse and fine; sand fine-grained	8.2	2.1
Recent alluvial deposits	68	Tp 7, R 22, Secs 25, 26	Gravel coarse and fine; sand fine-grained	8.5	4
Recent alluvial deposits	69	Tp 8, R 22, Sec 12	Sand fine-grained with lenses of coarse gravel	3	---
Recent alluvial deposits	70	Tp 8, R 21, Sec 18	Sand fine-grained, clean with lenses of coarse gravel	3.7	---
Recent alluvial deposits	71	Tp 9, R 22, Secs 12, 13	Sand fine-grained with coarse gravel	2.4	—

Size Distribution (percentage)			Source of Gravels and Cobbles			Approximate Area in hectares	Minimum Estimated Reserves in cubic metres	Reference Number	
>4.75 mm	0.075 mm to 4.75 mm	<0.075 mm	Rocky Mountains	Canadian Shield	Bedrock			Pits	Testholes
~30	~65	~5	96	4	0	225	2 750 000	88	197
36.0 to 50.5	48.6 to 62.0	0.9 to 2.0	76	16	8	125	1 000 000	87	198
~50	~50	0	---	---	---	90	1 000 000		206
62.4 to 76.1	23.3 to 37.2	0.4 to 0.6	100	0	0	175	2 700 000	4	207
55.0 to 70.0	29.7 to 44.8	0.2 to 0.3	100	0	0	83	610 000	5	
~65	~30	~5	82 to 90	4 to 10	5 to 8	42	300 000	120 121	
72.0	26.4	1.6	88	12	0	170	1 800 000	179	70
~65	~25	~10	---	---	---	48	460 000		261
65.2	31.4	3.4	---	---	---	1400	30 000 000		63, 64 65, 66
48.9	50.5	0.6	74	12	14	1.5	11 000	49 50	116
~50	~50	~0	---	---	---	24	760 000		112
~70	~30	~0	---	---	---	73	1 500 000		111
~10	~90	~0	---	---	---	8	38 000	15	
~25	~75	~0	90	10	~0	10	60 000	14	
~30	~70	~0	86	14	~0	16	76 000	30	

Origin	Number on Figure 2	Location (West of 4th Meridian)	Brief Description	Thickness in metres	
				Gravel and Sand	Overburden
Recent alluvial deposits	72	Tp 9, R 22, Sec 13	Sand fine-grained with fine gravel	1.8	---
Recent alluvial deposits	73	Tp 8, R 22, Secs 9, 10	Gravel coarse; sand fine-grained	7.6	0.3
Recent alluvial deposits	74	Tp 8, R 22, Sec 30; Tp 8, R 23, Sec 25	Gravel coarse; sand fine-grained	>5	0 to 2.5
Recent alluvial deposits	75	Tp 8, R 22, Sec 31; Tp 9, R 22, Sec 6	Gravel coarse and fine; sand fine-grained	4.9 to 7.9 Avg 6	0 to 1.2
Recent alluvial deposits	76	Tp 9, R 23, Sec 24	Gravel coarse; sand fine-grained	More than 1.5	0.6
Recent alluvial deposits	77	Tp 7, R 24, Secs 30, 31; Tp 7, R 25 Secs 35, 36	Gravel fine; sand fine-grained	4	0.6 to 1.5
Recent alluvial deposits	94	Tp 10, R 24, Sec 3	Gravel coarse; sand fine-grained	2.1 to 5.8 Avg 3.7	---
Recent alluvial deposits	95	Tp 9, R 23, Sec 31; Tp 10, R 23, Sec 6; Tp 10, R 24, Sec 1	Gravel coarse and fine; sand fine- and medium-grained	4.6 to 6.1	---
Recent alluvial deposits	96	Tp 9, R 23, Sec 33	Gravel coarse and fine; sand fine-grained	6.5	0.6
Recent alluvial deposits	97	Tp 9, R 23, Sec 33	Gravel coarse and fine; sand fine- and medium-grained	Up to 8.2	0.06
Recent alluvial deposits	98	Tp 9, R 23, Secs 34, 35	Gravel fine and coarse; sand medium- and fine-grained	4.6	0 to 0.9
Recent alluvial deposits	99	Tp 9, R 23, Secs 25, 26, 36	Gravel coarse and fine; sand fine- to coarse-grained	2.4 to 7.6 Avg 4.6	0 to 2.1
Recent alluvial deposits	100	Tp 9, R 22, Sec 24; Tp 9, R 21 Secs 19, 30	Gravel coarse and fine; sand fine-grained	2.1	---
Recent alluvial deposits	101	Tp 9, R 21, Secs 30, 31; Tp 10, R 21, Sec 6	Gravel fine and coarse; sand fine- to coarse-grained	6.1	2.1 to 4.2
Recent alluvial deposits	102	Tp 10, R 21, Secs 9, 10	Gravel coarse and fine; sand fine- to coarse-grained	2.1	---

