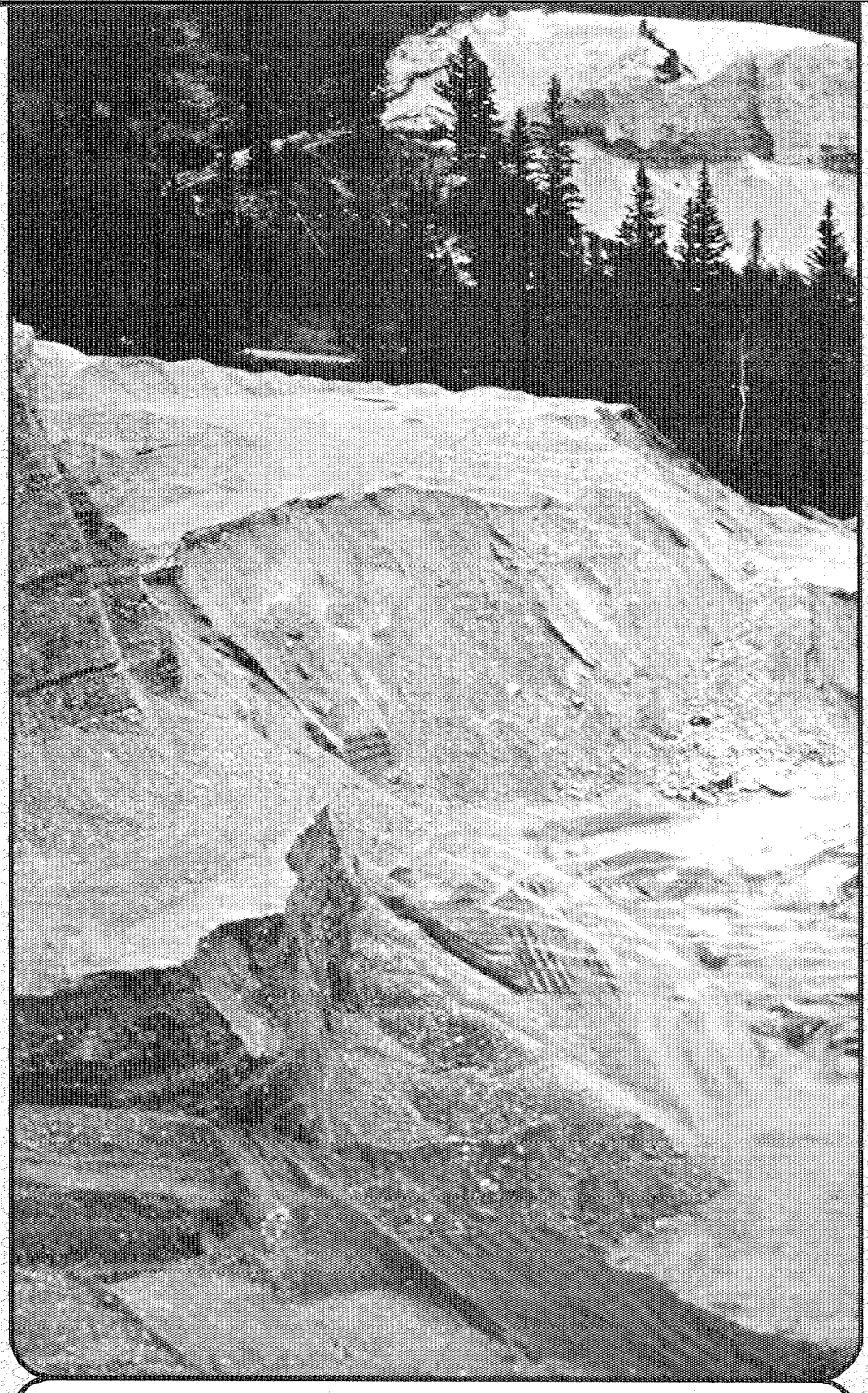
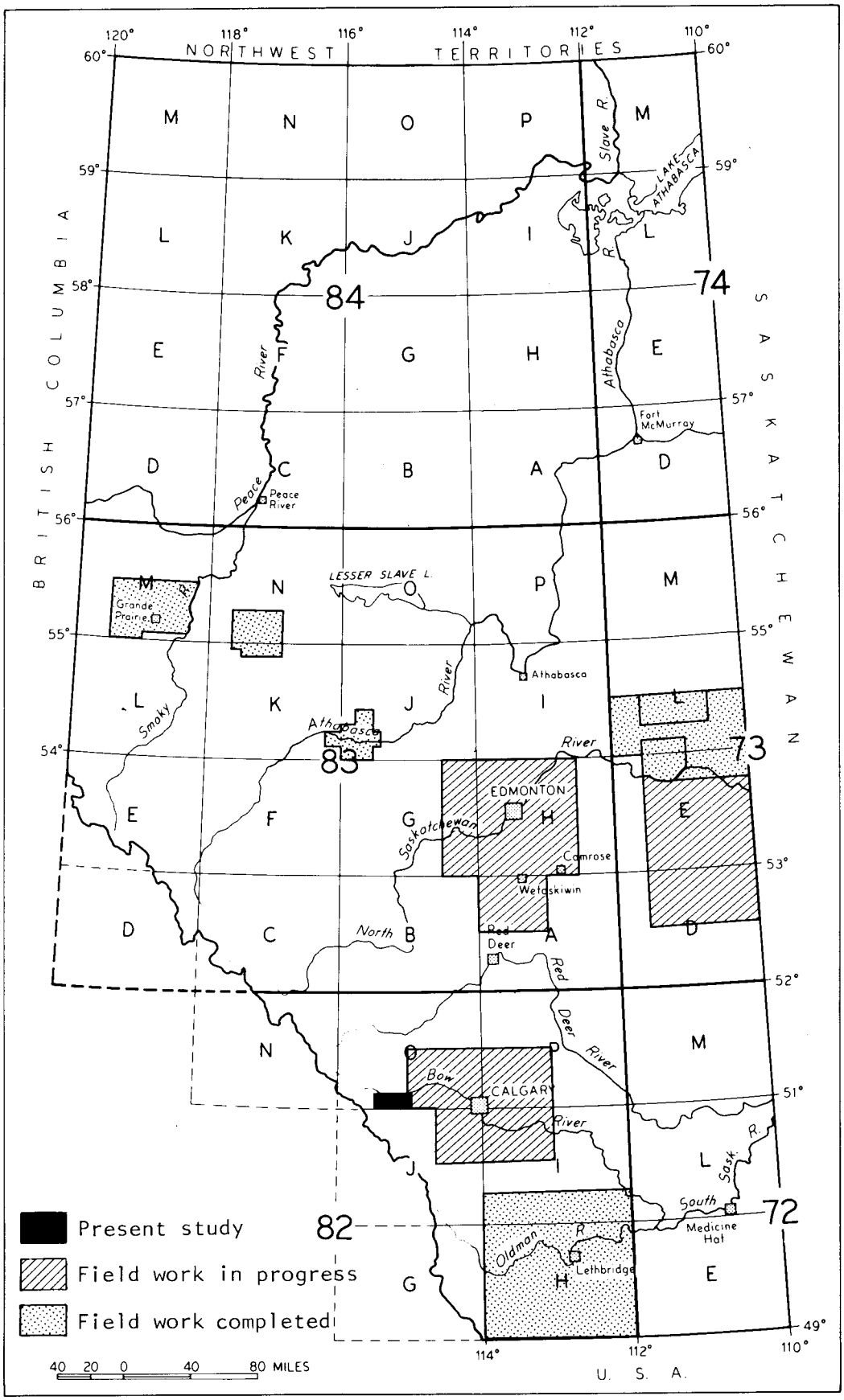


Earth Sciences Report 79-2

SAND AND GRAVEL DEPOSITS IN THE CANMORE CORRIDOR AREA, ALBERTA

W.A.D. Edwards

Alberta
RESEARCH COUNCIL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Sand and Gravel Deposits in the Canmore Corridor Area, Alberta

W.A.D. Edwards

Alberta Research Council
1979

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Price: $3.00

Editing: A. Campbell
Manuscript Production: D. Goodson, D. Harnden, M. Maduro
Drafting: R. Toth

Errata

Page 20: In the "terrace" section, the phrase (after sand and gravel) should be (usually sand and gravel).

Page 25: *Site E76-17. (17-24-24-10-5)* should be *E76-15 (2-24-24-10-5).*

Page 26: *Site E76-17* should be *Site E76-15.*

CONTENTS

ILLUSTRATIONS

FOREWORD

This report is one of a series intended to provide information on the sand and gravel resources of Alberta. This information can provide a starting point for detailed exploration programs and can aid planners in making decisions involving land use.

This survey is concerned with delineating and describing presently exploitable deposits and identifying deposits with future potential. The deposits described are mappable at a scale of 1:50,000, have a thickness of at least 1 m, and have a ratio of overburden to gravel and sand of no more than 1:1. Volume or tonnage figures are general estimates based on a geological interpretation of the deposits and not detailed subsurface data.

