Mineral Aggregate Commodity Analysis

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Foreword

This report is one of a series of mineral commodity profiles. Each profile represents a review and evaluation of a mineral, in a standard capsulate format that addresses the essential elements of a comprehensive resource analysis. It is intended to serve as a guide in the formulation of research and exploration programs and as support to resource management.

Commodities which have been profiled include dimension stone, gypsum, phosphate, silica, broken and crushed stone, platinum group elements, zirconium, limestone/dolostone, lead and zinc, sodium sulphate, and gold. These reports are available from Alberta Geological Survey Information Sales. The amount and quality of information available for any given section of the format may vary markedly with different commodities. The Mineral Aggregate Commodity Profile is relatively detailed. This is in large part due to the size, complexity, and regional variations of the mineral aggregate resource. This study had the advantage of time and support, which other commodity profiles did not, to gather data to supplement deficient aspects and investigate information of uncertain accuracy.

An overwhelming amount of literature exists on some aspects of mineral aggregate resources so this study focused on select publications relevant to Alberta. There were significant deficiencies in information at the provincial level. Some of these information deficiencies were addressed by gathering new data through a mail survey of mineral aggregate producers. Data from the mail survey only apply to the year 1991. Other data were contributed from geological studies underway as part of the MDA. The MDA projects contributing pre-publication data were: the Economic Development Sector project "Mineral Aggregate Data Base and Deposit Map Series" (Federally supported) and the Geoscience Sector project "Mapping and Resource Exploration of the Tertiary Formations of Alberta" (Provincially supported).

Abstract

The mineral aggregate industry in Alberta is composed of several thousand pits run by about 300 public and private sector producers. Total provincial production of sand and gravel in 1991 was 45 484 836 tonnes worth $153 226 689. This places Alberta fourth in total mineral aggregate production in Canada and second in sand and gravel production. The annual per capita consumption of mineral aggregate in Alberta for 1991 was 18.7 tonnes, considerably higher than the Canadian average of 10.4 tonnes.

Ninety-nine percent of the mineral aggregate produced in Alberta in 1992 was extracted from sand and gravel deposits. Sand and gravel deposit types which have produced mineral aggregate include: preglacial and Tertiary fluvial, post glacial fluvial (alluvial), glaciofluvial, glaciolacustrine, eolian, and colluvial deposits.

The preglacial deposits were deposited at various times over the last 50 million years by rivers flowing from the mountains. Preglacial deposits generally are gravelly or even cobbley, extensive, thick (may exceed 10 m in thickness) and can produce aggregate of high quality. They are ideal for hosting large operations and supplying major markets. Preglacial deposits supply both the Calgary and Edmonton markets. These deposits are critical resources and may become battlefields in land use conflicts. Preglacial deposits often require significant overburden removal and may require dredging or pumping water from the pit as preglacial deposits also may be aquifers.

Glaciofluvial deposits were formed by the deposition of sand and gravel from meltwater flowing in contact with glacial ice (ice contact deposits) or meltwater flowing away from glaciers (outwash). Outwash deposits producing mineral aggregate in Alberta include outwash plain deposits, valley train deposits, and meltwater channel deposits. Outwash deposits can be very large in size (>100 ha) and can contain huge volumes of material (>10 million m^3). They often are sandy. Valley train deposits are similar to outwash plain deposits in volume but may contain a higher percentage of gravel. Meltwater channel deposits represent small, but highly useful, sources of sand and gravel. Ice contact deposits which have produced mineral aggregate in Alberta include kames, kame terraces, eskers, and crevasse fillings. Ice contact deposits have a high to very high potential for the occurrence of granular materials, but some types (kames, crevasse fillings) may be very poorly sorted and difficult to mine.

Alluvial (post glacial fluvial) deposits were formed by the deposition of sand and gravel in Recent rivers as bars or terraces. Although the grain size distribution of alluvial deposits within Alberta is highly variable, coarse material from alluvial deposits can produce high quality aggregate. Alluvial deposits will decline in relative importance regardless of the amount of potential aggregate in them as a result of operating restrictions due to proximity to watercourses.

By-products such as silica, gold, platinum, garnet, and magnetite have been recovered from preglacial, glaciofluvial, and alluvial sands and gravels in Alberta. There is a need for research into more effective methods for the recovery of by-product minerals. The bedrock under the sand and gravel deposit and the overburden also should be evaluated for economic potential.

Very little information is published on the sand and gravel reserves available in Alberta. Sand and gravel deposits are mapped in level 3 detail for about 18% of Alberta (1:50 000 scale maps) and another 20% at level 4 (1:250 000 scale maps). Publications can be purchased

from Alberta Geological Survey Information Sales. Bedrock is not a major source of mineral aggregate produced in Alberta and with little immediate pressure to find bedrock aggregate sources very little mapping has been done to identify future bedrock sources.

This study includes a survey of producers to determine the size, value, and nature of the industry in Alberta for 1991. Sand and gravel is produced, transported, and used within various individual market regions. The greatest total consumption (production) is concentrated around Calgary and Edmonton, the two regions with the greatest population. The largest companies operate in the most populated regions. In Alberta, 4% of the producers mine 53% of the total production, and 66% of the provincial production comes from only 10% of the operators (those that mine over 250 000 tonnes annually). The greatest number of producers are situated in regions with intermediate populations. The average number of producers per region declines in a regular manner with decreasing population of the market region but the per capita consumption increases with decreasing population. Annual per capita consumption ranges from 67.5 tonnes for municipalities with less than 2500 people to 11.9 tonnes for the Edmonton and Calgary regions. The average cost of a tonne of sand and gravel at the pit was $3.37 in 1991. The less populated regions have a generally lower production cost than the heavily populated regions. The average cost for sand and gravel cited above does not include transportation. The transportation cost in many cases is greater than the cost of the mineral aggregate at the pit. Average maximum haul distance in Alberta regions was 42 km. Maximum haul distances ranged from 8 to 140 km.

All public and private sector producers surveyed were asked to estimate the number of years supplies of sand and gravel which they controlled. Half of all municipalities will be depleted of gravel in 20 years or less and of sand supplies in 21 years.

Increasingly important aspects in the ability of a company or municipality to open, develop, and operate a mineral aggregate pit or quarry are land use and environmental approvals. A major controversy erupted in the Calgary region during 1994 and 1995 over a proposed sand and gravel development. This case is typical of urban, land use controversies sparked by mineral aggregate developments around the world. This case is the most vehement confrontation to have taken place over mineral aggregate development in Alberta and it has most or all of the elements likely to be involved in other conflicts in the province. About one quarter of the mineral aggregate producers in Alberta say they have encountered situations where their efforts to mine an aggregate deposit were curtailed or prevented by land use or environmental restrictions. The restrictions which producers cited can be categorized into: residential opposition, environmental restrictions, regulatory restraints, and conflicting land use issues.

The restrictions due to residential opposition to mineral aggregate mining centre around concerns such as truck traffic, noise, and dust. Environmental restrictions are primarily due to the exclusion of areas to protect fauna, flora, or natural areas and restrictions due to proximity to a water course. Current regulations are mentioned in a significant number of responses. Some restriction to development comes through the loss of land to competing land uses(pipelines, road allowances, and construction of dwellings on land).

Concerns about both prevention of development and the potential harms of development are expressed from all parts of Alberta. These concerns are concentrated in the more densely settled areas of the province, particularly the Calgary region at this time. Concerns expressed revolve around a few key issues: the conflict between the need of the operators to develop close to the market and the desire of residents to defend their quality of life, protection of natural areas (particularly water courses) versus the desire of operators to maximize recovery from deposits, and the concern of all parties about the nature and enforcement of laws and regulations.

Alberta is fortunate in having ample natural supplies and complete control of the resource (no dependence on imports). Supplies are dwindling and signs are that a long term strategy must be designed soon if we are to sustain our mineral aggregate supplies.

First, it is essential to inventory our resources as most other provinces have done. There is no public accounting of mineral aggregate reserves. Although the amount of sand and gravel present apparently is vast, available reserves actually are much smaller and being consumed at twice the rate at which they are being discovered. No public mapping has taken place in Alberta for the last five years and existing resources are being removed from access through land use restrictions.

These resource data must be followed with a resource conservation strategy which identifies those resources to be preserved for the future. It is essential to understand our demand and use for mineral aggregate. An annual survey of all producers should be undertaken by the province in sufficient detail to enable regional resource evaluation. Decisions on the development of deposits which will affect more than one jurisdiction should have input from the province to aid the municipality in their land use decision.

This study is the first attempt to give a broad perspective on separate regions in Alberta. Alberta is not mature in terms of mineral aggregate: legislative procedures are incomplete, a resource inventory is not in place, and the industry and public concerns are still at a sparring stage. The mineral aggregate sector in Alberta is developing rapidly and the next 10 years will be critical in the development of a philosophy and procedures which will guide mineral aggregate development for many decades.

Acknowledgements

I would like to acknowledge the Alberta Geological Survey (formerly in the Alberta Research Council) and the Geoscience Sector of the Canada-Alberta Partnership on Minerals (MDA) for supporting this project.

I would like to thank Mrs. Shauna Miller (S.A.M. Geological Services). Without her computing expertise and ability to get things done, the mail survey, which was critical to this project, could not have been completed. She was able to combine digital data from three different Alberta departments into a single automated system for producing letters and forms for mailing to thousands of individuals. She then effectively entered all returning data into an utilitarian data base which fed not only this project but several associated projects as well.

Projects like this must all be proposed, evaluated, and defended. I would like to thank Mr. R. J. H. Richardson of the Alberta Geological Survey for taking this project forward and steering it through the Canada-Alberta Partnership on Minerals approval process. I would also like to thank Ms. Kathryn Wood of Alberta Energy for her co-ordination of the Canada-Alberta Partnership on Minerals projects.

The Alberta Sand and Gravel Association (ASGA) was most helpful in providing a general sense of the mineral aggregate industry in Alberta. I would particularly like to thank Mr. John Moquin, President of the ASGA in 1994, for the opportunity to attend an ASGA executive meeting and the ASGA Annual General Meeting. I also am indebted to Mr. Doug Badke, a consultant, who prepared a report and several pamphlets for the ASGA while this project was in progress. His information saved me considerable time.

Mr. Dale Fietz (ELAD Enterprises Inc.) was of great help in gathering data from the Municipal District of Rocky View Public Hearings and in editing the case study. Dale's considerable experience with the minerals industry and his familiarity with the Calgary scene made the case study possible.

Several other people helped along the way and deserve recognition: Dr. Don Scafe (AGS) for preparing and editing the manuscript, Mrs. Sherry Grolway for assisting with the mail survey, Mr. Tim Berezniuk, Mrs. Dianne Goulet, and Mr. Campbell Kidston for assisting Shauna in entering mail survey data into the data base.

Introduction

Background

Mineral aggregate is a multi-million dollar activity in Alberta. The actual size and value of the industry is uncertain. Natural Resources Canada (formerly Statistics Canada) is the traditional, sole source of data available for evaluating the aggregate industry in Alberta. The completeness of the Natural Resources Canada (NRCan) survey is disputed by members of industry and government. This study includes a survey of producers to determine the size and value of the industry in Alberta for 1991 and to test the accuracy of the on-going NRCan source of mineral aggregate data for Alberta.

The primary source of mineral aggregate in Alberta is sand and gravel deposits. Considerable information is published on the distribution and types of geological deposits which supply sand and gravel as mineral aggregate. This geological information is summarized briefly in this report. Depositional models for sand and gravel deposits are described in various geological reports. These models may be useful in locating new deposits. Exploration rules of thumb and clues are extracted from the models and included in this report.

Mineral aggregate is considered essential to develop and maintain our transportation infrastructure and for our construction industry. Understanding the availability and longevity of gravel and sand supplies is critical. This study uses data generated by producers and should provide a realistic estimate of the sustainability of sand and gravel as our major source of mineral aggregate.

Mineral aggregate commonly is mined, transported, and used in regions about the size of an Alberta county or municipal district. This study is the first attempt to give a broad perspective on separate regions in Alberta. True market regions are not defined in this study but a reasonable commodity overview is prepared by using existing municipal boundaries.

Presumed constraints to the development of sand and gravel deposits for mineral aggregate in Alberta are competition from other land uses and environmental restrictions. This study identifies examples of constraints to development which aggregate operators are experiencing. It is acknowledged that in many cases environmental concerns over mineral aggregate development are justified and that other land uses should take priority. The focus of this particular study, however, is on the development aspects of the mineral aggregate resource and those factors which may curtail exploitation of resource.

Definition of terms, grades, specifications

Aggregate is any mass of hard, inert materials used for the physical properties of good load bearing capacity in a bound or unbound condition, for the free draining nature, as biological or drainage filter media, in metallurgical and chemical applications, in protective uses, or for general fill. The term aggregate can include artificial, reclaimed, or recycled materials as well as natural rock or mineral fragments. The term mineral aggregate or natural aggregate is generally applied to rock fragments. Mineral aggregate includes natural (pit run), washed, crushed, or sized sand and gravel or crushed, washed, or sized quarried bedrock (rock, crushed stone, crushed rock). The natural properties of some materials can be altered by processing to make the material acceptable as aggregate. For example, clay or shale can be fired to increase the hardness or expanded to decrease the weight. Reclaimed or recycled materials are being used as substitutes for natural materials, especially in urban areas where these artificial materials are abundant. Such materials are called recycled aggregates and include recycled asphalt, concrete, broken brick, glass, rubber, and solid waste (Smith and Collis, 1993).

Most aggregate is used in the construction industry for such things as residential and commercial buildings, highways and roads, bridges, airports, and dams. Natural materials present in Alberta which could be used to produce mineral aggregate for the construction sector are listed in Table 1.

Aggregate also is used as an inexpensive material for protection from erosion by water (rip rap) or as well drained fill (usually fine sand) (Table 1). Some aggregates, generally bedrock formations, are used as sources of raw materials for the chemical and metallurgical industries. The chemical and metallurgical uses of aggregate are covered in reports describing commodities derived from limestone.

Table 1. Natural materials in Alberta which could be used for mineral aggregate uses.

Material	Source	Minimum Size	Maximum Size	Uses
sand	unconsolidated	0.075mm	4.75mm	1,2,3,4,5,6,7,8,9,10
gravel	unconsolidated	4.75mm	75mm	1,6,7,8,9,10,11,12,
cobbles	unconsolidated	75mm	200mm	12,13,14*,18
boulders	unconsolidated	>200mm		13,14*,18
crushed stone	bedrock	processed to size		1,2,4,6,7,9,10,11,12, 13,15,16,17,18

Uses: 1-road surfacing, 2-snow and ice control, 3-foundry sand casting, 4-glass manufacture, 5-abrasives, 6-filtration beds, 7-concrete (well graded mix of 45% sand, 55% gravel, 15% cement and water, 8-foundation drainage, 9-asphalt (well graded mix of sand and gravel (~equal) with 5-6% bituminous binder), 10-fill, 11-road base, 12-railway ballast, 13-rip rap, 14-source of crushed gravel, 15-fertilizer (calcium), 16-metallurgy, 17-cement and lime, 18-gabions (wire mesh baskets of rip rap used for erosion protection)

*Larger materials can, with processing, be reduced in size to produce material suitable for uses requiring finer natural materials; ie- crushing gravel, cobbles, or boulders can produce fine aggregate for use in ice control.

The final use for the aggregate determines the specific properties required and the specification tolerance. Detailed specifications for materials used in each part of the construction process are required for most projects. Guidelines to these specifications are not listed here but can be obtained from Alberta Transportation and Utilities or from the American Society for Testing and Materials (ASTM) manuals. The text by Smith and Collis (1993) is a good summary of aggregate testing. In general, desirable aggregate material is clean (uncoated), physically sound (resists weathering), hard, strong, is of the proper size, gradation, and shape, and has favourable chemical properties.

Industry setting

International industry

Mineral aggregate is produced world wide. In the U.S.A., and probably world wide, sand and gravel production (both value and tonnage) exceeds all other non-fuel mineral resources

(Harben and Bates, 1984). World production figures are not available but Table 2 is a list of the aggregate production from some countries (Badke, 1994; Smith and Collis, 1993).

Table 2. Construction aggregate production from select countries (Badke, 1994; Smith and Collis, 1993).

Country	Total Production (millions tonnes)	Per Capita Production (tonnes per capita)
Belgium	39	4.0
Denmark	39	7.5
Switzerland	43	6.2
Finland	58	11.6
Austria	84	8.4
Sweden	100	11.6
Spain	210	5.4
Great Britain	300	5.2
Italy	270	4.7
Canada	299	10.4
France	380	6.8
Germany	750	9.4
U.S.A.	1719	7.0

Although aggregate commonly is thought of as a local resource, there is an increasing international trade. Canada is involved in shipping mineral aggregate from our maritime provinces to destinations half a world away. In 1992 the primary destinations of exported construction aggregate were the United States (eastern seaboard, gulf coast, northwest seaboard, and Great Lakes regions), Bermuda, the Bahamas, and the Caribbean Islands. Exports in 1992 of sand, gravel and crushed stone for construction aggregate are shown in Table 3. An additional 1 650 556 tonnes ($13.5 million), primarily of crushed stone, was exported for other aggregate uses (mostly chemical and metallurgical) in 1992 (Vagt, 1994).

Exports of mineral aggregate for 1991 accounted for 0.9 % by tonnage (3 million tonnes of export in 317 million tonnes of total Canadian production) and 1.8 % by value ($24 million of exports in $1 331 million of total Canadian production value) of the total Canadian mineral aggregate production (Vagt, 1994).

Canada generally can supply its own internal needs. However, conditions such as regional shortages, proximity to the U.S.A., or the economics of marine backhaul make the importation of mineral aggregate practical. In 1991 total imports of mineral aggregate accounted for 1.3% by tonnage (4 million tonnes of import in 314 million tonnes of consumption) and 2.2% by value ($29 million of imports in $1 307 million of consumption) of the total Canadian consumption of mineral aggregate. Table 3 shows the source of aggregates entering Canada in 1992 (does not include metallurgical or chemical uses) (Vagt, 1994).

Table 3. Canadian exports and imports of sand, gravel and crushed stone for general aggregate use in 1992 (Vagt, 1994).

Destination/source	Exports (tonnes)	Exports ($000)	Imports (tonnes)	Imports ($000)
United States	1 990 760	11 880	1 145 899	10 283
Germany	-	-	416	12
Bermuda	56 846	514	-	-
France	97	22	437	6
Belgium	-	-	363	5
Bahamas	34 940	540	-	-
Caribbean	56 990	1 151	-	-
Japan	-	-	292	42
Philippines	-	-	4	....
United Kingdom	66	18	103	15
Other countries	187	54	993	23
Total	2 139 886	14 179	1 148 507	10 386

\- nil
.... not available

Alberta, due to its landlocked position, is not involved in international trade in mineral aggregate. International business practices are felt in Alberta through the activities of multi-national aggregate companies operating in the province.

Canada

Canada is one of the largest per capita consumers of mineral aggregate in the world (10.4 tonnes per capita in 1993, Table 2). This probably is due to our high quality transportation infrastructure (highways, roads, bridges), our expanding population, and the sporadic requirements for large amounts of aggregate in mega-projects such as the fixed transportation link between Prince Edward Island and New Brunswick, the Hibernia oilfield construction, or dam construction in Alberta.

All Canadian provinces and territories produce mineral aggregate (Table 4). The average value for Canadian aggregate was $3.87 per tonne for 1992 (Table 5). In 1992 the provincial values for sand and gravel ranged from $2.86 per tonne to $4.98 per tonne and averaged $3.16 per tonne (Table 5). In 1992 the provincial values for crushed stone ranged from $3.03 per tonne to $11.39 per tonne and averaged $5.78 per tonne (Table 5). Sand and gravel is generally less expensive to produce per tonne than crushed stone. Stone production in any province can be attributed to either a lack of adequate quality sand and gravel deposits or the export of stone. Newfoundland, Nova Scotia, and British Columbia have stone production partly because of the opportunity for export. Ontario and Quebec produce large amounts of crushed stone because of a lack of less expensive gravel. Prince Edward Island imports aggregate and presumably would produce crushed stone except that the local bedrock is inadequate for use as aggregate.