Size Distribution (percentage)			Source of Gravels and Cobbles			Approximate Area in hectares	Minimum Estimated Reserves in cubic metres	Reference Number	
>4.75 mm	0.075 mm to 4.75 mm	<0.075 mm	Rocky Mountains	Canadian Shield	Bedrock			Pits	Testholes
~20	~80	~0	---	---	---	16	60 000	39	
~60	~40	~0	---	---	---	30	690 000		40 41
~50	~50	~0	---	---	---	20	380 000		
~55	~45	~0	---	---	---	57	1 700 000		43 44 45
60.9	37.7	1.4	96	4	~0	24	340 000	162	
~35	~65	~0	---	---	---	100	1 500 000		20
68.6 to 80.2	18.5 to 30.8	0.6 to 1.3	96	4	~0	22	380 000	101	73 74
68.3	31.3	0.4	80	20	~0	90	2 000 000		236 237 238
~50	~50	~0	---	---	---	100	3 000 000		241 245 246
69.2	29.1	1.7	---	---	---	60	1 800 000		247 248
43.6	55.5	0.9	---	---	---	73	1 500 000		232 233 234 235
47.9 to 79.0	20.0 to 45.7	1.0 to 6.4	76 to 96	2 to 6	2 to 16	485	7 500 000	32 to 38	
~40	~60	~0	88	12	0	20	60 000	43	
71.2	26.6	2.2	96	4	0	100	1 500 000	42	106
81.2	16.6	2.2	80	20	0	36	760 000	29 165	224

QUATERNARY

RECENT

E	Eolian deposits: sand and silt
Atd	Alluvial terraces: gravel, sand and silt
AS	Alluvial fans: gravel and sand

PLEISTOCENE

GLACIOLACUSTRINE

LG	Lacustrine deposits: sand, silt and clay

GLACIOFLUVIAL

Proglacial deposits

AGSt	Valley train (high alluvial terrace) deposits: gravel, sand and silt
AGS	Marginal stream deposits: gravel and sand
AG	Outwash deposits: gravel and sand

Ice-contact deposits

AGK	Kame deposits: gravel, sand and silt
AGE	Esker deposits: gravel and sand

GLACIAL

Th	Hummocky moraine: till with sporadic lenses of gravel, sand and silt
Tr	Ground moraine: till with sporadic lenses of gravel, sand and silt

$\frac{Th}{6}$ * should read $\frac{Tr}{6}$

TERTIARY

Upper Tertiary

PA	Preglacial alluvium: gravel, sand

LITHOLOGIC TYPES

1	Sandstone, siltstone and shale (bedrock)
2	Gravel
3	Sand and gravel
4	Sand and silt
5	Silt and clay
6	Till

Geological boundary: defined, assumed

LEGEND

River or stream

Intermittent river or stream

Lake

Intermittent lake

Road, hard surface, all weather

Railway

Township boundary

Section line

Sources of Information

Surficial geology, High River, Alberta, by A. Mac S. Stalker. Geological Survey of Canada Map No. 14 - 1957.

Surficial geology, Fort MacLeod, Alberta, by A. Mac S. Stalker. Geologicial Survey of Canada Map No. 21 - 1958.

Surficial geology, Lethbridge, Alberta, by A. Mac S. Stalker. Geological Survey of Canada Map No. 41 - 1962.

Surficial geology, Bassano, Alberta, by A. Mac S. Stalker. Geological Survey of Canada Map No. 5 - 1965.

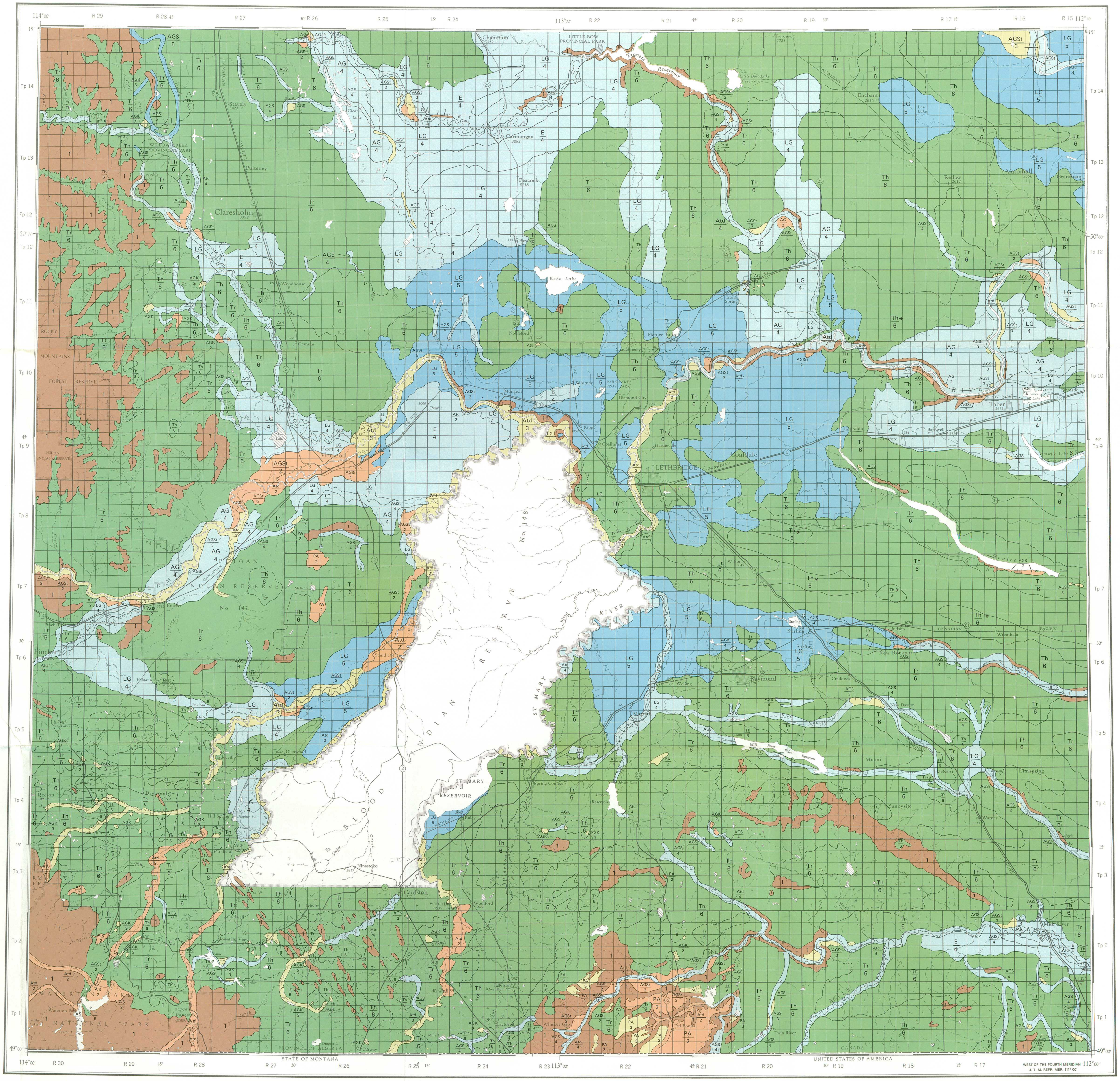
Surficial geology map of the Vauxhall District, Alberta, by L.A. Bayrock and J.F. Jones. Alberta Research Council Preliminary Report 63-2.

