Sociocultural Dimensions of Supply and Demand for Natural Aggregate—Examples from the Mid-Atlantic Region, United States

By Gilpin R. Robinson, Jr., and William M. Brown

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Abstract

The United States uses large quantities of natural aggregate to build and maintain a continuously expanding infrastructure. In recent years, per capita demand for aggregate in the United States has grown to about 9.7 metric tons (10.7 tons) per person per year. Over the next 25 years, the aggregate industry expects to mine quantities equivalent to all aggregate mined in the United States over the past 100 years. The issues surrounding supply and demand for aggregate in the mid-Atlantic states of Maryland, Pennsylvania, Virginia, and West Virginia illustrate competing requirements for industrial minerals and many simultaneous social and environmental objectives.

In the Mid-Atlantic region, the market area for aggregate is typically much larger than a county, but the county, township, or town is the land-management unit within which aggregate companies are typically regulated. This mismatch in scale creates a jurisdictional dilemma wherein conservation of high quality resources may not be appreciated. Nonetheless, the resource demand, particularly in urban and high-growth areas, remains large and continuous.

The aggregate industry is gradually transitioning to operations that provide large volumes of aggregate from smaller surface areas for long periods of time. This trend is illustrated by the increasing development of crushed stone quarries that operate at higher volume for many decades as compared to sand and gravel mines that generally operate for much shorter periods and produce less aggregate. Additionally, the industry is consolidating, with fewer and larger companies producing the bulk of aggregate in any region.

The economic benefits of large-scale operations favor the consolidation of smaller companies and the development of high-volume production sites that serve a large region. However, neighborhood opposition to aggregate operations often grows in proportion to the size and

intensity of the operation. Opposition to new aggregate operations is also significantly stronger than opposition to activities and expansions at existing operations. The problem of permitting a quarry is compounded because local decisionmakers involved with the permit process are often better aware of neighborhood opposition to mining than of the regional benefits that result from the local presence of any aggregate mining operation.

Although development and maintenance of infrastructure in metropolitan areas require a continuing supply of aggregate, aggregate production rates begin to fall in counties when the population density reaches approximately 1000 people per square mile. At population densities of about 2000 people per square mile, production of aggregate in many counties may diminish significantly. The effects of population growth, marketplace economics, and social pressures have created a mosaic of areas, on a county basis, that either produce and export significant amounts of aggregate, or import most of their needed aggregate from adjacent areas. About one-half of the counties in the region export aggregate primarily to adjacent urban or urbanizing counties. About one-sixth of the counties produce sufficient aggregate resources to meet their current demands, and about one-third of the counties import a significant fraction of their aggregate from adjacent counties.

The cost of aggregate to an end user is highly dependent upon the costs of transporting aggregate. Truck transport costs can double the cost of aggregate to the end-user at truck haul distances of 30 to 50 miles (48 to 80 kilometers). Lower-cost transportation of aggregate by railroad, barge, and ship, however, can offer significant cost advantages relative to truck transport along rail and water transit corridors. The aggregate industry is increasingly using transport by rail and water to move aggregate to redistribution centers, reducing the transport mileage by trucks. Such centers could also serve to extend the life of production sites that become surrounded by urban and suburban development. Transportation by truck from these centers to construction sites results in shorter truck transport distances and lower costs for aggregate to the end-user. With redistribution capabilities built into modern infrastructure, the industry can more easily meet demands and recover costs despite significant transport distances. “Superquarries” are one possibility for supplying aggregate to transfer or distribution stations. Superquarries can be located in other countries, provide quality materials by way of ocean transport, and may be economically viable relative to many smaller quarries at scattered locations, especially in densely populated coastal areas. Locating aggregate production sites far from densely populated areas may provide lower land acquisition costs, less neighborhood opposition to permit and develop the production site, and greater recognition of the economic benefits provided by the operation to the local community.

Rising land costs and reductions in the availability of land due to continuing population growth limit aggregate mining in some areas of the Mid-Atlantic region. Encroachment of residential development adjacent to operating aggregate mining operations makes the mining permit renewal and approval process more difficult and time consuming for aggregate mining companies. Production of aggregate may be limited by regulatory and zoning controls in the immediate vicinity of residential centers due to public concerns about the perceived problems and nuisances of aggregate mining on the local community. Recent trends in the industry include increasing mechanization and automation, increasing production from individual sites and industry consolidation leading to economies of scale, lower-cost rail and barge transport to redistribution centers, development of superquarries, and the recycling of aggregate. These trends demonstrate that the aggregate industry can adapt its operation and management practices to the modern complex of social, economic, and environmental conditions, while continuing to take advantage of the driving forces of supply and demand.

Introduction

Natural aggregate, consisting of crushed stone and sand and gravel, is the major raw material used by the construction industry. More than 90 percent of asphalt pavements and 80 percent of concrete are composed of aggregate. This report presents several examples of issues surrounding supply and demand for natural aggregate in the Mid-Atlantic region of the United States, and discusses some of the sociocultural drivers and constraints that influence the use and availability of natural aggregate in our society. The study is part of an attempt to understand the broader sociocultural dimensions of mineral supplies that include the legal, financial, environmental, cultural, and global implications of providing the mineral materials society demands. This study complements the series of reports described in Rodenburg (2001, p. 11-12).

This report draws upon data collected and compiled by the authors during 1995-2002. The authors analyzed production statistics and company information for natural aggregate production (crushed stone and sand and gravel categories) within selected counties in the states of Maryland, Pennsylvania, Virginia, and West Virginia for 1975-2000 (U.S. Geological Survey, 1994-2000; Valentin Tepordei, written communication, 1999; 2001). The analyses were used with county-level census data on population and housing units to identify the trends and relations described in this report. The authors also reviewed scientific and technical literature on the aggregate industry and conducted interviews with industry experts. The authors used the reviews and interviews to develop general and specific information about sociocultural drivers and constraints affecting aggregate supplies and industry practices.

The aggregate industry is the largest mining industry in the United States in terms of production either by weight or by volume, and in numbers of active operations. Production of natural aggregate in 1999, for example, accounted for more than 85 percent on the basis of either weight or volume of nonfuel minerals and more than 50 percent of all minerals (including coal) mined from 3,467 crushed stone and 6,137 sand and gravel operations (Tepordei, 2001). Since about 1965, production of natural aggregate in the United States has averaged approximately 7.5 metric tons (8.3 tons) per person per year. Since 1990, the per capita production rate for aggregate has risen steadily to a value near 9.7 metric tons (10.7 tons) per person for the year 2000. More than

2.72 billion metric tons (3 billion tons) of aggregate were produced in the United States in the year 2000 at a value of approximately $14.2 billion, and the aggregate industry workforce in 2000 included about 120,000 people (National Stone, Sand and Gravel Association, 2001§). More than one-half of the natural aggregate mined in the United States over the last century was placed in service during the last 25 years. Over the next 25 years, the aggregate industry expects to mine quantities equivalent to all aggregate mined in the United States over the past 100 years (Tepordei, 1999).

Long-term production and use of aggregate in the United States generally follows trends in population, changes in population distribution, and the overall length of surfaced roads, reflecting the major use of aggregate in road and building construction (figure 1). Short-term fluctuations in aggregate production mirror the economic cycle. Aggregate production declined during World Wars I and II, the Great Depression during the 1930s, and recessions in the early 1970s and 1980s. Long-term production and use of aggregate in the United States increased after the 1940s with the increase in homebuilding and road building that followed World War II, the start of the Interstate Highway Program, and changes in road construction standards that mandated increased use of high-quality aggregate in road building. Currently, there are approximately 1.4 miles (2.3 kilometers) of surfaced public roadways reported to the U.S. Federal Highway Administration (FHWA) for every 100 people in the United States (U.S. Federal Highway Administration, 1999; figure 2). The surfaced roadway category includes roadways paved with asphalt and cement concrete and unpaved roadways that are surfaced and maintained with aggregate. The fraction of public and private surfaced roadways that are not reported to the Federal Highway Administration is not well characterized for the nation. A comparison of reported overall length of surfaced roads with calculated values based on digital files for the Mid-Atlantic states (U.S. Geological Survey, 1987) indicates that approximately 20 percent of the existing surfaced road base is not reported to the FHWA in the Mid-Atlantic region; therefore, the national estimate could be closer to 1.7 miles (2.7 kilometers) of surfaced roadways for every 100 people in the United States.

The § indicates that the source is an Internet site, the citation for which is located in the sub-section “Internet References” within the section “References”.

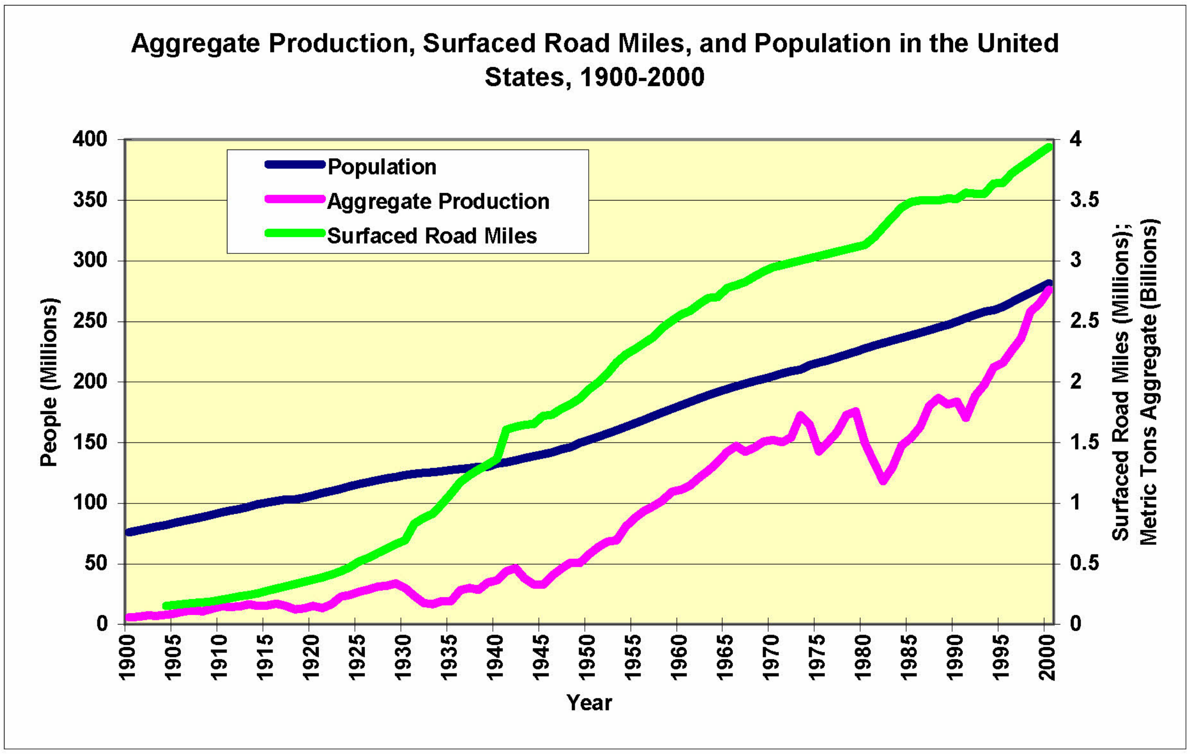

Figure 1. – Aggregate production, surfaced road miles, and population in the United States, 1900 – 2000. Data from U.S. Department of Commerce (1975); U.S. Geological Survey (published annually); and U.S. Federal Highway Administration (1999).