Table 4. Canadian production of sand and gravel (S&G) and stone for 1992 (Vagt, 1994).

Province	S&G	Stone	Total	S&G	Stone	Total
	(000 t)			($000)		
Newfoundland	3537	1000	4537	17610	4758	22368
Prince Edward Island	444	-	444	1699	-	1699
Nova Scotia	5976	4705	10681	20462	24910	45372
New Brunswick	6552	2784	9336	13161	15799	28960
Quebec	37307	36524	73831	116968	207500	324468
Ontario	87647	37666	125313	266368	219388	485756
Manitoba	9591	1549	11140	35239	7770	43009
Saskatchewan	6236	-	6236	17841	-	17841
Alberta	38094	316	38410	125277	3600	128877
British Columbia	39923	3910	43833	128624	30113	158737
Yukon/N. W. T.	5309	884	6193	17119	2679	19798
Total	240616	89338	329954	760367	516517	1276884

Table 5. Per tonne value of provincial and Canadian production of sand and gravel (S&G) and stone for 1992 (Vagt, 1994).

Province	S&G	Stone	Total
	($ per tonne)		
Newfoundland	4.98	4.76	4.93
Prince Edward Island	3.83	-	3.83
Nova Scotia	3.42	5.29	4.25
New Brunswick	2.01	5.67	3.10
Quebec	3.14	5.68	4.39
Ontario	3.04	5.82	3.88
Manitoba	3.67	5.02	3.86
Saskatchewan	2.86	-	2.86
Alberta	3.29	11.39	3.36
British Columbia	3.22	7.70	3.62
Yukon/N. W. T.	3.22	3.03	3.20
Total	3.16	5.78	3.87

There is inter-provincial movement of aggregate, primarily by ship (Nova Scotia aggregate to Prince Edward Island and Quebec) and rail (British Columbia crushed stone into Alberta as railway ballast). Some movement across provincial boundaries does occur by truck where the distance from source to market is short.

Alberta

The mineral aggregate industry has operated in Alberta since the turn of the century. Early photographs of Edmonton attest to the fact that gravel was applied to the streets a hundred years ago. Sand and gravel production in the amount of $229, 091 was recorded as early as 1922 (Allan, 1935) and 15 000 cubic metres of concrete were used in the piers of Edmonton's High Level Bridge in 1910 (Lord, 1995).

The modern industry in Alberta is composed of several thousand pits run by about 300 producers extracting over 45 million tonnes of mineral aggregate annually (Appendix A, Table A-1). This amount would place Alberta third or fourth in total mineral aggregate production in Canada and probably second in sand and gravel production. The annual per capita consumption of mineral aggregate in Alberta for 1991 was 18.7 tonnes. This is considerably higher than the Canadian average of 10.4 tonnes (Table 2).

Production varies dramatically between the most densely populated, urban regions and the sparsely populated regions of northern and westcentral Alberta (Figure 1). The urban areas are supplied by some large companies producing massive amounts of sand and gravel annually. About 10 producers in Alberta mine in excess of 500 000 tonnes per year and most of these operate near the populated centres. The rural regions form the bulk of Alberta geographically and the regions outside of Edmonton and Calgary account for about half of the total mineral aggregate production. The per capita consumption in the rural regions is highly variable and, on average, is much higher than Edmonton or Calgary.

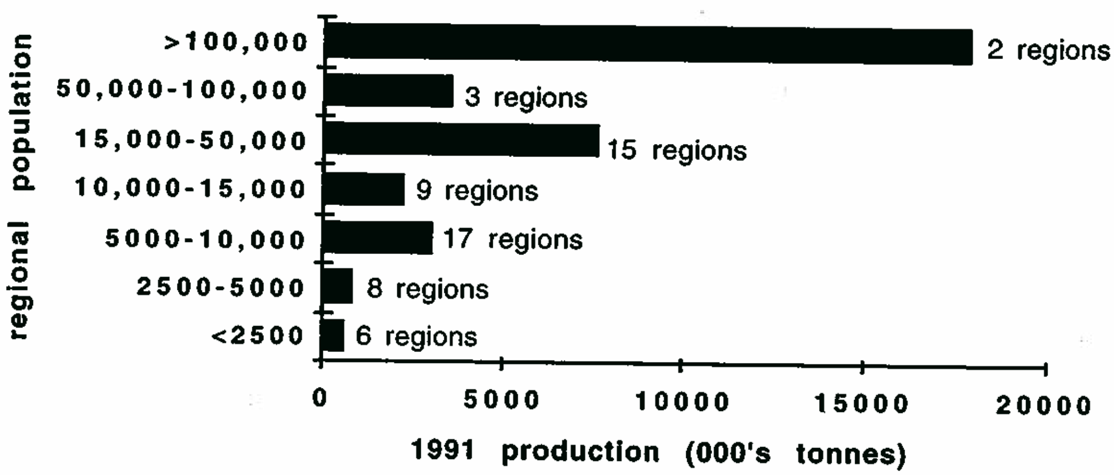

Figure 1. Mineral aggregate production in 1991 for Alberta municipal regions (Appendix A, Map 1). Regions are categorized by total regional population (Appendix A, Table A-1). The two regions with greater than 100 000 population are centred on Edmonton and Calgary.

Most of the mineral aggregate produced in Alberta is sand and gravel used for concrete in construction (~11%), in road construction and maintenance (~69%), or in asphalt (~7%). Most of the mineral aggregate is used in public works projects (roads, bridges).

Recently, conflicts between mineral aggregate producers and citizens concerned with aggregate pit development have delayed development of several new pits (see case study, Appendix B). The aggregate industry is in the midst of raising its profile through the activities of the Alberta Sand and Gravel Association (ASGA) in an attempt to mollify this trend. In 1994 a report (Badke, 1994) was sponsored by (ASGA) and the two brochures produced describe the resource.

The mineral aggregate sector in a given jurisdiction is sometimes described in terms of its 'maturity'. This term may be used to indicate the size and value of production but generally it is used to describe the legislative and public procedures and controls in place to satisfy environmental and public concerns and sustain production. Places such as southern Ontario, California, and Great Britain generally are thought to have mature mineral aggregate legislation and a mature industry or sector. A mature system often is complex but procedures are consistent and established. The mature system is supported by public, baseline data on the resource. The industry and the public are informed about the procedures and usually work within the system. Alberta is not mature in terms of mineral aggregate. Legislative procedures are inconsistent and somewhat awkward, a resource inventory is not in place,industry and public concerns are still at a sparring stage. The mineral aggregate sector in Alberta is rapidly developing and the next 10 years will be critical in the development of a philosophy and procedures which will guide mineral aggregate development for many decades.

Geology and resources

Mineral aggregate in Alberta is produced primarily from unconsolidated, sand and gravel deposits of fluvial or glaciofluvial origin. Public data are available on sand and gravel deposits for about 40% of Alberta. In the future, more reliance will be made on bedrock sources for mineral aggregate (crushed stone). Relatively little mapping of formations with potential for crushed stone has taken place. The following sections describe various geological and resource aspects for both sand and gravel and bedrock sources of mineral aggregate.

Geological setting

Ninety-nine percent of the mineral aggregate produced in Alberta in 1992 was extracted from sand and gravel deposits (Vagt, 1994). Sand and gravel deposit types which have produced mineral aggregate include: preglacial and Tertiary fluvial, post glacial fluvial (alluvial), glaciofluvial, glaciolacustrine, eolian, and colluvial deposits. A brief description of the geological characteristics and setting of each of these types of deposits follows.

Preglacial and Tertiary fluvial deposits were formed by the deposition of sand and gravel in rivers, braidplains, or pediplains issuing from the mountains prior to the last continental glaciation, hence the name 'preglacial sands and gravels' or 'preglacial deposits'. The oldest of the preglacial deposits is the Eocene-Oligocene Cypress Hills Formation in southeastern Alberta (Edwards et al, 1994). The Hand Hills Formation, Wintering Hills, Swan Hills, and several other deposits also are thought to have formed during Tertiary time and are commonly referred to as 'Tertiary deposits'. Deposits at Watino, Villeneuve, Wetaskiwin, Red Deer, Calgary, and in the Oldman River valley probably were formed during the Quaternary before continental glaciers occupied these regions. These deposits can be called preglacial deposits but not Tertiary deposits.

The preglacial deposits record the erosional history of the plains over a period of about 50 million years from the early Tertiary to late Quaternary. River systems ran eastward or northeastward from the mountains across the bedrock surface and eroded into it. These rivers deposited granular materials in their channels which eventually became sand and gravel deposits. During this long period of fluvial action continental uplift gradually lifted the entire plains surface. The earliest deposits (Cypress Hills Formation, Hand Hills Formation, etc) were raised by continental uplift for the longest period and therefore occupy the loftiest positions. As the river systems changed course and moved laterally, the early deposits became isolated remnants occupying topographic highs. Progressively younger deposits occur at decreasing elevations. The youngest of the preglacial deposits, those deposited during the Quaternary and just prior to continental glaciation, are the most deeply entrenched and occupy channels (preglacial channels) incised into the bedrock and generally below surrounding plains level.

Edwards et al (1994) separate the preglacial deposits into four age classes. The oldest category includes the Cypress Hills Formation, part of the Del Bonita Uplands, and the Swan Hills. Deposits in this category (unit 4 in Table 6) are considered to be early to mid Tertiary in age and cap the highest hills in Alberta outside the Foothills and Rocky Mountains. Deposits capping the Wintering Hills, Whitecourt Mountain, Halverson Ridge, and the Pelican Mountains probably were deposited during the late Tertiary and are listed as unit 3 in Table 6. Deposits such as those near Grimshaw, Lacombe, and Cluny occur at or near plains level. They probably were formed during the Quaternary. They are identified as unit 2 in Table 6. The youngest preglacial deposits, which include deposits near Villeneuve, Simonette, and Watino, were formed during the late Quaternary (unit 1 in Table 6). Dates on fossil materials recovered from these deposits are in the range of 22 000 to 40 000 years before present (Edwards et al, 1994).

The preglacial deposits generally are gravelly or even cobbley. The coarse nature of these sediments is the result of their fluvial deposition and results in attractive deposits from the point of view of the production of coarse aggregate.

The rock component is primarily derived from formations now found in Omenica Terrane in British Columbia and the Rocky Mountains of British Columbia and Alberta. A small proportion of the rocks are from plains bedrock sources and represent a fraction derived during plains erosion. The components of mountain source are primarily sandstone and quartzite although other rock types are important in deposits from different parts of the province.

Alluvial (post glacial fluvial) deposits were formed by the deposition of sand and gravel in Recent rivers. Deposits occur as alluvial or river bars in or next to the river or stream. During the last several thousand years, many rivers have incised into the plains bedrock and have left linear deposits of sand and gravel along the valley sides. These deposits are referred to as alluvial terraces. Some streams formed immediately after continental glaciation because of the abundant meltwater issuing from the melting glacier. After the glaciers receded these streams became much smaller or dried up. The channels which these streams cut are called meltwater channels and can contain terraces, point and channel bars. Meltwater channel deposits are widespread across Alberta.

Alluvial sand and gravel bars can be divided into point and channel bars. Point bars occur on the inside of meander bends of rivers at, or up to several metres above, river level. Channel bars are linear or tear shaped and occur in the river or at its edge on more or less straight stretches of the river. These bars occur slightly above or below water level depending on the time of year.

Table 6. The estimated distribution and general locations of sand and gravel deposits in Alberta. See text for definitions and descriptions of geological features.

Geological Feature	Distribution: Geological	Distribution: Aggregate Source[1]	Location	Suitability
Preglacial				
Unit 4	very limited	very rare	highest hills on plains	excellent
Unit 3	limited	rare	hills and ridges on plains	excellent
Unit 2	limited	rare	plains level	excellent
Unit 1	common	rare	buried channels	excellent
Glaciofluvial				
outwash plain	very common	very common	plains	very good
valley train	very limited	very rare	mountain valleys	very good
meltwater channel	very common	very common	dry plains channels	good
esker	limited	rare	plains	good
kame	very common	common	plains	fair
kame terrace	very limited	very rare	mountain valley sides	very good
kame delta	very limited	very rare	plains	good
crevasse filling	limited	very rare	plains	poor
Alluvial				
river	very common	common [2]	plains and mountains	very good
valley	very common	very common	major valleys	very good
Glaciolacustrine	common	very rare	plains, mountain valleys	very poor[3]
Eolian	very common	common	plains, mountain valleys	poor
Colluvial	common	rare	mountain valley sides	poor

[1] very rare= <5 areas mined; rare= 5-15 areas mined; common= 15-100 sites mined; very common= >100 sites mined
[2] formerly very common, sites in or adjacent to rivers are being limited by environmental regulations
[3] silt and clay is raw material for manufactured aggregate

Terrace deposits may range from several metres to over 100 m above river level. The same section of a river valley may contain terraces at several different elevations. The different levels often are grouped by elevation and referred to as 'low terraces', 'intermediate terraces', or 'high terraces' depending on the number and relative elevation of the terrace levels. The identification of different levels of terraces is important in exploration.

The rock component of alluvial deposits generally is derived from three sources: preglacial materials (mountain origin), glacial materials (Laurentide derived materials from the north or northeast, Cordilleran derived materials from the west), and plains bedrock.

Glaciofluvial deposits were formed by the deposition of sand and gravel from meltwater flowing in contact with glacial ice (ice contact deposits) or meltwater flowing away from glaciers (outwash). Outwash deposits producing mineral aggregate in Alberta include outwash plain deposits, valley train deposits, and meltwater channel deposits. Ice contact deposits which have produced mineral aggregate in Alberta include kames, kame terraces, eskers, and crevasse fillings.

Outwash plain deposits form when meltwater flows out and away from a glacier in an unconfined manner depositing a broad plain of granular materials. Outwash plain deposits often occur as very large sheets of sandy material. Being of glacial origin a significant rock component is derived from the Canadian Shield to the north.

A valley train deposit is similar in form and genesis to an outwash plain but the deposit is confined by valley sides. A valley train deposit forms in front of a valley or alpine glacier. Valley train deposits occur within the mountain or foothills corridors. Outwash sands and gravels in the Canmore Corridor are classified as valley train deposits (Edwards, 1979).

Meltwater channel deposits include point bars, channel bars, and terraces formed within stream channels that funnelled meltwater away from the melting Continental or Cordilleran glaciers. The channels are now dry or occupied by misfit streams.

Ice contact deposits include eskers, kames, kame terraces, and crevasse fillings. All of these deposits were formed by glacial meltwater as it flowed in direct contact with the glacier. Eskers are long, linear ridges of sand and gravel formed by meltwater streams flowing in contact with and confined by glacial ice. Kames are irregular mounds or hills of mixed sands, gravel, till, or stratified drift formed by meltwater in contact with the glacier. Kames terraces are deposits which are built against a linear wall of ice. Crevasse fillings are deposits of sand and fine materials which filled glacier crevasses. The deposits provide a relict pattern of the crevasses.

Lacustrine (lake) and glaciolacustrine (glacial lake) deposits are formed of fine sand, silt, clay, and occasionally coarse sand and gravel. Coarse sand and gravel occurrences in Alberta are rare and generally thin. Rivers or meltwater streams flowing into bodies of water can form deltas which can contain greater volumes of coarser materials. These are sometimes included with the glaciofluvial or alluvial types of deposits.

Eolian deposits were formed by the deposition of fine sand and silt by wind in the form of dunes or sheets. The mean grain size of dunes in the Bruderheim area is 0.19mm (Edwards et al, 1985). Eolian sand can occupy very large areas. In the Edmonton-Lloydminster region eolian sand accounts for about 10% of the sand mapped in the region.

Colluvial deposits were formed by the deposition of rock fragments by gravity as a sheet or triangle at the base of a cliff or steep slope in the mountains or foothills. Alluvial fan deposits were formed by the deposition of rock fragments by gravity and intermittent streams in the form of fans. These deposits can occupy very large areas and contain extensive volumes of material (Edwards, 1979).

Bedrock is not a major source of mineral aggregate produced in Alberta. Devonian and Mississippian age carbonate formations in the Rocky Mountain Front Ranges have been mapped because of petroleum exploration and academic interest. But little or no mineral aggregate exploration has been done on the formations. Devonian carbonate in the Ft. McMurray region is also well known as a result of mapping associated with surface mineable oil sands and underground mining to extract bitumen from the oil sands. Once again, little or no work has been done on these rocks as a source of mineral aggregate. Athabasca sandstone from the Athabasca Basin (northeastern Alberta) has been investigated for potential as a source of uranium or as a polymetallic source. This formation has not been investigate for its mineral aggregate potential. Precambrian granites on the Canadian Shield were mapped and some interest was shown as a possible dimension stone. Scafe (1994) considers red granite as a source of aggregate from the waste generated through dimension stone quarrying.

Distribution of deposits

Sand and gravel deposits are scattered across the plains of Alberta and into the foothills and mountains. These are the primary source of mineral aggregate. The general distribution of these unconsolidated deposits is provided in Table 6. Sand and gravel deposits are mapped in level 3 detail for about 18% of Alberta (1:50 000 scale maps) and another 20% at level 4 (1:250 000 scale maps) (Edwards and Chao, 1989). Publications can be purchased from Alberta Geological Survey Information Sales and a useful index is available (Edwards and Chao, 1989).

Bedrock with the greatest potential as a source of crushed stone is located in two regions: the Rocky Mountain Front Ranges and Foothills, and northeastern Alberta. The mountains and foothills have abundant carbonate rocks some of which would make excellent aggregate. Northeastern Alberta contains carbonate, sandstone, and granitic rocks which could be used for aggregate.

Potential reserves

Very little information has been published on the sand and gravel reserves available in Alberta. This type of information is contained in the files of Alberta Transportation and Utilities and private operators for confidential use. The closest thing to a public set of sand and gravel reserve data are the blue-line maps and open file reports sold by the Alberta Geological Survey (AGS). These publications delineate potential sources of sand and gravel for mineral aggregate and provide some volumetric data. These volumetric data identify prospective resources, not reserves. The AGS data set was gathered consistently, is displayed on maps in a standard manner, and covers a large portion of the province.

Glacially derived deposits (outwash, ice contact, meltwater channel) are the largest potential source of aggregate in Alberta (Table 7). In the Edmonton-Lloydminster region 289 of 585 known deposits are of glaciofluvial origin (Edwards et al, 1985). Unfortunately, most glaciofluvial deposits are composed of fine aggregate. In the Edmonton-Lloydminster region only about 19% of the glaciofluvial deposits are gravel, the remainder are sand or gravelly sand.

Table 7. Estimated occurrence and sources of production of sand and gravel in Alberta in 1988 (Edwards, 1991).

Type of deposit	Occurrence	Production
	%	%
Preglacial	20	25
Glacially derived	70	30
Recent, alluvial	10	45
Total	45 x 10^9 tonnes	42 x 10^6 tonnes

Preglacial deposits can be extensive and of high quality, ideal for hosting large operations and supplying major markets. Preglacial deposits supply both the Calgary and Edmonton markets. These deposits are critical resources and may become battlefields in land use conflicts.

Alluvial deposits are becoming a more restricted source of aggregate (Edwards, 1979) and will decline in relative importance regardless of the amount of potential aggregate which is contained in alluvial deposits. Proximity to watercourses was noted as a major operating restriction by producers (see Operating Factors).

Although the amount of sand and gravel present apparently is vast (Table 7), available reserves actually are much smaller and dwindling. It was stated at the 1995 Annual General Meeting of the Alberta Sand and Gravel Association that mineral aggregate resources are being consumed at twice the rate at which they are being discovered. No public mapping has taken place in Alberta for the last five years and existing resources are being removed from access through restrictions near watercourses and by other land uses. Mineral aggregate producers report that most supplies of sand and gravel available to them now will be consumed in the next 30 years (see Supply and Demand).

Perhaps the greatest deficiency in understanding the amount of reserves available is simply the fact that there is no public accounting of mineral aggregate reserves, no broad initiative to generate data, and no co-ordination of existing information.