W.A.D. Edwards

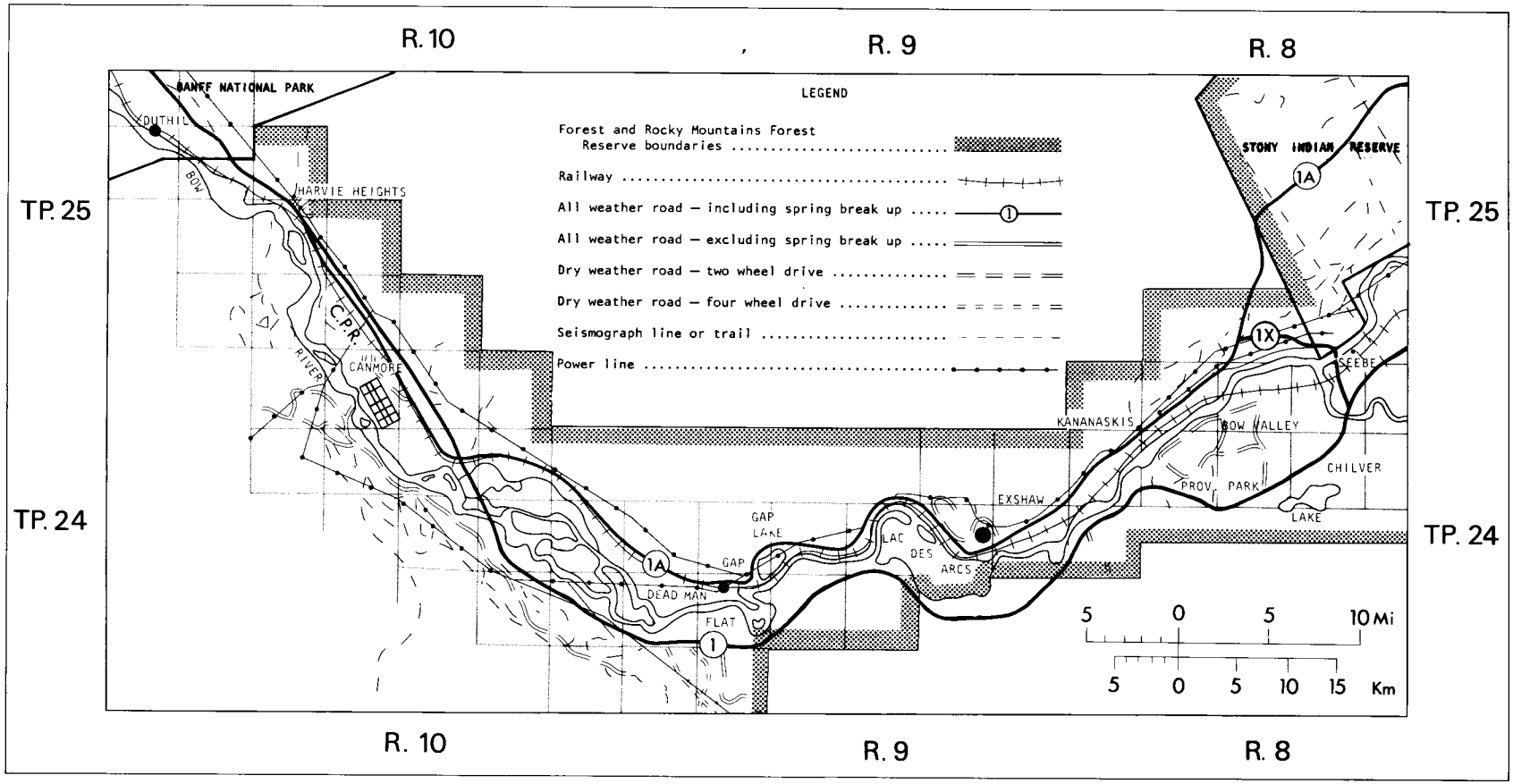

FIGURE 1. Geographic map of the Canmore Corridor

SAND AND GRAVEL DEPOSITS IN THE CANMORE CORRIDOR AREA, ALBERTA

INTRODUCTION

This report, *The Sand and Gravel Resources of the Canmore Corridor*, is the first of a series of reports which discuss the sand and gravel resources of the province of Alberta.

LOCATION

The Canmore Corridor is situated in the Bow River valley between the Stony Indian Reserve and the boundary of Banff National Park (Fig. 1). The area is located in NTS map area 82/0/3 (51°02' to 51°08' N. latitude and 115°03' to 115°26' W. longitude) and within Tp. 24, R. 8, 9, and 10 and Tp. 25, R. 8, 10, and 11 W. 5th Mer.

The town of Canmore occupies a central position in the Corridor and the Trans-Canada Highway and the Canadian Pacific Railway are major transportation arteries through the valley.

PREVIOUS WORK

Bedrock geology of the Canmore area was mapped by the Geological Survey of Canada (R.A. Price, 1970a and 1970b) at a scale of 1:50,000. The surficial geology of the area was studied by N.W. Rutter as his Ph.D. thesis (1965) and the results have been published in Geological Survey of Canada Bulletin 206 (Rutter, 1972).

METHODS OF STUDY

The surficial geology map produced by Rutter (1972) at a scale of 1:50,000 was used as a base for further mapping. During August, 1976, and May, 1977 field investigation and air-photo interpretation were used to define areal boundaries of units having sand and gravel potential. Samples of 10 to 15 kg (22 to 33 lb) were collected at this time for grain size and lithologic analyses. Bulk samples ranging in size from 170 to 585 kg (374 to 1287 lb) were collected in April, 1978 from the important sand and gravel units to obtain representative grain size distributions (Fig. 2). The industrial classification shown in Appendix A was used to categorize the coarse-grained sediments. The Wentworth scale was used to describe the sediments in sections (Appendix B) and from drillholes (Appendix C).

Subsurface data were collected by hammer seismic, resistivity, and rotary drilling methods. The hammer seismic and resistivity methods were used in September, 1976 at sites inaccessible to the drill and at sites close to drillholes for stratigraphic control. A Mayhew 1500 rotary rig using a rock bit and drilling mud was used to drill 27 holes during October, 1976.

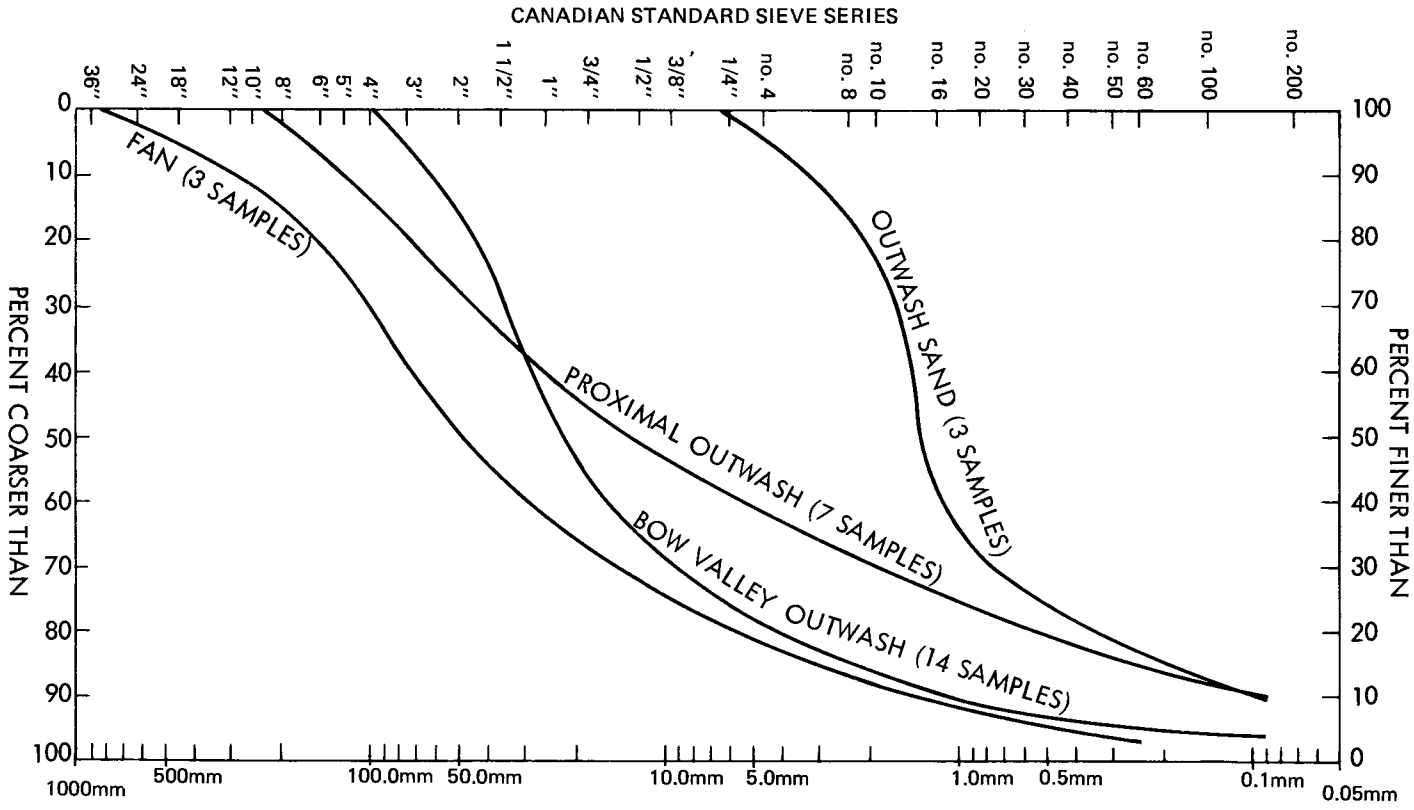

FIGURE 2. Cumulative curves showing grain size distribution of major sand and gravel types in the Canmore Corridor.

Sites were selected to test the depth of gravel-bearing units, to define the geology in the area, and to delineate deposits.

Most of the data are shown in figures 3 and 4 and recorded in Appendixes B and C.

GEOLOGY

BEDROCK GEOLOGY

The Canmore Corridor is situated in the Front Ranges of the Rocky Mountains. The Bow River valley parallels the structural grain in the western part of the Corridor but swings around to cut perpendicularly across the ranges in the eastern part. The ranges consist principally of resistant carbonates of Mississippian and Devonian age. The valley floors and lower slopes are composed of weaker clastic rocks of Mesozoic age. Lithologically the ranges and valleys can be divided as follows (after Price, 1970a, 1970b):

Mountain Ranges

(1) Mississippian - limestone and shale
(Rundle Group, Banff, and Exshaw Formations)

(2) Devonian - dolomite and limestone
(Palliser and Alexo Formations, Fairholme Group)

Valley Floors and Lower Slopes

(1) Jurassic and Cretaceous - shale and sandstone
(Kootenay Formation, Fernie Group)

(2) Triassic - shale and siltstone
(Sulphur Mountain Formation)

(3) Permian and Pennsylvanian - sandstone, dolomite and chert
(Rocky Mountain Group)

Most of the gravel in the Corridor is formed of durable carbonate clasts. Also present is a low percentage of quartzitic clasts which are probably derived from the Lower Cambrian Gog Group that outcrops farther up the valley to the west.

SURFICIAL GEOLOGY

The key to understanding the location, composition, and quality of the sand and gravel in the Canmore Corridor is the glacial geology (Figs. 3 and 5).

Rutter (1972) recognized three major glacial events in the Corridor which he called the pre-Bow Valley advance, Bow Valley advance, and Canmore advance.

