Supply/Demand Analysis of Aggregates in the Denver Metro Area

Published By the Jefferson County, Colorado Planning & Zoning Department
January 1987

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This research document was produced as a part of the Aggregate Resources Roundtable, a joint public-private effort initiated by the Jefferson County Board of County Commissioners in an attempt to help resolve the controversies involved with mining activities in this metropolitan area. Appreciation of the efforts and contributions of all the parties in this program is gratefully acknowledged.

Acknowledgements

Sincere appreciation is expressed to Leonard Mogno, Mike Hart, and John Rold for their, critical reading of this report and their valuable suggestions. Special acknowledgements are due to Marion Paul, Director of the Resource Assessment Study for the Planning of the New Airport, for her helpful assistance, encouragement and constructive criticism of this study.

Finally,the author would like to thank members of the local mining industry for their cooperation and their suggestions in improving this research endeavor.

Introduction

Mineral construction aggregates, including bedrock derived from crushed stone as well as naturally formed sand and gravel, are an essential commodity for an industrial society. They constitute the major raw material in the road building and construction industries. They are usually relatively cheap and tend to be considered inexhaustible. However, aggregates are a resource for which we often identify a continuing demand and diminishing availability trends in many growing metropolitan areas; and, in many cases, the reserves available for future extraction may not be sufficient to meet the demand of the market areas.

For reasonable construction and maintenance costs, aggregates should be available in large quantities and at a reasonable cost in any metropolitan area. The economic value of a given deposit is a function of its proximity to the market area as well as its quality and size. Oftentimes, as more and more land in a region becomes urbanized, closely located deposits tend to be either depleted by mining or lost to extremely competing land uses. As a result, more and more distant sources must be used to supply the region's needs. Increase in haulage distance brings increase in the cost of aggregates to consumers.

Over the last 30 years, a scenario has developed in the Denver Metropolitan Area reflecting similar situations in many other growing areas. Unchecked growth, coupled with rapid exploitation of available deposits and a general disregard for mineral conservation, has resulted in the depletion of much of the high quality alluvial resources along major drainages in the Denver region.

Local producers have developed pits and quarries on the less populated fringes of the market area for many years. With the rapid expansion in the Denver area, producers found themselves surrounded by new development, and production in some areas close to the urban centers reached levels which impacted the quality of life of the municipality. Furthermore, this expansion made many valuable resource lands inaccessible to extraction. Ironically, such growth increases the demands for aggregates and operators had to increase their production to satisfy consumers needs, more rapidly depleting their reserves. Concurrent with the increased demand for rock products, has been the growing concern by members of the public that we maintain and improve our unique natural environment and the quality of life.

In an attempt to help minimize the emerging conflicts between the citizens and the mining industry, an analysis of the regional aspects of this issue is essential. This study documents the findings regarding the extent of the current, potential and identified reserves in the area, and analyzes the need of aggregates to support future economic development in the Denver Metropolitan Area. An econometric supply/demand model for the Denver region is presented to assist in making policy and regulatory recommendations, to balance the needs of mining versus quality of life and environmental factors.

The assessment of sand, gravel and crushed stone supply and demand trends in this study are based upon the most recent information collected. As new information is made available, revisions of the enclosed data may become necessary.

Previous Work

In the mid 1950's, the problem of a possible shortage of high quality construction aggregates was first recognized by the local producers in the Denver Metropolitan Area. They determined that continued depletion of the alluvial resources closest to the market, without any sort of management, might lead to shortages in the near future.

The Colorado Sand and Gravel Producers Association pointed out, in their 1957 study, that significant deposits were lost to development. They forecasted that, without any serious conservation effort, the alluvial deposits within a 10-mile radius of downtown Denver would be depleted by 1977. These figures assumed no accelerated growth and a constant annual production level of 3.5 million tons. In comparison, Denver Metro's annual production was about 14 million tons in the mid 1970's due to the rapid expansion at this time. The association recommended the creation of temporary sand and gravel districts in which mining would require performance bonds to regulate extraction procedures.

The Inter-County Regional Planning Commission (ICRPC), now the Denver Regional Council Of Governments (DRCOG), initiated a two-year drainage course study in 1961. This study was the first attempt to include sand and gravel resources in a comprehensive land use plan. Among its multiple objectives, the study evaluated the developed pits and analyzed the best alternatives for a more efficient mineral conservation plan. The ICRPC study estimated that as of 1960, 26% of the original resources are still available within a 15-mile radius of downtown Denver. A shortfall between the supply and demand for aggregate was predicted to occur by 1984.

In 1967, the U.S. Bureau of Mines published an overview of the history of aggregates production and consumption in the Denver area. Sheridan, in his study, evaluated the effects of urbanization on the area's aggregate resources. The emphasis was on deposits along Clear Creek and the South Platte River that, due to the spread of development, became unavailable for extraction through the years. Sheridan recommended a multiple-use concept for conversion of mined lands to other beneficial uses.

Through the prompting of the local aggregate industry, the Colorado Legislature passed House Bill 1529, in 1973. The Bill recognized the importance of construction aggregates in the populated areas of the state. It mandated the Colorado Geological Survey to conduct a one year study to map aggregate resources in the front-range counties. Using those maps, planning commissions would devise master plans of ex traction that preserve access to the commercial mineral deposits. The Colorado Geological Survey completed its mapping program within the allocated time, and a report and atlas were published in 1974 (Special Publication 5-A and 5-B, Schowchow and others, 1974a, 1974b). Within the subsequent years, the required "Master Plan" for each county had been completed. However, several inherent problems with HB 1529 limited its success in conserving mineral zones.

Trimble and Fitch, 1974, published a map showing the potential gravel and crushed rock resources in the Greater Denver Area. The map classified the deposits in terms of their geological nature and quality. It provided thickness and sieve analysis data at various locations, collected from the Colorado Division of Highways and the United States Geological Survey. The map also showed petrographic data at certain locations. Similar maps were published by Colton and Fitch in 1974 for the Boulder-Fort Collins and Greely area, and by Maberry, for Arapahoe and Douglas counties.

The local producers frequently evaluate the changes in the trends of supply and demand for aggregates in the Denver Market Area. However, those studies are not available for public review and are essentially used for marketing strategies. This report is the first attempt in the public domain to build a detailed econometric supply/demand model for mineral aggregates in the Denver region. The most recent information was used to achieve the scope of this study, and an update of the data may be necessary in the future.

Similar supply/demand analyses for aggregates were done in many other metropolitan areas. These studies often included an evaluation of the available resource deposits within and/or in the vicinity of the market area. In 1980, the Ministry of Natural Resources in Ontario, Canada, published an "Aggregate Resources Inventory of South Dumfries Township in southern Ontario". The California Division of Mines and Geology published, in 1981, a "Mineral Land Classification of Ventura County" (Special Report 145). This later study forecasted the aggregate demand in the area for the next 50 years and included a detailed evaluation of the potential resource deposits. Similar studies were done for many other metropolitan regions in the United States.

Methods For The Determination Of Aggregate Supply

An analysis of the mineral aggregate supply in the Denver region is presented in this section of the report. It was conducted on the basis of quantitative evaluation of aggregate reserves in each operating mine, using the most recent available data.

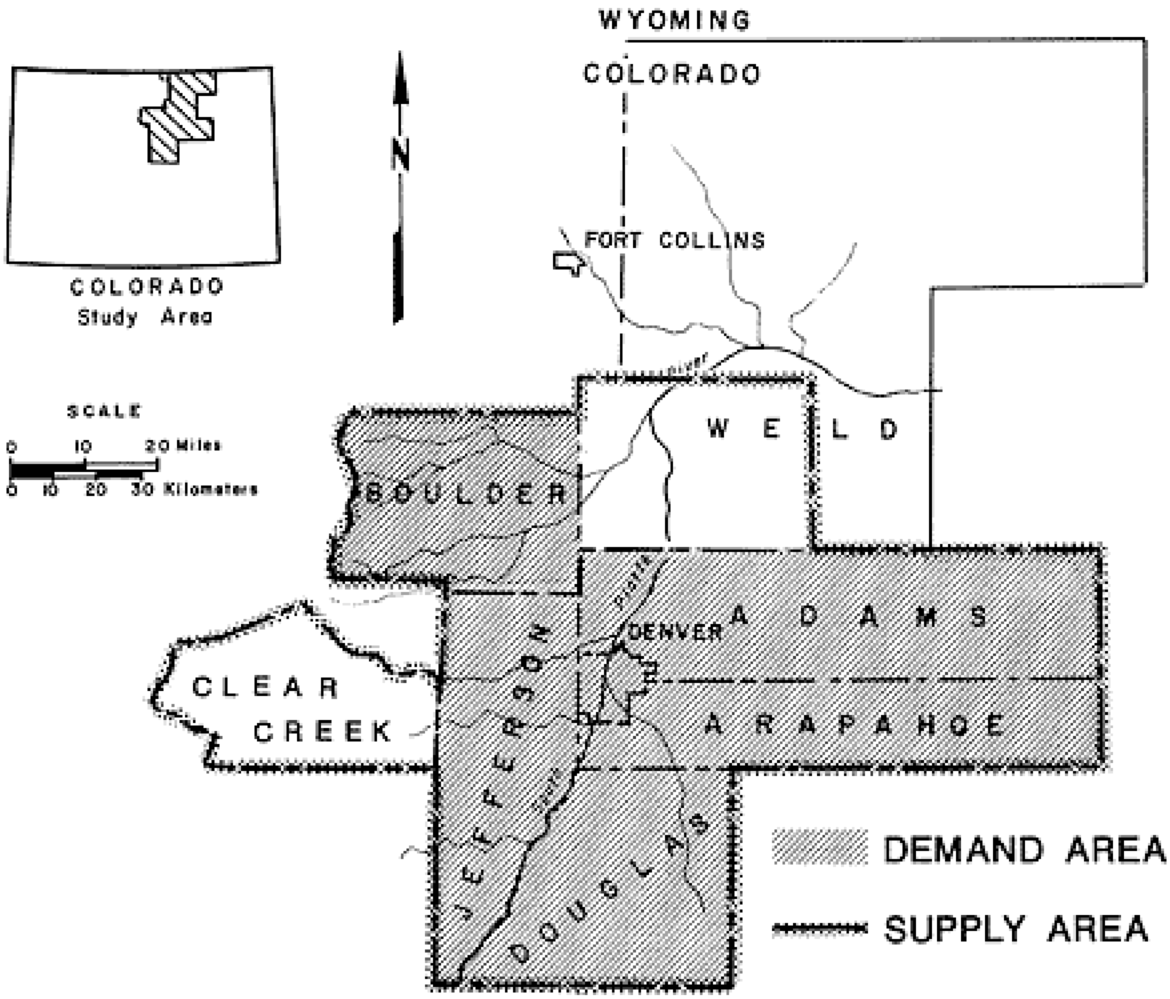
To achieve this purpose, it was necessary to determine the boundaries of the Denver Metropolitan Supply Area where the commodity is produced, and those of the demand area where the commodity is consumed.

Definition of the Study Area

Large metropolitan areas usually obtain sand and gravel or crushed stone for construction purposes from several sources within their region. The location of these sources will define the market area of a given region.

The Denver Metropolitan Demand Area includes the City and County of Denver and adjoining Adams, Arapahoe, Boulder, Douglas and Jefferson counties. Based on recent industry activities, current regional aggregate supply, and reasonable projections, the Supply Area was extended to include, in addition to the six counties of the Denver Metro Area, Clear Creek and southwestern Weld counties. Both the Supply and the Demand areas are shown in Figure 1.