Exploration and development

Geological models were developed by AGS staff to explain the occurrence of sand and gravel deposits. These models can be used to find other deposits of the same origin and estimate the probable material quality and deposit size. Following are brief descriptions of the deposit characteristics important in sand and gravel exploration and development.

Preglacial and Tertiary fluvial deposits

Deposits were formed by laterally active fluvial systems during a period of continental uplift. The oldest preglacial deposits occupy topographic highs and progressively younger deposits occur at decreasing elevations. The youngest preglacial deposits, emplaced just prior to continental glaciation, are incised into the bedrock and occur below plains level. An older set of preglacial deposits cannot overlie a younger sand and gravel deposit. Preglacial deposits are fluvial and often contain coarse aggregate (Table 8).

Table 8. General grain size distribution for samples collected at ten preglacial deposits (Edwards et al, 1994; Edwards et al, 1985).

Size fractions	Preglacial deposits* (values as percentages) 1	2	3	4	5	6	7	8	9	10
Gravel	**58**	**66**	**75**	**78**	**70**	**63**	**81**	**80**	**77**	**70**
Boulders	-	-	-	3	-	-	2	-	-	-
Cobbles	1	-	5	20	10	3	24	10	7	3
Pebbles	57	66	70	55	60	60	55	70	70	67
Sand	**41**	**33**	**23**	**19**	**28**	**36**	**17**	**19**	**21**	**29**
Coarse	17	9	2	4	3	8	1	3	5	10
Medium	15	8	5	5	7	7	2	4	4	8
Fine	9	16	16	10	18	21	14	12	12	11
Fines	**1**	**1**	**2**	**3**	**2**	**1**	**2**	**1**	**2**	**1**

* deposits located on or near: 1 Halverson Ridge, 2 Grimshaw, 3 Watino, 4 Swan Hills, 5 Pelican Mountains, 6 Villeneuve, 7 Lacombe, 8 Wintering Hills, 9 Cluny, 10 Del Bonita Uplands; data for all sites except deposit 6 from (Edwards et al, 1994), data for deposit 6 from (Edwards et al, 1985).

Deposits can be extensive and exceed 10 m in thickness. They usually are buried by till, clay, or sand. Common rock components in preglacial deposits are sandstone and quartzite, (Table 9). Constituents generally are hard and tough. The coarse aggregate from the preglacial deposits makes some of the highest quality mineral aggregate produced in Alberta.

Table 9. Rock types in the gravel (19-38 mm) fraction of preglacial deposits.

	Preglacial deposits* percentage of rock type									
Rock Type	1	2	3	4	5	6	7	8	9	10
Quartzite	33	23	24	54	31	10	35	26	57	29
Sandstone	37	28	68	35	59	67	49	42	9	32
Conglomerate	-	6	4	11	1	6	1	<1	6	14
Shale[1]	-	-	<1	<1	7	3	3	2	-	1
Chert	4	5	2	<1	2	12	4	1	6	<1
Carbonate	-	-	-	-	-	-	8	29	20	-
Argillite	1	1	-	-	-	-	<1	-	-	23
Igneous[2]	-	11	<1	-	-	-	-	-	-	1
Quartz	25	14	2	-	-	2	-	<1	2	-
Other metamorphic [2]	-	13	-	-	-	<1	-	-	-	-

* deposits located on or near: 1 Halverson Ridge, 2 Grimshaw, 3 Watino, 4 Swan Hills, 5 Pelican Mountains, 6 Villeneuve, 7 Lacombe, 8 Wintering Hills, 9 Cluny, 10 Del Bonita Uplands

1 includes mudstone and ironstone

2 igneous and metamorphic rocks of mountain origin, not Canadian Shield origin

Alluvial (post glacial fluvial) deposits

The basic change in most fluvial systems is a fining of sediment size downstream. This change is important to remember in exploration for granular resources. This change occurs in a series of alluvial bars and in terraces. For example, alluvial terraces along the Peace River become progressively finer in a downstream direction. Terraces between Tp 81, R 24 and Tp 92, R 21 are primarily gravel, between Tp 93, R 20 and Tp 107, R 15 terraces are mixed sand and gravel, and downstream from Tp 107, R 15 the terraces are sand (Scafe et al, 1989, Fox et al, 1987).

Many rivers have incised into the plains bedrock and have left linear alluvial terrace deposits of sand and gravel along the valley sides. A series of terraces belonging to a former river level can often be traced along the river valley. Series or sets of terraces along the same valley can be coarser or finer and the identification of different levels of terraces is important in exploration. The terrace level will decrease in elevation downstream and increase in elevation upstream and often will change in relation to the height above the present river level (Figure 2). The Beaver River is an excellent example of the use of a terrace model in exploration (Edwards and Fox, 1980). Along the Beaver River Valley the intermediate level terraces are coarser in composition than either the high or the low level terraces (Figure 2). Terraces which formed in major river valleys commonly contain gravel. Alluvial terraces often contain a lower percentage of fines and a higher percentage of gravel than point bars currently forming in the river.

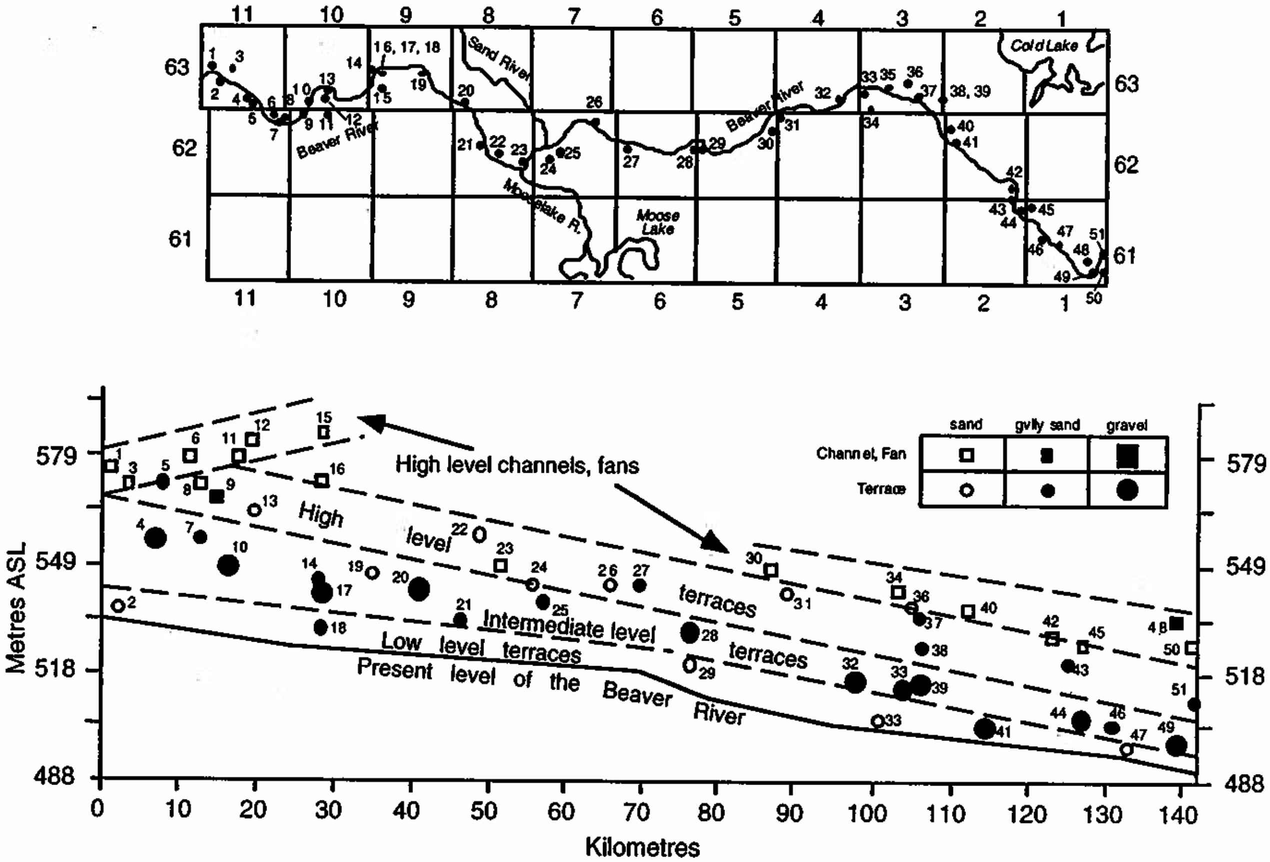

Figure 2. The inset map shows the location of the deposits. The cross section plots the elevation of terrace deposits along the Beaver River valley and shows the deposit composition (Edwards and Fox, 1980).

At or near river level, gravel may be present in point bars and channel bars. Point bars occur on the inside of meander bends. They can contain gravel but the material commonly is interbedded with fine sand, silt and clay and often is overlain by a bed of fine materials. Channel bars are linear or tear shaped and occur in the river or at its edge on more or less straight stretches of the river. Channel bars commonly are composed of gravel if the river system contains coarse materials. These bars occur slightly above or below water level, depending on the time of year.

Although the grain size distribution of alluvial deposits within Alberta is highly variable and can range from silty deposits to bouldery deposits, trends can be established within a single river system and exploration models can be developed. Variability is due to differences in the sediment supply and the fluvial conditions. Coarse material from alluvial deposits can be high quality aggregate but these deposits are more variable in quality across the province than the preglacial deposits.

Glaciofluvial deposits

Outwash deposits can be excellent sources of aggregate but are often sandy in grain size. They can be very large in area (>100 ha) and can contain huge volumes of material (>10 million m^3) (Edwards and Fox, 1980). Canadian Shield derived granite, gneiss, and schist commonly accounts for more than 50% of the coarse fraction in outwash deposits in central and northern Alberta and 35 to 55% in southern Alberta (Edwards and Fox, 1980, Shetsen, 1980). Near the foothills or near preglacial channels, rocks of mountain origin (particularly quartzite) become predominant with stones derived from the Canadian Shield accounting for less than 25% (Edwards et al, 1985, Shetsen, 1980). Rocks of local origin, often deleterious, usually account for <10% of the pebble fraction of most deposits (Edwards and Fox, 1980; Edwards et al, 1985, Shetsen, 1980).

Meltwater channel deposits represent small, but highly useful, sources of sand and gravel. In the Cold Lake area, nine meltwater channel deposits were mapped with an average volume of about 1 million m^3 and area of about 30 ha (Edwards and Fox, 1980). All the deposits in Cold Lake area are described as sand or gravelly sand but several are worked for pockets of gravel. Meltwater channel deposits can occur as terraces or point bars.

Valley train deposits are similar to outwash plain deposits in volume but may contain a higher percentage of gravel. The deposit below Grotto Mountain in the Canmore Corridor has about 14 million m^3 of material with 69% gravel (Edwards, 1979). The gravel is usually high in carbonates (>80%) and sandstones-quartzites (5-20%).

Ice contact deposits have a high to very high potential for the occurrence of granular materials. Some types (kames, crevasse fillings) may be very poorly sorted and difficult to mine. Ice contact deposits in the Cold Lake area have an average size of ~12 ha, an average volume of ~300 000 m^3, and an average composition of gravelly sand (Edwards and Fox, 1980). These deposits all have distinctive shapes which can be useful in exploration. Kames are conical hills, eskers are narrow ridges and crevasse fillings are low and curvilinear.

Glaciolacustrine deposits

Glaciolacustrine and lacustrine deposits are primarily fine materials which have little application as conventional mineral aggregate. The margins of these deposits may have been reworked by waves or currents to winnow out the finer materials to leave coarser beds of sand and gravel (bars or beaches). Areas where rivers or meltwater streams may have entered the lake should be checked for deltas. Deltas are triangular or fan shaped and can contain sand and gravel.

Eolian deposits

Eolian sand occurs as large, thin sheets or as dunes. Sand areas often are covered by open pine forest. The fine sand from sheet or dune deposits has limited use as a mineral aggregate but it is important to recognize eolian sand deposits, if only to eliminate them during a gravel search.

Colluvial and Alluvial fan deposits

These deposits can occupy very large areas and contain extensive volumes of material. The material is generally too coarse and poorly sorted to be used. Development of these deposits can result in flash flooding and disturbance of the groundwater movement (Edwards, 1979).

Associated minerals

Minerals with economic value may be present in sand and gravel deposits. These may be recovered as by-products during aggregate processing and sold for a higher unit value than the aggregate. Heavy minerals such as gold, platinum, garnet, and magnetite have been recovered from sands and gravels in Alberta. Silica has also been separated and sold. Preglacial, glaciofluvial, and alluvial deposits can contain viable by-product heavy minerals or silica. Preglacial deposits may even contain diamonds. The bedrock under the sand and gravel deposit should also be evaluated for possible ceramic, crushed stone, ammolite, coal, bentonite or other potential. The overburden should be examined for ceramic or silica sand potential.

Bedrock

Bedrock formed 27% of the total mineral aggregate produced in Canada in 1992 (Vagt, 1994). In Alberta crushed stone accounted for <1% of the aggregate produced in 1992 (Table 4). The necessity of producing more expensive crushed stone is still in Alberta's future.

With little immediate pressure to find suitable bedrock for use as aggregate very little mapping has been done to identify future bedrock sources. Massive formations of carbonate bedrock of Devonian and Mississippian age in the Rocky Mountain Front Ranges have major potential. Carbonate rocks are quarried at Cadomin and Exshaw for use in cement manufacture at Edmonton and Exshaw, respectively. These formations and others nearby could be used as a source of crushed stone. Devonian carbonate in the Ft. McMurray region has potential as a source of crushed stone. Underground mining to extract bitumen from the oil sands could prove to be a source of stone for mineral aggregate or stone could be quarried from outcrop exposures along the major river valleys. Further north, Athabasca sandstone from the Athabasca Basin or Precambrian granites on the Canadian Shield could prove to be sources of rock with excellent properties.

Alternate sources

Glaciolacustrine deposits

Common clay can be a raw material for manufactured or synthetic aggregate. In 1983 about 40 000 m^3 of synthetic aggregate was manufactured in the Edmonton region using glaciolacustrine deposits as the source of the silt and clay (Edwards et al, 1985).

Till

Till is an ubiquitous material that would prove to be an almost limitless source if it were suitable for the manufacture of aggregate. In parts of the country situated on Precambrian Shield the till contains a very high percentage of pebbles and cobbles and has been used as a source of coarse aggregate. Most of the tills in Alberta are very fine textured and are not suitable as a source of coarse materials. The only exception may be the tills above the Precambrian Shield in the extreme northeastern part of the province. The high clay content of till does make it an interesting candidate for synthetic aggregate. Till was considered by Edwards et al (1985) and found to have numerous other deleterious properties. The only till of those studied which could have potential was above the Paskapoo Formation.

Ash

Much of the power generation in Alberta is through the burning of coal. Two types of ash are produced from this process: bottom ash (boiler slag) which falls to the bottom of the furnace, and fly ash which is removed from the flue gases. Bottom ash is coarse grained and has been used as granular fill, as road subbase, in concrete, and as filter material. Fly ash is fine grained and has been used as an alternative in construction fill, with lime for soil stabilization in highway construction, in base courses in roads, and as a filler in asphaltic concretes (Edwards et al, 1985). There will continue to be large amounts of ash available as long as Alberta consumes coal.

Recycled concrete and asphalt

The recycling of concrete and asphalt from demolitions and road improvements has provided a viable source of aggregate in the larger urban areas in Alberta for over fifteen years (Edwards et al, 1985). The volumes recycled are increasing dramatically each year and this source of aggregate is expected to be fully utilized as haul distances for natural aggregates increases and as dumping charges at land fill sites escalate (now $15-$30 per tonne). In 1994 it was estimated that 500 000 tonnes of aggregates were recycled in Alberta (Badke, 1994).

Glass

Glass commonly is listed as a recyclable material suitable for use as aggregates. As there is higher value in other uses, and the supply is limited, it is unlikely that glass will provide an alternative for aggregate in Alberta (Edwards et al, 1985).

Sulphur

Sulphur can be used as an extender in asphaltic concrete and adds a number of positive attributes such as reducing pavement thickness and improvement of aggregate quality. The former large surpluses and low prices of sulphur in Alberta made it an attractive material to consider for extending aggregate resources (Edwards et al, 1985). However, with increases in prices and reduction of the stockpiles, the potential for use of sulphur with aggregate has dwindled.

Research needs

A public record of sand and gravel deposit locations and general characteristics is available for about 18% of Alberta. In comparison, southern Ontario (Planning Initiatives, 1992), Nova Scotia, and Great Britain are completely mapped (Smith and Collis, 1993). To sustain sand and gravel resources a more complete resource inventory is required.

Additional information exists in Alberta but it is scattered about various government departments and often is not publicly available. New inventory data and existing data should be integrated, through a digital data base, between provincial departments and municipalities.

A digital data base of sand and gravel deposits has been developed through an MDA project. This data base, or others within government, should be evaluated as a possible prototype for a broader, generally accessible source of mineral aggregate resource information.

The existing public data are available at level 3 (Edwards and Chao, 1989). Volumetric data cited on the AGS map series (1:50 000) are not reserves and the values almost always overestimate actual volumes available. In comparison, southern Ontario (Planning Initiatives, 1992) and all of Nova Scotia have been mapped at level 3 or greater detail and much of Great Britain has been mapped at level 2 (1:25 000) or greater (Smith and Collis, 1993). Volumetric data in these other places appear to be much more precise. Deposits in Alberta must be evaluated in greater detail, volumes assessed in a statistical manner, and materials evaluated using additional tests to determine the economic potential.

Bedrock will be the future source of mineral aggregate for Alberta. Formations should be evaluated for crushed stone potential and the favourable formations should be mapped.

Edwards et al (1994) note that by-product minerals are not being exploited in some deposits and that a site was investigated where the bedrock below a sand and gravel deposit has ceramic potential. These cases represent a lost resource, both to the producer and to the province. All deposits producing sand and gravel for mineral aggregate should be evaluated for by-product recovery, the underlying bedrock investigated, and the overburden checked.

Mineral technology

Mining and processing

The variety of equipment available for aggregate extraction is extensive. The choice of equipment depends on the climatic conditions (or preferred season of operation), the production rate, and the life of the operation. For example, a machine capable of large scale production may be suitable for a permanent plant whereas a smaller, more manoeuvrable machine may be more suitable for a smaller, perhaps temporary operation (Smith and Collis, 1993).

In a few cases, such as some fill or rip rap, material may be sold in a natural, "pit run" or "as dug" condition. In general, most material is passed through a single screen or crusher to produce an uniform maximum size. For most uses, such as concrete or asphaltic aggregate and roadstone, natural material will not meet the specifications required by design engineers and size reduction and particle sizing may be required to produce material that does meet specifications.

Mechanical size reduction is achieved through crushing, the object being to reduce the material to a specified size range with a minimum production of finer material. The two general means of crushing the material are nipping the rock (jaw, gyratory or cone crushers) or direct impact (hammer mills) (Smith and Collis, 1993). Jaw crushers are used to crush rocks down to 75 mm (3 in). Cone, roll or impact crushers then crush materials down to about 20 mm (3/4 in).

Particle sizing is accomplished by screening and classification. Screening grades particles according to the minimum cross section presented to a wire mesh, a hole in a plate, or a gap between parallel bars. The function of a screen is to protect a crusher or other machine from receiving oversize material which it cannot handle, to remove fine material before reaching a crusher set to give coarser product, and to grade crushed material into specific size ranges (Smith and Collis, 1993). Screening by rejection allows unwanted material to be discarded and screening by selection discards unwanted material as oversize. Classification used in the treatment of fine aggregate usually involves a water filled tank which discharges the fine particles over a weir, retaining the coarser material in the bottom for discharge by valve, or elevated upwards by buckets, spiral or rakes (Smith and Collis, 1993).

Classifiers or de-watering augers also have a dewatering action which can reduce the water content of the slurry by as much as 75%. Settling ponds usually are employed to remove the clay and silt through long settling times under still water conditions.