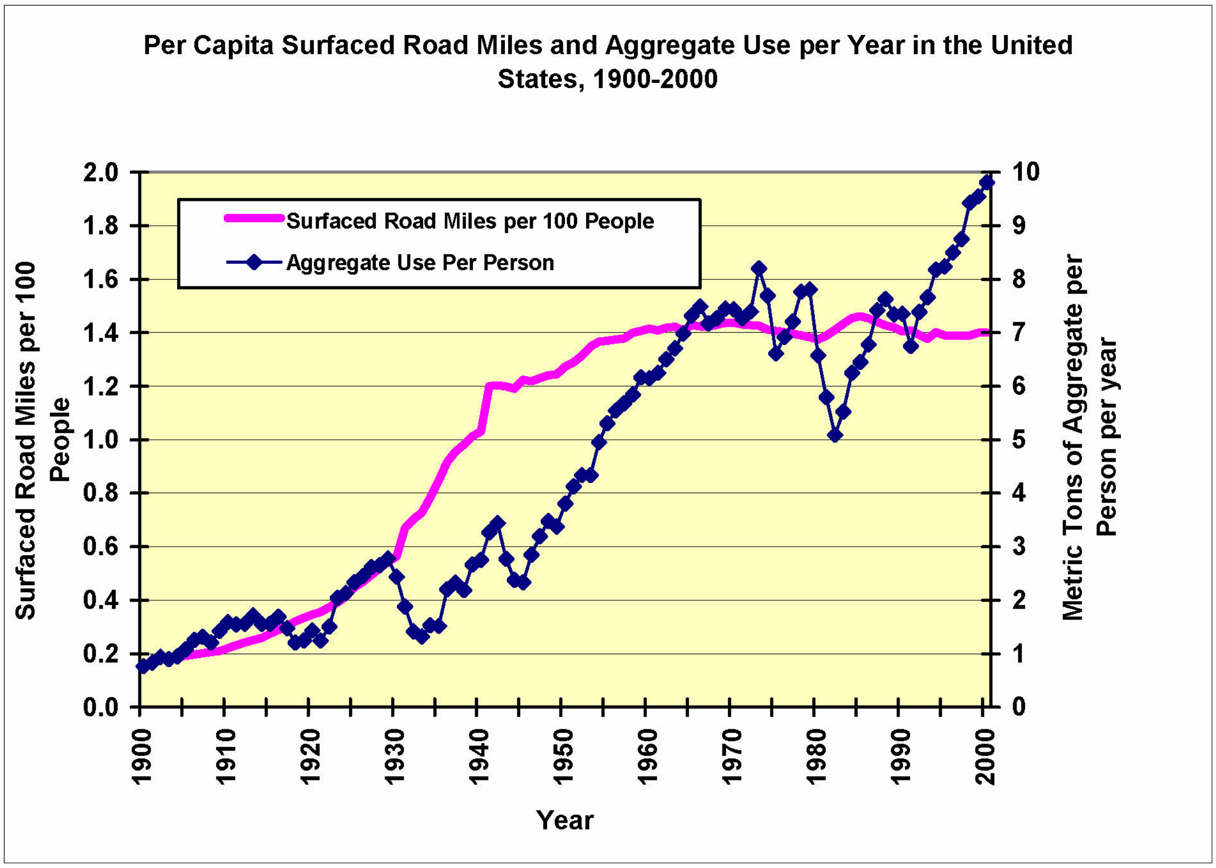

Figure 2. – Per capita surfaced road miles and aggregate use in the United States, 1900-2000.

If these trends continue, large quantities of crushed stone and sand and gravel will be used in the future. The supply of aggregate is not likely to be exhausted, but it can become locally scarce. Near areas where demand is great, such as large urban-suburban complexes, rocks suitable for aggregate may not exist in adequate quantities or they may have been depleted through use. In many instances where abundant resources exist, they are rendered unavailable because of high land costs, preexisting development, and other land-use restrictions (Werth, 1980, p. 1).

Aggregate resources commonly are managed, zoned, and regulated at the local or county level. However, aggregate production data for the Mid-Atlantic region indicates that the market area for aggregate is typically larger than a county (Valentin Tepordei, written communication, 1999). Urban counties in particular import most or all aggregate from elsewhere to meet their demands.

More rural counties, particularly those bordering urban areas, typically export large amounts of aggregate to neighboring urban counties. Because construction costs for aggregate in large public-works projects is small relative to land and labor costs, and the cost of aggregate is not explicit in the typical construction bid process, land managers have difficulty recognizing how aggregate availability and quality affects construction costs. The mismatch between the scale of the land management activity and the scale of the aggregate market area creates a jurisdictional dilemma. In this situation, the regional benefits of local access to natural aggregate resources, that encourage the conservation and protection of areas containing these resources, may be less appreciated than local concerns opposing the development of aggregate operations (p. 22-24, this volume).

Transportation costs are significant for aggregate

Construction aggregate is usually mined near urban and high-growth areas with a high rate of construction activity because the materials are costly to transport by truck over long distances. Commonly, natural aggregate is used within 30 to 50 miles (48 to 80 kilometers) of the place of extraction, although remoteness is no longer an absolute disqualifier for aggregate production (Langer, 1995, p. 304). Transportation costs from the site of extraction to the site of use represent a significant part of the total cost of aggregate to the end user. Transportation by truck in the mid-Atlantic region costs an average $0.18 per ton per mile driven (Palmer Sweet, Virginia Division of Mineral Resources, oral commun., 1999, at the Short Course for Planners, Virginia Division of Mineral Resources, June 22, 1999, Charlottesville, Virginia). Transport distances of 30 miles to 50 miles (48 to 80 kilometers) may thus increase the costs of natural aggregate to the user by a factor of 2 to 4 relative to the unit cost of aggregate at the extraction site (Bush and Hayes, 1995, p. 19; Isaacson, 2001). Transport of aggregate by rail and water can offer significant cost advantages over truck transport. Rail and barge transport, where possible, is increasingly being used to move aggregate to redistribution centers from which truck transport distances to construction sites can be reduced. Rail transport costs are approximately one-third truck transport costs, and, in 1999, barge transport of aggregate cost approximately $0.03 per ton per mile (Palmer Sweet, Virginia Division of Mineral Resources, oral commun., 1999, at the Short Course for Planners, Virginia Division of Mineral Resources, June 22, 1999, Charlottesville, Virginia).

Transporting Aggregate From Distant Sources

> ***Interstate and Foreign Aggregate Shipments***
>
> ***"However, remoteness is no longer an absolute disqualifier for the production of aggregate. Today (1995) interstate aggregate routinely is shipped hundreds of kilometers by rail and barge. In addition, during 1992, the United States imported 1,317,000 metric tons of aggregate from Canada and 1,513,000 metric tons from Mexico. A number of ports on the Atlantic Coast and Gulf Coast of the United States receive imports of crushed stone from foreign sources for transport to various parts of the eastern United States." -- (Langer, 1995, p. 303)***

Truck transport costs of $0.18 to $0.25 per metric ton per road mile transported in the Mid-Atlantic region can equal the production (mining and processing) costs of crushed stone aggregate at truck haul distances of 30 to 50 miles (48 to 80 kilometers). This example illustrates a common feature of aggregate production, namely that truck transportation costs are a consideration in selecting sites for obtaining aggregate (Leighton and others, 1995, p. 19), and that these costs may significantly limit the market areas for major and minor aggregate producers. However, Langer (1995, p. 304) notes that there are a variety of geologic, marketing, and production factors that enable aggregate to be hauled over long distances by rail, barge, and oceanic shipping. For example, the Consolidated Metropolitan Statistical Area (CMSA) of New York City, northern New Jersey, and Long Island with a population of more than 20 million people in 2001 demands enormous quantities of aggregate. In response, the CSMA is supplied by a diverse group of aggregate producers, including some that ship material from as far away as Newfoundland, Canada (Banino, 1994). Martin Marietta Materials, Inc. ships aggregate to New York City from Nova Scotia, and Oldcastle Company ships aggregate from northern New York State to New York City by way of the Hudson River. Martin Marietta Materials, Inc. also ships crushed stone from Nova Scotia to Philadelphia and Florida (Valentin Tepordei, written communication, 2002). Langer further asserts that the greater demand in the New York region could lend stability to the broader market, thus improving the economic viability of importing aggregate to other Mid-Atlantic locations such as the Philadelphia region. In another example, Langer (1995, p. 307-308) describes how Tampa, Florida, and New Orleans, Louisiana must transport aggregate from long distances simply because these metropolitan areas lack local sources. Vulcan Corporation, for example, ships crushed stone from the Yucatan Peninsula to

Florida and the Gulf Coast. In these regions, regulations, environmental considerations, local reactions to mining, and land uses that preclude mining (Knepper, 2001, p. 19) are not principal concerns with respect to aggregate supplies, although there may be other concerns related to transport of material from ports to railheads.

Natural Aggregate in the Mid-Atlantic Region of the United States

This Mid-Atlantic region is a major producer and user of natural aggregate with long-term average production rates ranging from 7 to 11 metric tons (7.7 to 12.1 tons) of aggregate per person per year (figure 3). Aggregate is used on a continuing basis to develop, maintain, and improve the infrastructure in the region.