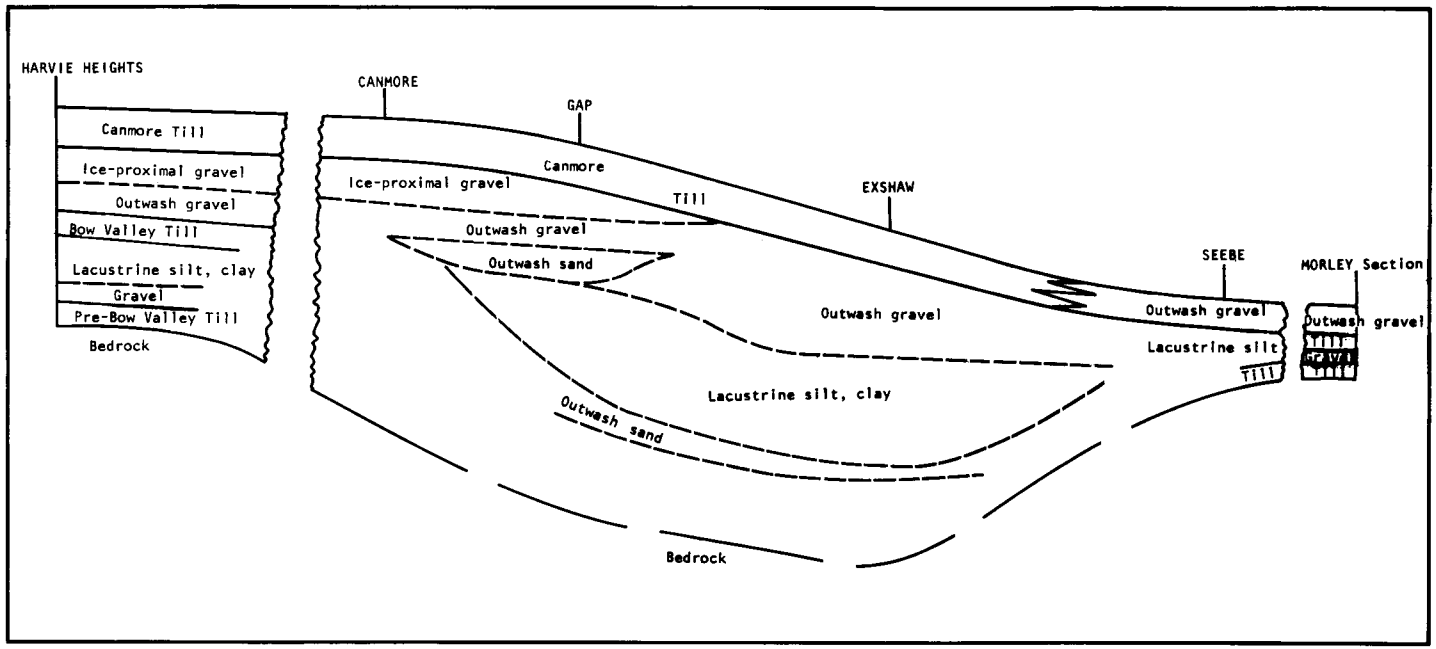

FIGURE 5. Glacial stratigraphy of the Canmore Corridor

Pre-Bow Valley Deposits

Pre-Bow Valley till was penetrated in a hole at Harvie Heights (Rutter and Wyder, 1969) and may be seen in section 4.8 km (3 miles) southwest of Morley. No significant glaciofluvial or fluvial deposits of pre-Bow Valley age (that is, prior to the Bow Valley advance) were found.

Bow Valley Deposits

A gray-brown silty sandy till was penetrated in three drillholes between Harvie Heights and Canmore and was described in section west of Harvie Heights (Rutter, 1965). The till was deposited by the Bow Valley advance and is overlain by outwash gravel (Fig. 5). Between Canmore and Kananaskis thick outwash sand and gravel and lacustrine sediments are found which are classified as Bow Valley sediments although Bow Valley till was not encountered.

Bedrock in the Seebe area is higher in elevation than the floor of the Bow River valley and acted as a sill which ponded meltwaters in the valley as the Bow Valley ice retreated. The lake depression was filled with thick lacustrine and outwash sediments, and these thick outwash deposits are the best source of sand and gravel in the Corridor.

Canmore Deposits

A stony, brown, silty sandy till is traceable as the surface unit along the north side of the valley from Harvie Heights to Gap. This till was deposited during the most recent or Canmore glacial advance. East of Kananaskis the surface unit is cobbly outwash and ice-contact materials deposited at or beyond the terminus of the Canmore ice.

The surface till exposed east of Seebe and the upper till at the Morley section are probably the Bow Valley till showing through the Canmore outwash.

Recent Deposits

The Bow River and intermittent streams have deposited most of the alluvium in the Corridor.

Well-sorted gravel bars are present in the river, and fine-grained floodplain sediments on either side of the main channel mask alluvial or outwash gravel. Numerous alluvial fans are forming on the valley sides and major fans extend onto the valley floor at Canmore and Exshaw. Eolian sand is found in a small area along the south shore of the Bow River, 3.2 km (2 miles) east of Exshaw (Rutter, 1972).

SAND AND GRAVEL

The sand and gravel deposits which outcrop in the Canmore Corridor are shown in figure 3. For descriptive purposes the deposits have been divided into six groups based on the type of deposit, relative age, and potential as a source of sand and gravel. These groups are:

(1) Bow Valley outwash sand (map unit 2)
(2) Bow Valley outwash gravel (map unit 3)
(3) Bow Valley ice-proximal outwash dirty sandy gravel (map unit 4)
(4) Canmore outwash and ice-contact gravel (map units 6 and 7)
(5) Recent Bow River bar and floodplain deposits (map unit 12)
(6) Recent alluvial fan gravel (map unit 11)

Each class is described in the following discussion. The location and extent of each unit is discussed and shown (Figs. 3 and 4). Present exploitation is noted and the resource potential of the deposits are estimated.

BOW VALLEY OUTWASH SAND

Description

Outwash sand (Plate 1) outcrops along Highway 1A west of Steel Brothers quarry road (Fig. 4). At the Steel Brothers pit (site E76-14) 15 m (50 ft) of medium to coarse sand with pebbles is exposed (Plate 2). The total thickness of the unit in this area is in excess of 30 m (100 ft). The unit coarsens upward from interbedded fine sand and silt to medium and coarse sand with occasional pebbles and pebble beds. Figure 2 shows the grain size distribution for the sand from this pit. The sand contains a high percentage of quartz with rare coal particles. Grains are subrounded to rounded. Beds are horizontal to gently dipping and are ripple-marked and cross-bedded. The lower boundary is gradational into finer-grained lacustrine sediments and the upper boundary is marked by a change over an interval of about 5 m (16 ft) into well-sorted outwash gravel.

These sediments were deposited by meltwater flowing down valley. The upward coarsening indicates that the velocity of flow increased with time, probably as the Canmore ice advanced. Cross-bed orientations are highly variable and indicate an anastomosing pattern of braided channels. Sedimentation was probably confined by the valley walls and may be considered a valley train deposit.

Extent

Outwash sand is exposed only near the Steel Brothers pit. West of the outcrop area the sand dips below the outwash gravel. The outwash-lacustrine sequence in the eastern part of the valley is extremely thick, up to 360 m (400 ft), but lies at or below river level.

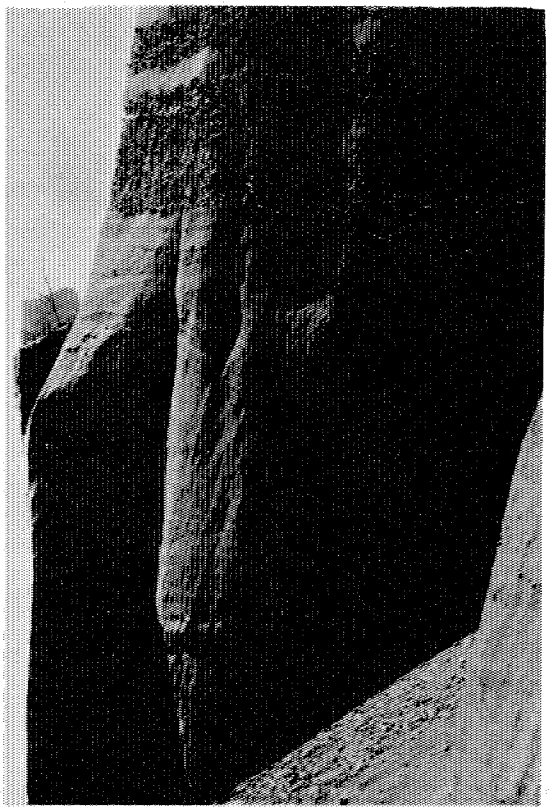

PLATE 1. Bow Valley outwash sand at site 14

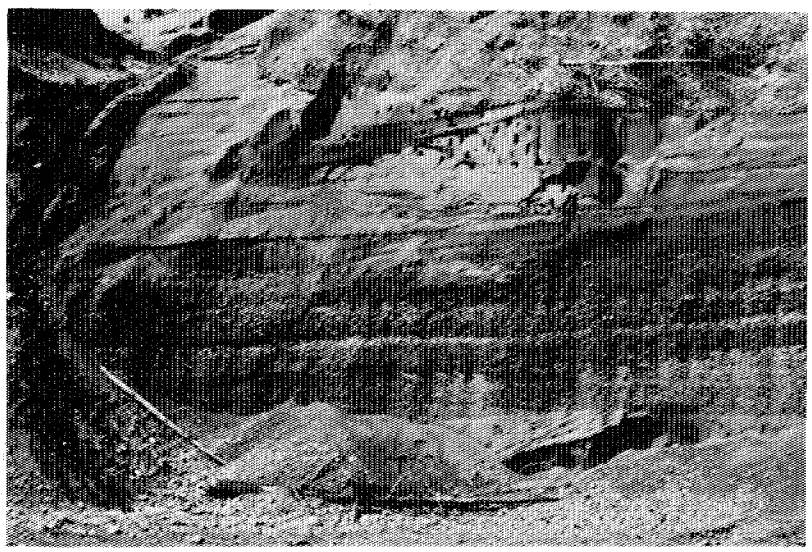

PLATE 2. Bow Valley outwash sand at Steel Brothers pit

Resource Potential

In general the outwash sediments in the Corridor contain a higher percentage of gravel than sand; therefore, the presence of medium to coarse sand in the Bow Valley outwash is valuable.

The amount of outwash sand in the Corridor is estimated (see Foreword) to exceed 14 million m^3 (18 million yd^3). About 10 percent of this is above water table (that is, between site E76-12 and site E76-14 on Fig. 4) and would be useful if extracted along with the overlying outwash gravel which exceeds 15 m (50 ft) in thickness.

BOW VALLEY OUTWASH GRAVEL

Description

Outwash gravel crops out on the north side of the valley between Canmore and the Steel Brothers quarry and on the south side near the Canmore power house.

The outwash is composed principally of gravel [60 to 80 percent in the 9.5 to 76.2 mm (3/8 to 3 in) size range] with little or no material greater than 152 mm (6 in); (see Fig. 2). The gravel is clean, well-sorted, and formed of planar and cross-bedded units which vary in thickness from 15 cm to 2 m (6 in to 6 ft) (Plate 3). The gravel generally contains 60 percent limestone clasts, 20 percent dolomite, and 20 percent clasts of other rock types (quartzite, sandstone, and chert). The majority of clasts are rounded [average 0.55 on the Krumbein (1941) scale] with only the chert pebbles being subangular to subrounded. The underlying formation is outwash sand and the upper is dirty (ice-proximal) outwash sandy gravel. Both boundaries are gradational.

The gravel was deposited in a fluvial environment. The source of sediment and water is interpreted to be the retreating Bow Valley ice or the advancing Canmore ice. The well-sorted nature of the deposit and the rounded clasts suggest the ice was distant.

Extent

Outwash gravel appears to extend from Harvie Heights to Steel Brothers pit (site E76-14). Between Canmore and Harvie Heights the outwash is 6 to 12 m (20 to 40 ft) thick and covered by dirty outwash sandy gravel and, in some places, till. From Canmore to Burnco's pit (site E76-10) the gravel is thicker, up to 25 m (80 ft), and better exposed (Fig. 4). At the Steel Brothers pit (site E76-14) the outwash gravel is only 9 m (30 ft) thick and both the upper and lower contacts can be seen.

Overburden cover (till) increases rapidly towards the valley wall and will limit extraction in this direction.