Figure 1: The Denver Metropolitan Supply and Demand Areas.



Definition of the Aggregate Supply

The two most important aggregate categories considered for estimating the supply in the study area are the current reserves and the potential reserves.

The current reserves include the commercial aggregate quality material that are in place in the currently operating mines within the defined supply area. These have a local government zoning or special use permit and a state permit issued by the Colorado Mined Land Reclamation Board.

The potential reserves do not form part of the current reserves, mainly because they are not yet permitted. These are in-place deposits with local government zoning or special use permits and/or awaiting action by the Colorado Mined Land Reclamation Board. This category ranks after the previous one in terms of feasibility of forming part of the supply.

It is important to note that the categories outlined above cannot simply be added together to obtain an assessment of the supply. In some cases the second category, potential reserves, may contain material with inferior economic or geologic characteristics. The first category, current reserves, is the amount that is available in the short run to meet the market's demand. The potential reserves are aggregate resources, which can be added ,to the area's supply only when the permit process is complete. However, for the purposes of material potentially available, the significance of these reserves to metropolitan demand will be estimated.

A third category, identified resources, was also considered. These are sites that have been proposed for rezoning or special use mining permits, but have been denied. There is currently no evidence indicating whether or not these reserves will be part of the future area's supply; these identified resources have no significance in the quantitative evaluation of the current and potential reserves.

A fourth category, potential resources, would fill any projected shortage beyond the supply abilities of the current and potential reserves. These are the geologically available deposits, within or in the vicinity of the market area, for which extraction might be economically feasible. Their evaluation is beyond the scope of this study.

Data Collection

The current and potential reserves in the Denver Metropolitan Supply Area were determined using data collected primarily from the Mined Land Reclamation Division permit files. Data was also obtained from the local county planning departments, as needed. The cooperation of the above named groups in the compilation of the data is gratefully acknowledged.

A data base available at the Colorado Mined Land Reclamation Division provides a listing for all the operating and terminated mines classified by county or by operator. It also lists pending applications for mining permits. This data base was used to identify all the operating mines and the pending applications for every county in the study area. Subsequently, the file pertaining to each operation was thoroughly researched to collect the data necessary to calculate its reserves using conventional calculation techniques.

The operator and the operation's name were recorded for each mine. The geographic location: County, city, section, township and range were also obtained. The data collected from these files also included the annual production rate, the permitted and mineable acres, and the depth of extraction. The latest available annual report kept in each file, usually the 1986 report, was used to determine by a planimeter, the acreage still available to mine. Comments concerning the development history of each mine were also documented. The data collected was recorded for each separate case on a formatted data sheet, as shown in Appendix A. A data base was constructed to computerize the collected data using the SMART software. This data is kept on file in the Jefferson County Planning Department.

The permitted acres of the operating mines containing the current reserves, and the acres awaiting for a mining permit containing the potential reserves were plotted on 1:100,000 scale maps for the study area. Each mine is indicated on the map by its reference number, as documented in Appendices B and C, for the current and potential reserves, respectively.

Calculation Techniques

Alluvial Pits

Quantitative estimates of the sand and gravel reserves available in a given mine were made using the data collected. The volume of a mineable area can be calculated if its areal extent and average thickness are known or can be estimated. The computation method used is as follows: First, the permitted area of the mine was obtained in acres. An approximation of the deposit thickness, based on the data given in the permit application or from published subsurface data, was also used. Original tonnage values were then calculated by multiplying the volume of the mine by 2420 (the density factor). This factor is approximately the number of tons in a one foot thick layer of sand and gravel, one acre in extent, assuming an average density of 0.0556 tons per cubic feet or 1.5 tons per cubic yard.

Tonnage = Area (acres) * Thickness (feet) * 2420

Given the acreage still available to be mined, as of the date of this study, the same method was used to estimate the remaining reserves. It is important to note that these tonnage figures are only estimates. Furthermore, these values do not take into account the effects of technological constraints (slope requirements, drainage, etc.), and the amount of waste generated. However, to consider the technological constraints whenever they existed, the area of the actual excavation was used in the equation. Also, silt and clay were assumed to be the waste and were calculated using published sieve analysis data. Whenever sieve data was not available from the considered site, it was assumed that 80% of the total material is useable, while the remaining 20% is waste.

Bedrock Quarries

The estimation of the original and remaining reserves is a more complicated process for a quarry site. These vary greatly with the material in question and the design of the mine itself. Whenever the needed figures were not readily available, they were calculated using the graphical method described below.

The mining and final reclamation plan of the quarry were obtained from the permit application at the Mined Land Reclamation Division. Using those plans, the number and the design specifications of the benches to be generated by mining were recorded (thickness and width of each bench). The area to be mined, associated with every bench, was determined by the planimeter. The volume of the mined disk associated with each bench was calculated in cubic yards, by multiplying the area by the thickness of each bench. Assuming a density of 2.2 tons per cubic yard, the tonnage extracted by the creation of each bench was determined. This process was repeated for each bench to be created, and the total amount of the original reserves was obtained by summing up all the calculated figures. The topography was accounted for whenever necessary.

An estimate of the removed tonnage, as of the current date, was obtained using the rate of annual production and/or the number of operating years. The removed tonnage value was subtracted from the original reserves value to obtain a figure of the remaining reserves. These numbers were then corrected by the producers whenever necessary. Whenever an estimate of the waste material in a quarry was not documented, it was assumed that the percentage of waste generated by quarrying varies between 0% and 25% depending on the physical and chemical characteristics of the material in question. The remaining percentage is useable as crushed stone.

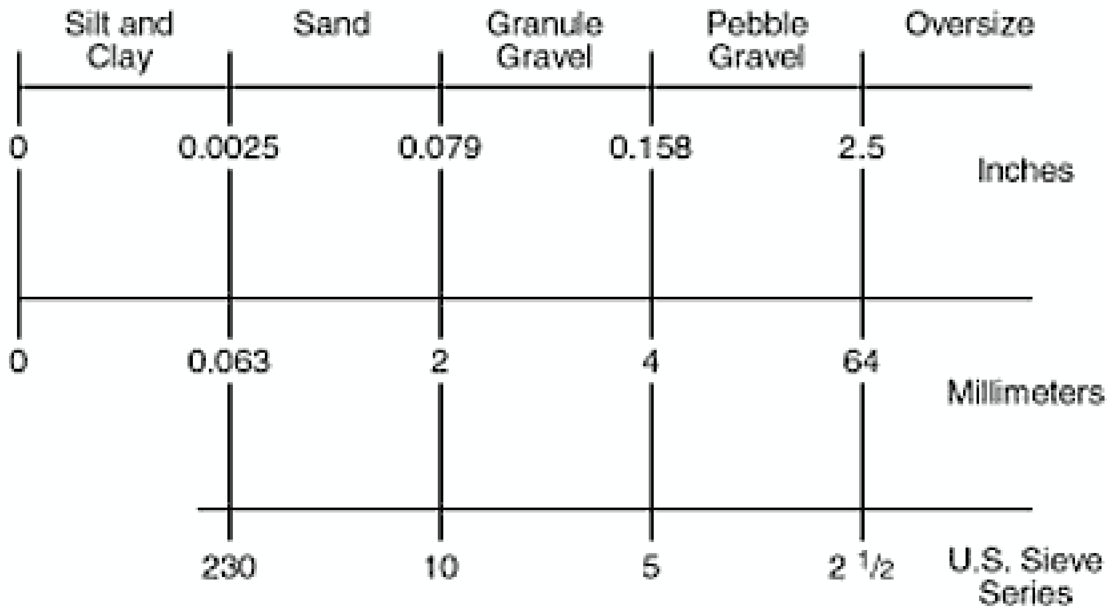
Sieve Analysis Data

For most uses, consumers of rock products prefer either sand and gravel or crushed stone. These preferences stem from differences between the two commodities in their physical properties or in their price. Rigid specifications regarding hardness, particle size gradation, shape, and certain chemical properties are imposed on the rock materials for much concrete construction and road building. Because of these strong preferences by consumers of rock materials, the supply for the two commodities was analyzed separately. It was necessary to evaluate the tonnage attributable to sand, because of the large amount of sand available in the Denver Metro Area, and the supply is much higher than the demand. Separate figures for sand, gravel and crushed stone were therefore generated.

To estimate the tonnage attributable to sand and the amount of waste in an alluvial pit, sieve analysis data collected from the Colorado Division of Highways and the U.S. Geological Survey and published by Trimble and Fitch, 1974, were used. The sand and gravel sieve size distribution is shown in Table 1. (It was assumed that silt and clay sized material passing the #200 U.S. sieve are waste.) The percentage of sand corresponds to that passing the #10 sieve, and the percentage remaining is the gravel fraction in the deposit. Whenever direct data was not available, estimates were obtained from analogies with similar areas.

TABLE 1 - Sand and Gravel Size Distribution

Figures are percentages by weight which fall into class size classes:



Quality Specifications

Rarely is aggregate raw material at the pit or quarry site, even from the highest grade deposits, physically or chemically suited for every type of aggregate use. Therefore, every potential deposit must be tested to determine how large a tonnage of its various components can meet the specifications for a particular type of use and what processing is required. This requires large quantities of information not readily available, especially within the confines of the study time frame. However, for the scope of this study, aggregate material within a pit or quarry were classified, in terms of their quality, as good or moderate. This classification was adopted from Trimble, Fitch and Maberry, 1974.

Gravel Deposits

According to Trimble and Fitch, the physical and chemical characteristics of gravel are dependent upon the age of the deposit, which also determines their topographic location. The highest quality gravel is the youngest, the least altered (soundest), the least cemented, and contains the least amount of calcium carbonate in the form of interstitial caliche. These are the gravel deposits of the floodplains and the lower terraces of the major streams and their tributaries. They are the source of the best quality gravel for concrete aggregate and road material.

The moderate quality gravel deposits, being older and more weathered, contain an abundance of unsound stones and much calcium carbonate. These are the gravel deposits of pediments (mesa tops) and upland tertiary remnants in the mountains. They are generally of poor quality for a concrete aggregate; locally useful as a source of road or subgrade material. They are cobbly and bouldery near the mountains and pebbly to sandy farther east. Cemented gravel or conglomerate were also considered in this category.

Bedrock Deposits

Bedrock-derived crushed stone were also classified, in terms of their quality, as good or moderate according to Trimble and Fitch. Good quality crushed stone may be obtained from fine grained or coarse grained igneous rocks, while moderate quality aggregate is derived from metamorphic rocks or quartzite.

Fine grained igneous rocks: Dikes, flows, sills and ash flow tuffs, occur in a number of localities adjacent to the mountains. This rock is best suited as a source of crushed rock for road material and building stone. Its suitability for concrete aggregate may be diminished by reactive constituents. Coarse grained igneous rocks crop out widely in the mountains and are a potential source of high quality crushed rock aggregate. Moderate quality crushed stone is derived from metamorphic rocks. Foliated metamorphic rocks underlie most of the mountainous area from Jarre Creek north. These are not generally as good a source of crushed rock aggregate as the igneous rocks, but some of the more gneissic rocks have been so utilized. These have highly variable suitability for crushing. Quartzite was also classified as a potential source of high quality crushed-rock aggregate.

Aggregate Supply In the Denver Metropolitan Area

The methods described above were used to determine the aggregate supply in the Denver Metro Supply Area. An estimation of the total supply requires the determination of both the current and potential reserves, as described earlier in this report.