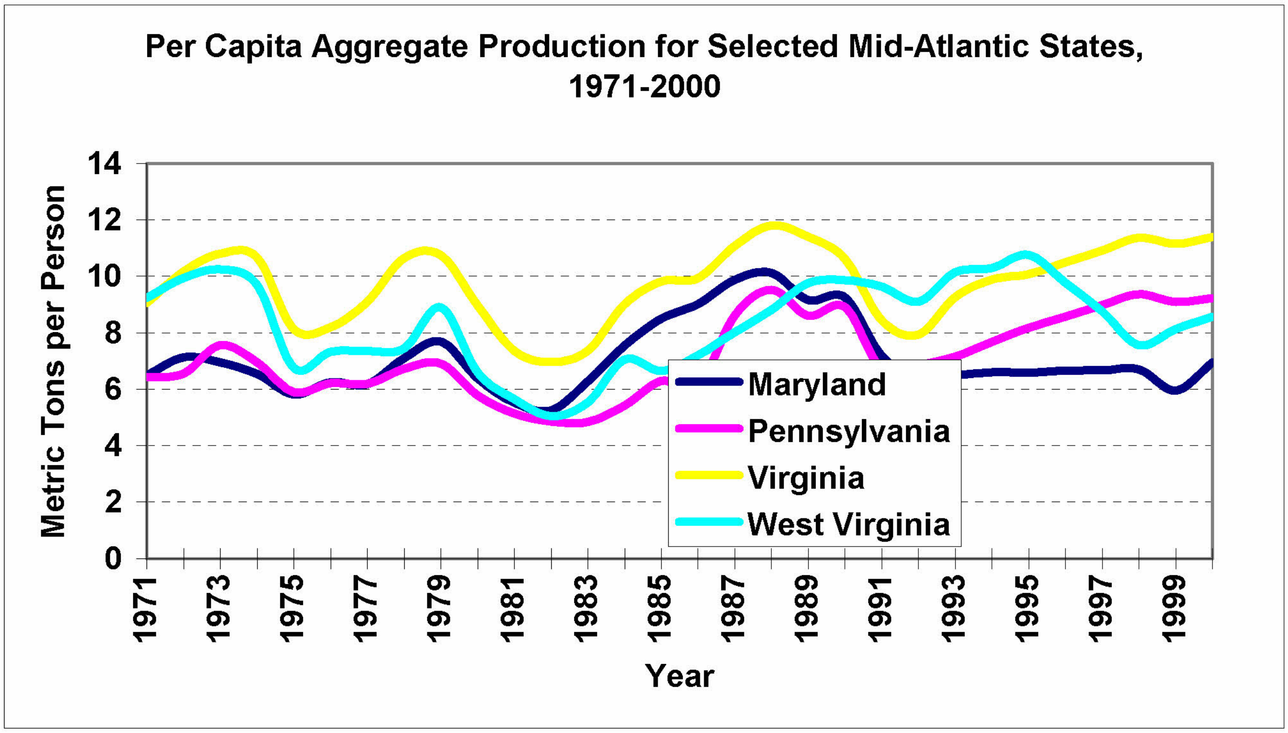

Figure 3. – Per capita aggregate production for selected Mid-Atlantic States, 1971-2000.

The following review of the Baltimore-Washington urban corridor focuses on the 40-county, 17,300-square-mile (44,800-square-kilometer) region surrounding Baltimore, Maryland, and Washington, D.C. In 1995, the Baltimore-Washington urban corridor produced and used about 76 million metric tons (84 million tons) of natural aggregate, at a cost of $480 million. This corresponds to an average production and use of more than 4,400 metric tons (4,850 tons) of aggregate per square mile in the region, or about 8 metric tons (8.8 tons) per capita demanded by the regional population. This figure is similar to the average for the United States as a whole. Over the past decade, the population of this area grew by over 1 million people, a 13-percent increase from its 1985 population. During that time, the area added 550,000 housing units (18.5 percent growth) and 5,500 additional road miles (8,850 kilometers; 8 percent growth). By 2010 the regional population is projected to grow by 14 percent leading to a demand for natural aggregate projected to exceed 86 million metric tons (95 million tons) per year (U.S. Census Bureau, 2000).

Changes in the aggregate industry profile for the Mid-Atlantic region from 1975 to 1995 illustrate some recent industry trends. In 1975, 116 natural aggregate companies were active in the Baltimore-Washington region (Valentin Tepordei, written communication, 1999). These companies produced 36 million metric tons (39.7 million tons) of aggregate from 135 sand and gravel pits (32 percent of total aggregate production for the region) and 78 crushed stone quarries (68 percent of total aggregate production for the region). In 1995, 53 natural aggregate companies were active in the Baltimore-Washington region and produced 76 million metric tons (84 million tons) of aggregate from 61 sand and gravel pits (17 percent of total aggregate production for the region) and 89 crushed stone quarries (83 percent of total aggregate production for the region). The changes illustrate an increasing consolidation in the industry, with fewer companies and mining sites accounting for larger shares of the aggregate production in the region. These changes also illustrate a regional shift in the source of aggregate from sand and gravel, which is supplied by many aerially extensive but low volume operations such as shallow open pits in alluvial deposits, to crushed stone, which is supplied by quarries that produce aggregate in large volume from aerially more restricted deep quarries or underground mines. Tepordei (2001, p. 13) notes that since 1974, more crushed stone than sand and gravel has been produced in the United States, reflecting a national trend toward greater reliance on rock quarries for aggregate.

In the Mid-Atlantic region, a small share of the active aggregate production sites account for a large proportion of the regional aggregate production. Production information for the region in 1995 (Valentin Tepordei, written communication, 1999), when ranked by production from individual sites, indicate that the top 6 percent of the sites provided 20 percent of the total regional aggregate production (figure 4). The top 10 percent of the sites provided 35 percent of the production, and the top 25 percent of the sites provided nearly 60 percent of the production.

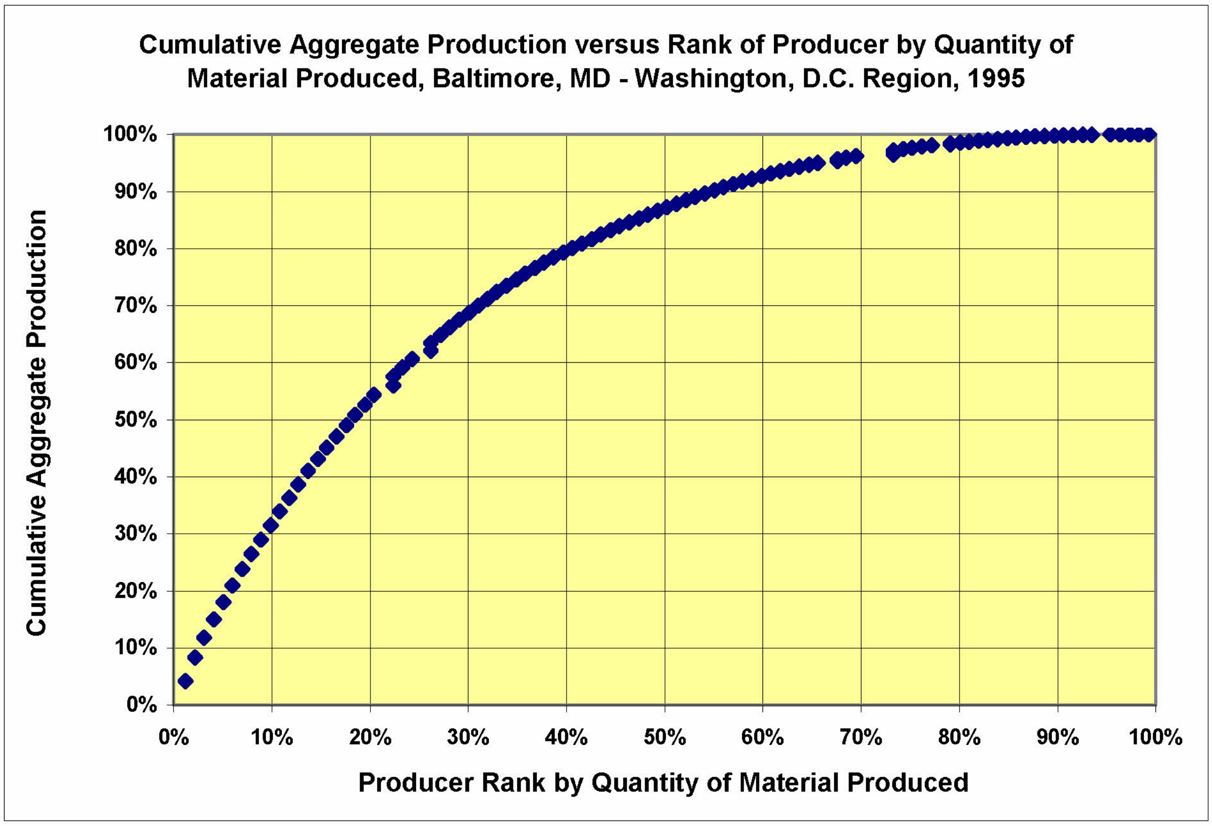

Figure 4. – Cumulative aggregate production versus rank of producer by quantity of material produced, Baltimore, MD – Washington, D.C. Region, 1995.

The cumulative production from at least the lower 45 percent of production sites provided less than 10 percent of the regional production of aggregate (sand pits with small production of only construction fill are underrepresented in the database). This consolidation of regional aggregate production at few sites has implications for regional land management. Local opposition to aggregate production sites often grows in proportion to the size and intensity of the operation (Wernstedt, 2000). The mismatch between the scale of the land management activity and the scale of the aggregate market area creates a jurisdictional dilemma where managers may not recognize the impact on surrounding communities of the loss of aggregate production from a major producer that is within their jurisdiction. Local opponents of the development of aggregate operations may not appreciate the regional benefits that encourage the extraction and production of high-quality natural aggregate resources (p. 22-24, this volume).

Regional Demand for Aggregate

Construction activities that maintain existing infrastructure dominate aggregate use in the Mid-Atlantic region. A relatively small percentage of aggregate is used to construct new buildings and roads in response to growth in the region. For example, in Maryland between 1995 and 2000, approximately 78 percent of aggregate production in the region was used to maintain, improve, and modify existing roads and structures, and 22 percent of the production was used for constructing new roads and buildings (figure 5).

