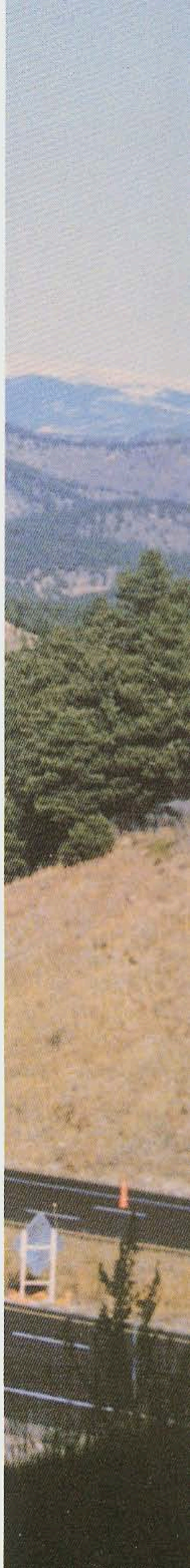
INTRODUCTION

Crushed stone and sand and gravel are the main types of natural aggregate used in the United States. Aggregate is used in nearly all residential, commercial, and industrial building construction and in most public-works projects such as roads and highways, bridges, railroad beds, dams, airports, water and sewer systems, and tunnels. The widespread use of aggregate results not only from its general availability but also from economic considerations. Aggregate of good quality commonly is available near the site of use at relatively low cost. This aggregate can essentially be obtained and used with a minimum of processing. However, even though crushable stone and sand and gravel resources are widely distributed throughout the United States, availability is not universal. Some areas are devoid of sand and gravel, and some potential sources of crushed stone may be lacking or covered by overburden that is too thick to allow economical surface mining. In some areas, moreover, aggregate does not meet the physical-property requirements for certain uses, or it contains mineral constituents that react adversely when used in cement concrete. Furthermore, citizens commonly prefer that stone and sand and gravel not be mined nearby. Many citizens do not support mining, in part because they do not recognize the dependence of society on aggregate. Personal use is very little, if any, and individuals may not recognize aggregate mining as a necessary land use, even though the need for the commodity is constant. Thus, zoning, regulations, and competing land uses may restrict or preclude aggregate mining.