The calculated reserves are only the best estimates possible, although reliable conventional methods of calculations were employed. This is due to the nature of the information in the files and the variable nature of the aggregate deposits themselves. However, to improve our accuracy, we corroborated the estimated reserves of most of the operations with their respective producers, and adjusted our estimates if indicated.

Current Reserves

The current aggregate reserves in the Denver Supply area are those in place in the currently operating pits and quarries, as described earlier in this report. Appendix B lists all the currently operating mines in the study area.

To estimate the current reserves in the Denver area, a list of all the operating aggregate mines in the study area was prepared for each county. This list includes the permitted acreage for each mine, the remaining acreage to be mined as of the current date of this study, and the original and remaining tons of reserves available for extraction. This data is kept on file in the Jefferson County Planning Department for public review. The remaining or current reserves in each of the operating mines were summed up for each county and subsequently, for the total Denver Metropolitan Supply Area, as shown in Table 2.

TABLE 2 - Current Reserves in the Denver Metropolitan Supply Area

County	Commodity	Acreage Permitted	Acreage to be Mined	Original Reserves	Remaining Reserves	Remaining % of Original
Adams	Stone	-	-	-	-	-
	Gravel	3098.45	2507.15	56 079 579	39 347 819	68 38
	Sand			80 547 835	44 930 573	55 78
Arapahoe	Stone	-	-	-	-	
	Gravel	866.82	563.15	11,487,839	5,943,621	51.70
	Sand			17,921,706	12.825.579	71.50
Boulder	Stone	54.00	54.00	?	5,000,000	?
	Gravel	1703.08	1281.37	21,608,469	14,701,264	67.95
	Sand			10,182,542	7,235,232	71.03
Clear Creek	Stone	130.00	65.00	20,724,795	19,130,580	92.30
	Gravel	150.00	114.00	4,939,424	4,113,593	83.20
	Sand			2,116,896	1,762.969	83.20
Douglas	Stone	-	-	-	-	-
	Gravel	596.63	437.99	8.862.923	6.144.002	69.30
	Sand			16,398,518	12,816,719	78.20
Jefferson	Stone	789.25	448.41	141,550,000	115,000,000	81.24
	Gravel	923.52	652.51	13.727,930	7,114,536	57.00
	Sand			6.018,374	3,060.012	54.00
Weld	Stone	-	-	-	-	-
	Gravel	2616.03	1653.04	40,524,343	26,515,989	65.00
	Sand			27,796,212	18,934,479	68.11
Total D M A	Stone	973.25	567.41	162.274,000	139,130.000	85.73
	Gravel	9804.26	7995.22	157,230,000	102,880.000	65.43
	Sand			160,982,000	101,565.000	63.09
Total				480,486,000	343,575,000	71.50

The current aggregate reserves in the Denver Supply Area are 343 million tons. This includes the tonnage attributable to crushed stone, gravel and sand. Of the total current reserves, 40.49% are crushed stone, located primarily in 4 operating stone quarries in Jefferson county. The remaining percentage of the current reserves is sand and gravel from alluvial pits. Gravel is 29.9% of the current reserves, and sand is 29.6%. The current reserves, in terms of crushed stone, gravel, and sand, are detailed for each county in Table 3.

TABLE 3 - Current Reserves in Each County of the Denver Supply Area

County	Current Reserves Stone,Gravel,Sand	* Stone %	* Gravel %	* Sand %	% of DMA Total Reserves
Jefferson	125,174,00 0	91.87	5.68	2.44	36.43
Adams	83,278,392	0.00	46.04	53,95	24.23
SW Weld	45,450,468	0.00	58.34	41.65	13.22
Boulder	26,936,496	18.56	26.86	54.57	7.84
Clear Creek	25,007,142	76.50	16.44	7.04	7.27
Douglas	18,960,121	0.00	32.40	67.59	5.51
Arapahoe	18,769,200	0.00	31.66	68.33	5.46
Denver	0	0.00	0.00	0.00	0.00
Total	343,576,000	40.49	29.90	29.56	100.00

* % of each commodity represented in total County average

County	Stone and Gravel (Tons)	% of Total Stone and Gravel
Jefferson	122,114,000	50.2
Adams	38,347,819	15.8
SW Weld	26,515,989	10.9
Boulder	19,701,264	8.2
Clear Creek	23,244,173	9.6
Douglas	6,144,002	2.5
Arapahoe	5,943,621	2.4

Jefferson County provides 36.43%, the highest percentage of these reserves. This is due to the large reserves located in four major Stone quarries in the County. These quarries contain 115 million tons of crushed stone, or 33.5% of the total area's reserves. Adams County contains 24.23% of the current reserves of the area. Aggregate is produced from the mining of alluvial deposits along the South Platte river drainage course. 13.22% of the reserves are located in South-western Weld County and 7.84% are In Boulder County. Clear Creek County contains 7.27% of the reserves, most of which being located in a single stone quarry. Both Arapahoe and Douglas Counties contribute 11% of the total current reserves. A summary of the current reserves, by County, is shown separately in Table 3.

Potential Reserves

The potential reserves, as defined earlier, are those located in areas that are zoned and/or await a permitting action by the Mined Land Reclamation Board. This category of reserves will meet the demand, should it be projected to exceed the supply from the current reserves. Table 4 lists the potential reserves in the area.

TABLE 4 - Potential Reserves in the Denver Metropolitan Supply Area

Adam	Ready Mixed Concrete Co.	Ready Mixed Concrete pit #1
Boulder	Frontiers Materials	Hygiene Pit
	Golden Gravel Co.	Dickens Farms
Douglas	Cooley Gravel Co.	Cherokee Ranch
Jefferson	Brannan Sand & Gravel Co.	Church/McKay pit #22
	Church Ranch	Rocky Flats/Church Pit
	Cooley Gravel Co.	Old Woman Mine
	L.G. Everist	Mt. Olivet Development

The potential aggregate reserves in the Denver Supply Area are 57 million tons. 78.75% of the potential reserves are located in Jefferson county. Douglas County contains 12.27% of these reserves, while both Adams and Boulder Counties provide 8.97% of the potential reserves. Weld and Arapahoe Counties do not contain any potential reserves. A summary of the potential reserves in every county is shown in Table 5.

TABLE 5 - Potential Reserves in Each County of the Denver Supply Area

County	Potential Reserves	Percent of Total
Jefferson	44,917,625	78.74
Douglas	7,000,000	12.27
Adams	3,329,920	5.83
Boulder	1,792,833	3.14
Arapahoe	0	0.00
S.W. Weld	0	0.00
Total	57,040,378	100.00

All potential reserves are Alluvial Sand & Gravel pits.

Identified Resources

For various reasons, many applications for mining permits in the Denver area were denied The reserves located in these deposits were classified as "Identified resources . There is no evidence, as of the date of this study, that these reserves will be available for development in the future. Therefore, these resources cannot be added to the area's total supply. However, they represent identified resources of commercial size and quality. Some of the most interesting cases are shown in Table 6.

TABLE 6 - Identified Resources in the Study Area

County	Operator	Operation	Acres to be permitted	Acres to be mined	Tonnage	Remarks
Boulder	C & M Sand and Gravel Co.	Heil Quarry	195.0	138.0	19,053,000	Special Use Permit denied
	Varra Companies Inc.	Gravel plant # 3	300.0	290.0	6,534,000	Special Use Permit denied
Douglas	Gravel Co., Inc.	Gravel pit	9.1	9.1	5,000,000	Special Use Permit denied
	Jarre Canyon Gravel Co.	Jarre Canyon pit	94.1	76.2	-	Special Use Permit denied
	Siegrist Construction Co.	Badger Gulch Gravel	44.0	44.0	2,000,000	Application withdrawn in 1982
Gilpin	Siegrist Construction Co.	Gilpin Quarry	210.0	96.0	40,000,000	Denied for rezoning
Jefferson	Brannan Sand & Gravel Co.	Pit # 24	327.5	168.9	-	Denied for zoning
	Cooley Gravel Co.	Rattle Snake Gulch	350.0	58.0	-	Denied for zoning
	Colorado Rock Co.	South Draw Quarry	322.6	159.0	100,000,000	Denied for zoning
	Mobile Premix Co.	South Table Mountain	815.3	328.0	150,000,000	Denied for zoning

Forecasting Aggregate Demand in the DMA

An estimate of the total quantity of aggregate required to supply the needs of the Denver Metropolitan Demand Area, up to the year 2010, will be presented in this part of the report.

Twenty-five year forecasts of the aggregate demand are made on the basis of aggregate that was historically consumed during the years 1960-1985. For the purpose of these calculations, it is assumed that all the aggregate produced in a particular region was also consumed within that region.

Factors Affecting the Per Capita Consumption of Aggregate

In general, changes in the level of demand for rock materials occur because of previous or present changes in the characteristics of the overall economy. Thus, it would be expected that a relationship exists between trends in the level of rock production and various indicators of the general economic activity. Factors such as the number of new residential and non-residential building permits issued, miles of new highway constructed, and population data were compared with aggregate production records for various metropolitan areas to determine whether or not they bore a direct relationship to the aggregate consumed. However, simple linear regression analysis showed that population is the factor that most closely correlated with the amount of aggregate consumed in a given area.

Per capita consumption rates vary greatly, depending upon the degree of urban maturity reached within a region. High per capita consumption rates are generally characteristic of regions where the overall population density is relatively low and the rate of urban development is high. High consumption rates will probably be maintained in such regions until growth rates decline with the onset of urban maturity. Per capita consumption then usually decreases, eventually leveling off to a general maintenance level.

However, per capita consumption levels vary erratically over time without correlating to urban growth. This unpredictability arises from the fact that many projects using aggregates are so large that they create anomalies in the demand for rocks. Consequently, quantities jump during the project and fall upon its completion. Second, some of the demand for aggregates comes primarily from governmental construction projects. These occur for reasons bearing little or no relationship to the local economic conditions. Instead, the scheduling of these projects depends on less predictable political factors at local, state and national level.

Per capita consumption rates for any metropolitan region can then be interpreted in light of the above-listed factors to determine average trends of supply and demand of rock materials in the area.

Basis for the 24 Years Forecast

The most accurate method of predicting aggregate consumption is to use sophisticated computer models which analyze such factors as the overall health of the economy, proposed highway construction, housing development, and the commercial construction outlook. However, a wealth of information is required by the models, and the use of this method to predict the needs of the Denver Area for the next 24 years was beyond the scope of this study.

Instead, simple linear regression analysis of historical data for the Denver Metro Area were made to identify basic trends in the per capita consumption rates. The projected per capita consumption rates were then correlated with the population projections for the study area, on a yearly basis, in order to estimate the total aggregate consumption needs for the region for the year 2010.

Historical Consumption of Aggregate in the DMA

A 25 year old population record (1960-1985) was compiled for the region of the project area. The historical population data for this period was obtained from statistical bulletins that have been published by the counties on a quarterly or annual basis, and from the Denver Regional Council of Governments.

Historical annual aggregate production data for these years was obtained from the U. S. Bureau of Mines and from the local rock producers, whenever possible.

Data Interpretation

Historically, the demand for aggregate in the Denver Metro Area has been determined using the rates of production. This is because there is no accurate source of information in the public sector to compile the quantities of aggregates actually delivered to consumers. The assumption made, in order to substitute production rates for consumption rates, is that the market adjusts its production rate within a relatively short period of time to meet the consumption. Both the Bureau of Mines and the Colorado Rock Product Association indicate that these assumptions are valid in our area.