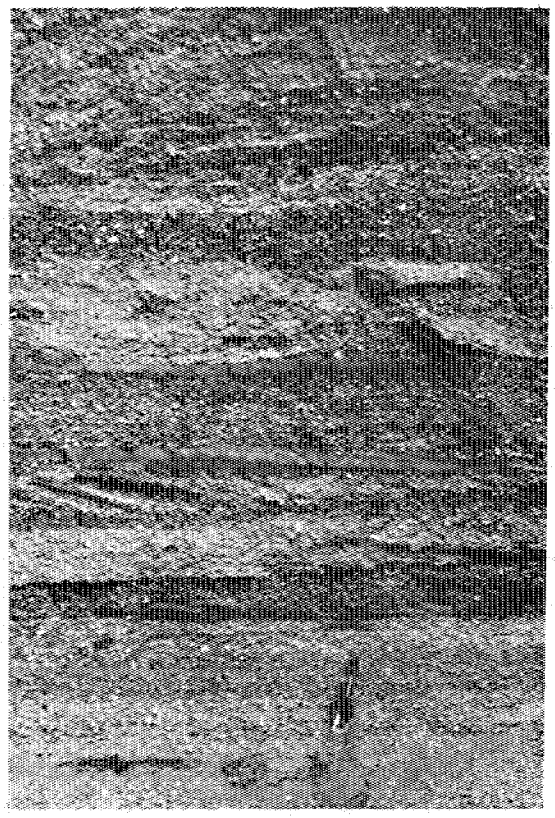

PLATE 3. Bow Valley outwash gravel at site 9

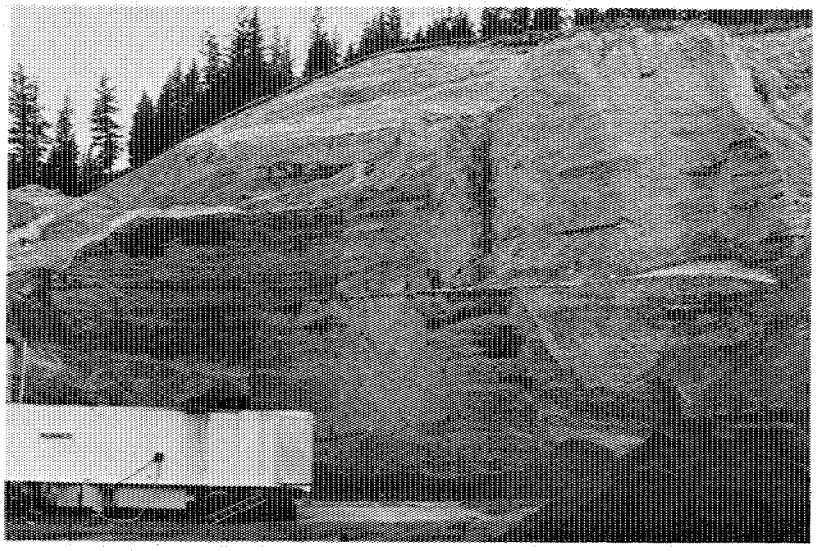

PLATE 4. The Burnco pit

Resource Potential

This outwash represents the best source of sand and gravel in the Canmore Corridor with the major reserves found along a 3.2-km (2-mile) section along Highway 1A, 5 km (3 miles) east of Canmore. The large scale map (Fig. 4) shows this area and the four pits which are presently located in it.

The Burnco operation (site E76-10) was the largest in the Corridor at the time of investigation (Plate 4). The pit is situated along the edge of a terrace-like deposit of outwash where the material has little overburden and is easily extracted. Little oversize material [greater than 152 mm (6 in)] is encountered and the percentage of fines is low except when included till blocks or the overlying dirty ice-proximal sandy gravel is mined. Cementation of the gravel is a minor problem.

A community pit (site E76-11) is located immediately north of the Burnco pit, towards the mountain side. Overburden is a problem and 9 m (30 ft) of till caps the gravel on the northwest side of the pit.

The Alberta Transportation pit (site E76-12) and the Steel Brothers pit (site E76-14) were not operated during 1976. The Alberta Transportation pit (Plate 5) could yield large quantities of gravel after stripping up to 3 to 4.5 m (10 to 15 ft) of till. The Steel Brothers pit has a maximum thickness of 9 m (30 ft) of quality gravel with an overburden thickness of up to 4.5 m (15 ft).

Over 6.8 million m^3 (9 million yd^3) of outwash gravel is estimated to be available in the terraces along Highway 1A under relatively thin overburden. An additional 1.5 million m^3 (2 million yd^3) of outwash may be present under overburden which is 3 to 15 m (10 to 50 ft) thick. The total estimate of 8.3 million m^3 (11 million yd^3) represents the volume of sand and gravel with an overburden:gravel ratio of 1:1 or less.

BOW VALLEY ICE-PROXIMAL OUTWASH DIRTY SANDY GRAVEL

Description

Ice-proximal outwash dirty sandy gravel crops out along stream cuts and terrace bluffs on the north side of the valley from Harvie Heights to the Steel Brothers quarry road.

The unit generally carries 5 to 10 percent fines, 5 percent oversize materials and 50 to 60 percent gravel (Fig. 2 and Plate 6). Limestone clasts form 70 percent of the pebbles, dolomite 20 percent, and other rock types 10 percent. Limestone and dolomite pebbles are subrounded to rounded (average 0.5 on the Krumbein scale). Bedding is poorly developed

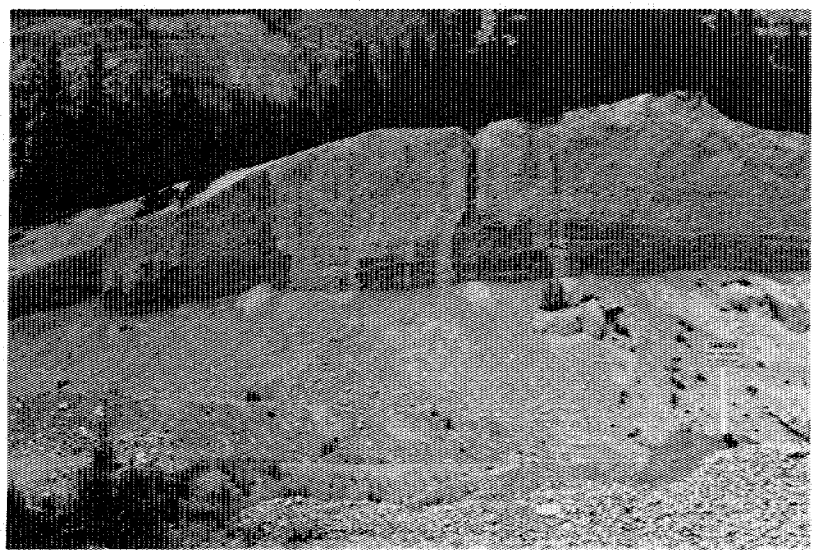

PLATE 5. The Alberta Transportation pit

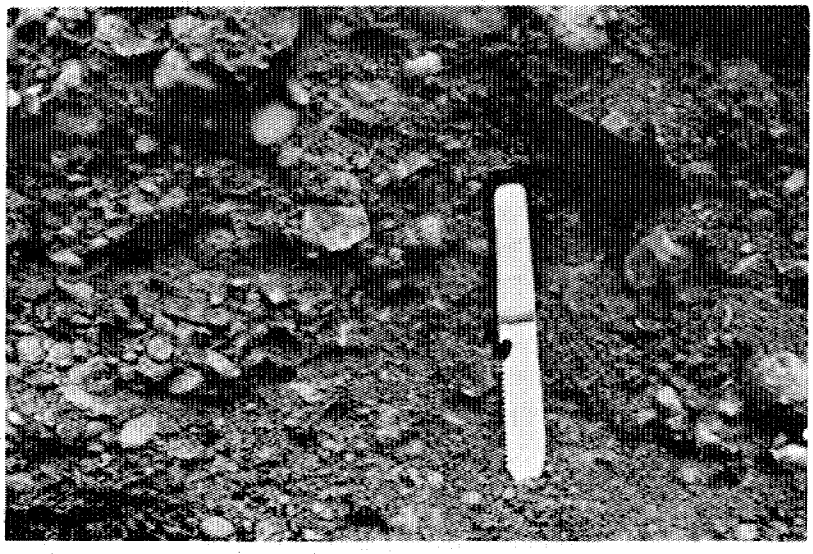

PLATE 6. Dirty gravel in the community pit

and often difficult to detect because of a light brown coating which commonly covers sections. This film is due to fine material which washes out of the section and runs down the face. The lower contact is gradational into clean outwash gravel. Dirty and clean beds alternate in a zone which can be as thick as 5 m (15 ft). The upper contact is with the sandy Canmore till (Plate 7).

A coarsening upward sequence, from outwash sand to outwash gravel to dirty sandy gravel, and a decrease upward in degree of sorting and clast roundness indicates that Canmore ice was gradually approaching. This sequence is completed by the Canmore till which denotes the actual overriding of the outwash sediments by ice.

Extent

As much as 30 m (100 ft) of moderately to poorly sorted gravel and sand are present at site E76-9 at the edge of the terrace (Fig. 4). The unit thins eastward and at sites E76-14 and E76-15 only 6 to 12 m (20 to 40 ft) of dirty sandy gravel are present. In the Harvie Heights area 9 to 18 m (30 to 60 ft) of poorly sorted sandy gravel are present with up to 3.5 m (12 ft) exposed in section.

Till overburden caps most of the proximal outwash. Along the terraces east of Canmore the till thickness varies from less than a metre near the margin of the terrace to 18 to 21.5 m (60 to 70 ft) towards the mountain side.

Resource Potential

Although the upper part of the dirty sandy gravel (possibly 10 to 30 percent) contains excessive amounts of fine material, the lower part requires only screening and minor crushing to produce good quality gravel. The Burnco, Alberta Transportation, and Steel Brothers pits all exploit dirty sandy gravel along with the underlying well-sorted outwash gravel. The primary physical restriction to development of the dirty material is the increasingly thick overburden which exists north of the terrace edge. This is the problem already encountered in the community pit (site E76-11, Fig. 4). The Kernick pit (site E76-5) was operating in poorly sorted outwash in 1977 and supplied pit run material for fill in Canmore (Fig. 3).

More than 3.8 million m^3 (5 million yd^3) of gravel and sand may be present in the lower part of the dirty sandy gravel along the margin of the terraces where overburden would not present serious problems. An additional 3 million m^3 (4 million yd^3) of sandy gravel is found under 4.5 to 7.5 m (15 to 25 ft) of till overburden. A total of 5.1 million m^3 (9 million yd^3) of dirty sandy gravel is present with an overburden:gravel ratio of less than 1:1.