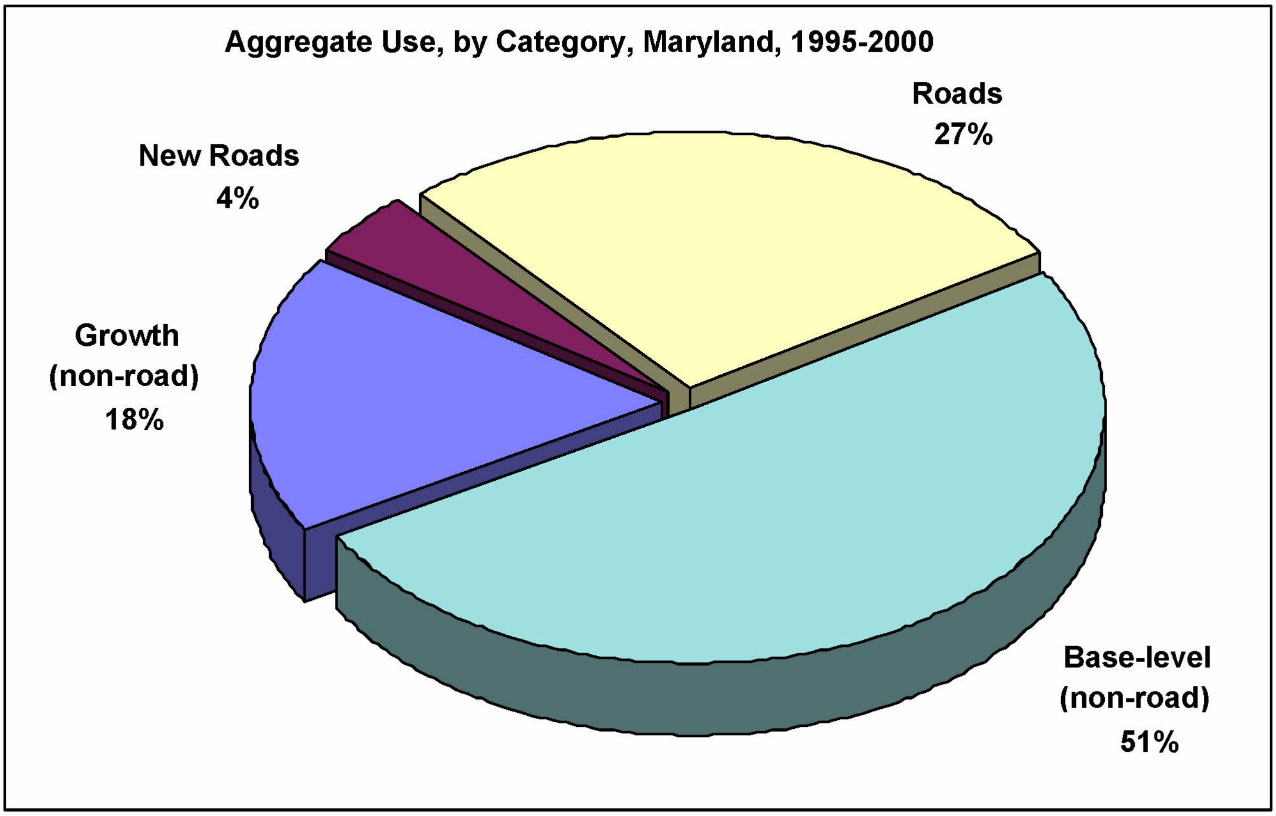

Figure 5 – Estimated aggregate use by category, Maryland, 1995-2000. Estimates are based on aggregate production data and types of crushed stone sold or used by producers (U.S. Geological Survey, 1996-2000, Table 1 and Table 3 for Maryland), Census Bureau estimates of population and housing unit changes, and changes in the road base reported to the Federal Highway Administration for Maryland.

The low allocation of aggregate to construction of new buildings and roads is consistent with how construction activity is reported and tracked. For example, the increase in total road and street mileage construction tracked by and reported to the FHWA each year is relatively small (U.S. Federal Highway Administration, 1997). Most road construction is for improvements that provide safer and more efficient roads and greater traffic and load-bearing capacities. These improvements include resurfacing roads previously paved, widening right-of-ways, reducing grades, minimizing curves, and eliminating grade crossings. In areas with strong growth, there is a demand for frequent road improvements. New road construction typically occurs in commercial and residential projects where roads are part of the development of privately owned land. After construction, these roads are typically turned over to local governments for maintenance and repair. New road construction funded by governments in growing counties usually lags population growth by large margins. This is because land acquisition and other costs make the process of adding new road mileage very expensive for governments, and it takes considerable time and political effort to provide adequate financing. However, there is a tendency for local governments to improve their existing road base as they grow. The significant implication of the patterns of use of aggregate is that the resource use in developed regions, particularly urban areas, is large and continuous. Urban areas use aggregate resources largely in proportion to their established infrastructure to maintain and sustain the economic and social character of the region.

Trends in Aggregate Demand, Availability and Production

Regional information on aggregate production and use provide some guidelines and correlations that can be used to estimate and model long-term demand for aggregate. Future demand for construction aggregate in a region can be estimated from population density and the size of the planning area (figure 6). Demand projections for aggregate is for broad planning and projection purposes, and should be viewed as benchmark estimates with large uncertainties of approximately 25 percent.

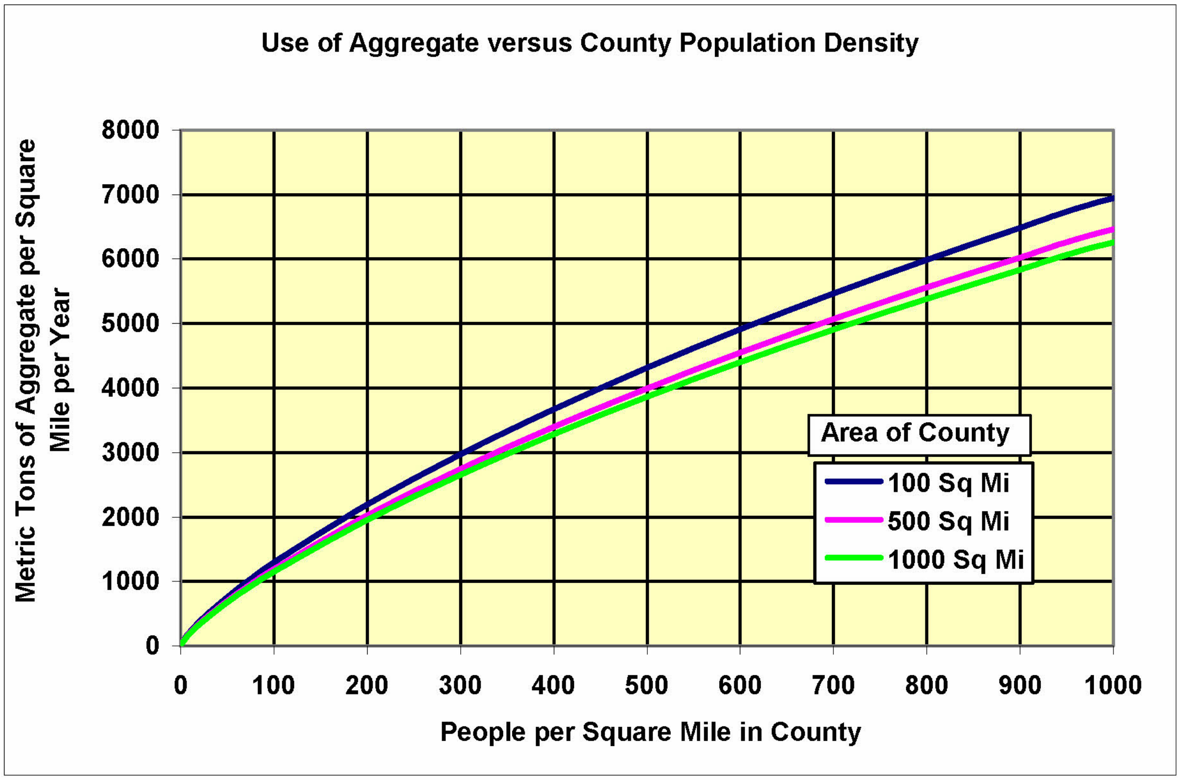

Figure 6. – Use of aggregate versus county population density.

Competing land uses may restrict or preclude the local availability of aggregate (Knepper, 2001, p. 17-21). For example, by 1978 it was estimated that more than 86 percent of the potential aggregate resources in Anne Arundel County, Maryland, were unavailable due to regulation or competing land development (Kuff, 1984). A reanalysis of the land management data indicates that available aggregate resources tend to decrease as a function of population density, used here as a proxy for the state of development in the county (figure 7). The data suggest that each increase in population density of approximately 300 people per square mile will halve the amount of land potentially available for future extraction of aggregate.

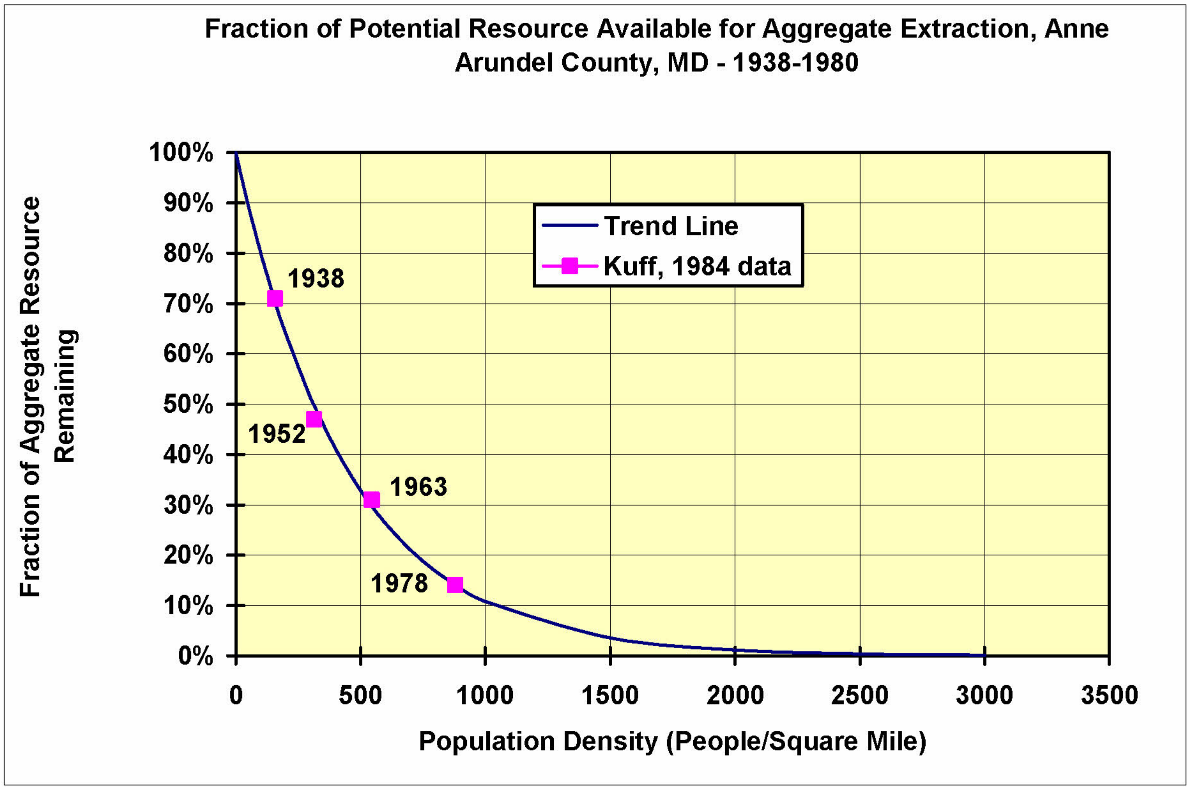

Figure 7. – Fraction of potential resource available for aggregate extraction, Anne Arundel County, MD, 1938-1980. Data from Kuff (1984).

The Kuff (1984) study defined the area of potential aggregate resources that became unavailable for future development through regulation, zoning, and preemptive land development in Anne Arundel County, Maryland. The Anne Arundel County, Maryland, data show that the availability of land suitable for aggregate extraction declines at a significantly faster rate than that of undeveloped land in general (figure 8). The rapid decline in lands available for aggregate production indicates that regulatory and zoning changes that preclude future mining outpace land development, thereby causing a decline in the resource base for aggregate production. This trend in loss of aggregate resource lands parallels the rapid declines observed for wetlands and other development-sensitive lands in the Mid-Atlantic region relative to urban-suburban development (figure 8). The estimates of wetlands remaining in the Mid-Atlantic States and fraction of land area undeveloped are derived from data published by the National Resources Conservation Service (2000) and county-level population data.