Coarse screens have very large capacities while the capacities of successively finer screens eventually becomes so limited that industrial screening is impractical. Screening is not normally performed at sizes below 3 mm. Fine sizing exploits differences in particle velocity in water. The principle is known as classification and forms the basis of a sensitive sizing method. Classification usually is applied to materials finer than 5 mm. Water spray is used to deslime material before screening or screening under spray (wash plants). This prevents adhesion of fine particles and blinding of the screen and also helps lubricate the particles (Smith and Collis, 1993).

Screens are made of a variety of materials (steel, rubber, polymer). Factors in screen selection include flexibility to aid the screening process, screen wear, cost, and level of operating noise (environmental concern). There is a mechanical optimum screen motion, inclination and aperture size which limits the use of multiple parallel decks in a single machine. However, economic factors rarely justify the cost of a separate machine for each screening operation and double or triple decks are used frequently, the machines being optimised on the most critical size with excess capacity on the other sizes (Smith and Collis, 1993). Grizzlies are robust screens consisting of parallel bars used mainly to remove unsuitable oversize material before crushing or washing.

Machines for separating deleterious minerals from the aggregate are rarely employed but in Alberta mineral separation of fine gold and platinum takes place at several operations. In addition, jigs are used in at least one operation which separates and markets separate minerals fractions from the sand size feed.

A typical dry processing system in Alberta composed of a loader, grizzly, feeder, jaw and cone crusher, screener, and conveyors has a value of approximately $1.5 million (Badke, 1994).

Research needs

The technology for processing mineral aggregate from sand and gravel is well established. There is a need for research into more effective methods for the recovery of by-product minerals.

Economic factors

Prices and costs

Total provincial production of sand and gravel in 1991, based on an AGS survey of Alberta producers, was worth $153 226 689. The average cost of a tonne of sand and gravel at the pit was $3.37 in 1991 (Table 10). Table 10 subdivides this production.

Table 10. The estimated amounts, values, and unit values of sand and gravel products in Alberta for 1991.

	Sand	Gravel	Crushed gravel	Other	Total
Production amount					
(tonnes)	4 467 634	6 070 748	26 838 076	8 108 378	45 484 836
(%)	10	13	59	18	100
Production value					
($)	17 723 871	15 563 877	107 770 556	12 168 385	153 226 689
(%)	12	9	71	8	100
Value per tonne					
($/tonne)	3.97	2.56	4.02	1.50	3.37

Regional costs per tonne of sand and gravel produced in 1991 varied from $0.48 per tonne to $9.51 per tonne. Although there is a wide variation in costs they appear to be normally distributed (Figure 3).

Comparing the per tonne costs by region (Figure 4) shows that the less populated regions have a generally lower production cost than the heavily populated regions (compare the regions with <5000 population to regions > 25 000 population). These data give us a starting point and baseline from which to identify other factors, for example, the identification of regions with inadequate supplies of aggregate or artificially low costs (all supplies coming from Crown Lands).

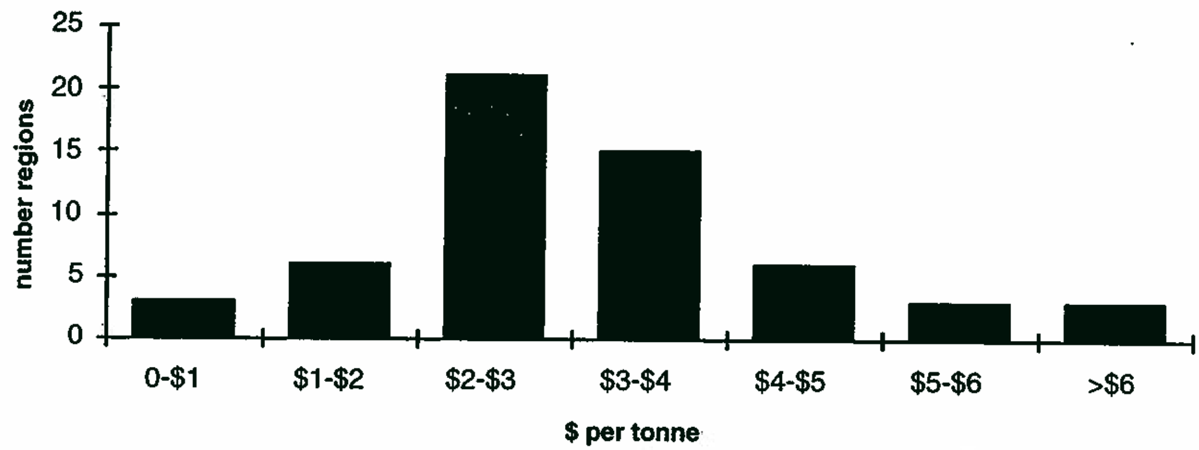

Figure 3. Regional costs per tonne of sand and gravel at the pit in Alberta for 1991.

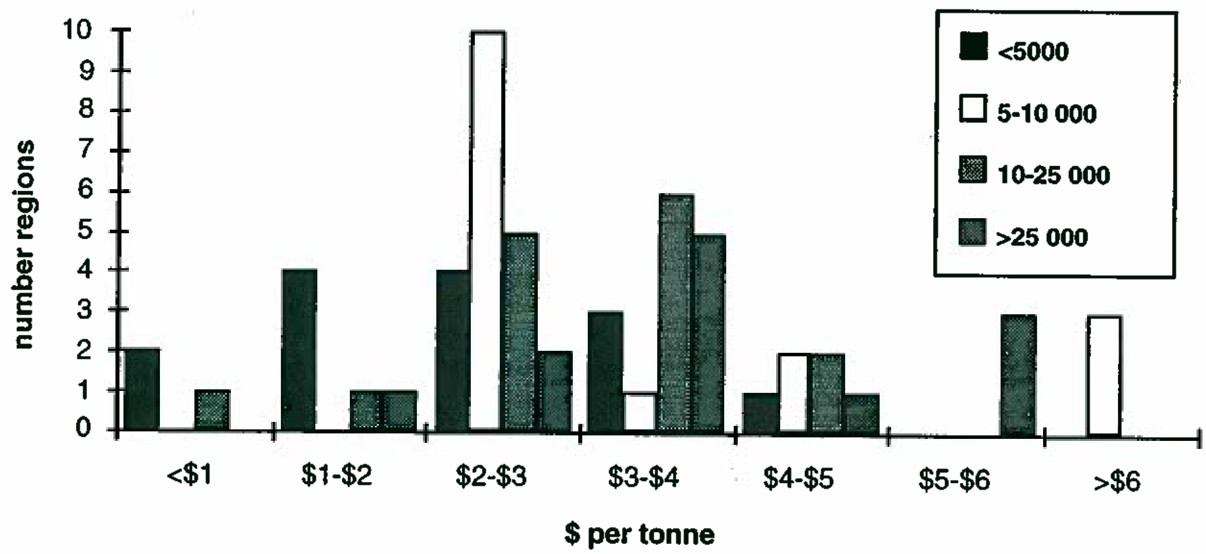

Figure 4. Costs per tonne of sand and gravel at the pit for regions of different populations (1991).

Sand and gravel has lower production costs in Canada than rock sources: $3.16 per tonne of sand and gravel compared to $5.78 per tonne of stone (Table 4). As sand and gravel deposits become exhausted and constraints sterilise replacement reserves the industry turns to rock sources. Such a swing occurred in Great Britain between 1965 and 1973. In 1965, 55% of the mineral aggregate (102.4 million t) came from sand and gravel and 45% (83.8 million t) from bedrock sources. By 1973 the source of supply had reversed with 45% (142.4 million t) coming from sand and gravel and 55% (171.6 million t) from rock (Smith and Collis, 1993). By 1992 Great Britain's sand and gravel production was 38% (89 million t) of total construction aggregates and stone was 62% (144 million t) (Badke, 1994). The cost of mineral aggregate from sand and gravel is highest near the major markets of Calgary and Edmonton. As this cost becomes comparable to that of crushed stone the possibility of conversion to bedrock supplies are considered. Factors in this replacement would include availability of bedrock sources, quality of stone, transport, off-loading sites, change in haul patterns, and any environmental and regulatory conditions.

Transportation

The costs for sand and gravel cited above are for the mining and processing on site of the mineral aggregate. They do not include costs due to the transportation of the aggregate from the site for further processing, use as a raw material in other products, or for direct use. The transportation cost in many cases is greater than the cost of the mineral aggregate at the pit.

Public and private sector mineral aggregate producers reported haul distances (all by truck) for 51 regional municipalities. Average maximum haul distance was 42 km. Maximum haul distances ranged from 140 km. to 8 km. (Figure 5). Haul distance is a factor which indicates depletion or scarcity of the resource. Edwards (1989) reported a maximum haul in Alberta of 100 km. for 1983. Beyond this single report there is little historical data on haul distance with which to compare.

In many situations, especially in urban settings, haul route is a more important development factor than haul distance. In a land use conflict northwest of Calgary one of the primary issues was the number of trucks and the routes they would take (Appendix B).

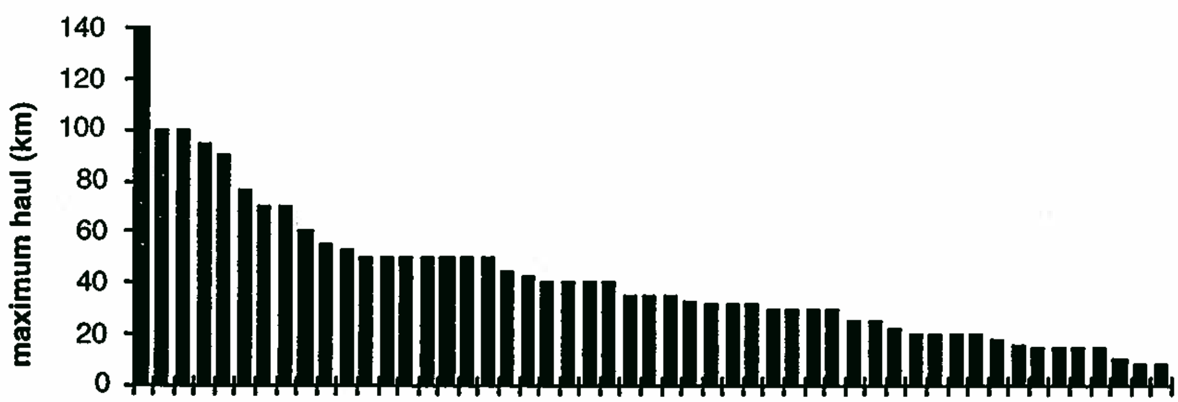

Figure 5. Maximum haul distance (km.) for sand or gravel for each of 51 regional municipalities.

Research needs

National and provincial statistics are useful for provincial comparisons and the identification of long term trends in production but have relatively little application at the local level. An annual survey of all producers should be undertaken by the province to enable regional evaluations. Annual evaluation of regional per tonne costs can provide important clues to the state of the resource.

Operating factors

Factors which impact on the ability of private and public sector producers to operate include physical conditions, environmental and land use issues, and regulatory requirements. The physical conditions include the geological distribution and character of deposits, available technology, climate, and the value of the local product compared to substitutes or imports. Environmental and land use issues are becoming increasingly important. These will be addressed at some length as it is a relatively new consideration in Alberta and an area that is not adequately documented or described from the resource perspective. Any operation in Alberta is required to follow various regulations. Provincial legislation is outlined in this report. Requirements at the local level are critical to the operation of a pit but it is beyond the scope of this profile to describe these. A case study of a development proposal near Calgary is included in Appendix B.

Physical conditions

Some basic geological characteristics of deposits in Alberta require special extraction. Preglacial deposits often require significant overburden removal (Units 1 and 2 in Table 5). Extraction may require dredging or pumping water from the pit as preglacial deposits may also be aquifers (Unit 1 in Table 5). Kame deposits commonly are poorly sorted and require selective recovery. Resulting operations generally are small in scale and create a 'moonscape' appearance to the pit. If colluvial fans with intermittent streams are excavated changes to dry channels can alter the water flow during spring run-off. Such diversions can endanger other land uses on the fan. Glaciofluvial deposits commonly have a high percentage of fine sand. Processing is required to separate the sand and extra costs ensue for discarding the excess. Settling ponds are incorporated in operations on many types of deposits but they are especially important in alluvial deposits near river courses. It is essential that sediment does not escape into natural water bodies.

There are regions of Alberta where sand and gravel deposits suitable for mineral aggregate are scarce or do not occur (Valleyview, Wabasca, and Oyen areas). Producers in these areas should be aware of alternate sources such as synthetic aggregate. This requires a different raw material source.

The technology required for excavation and processing of sand and gravel for mineral aggregate is well established (see Mineral technology). Mining almost always takes place in the summer and fall to avoid the problems associated with the cold winter months. This requires that the annual supply of aggregate is produced in half the year. Any difficulties during the summer and fall which curtail the mining process can have serious effects on the operation for the entire year. Processing also proceeds during the summer and fall but may be carried on into the winter in larger operations using stockpiled materials. By-product recovery is not nearly as well implemented in Alberta and there is considerable scope for the application of technology used in other places.

Local resources have an advantage over imports from other regions because of proximity to the market and lower haulage costs. The primary method of transport in Alberta is truck. For medium and long haul distances rail can be cheaper than truck haulage. Markets near existing rail lines should look closely at the related costs of truck and rail transport to see which is most cost effective. A few places in Alberta are located on navigable waterways (for example Fort McMurray). If a mineral aggregate source is located on or near the waterway a viable operation could result, especially if the aggregate is of exceptional quality.

Environmental and land use issues

Increasingly important aspects in the ability of a company or municipality to open, develop, and operate a mineral aggregate pit or quarry are land use and environmental approvals. About one quarter of the mineral aggregate producers in Alberta say they have encountered situations where their efforts to mine an aggregate deposit were curtailed or prevented by land use or environmental restrictions. Producers surveyed were from the private sector (companies and individuals) and the public sector (Counties, Municipal Districts, Improvement Districts, Special Areas, cities, and towns). The breakdown of this response is shown in Table 11.

Table 11. Summary of a survey to identify mineral aggregate producers who encountered situations where their efforts to mine an aggregate deposit were curtailed or prevented by land use or environmental restrictions.

	Number responding	Number encountering restrictions
Private sector	80	20
Public sector	82	22
Total	162	42

The restrictions which producers cited can be categorized into: residential opposition, environmental restrictions, regulatory restraints, and conflicting land use issues (Table 12). Private and public sector producer responses were not separated as they cited similar issues and in similar proportion.

Table 12. Restrictions to mineral aggregate mining identified by producers. Regions are separated according to population.

	Number of situations reported per region (population in 000s)								
	<2.5	2.5-5	5-10	10-15	15-25	25-50	50-100	>100	Total
Residential opposition	-	-	-	1	1	-	-	5	7
Environmental restrictions									
unidentified[1]	-	-	3	1	-	-	-	-	4
due to wildlife and vegetation[1]	-	-	-	-	1	2	-	-	3
natural areas	3	1	-	1	1	-	-	-	6
environmentalists	-	-	1	-	-	-	-	-	1
reclamation costs[2]	-	-	1	-	-	-	-	-	1
watercourse proximity[1]	1	-	3	-	4	3	2	-	13
Current regulations[3]	2	2	3	-	2	-	-	-	9
Conflicting land use[4]	-	-	2	-	-	-	-	1	3
Total	6	3	13	3	9	5	2	6	47

1 restriction resulted from regulations requiring buffers or denying development
2 reclamation costs are a requirement of all operations but may affect operations differently
3 regulations may be environmental in nature, may concern various levels of authority
4 conflict with pipelines, road allowances, and urban residences which cover deposits

The restrictions due to residential opposition to mineral aggregate mining centre around concerns such as truck traffic, noise, and dust. A dramatic example of the opposition which residents can generate came at the public hearings of the M.D. of Rocky View in late 1994 and early 1995 into the proposals of Burnco Rock Products Ltd. and Consolidated Aggregates to develop land for mineral aggregate mining (Appendix B). Public protest can result in the delay or rejection of an application to develop an aggregate operation (as was the case in Calgary). Such protest also can result in the implementation of bylaws or regulations which require the attention of all subsequent applicants. There is a link or continuum between the category of residential or lobby group opposition and restrictions listed in Table 12 under restrictions resulting from current regulations or conflicting land uses. The majority of restrictions due to residential opposition were reported from regions with high population density (Calgary region) or a long history of settlement (Red Deer region) (Table 12).

Environmental restrictions include four basic aspects. One is the opposition to mining by an individual or group. This 'environmentalist' opposition is cited in only one response. Greatest conflict over this issue comes from regions considered to be the most environmental sensitive such as the foothills.

A second type of environmental restriction is exclusion of areas, or regulations intended to protect fauna, flora, or natural areas. Specific exclusions to mineral aggregate are noted for wildlife protection, for protection of vegetation, for protection of natural or sensitive areas, and protection of land through the formation of Parks or recreation areas. These restrictions are through particular land designation or zoning and can be considered as land use management issues. These restrictions are noted by operators in central and northern Alberta outside of the major urban centres.

The third aspect of environmental restriction to mineral aggregate mining is the cost of reclamation. There is one response specific to this topic but others in the current regulations category probably included reclamation. The intention of reclamation is to return the land to a useful or natural state after mining. Most operators pay reclamation costs and did not respond that this cost was a restriction to development. It should be recognized, however, that reclamation costs can be a major disincentive to development if the requirements are not reasonable or fairly applied and that reclamation costs can affect operations differently. Reclamation costs can become a block to development.

The fourth and most common environmental restriction to mining described is due to proximity to a water course. Restrictions cited are primarily for development near, but not in, a river or lake. The restrictions usually are in the form of a buffer between the operation and the water course. This issue is raised by operators in all parts of Alberta and appears to be a result of geographic and geologic circumstance and not due to population or settlement.

Current regulations are mentioned in a significant number of responses. The regulatory issues mentioned include the enforcement of national, provincial, or municipal regulations to prevent possible damage to wildlife or vegetation, to restrict possible damage to natural systems (rivers and lakes), to reclaim the site, and to ensure the safety and quality of life of citizens. These responses came primarily from the rural regions.

Some restriction to development comes through the loss of land to competing land uses. These alternate land uses include pipelines, road allowances, and construction of dwellings on land which could have produced mineral aggregate. These restrictions occur in both urban and rural areas.

Current environmental and land use legislation and regulations

Legislation which regulates aggregate mining and the lands disturbed by aggregate mining was initiated because of concerns about the effects of resource exploration or testing. Much of the early impetus (1963-1973) for provincial regulation of mineral activities in Alberta came as a result of oil and gas activities. The early legislation is described below (Badke, 1994; Alberta Sand and Gravel Association, 1994). Later regulations became more specific to aggregate mining.

Surface Reclamation Act 1963-1973

Encourages industry to return landscape to condition for agricultural use.

Land Surface and Reclamation Act 1973-1992
(Land Conservation Regulations) 1974

Outlines Development and Reclamation plan requirements, security deposits, land conservation guidelines.

(Part 3) 1978

Provides Land Conservation and Reclamation Council with authority to enforce good reclamation procedures on all disturbed lands.

Land Conservation and Reclamation Council 1963
Consists of reclamation officers responsible for inspecting surface disturbances and ensuring reclamation (primarily well sites and pipelines).

Land Conservation and Reclamation Council 1973
Responsibilities broadened to include gravel pits.

Forestry, Lands and Wildlife 1969
Requires operators to obtain reclamation certificates on Crown Lands (green zone).

A current outline of regulations governing aggregate mining is presented in Badke (1994) and in a pamphlet entitled 'Aggregates and Our Environment' (Alberta Sand and Gravel Association, 1994). Basic information is presented here. Early legislation in the form of the Surface Reclamation and Land Surface and Reclamation Acts was revised and expanded in the Environmental Protection and Enhancement Act introduced in 1992. This is the main body of legislation which currently regulates the activities of the aggregate industry for reclamation or environmental issues. The Public Land Act is the primary legislation dealing with the management of the resource on Public Lands. The Planning Act is major legislation affecting aggregate producers through municipally generated and enforced land use and development regulations. The Water Resources Act regulates development near water bodies. The other acts described can affect operations under more specific situations.