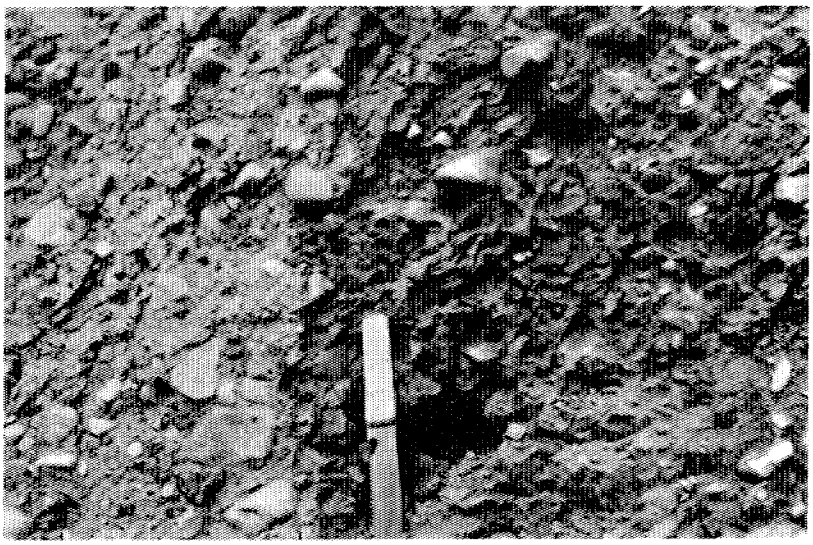

PLATE 7. Canmore till in the community pit

PLATE 8. Alluvial fan gravel at site 7

CANMORE OUTWASH AND ICE-CONTACT GRAVEL

Description

Outwash, pitted outwash, and ice-contact deposits cover most of the eastern end of the Canmore Corridor (Fig. 3). The outwash is present as wide channels through higher, more irregular pitted outwash and ice-contact deposits.

The Canmore outwash is slightly coarser than the Bow Valley outwash (Fig. 2) but the pebble lithologies and degree of clast roundness are similar. The pitted outwash contains numerous kettles and is littered with rounded to well-rounded quartzite cobbles. Kames and short esker segments (ice-contact deposits) can be found in a number of places within the pitted outwash. The ice-contact deposits are less sorted than the outwash and sediments range in size from silt to boulders.

The absence of till on the surface and the presence of glaciofluvial deposits suggest the Canmore ice advanced to the end of the valley but did not extend far beyond.

Extent

The outwash and ice-contact deposits cover an area of about 2300 ha (5700 acres) with a thickness which varies from 3 to 15 m (10 to 15 ft) but averages 4.5 to 6 m (15 to 20 ft).

Resource Potential

This deposit contains a very large volume of gravel - about 99 million m^3 (130 million yd^3). About 10 percent of the material is over 76 mm (3 in) in size and would require crushing. Because the deposit is thin and covers a large area, its use as a gravel resource would conflict with other land uses. At present 35 percent of the total area underlain by gravel, representing about 34 million m^3 (45 million yd^3) of material, can be excluded from consideration as a resource because it includes land occupied by major roads and the Bow Valley Provincial Park.

Four pits (sites E76-17, E76-18, E76-20, and E76-21) are located in this area but all were inactive in 1976-77 (Fig. 3).

BOW RIVER CHANNEL AND FLOODPLAIN DEPOSITS

High quality gravel deposits are present along the Bow River in the form of alluvial bars. Restrictions to the development of this gravel because of environmental considerations and the presence of alternative sources make these deposits of no immediate value as a resource.

Wide floodplain deposits exist in the western half of the Corridor. Areas of gravel certainly exist within and under the fine surficial materials but at present the uncertain quantity and quality and the cost of extraction of material situated below the water table make floodplain areas of little value for gravel extraction.

ALLUVIAL FAN GRAVEL

Description

Numerous alluvial fans are present on the valley sides with major fans extending out onto the valley floor (Fig. 3). Fan formation is the result of sedimentation by intermittent streams which issue from adjacent mountain slopes. The material within the fans is of local origin (95 to 100 percent limestone), poorly sorted [35 percent greater than 7.5 cm (3 in)] (Fig. 2), and angular (about 0.45 on the Krumbein scale) (Plate 8). Fans vary in thickness from 1.5 to 3 m (5 to 10 ft) near the toe in minor deposits to 15 m (50 ft) or more in major fans such as the one east of Canmore.

Extent and Resource Potential

Fans occupy a large proportion of the surface area of the valley and their total volume is very large; however, the material would require extensive crushing and screening before it could be used. Other restrictions to development include the unknown effect of disturbing the surface and groundwater movement through the fan.

A few borrow pits were operated in fans during the construction of Highway 1.

Fans will probably not be used as a source of gravel until the more exploitable outwash deposits have been exhausted.

CONCLUSIONS AND RECOMMENDATIONS

The Canmore Corridor is rich in sand and gravel. Four areas could be utilized as gravel resources: the outwash terraces east of Canmore, the outwash plain at the east end of the Corridor, gravel bars in the Bow River, and alluvial fans.

The outwash terraces contain an estimated 16 million m^3 (21 million yd^3) of high quality gravel of which 75 percent is under overburden less than 3 m (10 ft) thick. The deposit is only 5 km (3 miles) from Canmore and is the closest deposit to Banff outside the Park boundaries. Access to the terraces is easy from Highway 1A. The high quality, large volume, lack of physical constraints on extraction, and the location of this deposit make the terraces the prime choice for gravel extraction.

The outwash plain contains a very large volume of good quality material. However, the deposit encompasses a large area, one third of which is already restricted from gravel development because of conflicting land use. The deposit is farther from both Canmore and Banff than the terraces and haul costs would be higher than from the terraces.

Extraction of gravel from the Bow River is restricted because of environmental concerns and the presence of alternative sources. No detailed investigation of river gravel was made and the deposit is not presently considered a resource.

Alluvial fans contain a large volume of coarse gravel in the form of numerous thin blanket-like deposits. Considerable expenditure would be necessary for developing this source and processing the gravel. Fans are unlikely targets for development as long as the better quality outwash deposits are available.

ACKNOWLEDGMENTS

This project is part of the Sand and Gravel Inventory of Alberta being conducted by the Alberta Research Council. Funds for this project were supplied by the Department of Energy and Natural Resources.

I would like to thank P. Salamon for his assistance in the field and the laboratory, J.M. Edwards for her assistance in the field, and E.A. Babcock and R. Green for their critical reading of the manuscript.

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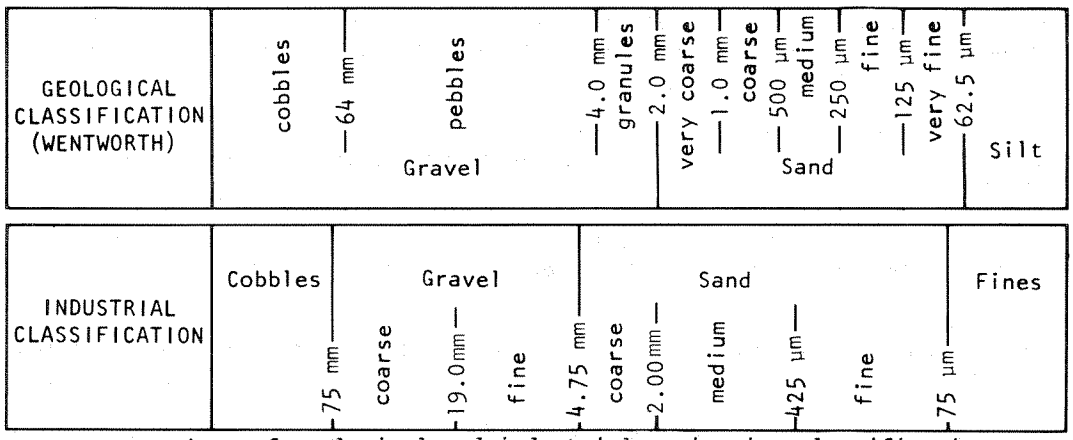
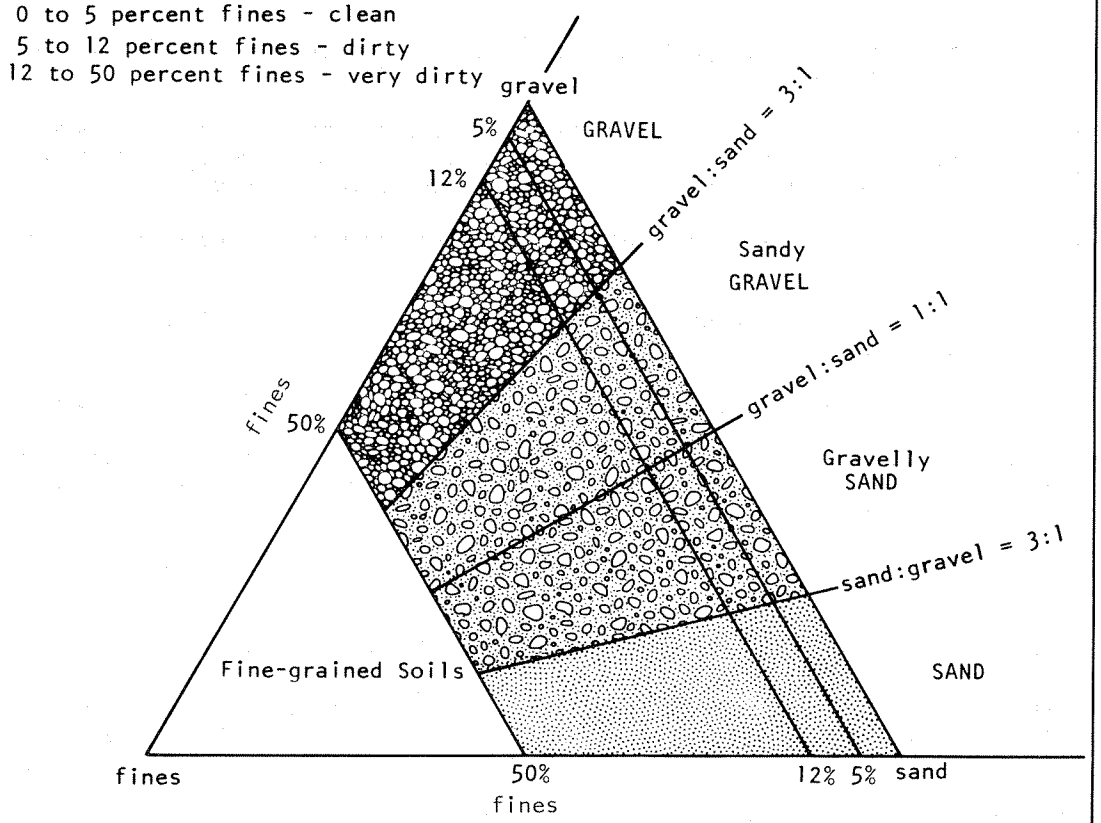
APPENDIX A

DEFINITION OF TERMS



Comparison of geological and industrial grain size classifications

0 to 5 percent fines - clean
5 to 12 percent fines - dirty
12 to 50 percent fines - very dirty



Classification of unconsolidated sediments (coarse-grained fraction) - after the Unified Soil Classification System

APPENDIX A (continued)

GLOSSARY

alluvial - pertaining to material deposited by running water.

alluvial bar - a ridge-like accumulation of sand, gravel, or other alluvial material formed in the channel (or former channel) of a stream where a decrease in velocity induces deposition.

alluvial fan - a flat to gently sloping stream deposit shaped like an open fan, formed wherever a constriction in a valley abruptly ceases or the gradient of the stream suddenly decreases.