Compiled by I. Shetsen

SCALE 1:250,000

Miles 5 0 5 10 15 20 Miles

Kilometres 5 0 5 10 15 20 25 30 Kilometres



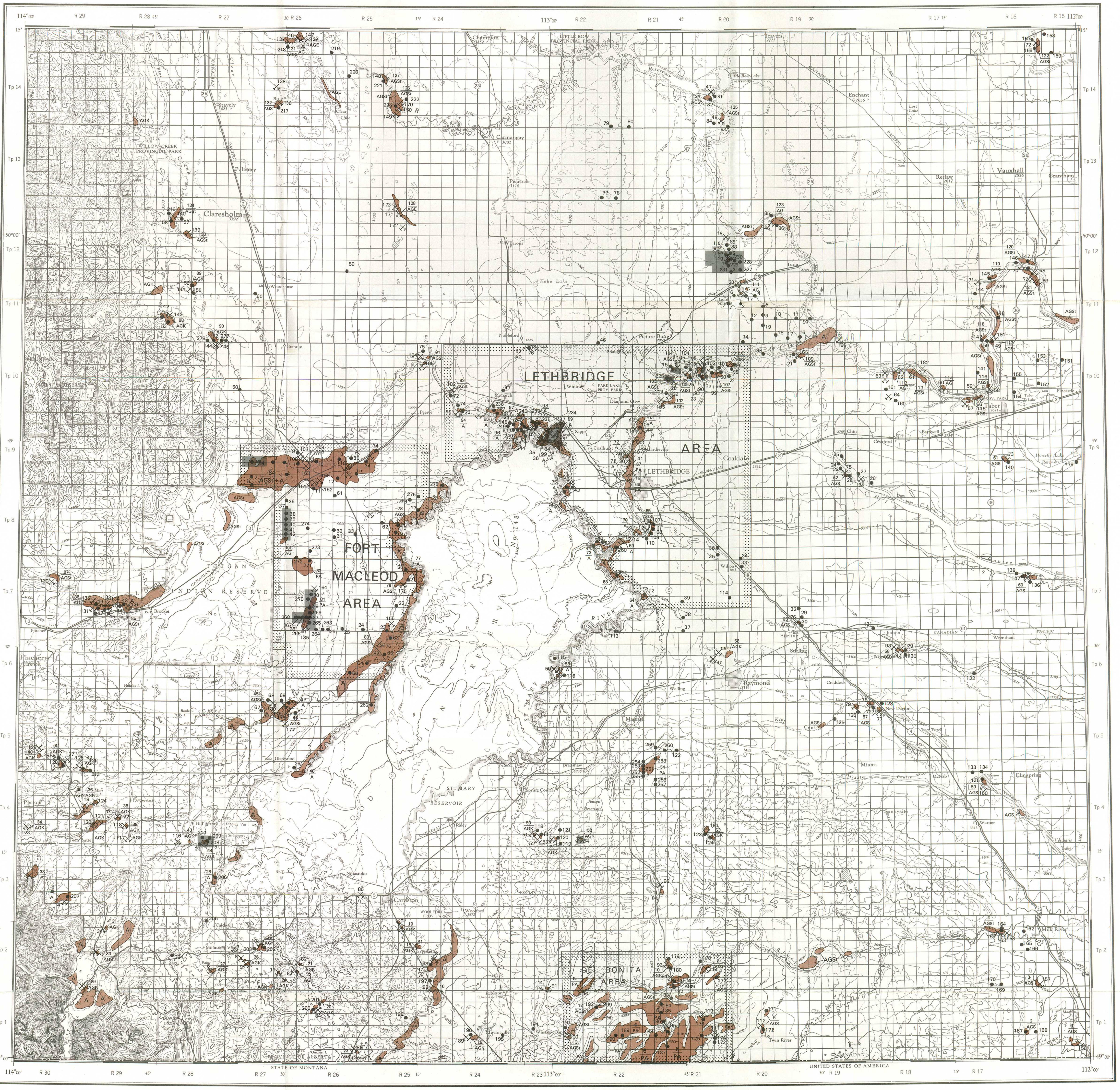
SURFICIAL GEOLOGY LETHBRIDGE

ALBERTA

NTS 82 H, 82 I

Cartography by A.R.C. Drafting Services

Published 1981



Compiled by I. Shetson
Cartography by A.R.C. Drafting Services

Published 1981

SCALE 1:250,000

Miles 5 0 5 10 15 20 Miles
Kilometres 5 0 5 10 15 20 25 30 Kilometres

GRAVEL AND SAND DEPOSITS

- Defined on basis of drilling or outcrop information
- Assumed on basis of surface mapping or airphoto interpretation

GENETIC GROUPS

PA	Preglacial alluvial deposits
AGK	Kame deposits