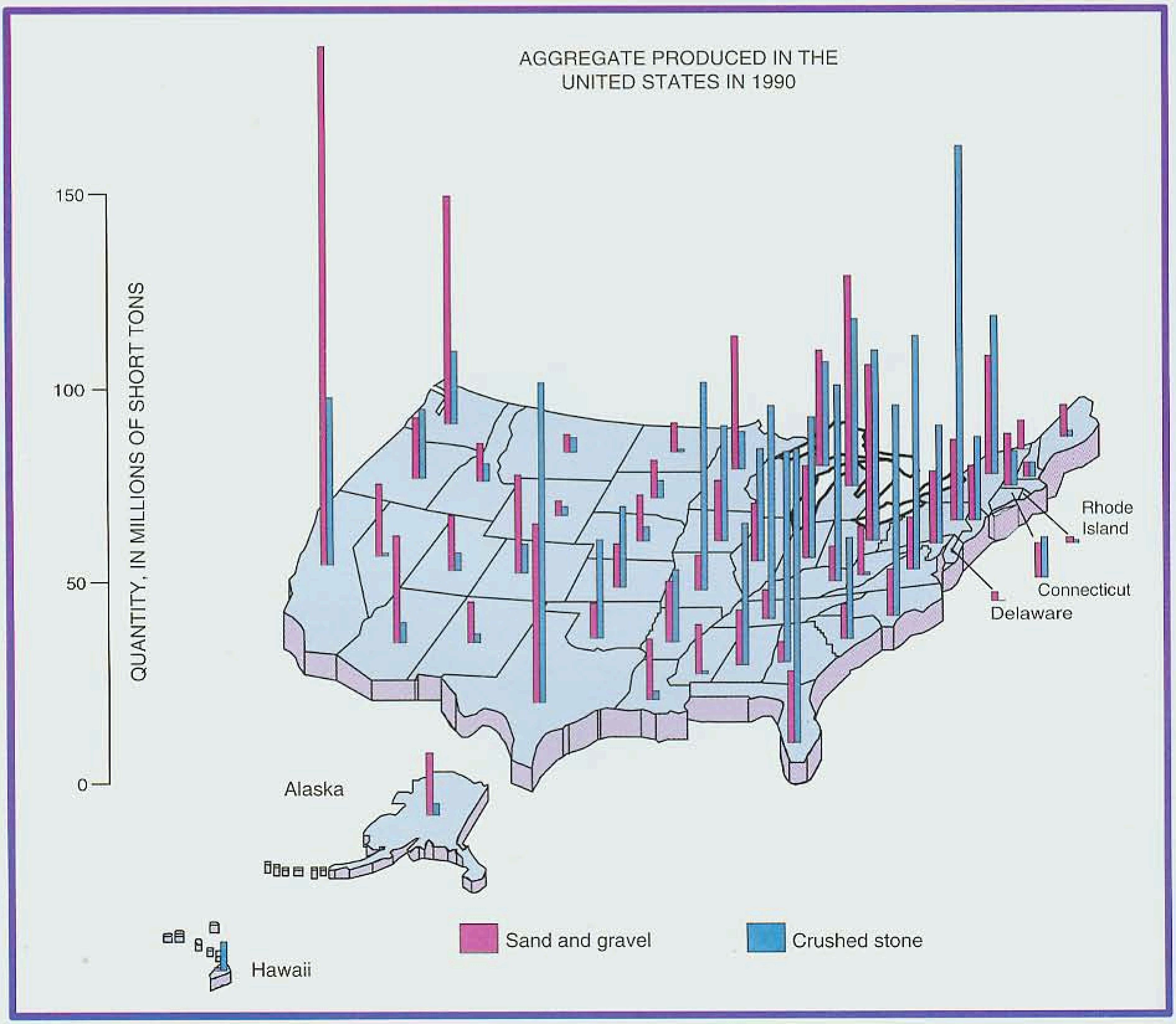
Aggregate production accounts for about half of the nonfuel-mining volume in the United States.

Between 1970 and 1990, aggregate use averaged 1.84 billion short tons per year, reaching a maximum of 2.17 billion tons during 1988. In the future, the rebuilding of deteriorated roads, highways, bridges, airports, seaports, waste disposal and treatment facilities, water and sewer systems, and private and public buildings will require that enormous quantities of aggregate be mined or quarried. Long-range planning is necessary to help ensure adequate economical supplies of high-quality aggregate in the future, while simultaneously protecting the public from unwanted effects of mining. This report provides an overview of the aggregate industry and of the availability of natural aggregate as an aid to those involved in protecting, conserving, and developing the Nation's resources.



Sand and gravel are produced commercially in every State in the United States, and crushed stone is produced in every State except Delaware. Aggregate production accounts for about half of the nonfuel-mining volume in the United States; during 1990, production yielded a gross value of about $9.1 billion. The 1990 gross value far exceeded that of iron ($1.8 billion), copper ($4.2 billion), or the combined value of precious metals including gold, silver, and the platinum-group metals ($4.7 billion).

In 1989 (the last year for which a complete survey of crushed-stone production was taken), 1,716 companies produced 1.2 billion short tons of crushed stone from 3,416 active quarries. Individual crushed-stone quarries range in size from small operations reporting production of less than 50,000 short tons annually to those with production of more than 10 million tons. For a variety of reasons, including the large investment in capital equipment, crushed-stone operations tend to be very large. For example, in 1989, 10 companies operating 477 quarries produced 27.8 percent of the total output of crushed stone in the United States.