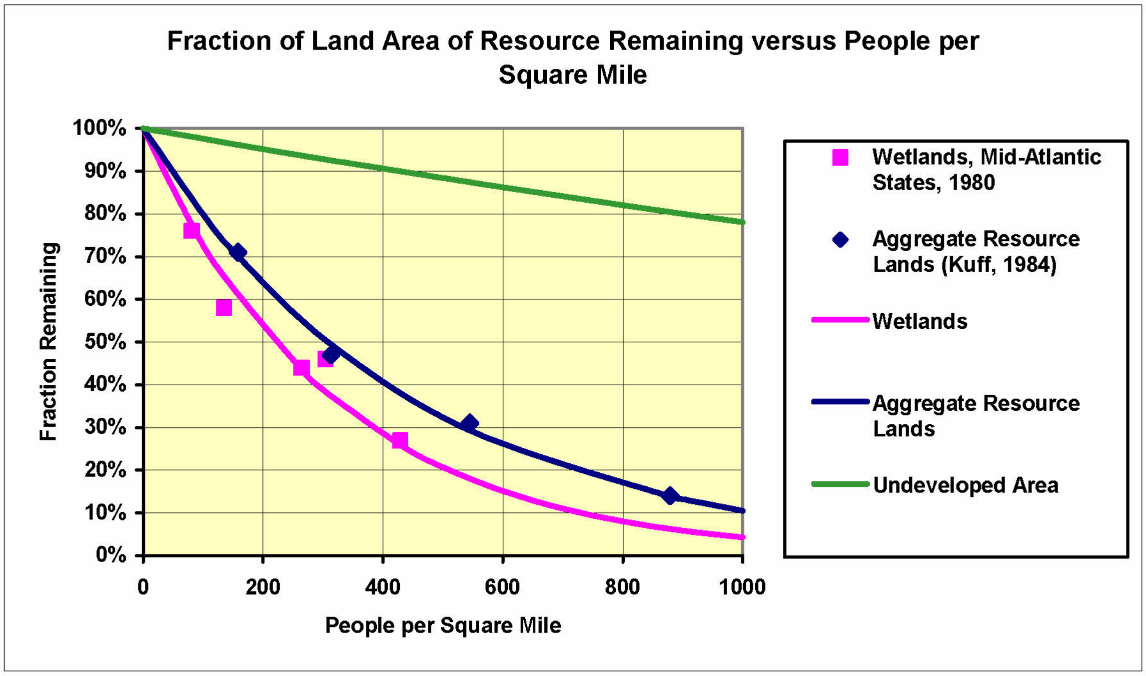

Figure 8. – Fraction of land area of resource remaining versus people per square mile. The fraction of aggregate resource lands available is calculated from data in Kuff (1984) and population data for Anne Arundel County, Maryland. The estimates of wetlands remaining in the Mid-Atlantic States and fraction of land area undeveloped are derived from data published by the National Resources Conservation Service (2000) and county-level population data.

Aggregate production levels and the development of new crushed-stone quarry sites for the Mid-Atlantic region show correlations with population density (figures 9 and 10). The curve in figure 9 is an estimate of the aggregate production rate that meets the average aggregate resource use of a county as a function of population density. The resource use model is shown in figure 6.

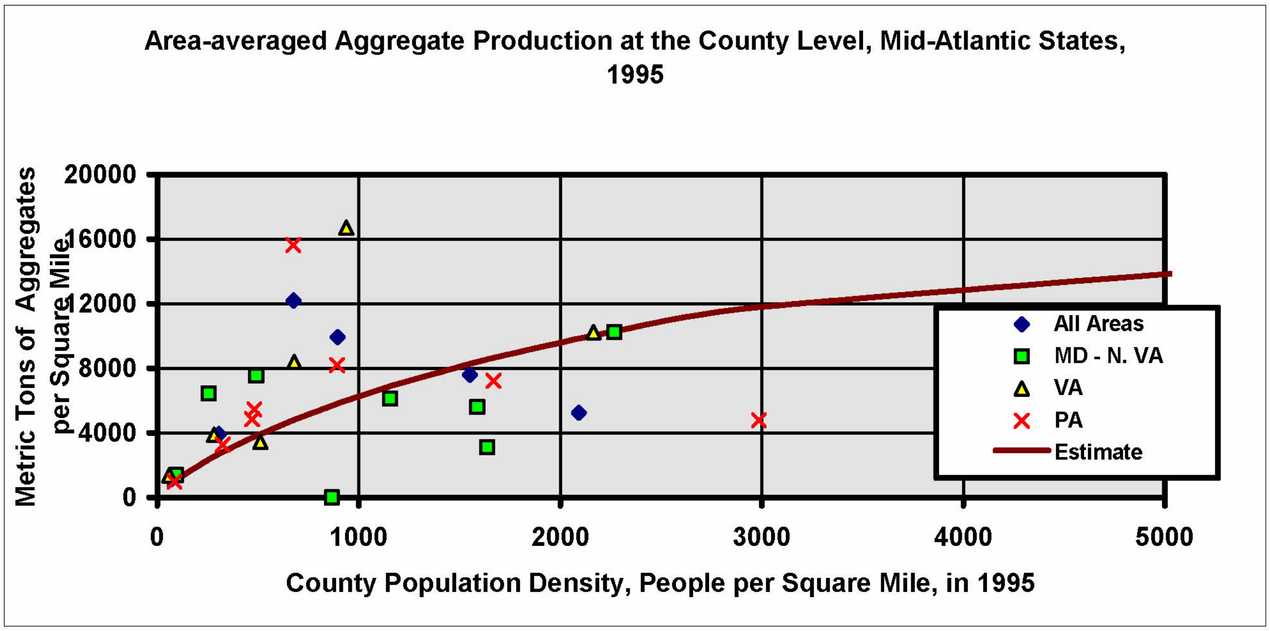

Figure 9. – Area-averaged aggregate production at the county level, Mid-Atlantic States, 1995.

For population densities below 1000 people per square mile, average production rates for aggregate generally exceed the average aggregate use curve. At population densities greater than 1000 people per square mile, production rates for aggregate tend to fall below the average use curve (figure 9). Typically, aggregate production diminishes significantly at population densities greater than 2000 people per square mile. Relying on neighboring areas for aggregate supply is a common strategy for counties with population densities greater than 1000 people per square mile. On a regional basis, these changes appear to reflect a variety of factors, including loss of land availability, land costs, community opposition to industrial expansion, and different economic, aesthetic or other values associated with land use.

Figure 10 shows data on new crushed stone quarries developed during the last decade in Maryland, Pennsylvania, Virginia, and West Virginia. The line in figure 10 is an estimate of the long-term quarry development rate that meets the average resource demands of a county as a function of population density. During this period, the development rate of new quarries dropped below the numbers that meet the long-term aggregate resource demands of counties with population densities greater than 1000 people per square mile. At this state of development, many counties begin a transition towards reliance on aggregate supplied from other areas. The only exceptions to this generalization were for counties experiencing population loss, such as those surrounding Pittsburgh, Pennsylvania, although production at these newly permitted sites in the Pittsburgh area is currently small. At population densities below 1000 people per square mile, new quarry permit rates tend to fall above the line. On average, new quarry permit rates fall below the line at population densities greater than 1500 people per square mile.

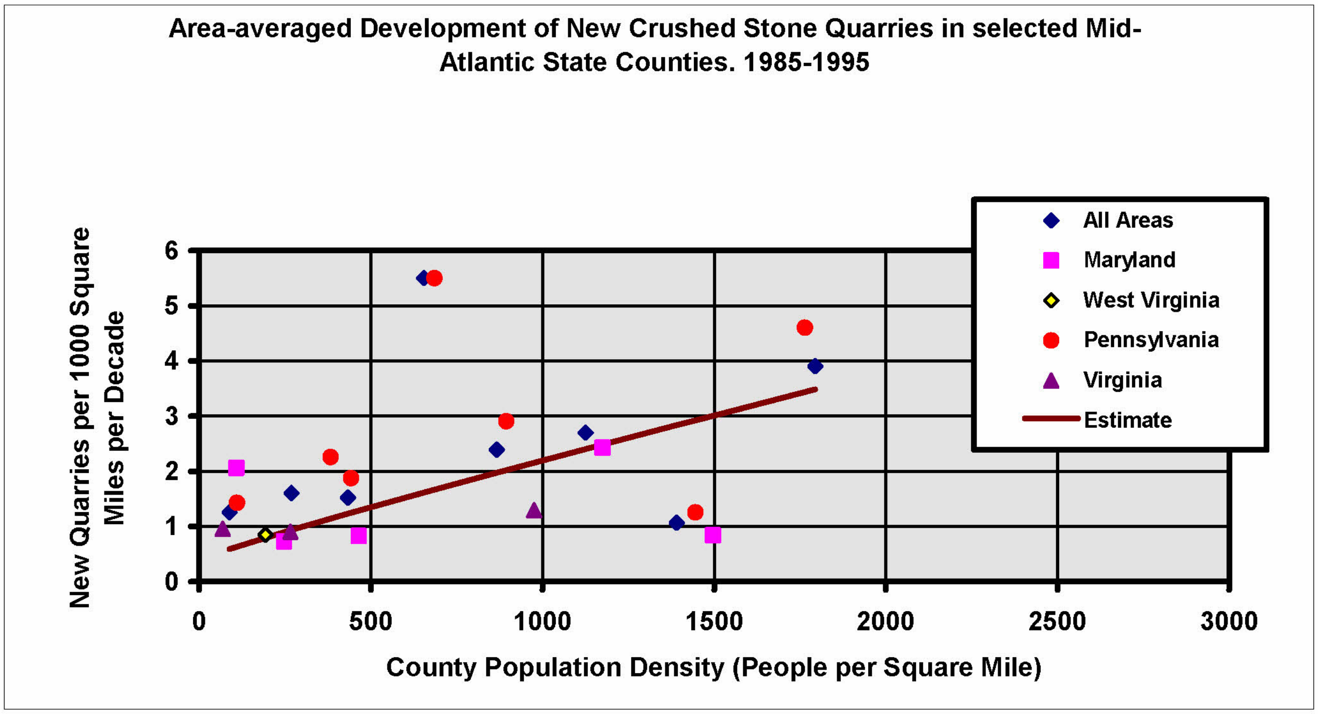

Figure 10. – Area-averaged development of new crushed stone quarries in selected Mid-Atlantic State counties, 1985-1995. The trend line for sustained production was calculated using the average resource use model shown in figure 6, an average quarry production rate of 700,000 metric tons per year (771,000 tons per year) and an average quarry lifetime of 40 years.