The best source of data in the public domain on the production quantity, the value of production, and the uses of aggregate, is the " Mineral Industry of Colorado " published by the U. S. Bureau of Mines. These records are compiled by the voluntary reporting of some mine operators in the region. Because only major operators report their figures to the Bureau of Mines, the numbers quoted for the Denver region are considered low, and in many cases unreliable, by the aggregate industry. The figures do not account for the fluctuations of the smaller operators in meeting the demands of the area. Using the Bureau of Mines figures as a basis for projecting demand will, therefore, provide a demand estimate which is lower than the actual consumption.

However, the Bureau of Mines figures offer a look at the cycles and the rates of aggregate production for the majority of the large operators serving the area. The production rates, both in gross tonnage and in per capita consumption, and the population and growth rates for the years 1960-1985 are shown in Table 7. The growth rates and the tons per capita rates over the considered historical period were plotted and shown in Figure 2.

Figure 2: Historical Per Capita Consumption and Population Growth Rates in the Denver Metropolitan Area

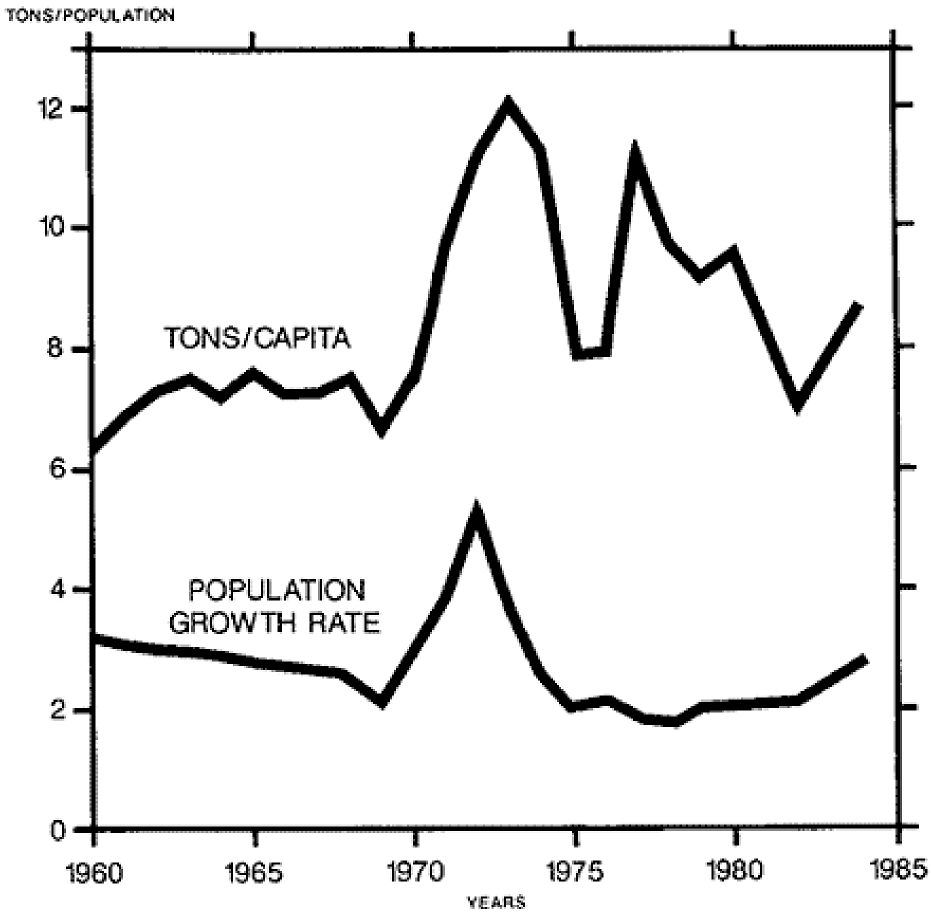


TABLE 7 - Historical Per Capita Consumption of Aggregates and Population Growth Rates in the DMA 1960-1985

Year	DRCOG Population	USBM Tonnage	Tons/Capita	Growth rate (%)
1960	934,199	5,997,397	6.41	3.2
1961	964,600	6,695,335	6.94	3.1
1962	995,000	7,252,213	7.29	3.0
1963	1,025,401	7,717,388	7.53	3.0
1964	1,055,801	7,564,445	7.16	2.9
1965	1,086,202	8,259,475	7.60	2.8
1966	1,116,603	8,108,017	7.26	2.7
1967	1,147,003	8,372,941	7.30	2.65
1968	1,177,404	8,832,827	7.50	2.58
1969	1,207,804	7,919,137	6.56	2.0
1970	1,231,100	9,218,736	7.44	3.0
1971	1,268,500	12,258,393	9.66	3.8
1972	1,317,600	14,762,190	11.19	5.4
1973	1,380,400	16,619,089	12.04	3.7
1974	1,431,600	16,220,276	11.33	2.5
1975	1,467,700	11,508,075	7,84	2.0
1976	1,498,100	11,831,049	7.89	2.1
1977	1,530,100	17,184,443	11.23	1.8
1978	1,558,900	15,166,179	9.73	1.7
1979	1,585,500	14,551,716	9.18	2.0
1980	1,617,700	15,437,000	9,54	2.0
1981	1,656,600	-	-	-
1982	1,689,950	11,981,000	7.08	2.1
1983	1,717,850	-	-	-
1984	1,764,250	15,297,000	8.67	2.8
1985	1,815,050	-	-	-

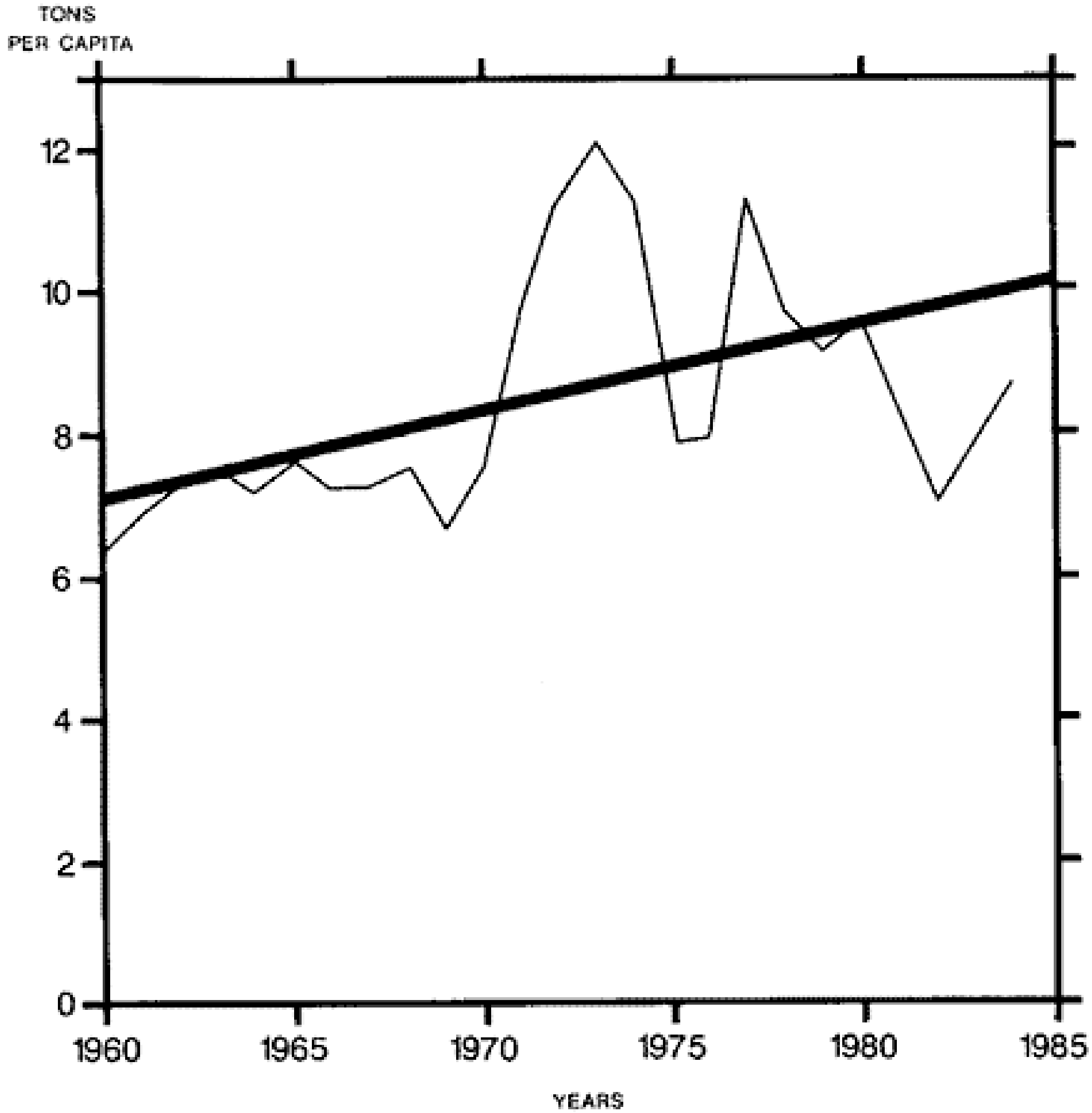
The average Tons per Capita for the years 1960-1984 is 8.45
The average Tons per Capita for the years 1975-1985 is 8.89-
USBM data is available every other year starting 1980.

The 1960-1985 per capita consumption record for the DMA is marked by several distinguishable trends. A remarkable correlation between the rates of growth and aggregate consumption is observed up to the year 1976. During this period the DMA was characterized by an overall low population density and high rates of urban development. Consequently, high consumption rates were maintained in the region until the onset of urban maturity after 1976, evidenced by a growth rate leveled at an average of 3.2%.

It would be expected that consumption rates will decline after 1976 with increased urban maturity in the area. However, a high consumption trend was observed in the region between 1976 and 1982. This unpredictable high consumption was correlated to the major highway construction projects triggered by large Federal Highway Funds and by the construction boom that occurred in downtown Denver.

To determine the broad scope of the aggregate supply and demand in the DMA for the next 24 years, a reasonable tons per capita consumption multiplier needed to be developed. The average tons per capita since 1960 is 8.49. However, a linear regression analysis of the historical data, shown in Figure 3, indicated that the historical tons per capita consumption of aggregates in the Denver Metro area increased over time, from 7 tons per capita in the 60's up to 10 tons per capita in 1985.

Figure 3: Linear Regression Analysis of the Historical Tons Per Capita Ranges in the Denver Metropolitan Area



Because the linear regression analysis of the historical data showed that aggregate consumption rates tend to increase with time, and due to the cyclical nature of the construction industry and the Colorado economy, it was decided that a range of demand would provide the most useful information for long-term forecasting. Accordingly, models for the future needs of aggregates in the area were examined using 8.5, 9.0, 10.0, and 11.0 tons per capita consumption rates. 8.5, 9.0, and 10.0 tons per capita ranges were derived from the regression analysis of the U.S. Bureau of Mines data. The major local producers also use these consumption rates in their long-term forecasting. The 11.0 tons per capita consumption rate is used by some local producers and was, therefore, considered in this study.

Future Demand for Aggregate in the DMA

The historical aggregate consumption data for the DMA was used to identify basic trends in the per capita consumption rates. The projected per capita consumption rates were then correlated with the population projections for the Denver Metro Area, on a yearly basis, in order to estimate the region's total aggregate consumption needs for the year 2010.

Population projections for the years between 1986-2010 were made using area projections furnished by the Denver Regional Council of Governments. These projections are available on a 5 year interval basis and are listed in Table 8. Data for the intermediate years was determined by extrapolation.