AGE	Esker deposits
AG	Outwash deposits
AGS	Marginal stream deposits
AGSt	Valley train deposits
A	Recent alluvial deposits

DISTRIBUTION OF GRAVEL, SAND DEPOSITS, PITS, TESTHOLES AND RESISTIVITY SITES LETHBRIDGE – GLEICHEN, ALBERTA

NTS 82H, 82I

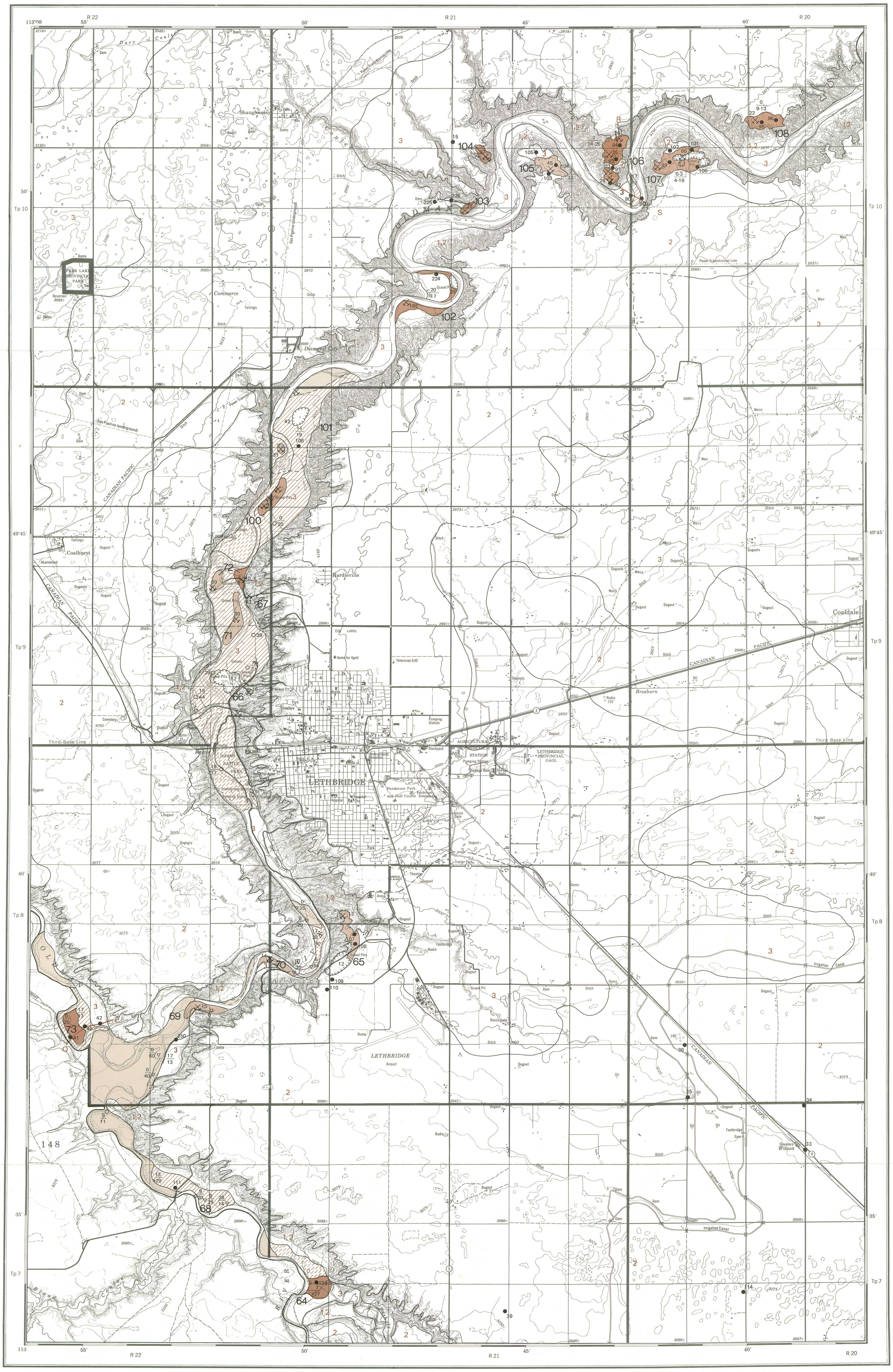
Geological boundary
Deposit number / Origin .... 65 / AGSt
Sand and gravel pit, number 96
ARC testhole, number 219
Resistivity site
Areas mapped at scale 1:50,000

LEGEND

River or stream
Intermittent river or stream
Lake
Intermittent lake
Road, hard surface, all weather 2

Railway
Township boundary
Section line
Contours definite, approximate 2000

Fig. 2.