Environmental Protection and Enhancement Act 1992-present
The main body of legislation regulating reclamation of sand and gravel pits on private and public lands is administered by Alberta Environmental Protection. There is an established application procedure with the possible requirement of an Environmental Impact Assessment. An appeal procedure is in place for citizens or applicants (Environmental Appeal Board). Public participation is encouraged.

Conservation and Reclamation Regulations 1993-present
These regulations established the environmental assessment process which includes the submission of detailed development, conservation and reclamation plans (reclamation to equivalent capability), posting of a security deposit equal to the cost of reclamation, penalties for environmental offenses, and regulation of pollution or emissions from pits or processing plants.

Public Lands Act
Sand and gravel resources are managed and regulated on public white areas by Alberta Agriculture, Food and Rural Development (Public Lands) and on public green areas by Alberta Environmental Protection (Land and Forest Services).

Surface Materials Regulations
Authorization to remove sand or gravel by a variety of licences or leases. A royalty of $0.60 per yd^3 or $0.47 per tonne is collected for aggregate removed.

Planning Act-currently under revision

Provides for creation of Regional Planning Commissions which create Regional Plans that include guidelines for municipalities on land use and development issues and requires each municipality to create General Municipal Plans that provide broad guidelines for land use and development, Area Structure Plans for parts of the municipality, Land Use Bylaws for specific land use districts (there is no appeal mechanism for refused re-zoning applications but a 6 month re-application), and require that a Development Permit is obtained for all developments (applicants can appeal to Development Appeal Board).

Fisheries Act

A Federal Government Act regulating impact on fish or their habitants.

Mines and Minerals Act

Applies to bedrock aggregates on privately owned lands but not to the sand and gravel which is owned by the surface rights holder.

Water Resources Act

Regulates any construction or disturbance in or near a river or water body.

Municipal Government Act

Municipal Affairs regulates activities of municipalities under the act which allows municipalities to collect property taxes and set business licence fees.

Historical Resources Act

Alberta Community Development administers the act which requires an archeologist to visit proposed pit sites to determine the archeological sensitivity of the area and potential requirement for further study before surface disturbance.

Impacts of mineral aggregate mining

Mineral aggregate is an essential commodity in the development of our society. Yet the mining and transportation of aggregate can have a definite impact on the environment and the quality of life of individuals in the region.

Municipalities have a dual role. They produce mineral aggregate for the development and maintenance of the physical infrastructure. They also have a responsibility to maintain a desirable environment for their residents. Commonly they are aware of the conflicts which mineral aggregate production can generate. Municipalities were asked to identify situations where mineral aggregate mining or transport had an impact on the environment or quality of life. Nineteen of 81 municipalities responding cited situations where mining is perceived to impact on the residents or the environment (Table 13).

The situations documented can be divided into four basic areas of concern: economic concerns, quality of life concerns, concerns for the natural environment, and concerns with existing controls on mineral aggregate resource development.

Table 13. Environmental and quality of life concerns resulting from mineral aggregate mining.

	Number of situations reported per region (population in 000s)								
	<2.5	2.5-5	5-10	10-15	15-25	25-50	50-100	>100	Total
Economic concerns									
top soil loss	-	-	1	-	-	-	-	-	1
unreclaimed pits	-	-	1	-	-	-	1	-	2
devaluation of property	-	-	-	-	-	-	-	1	1
Quality of life									
resident/ratepayer concerns[1]	-	-	1	1	1	1	1	3	8
impact on recreation area	-	-	1	-	-	-	-	-	1
Natural environment concerns									
impact on natural areas	-	1	-	-	-	-	-	-	1
elevation change	1	-	-	-	-	-	-	-	1
vegetation change	1	-	-	-	-	-	-	-	1
effect on wildlife, vegetation	1	-	-	-	-	-	-	-	1
damage, change to river	-	-	1	-	-	-	1	-	2
Concerns with lack of controls									
poor regulation enforcement	-	-	1	-	-	-	1	-	2
poor environmental controls	-	-	-	-	-	-	1	-	1
lack of data	1	-	-	-	-	-	-	-	1
Total	4	1	6	1	1	1	5	4	23

1 concerns include noise from crushing operations, hours of operation, truck traffic, dust

The greatest number of situations reported involve concerns that the quality of life of residents is being disrupted by mining operations and the transport of aggregate materials by truck. All the types of concerns cited in this survey were identified by opponents to mineral aggregate development in the Calgary region (Appendix B).

Some concerns identify the economic effect on the land by an aggregate operation. For example, an unreclaimed pit cannot be used for agriculture, and soil loss affects reclamation and ultimately the post-mining value of the land. These concerns reflect rural concerns that land developed for aggregate has not been returned to a viable state for agriculture and concerns that aggregate operations are lowering the value of adjacent lands. Loss of residential property value close to aggregate operations, presumably as a result of the decline in the quality of life factors, was cited by urban respondents.

Concern for the effects of mineral aggregate on the natural environment are reported mainly, but not exclusively, from the rural areas. These concerns include the impact on wildlife, flora, natural areas, and on lands already set aside for the conservation of natural areas. These concerns overlap with those maintaining that current regulations are not adequately controlling mineral aggregate development.

The view is expressed that present regulations and enforcement are inadequate to control the development of aggregate operations. These situations are related to the effect that aggregate mining is having on the environment, particularly in areas near water bodies. This opinion contrasts dramatically with the fact that many operators feel controls hamper their opportunity to develop pits.

Certain conclusions can be drawn from the results of the surveys. Concerns about both prevention of development and the potential harms of development are expressed from all parts of Alberta. These concerns are concentrated in the more densely settled areas of the province, particularly the Calgary region at this time. Concerns expressed revolve around a few key issues: the conflict between the need of the operators to develop close to the market and the desire of residents to defend their quality of life; protection of natural areas (particularly water courses) versus the desire of operators to maximize recovery from deposits; and the concern of all parties about the nature and enforcement of laws and regulations.

Research needs

Procedures are in place to restrict development, based on environmental concerns, and to reclaim sites after mining. There is little information on the economic value and benefit of resource development going into the evaluation process.

Mineral aggregate resource data should be gathered on a province wide basis. When decisions on mineral aggregate development at the regional and municipal level will affect more than one jurisdiction, the province should be prepared to present data for appropriate use by the regional and municipal levels in their land use process.

Resource market areas should be defined and data should be provided for land management discussions within the context of the market areas.

The long term impacts of resource exclusions or approvals must be considered and a working relationship needs to be established and maintained between the various stakeholders in the mineral aggregate resource sector.

Strategic considerations

Unlike other minerals used in Alberta, mineral aggregate is not imported save for small amounts of speciality sands (for example for golf courses), decorative stone, and railway ballast. The province is fortunate in having large, widespread supplies of sand and gravel and major potential bedrock sources in the southwest and northeast corners of the province. Alberta has ample natural supplies and complete control of the resource.

The province has not needed a resource conservation strategy to date. But signs are that a long term strategy must be designed soon if we are to sustain our mineral aggregate supplies. First it is essential to inventory our resources as most other provinces have done. This resource data must be followed with a resource conservation strategy which identifies those resources to be preserved for the future. Southern Ontario is a leader when it comes to legislation and policy conserving their resources (Planning Initiatives, 1992).

This resource conservation must be implemented through a consistent and co-operative effort of the province, regional municipalities, and the industry. It is important to have an advocate for the mineral aggregate resource. In California the Department of Mining and Geology attends local hearings and speaks on behalf of the resource. Through their efforts, great amounts of natural resource have been preserved for future use.

Outlook

Supply and demand

Sand and gravel has been produced in Alberta the turn of the century. Concern that supplies from existing sources were running short was reported as early as 1946: "Since the demand for gravel ... is increasing year by year, and since many of the gravel deposits are being worked out, it is imperative that new sources of this material be found. ... It is planned in the future to devote part of the time spent in the field to the study of gravel deposits." (Research Council of Alberta, 1946). More supplies were found as sand and gravel is still the main source of mineral aggregate in Alberta. The public knowledge of our supplies is still very much uncertain. Maps with preliminary information on the size of the resource are available for only about 18% of Alberta (Edwards and Chao, 1989).

In this report it is assumed that supply for mineral aggregate equals demand. The demand for mineral aggregate in Alberta commonly is measured through the annual production statistics of Natural Resources Canada (NRCan). Data are gathered through a mail survey of producers. Annual production of mineral aggregate for all provinces and territories is presented in the Canadian Minerals Yearbook. Alberta production of mineral aggregate in 1991 is reported by NRCan as 38 722 000 tonnes, of which 38 303 225 tonnes was sand and gravel. This production was gathered from 172 survey respondents.

NRCan data are valuable for comparing provincial production and establishing production and consumption trends. An evaluation of the NRCan data in 1981 (Edwards, 1989b) and personal communication with industry (ASGA AGM) suggests that NRCan data are deficient for Alberta. A survey of possible mineral aggregate producers was conducted during the course of this study. The NRCan survey for 1991 is incomplete by 128 producers (Table A-1). An additional 7 181 611 tonnes of sand and gravel are identified by producers additional to those contacted by NRCan. It is assumed that the production number generated from a combination of the AGS and NRCan surveys (45 484 836 tonnes) still represents a minimum amount of sand and gravel as some producers did not respond to the AGS survey.

Although the combined survey results are imprecise, it is presumed that most of the production for 1991 has been captured between the two surveys. The AGS survey recovered more data from smaller producers than the NRCan survey (Table 14). Seventy-seven percent of the AGS survey data was recovered from operations producing less than 50 000 tonnes in 1991 whereas the NRCan survey recovered 62% of its data from operators producing in excess of 50 000 tonnes.

Table 14. Mineral aggregate production from AGS and NRCan surveys for 1991.

	Amount of production in 000s tonnes						
	>500	>250	>100	>50	>10	<10	Total
NRCan survey							
# reporting production	10	16	47	33	48	18	172
% of respondents	6	9	27	19	28	11	100
AGS survey							
# reporting production	3	3	13	11	37	61	128
% of respondents	2	2	10	9	29	48	100
Total distribution							
# reporting production	13	19	60	44	85	79	300
% of respondents	4	6	20	15	29	26	100

In Alberta 4% of the producers mine more than 500 000 tonnes of sand and gravel annually (Table 14). These 4% produce 53% of the total production (Table 15). Sixty-six percent of the provincial production comes from only 10% of the operators (those that mine over 250 000 tonnes annually.

Table 15. Sand and gravel production for 1991 categorized by producer size.

	Amount of annual production by producer size (000s tonnes)						
	>500	>250	>100	>50	>10	<10	Total
Production	23 867	6 141	9 780	3 131	2 102	464	45 485
% total production	53	13	21	7	5	1	100

Sand and gravel is produced, transported, and used within various regions in Alberta. These regions act as individual markets. Nothing has been published on market regions for mineral aggregate in Alberta. It is known that most Counties, Municipal Districts, and Improvement Districts try to produce mineral aggregates for use within their jurisdictions. It also is known that the larger urban areas (Edmonton, Calgary, Lethbridge, Red Deer) consume supplies from surrounding counties and municipal districts and represent market areas larger than the urban municipality itself. For the purposes of this report, market regions will be delineated by the municipal boundaries with three regions, the Calgary region, the Edmonton region, and the Grande Prairie region including these metro areas plus surrounding municipalities. Map 1 (Appendix A) shows the distribution of villages, towns, and cities from which production is recorded (private and public sector). Map 2 (Appendix A) identifies the municipalities which are used as market areas in this report. Production/consumption figures used for these market or municipal regions does not include provincial transportation data or railway data as these could not be attributed to municipal regions. Per capita consumption figures for the regions will be lower by an average of about 3.7 tonnes.

The greatest total consumption (production) is concentrated around Calgary and Edmonton, the two regions with the greatest population (Figure 1) and it is here that the largest companies operate. The greatest number of producers however are situated in regions with intermediate populations (Figure 6). The average number of producers per region declines in a regular manner with decreasing population of the market region (Figure 6).

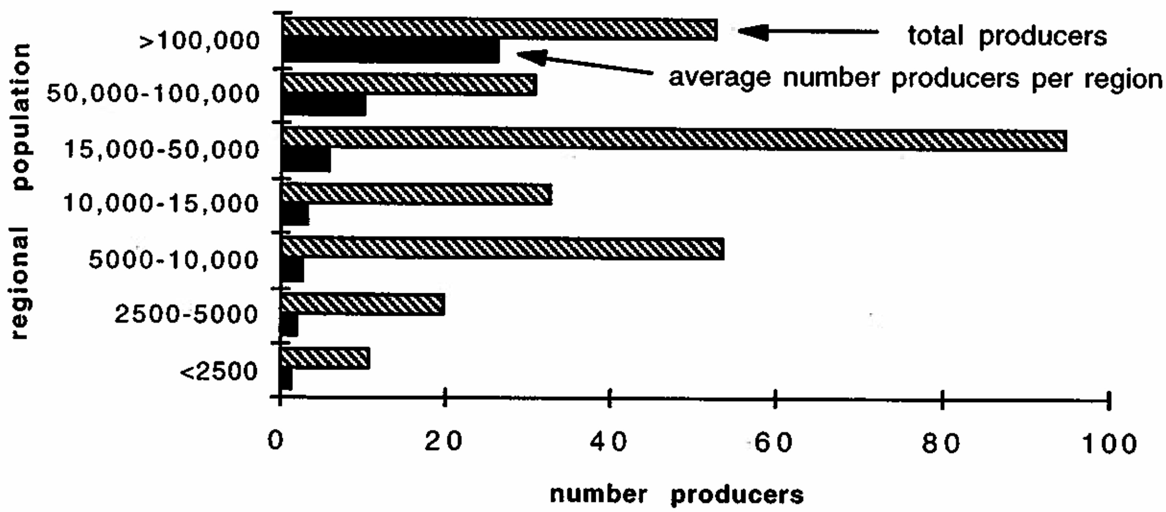

Figure 6. The total and average number of producers operating in each region during 1991.

The average annual per capita consumption of sand and gravel in 1991 for each region is plotted in Figure 7. These data are tabulated in Table A-1 (Appendix A). As there is a great difference in the populations of the regions with most regions having populations less than 50 000, Figure 7 does not resolve readily into a trend.

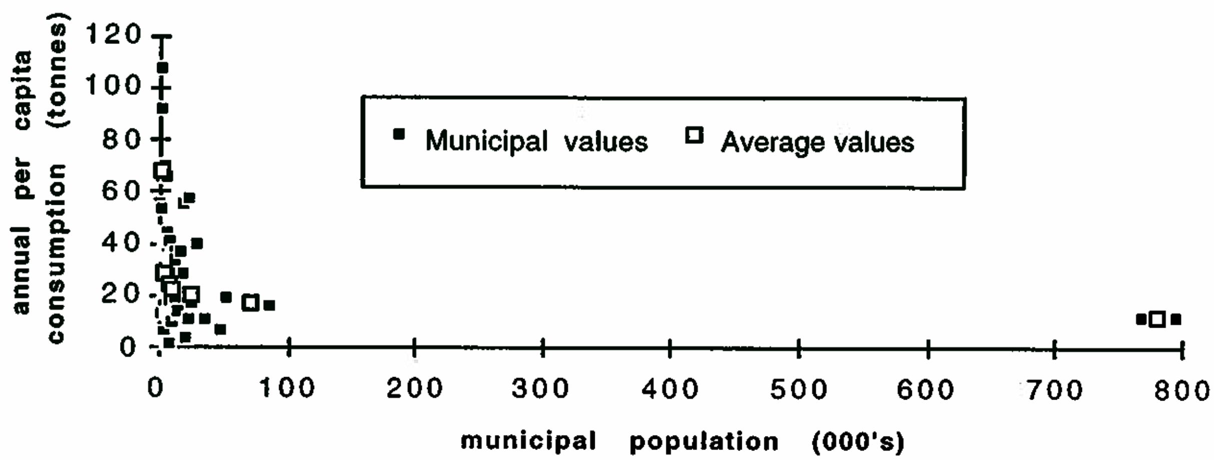

Figure 7. Per capita mineral aggregate consumption for 1991 for Alberta municipalities.

The number and scatter of data points for municipalities with less than 50 000 population (60% of regions) and the annual differences in production (consumption) makes the identification of trends difficult. Average per capita consumption values for 1991 determined for groups of regions fall into seven population categories. These average values are shown in Figure 8. In Figure 8 it is clear that average per capita consumption decreases with increasing regional population. Values range from 67.5 tonnes annual per capita consumption for municipalities with less than 2500 people to 11.9 tonnes for the Edmonton and Calgary regions (~ 800 000 population each).

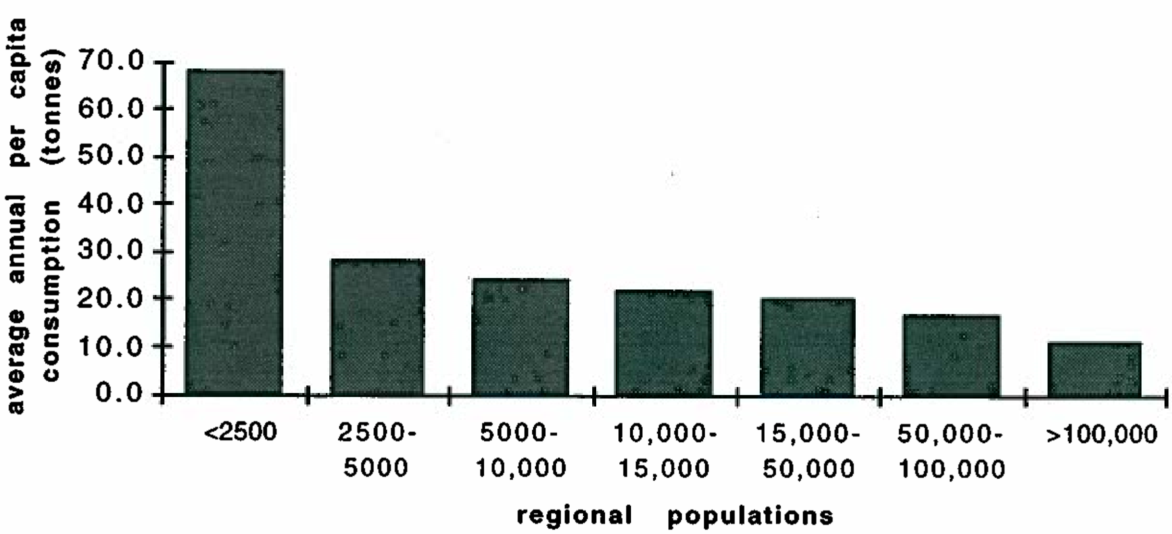

Figure 8. Average annual per capita consumption (tonnes) of sand and gravel for Alberta regions in 1991.

Municipalities with populations less than 5 000 are scattered across Alberta, occurring in the central and southern plains as well as in northern Alberta. Consumption of mineral aggregate (Figure 9a and b) is highly variable. Any amount of infrastructure development or upgrading in these regions will produce a large per capita consumption value. Considerable annual variation is expected for a given region.

Municipalities with intermediate populations between 5 000 and 50 000 (Figure 9 c, d, and e) show decreasing scatter in the data. These regions, or parts of them, typically have been settled for a long period of time, may have an agricultural base, and contain one or more small to medium sized towns. The transportation infrastructure in these regions is well established although up-grading of roads is usually underway. The greatest number of producers are active in these regions (Figure 6).

There are only five regions with populations over 50 000 (Figure 9 f and g). These have relatively little scatter in the per capita consumption. This probably is due to the similar mineral aggregate requirements of cities and sufficient consumption to show less scatter due to single construction events. The infrastructure in these populated regions is highly developed with most roads paved and requiring a more constant maintenance requirement. There is also a larger industrial and residential construction component in these urban regions. There are a large number of producers serving the needs of these regions.