TABLE 8 - Population Forecast Distribution DRCOG

County	1980	1985	1990	2000	2010
Adams	245,944	260,250	310,700	379,600	450,400
Arapahoe	293,621	370,500	416,000	489,700	555.200
Boulder	189,625	215,775	241,600	276,100	310,600
Denver	490,011	510,700	524,100	547,600	565,800
Douglas	25,153	39,750	69,400	130,600	202,000
Jefferson	374,107	418,075	467,100	517,200	545,900
Region	1,618,461	1,815,050	2,028,900	2,340,800	2,629,900

Future Per Capita Consumption of Aggregates

Because the Bureau of Mines figures are inherently conservative and the regression analysis indicates continued growth in tons per capita, it was determined that a demand scenario of 8.5 tons per capita for the next 24 years would be the low range of demand forecasts. In fact, over the last ten years, the Bureau of Mines figures indicate that the DMA has consumed 9 tons per capita.

A consumption rate of 10 tons per capita is generally thought to provide an average rate of consumption for the area in the future. Currently, several major producers in the area are using 10 tons per capita for their long-range planning. In addition, the Colorado Geological Survey has been using 10 tons per capita since the mid-70's as a method of predicting aggregate demand in their long-range planning.

To complete the scenarios for the aggregate demand, a consumption rate of 11 tons per capita was chosen for the high end of our range. This was chosen because some of the producers tend to believe that the aggregate consumption rate might increase further in the future, to reach a level of 11.0 tons per capita consumption rate.

Models for Future Aggregate Demand in the DMA

Models for rock materials demand in the Denver Metropolitan Demand Area were built for the established future tons per capita consumption rates. For each considered tons per capita value, the model was considered both with and without the large projects planned for the area in the near future.

To show the effects of population growth, a non growth or baseline scenario is also shown.

The Large Projects

Two major projects, the construction of a new airport and the completion of the beltway system (E-470), are planned for the Denver region in the next 24 years. Both projects will consume large volumes of aggregates, and were considered in the demand forecasts. The combined aggregates requirement by the large projects in the critical construction years is 11,342,000 tons. A summary of the total and annual aggregate needs for these projects is shown in Tables 9 and 10.

TABLE 9 - Total Estimated Aggregate Needs for Large Projects During Construction Years 1989 - 1994

	Sand	Gravel	Crushed Stone	Total
New Airport	1,700,000	3,820,000	1,680,000	7,200,000
E-470	1,114,000	2,800,000	228,000	4,142.000
Subtotals	2,814,000	6,620,000	1,908,000	11,342,000

TABLE 10 - Total Estimated Annual Aggregate Consumption Of Large Projects (Tons)

Year	New Airport	E-470	Total
1989	-	416,000	416,000
1990	1,800,000	624,000	2,424,000
1991	1,800,000	832,000	2,632,000
1992	1,800,000	1,040,000	2,840,000
1993	1,800,000	814,000	2,614,000
1994	-	416,000	416,000

Where the actual annual data was not available, the total project tonnage was divided by the construction years.

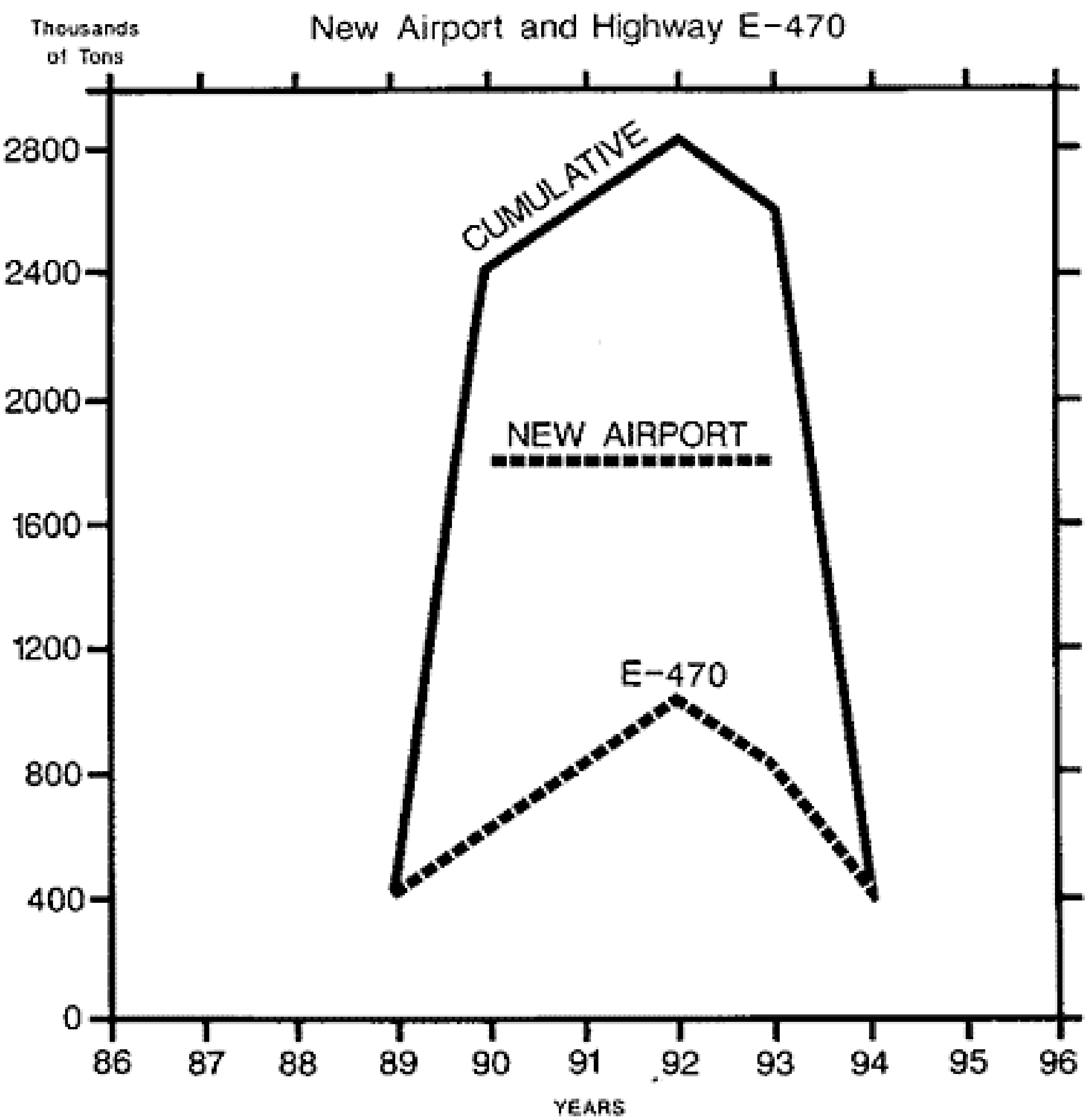
The RTD Busways, the clean-up of the Rocky Mountain Arsenal, and the construction of Two Forks Dam are also among the large construction projects in the area. However, they are not expected to impact the local aggregate industry. The Arsenal clean-up and the RTD busways are not large consumers of aggregate, and the aggregate for Two Forks Dam will be excavated and crushed on-site to meet the required specifications.

The new airport, being constructed for 1995, will require 7.2 million tons of aggregates between the years 1990 and 1993. The 6 runways of the new airport require 1,680,000 tons of high grade crushed stone capable of meeting the specifications of the Federal Aviation Administration. Each of the 6 runways will be 16,000 feet long and 150 feet wide, and will require 15" of concrete over a 15" cement treated subbase.

E-470 will be an asphaltic concrete highway. It was estimated by the State Highway Department that this section of the beltway system will consume 4.14 million tons of aggregate between the years 1989-1994. Road base and asphalt will comprise the project's highest aggregate consumption at 3.8 million tons or 91.7%; the remaining percentage required will be crushed stone.

Figure 4 shows the total annual aggregate consumption by the large projects.

Figure 4: Annual Aggregate Consumption Large Projects

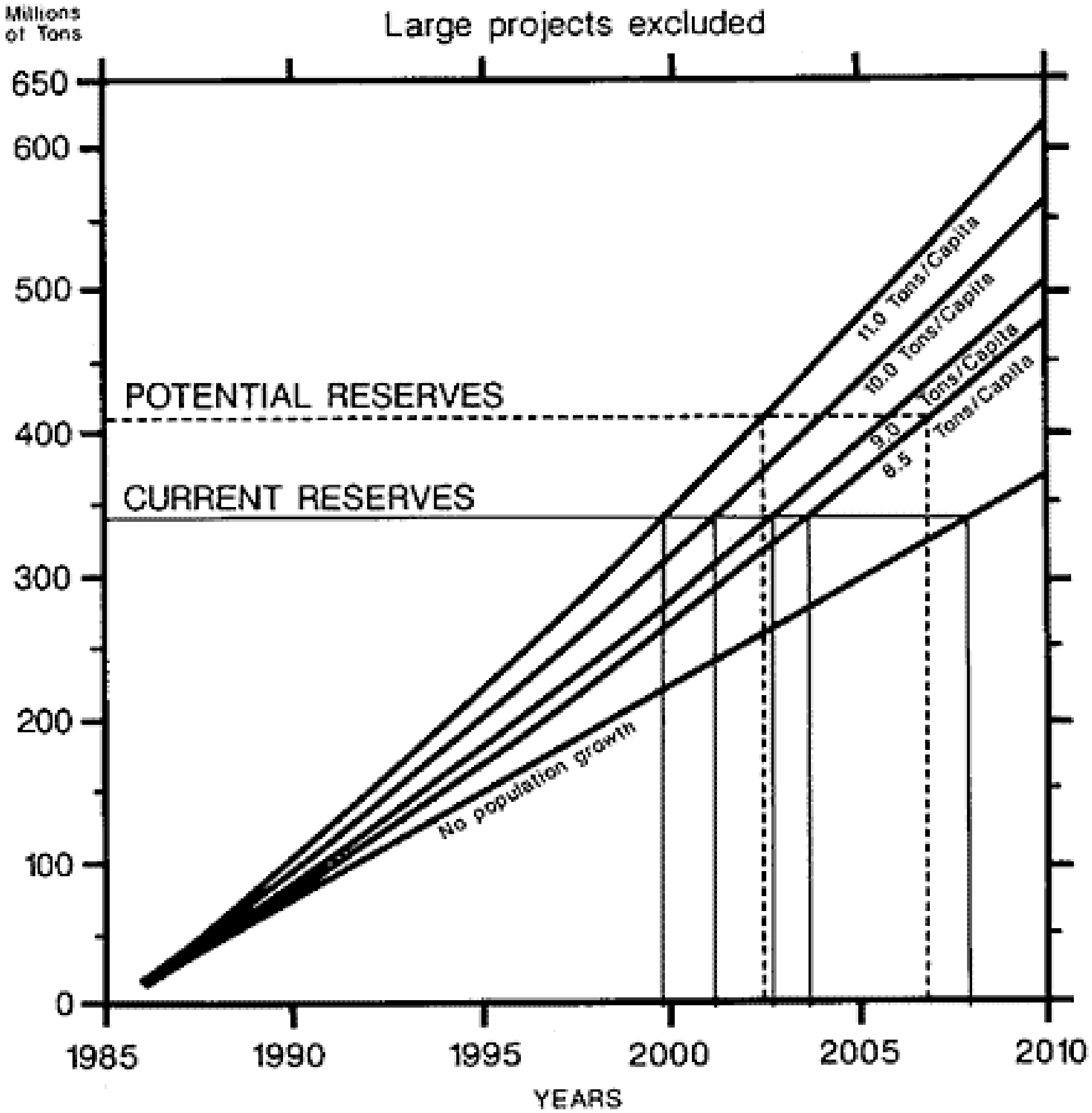


Models for Cumulative Consumption of Aggregate

A model for the cumulative consumption of aggregate was constructed for the 4 considered tons per capita consumption rates (8.5, 9.0, 10.0, and 11.0). Each range was considered with and without the large projects. The region's need for aggregate for all the ranges, with and without the large projects up to the year 2010, are shown in Appendix D.