GRAVEL AND SAND EXPOSED AT SURFACE OR COVERED BY LESS THAN 10 FEET OF OVERBURDEN

- Gravel — gravel 75-100%, sand 0-25%, fines 0-10%
- Sandy gravel — gravel 50-75%, sand 25-50%, fines 0-10%
- Gravelly sand — gravel 25-50%, sand 50-75%, fines 0-10%
- Sand — gravel 0-25%, sand 75-100%, fines 0-10%
- Possible gravel and sand deposits

GRAVEL AND SAND COVERED BY MORE THAN 10 FEET OVERBURDEN

- Recorded in testholes and well logs
- Assumed on basis of geological associations
- 1 Sandstone, siltstone and shale (bedrock)
- 2 Till
- 3 Silty sand, silt and clay
- 4 Sand fine-grained

Geological boundary; defined, assumed

Sand and gravel pit, pit number — 81

Pit area if it is extensive

Testhole drilled by ARC, hole number — 117

Water well log

Seismic shothole

Deposit reference number on map 2 in appendix C — 70

Thickness of overburden / Thickness of gravel and sand — 15/25

Geological profile location — A B

Ground resistivity traverse location

LEGEND

River or stream

Intermittent river or stream

Lake

Intermittent lake

Road, hard surface, all weather — 2

Railway

Township boundary

Section line

Contours definite, approximate — 3500

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Cartography by A.R.C. Drafting Services

Published 1981

Scale 1:50,000

1 0 1 2 3 Miles
1 0 1 2 3 4 Kilometres

GRAVEL AND SAND DEPOSITS
LETHBRIDGE AREA (EAST HALF)

ALBERTA

NTS 82H/10, 82H/15

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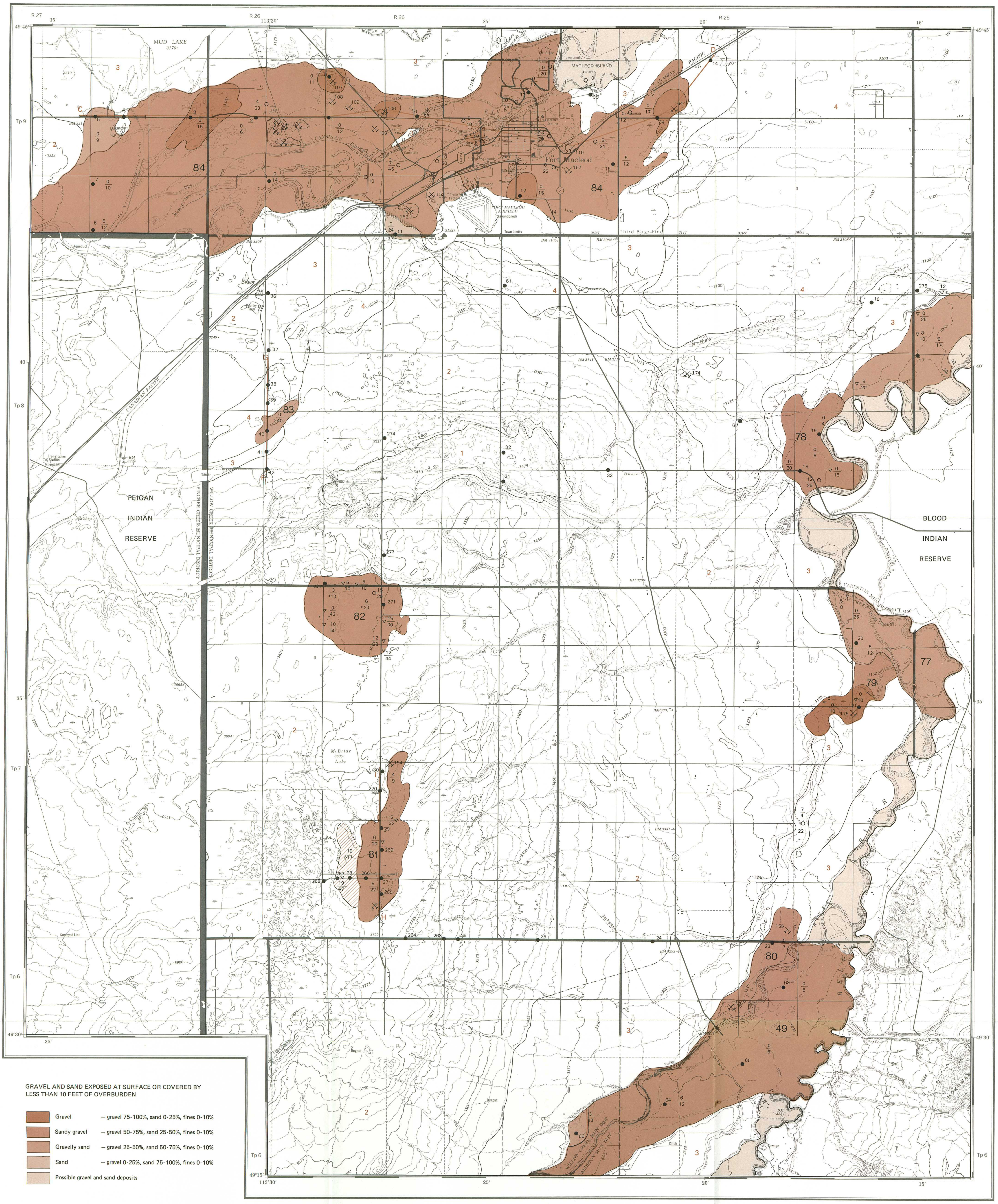
Cartography by A.R.C. Drafting Services