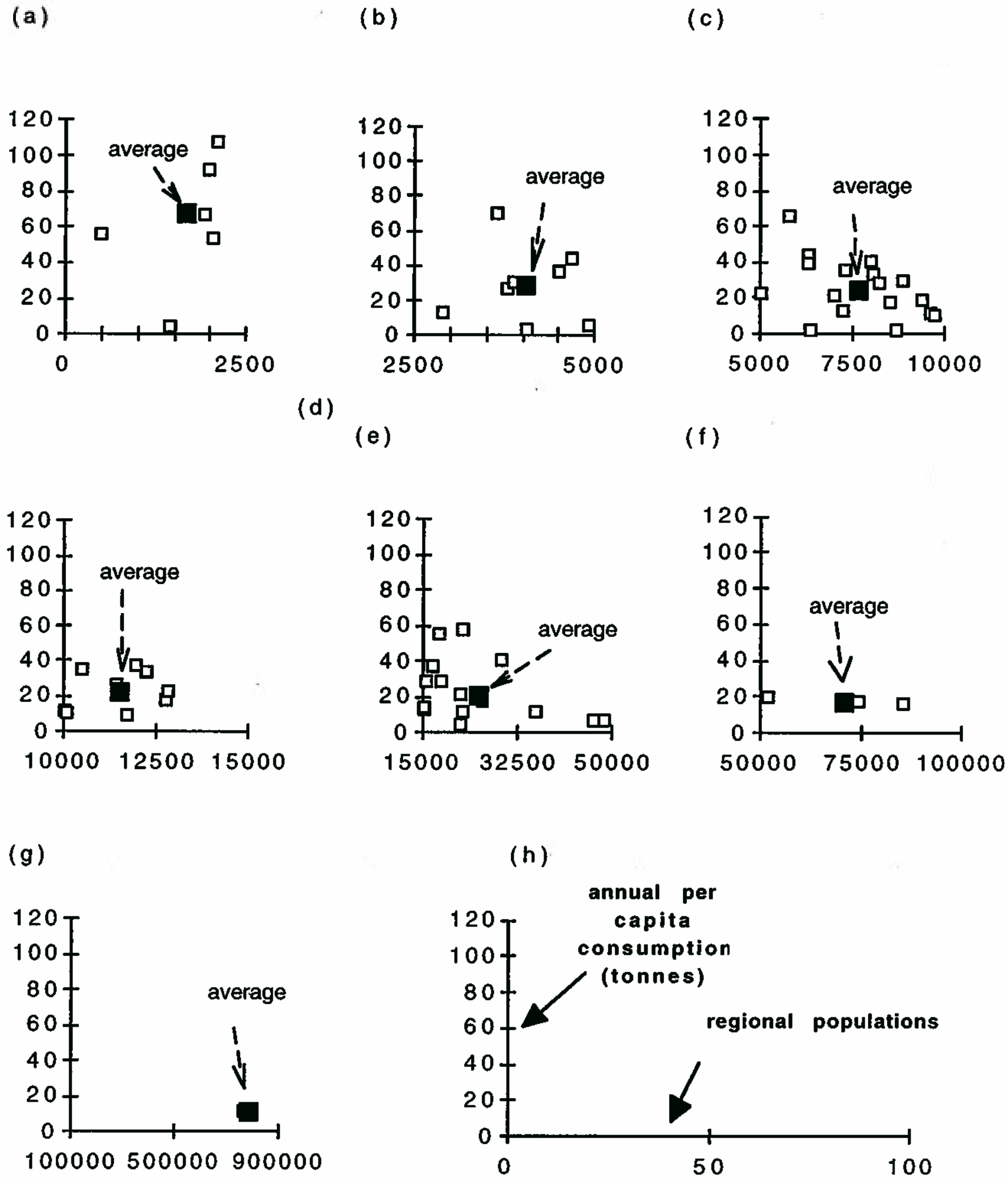

Figure 9. Per capita consumption for 1991 for regions with populations of: (a)<2 500, (b) 2 500 to 5 000 (c) 5 000 to 10 000, (d) 10 000 to 15 000, (e) 15 000 to 50 000, (f) 50 000 to 100 000, (g) >100 000, and (h) explanatory graph .

All public and private sector producers surveyed were asked to estimate the number of years supplies of sand and gravel they controlled. The maximum years supply of gravel identified for a region by a producer is shown in Figure 10. This method of reporting can be misleading in that a small producer with no anticipation of increasing annual production will report a great number of years of supply even if the municipality as a whole is in dire need of mineral aggregate.

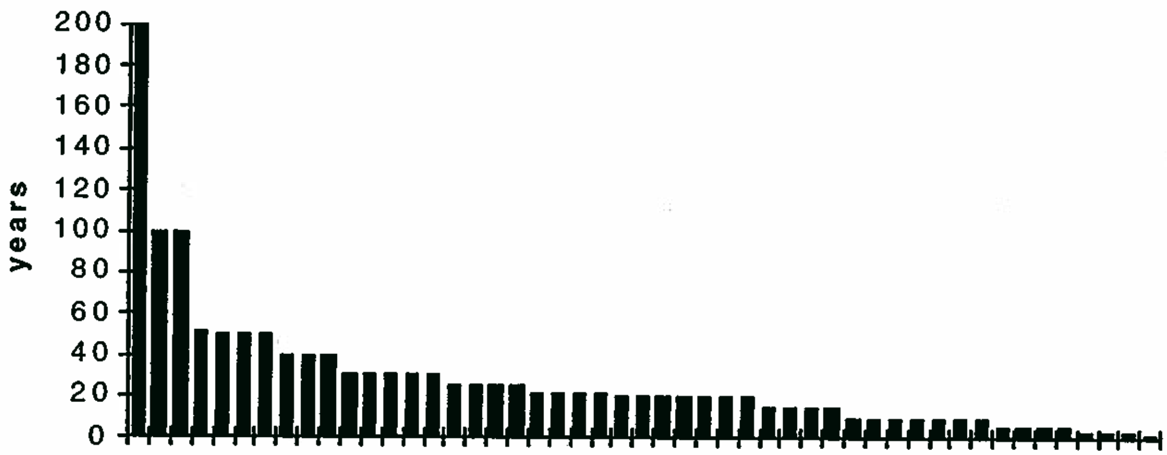

Figure 10. Maximum numbers of years supply of gravel by a producer in each of 49 regional municipalities.

A more representative but complex visualization of depletion data is shown in Figure11. The stippled bar identifies regions based on the first report by a producer in that region that his supplies of gravel will be expired in that time period. For example, initial depletion of gravel will occur for at least one producer in ten years or less in 34 of the 49 municipalities reporting and in half of the municipalities in 12 years. Figure 11 also reports, through the solid bar, when the last producer in a region reports that his supplies of gravel will expire. For example, maximum supplies will give out within 10 years or less in 15 of 49 municipalities and half of all municipalities will be depleted in 20 years or less.

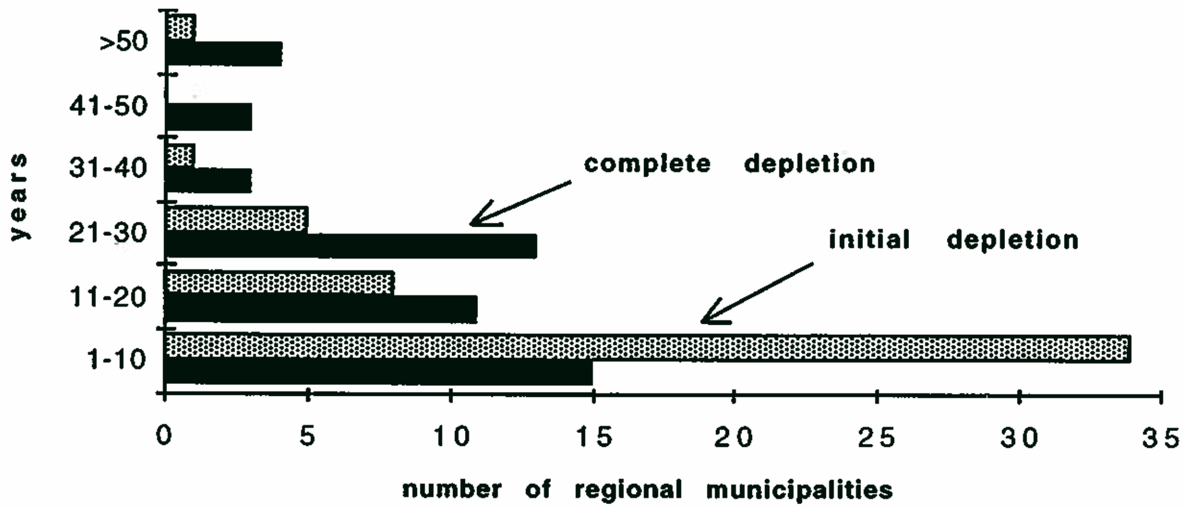

Figure 11. The initial producer depletion of gravel (stippled bar) and the maximum producer supply of gravel (solid bar) for 49 regional municipalities.

Producers reported sand supplies for 48 regions. Initial depletion of sand will occur within 10 years in 24 (half) of all regional municipalities reporting (Figure 12). Supplies held by all producers in the municipality will expire within 10 years in 10 municipalities and will expire in 21 years for half of all municipalities reporting.

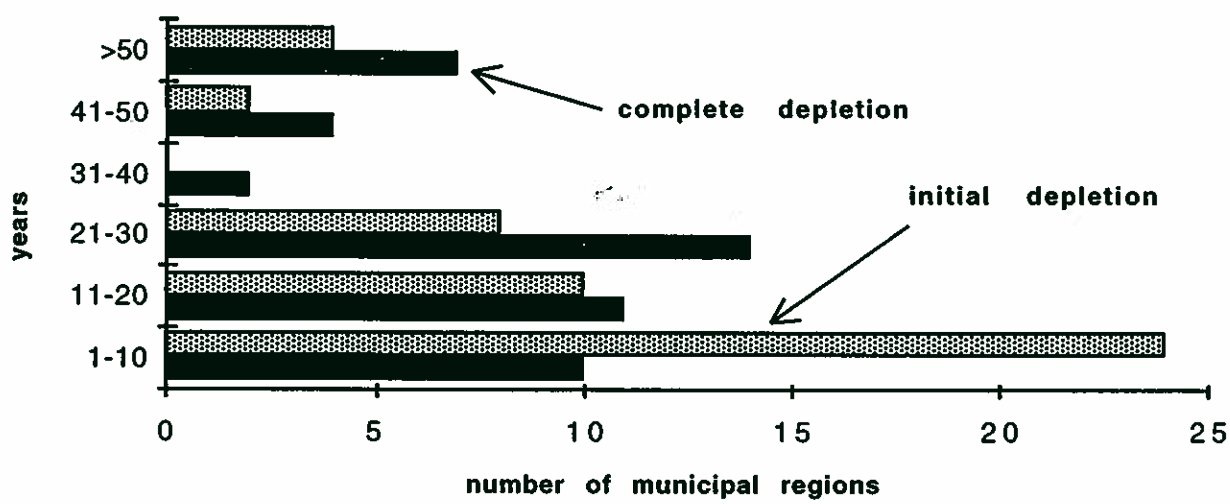

Figure 12. Years to initial depletion of sand supplies by one producer (stippled bar) and the depletion of all supplies (solid bar) for each of 48 municipalities.

Research needs

This is the first attempt to identify market regions in Alberta. It appears that this could be a valuable way of tracking the use of the resource and determining long term trends. This would require a consistent, annual survey of producers.

High consumption takes place in the urban areas. It is in these areas where mineral aggregate producers come into the greatest contact with residents. Conflict can result over differing visions of land use. These areas also are centres which have required aggregate for long periods of time and now may have limited sources of supply without long haul distances. These regions require very intense land use assessments as to the need and value of future mineral aggregate resources.

Regions with lower populations have different, but no less important, requirements for management of the mineral aggregate resource. They are in the process of developing the basic transportation and industrial infrastructures. Careful selection and use of mineral aggregate at this stage of development is extremely important and has more flexibility than in the urban areas. It is also in these regions that the provincial government has a greater ability to manage the aggregate resource and plan for the future.

New uses, markets

The current sand and gravel industry is well established in terms of uses and markets. Potential for new uses may come through substitutes for sand and gravel and other materials recovered through the mining of the sand and gravel. Substitutes (synthetic aggregate), produced from new sources such as clay or till, could enter the market as traditional gravel supplies are depleted, haul costs escalate, or if deposits are sterilized through land use conflicts. A major factor in the costs of synthetic aggregates are fuel costs for the burning of the raw materials. Many other minerals could be recovered from the sand and gravel which may have multiple uses in Alberta. Each of these opportunities must be assessed in a regional context.

The greatest change which will occur in Alberta in the mineral aggregate industry over the next 25 years is the switch from dependence on unconsolidated resources (sand and gravel) to crushed stone (bedrock resource).

Summary of research needs

Alberta is producing adequate amounts of mineral aggregate without relying on imports. But Alberta is not mature in terms of mineral aggregate: legislative procedures are inconsistent and somewhat awkward, there is no public accounting or inventory of mineral aggregate reserves, and the industry and public concerns are still at a sparring stage. The mineral aggregate sector in Alberta is rapidly developing and the next 10 years will be critical in the development of a philosophy and procedures which will guide mineral aggregate development for many decades.

There is no public accounting of mineral aggregate reserves. Although the amount of sand and gravel present apparently is vast, available reserves are actually much smaller and dwindling. Mineral aggregate resources are being consumed at twice the rate at which they are being discovered. No public mapping has taken place in Alberta for the last five years and existing resources are being removed from access through restrictions near watercourses and by other land use restrictions.

When a mineral aggregate pit or quarry is opened it is essential that the potential of that property is maximized. All potential minerals at the site should be exploited and the best technology possible for extracting the minerals should be employed.

It is essential to know about the natural occurrence of the deposits but, as an essential commodity, it is just as essential to understand our demand and use for mineral aggregate. With this combination of information in place it is possible to plan and manage the resource.

To develop an effective resource accounting

More complete resource inventory is required. Remainder (80%) of province to be mapped. Deposits must be evaluated in greater detail, volumes assessed in a statistical manner, and materials evaluated using additional tests to determine the economic potential.

Information scattered about various government departments should be integrated in a digital data base and made available to all provincial departments and municipalities.

Existing digital data bases of sand and gravel deposits (for example the current AGS data base) should be evaluated as a starting point for a broader, generally accessible source of mineral aggregate resource information.

Bedrock formations should be evaluated for crushed stone potential and favourable formations mapped.

To maximize our mineral recovery

All sand and gravel deposits should be evaluated for by-product mineral potential, the underlying bedrock investigated, and the overburden checked

Research into more effective methods for the recovery of by-product minerals.

To understand the value, use and demand for the resource

An annual survey of all producers should be undertaken by the province to enable regional evaluation and identification of high consumption areas for intense land use assessment.

Resource market areas should be defined through a consistent, annual survey of producers and data should be provided for land management discussions within the context of the market areas.

To manage the mineral aggregate resource effectively

Generate information on the economic value, long term impacts of resource exclusions or approvals and benefit of resource development for use in the land use management process.

Decisions on the development of deposits made at the municipal level which will affect more than one jurisdiction should have input from the province to aid the municipality in their land use decision.

A working relationship needs to be established and maintained between the various stakeholders in the mineral aggregate resource sector.

The province should develop a more effective approach to the management of mineral aggregate resources on Crown lands and plan for the future.

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Appendix A

(Materials are in the pocket)

Table A-1 Summary statistics for 1991

Description of terms

Calgary Region, Edmonton Region, Grande Prairie Region: the municipalities comprising these regions are listed below the main table. Total values for each region are carried into the main table so that each municipality within these regions is not listed separately.

Population: numbers are for 1991.

Production and Value of Production: includes both public and private sector data as reported by the producer.

Other: includes public works and railway data that could not be identified with specific regions.

Map 1 Index Map to Regional Municipalities

Map 2 Index Map to Villages, Towns and Cities

Appendix B

A case study of events surrounding the 1994 proposal by Burnco Rock Products Ltd. and Consolidated Aggregates to develop sand and gravel pits in the Municipal District of Rocky View.

A major controversy erupted in the Calgary region during 1994 and 1995 over a proposed sand and gravel development. This case is typical of urban, land use controversies sparked by mineral aggregate developments in Canada and around the world. This case is the most vehement confrontation to have taken place over mineral aggregate development in Alberta and it has most or all of the elements likely to be involved in other conflicts in the province.

The situation escalated when two companies, Burnco Rock Products Ltd. and Consolidated Aggregates, sought to develop sand and gravel pits on the northwestern outskirts of the City of Calgary within the Municipal District of Rocky View. There was a history of conflict over gravel mining and transportation in adjacent northwest Calgary. City of Calgary Alderman J. Kerr (northwest Calgary) mentioned 'distressing and dangerous impacts of the five existing gravel pits in the area' in a Calgary Herald article on November 30, 1994. Development within the M.D.of Rocky View required the redesignation of country residential and agricultural lands into gravel extractive and involved a public hearing before the Council of the M.D.of Rocky View. The resident population mounted a co-ordinated, vocal, and highly visible opposition to the proposed development. Minutes from the Public Hearings form the primary source of information used in this description of events. Information presented at the hearing by the applicants and those opposed clearly represents personal opinion as well as fact and mention in this case study is not meant as validation of information or support of a particular viewpoint. The other sources of information are newspaper articles which appeared during the conflict. Where newspaper information is used, the date and source of the article is listed. The one aspect of the situation which cannot be conveyed in this review is the emotion which residents carried into the Public Hearings. Headlines have been duplicated here to give a sense of the drama which unfolded during this period.

Burnco Rock Products Ltd. and Consolidated Aggregates are major mineral aggregate producers in the Calgary region. Both companies operate other pits in the region. These companies purchased land in the M.D.of Rocky View on the northwest boundary of the City of Calgary (called the Bearspaw area) for the purpose of future mineral aggregate production. In 1994 both companies decided to open pits and approached the M.D.of Rocky View for redesignation of the land to allow development of gravel pits. Burnco's application was for W1/2 of 4-26-2-W5 and SE-4-26-2-W5 and Consolidated's application was for E1/2 of 5-26-2-W5. The mineral aggregate from these operations would be trucked into the City of Calgary along 85 Street or 144 Ave. N. W. These routes already are used by trucks leaving several of the five gravel pits operated in northwest Calgary.

As part of the land rezoning process, a public announcement is required in a local newspaper. A notice was published in the Rocky View / Five Village Weekly on November 15 and 22, 1994 announcing a Public Hearing on November 29, 1994 to change the land use designation to 'Direct Control District- Aggregate Extractive Industry'.

Residents were aware of the intentions of Burnco Rock Products Ltd. and Consolidated Aggregate to open pits long before the formal hearing. A resident organization calling itself the Concerned Citizens' Organization began organizing and accumulating information during the summer and fall of 1994. Prominent road signs decrying the proposed development appeared along the roads in the area, one announced 'BEAT BURNCO RALLY OCT 12 7-9 PM BEARSPAW COMMUNITY HALL'. Burnco answered residents questions and concerns by letter and telephone, met with residents at their homes, and held an open house.

The public notice gave a focus to resident opposition to gravel development in the Bearspaw and northwest Calgary areas and made the issue newsworthy. The Public Hearing began at 1:17 p.m. November 29, 1994 at the M.D.of Rocky View offices. Over 200 persons packed the hall to overflowing and signs outside the offices (photo 1 below) announced the presence of the opposed faction.