As mentioned earlier in this report, the current reserves available in the Denver region from the currently operating mines, are 343 million tons. As shown in Figure 5, The Denver Demand Area will consume what is equivalent to the current available reserves between the years 2000 and 2004, at consumption rates varying between 8.5 and 11.0 tons per capita. This represents a 14-18 year supply. If the potential reserves are added, it would represent an additional 3 year supply at 8.5 tons per capita and a 2 year supply at 11.0 tons per capita, for a possible total supply of 16-21 years.

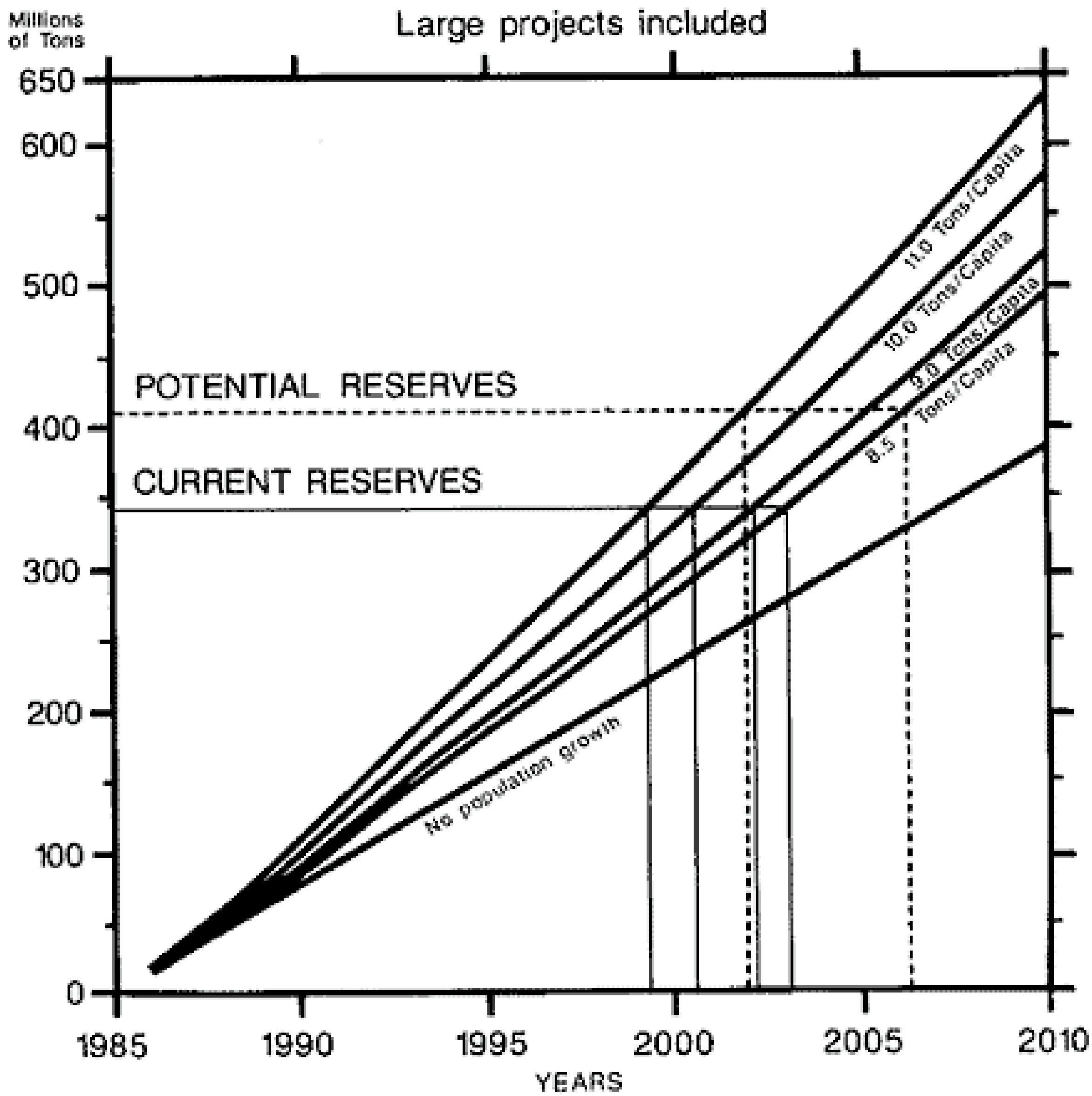
Figure 5: Cumulative Aggregate Consumption in the Denver Metropolitan Area.



This analysis is predicated on the population growth shown on Table 8 as projected by the Denver Regional Council Of Governments. Should the population growth rate be slower or faster, the rate of consumption will be proportionally changed. To illustrate the extreme case, no population growth, the historical average consumption ratio (8.5 tons per capita) is shown without change. This would represent an average annual consumption of 15.5 in tons, which would result in 22 years of supply for the current reserves and an additional 3.7 years if the potential reserves were consumed.

A model for the cumulative consumption of aggregates, taking into consideration the large projects, was also considered. This model is shown in Figure 6. Although the large projects did not seem to significantly affect the cumulative future consumption of aggregates, it is believed that the construction of these projects will affect the market during the critical construction years. A possible strain in the aggregate market might cause a significant increase in the commodity's price. To evaluate this effect, models for the yearly consumption of aggregates in the next 24 years were also considered.

Figure 6: Cumulative Aggregate Consumption in the Denver Metropolitan Area.

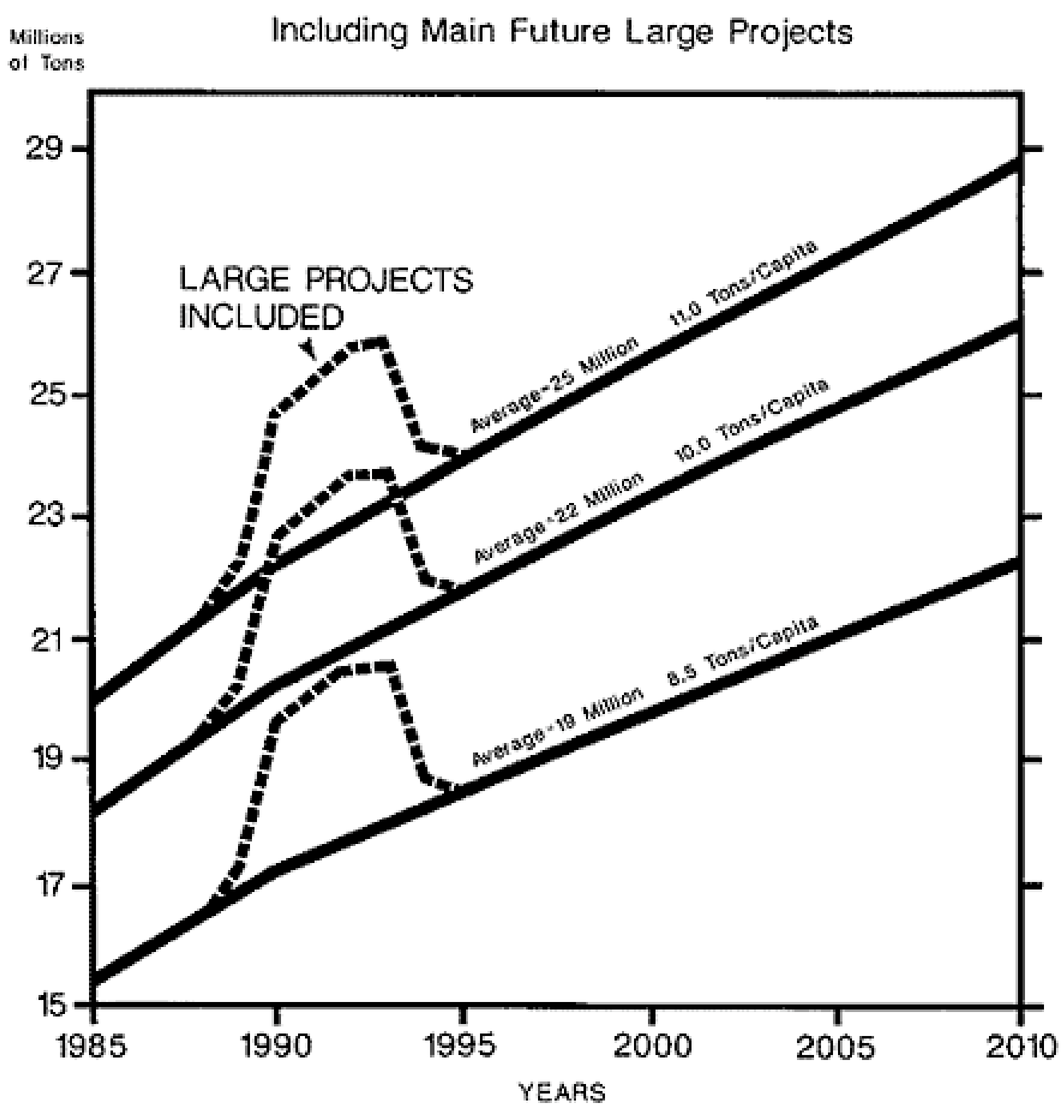


Models for Yearly Consumption of Aggregate

A historical average value of yearly production of aggregate in the Denver Metro Area is 16 million tons, as determined by many large local producers. However, it is predicted that the yearly demand of aggregate will be increased dramatically in the region during the construction of the new airport and E-470. Local producers believe that their production capacity will adjust quickly to the increased demand.

The yearly consumption of aggregate for the years 1987-2010, for all four ranges of consumption rates, was determined. These are listed in Appendix E, and shown in Figure 7.

Figure 7: Yearly Consumption of Aggregates in the Denver Metropolitan Area.



At the lower scenario, 8.5 tons per capita, the annual consumption of aggregate, will vary from 15 to 22 million tons with an average of 19 million tons. A maximum of 20 million tons might be required during the critical construction years of the large projects.

The intermediate scenario of 10.0 tons per capita consumption rate indicates an average annual consumption rate from 18 million tons to about 26 million tons in the 2000's. Up to 24 million tons per year might be required between the years 1992-1993 if the large projects were built simultaneously, as scheduled.

At the highest perceived aggregate consumption rate, 11.0 tons per capita, the annual consumption ranged from 20 million tons a year to about 29 million tons. The average yearly consumption rate at this scenario is 25 million tons. At this consumption rate, up to 26 million tons a year might be required during the large projects' construction time frame.

In summary, the future average annual consumption rate in the Denver region is projected to range between 19 and 25 million tons a year. While the capacity of the local industry will probably handle these levels of demand, a strain in the local rock products market might be foreseen in the future, especially during the construction years of the new airport and E-470.

Overview of Aggregate Usage

The economic significance of aggregates arises from its use as a basic construction material. Sand, gravel and crushed stone, collectively referred to as aggregates, provide bulk and strength to portland cement concrete and asphaltic concrete. Aggregates are also used as road base, subbase and fill. Aggregates normally provide from 80% to 100% of the material by volume, in the above uses.