Published 1981

GRAVEL AND SAND DEPOSITS LETHBRIDGE AREA (WEST HALF)

ALBERTA

NTS 82H/11, 82 H/14



GRAVEL AND SAND EXPOSED AT SURFACE OR COVERED BY LESS THAN 10 FEET OF OVERBURDEN

- Gravel — gravel 75-100%, sand 0-25%, fines 0-10%
- Sandy gravel — gravel 50-75%, sand 25-50%, fines 0-10%
- Gravelly sand — gravel 25-50%, sand 50-75%, fines 0-10%
- Sand — gravel 0-25%, sand 75-100%, fines 0-10%
- Possible gravel and sand deposits

GRAVEL AND SAND COVERED BY MORE THAN 10 FEET OVERBURDEN

- Recorded in testholes and well logs
- Assumed on basis of geological associations
- 1 Sandstone, siltstone and shale (bedrock)
- 2 Till
- 3 Silty sand, silt and clay
- 4 Sand fine-grained

Geological boundary; defined, assumed

Sand and gravel pit, pit number 74

Pit area if it is extensive

Testhole drilled by ARC, hole number 192

Water well log

Seismic shothole

Deposit reference number on map 2 in appendix C 82

Thickness of overburden / Thickness of gravel and sand 6/20

Geological profile location .... A B

Ground resistivity traverse location

Compiled by I. Shetson
Cartography by A.R.C. Drafting Services

Scale 1:50,000

1 0 1 2 3 Miles

1 0 1 2 3 4 Kilometres

Published 1981

GRAVEL AND SAND DEPOSITS FORT MACLEOD AREA ALBERTA

LEGEND

- River or stream
- Intermittent river or stream
- Lake
- Intermittent lake
- Road, hard surface, all weather
- Railway
- Township boundary
- Section line
- Contours definite, approximate

Fig. 4

GRAVEL AND SAND EXPOSED AT SURFACE OR COVERED BY LESS THAN 10 FEET OF OVERBURDEN

Gravel	— gravel 75-100%, sand 0-25%, fines 0-10%
Sandy gravel	— gravel 50-75%, sand 25-50%, fines 0-10%
Gravelly sand	— gravel 25-50%, sand 50-75%, fines 0-10%
Sand	— gravel 0-25%, sand 75-100%, fines 0-10%
Possible gravel and sand deposits	