Marketplace and Management Issues

The market area for a major aggregate producer in the Mid-Atlantic region is on the order of 1000-2000 square miles (2600 – 5200 square kilometers), which is significantly larger than management areas defined by political boundaries for counties or townships in the region. Situations where management areas are smaller than the areas of influence of an activity create difficulties for land management, particularly when the benefits and social costs of the activity are actualized at different spatial scales. For example, air and water pollution typically result from situations where benefits are local and problems (wastes) are dispersed. For aggregate production, there is typically the reverse situation where problems are local and benefits are dispersed, particularly economic benefits. The economic and supply benefits are distributed throughout the market area of the aggregate producer. In the Mid-Atlantic region, this market area may exceed 2000 square miles (5200 square kilometers). However, most of the problems associated with mining and processing of aggregate will be concentrated within a few miles of the operation (Dunn, 1983).

Local opposition to problems and nuisances with localized effects and dispersed benefits, whether they are aggregate operations or a host of other activities, is commonly referred to as a Not-In-My-Back-Yard (NIMBY) reaction. One particularly challenging aspect of the NIMBY viewpoint is that the perception of problems often exceeds reality in the local community. Wernstedt (2000) conducted a phone and mail interview with county-level land managers involved with the site permitting process for aggregate operations in Maryland and northern Virginia to measure their perception of public reaction to both proposed and existing sand and gravel mines and rock quarries (Table 1). Interviewees were asked to assign their perception of the degree of local opposition into categories ranging from “never any” to “always”. The categories of “always”, “usually”, and “often” were judged to represent significant opposition to the mining operation. Fewer than 20 percent of the respondents reported significant local opposition to existing aggregate operations, whereas an average of 75 percent reported significant opposition to proposed new aggregate operations. The respondents suggested that community reaction appears to vary relative to the size, nature, and location of the operation.

Some of the county managers commented that community opposition may be greater for crushed stone operations than for sand and gravel operations because the former tend to have more truck traffic over longer periods of time, they use explosives, and they potentially create more noise and dust from crushing, grinding, and drilling equipment.

Table 1. – A sample of opposition to existing and proposed aggregate production facilities in the Mid-Atlantic region based on a poll of selected county-level land managers (Wernstedt, 2000).

How Common is Opposition?	Existing Sand and Gravel (%)	Existing Crushed Stone (%)	Proposed Sand and Gravel (%)	Proposed Crushed Stone (%)
Never Any	8	0	19	0
Seldom Any	75	80	25	7
Often	13	15	6	21
Usually	4	0	13	7
Always	0	5	38	64
Number of Responses	24	20	16	14

The local opposition to aggregate production typically increases the difficulty of permitting new and re-permitting existing production sites. This phenomenon inhibits local production of aggregate (Langer and Glanzman, 1993) without changing the resource use rate of the region. As production rates decline below the local use rate for aggregate, additional resources are developed elsewhere, commonly resulting in increased transportation distances and new infrastructure development to support the operations. As a result, the regional aggregate marketplace evolves into a mosaic of producing and non-producing areas defined by county and local political boundaries. In the Mid-Atlantic region, about one-third of the counties produce less than 67 percent of their estimated use of aggregate (estimated use of aggregate as a function of population density and county size is shown in figure 6). About one-half of the counties export aggregate primarily to adjacent urban or urbanizing counties, or rural counties with a small infrastructure base. About one-sixth of the counties produce sufficient aggregate resources to meet their current demands (Table 2).

Table 2. -- County-level status in production of aggregate resources in the Mid-Atlantic region (percent by number of counties and area of counties). Aggregate use is estimated from the population density and area relations shown in figure 6. Import status is assigned to counties with aggregate production less than 67 percent of estimated use. Sufficient production status is assigned to counties with aggregate production greater than 67 percent and less than 133 percent of estimated use. Export status is assigned to counties where aggregate production is greater than 133 percent of estimated use. Production status is reported in two ways: 1) by percent of the count of the number of counties in each category divided by the number of counties in the region and 2) by percent of the respective areas of the counties in each category divided by the area of all counties in the region. County-level production information for 1995 was provided by Valentin Tepordei (written communication, 1999).

Region	Import Aggregate (percent)		Significant Aggregate Production (percent)					
			> Sufficient		Sufficient		Export	
Counties	number	area	number	area	number	area	number	area
Maryland and northern Virginia	31.0	20.0	69.0	80.0	16.6	18.6	52.4	61.4
Pennsylvania	32.8	32.8	67.2	67.2	27.0	27.3	40.2	39.9
Virginia	40.6	37.2	59.4	62.8	9.4	9.1	50.0	53.7

Sociocultural Constraints and Drivers to Aggregate Supplies

The following discussion of sociocultural constraints and drivers to aggregate supplies are derived in part from Langer (2001; 1995), Drew and others (2002), Wilmshurst (2000), Werth (1980), and from interviews with company experts (Rogers Group, Inc., 2001§; Vulcan Materials Company, 2001§; Tilcon Delaware, 2001§). Langer (2001) and Drew and others (2002) present an overview of the operational features of the aggregate industry that are significant in shaping public attitudes towards aggregate mining at both the local community and regional level. Barksdale (2000) provides guidelines and management strategies for the aggregate industry to address and mitigate a variety of environmental concerns by using modern technology, operational procedures, site management, and site planning. The natural aggregate industry can mitigate environmental problems such as dust and noise associated with pit and quarry operations (Barksdale, 2000), and it has developed guidelines for effective reclamation and redevelopment of aggregate production sites after mining is completed (Bauer, 2000).

Nonetheless, many social and political concerns arise when companies attempt to develop or expand mining operations near developed areas, and when residential areas encroach on sites where aggregate is produced. These concerns are difficult to resolve because they are rooted in human perceptions that technology and management may not adequately protect them from risk or damage to property or the environment. The concerns are difficult for the industry to address because the risk perceived by the public may differ from the risk identified by the industry. Public concern about risks tends to increase relative to the perception of benefits in situations where the individual risks are involuntary (lack of choice) and the individual cannot take actions to mitigate the risk (lack of control) (Slovic, 1987). These concerns are further complicated by the tendency to disassociate the inevitable effects of resource production and use from the benefits of and requirement for a supply of natural aggregate necessary to make safer and longer-lasting roads and buildings (Drew and others, 2002). The information below presents some of the complexities of the social and environmental concerns that apply to the natural aggregate industry and illustrates how the industry has adapted these concerns and situations.

Sociocultural Constraints

The sociocultural constraints and the economic and marketplace drivers affecting the natural aggregate industry are both most intense in developing areas with increasing population density and rapid changes in land use and residential development. Sociocultural constraints to aggregate mining are generally driven by public concerns and perceptions about quality of life, health, value of property, aesthetics, environmental quality, and the zoning and regulatory environment. Local citizen groups and more broadly based non-government organizations (NGOs) that oppose aggregate mining may focus on these concerns as the most effective way to influence the regulatory and zoning process to limit the industry and thereby mitigate their perception of risk. These types of groups and organizations can be highly sophisticated and often well funded, and they communicate widely using the Internet. Citizen groups can exert significant pressure on local opinion leaders and elected officials. As a response to this pressure, some officials may delay decisions on or deny permit applications, even if it is likely that these decisions may be overturned in an appeals process (c.f. site studies reported in Drew, 1998). Quality-of-life concerns include noise, dust, traffic congestion, and deterioration of highways and bridges due to heavy truck traffic. Aggregate mining operations have a variety of noise sources, some of which are mobile and tend to vary as mining progresses over the years. Common noise sources to which people object include heavy trucks, other heavy equipment and blasting. Mining and transportation activities create dust that is generally regarded as a nuisance and a possible health hazard. To mitigate some of these problems, the natural aggregate industry has developed guidelines that specify a variety of site management techniques and technologies for noise and dust abatement (Barksdale, 2000).

Aggregate transportation usually requires many heavy trucks running over local roads. Truck traffic can deteriorate roads and bridges not suited for heavy use, can increase maintenance and street cleaning costs due to spills, and can cause traffic and safety problems. In particular, the potential for accidents on the local roads surrounding aggregate operations involving heavy trucks used to haul aggregate is a cause for neighborhood concern and opposition (Drew, 1998, p. 247). This public concern with truck accidents in general is supported by statistics from the National Highway Traffic Safety Administration (1999), who reported that large trucks accounted for 3 percent of all registered vehicles, 7 percent of total vehicle miles, and 12 percent of traffic fatalities in 1998.

Property concerns generally involve damage to structures, loss of water supply, land subsidence or other ground failure, and loss of property value due to proximity to mining operations. Structures have been reported to have been damaged by ground shaking during blasting in a nearby quarry. Poorly managed mining of aggregate can disrupt the groundwater system, causing changes in groundwater flow, yield, and quality. Under certain conditions, land subsidence and slope failures can occur in the vicinity of mining operations, causing damage to nearby properties. Whereas aggregate resources are important to the general economy of an area, some communities are concerned that proximity to an active aggregate production site will depress the value of nearby residential property (Werth, 1980, p. 1). Aggregate mines typically operate for periods of several years up to several decades. Rock quarries (producing crushed stone) can operate for several decades to a century or more. The duration of operations has major implications for the economies of nearby property owners, local communities and long-range land-use planning.

Concerns about viewscapes include loss of vegetation, pit and other excavation scars, mine structures and equipment, stockpiles, and overall loss of pastoral or other aesthetic qualities of the landscape. Aggregate mining creates pits and quarries, some of which are quite large and deep. These holes in the ground and surrounding disturbed areas can be devoid of vegetation and animal habitat and have a negative visual and biological impact (Knepper, 2001, p. 6; Werth, 1980, p. 1). Aggregate operations and reclaimed mine sites are seldom isolated from their surroundings, particularly in the face of rapid urban-suburban expansion and in highly developed regions. Because of these visual impacts, the industry has developed guidelines for site reclamation and redevelopment (Bauer, 2000). A challenge for the industry is that mine sites that are redeveloped and effectively reclaimed may lose public recognition as a former mine site while poorly reclaimed sites or eyesores remain identified with the mining industry. Mining of natural aggregate generally produces minimal mining-related wastes compared with other hard-rock and coal mine operations. However, the mining of aggregate deposits that are thin, in the case of some gravel pit operations, or that contain much unmarketable material, can generate both large mined areas and large amounts of waste material that does not meet the physical and chemical specifications desired by the operator. Abandoned sites can be a safety hazard as well as an eyesore, and land reclamation after mining may not occur or may be of poor quality. Abandoned mines frequently become sites for unplanned and unregulated uses such as waste disposal and various recreational activities. People pay attention to where they engage in recreation, as well as where they live. Thus, the desire for peace and quiet, unmarred viewscapes, and other amenities can work against permitting aggregate mining even in more remote areas.