Aggregates are used primarily for road base and asphalt in the Denver Metro area. Road base consists of sand and gravel of sizes up to 1 1/2 inches, and provides the level surface over which asphalt can be laid. Asphalt is a mixture of uniform size gravel (usually 1/2 to 3/4 inch) and 6% bitumen, an oil refinery residue. This mixture is compacted over the road base to make asphalt roads. Historically, about 66% of the aggregates used in the Denver area is for road base and asphalt. However, the percentage of aggregate used for road base and asphalt has probably increased due to the present downturn in the construction industry.

An additional 30% of the market in the Denver area is for coarse and fine concrete aggregate use. Sizes for coarse concrete aggregate range from 3/4 inch to 1 1/2 inches, with differing qualities depending on the contract specifications.

Other uses for aggregate include pipe drainage, leach fields, rip-rap, landscaping and street sanding. These uses require varying sizes and specifications, and comprise the remainder of the Denver area's aggregate use.

Specifications for Aggregate Usage

Rarely is aggregate raw material at the pit or quarry site, physically or chemically suited for every type of aggregate use discussed above. Therefore, every potential deposit must be tested to determine how large a tonnage of its various components can meet specifications for a particular type of use and what processing is required.

Specifications for various uses of aggregate material have been established by several agencies to ensure that aggregate is satisfactory for particular uses. These agencies, as well as other major consumers of concrete, evaluate aggregate for acceptance by using standard test procedures outlined by such organizations as the American Society for Testing Materials and the American Association of State Highways Officials.

Specifications also call for various grain size ranges and particle size distributions in the various uses of aggregates. For some uses such as asphalt paving, particle shape is specified. Specification standards, set by the California Department of Transportation in 1975, require that at least 25% by weight of coarse aggregate (3/4 inch material retained on the # 4 sieve) used as a class 2 aggregate base material shall be crushed particles. Furthermore, aggregate material used with bituminous binders to form sealing coats on road surfaces shall consist of at least 90% by weight of crushed particles. Crushed stone is preferable to natural gravel in asphaltic concrete because broken surfaces adhere to asphalt better than rounded surfaces and the interlocking of angular particles strengthens the asphaltic concrete.

Most aggregate specifications have been established to ensure the manufacture of strong, durable concrete. However, these specifications often require additional processing of the material that translates in the generation of more wastes and a significant shortening in the life of the deposit, for example. The State Highway Department recently changed its specifications for asphaltic rock concrete. More fractured rock faces are now required, causing additional processing and crushing operations. This is expected to generate at least an additional 10% of waste within a deposit.

Economics of Aggregate Usage

The preferred use of one aggregate material over another in construction practices depends not only on specification standards but also on economics. The cost of delivered aggregate includes the plant-site cost plus charges for handling, haulage and mixing. The charge for haulage is the most influential factor in determining the cost of the final product at delivery point. Aggregate generally sells at prices ranging from $2 to $5 per ton at the plant site after washing, sizing and stockpiling. The availability of aggregates from local sources is, therefore, essential to the general economic strength of the Denver Metro Area.

Alluvial sand and gravel is preferred to crushed stone for Portland cement concrete aggregate, because the natural material is less expensive and because a wet mix made with rounded particles of alluvial sand and gravel has better workability than one made with angular particles. The workability of a wet mix consisting of portland cement with crushed rock aggregate is improved by adding more sand and water. However, this also requires that more cement be added to the mix in order to maintain concrete durability standards. Normally, the additional cement amounts to about 1/4 sack per yard of concrete, causing an additional cost per yard of mix (1986 prices).

Aggregate for asphaltic concrete and portland cement concrete generally meet the same physical and chemical requirements. In localities where only one type of aggregate is readily available, the type is ordinarily used in both types for concrete; however, all material from the DMA cannot be used in high use categories such as the Portland cement concrete use. Most crushed stone that is produced in the DMA for use in asphaltic concrete is obtained from alluvial deposits at most of the larger sand and gravel plants. Oversize rock clasts (loose rocks), usually larger than 1 1/2 inch diameter, are screened from the alluvial raw material and crushed for use as crushed stone.

Crushed rock is commonly used for Portland cement concrete aggregate under geologic conditions where shortages of alluvial sand and gravel exist. Although slightly more care is required in pouring and placing a wet mix that contains crushed rock, Portland cement concrete made with this aggregate is as satisfactory as that made with sand and gravel of comparable quality. However, production costs are considerably greater, and the recent tendency to use crushed rock in the Denver region would involve additional haulage costs, truck traffic, and fuel consumption.

Emerging Supply Trends and Options Available to the Local Industry

Since the passage of HB 1529, it appears that significant changes have been and are being affected in the structure and economics of the Denver area construction materials industry. Besides the most visible and audible public opposition, the industry faces serious challenges with respect to aggregate supply, largely as the result of local governmental actions and attitudes toward development and mining. Several major emerging trends are foreseen for the local aggregate industry.

The first, most obvious trend is the search for coarse alluvial aggregate deposits in known resource areas further away from existing metropolitan market areas. All producers know that this means a longer haul either to the plant site, to the job site, or both, which translates into a higher ton mile haulage cost. The economic implications are readily apparent. Assuming for the moment that aggregate unit value and the cost of finished products will increase over the intermediate and long terms to offset increased transportation costs, producers now consider finding, securing and developing more remotely located alluvial deposits. The potential areas seem to be Clear Creek, Gilpin, Larimer, and Weld counties.

The second option is the search for suitable property in the Front-Range area to sustain a long-term high tonnage, crushed rock quarry operation. From the standpoint of haul distance, the mountain front corridor in Boulder, Jefferson, and Douglas counties is the main objective, but the foothills development and the low success rate of operators in this area over the last 10 years is discouraging to the location of new sites.

A newly emerging trend in the region is the recycling of available asphalt and concrete to avoid long haul distances. A pilot plant is currently available in the Denver area just for this purpose. It was estimated that recycled rock products currently constitute up to 5% of the local market. One major problem in the recycling process is the presence of rebar that prevent processing.

Another option is the long range truck haulage, intermediate to long distance unit train, and currently, lowest priority is the possibility of aggregate manufactured from natural and man made materials. In the front range area, this option has been exercised at only two or three locations and was not found to be economically feasible.

APPENDIX A: SAMPLE DATA SHEET

Investigator:_________Date: _________

Name of Operator:________________________

Name of Operation:________________________

Address:______________________________

____

Geographic Location:________________________

Section:________________________

Township:________________________

Range:________________________

City/County:________________________

Plotted on:________________________

Commodity

[ ]Alluvial Sand & Gravel Pit

[ ]Crushed Rock Quarry

End Use.________________________

Acreage:

Permitted:________________________

To be Mined:________________________

Annual Production:

Life of Mine:

[ ]Public [ ]Commercial

Status:________________________

Final reclamation :________________________

MLRD Permit Issue Date: __________

Base Data Located At:________________________

Data corroboration (name & comment):________________________

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APPENDIX B: LIST OF THE OPERATING MINES

A listing of all the currently operating alluvial pits and rock quarries in the study area is presented in this part of the report. The reference number assigned for each operation is used for reference purposes and refers mainly to the county where the deposit occurs.

The areal extent of each operation is plotted on 1:500,000 U.S.G.S. maps of the study area. Each operation was indicated by its corresponding symbol in this present report. A summary sheet, as that shown in Appendix A, was also prepared for each individual operation. Each sheet records the location, quantity and quality of the deposit under consideration. A brief history of the mine development is also included. These summary sheets for the currently operating mines are kept on file at the Jefferson County Planning Department, together with the location maps.

ADAMS COUNTY		
Alluvial Pits		
Operator	Operation	Reference No.
Aggregate Resources	Aggregate Resources Pit	AD1
Albert Frei Sons, Inc.	Worthing Pit	AD2
Albert Frei Sons, Inc.	Miller Pit	AD3
Barnett companies	Gran-Pal Pit	AD4
Brannan Sand & Gravel Co.	Pit #29	AD5
Brinkmann-Woodward Const.	Henderson Ind. Park	AD6
Colorado Sand & Gravel Co.	Henderson Development	AD7
Cooley Gravel Co.	Thornton Pit	AD8
Fritz Easterberg	Brighton Quarry	AD9
George Speer	Speer Development	AD10
Hazeltine Invest. Assoc.	Reclamation Pit #1	AD11
Mobile Premix Inc.	Adams Pit	AD12
Mobile Premix Inc.	Howe Pit	AD13
Mobile Premix Inc.	Nyholt Pit	AD14
Ready Mix Concrete	Riverdale Estate #1	AD15
Riverdale Sand & Gravel Co.	Art Eppinger Farms	AD16
Robert Vickroy	Kiowa Nursery Sand & Gravel	AD17
Siegrist Construction Co.	Clear Creek Concepts	AD18
Suburban Sand & Gravel	Road Runner Rest. II	AD19
Tarco Inc.	Swink Pit 1, 2, 3	AD2O
Ted zigan	zigan Pit #2	AD21
Western Paving Const. Co.	Lowell Pit	AD22
Western Paving Const. Co.	Stage Coach Stop Pit	AD23
Western Paving Const. Co.	Tani Pit	AD24

ARAPAHOE COUNTY		
Alluvial Pits		
Cooley Gravel Co.	Grant Cenco Bench/NYE	AR1
Cooley Gravel Co.	Littleton Pit	AR2
Posco Inc.	Lowry Bombing Range #3	AR3
Strasburg Sand & Gravel	Pit #1	AR4
Superior Sand & Gravel	Superior Pit	AR5
Arapahoe County	Union Street Pit	AR6
BOULDER COUNTY		
Quarries		
L.G. Everist	Andesite	B01
Alluvial Pits		
Boulder Ready Mix	Walker Pit #2	BO2
C & M Companies	Henderson Mine	BO3
C & M Companies	Zweck Gravel Pit	BO4
Flatiron Sand & Gravel Co.	Boulder Valley Farms	BO5
Flatiron nsand & Gravel Co.	Deep Farm Pit	B06
Flatiron Sand & Gravel Co.	Stelter/Teets Pit	BO7
Flatiron Paving Co.	Valmont/Keeter Pit	B08
Golden Gravel Co.	Hygiene Pit	BO9
Golden Gravel Co.	Marlatt Pit	BO10
Golden Gravel Co.	Neighbors Pit	BO11
Goose Haven Sand & Gravel	Goose Haven II	BO12
Goose Haven Sand & Gravel	Lafayette Reservoir	BO13
Landfill Inc.	Landfill Inc. Pit	BO14
R. W. Gregory	Gregory Pit	BO15
Western Paving Const. Co.	Rocking WP Pit/Weng Farm	BO16