GRAVEL AND SAND COVERED BY MORE THAN 10 FEET OVERBURDEN

Recorded in testholes and well logs

Assumed on basis of geological associations

1 Sandstone, siltstone and shale (bedrock)

2 Till

3 Silty sand, silt and clay

4 Sand fine-grained

Geological boundary; defined, assumed

Sand and gravel pit, pit number 91

Pit area if it is extensive

Testhole drilled by ARC, hole number 192

Water well log

Seismic shothole

Deposit reference number on map 2 in appendix C 3

Thickness of overburden / Thickness of gravel and sand 5/28

Geological profile location .... A—B

Ground resistivity traverse location

LEGEND

River or stream

Intermittent river or stream

Lake

Intermittent lake

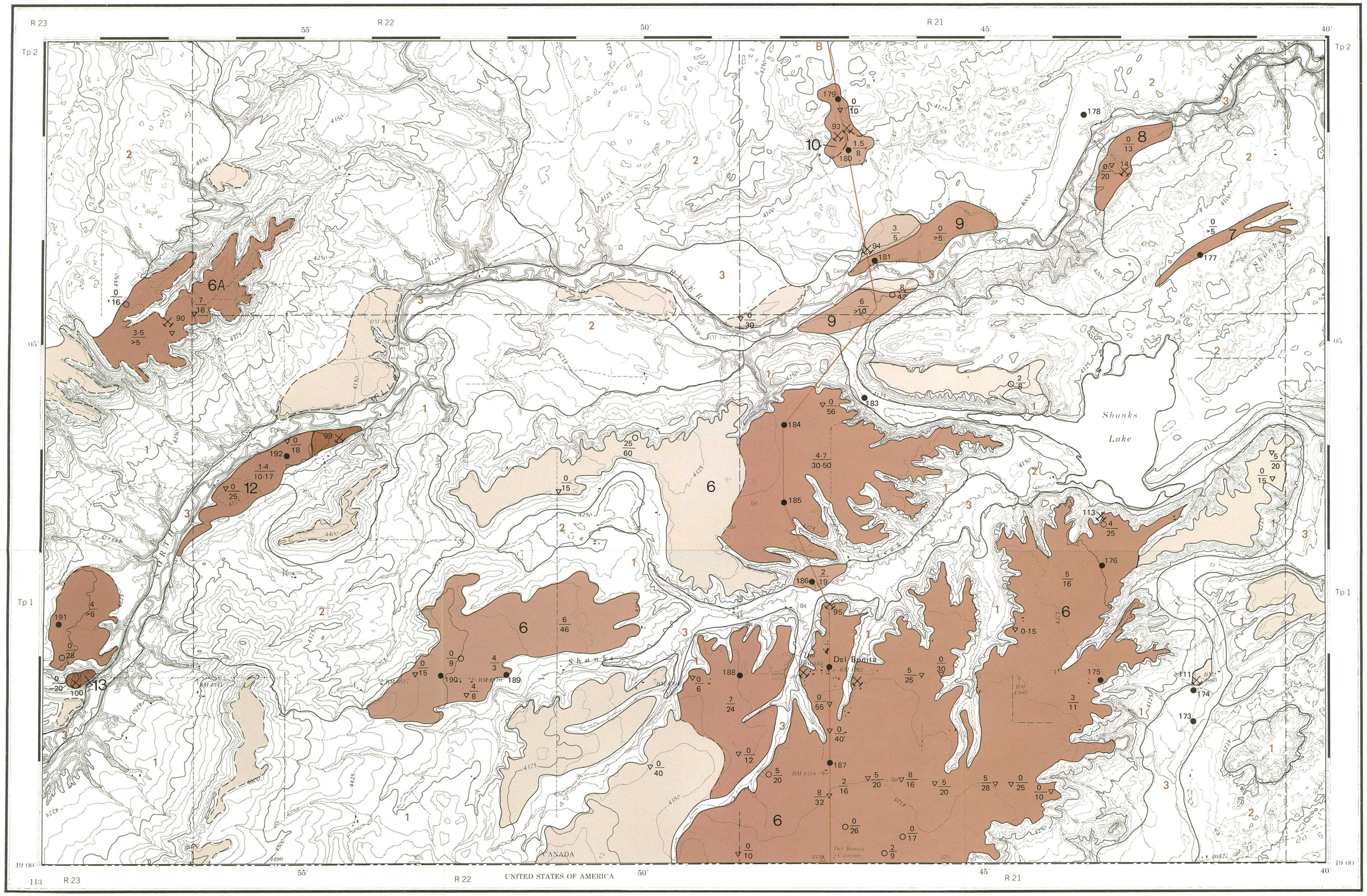
Road, hard surface, all weather

Railway

Township boundary

Section line

Contours definite, approximate



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Cartography by A.R.C. Drafting Services