Environmental concerns overlap somewhat with other concerns expressed above, and include vegetation loss, loss or change of habitat for wildlife, changes in surface hydrology, increased sedimentation in streams or other water bodies, site hazards such as illegal dumping of trash or toxics on site, or illegal or accidental waste spills on or off the site. Aggregate mining in certain dynamic environments, such as stream channels, areas prone to landslides, and sensitive ecosystems, can have significant adverse impacts with irreversible consequences (Langer, 1999). Whereas the aggregate industry may not want to leave behind a spoiled landscape, some operators may lack the professional knowledge and experience to successfully reclaim the site; there are also those who are not concerned about the consequences (Langer, oral commun., 2000). In addition, adverse environmental impacts caused by irresponsible mining of any type can compromise the future development of natural aggregate and other mines in the region.

The zoning and regulatory situation, whether local or regional, can be a major constraint on aggregate mining. Data from the Mid-Atlantic region of the United States, as stated earlier, indicate that at population densities near 1000 people per square mile, counties typically transition from exporting aggregate production to importing aggregate from neighboring counties (p. 16-21, this volume). This transition can result from increased costs, the difficulty of maintaining and obtaining production permits, or resource availability in the face of urban-suburban growth (Knepper, 2001, p. 17-21). Restrictive zoning can keep a high quality resource from being developed, or impose requirements that make an operation uneconomic. Drew (1998) describes several recent situations in Maryland and Virginia where permits to mine aggregate from high quality sources were denied or restricted in response to community opposition. The long-term protection of aggregate resources from urban development using zoning may be as difficult to implement as the long-term protection of agricultural land from urban development. Sites with gravel deposits in the Mid-Atlantic region tend to occur in flat upland areas well suited for residential development or in the flood plains of stream drainages. In these areas, residential development or wetland protection restrictions may preempt aggregate mining. Also, the high cost of land in metropolitan areas may inhibit its development as an aggregate mine, whereas an aggregate deposit on less expensive land far from the growing areas of an urban complex may not be a valuable asset because of the high cost of transporting the material. There may also be reclamation bonding requirements at the startup of an operation. Upon closing an operation, there may be high costs to operators for reclamation and liability insurance. In many cases, oversight and regulation by several different agencies can make permitting and operations cumbersome, and companies are likely to find difficulties in coping with inconsistent management and regulation across states and regions.

A current (2002) situation in the United Kingdom demonstrates taxation as a potential constraint on aggregate supply and demand. The Department of Transport, Local Government and Regions

(DTLR), as part of wholesale revisions of planning policies nationwide, launched a government consultation in October 2000 for the purposes of "…securing a sustainable supply of aggregate minerals in England." The study sought to find ways "… to meet the needs of society and the economy for aggregate while providing the necessary environmental protection and mitigation which we owe to our society and to future generations." (Department of Transport Local Government and Regions, 2001). The subsequent DTLR report (2001) showed that there are significant external environmental costs to aggregate operations, calculated to be $400 million annually. A response to these costs is an aggregate tax of $2.50 per metric ton to be levied for each metric ton of newly mined aggregate in the United Kingdom beginning April 2002 (Wilmshurst, 2000, p. 8). The tax was designed to recover the full environmental costs of aggregate extraction and to encourage the use of recycled materials. The money raised is to be placed in a special fund known as a "Sustainability Fund for the United Kingdom" to create environmental benefits in areas subject to the environmental costs of aggregate extraction. Armstrong (2000), on behalf of the British Aggregate Association, made provisional calculations to suggest that the imposition of an aggregate tax of $2.50 per metric ton would reduce demand by some 17 million metric tons (18.7 million tons) per year and could lead to the closure of perhaps 200 small quarries and the loss of about 1,400 quarry workers. Wilmshurst (2000) asserts that the industry did not take the threat of the tax seriously enough, and was fragmented in its attempts to oppose the tax.

Sociocultural Drivers

Sociocultural drivers that encourage aggregate mining generally fall under the categories of economics, and patterns and types of resource use. Widespread demand for aggregate in the United States, for example, has risen steadily to consumption amounting to 9.7 metric tons (10.7 tons) per person for the year 2000 (p. 5-6, this volume). Aggregate is the primary source of material for the construction industry, and is used extensively as a base or subgrade material for buildings, construction access roads, highways, railroads, airport runways, dams, and road surfaces. Aggregate is the preferred material for fills, for use in utility trenches and storm drains, and for bringing houses and building pads up to grade.

In terms of economics, modern aggregate operations can be profitable because of consistent, long-term high demand for the product. Aggregate is so vital to the general urban economy that measures of aggregate use are considered some of the best indices of economic activity for a region or for a nation (Werth, 1980, p. 1; Tepordei, 2001, p. 13). Aggregate use is a leading indicator for the business cycle, and continues to show long-term growth in demand in most regional markets. The industry exhibits flexible economies of scale, with large-volume, long-term production of crushed stone and small-volume, short-term production of sand and gravel. The most economical operations tend to be dependent upon proximity to the market and costs of transportation from the mining site to the market. In many areas of the United States, the aggregate industry has room to move, for example, another 10 miles (16 kilometers) or more beyond urban and suburban centers to stay ahead of growth without impinging upon other urban and suburban centers. High costs of land could inhibit developing the aggregate resource, but the high initial costs could be mitigated if the property can be reclaimed and converted to an economic asset in the form of commercial, residential, or recreational property. The trend for the Mid-Atlantic region is toward decreasing reliance on short-duration, open-pit mining and increasing reliance on long-duration quarry mines because these types of operations can produce aggregate in large volume from smaller areas and for longer periods of time.

Resource Conservation and Availability Strategies

One strategy that has been successfully applied to resource conservation and environmental protection is to move management planning, review, or oversight to a scale that is equal to or larger than the area of influence of the activity. Avery and others (1990) report on California's Surface Mining and Reclamation Act (SMARA) that successfully use state-level oversight to help preserve high-quality aggregate resources from preemption. Joint coordination and planning at the multi-county level could be used to identify and conserve quality resources and better identify emerging changes in resource supply and demand. Planning before or early in the development cycle is important to identify and protect resources that are scarce in the region. Both industry and management can make efforts to offset problems and increase benefits at the local level. Protecting land values is often a key issue. Education campaigns can be useful to build public awareness of issues and management tradeoffs. Permits at existing aggregate production sites can be modified to extend supply by allowing underground mining, or allowing the sites to transition into transfer stations. There, raw aggregate can be received by rail or barge, processed, and shipped out by truck (p. 9-10, this volume), and demolition debris can be processed and recycled for use as aggregate at the same location (Kelly, 1998; Wilburn and Goonan, 1998).

Industry Response to Sociocultural Constraints and Drivers

The aggregate mining industry currently has available many responses to sociocultural and environmental constraints while taking advantage of the driving forces of continuing demand. Wilmshurst (2000, p. 8-9) advocates replacing over-the-road truck engines with ones that are more fuel efficient; designing new processing plants to consume less energy; embracing the use of recycled aggregate; selecting the lowest possible content of volatile organic compounds (VOCs) in chemical supplies; expanding ready-mix silo capacities to allow more cement substitution with blast furnace slag and utility fly ash; replacing old motors with high efficiency motors; reducing the amount of water withdrawn from surface and ground water; and measuring the quantity of fuel and energy consumed per unit of production in order to help understand how to reduce consumption.

Management options include locating plants near principal rail transportation corridors and near, but outside urban and growth centers. Another avenue is to develop large rock quarries or “superquarries” located in acceptable sites that may be preferable to many smaller quarries at scattered locations (p. 35-36, this volume). Large quarries require economical, high-volume storage and transportation facilities such as barge or rail in addition to support from local and regional government. In settings where high-quality source materials for aggregate is scarce, and where obtaining new production site permits are difficult, there is a strong economic incentive for industry consolidation. In these settings, the aggregate industry does not have room to move, for example, another 10 miles (16 kilometers) or more beyond growing urban and suburban centers without running into the physical and jurisdictional boundaries of other centers. Here the industry must seek other alternatives for transporting aggregate over long distances where truck transport is not economical. Smaller companies in such areas may lack the necessary financial and administrative resources to comply with the growing regulatory requirements and changing market forces affecting the industry. In such cases, it may be faster, easier, and cheaper for companies to buy existing aggregate production sites than to permit and develop new production sites.

Strategies to extend the resource base of existing operations include underground mining and on-site reprocessing of demolition debris. Companies can extend the lifetime of production sites by using the sites to store and process aggregate shipped from elsewhere. They can reduce waste using technologies and processing techniques that minimize repetitive handling of materials and increase energy efficient practices. The economic success of transoceanic shipments and long-distance rail and barge shipments can be due in part to shippers "backhauling" other commodities rather than transiting with empty holds. Thus, oceanic shipping and rail and barge transport of aggregate can take advantage of storage and transfer facilities in optimal locations. The aggregate industry is increasingly using rail and barge transport, particularly where it is available in highly developed regions, to move aggregate to redistribution centers. Transportation by truck from these centers to construction sites results in shorter transport distances and lower costs (p. 9-10, this volume). With transfer station capabilities built into modern infrastructure, the industry can more easily meet demands, convert "waste" into usable material, and recover costs despite significant transport distances. Aggregate recycling, particularly in urban areas where considerable construction and demolition debris is generated, is becoming an increasing component of aggregate supply, and the economics of recycling aggregate can be favorable under certain conditions (Wilburn and Goonan, 1998; Kelly, 1998). Long-term economic benefits can be realized from reclaimed land transformed into wetlands, new residential development, lakes, and similar uses. Such uses of mined-out aggregate operations can often equal or exceed the value of pre-mining land use, although wetlands and lakes can be difficult to construct and maintain, and should not be viewed as the best reclamation option in all cases. The benefits of well-performed reclamation can include improved public relations for the industry if the post-mining uses are economically and otherwise attractive.

The aggregate industry has a record of successes and continuing potential for opportunities to develop a variety of "good neighbor" policies to counteract its public nuisance activities

(Wilmshurst, 2000, p. 9; Werth, 1980, p. 1). Major companies in the Mid-Atlantic region, for example, have developed public relations departments that address complaints, compile information on "good neighbor" activities, and provide outreach materials to local operators. The "good neighbor" approach, derived from interviews with some of these companies (Rogers Group, Inc., 2001§; Tilcon Delaware, 2001§; Vulcan Materials Company, 2001§) involves a wide range of activities focused on the local community, including:

- Encouraging employees to be active in the local community in activities such as adopt-a-school programs, adopt-a-road programs, and reading literacy programs
- Engaging in community outreach directed toward schools, youth activities, and community groups to provide awareness of the importance of the industry and its career opportunities
- Developing citizen advisory groups to address problems
- Harmonizing the aggregate operation with the local community by landscaping public view areas, providing habitat improvements and buffers where feasible, placing large equipment in settings that are out of view and that minimize noise and dust, and, where possible, designing road access that minimizes truck traffic on residential roads
- Planning in advance to avoid adversely impacting residential property values under certain conditions. Building up to and near existing mining operations seems to be far more acceptable than allowing mining operations to move into areas already zoned for other uses.
- Providing company equipment in times of need to help the local community deal with excessive snow removal, flood control or drainage problems
- Donating aggregate and other company-produced rock materials that are needed for the construction and maintenance of local schools, churches, habitat-for-humanity projects, and community buildings, parking lots, and play fields.
- Providing recreational and educational activities on company property, such as fishing tournaments, nature trails, school tours, community picnics and "open house" events. Some quarries let local rock-hound clubs collect minerals and fossils on their property.