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.

borrow pit - an excavated area where earth material (sand, gravel, etc.) is taken for use as fill (for example, embankment material) at another location.

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

chert - a hard, extremely dense, dull to semi-vitreous sedimentary rock with a tough, splintery to conchoidal fracture; may have various colors; some chert reacts when cemented to weaken the concrete, may be considered deleterious.

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

clay - a rock or mineral fragment or detrital particle of any composition having a diameter less than 1/256 mm (Wentworth scale).

cobble - a rock fragment having a diameter in the range of 64 to 256 mm (Wentworth scale).

cross-bedding - an internal arrangement of layers in stratified material characterized by minor beds or laminae inclined to the original depositional surface and produced by swift currents of air or water.

deposit (sand, gravel, aggregate) - an accumulation of sand or gravel or both left by a natural process or agent, usually wind, water, or gravity.

dirty gravel - said of gravel that contains between 5 and 12 percent fines.

dolomite - a sedimentary rock containing more than 90 percent of the mineral dolomite and less than 10 percent calcite; usually forms a good aggregate material, often used to make crushed stone.

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.

fines - sediment with particle diameters less than 0.075 mm.

floodplain - the strip of relatively flat land adjacent to a river channel which is covered with water when the river overflows its banks at times of high water; built of alluvium (usually sand, silt, and clay) carried by the river during floods and deposited in the sluggish water beyond the swifter current in the river channel.

fluvial - pertaining to rivers or streams.

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.

gravel - naturally occurring rock or mineral fragments larger than 4.75 mm in diameter; an unconsolidated, natural accumulation of granular material which contains more than three parts gravel for every part sand.

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

ice-proximal outwash - that part of an outwash deposit formed nearest to, but not in contact with, the glacier margin.

kame - a steep-sided irregular mound, hill, or knob deposited in contact with glacier ice by meltwater; may be poorly sorted to sorted; irregularly stratified; composed of sand and gravel and occasional till blocks.

kettle - a steep-sided, usually basin- or bowl-shaped depression without surface drainage in glacial drift deposits (especially outwash), often containing a lake or swamp, and believed to have formed by the melting of a large block of stagnant ice that had been buried in the glacial drift.

limestone - a sedimentary rock containing more than 95 percent of the mineral calcite and less than 5 percent dolomite; usually forms a good aggregate material, often used to make crushed stone.

outwash - a glaciofluvial deposit formed in front of the margin of glacier ice; a pitted outwash deposit is a deposit whose otherwise flat surface is marked by many irregular shallow depressions.

pebble - a small, roundish rock fragment having a diameter in the range of 4 to 64 mm (Wentworth scale); synonym: gravel.

plain - a flat to gently undulating surface.

poorly sorted - said of a sediment that is not sorted or consists of particles of many sizes mixed together in an unsystematic manner so that no one size class predominates.

quartz - crystalline silica, an important rock-forming mineral: SiO_2, and a very common mineral which forms the major proportion of most sands; generally colorless, vitreous in luster and hard (7 on Mohs' scale).

quartzite - a sedimentary or metamorphic rock consisting of quartz grains or crystals cemented with secondary silica such that the rock breaks across or through the grains rather than around them; an excellent aggregate material, highly resistant to weathering and very hard.

ripple mark - an undulatory surface consisting of alternating small-scale ridges and hollows formed at the interface between a fluid (air or water) and incoherent sedimentary material (especially sand) by the flow of the fluid and trending at right-angles to the direction of flow of the fluid.

sand - naturally occurring rock or mineral fragments larger than 0.75 mm in diameter and smaller than 4.75 mm; an unconsolidated, natural accumulation of granular material which contains more than three parts sand for every part gravel.

sandstone - a clastic sedimentary rock composed principally of fragments of sand size (usually quartz) united by a cementing material (commonly silica, iron oxide, or calcium carbonate); an excellent to poor aggregate material depending on the strength of the cementing bond, and the amount of weathering it has been subjected to, and the reaction of the rock to weathering.

sandy gravel - an unconsolidated, naturally occurring granular material which contains a ratio of gravel to sand between 3:1 and 1:1 (50 to 75 percent gravel).

shale - a fine-grained sedimentary rock formed by the consolidation of clay, silt, or mud, and characterized by finely stratified structure; shale is generally soft but sufficiently indurated so that it will not fall apart on wetting; a poor aggregate material because of its softness and fissility.

silt - a rock or mineral fragment or detrital particle having a diameter in the range of 1/256 to 1/16 mm (Wentworth scale).

siltstone - an indurated or somewhat indurated silt having the texture and composition but lacking the fine lamination or fissility of shale; a poor to fair aggregate depending on the hardness of the rock.

terrace - a large bench or step-like ledge breaking the continuity of a slope and marking a former water level; terrace commonly denotes an aggradational form contained in a valley, composed of unconsolidated material (after sand and gravel).

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

valley train - outwash confined within a valley.

well sorted - said of a sorted sediment that consists of particles all having approximately the same size.

APPENDIX B

DESCRIPTIONS OF MAJOR SECTIONS

Site E76-9. (3-26-24-10-5). Northwest side of Route 1A and 4.8 km (3 miles) southeast of Canmore. Section described August, 1976 from top to base.

Unit	Thickness (m)	Cumulative Thickness (m)	Description
Top	1.5	1.5	moderately sorted gravel beds (15 to 30 cm thick); 50 to 60 percent pebbles; mode 2 to 5 cm; maximum 15 cm - SAMPLE 9A
	0.5	2.0	fine gravel; 90 percent pebbles; mode 2 cm; maximum 5 cm
	4.0	6.0	gravel in faint 10 to 15 cm thick beds and two 1 m thick massive beds; 75 to 90 percent pebbles; mode 2 to 5 cm; maximum 25 cm; beds planar; pebbles flat-lying - SAMPLE 9B
(A)	2.0	8.0	alternating thin beds (fine gravel) and thick (1/2 m) beds of gravel; mode 2 to 5 cm; maximum 10 to 15 cm; clasts subrounded to well-rounded; beds planar; some pebble imbrication
	2.0	10.0	as above (A); slightly finer; mode 2 to 4 cm; one discontinuous sand lens
	2.0	12.0	5 to 50 cm thick gravel beds; 75 to 90 percent pebbles; mode 2 to 3 cm; maximum 20 cm; clasts subrounded to rounded - SAMPLE 9C
	2.0	14.0	cross-bedded gravel bed, well-sorted; 60 percent pebbles; mode 2 to 4 cm; some pea gravel lenses; openwork; mode 1 cm; flow direction from WNW to ESE; 20 cm lens of medium- to coarse-grained sand
	1.0	15.0	poorly sorted gravel bed; pebbles well-rounded; mode 1 to 4 cm; maximum 10 cm; silty sand matrix - SAMPLE 9D

Site E76-9 (continued)

Unit	Thickness (m)	Cumulative Thickness (m)	Description
	0.5	15.5	well-sorted gravel; 90 percent pebbles; mode 1 to 2 cm; maximum 5 cm; imbricate - SAMPLE 9E
	0.5	16.0	moderately sorted gravel beds (20 to 30 cm thick); mode 1 to 3 cm; maximum 6 cm; one 10 cm silty sand lens
	2.0	18.0	moderately sorted gravel bed; mode 1 to 2 cm; maximum 10 cm; medium sand matrix; one 0.5 cm sand lens
Base	2.0	20.0	covered (base at Highway 1A level)

Site E76-10. *(16-23-24-10-5).* Burnco pit. Northwest side of Route 1A about 5.6 km (3 1/2 miles) southeast of Canmore. Section described August, 1976 from top to base.

Unit	Thickness (m)	Cumulative Thickness (m)	Description
Top	7.0	7.0	inaccessible for description; dirty gravel or till removed as overburden
	4.0	11.0	poorly-sorted ('dirty') gravel with silty sand matrix; sorting poor in large beds, moderately- to well-sorted in thinner beds; some planar stratification; clasts subangular to subrounded; coated with silty sand; pebble mode 2 to 5 cm; maximum 30 cm - SAMPLE 10A
(A)	4.0	15.0	cross-bedded gravel (outwash); well-sorted; 60 percent gravel; mode 1 to 3 cm; maximum 10 cm; clasts subrounded to well-rounded
	4.0	19.0	cross-bedded gravel; part of bar; as in (A) above

Site E76-10 (continued)

Unit	Thickness (m)	Cumulative Thickness (m)	Description
	2.0	21.0	100 cm bed of fine gravel; 60 percent pebbles; mode 1 to 3 cm; with 50 cm lens of cobbly gravel included; mode 15 to 25 cm; moderately sorted gravel bed; pebbles 75 to 80 percent; mode 3 to 5 cm; maximum 15 cm; subrounded to well-rounded - SAMPLE 10B
	1.0	22.0	cross-bedded, well-sorted gravel beds; mode 1 to 3 cm; openwork; contains pea gravel and coarse sand lens
	1.0	23.0	moderately to poorly sorted gravel; maximum 25 cm
Base	9.0	32.0	covered; base of pit about 26 m above railway

Site E76-12. *(16-23-24-10-5).* Alberta Transportation pit. Northwest side of Route 1A about 5.6 km (3 1/2 miles) southeast of Canmore. Section described August, 1976 from top to base.

Unit	Thickness (m)	Cumulative Thickness (m)	Description
Top	2.5	2.5	moderately stony, sandy till
	6.5	9.0	poorly-sorted gravel ('dirty' gravel); with silty sand matrix, faint bedding
	8.0	17.0	clean, well-sorted gravel; coarse gravel beds 10 cm to 1 m thick; pebble mode 2 to 5 cm; maximum 35 cm; subrounded to rounded; pea gravel beds 2 to 10 cm thick; SAMPLE 1.5 m above base of unit
Base	14.0	31.0	covered; base of pit about 24 m above railway

Site E76-14. (2-24-24-10-5). Steel Brothers pit. Northwest side of Route 1A about 7.2 km (4 1/2 miles) southeast of Canmore. Section described in August and October, 1976 from top to base.