Scale 1:50,000

Published 1981

GRAVEL AND SAND DEPOSITS DEL BONITA AREA ALBERTA

NTS 82H/2

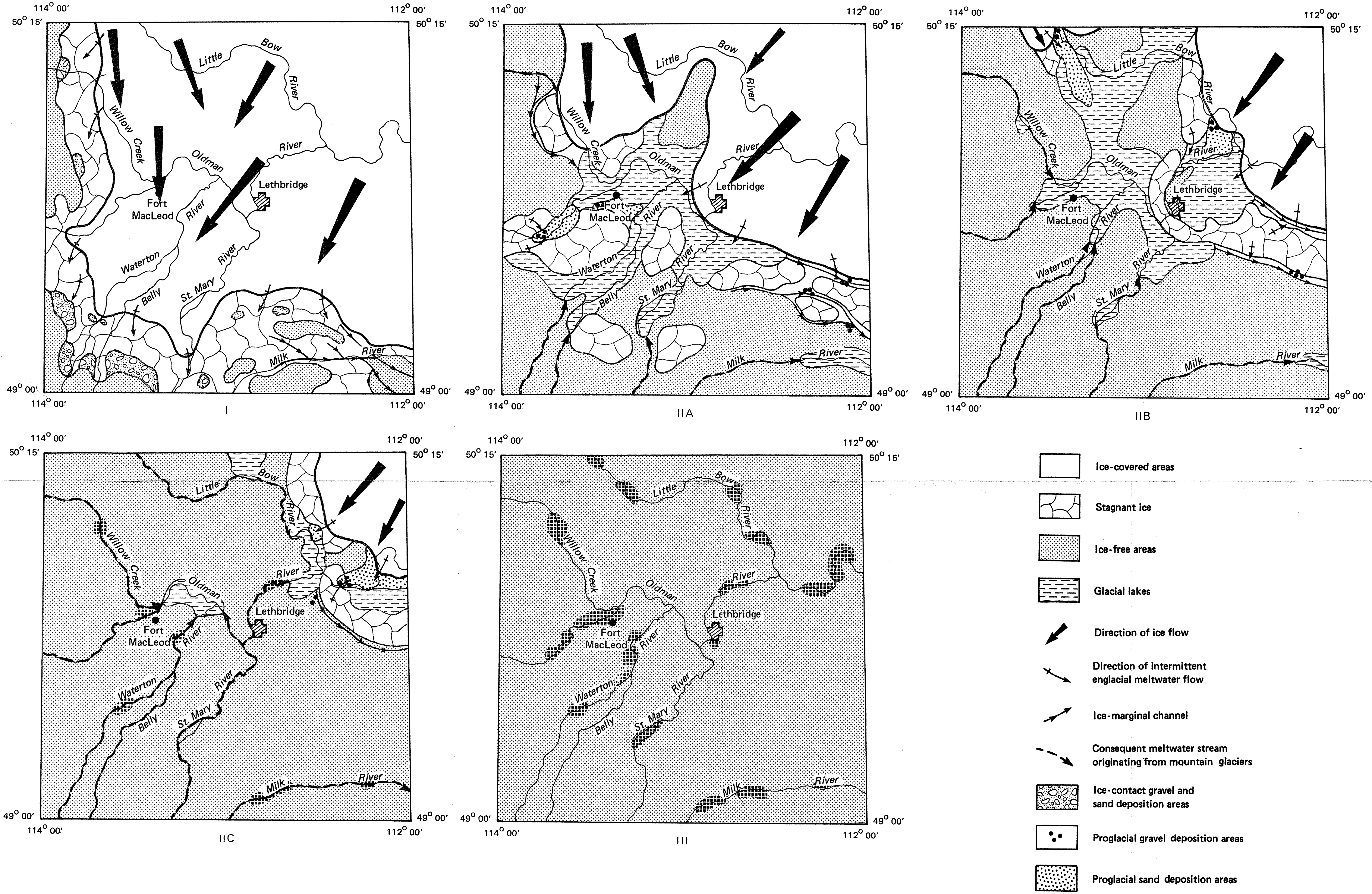

FIGURE 6 Deglaciation of Lethbridge area. I Incipient stage; II Intermediate stage/ A, B and C — successive sub-stages of ice retreat, with A representing the oldest/; III Final stage

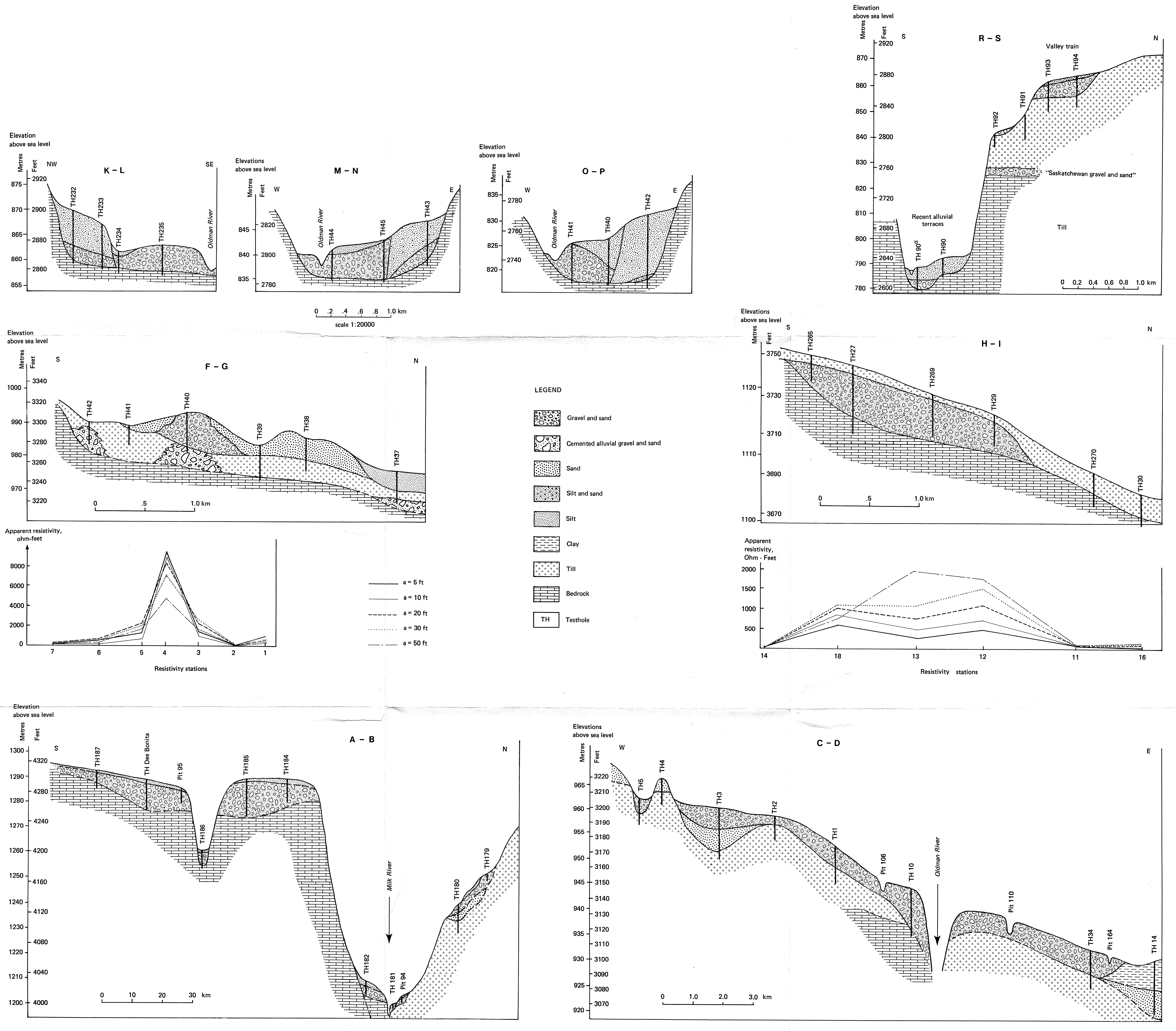

FIGURE 19. Geological profiles