- Creating and funding non-profit foundations to support projects in the local community and scholarship funds awarded to deserving college-bound students, usually at the high school closest to the aggregate operation.
- Providing matching funds to augment charitable gifts by employees.
- Sponsoring athletic teams
- Notifying local residents and businesses prior to blasting

In some cases, companies have donated historic buildings or land to communities to aid preservation of historic sites. The focus of these activities tends to be the community near the operating plants within a few tens of square miles, as opposed to the market area of the aggregate producer that is on the order of a few thousand square miles. Although the focus of the "good neighbor" activities is local, many companies make efforts to gain broader recognition of their activities. Vulcan Materials Company, for example, has certified 27 of its nationwide quarry sites as wildlife habitats under a program developed by the Wildlife Habitat Council (2001§), and there are thirteen additional sites in the certification process in 2001. The company also has made significant contributions to The Nature Conservancy (2001§) to help purchase and maintain wildlife habitat lands near company properties (Vulcan Materials Company, 2001§).

Another approach involves using a business park or other non-industrial commercial activity as a buffer between aggregate mining operations and residential or other conflicting land uses. In this design, the aggregate company creates and maintains a business park as one part of its venture. The business park either surrounds the pit or quarry operation, or otherwise separates the industrial operation from other land uses. With this type of arrangement, permitting can be simplified, and the impacts of opposition to the mining activity can be mitigated early in the planning stages of the project. For example, permits for aggregate mining must be renewed frequently for typical operations. If the mining operation is within a business park, the owner-operator may be granted the opportunity to mine aggregate with a long-term permit requiring infrequent renewal. In Colorado, Lafarge North America Inc. purchased property and developed an amusement park and numerous specialty shops, museums, and other attractions to screen its operations at the Specification Aggregate Quarry near Golden, CO. Known as Heritage Square, the business park has proven to be a land use compatible with the nearby quarry while acting as a buffer between the quarry and nearby residential and open-space developments. Currently (2002), Lafarge North America Inc. is seeking to consolidate some of its operations by trading land it owns elsewhere in the area for land bordering its Specification Aggregate Quarry and Heritage Square holdings. The proposed land trade with the local county open-space program could result in enhancing Lafarge's relationship with the local community while allowing the company to continue mining aggregate for 15 years or more beyond the expected life of the current quarry (The Denver Post, 2002§; Nicholson, 2002§).

Superquarries

Large, efficient operations producing aggregate that are located in low-cost transportation corridors can serve large market areas. The "superquarry" concept of extremely large crushed stone or sand and gravel production sites having ready access to low-cost barge and rail transport is based on this economic business model. Pearce (1994), commenting on "superquarries" in the United Kingdom, notes that hard rocks are increasingly being traded internationally, and that the first customers for aggregate from the Glensanda (Scotland) superquarry were in Texas in the late 1980s. Weaver (1992) notes that the economic success of this venture was due in part to using the same vessels that shipped the aggregate to return to Europe with petrochemicals and other Houston products. Part of the impetus for creating the superquarry and international trade was an increasing shortage of land in densely populated areas of Europe, a lack of local sources of aggregate material in the southeastern United States, and the growing technical and economic feasibility of creating a market for rock delivered by oceanic transport.

Superquarries

The concept of "superquarries" was developed for coastal areas in western Europe in the 1970s. Coastal superquarries are defined in National Planning Policy Guidance Note 4 (Land and Mineral Working) as "…those quarries capable of producing 5 million metric tons (5.5 million tons) or more of crushed aggregate per annum with reserves of at least 150 million metric tons (165 million tons) where the transport of the aggregate to market is by sea" (Scottish Office, Environment Department, 1994, p. 17). In 1996, there was one operational coastal superquarry in the United Kingdom at Glensanda on the west coast of Scotland, and a public inquiry was being held on the development of another coastal superquarry at Lingarabay on the Isle of Harris in the Outer Hebrides (Black and Conway, 1996, p. 285).

Some large quarries in North America have production capacities and reserves similar to those in the United Kingdom, but these are not defined specifically as "superquarries." Examples of large coastal operations in North America include the Bella Coola Rock Corporation project in British Columbia, Canada (Bella Coola Rock Corporation, 2002§), and the Construction Aggregate Ltd. (CAL) project near Sechelt British Columbia. The CAL-Sechelt operation began in 1989, and is the largest gravel mine operation in North America (District of Sechelt, 2002§). In 2001, the CAL – Sechelt operation produced slightly more than 3 million metric tons (3.3 million tons) of aggregate, and estimated total reserves at 240 million metric tons (264 million tons)(Quinn, written commun., 2002).

Douglas and Lawson (2000, p. 21) discuss new coastal superquarries in the United Kingdom, and pose a hypothetical question for the future of whether six superquarries on the Scottish coast are preferable to 45 large inland quarries, or even to 450 sand and gravel pits near places of demand in southeast England. Black and Conway (1996) also treat planning issues for superquarries in the United Kingdom, and set out the arguments surrounding the development of superquarries in terms of projected economic, environmental and social issues. Pearce (1994) concludes that there is strong international competition for developing superquarries, with Mexico, Canada, Norway, Scotland and Spain, among other countries, currently seeking footholds in the United States and European aggregate markets. For example, the Bella Coola Rock Corporation project in British Columbia, Canada, is being planned in part on the basis of demand for aggregate along the west coast of the United States, particularly in California (Bella Coola Rock Corporation, 2002§).

Summary

Natural aggregate production on the basis of either weight or volume accounts for about 85 percent of nonfuel minerals mined in the United States at the turn of the 21st century (Tepordei, 2001, p. 13). Natural aggregate is produced in most counties in the United States (Tepordei, 1999) because it is a high-volume low-value bulk commodity that is sensitive to transportation costs. The production of natural aggregate is related to the population and level of development of a region. However, at local level (county and township scale) the rates of aggregate production and use can differ significantly; these differences reflect both the variety of social and economic factors that influence the local availability of aggregate and the differences in scale between the land-management unit and the market area for a typical aggregate producer. The market area for a typical aggregate producer is often larger than the areas that are managed, zoned, and regulated for aggregate production. The market area for a major aggregate producer in the Mid-Atlantic region of the United States is on the order of 1000-2000 square miles (2600 to 5200 square kilometers), which is significantly larger than management unit areas for counties or townships. This mismatch in scale creates conditions where potential sources of high quality aggregate may be preempted by other land uses and creates an environment where it may be difficult for the industry to get approval to develop or expand an aggregate production site at the local level.

Examples from the Mid-Atlantic region of the United illustrate the range of issues with aggregate supply and demand. The region is a major producer and user of natural aggregate, and demands a continuing supply of aggregate to develop, maintain, and improve its infrastructure. By 2010 the regional population is projected to grow by 14 percent leading to a demand for natural aggregate projected to exceed 86 million metric tons (95 million tons) per year. Competing land uses tend to restrict or preclude the local availability of aggregate. For example, as population and development increase, most of the potential aggregate resources at the county level become preempted from availability either by other permanent uses of the land or by regulation. Aggregate production levels and aggregate mining permit approvals for the Mid-Atlantic region show correlations with population density. Each increase in population density of approximately 300 people per square mile tends to halve the amount of land potentially available for future extraction of aggregate. Population changes appear to reflect a variety of factors, including loss of land available for mining, land costs, and community opposition to aggregate mining in heavily populated areas. In general, production of natural aggregate throughout rapidly developing counties in the region declines significantly at population densities exceeding 1000 people per square mile, implying that the resource supply will come from elsewhere. This finding could be used in part for planning aggregate production in other rapidly growing areas on the basis of population growth projections.

The aggregate industry has changed over time to meet demands for its products and to counter opposition to its activities. Recent data for the Mid-Atlantic region show an increasing consolidation in the industry, with a few sites accounting for a large share of the aggregate production. In 1995, for example, the top 6 percent of the aggregate production sites provided 20 percent of the total regional production. The top 10 percent of the sites provided 35 percent of the production, and the top 20 percent of the sites provided nearly 60 percent of the production.

Environmental issues, regulations, societal issues, and preexisting land development have precluded aggregate mining in many areas of the Mid-Atlantic region. Therefore, there is a trend for production to take place farther and farther from markets. This trend could lead to the development of large rock quarries in a few locations to replace production from smaller gravel mines at many locations. Another trend is the development of very large rock quarries or “superquarries,” whether located in acceptable sites in the United States or other countries. Superquarries produce huge quantities of aggregate, and may be economically viable and easier to develop relative to many smaller quarries at scattered locations. Currently, there is strong international competition for developing superquarries, with several countries seeking footholds in the United States and European aggregate markets.

The benefits of aggregate production are likely to be dispersed throughout a broad market area, but most of the problems and nuisances associated with production will be concentrated close to the operation. The problems and nuisances, whether real or imagined, typically cause stiff local opposition, and how the problems are perceived often leads to government regulation or control that inhibits further production. Sociocultural constraints to aggregate mining generally fall under public concerns for quality of life, health, property, visual impairment, environmental quality, and the zoning and regulatory environment. Sociocultural drivers to aggregate mining generally fall under the headings of patterns and types of resource use, and economics. The aggregate mining industry currently has available many responses to sociocultural and environmental constraints while taking advantage of the driving forces of continuing demand. The impacts of aggregate mining occur over different time periods depending upon the operating life of the production site. Most of the impacts are easy to predict and easy to observe. The natural aggregate industry can use modern technology and site management to reduce and mitigate environmental problems such as noise and dust that are associated with quarry and pit operations (Barksdale, 2000). The industry also has developed guidelines and a variety of innovative practices for site reclamation and redevelopment following mining (Bauer, 2000). Most impacts can be controlled, mitigated, or kept at tolerable levels, and can be restricted to the immediate vicinity of the aggregate operation. The industry can counter local opposition to their operations by becoming involved with the local community, providing benefits to the local community, and by engaging in environmentally sound and socially responsible behaviors and practices. In areas where it is difficult to zone and permit aggregate mining operations, the industry has adapted by consolidating companies, developing sales yards and transferring aggregate from other distant production sites by rail or barge, increasing recycling of construction debris into aggregate, and using mobile crushers that can be moved to local sites for short-term production of aggregate. In some areas, companies are developing and submitting long-term land development plans for zoning approval. In these plans, aggregate mining is restricted to a limited area or time, with the hope that the plan will be more easily approved than a standard mining permit. These trends demonstrate that the aggregate industry can adapt its operation and management practices to the modern complex of social, economic, and environmental conditions, while continuing to take advantage of the driving forces of supply and demand.

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