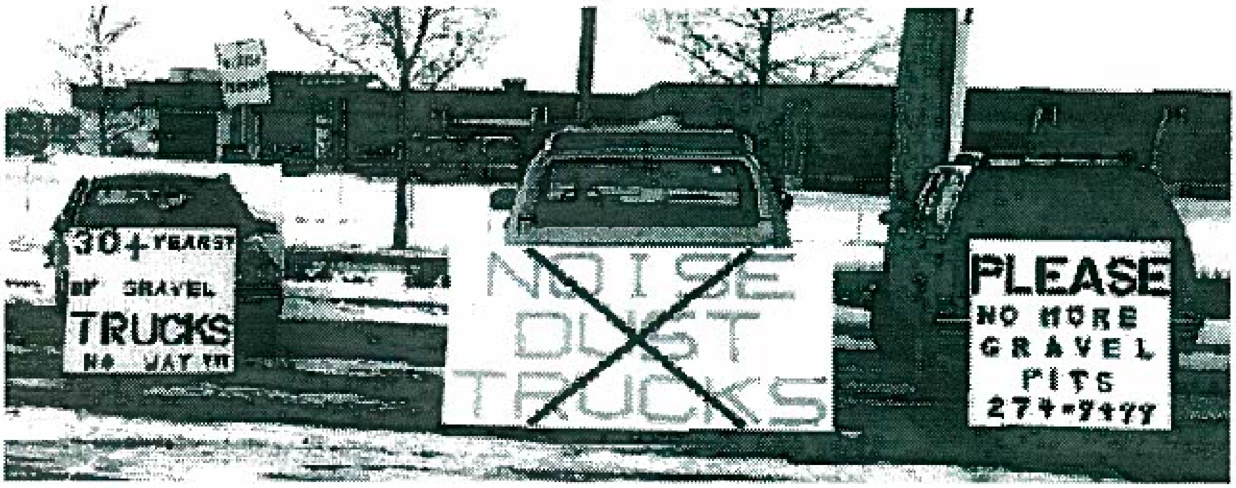


Photo 1. Signs outside the M.D.of Rocky View offices at the start of the Public Hearing on November 29, 1994.

Council heard first from Burnco Rock Products Ltd. Five members of Burnco Rock Products Ltd., including president Scott Burns, and six consultants (planner, appraiser, hydrogeologist, transportation engineer, biologist, and solicitor) were present. The history of the company was described and a professionally made video describing the Burnco operations was shown. The plan for pit development was explained and the following issues surrounding resident concerns were addressed: dust (application of dust suppressants, paving), noise (enclosed crusher plant), environment (preserve grasslands in SW corner of property and wildlife corridor on west boundary), trucking (implement stringent truck policy, participate in road upgrading, use City of Calgary truck routes), property values (guaranteed property value up to 25% loss), and benefits to the M.D.and the community (interim land uses, revenue through taxes, licenses, donations). Council then directed questions to the applicants (including date of title to property, distance to closest adjacent property, number of residents, sound levels, truck routes, and traffic volume).

After a brief recess two individuals spoke in favour of the redesignation citing their opinion that: the operation would be a revenue source for the M.D.of Rocky View, Burnco was trying to meet all concerns, there would be a minimum of dust, noise, engineering, traffic, and property value concerns.

Those opposing the redesignation were invited to speak (5 minutes per individual, 10 minutes per group). As many of the concerns were repeated and a great number of speakers participated, the information has been tabulated (Table B-1). The table summarizes the concerns as described in the Council Minutes. Individuals are named in order as they appear in the Minutes. The Public Hearing proceeded until 7:20 p.m.

At 7:39 p.m. Burnco and its consultants proceeded with a rebuttal. They assured Council they would comply with all promises made. Pit depth of 130' virtually eliminates dust, dry crushing reduces the effects, and a wind study suggests little problem. Pit depth of 130' virtually eliminates noise, and a wind study suggests little problem. Pit depth of 130' virtually eliminates the problem of visibility. Wildlife habitat already is disturbed, and more compatible coulees are in the pit design to preserve habitat. The reclamation process eliminates any effect on water wells. If water wells go dry Burnco would supply water or drill new wells. The main roads are designated as truck routes at present (City of Calgary confirmed providing truck routes to serve the gravel industry). In the long term there will be little or no use 85 Street. There is no obligation by Burnco to load any truck unless it is satisfied with the performance of the trucker. Car windshields damaged by Burnco trucks will be replaced by the company. The company has a history of attractive reclamation in Calgary that includes a park, shopping centre, and a lake. The depressing effect on land values should be only around 'the gate' of the operation. Benefits of $45 000 will accrue to the Municipality for licences, donations, and 1995 taxes if the application is approved. At 9:19 p.m. Council agreed to recess the Hearing to January 17, 1995.

The Public Hearing provided information for the media and on November 30 and December 4, 1994 articles appeared in two Calgary newspapers (headlines below).

Calgary Herald Nov. 30, 1994

Gravel industry criticized

Residents complain of noise, dust, and dangerous driving

THE CALGARY MIRROR Dec. 4, 1995

Gravel controversy brewing

Alderman says development freeze eyed

Table B-1. Views and concerns expressed by speakers opposed to redesignation of land as proposed by Burnco Rock Products Ltd. Information was obtained from the Council Minutes of the Public Hearing.

Speaker	Represented[1]	Concerns	Speaker	Represented[1]	Concerns
(November 29, 1994)					
S. Loeppk	3	L	D.Nikiforuk	5	O,T,AH,C,AE
J. Weisbrot	5	C,D,E	N. Molbank	1	E,O,V,AJ,AK,E
J. Kerr	1[2]	G,H,I,J,K	R. Jackson	5	AL
E. Park	1[3]	T	M. Jahn	6	AL
B. Bruce	1[3]	J	Rob. Himes	5	S,H,AS
E. Frost	1[4]	A,D,M,N,O,P,Q,R	D. Festeryga	1	AM,AS
A. Constable	1	S,T,U	A. Cornett	5	AN,AO,AP,J,AQ
B. Richards	1	V,M,W,AR	R. Dixon	1	AS,H
L. Forbes	5	V,Z,P,X,S,R,AA,O	Ron. Himes	5	X,AT,O,D
		AB,E,AC,N,AD,D	A. Munzel	1	C
L. Pendlebury	1	E,AE	M. Zipfel	1	C
C. Von Wedel	1	O,AF,V	M. Edwards	8[5]	W,F,B
B. Tomanik	5	AF,Q,AT	P. Knoll	1	E
R. Johnson	1	AB,AG,V			
(January 17, 1995)					
D. Swan	1	AU	B. Tomanik	1	AY
J. Charette	1	V,D	L. Forbes	1	F,D,O,S,AU,AG
K. McKerracher	1	AS	Harms	1	AZ
D. Nikiforuk	1	AJ	R. Himes	1	Q
N. Clayton	1	AU,AV	M. Edwards	1	BA
N. Molbank	1	AW	J. Lavertu	1	O
M. Jahn	1	P,V,AX	R. Dixon	1	Q

[1] the number of individuals represented (including speaker) as stated in the minutes of Public hearing; if a group is represented the number is listed as 1 and the grouped identified through the footnote.
[2] representing herself (not City of Calgary) and her constituents in Calgary Ward 2.
[3] representing City of Calgary.
[4] Arbour Lake Community Association (City of Calgary).
[5] also submitted letters representing opposition by 62 others and a questionnaire signed by 112 people saying they agree there is no need for another gravel operation.

Concerns

A truck noise
B country residences were here before the pit
C endanger, kill, or eliminate wildlife
D pit noise
E reduction of property values (>20% and 15% mentioned)
F gravel is only small cost of value of new house (1.8%)

Table B-1 (continued)

G	lack of City of Calgary budget for road maintenance
H	traffic control (lack of City of Calgary budget; difficulty in policing)
I	noise control (lack of City of Calgary budget)
J	hours of operation
K	no industry standards
L	deserves to go before Alberta Environmental Board and Natural Resources Conservation Board
M	road damage
N	community safety
O	dust and dust control
P	the need for the pit
Q	traffic safety
R	impact assessment
S	truck traffic
T	truck routes
U	longevity of pit (60 years mentioned)
V	incompatibility with country residential living, tranquility, quality of life
W	no gravel shortage in Calgary
X	water (wells) could be affected
Y	no guarantees about resolution of resident concerns in pre-hearing Burnco letter
Z	Burnco report false
AA	erosion
AB	rehabilitation of land
AC	visual impact of operation
AD	false benefits to landowners
AE	negligible cost benefit; loss to M.D.of $100 000s
AF	weed control
AG	lack of commitment by Burnco
AH	environmentally disruptive
AI	pit development would block residential development further north
AJ	no tax benefit (or loss of tax revenue) to M. D.
AK	potential buyers of residences would be apprehensive of buying
AL	noise (health concerns)
AM	automobile insurance restrictions due to gravel trucking
AN	lack of responsible long range planning
AO	blasting
AP	flooding
AQ	Burnco negligent in their operations
AR	traffic safety due to damaged roads
AS	traffic safety due to gravel trucks
AT	loss of view
AU	dust (health concerns)
AV	new roads intended for residential traffic not gravel trucks
AW	industrial tax base for education not required
AX	no community support for gravel operation
AY	pit equipment suggested is untested

Table B-1 (continued)
AZ lack of information provided by Burnco for open meetings
BA benefits accrue to residents of City of Calgary not the M.D.residents

The Consolidated Aggregates application for redesignation on a parcel of land adjacent to Burnco Rock Products land, originally scheduled to take place on the same afternoon after the Burnco hearing, was rescheduled to begin on December 6 because of the length of the Burnco hearing. The Public Hearing to discuss Consolidated Aggregates' application began at 1:31 p.m. and proceeded until about 6:00 p.m. when it was recessed until January 24, 1995. This hearing followed in much the same manner as the Burnco Public Hearing. Consolidated Aggregates and their consultants spoke about the proposal. Three others spoke in favour of the redesignation. Two of these represented trucking interests. Presentations opposed to redesignation came from 16 speakers representing 42 individuals, one alternative development (school), a community association (in Calgary), and Ward 2 (Calgary). Details of the opposition are not listed as they are very similar to those items listed in Table B-1. Newspaper articles (see below) appeared after the first day of the Consolidated hearing, on December 10 and December 17, 1995.

THE CALGARY MIRROR Dec. 10, 1994

Residents Blast Gravel Pit Plans

THE CALGARY MIRROR Dec. 17, 1994

Gravel development on rocky road

N.W. residents continue to oppose mining companies' operating agenda

The Burnco Public Hearing continued on January 17, 1995 at 2:36 p.m. Representatives of Burnco noted that additional information had been gathered through open meetings since the November 29, 1994 hearing. Burnco submitted an agreement to work as an industry on enhanced standards of operation, with the City of Calgary on truck routes, with the M.D. of Rocky View, M.D. of Foothills and the City of Calgary on universal standards and fees, and as a company with Consolidated Aggregates on mutual access to the pits. Mr. E. Parks and Mr. B. Bruce of the City of Calgary reported that truck routes would be unrestricted and open 24 hours. Mr. B. J. Vickery of Alberta Environmental Protection noted that Burnco's application meets all A.E.P. requirements. Council then heard from residents opposed to the application for redesignation (see Table B-1). Burnco was asked for rebuttal and their representative noted that upgrades would take place to 85 Street and that Burnco intended to provide an Indemnity Agreement to cover some ratepayer concerns.

The Public Hearing closed at 6:55 p.m. on January 17, 1995. A total of 40 speakers representing 86 residents, the City of Calgary, Ward 2 of the City of Calgary, and a community association spoke against the redesignation. Letters representing 62 residents and a questionnaire signed by 112 opponents to an aggregate operation were submitted at the Hearing.

The concerns expressed are difficult to categorize because of overlap and the fact that the minutes from the meetings are brief. With such a number of speakers and concerns expressed it is useful to organize the statements in order to understand the fundamental opposition. There appears to be about ten basic categories of concerns: quality of life (incompatibility of country residential life with a gravel operation), health (primarily dust and noise), safety (especially due to increased traffic of gravel trucks), economic (including residential, business, and community), direct physical effects of pit development, indirect effects of the operation (on wildlife), increased traffic of gravel trucks, reasonable process (regulations are not being followed, control cannot be maintained, and precedents are ignored), belief that there is no justification for the change, and concerns with the credibility of the company.

In a 6 to 2 vote, Council approved Burnco's application, giving second reading to the rezoning request. Headlines for January 19, 24 (3 examples), and 28, 1995 (below) announced the Council support for the gravel pits and reflected the surprise which residents felt at the approval. One writer described the decision as 'the most politically unpopular move Rocky View council has ever made' (Calgary Rural Times, January 24, 1995).

Calgary Herald Jan. 19, 1995

Residents stunned by ruling

CALGARY RURAL TIMES Jan. 24, 1995

Council clears the way for Bearspaw gravel pits

CALGARY RURAL TIMES Jan. 24, 1995

M.D. Council supports Bearspaw gravel pit application

THE CALGARY MIRROR Jan. 28, 1995

Pit approval suprises residents

Many of the Councillors supporting the Burnco development noted that Council would impose strict guidelines in the development permit. Rocky View Reeve Bob Cameron noted that 'the Burnco application was approved with the understanding that the operation would be shut down if the company doesn't adhere to its assurances of safe conduct and minimal effect on the surrounding area' (Calgary Mirror, January 28, 1995). Final approval by Council was scheduled for Feb. 21, 1995. Alderman Kerr noted that the 'municipal district will receive a 20-cent-per-ton royalty from the pits' but was concerned that the City of Calgary would be obliged to spend millions on building roads to handle the increased truck traffic (Calgary Mirror, January 28, 1995).

When the Consolidated Aggregates Public Hearing resumed at 1:30 p.m. on January 28, 1995 another 12 presenters representing 21 residents, one realtor, and a doctor from the Mount View Health Unit spoke against the proposal. Many speaking against the application expressed their feeling that approval of the adjacent pit was a forgone conclusion as a result of the Burnco approval. Consolidated Aggregates then offered a rebuttal. The Hearing concluded at 5:43 p.m. and Council voted 7 to 2 against Consolidated Aggregates' application. Headlines on January 31 and February 4 (see below) noted the fact.

Rocky View / Five Village Weekly Jan. 31, 1995

Second Gravel Pit Rejected

THE CALGARY MIRROR Feb. 4, 1995

Second Gravel Pit Turned Down

Letters to the editor of the Rocky View / Five Village Weekly on February 6, 1995 not only conveyed the dismay which residents felt about approval of Burnco's application but confusion at the events which led to the rejection of Consolidated's application. Council's decision on Consolidated Aggregates application appeared to surprise other participants as well: D. MacFarlane (Councillor) noted 'It baffles my mind- what changed in one week?' (Calgary Mirror, February 4, 1995) and Dave Clark (spokesman for Consolidated Aggregates) said 'We were as surprised as anybody else' (Calgary Mirror, February 4, 1995). Consolidated Aggregates can reapply again in one year.

The furore was not over yet. At third reading of Burnco's application for the land use bylaw change on February 22, 1995 the M.D. of Rocky View Council lost quorum when two Councillors left chambers before the vote. Reeve Cameron said he 'wouldn't bring it (to Council) until he was assured of having a stable quorum' (The Calgary Mirror, March 4, 1995). One resident noted other options to continue the fight 'One is to fight it out at a development appeal hearing, two is to force a plebiscite, three is to take legal action' (The Calgary Mirror, March 4, 1995).

THE CALGARY MIRROR March 4, 1995

N.W. gravel pit approval delayed

At the time of this report (April, 1995) the status of gravel pit development in the Bearspaw area is unknown.

Reference to Map 1

County

Map Ref. No.	County Name	County No.
1	County of Athabasca	12
2	County of Barrhead	11
3	County of Beaver	9
4	County of Camrose	22
5	County of Flagstaff	29
6	County of Forty Mile	8
7	County of Grande Prairie	1
8	County of Lac Ste Anne	28
9	County of Lacombe	14
10	County of Lamont	30
11	County of Leduc	25
12	County of Lethbridge	26
13	County of Minburn	27
14	County of Mountain View	17
15	County of Newell	4
16	County of Paintearth	18
17	County of Parkland	31
18	County of Ponoka	3
19	County of Red Deer	23
20	County of Smoky Lake	13
21	County of St. Paul	19
22	County of Stettler	6
23	County of Strathcona	20
24	County of Thorhild	7
25	County of Two Hills	21
26	County of Vermilion River	24
27	County of Vulcan	2
28	County of Warner	5
29	County of Wetaskiwin	10
30	County of Wheatland	16
31	Special Area 2	
32	Special Area 3	
33	Special Area 4	

Municipal District

Map Ref. No.	MD Name	MD No.
1	MD of Acadia	34
2	MD of Badlands	7
3	MD of Bighorn	8
4	MD of Bonnyville	87
5	MD of Brazeau	77
6	MD of Cardston	6
7	MD of Cardston	6
8	MD of Clearwater	99
9	MD of Cypress	1
10	MD of Fairview	136
11	MD of Foothills	31
12	MD of Kneehill	48
13	MD of Peace	135
14	MD of Pincher Creek	9
15	MD of Provost	52
16	MD of Rocky View	44
17	MD of Smoky River	130
18	MD of Spirit River	133
19	MD of Starland	47
20	MD of Sturgeon	90
21	MD of Taber	14
22	MD of Wainwright	61
23	MD of Westlock	92
24	MD of Willow Creek	26

Improvement District

Map Ref. No.	ID No.
1	ID 4
2	ID 5
3	ID 6
4	ID 8
5	ID 9
6	ID 12
7	ID 13
8	ID 14
9	ID 15
10	ID 16
11	ID 17
12	ID 18
13	ID 19
14	ID 20
15	ID 21
16	ID 22
17	ID 23
18	ID 24

Other

Map Ref. No.	Name
1	CFB Cold Lake
2	CFB Edmonton
3	Municipality of Crowsnest Pass

Reference to Map 2

Cities

Map Ref No.	Name
1	Airdrie
2	Calgary
3	Camrose
4	Drumheller
5	Edmonton
6	Fort McMurray
7	Fort Saskatchewan
8	Grande Prairie
9	Leduc
10	Lethbridge
11	Lloydminster
12	Medicine Hat
13	Red Deer
14	Sherwood Park
15	Spruce Grove
16	St. Albert
17	Wetaskiwin

Towns

Map Ref No.	Name
1	Athabasca
2	Barrhead
3	Bashaw
4	Bassano
5	Beaverlodge
6	Blackfalds
7	Bonnyville
8	Bowden
9	Bow Island
10	Brooks
11	Cardston
12	Carstairs
13	Claresholm

Towns (continued)

Map Ref No.	Name
14	Cochrane
15	Devon
16	Didsbury
17	Drayton Valley
18	Edson
19	Elk Point
20	Fairview
21	Falher
22	Fort Macleod
23	Fox Creek
24	Hardisty
25	High Prairie
26	Hinton
27	Innisfail
28	Jasper
29	Killam
30	Lac La Biche
31	Lacombe
32	Lamont
33	Magrath
34	Manning
35	Millet
36	Morinville
37	Nanton
38	Olds
39	Peace River
40	Picture Butte
41	Pincher Creek
42	Ponoka
43	Provost
44	Rainbow Lake
45	Raymond
46	Rimbey
47	Rocky Mtn House

Towns (continued)

Map Ref No.	Name
53	Swan Hills
54	Sylvan Lake
55	Taber
48	Slave Lake
49	Smoky Lake
50	Stettler
51	St. Paul
52	Sundre
56	Three Hills
57	Two Hills
58	Valleyview
59	Vegreville
60	Viking
61	Wainwright
62	Westlock
63	Whitecourt

Villages

Map Ref No.	Name
1	Andrew
2	Big Valley
3	Bittern Lake
4	Carseland
5	Cayley
6	Clive
7	Cowley
8	Debolt
9	Duchess
10	Empress
11	Entwistle
12	Evansburg
13	Exshaw
14	Fabyan
15	Fort Vermillion

Villages (continued)

Map Ref No.	Name
16	Glenwood
17	Grovedale
18	Gwynne
19	Holden
20	Iddesleigh
21	Kelsey
22	Kinsella
23	Kipp
24	La Crete
25	Legal
26	Leslieville
27	Lundbreck
28	Mannville
29	Markerville
30	Marwayne
31	Metiskow
32	Monitor
33	Mossleigh
34	Niton Junction
35	Nobleford
36	Ohaton
37	Opal
38	Peers
39	Pine Lake
40	Rosebud
41	Rosedale
42	Rycroft
43	Shaughnessy
44	Spring Coulee
45	Twin Butte
46	Vilna
47	Wardlow
48	Warner
49	Winfield

TABLE A-1. Summary statistics for 1991.