Unit	Thickness (m)	Cumulative Thickness (m)	Description
Top	3.0	3.0	silty sandy till or flow till?; compact; blocky; subangular to subrounded striated clasts
(A)	2.0	5.0	moderately-to poorly-sorted gravel; sandy matrix; pebble mode 5 cm; maximum 25 cm; gravel 45 percent; sand 40 percent, fines 15 percent; one discontinuous sand lens
	2.0	7.0	as above (A)
	2.0	9.0	moderately- to well-sorted gravel and sand beds; beds 20 to 40 cm thick; range from pea gravel beds to pebbly sand beds (10 to 15 percent pebbles); bedding evident
	2.0	11.0	faintly bedded; pea gravel beds to gravel beds; mode 3 to 5 cm; maximum 15 cm; 75 percent gravel
	2.0	13.0	moderately- to well-sorted gravel beds; moderately-sorted - mode 5 to 8 cm; maximum 20 cm; 50 to 60 percent gravel; well-sorted - mode 5 to 8 cm; maximum 15 cm; 80 to 90 percent gravel; little matrix
	2.0	15.0	moderately-sorted gravel; bedding indistinct; mode 3 cm; maximum 12 cm; 70 percent gravel - SAMPLE 14A
	2.0	17.0	moderately- to well-sorted gravel; mode 2 to 3 cm; maximum 10 cm; 75 to 85 percent gravel; sand lenses (up to 50 cm thick); cross-bedded
	1.0	18.0	cross-bedded pea gravel; mode 0.5 to 1 cm; sand matrix

Site E76-14 (continued)

Unit	Thickness (m)	Cumulative Thickness (m)	Description
	5.0	23.0	well-sorted, cross-bedded sand; compact; medium grained
	4.0	27.0	medium- to coarse-grained sand; 10 to 50 cm cross-beds
	2.0	29.0	massive-looking medium-grained sand; very compact; faint cross-beds (2 to 10 cm); lenses (2 to 5 cm long) of coarse sand and granules; lenses containing coal particles
	4.0	33.0	medium sand; few pebbles; faintly cross-bedded
	3.0	36.0	well-sorted sand and gravel in beds 30 to 60 cm thick; gravel mode 1 to 2 cm; maximum 5 cm; 60 to 65 percent pebbles; pebbles well-rounded; planar beds
Base	2.0	38.0	coarse- to medium-grained sand; well-sorted; some pebbles along lag surface of large trough; base of pit about 3 m above railway

Site E76-17. *(17-24-24-10-5).* North side of Steel Brothers quarry road about 7.2 km (4 1/2 miles) southeast of Canmore. Section is oblique but described vertically from top to base in August, 1976.

Unit	Thickness (m)	Cumulative Thickness (m)	Description
Top	1.0	1.0	loamy soil
(A)	5.0	6.0	yellow-brown stony sandy till; blocky fracture; clasts subangular; striated; maximum 1 m
	2.0	8.0	gullying, no exposure
	2.0	10.0	as above (A)

Site E76-17 (continued)

Unit	Thickness (m)	Cumulative Thickness (m)	Description
	2.0	12.0	massive, poorly-sorted gravel beds with minor well-sorted beds; pebbles subrounded; mode 3 to 5 cm; maximum 25 cm; partially cemented
	1.0	13.0	coarse- to fine-grained sand in form of a trough 1 m deep, 6 m wide; rippled; truncated by 75 cm thick well-sorted gravel bed
	1.0	14.0	poorly-sorted gravel bed; appears to wedge out
	1.0	15.0	trough-bedded sand with pebble lag on eroded surface
(B)	1.0	16.0	poorly-sorted, dirty gravel; pebbles 65 to 80 percent; mode 3 to 5 cm; maximum 25 cm
	4.0	20.0	gullying, no exposure
	2.0	22.0	as above (B)
	2.0	24.0	interbedded dirty and clean gravels, as described in (B) and (C)
(C)	2.0	26.0	moderately- to well-sorted, clean gravel; pebbles 60 to 70 percent; mode 2 cm; maximum 6 to 8 cm
	2.0	28.0	well-sorted, clean gravel; beds 10 to 20 cm thick
	3.0	31.0	coarse-grained sand; well-sorted cross-bedded
Base	2.0	33.0	covered

APPENDIX C

DRILLHOLE LOGS

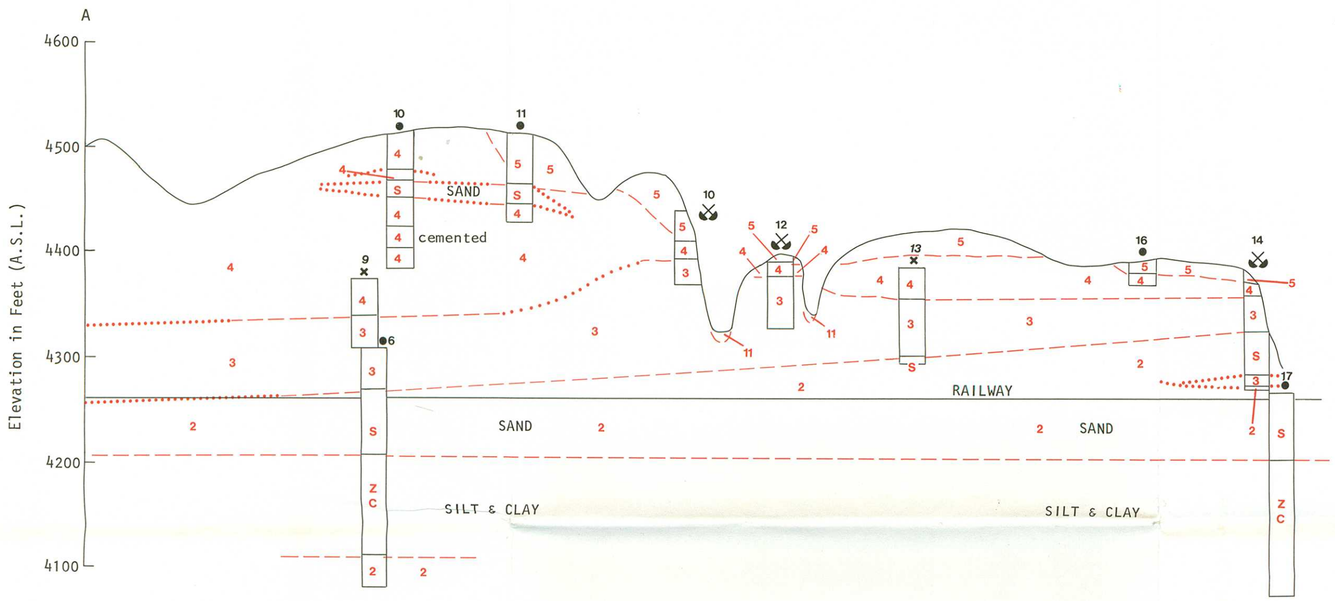
The logs for these holes were made by on-site description of the cuttings and by the drilling rate as registered on a geolograph (ft/min).

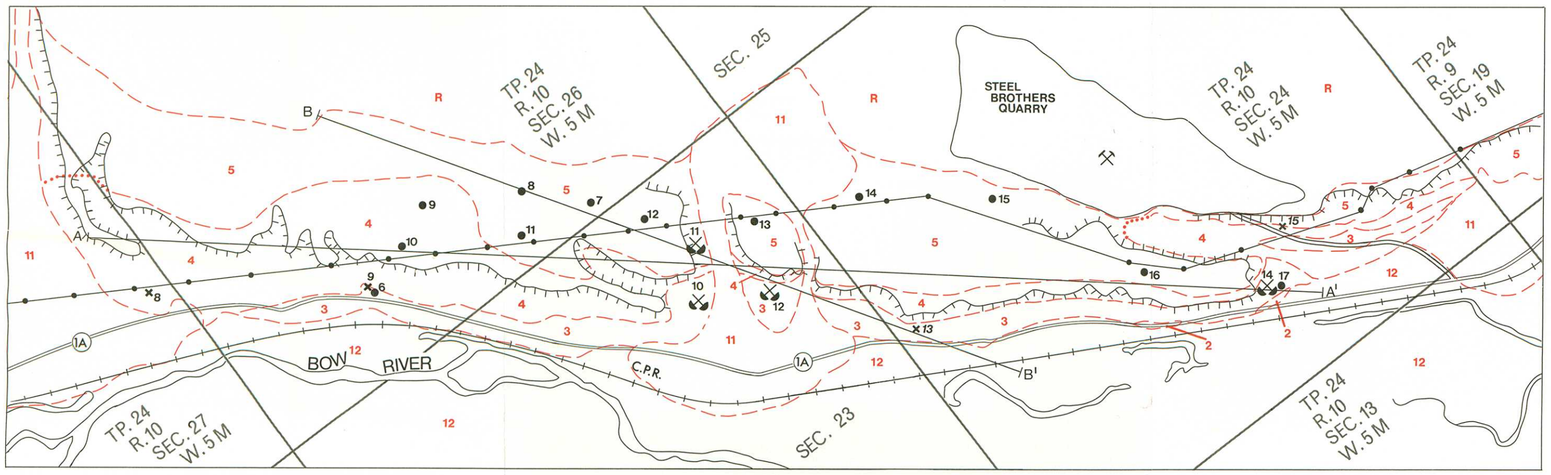
Drill Hole Number	Depth (ft)	Description
DH-76-1	0-15	coarse, poorly-sorted gravel
	15-27	stony sandy till
	27-35	poorly-sorted, coarse gravel ('dirty' gravel)
	35-58	well-sorted gravel (outwash)
	58-67	stony sandy till
	67-89	poorly-sorted gravel
DH-76-2	0-11	silt with some pebbles (floodplain)
	11-15	poorly-sorted gravel
	15-38	clean, well-sorted gravel (outwash)
DH-76-3	0-30	medium to coarse gravel and sand
	30-40	interbedded gravel and sand
	40-52	sand with gravel beds
	52-67	shale
DH-76-4	0-39	coarse, poorly-sorted gravel
	39-58	well-sorted sand and gravel (outwash)
	58-72	poorly-sorted, medium to coarse gravel
	72-86	silty sandy till
	86-108	clayey silt with very fine sand and pebbly sand beds
	108-125	interbedded gravel and sand
	125-150	fine to medium sand with gravel, silt beds
	150-164	sand and gravel
	164-189	poorly-sorted, coarse gravel
DH-76-5	0-36	coarse, well-sorted gravel

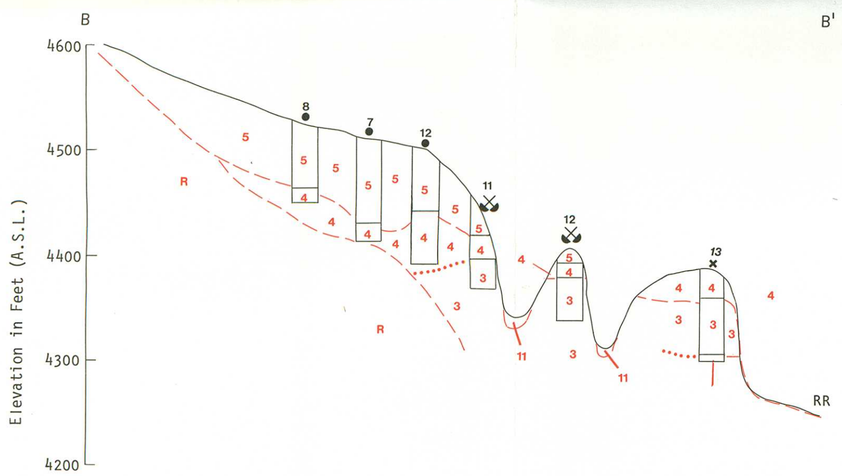
Drill Hole Number	Depth (ft)	Description
DH-76-6	0-41	well-sorted gravel and sand (outwash)
	41-51	pebbly sand
	51-95	medium to fine sand
	95-110	sand and silt
	110-199	clayey silt with some interbedded sand
	199-231	sand and gravel (outwash)
DH-76-7	0-98	stony sandy till
	98-100	limestone
DH-76-8	0-64	stony sandy till
	64-78	coarse gravel and sand
DH-76-9	0-16	moderately-sorted gravel ('dirty' gravel)
	16-52	well-sorted gravel (outwash)
DH-76-10	0-35	poorly-sorted gravel ('dirty' gravel)
	35-60	interbedded sand and gravel
	60-88	poorly-sorted gravel
	88-104	sand and gravel
	104-132	poorly-sorted, partially cemented gravel ('dirty' gravel)
DH-76-11	0-56	stony sandy till
	56-59	poorly-sorted gravel ('dirty' gravel)
	59-76	well-sorted, interbedded sand and gravel (outwash)
DH-76-12	0-80	silty sandy till
	80-114	till with interbedded sand and gravel
DH-76-13	0-30	sandy till
	30-48	poorly-sorted gravel ('dirty' gravel)
	48-58	interbedded clean and dirty gravel
DH-76-14	0-26	stony sandy till
	26-37	poorly-sorted gravel ('dirty' gravel)