CLEAR CREEK COUNTY		
Quarries		
Operator	Operation	Reference No.
Associated Aggregates	Waistrum Mine	CL1
Alluvial Pits		
Moritz Mining Co., Inc.	Clear Creek Pit	CL2
Mountain Aggregates	Empire Pit	CL3
DOUGLAS COUNTY		
Alluvial Pits		
Braley Sand & Gravel	Pit#1	DO1
Colorado Clay & Gravel	Whisenhunt Pit	DO2
Cooley Gravel Co.	LawrencePit	D03
Gil-Son Paving Co.	Larkspur Pit #1	DO4
Hallett Const. Co.	Walker Pit	DOS
John H. Lewis	Big John Pit	D06
Mobile Premix Inc.	Cherokee Pit#1	DO7
Owens Brothers Co.	Willow Creek Mine	D08
Hwy Dept. Douglas County	Lowell Gravel Pit	D09
JEFFERSON COUNTY		
Quarries		
Asphalt Paving Co.	Ralston Quarry	JF1
Cooley Gravel Co.	Morrison Quarry	JF2
Jefferson County	Deer Creek Canyon	JF3
Mobile Premix Inc.	Heidelberg Quarry	JF4
Western Paving Const. Co.	Deer Creek Quarry	JF5
Alluvial Pits		
Asphalt Paving Co.	Applewood Pit	JF6
Brannan Sand & Gravel	Deer Creek Canyon #9	JF7
C. Ryan & Sons, Inc.	Leyden Pit	JF8
Mobile Premix Inc.	Crane/South Crane Pit	JF9

SOUTHWESTERN WELD COUNTY		
Alluvial Pits		
Andesite Rock Co.	Del Camino Pit	WD1
Associated Aggregates	Pit C & M, Brighton East	WD2
Dakolios Const. Co.	Dakolios Pit #1	WD3
Flatiron Paving Co.	Nelson Pit	WD4
Frontiers Materials	Frontier-Olson Pit	WD5
Frontiers Materials	Stromquist Pit	WD6
Jose Chavez	Dawn Sand and Gravel	WD7
Leslie & Martha Williams	Boulder Pit	WD8
Siegrist Const. Co,	Siegrist Pit	WD9
South Platte Aggregates	Brighton Pit	WD1O
Tectonic Const. Co.	Bailey Pit	WD11
Turnpike Const. Co.	Gravel Pit	WD12
Varra Companies Inc.	Varra Co. Pit #1	WD13
Western Paving Const. Co.	Del Camino, Groom Addition	WD14
Zigan Gravel Inc.	Zigan Pit #1	WD15
Weld County	Armstead Pit	WD16
Weld County	Hokestra Pit	WD17
Weld County	Koenig Pit	WD18

APPENDIX C: LIST OF THE POTENTIAL RESERVES

Alluvial Pits

County	Operator	Operation	Reference No.
Adams	Ready Mixed Concrete Co.	Pit #1	PT1
Boulder	Frontier Materials	Hygiene Pit	PT2
	Golden Gravel Co.	Dickens Farms	PT3
Douglas	Cooley Gravel Co.	Cherokee Ranch	PT4
Jefferson	Brannan Sand & Gravel Co.	Church/McKay Pit #22	PT5
	Church Ranch	Rocky Flats/Church Pit	PT6
	Cooley Gravel Co.	Old Woman Mine	PT7
	L.G. Everist	Mt. Olivet Development	PT8

Note: Maps depicting the location of all sites referenced here are available at the JCPD.

APPENDIX D: CUMULATIVE CONSUMPTION OF AGGREGATES

Cumulative Aggregate Consumption in the Denver Metropolitan Area at 8.5, 9.0, 10.0, 11.0 tons per capita - Large Projects Excluded

Year	8.5 Tons/ Capita	9.0 Tons/ Capita	10.0 Tons/ Capita	11.0 Tons/ Capita
1986	15,788,750	16,717,500	18,575,000	20,432,500
1987	31,938,750	33,817,500	37,575,000	41,332,500
1988	48,467,000	51,318,000	57,020,000	62,722,000
1989	65,339,500	69,183,000	76,870,000	84,557,000
1990	82,577,500	87,435,000	97,150,000	106,865,000
1991	100,087,000	105,975,000	117,750,000	129,525,000
1992	117,852,000	124,785,000	138,650,000	152,515,000
1993	135,872,000	143,865,000	159,850,000	175,835,000
1994	154,173,000	163,242,000	181,380,000	199,518,000
1995	172,728,000	182,889,000	203,210,000	223,531,000
1996	191,556,000	202,824,000	225,360,000	247,896,000
1997	210,638,000	223,029,000	247,810,000	272,591,000
1998	229,984,000	243,513,000	270,570,000	297,627,000
1999	249,577,000	264,258,000	293,620,000	322,982,000
2000	269,467,000	285,318,000	317,020,000	348,722,000
2001	289,595,000	306,630,000	340,700,000	374,770,000
2002	309,978,000	328,212,000	364,680,000	401,148,000
2003	330,607,000	350,055,000	388,950,000	427,845,000
2004	351,475,000	372,150,000	413,500,000	454,850,000
2005	372,589,000	394,506,000	438,340,000	482,174,000
2006	393,949,000	417,123,000	463,470,000	509,817,000
2007	415,565,000	440,010,000	488,900,000	537,790,000
2008	437,410,000	463,140,000	514,600,000	566,060,000
2009	459,535,000	486,567,000	540,630,000	594,693,000
2010	481,882,000	510,228,000	566,920,000	623,612,000

Cumulative Aggregate Consumption nin the Denver Metropolitan Area at 8.5, 9.0, 10.0, 11.0 tons per capita - Large Projects Included

Year	8.5 Tons/ Capita	9.0 Tons/ Capita	10.0 Tons/ Capita	11.0 Tons/ Capita
1986	15,788,750	16,717,500	18,575,000	20,432,500
1987	31,938,750	33,817,500	37,575,000	41,332,500
1988	48,467,000	51,318,000	57,020,000	62,722,000
1989	65,755,500	69,599,000	77,286,000	84,973,000
1990	85,417,500	90,275,000	99,990,000	109,705,000
1991	105,559,000	111,447,000	123,222,000	134,997,000
1992	126,164,000	133,097,000	146,962,000	160,827,000
1993	146,798,000	154,791,000	170,776,000	186,761,000
1994	165,515,000	174,584,000	192,722,000	210,860,000
1995	184,070,000	194,231,000	214,550,000	234,873,000
1996	202,898,000	214,166,000	236,702,000	259,238,000
1997	221,980,000	234,371,000	259,152,000	283,933,000
1998	241,326,000	254,855,000	281,912,000	308,969,000
1999	260,919,000	275,600,000	304,962,000	334,324,000
2000	280,809,000	296,660,000	328,362,000	360,064,000
2001	300,937,000	317,972,000	352,042,000	386,112,000
2002	321,320,000	339,554,000	376,022,000	412,490,000
2003	341,949,000	361,397,000	400,292,000	439,187,000
2004	362,817,000	383,492,000	424,842,000	466,192,000
2005	383,931,000	405,848,000	449,682,000	493,516,000
2006	405,291,000	428,465,000	474,812,000	521,159,000
2007	426,907,000	451,352,000	500,242,000	549,132,000
2008	448,752,000	474,482,000	525,942,000	577,402,000
2009	470,877,000	497,909,000	551,972,000	606,035,000
2010	493,224,000	521,570,000	578,262,000	634,954,000

APPENDIX E: Yearly Consumption of Aggregates

Yearly Consumption of Aggregate the Denver Metropolitan Area at 8.5, 9.0, 10.0, 11.0 tons per capita - Large Projects Excluded

Year	Population	8.5 Tons/ Capita	9.0 Tons/ Capita	10.0 Tons/ capita	11.0 Tons/ capita
1985	1,815,OOO	15,427,500	16,335,OOO	18,150,OOO	19,965,000
1986	1,857,500	15,788,750	16,717,500	18,575,000	20,432,500
1987	1,900,000	16,150,000	17,100,000	19,000,000	20,900,000
1988	1,944,500	16,528,250	17,500,500	19,445,000	21,389,500
1989	1,985,000	16,872,500	17,865,000	19,850,000	21,835,000
1990	2,028,000	17,238,000	18,252,000	20,280,000	22,308,000
1991	2,060,000	17,510,000	18,540,000	20,600,000	22,660,000
1992	2,090,000	17,765,000	18,810,000	20,900,000	22,990,000
1993	2,120,000	18,020,000	19,080,000	21,200,000	23,320,000
1994	2,153,000	18,300,500	19,377,000	21,530,000	23,683,000
1995	2,183,000	18,555,500	19,647,000	21,830,000	24,013,000
1996	2,215,000	18,827,500	19,935,000	22,150,000	24,365,000
1997	2,245,000	19,082,500	20,205,000	22,450,000	24,695,000
1998	2,276,000	19,346,000	20,484,000	22,760,000	25,036,000
1999	2,305,000	19,592,500	20,745,000	23,050,000	25,355,000
2000	2,340,000	19,890,000	21,060,000	23,400,000	25,740,000
2001	2,368,000	20,128,000	21,312,000	23,680,000	26,048,000
2002	2,398,000	20,383,000	21,582,000	23,980,000	26,378,000
2003	2,427,000	20,629,500	21,843,000	24,270,000	26,697,000
2004	2,455,000	20,867,500	22,095,000	24,550,000	27,005,000
2005	2,484,000	21,114,000	22,356,000	24,840,000	27,324,000
2006	2,513,000	21,360,500	22,617,000	25,130,000	27.643,000
2007	2,543,000	21,615,500	22,887,000	25,430,000	27,973,000
2008	2,570,000	21,845,000	23,130,000	25,700,000	28,270,000
2009	2,603,000	22,125,500	23,427,000	26,030,000	28,633,000
2010	2,629,000	22,346,500	23,661,000	26,290,000	28,919,000

Yearly Consumption of Aggregate the Denver Metropolitan Area at 8.5, 9.0, 10.0, 11.0 tons per capita - Large Projects Included

Year	Population	8.5 Tons/ Capita	9.0 Tons/ Capita	10.0 Tons/ capita	11.0 Tons/ capita
1985	1,815,000	15,427,500	16,335,000	18,150,000	19,965,000
1986	1,857,500	15,788,750	16,717,500	18,575,000	20,432,500
1987	1,900,000	16,150,000	17,100,000	19,000,000	20,900,000
1988	1,944,500	16,528,250	17,500,500	19,445,000	21,389,500
1989	1,985,000	17,288,500	18,281,000	20,266,000	22,251,000
1990	2,028,000	19,662,000	20,676,000	22,704,000	24,732,000
1991	2,060,000	20,142,000	21,172,000	23,232,000	25,292,000
1992	2,090,000	20,605,000	21,650,000	23,740,000	25,830,000
1993	2,120,000	20,634,000	21,694,000	23,814,000	25,934,000
1994	2,153,000	18,716,000	19,793,000	21,946,000	24,099,000
1995	2,183,000	18,555,500	19,647,000	21,830,000	24,013,000
1996	2,215,000	18,827,500	19,935,000	22,150,000	24,365,000
1997	2,245,000	19,082,500	20,205,000	22,450,000	24,695,000
1998	2,276,000	19,346,000	20,484,000	22,760,000	25,036,000
1999	2,305,000	19,592,500	20,745,000	23,050,000	25,355,000
2000	2,340,000	19,890,000	21,060,000	23,400,000	25,740,000
2001	2,368,000	20,128,000	21,312,000	23,680,000	26,048,000
2002	2,398,000	20,383,000	21,582,000	23,980,000	26,378,000
2003	2,427,000	20,629,500	21,843,000	24,270,000	26,697,000
2004	2,455,000	20,867,500	22,095,000	24,550,000	27,005,000
2005	2,484,000	21,114,000	22,356,000	24,840,000	27,324,000
2006	2,513,000	21,360,500	22,617,000	25,130,000	27,643,000
2007	2,543,000	21,615,500	22,887,000	25,430,000	27,973,000
2008	2,570,000	21,845,000	23,130,000	25,700,000	28,270,000
2009	2,603,000	22,125,500	23,427,000	26,030,000	28,633,000
2010	2,629,000	22,346,500	23,661,000	26,290,000	28,919,000