Municipality/Region	Population	Production, 1991 metric tonnes	Consumption, 1991 annual per capita	Value of production	Number producers public & private	Maximum haul km
COUNTY OF WETASKIWIN (10)	22705	246043	10.8	$689,689	6	
COUNTY OF BARRHEAD (11)	9751	98884	10.1	$199,645	2	20
COUNTY OF ATHABASCA (12)	8507	143680	16.9	$916,750	2	50
COUNTY OF SMOKY LAKE (13)	4060	13000	3.2	$42,820	3	40
COUNTY OF LACOMBE (14)	18801	531377	28.3	$1,833,383	5	15
COUNTY OF WHEATLAND (16)	6320	277665	43.9	$630,709	3	50
COUNTY OF MOUNTAIN VIEW (17)	22564	1297013	57.5	$2,957,543	9	40
COUNTY OF ST. PAUL (19)	12851	280872	21.9	$808,159	4	42
COUNTY OF VULCAN (2)	3648	252693	69.3	$558,148	2	
COUNTY OF TWO HILLS (21)	3884	117864	30.3	$228,446	2	15
COUNTY OF CAMROSE (22)	22268	457231	20.5	$1,898,185	9	95
COUNTY OF RED DEER (23)	85866	1369444	15.9	$5,274,184	11	100
COUNTY OF VERMILION RIVER (24)	18240	1006137	55.2	$2,422,837	8	55
COUNTY OF LEDUC (25)	29688	1177686	39.7	$3,123,346	10	90
COUNTY OF LETHBRIDGE (26)	74260	1249690	16.8	$4,449,052	10	50
COUNTY OF MINBURN (27)	9402	169546	18.0	$699,295	3	
COUNTY OF LAC STE ANNE (28)	8059	266598	33.1	$798,257	2	
COUNTY OF FLAGSTAFF (29)	5808	380208	65.5	$1,567,789	4	53
COUNTY OF PONOKA (3)	15505	210271	13.6	$794,302	4	8
COUNTY OF LAMONT (30)	6360	247537	38.9	$2,352,956	4	20
COUNTY OF PARKLAND (31)	36086	396460	11.0	$1,139,815	5	25
COUNTY OF NEWELL (4)	17114	622517	36.4	$1,018,087	7	50
COUNTY OF WARNER (5)	7257	87967	12.1	$637,369	3	35
COUNTY OF STETTLER (6)	10501	357465	34.0	$171,965	3	60
COUNTY OF THORHILD (7)	2912	36530	12.5	$96,293	2	
COUNTY OF PAINTEARTH (18)						32
COUNTY OF FORTY MILE (8)	4702	202401	43.0	$301,157	3	22
COUNTY OF BEAVER (9)	7004	145602	20.8	$352,481	4	25
CALGARY REGION	768699	8505055	11.1	$41,694,828	28	140
EDMONTON REGION	795371	9438016	11.9	$43,132,437	25	70
GRANDE PRAIRIE REGION	52038	994912	19.1	$3,875,007	10	16
ID 4, WATERTON NAT'L PARK						
ID 5						
ID 6						
ID 8						
ID 9, BANFF NAT'L PARK						30
ID 12, JASPER NAT'L PARK	8683	10595	1.2	$26,294	1	50
ID 13, ELK ISLAND NAT'L PARK						
ID 14	25984	445724	17.2	$1,494,368	8	45
ID 15	10135	98117	9.7	$348,812	2	8
ID 17	22139	73559	3.3	$320,824	3	15
ID 18	46886	270598	5.8	$1,511,502	4	50
ID 19						
ID 20						
ID 21						
ID 22	4928	27352	5.6	$54,704	1	
ID 23	9652	105850	11.0	$215,007	3	
ID 24 WOOD BUFFALO PARK NAT'L PARK						
MD OF CYPRESS (1)	48829	284157	5.8	$1,033,869	4	40
MD OF SMOKY RIVER (130)	3796	98016	25.8	$411,515	4	30
MD OF SPIRIT RIVER (133)	1446	4792	3.3	$17,977	2	10
MD OF PEACE (135)	8255	230263	27.9	$889,947	5	40
MD OF FAIRVIEW (136)	5074	112065	22.1	$257,050	2	18
MD OF TABER (14)	11977	439788	36.7	$1,328,372	4	20
MD OF WILLOW CREEK (26)	12785	218771	17.1	$849,706	4	76
MD OF FOOTHILLS (31)	11477	297646	25.9	$665,098	3	
MD OF ACADIA (34)	522	28782	55.1	$42,597	1	
MD OF STARLAND (47)	2055	108951	53.0	$302,884	1	
MD OF KNEEHILL (48)	8010	322404	40.3	$1,270,830	2	
MD OF PROVOST (52)	4522	162937	36.0	$493,397	3	33
MD OF CARDSTON (6)	10064	106804	10.6	$322,265	8	35
MD OF WAINWRIGHT (61)	8908	254487	28.6	$694,465	5	32
MD OF BADLANDS (7)	6416	5202	0.8	$11,400	2	
MD OF BRAZEAU (77)	12284	411678	33.5	$1,620,388	3	15
MD OF BONNYVILLE (87)	15401	192294	12.5	$403,692	4	35
MD OF PINCHER CREEK (9)	7306	258349	35.4	$724,018	7	50
MD OF WESTLOCK (92)	11713	106172	9.1	$363,371	2	
MD OF CLEARWATER (99)	15706	443868	28.3	$1,106,641	9	30
SPECIAL AREA 2	2111	226370	107.2	$354,522	4	30
SPECIAL AREA 3	1922	126760	66.0	$205,204	1	70
SPECIAL AREA 4	1994	182624	91.6	$143,930	2	100
Regional total	**2431211**	**36235339**	**14.9**	**$142,149,582**	**297**	
Other		9249497		$11,077,107	3	
GRAND TOTAL	**2431211**	**45484836**	**18.7**	**$153,226,689**	**300**	
EDMONTON	626999	7707673	12.3	$33,367,781	17	70
MD OF STURGEON (90)	66845	1673788	25.0	$9,539,992	6	20
COUNTY OF STRATHCONA (20)	101527	56555	0.6	$224,664	2	
EDMONTON REGION	795371	9438016	11.9	$43,132,437	25	70
MD OF BIGHORN (8)	1640	24235	14.8	$23,750	1	
MD OF ROCKY VIEW (44)	39340	690845	17.6	$1,051,813	5	32
CALGARY	727719	7789975	10.7	$40,619,265	22	140
CALGARY REGION	768699	8505055	11.1	$41,694,828	28	140
ID 16	9674	568668	58.8	$2,259,081	5	
COUNTY OF GRANDE PRAIRIE (1)	42364	426244	10.1	$1,615,926	5	16
GRANDE PRAIRIE REGION	52038	994912	19.1	$3,875,007	10	16

Regional populations	**Number regions**	**Population** average	**Per capita consumption** average (tonnes)	**Per capita consumption** high value (tonnes)	**Per capita consumption** low value (tonnes)
<2500	6	1675	68.0	107.2	3.3
2500-5000	8	4057	28.0	69.3	3.2
5000-10,000	17	7692	24.0	65.5	0.8
10,000-15,000	9	11532	22.0	36.7	9.1
15,000-50,000	15	25194	20.0	57.5	3.3
50,000-100,000	3	70721	17.0	19.1	15.9
>100,000	2	782035	11.0	11.9	11.1

Reference to Map 1

County

Map Ref. No.	County Name	County No.
1	County of Athabasca	12
2	County of Barrhead	11
3	County of Beaver	9
4	County of Camrose	22
5	County of Flagstaff	29
6	County of Forty Mile	8
7	County of Grande Prairie	1
8	County of Lac Ste Anne	28
9	County of Lacombe	14
10	County of Lamont	30
11	County of Leduc	25
12	County of Lethbridge	26
13	County of Minburn	27
14	County of Mountain View	17
15	County of Newell	4
16	County of Paintearth	18
17	County of Parkland	31
18	County of Ponoka	3
19	County of Red Deer	23
20	County of Smoky Lake	13
21	County of St. Paul	19
22	County of Stettler	6
23	County of Strathcona	20
24	County of Thorhild	7
25	County of Two Hills	21
26	County of Vermilion River	24
27	County of Vulcan	2
28	County of Warner	5
29	County of Wetaskiwin	10
30	County of Wheatland	16
31	Special Area 2	
32	Special Area 3	
33	Special Area 4	

Municipal District

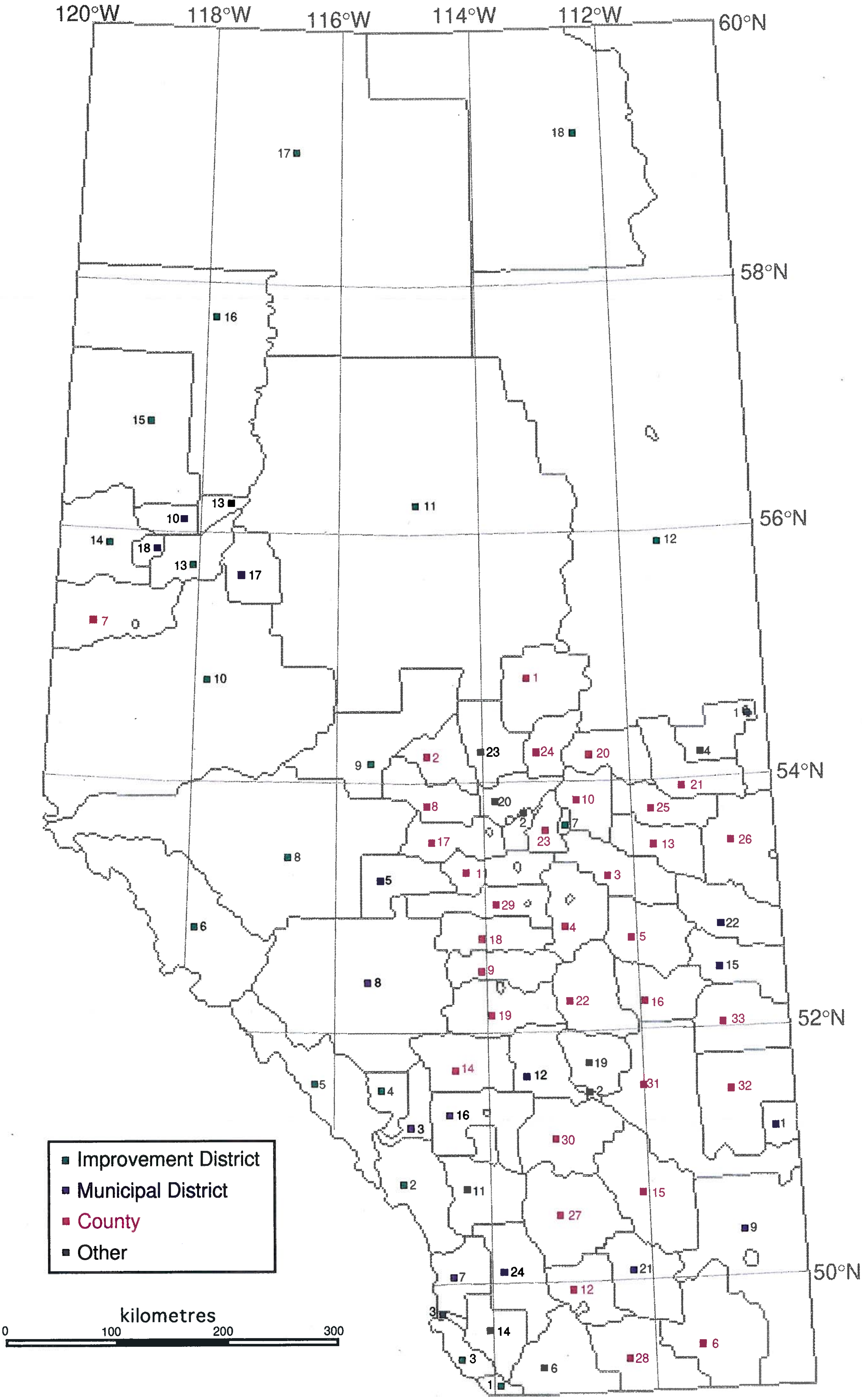
Map Ref. No.	MD Name	MD No.
1	MD of Acadia	34
2	MD of Badlands	7
3	MD of Bighorn	8
4	MD of Bonnyville	87
5	MD of Brazeau	77
6	MD of Cardston	6
7	MD of Cardston	6
8	MD of Clearwater	99
9	MD of Cypress	1
10	MD of Fairview	136
11	MD of Foothills	31
12	MD of Kneehill	48
13	MD of Peace	135
14	MD of Pincher Creek	9
15	MD of Provost	52
16	MD of Rocky View	44
17	MD of Smoky River	130
18	MD of Spirit River	133
19	MD of Starland	47
20	MD of Sturgeon	90
21	MD of Taber	14
22	MD of Wainwright	61
23	MD of Westlock	92
24	MD of Willow Creek	26

Improvement District

Map Ref. No.	ID No.
1	ID 4
2	ID 5
3	ID 6
4	ID 8
5	ID 9
6	ID 12
7	ID 13
8	ID 14
9	ID 15
10	ID 16
11	ID 17
12	ID 18
13	ID 19
14	ID 20
15	ID 21
16	ID 22
17	ID 23
18	ID 24

Other

Map Ref. No.	Name
1	CFB Cold Lake
2	CFB Edmonton
3	Municipality of Crowsnest Pass



Map 1. Index Map to Regional Municipalities

Reference to Map 2

Cities

Map Ref No.	Name
1	Airdrie
2	Calgary
3	Camrose
4	Drumheller
5	Edmonton
6	Fort McMurray
7	Fort Saskatchewan
8	Grande Prairie
9	Leduc
10	Lethbridge
11	Lloydminster
12	Medicine Hat
13	Red Deer
14	Sherwood Park
15	Spruce Grove
16	St. Albert
17	Wetaskiwin

Towns

Map Ref No.	Name
1	Athabasca
2	Barrhead
3	Bashaw
4	Bassano
5	Beaverlodge
6	Blackfalds
7	Bonnyville
8	Bowden
9	Bow Island
10	Brooks
11	Cardston
12	Carstairs
13	Claresholm

Towns (continued)

Map Ref No.	Name
14	Cochrane
15	Devon
16	Didsbury
17	Drayton Valley
18	Edson
19	Elk Point
20	Fairview
21	Falher
22	Fort Macleod
23	Fox Creek
24	Hardisty
25	High Prairie
26	Hinton
27	Innisfail
28	Jasper
29	Killam
30	Lac La Biche
31	Lacombe
32	Lamont
33	Magrath
34	Manning
35	Millet
36	Morinville
37	Nanton
38	Olds
39	Peace River
40	Picture Butte
41	Pincher Creek
42	Ponoka
43	Provost
44	Rainbow Lake
45	Raymond
46	Rimbey
47	Rocky Mtn House

Towns (continued)

Map Ref No.	Name
53	Swan Hills
54	Sylvan Lake
55	Taber
48	Slave Lake
49	Smoky Lake
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52	Sundre
56	Three Hills
57	Two Hills
58	Valleyview
59	Vegreville
60	Viking
61	Wainwright
62	Westlock
63	Whitecourt

Villages

Map Ref No.	Name
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3	Bittern Lake
4	Carseland
5	Cayley
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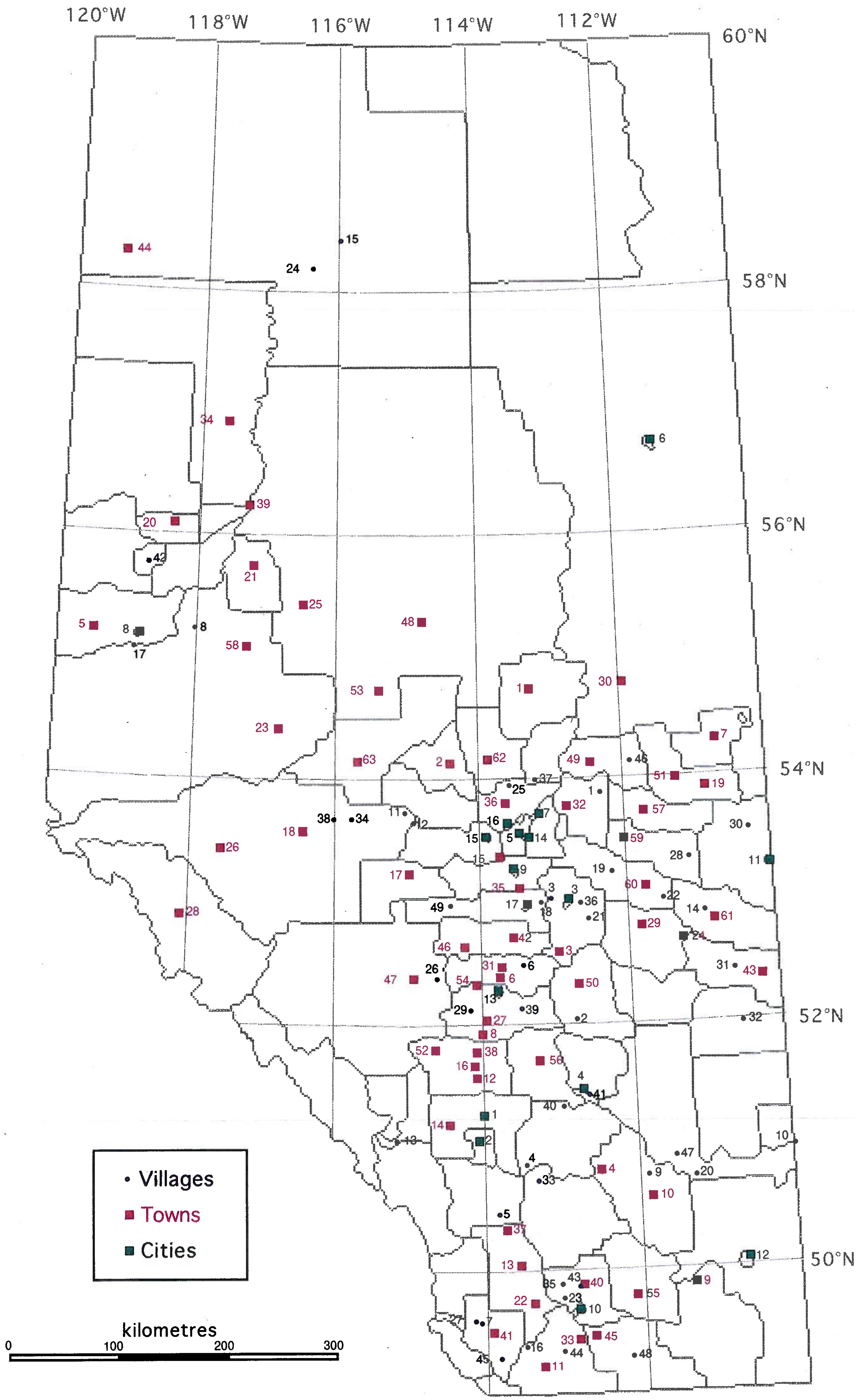
7	Cowley
8	Debolt
9	Duchess
10	Empress
11	Entwistle
12	Evansburg
13	Exshaw
14	Fabyan
15	Fort Vermillion

Villages (continued)

Map Ref No.	Name
16	Glenwood
17	Grovedale
18	Gwynne
19	Holden
20	Iddesleigh
21	Kelsey
22	Kinsella
23	Kipp
24	La Crete
25	Legal
26	Leslieville
27	Lundbreck
28	Mannville
29	Markerville
30	Marwayne
31	Metiskow
32	Monitor
33	Mossleigh
34	Niton Junction
35	Nobleford
36	Ohaton
37	Opal
38	Peers
39	Pine Lake
40	Rosebud
41	Rosedale
42	Rycroft
43	Shaughnessy
44	Spring Coulee
45	Twin Butte
46	Vilna
47	Wardlow
48	Warner
49	Winfield



Map 2. Index Map to Villages, Towns and Cities