Drill Hole Number	Depth (ft)	Description
DH-76-15	0-20	stony sandy till
	20-30	interbedded clean and dirty gravel
	30-135	sand and gravel (outwash)
	135-155	dirty sand and gravel
DH-76-16	0-14	stony sandy till
	14-25	sand and gravel
DH-76-17	0-29	sand with pebbles
	29-100	massive sand with minor silt beds
	100-164	interbedded sand and clayey-silt beds
	164-198	sand with minor silt beds
DH-76-18	0-25	medium to coarse gravel and sand
	25-44	weathered shale
DH-76-19	0-35	coarse gravel with minor silt
	35-57	pebbly sand
	57-80	interbedded sand and clay
	80-101	clay and weathered shale
	101-110	shale
DH-76-20	0-18	coarse gravel and sand (outwash)
	18-58	silty till with sandy silt beds
	58-98	till
	98-110	shale
DH-76-21	0-11	medium to coarse gravel (outwash)
	11-18	pebbly sand with silt and clay beds
	18-50	dirty gravel with silt and clay beds
	50-58	weathered shale
DH-76-22	0-30	fan gravel
	30-38	limestone
DH-76-23	0-15	fan gravel

Drill Hole Number	Depth (ft)	Description
DH-76-24	0-25	fan gravel
	25-41	stony clayey till?
	41-77	medium to coarse gravel with some silt
DH-76-25	0-25	fan gravel
	25-41	stony clayey till
	41-77	medium to coarse gravel
DH-76-26	0-18	stony sandy till
	18-38	medium to coarse gravel
DH-76-27	0-18	disturbed materials?
	18-41	stony till
	41-50	weathered shale







0 1000 2000 3000 FEET
0 500 1000 METRES

LEGEND
(Refer to Figure 3 for complete legend)

12 Bow River Channel and Floodplain Deposits: *gravel occurs as bars in the main river channel and buried beneath the fine floodplain deposits; severe restrictions to development in the form of water table problems and environmental restrictions.*

11 Alluvium and Fan Deposits: *coarse, angular gravel; mostly local limestone; poorly sorted and variable; restrictions to development include coarse grain size and semi-active nature of deposit. See figure 3 for grain size and lithologic data.*

5 Morainal Deposits: *stony sandy till*

4 Ice Proximal or Dirty Outwash: *poorly sorted outwash gravel, fines content may exceed 10 percent, especially near upper contact; can be exploited in conjunction with unit 3; main restriction to development is till overburden cover; more than 5 million cubic yards should be easily developed (in area of (Fig. 4).*

	Amount Retained on Canadian Standard Sieve (Wt. %)								Pebble Lithologies (%)				
	3"	1-1/2"	3/4"	#4	#10	#40	#200	<#200	Ls	Dol	Q-Ss	Cht	Sh
Site 8	10	9	23	25	4	23	3	3	68	28	4	-	-
Site 10	20	16	21	28	5	6	4	-	No Data				
Site 11	20	14	22	23	6	10	4	1	71	22	7	-	-
Site 12	25	14	20	25	4	5	6	1	No Data				
Site 13	15	22	23	23	4	5	7	1	63	32	5	-	-

3 Outwash: *very well sorted, clean outwash gravel; very low oversize and fines content; an estimated 9 million cubic yards with little overburden and 2 million cubic yards under 10 to 50 feet.*

	Amount Retained on Canadian Standard Sieve (Wt. %)								Pebble Lithologies (%)				
	3"	1-1/2"	3/4"	#4	#10	#40	#200	<#200	Ls	Dol	Q-Ss	Cht	Sh
Site 9	-	13	20	26	9	25	7	-	60	22	17	1	-
Site 9	-	26	24	25	4	3	18	-	57	26	14	3	-
Site 10	5	14	25	31	7	6	11	1	No Data				
Site 11	-	11	24	43	7	5	9	1	46	47	6	1	-
Site 13*	-	6	26	45	9	8	6	-	46	45	9	-	-
Site 14	5	10	31	33	7	4	9	1	62	30	7	1	-

*Bulk Sample

2 Outwash: *well sorted, clean sand; medium to coarse sand with pebble beds in upper part to fine and with silt in lower part of zone; limited exposure (see Fig. 3): 1 to 2 million cubic yards lies above water table in the area of figure 4 and could be exploited with the outwash gravel (unit 3).*

	Amount Retained on Canadian Standard Sieve (Wt. %)							
	3/4"	#4	#10	#40	#60	#100	#200	<#200
Site 14*	-	1	1	18	40	39	1	-

*Bulk Sample

R Bedrock

Abbreviations: Ls - *Limestone;* Dol - *Dolomite;* Q - *Quartzite;* Ss - *Sandstone;* Cht - *Chert;* Sh - *Shale*

Geological boundary:
approximate
assumed

Drill site ● 7

Sample and section site × 2

Line of cross section A — A'

Gravel pit

Quarry

Steep slope

Road

Railway

Power line

GEOLOGY BY W.A.D. EDWARDS

Alberta RESEARCH COUNCIL

To accompany
Alberta Research Council
Earth Sciences Report 79-2
by W. A. D. Edwards

FIGURE 4: Sand and gravel distribution in the area of Bow Valley outwash

LEGEND

POSTGLACIAL

12 Bow River Channel and Floodplain Deposits: *gravel occurs as bars in the main river channel and buried beneath the fine floodplain deposits; severe restrictions to development in the form of water table problems and environmental restrictions.*

11 Alluvium and Fan Deposits: *coarse angular gravel; mostly local limestone; poorly sorted and variable; restrictions to development include coarse grain size and semi-active nature of deposit.*

	Amount Retained on Canadian Standard Sieve (Wt. %)								Pebble Lithologies (%)				
	3"	1-1/2"	3/4"	#4	#10	#40	#200	<#200	Ls	Dol	Q-Ss	Cht	Sh
Site 6*	35	17	16	16	4	6	5	1	100	-	-	-	-
Site 7	35	11	16	19	6	11	2	-	95	5	-	-	-
Site 16	20	18	19	26	7	6	3	1			No Data		

*Bulk Sample

10 Colluvium, Talus and Landslide Deposits: *rock rubble and disturbed drift.*

9 Eolian Deposits: *thin, fine sand and silt.*

CANMORE ADVANCE

Glaciolacustrine

8 Glaciolacustrine Deposits: *sand, silt and clay.*

Glaciofluvial

7 Outwash (described below)

6 Pitted Outwash and Ice Contact Deposits: *extensive area of outwash plain, pitted outwash and ice contact deposits; outwash is well sorted, fining downward, depth varies from 10 to 20 feet; ice contact and pitted outwash more variable; restrictions to development include Bow Valley Provincial Park and other recreational land-uses; volume of aggregate (excluding Bow Park) may exceed 80 million cubic yards.*

	Amount Retained on Canadian Standard Sieve (Wt. %)								Pebble Lithologies (%)				
	3"	1-1/2"	3/4"	#4	#10	#40	#200	<#200	Ls	Dol	Q-Ss	Cht	Sh
Site 17	10	23	14	28	9	13	3	-	56	20	18	6	-
Site 18	22	9	50	15	-	3	1	-	59	18	22	1	-
Site 19	10	11	20	36	9	9	4	1	54	27	18	-	1
Site 20*	10	29	19	21	10	7	4	-	83	1	15	1	-

*Bulk Sample

Glacial

5 Morainal Deposits: *stony sandy till*

LEGEND

BOW VALLEY ADVANCE

Glaciofluvial

4 Ice Proximal or Dirty Outwash: *poorly sorted outwash gravel, fines content may exceed 10 percent especially near upper contact; can be exploited in conjunction with unit 3; main restriction to development is till overburden cover; more than 5 million cubic yards should be easily developed (in area of Fig. 4).*

	Amount Retained on Canadian Standard Sieve (Wt. %)								Pebble Lithologies (%)				
	3"	1-1/2"	3/4"	#4	#10	#40	#200	<#200	Ls	Dol	Q-Ss	Cht	Sh
Site 1	20	18	14	17	4	16	9	2	41	29	21	2	7
Site 2	20	7	22	26	8	10	7	-	73	14	13	-	-
Site 3	20	-	15	23	12	16	13	1	64	22	13	1	-
Site 4	20	10	19	25	7	8	10	1	72	19	9	-	-

Site 8, 10, 12, 13 - see large scale map (Fig. 4)

3 Outwash: *very well sorted, clean outwash gravel; very low oversize and fines content; an estimated 9 million cubic yards with little overburden and 2 million cubic yards under 10 to 50 feet. For results of samples from sites 9, 10, 11, 13 (bulk sample), see large scale map (Fig. 4).*

2 Outwash: *well sorted, clean sand; medium to coarse sand with pebble beds in upper part to fine and with silt in lower part of zone; limited exposure (see Fig. 4); 1 to 2 million cubic yards lies above water table in the area of figure 4 and could be exploited with the outwash gravel (unit 3). For sample results from site 14 (bulk sample), see large scale map (Fig. 4).*

Glacial

1 Morainal Deposits: *stony sandy till; drumlinized*

PREGLACIAL

R Bedrock

Abbreviations: Ls - *Limestone;* Dol - *Dolomite;* Q - *Quartzite;* Ss - *Sandstone;* Cht - *Chert;* Sh - *Shale*

Geological boundary

Sample site

Drillhole site

Area of large scale map (Fig. 4)

Gravel pit:
active
inactive

GEOLOGY AFTER N.W. RUTTER, 1972, MODIFIED BY W.A.D. EDWARDS

Drafting by R.M. Toth

Miles 1 0 1 2 3 Miles

Metres 1000 0 1000 2000 3000 4000 Mètres

To accompany
Alberta Research Council
Earth Sciences Report 79-2
by W. A. D. Edwards

FIGURE 3: Glacial geology and the sand and gravel distribution of the Canmore Corridor

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