Production and Uses of Aggregate

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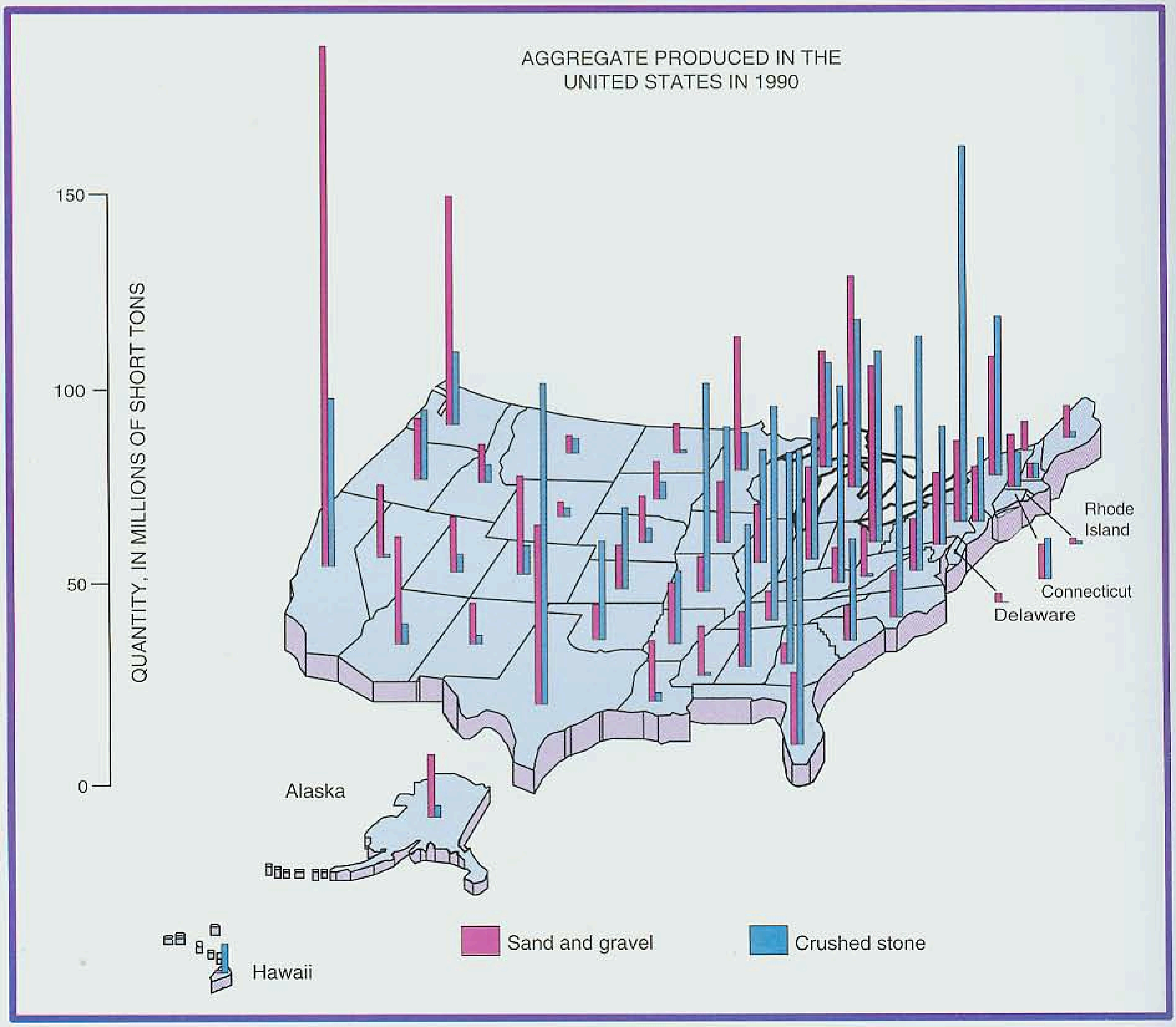
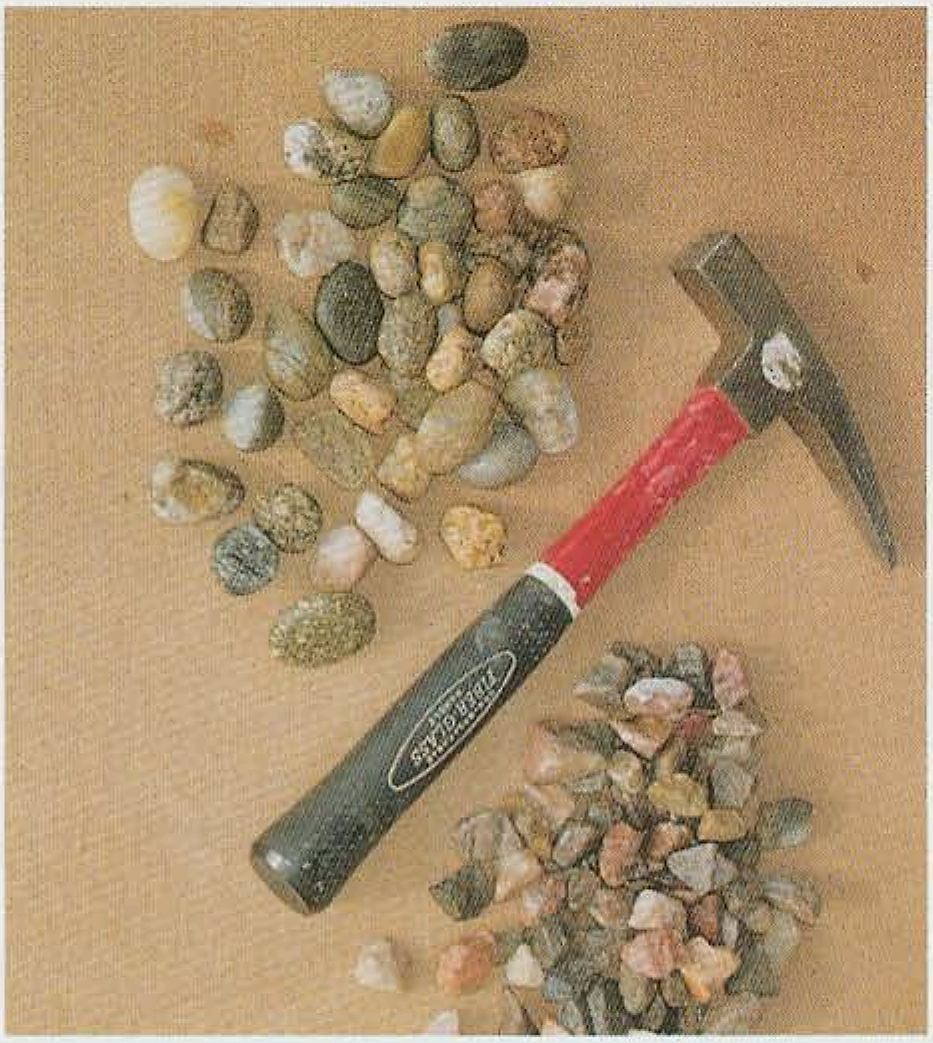
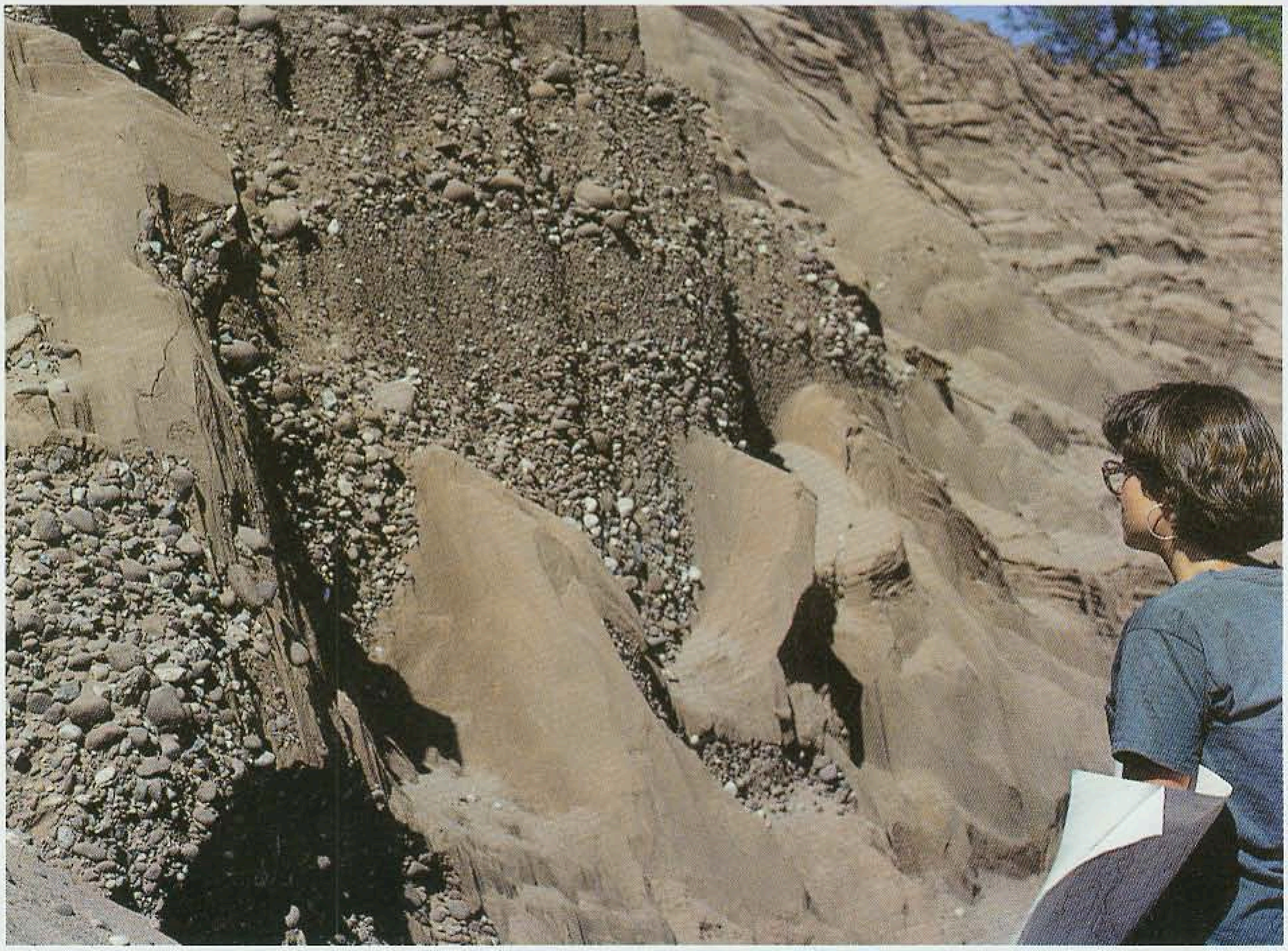


Natural aggregate consists of rock fragments that are used in their natural state or are used after mechanical processing such as crushing, washing, and sizing. Quarry stone is crushed and processed to produce aggregate. In this report, the term natural aggregate (or aggregate) includes mined or quarried stone that has been crushed, washed, and sized, as well as sand and gravel.

Gravel generally is considered to be material whose particles are 3/16 inch to 3 inches in diameter and tend to be rounded with smooth edges. Sand and gravel aggregate is a mixture (aggregation) of sand and gravel in which gravel constitutes about 25 percent or more of the mixture. Gravel may be the predominant material in a natural deposit, but typically it occurs in layers or lenses with sand.





Crushed stone, as its name implies, is artificially crushed rock, boulders, or large cobbles. Crushed stone tends to be angular with sharp edges. Most or all of the surfaces on the clasts or particles are produced by the crushing operation. Most crushed stone is quarried from bedrock that is blasted, mined, crushed, and processed into aggregate. Selection of the bedrock to be used for crushed stone depends primarily on the physical and chemical properties of the rock.

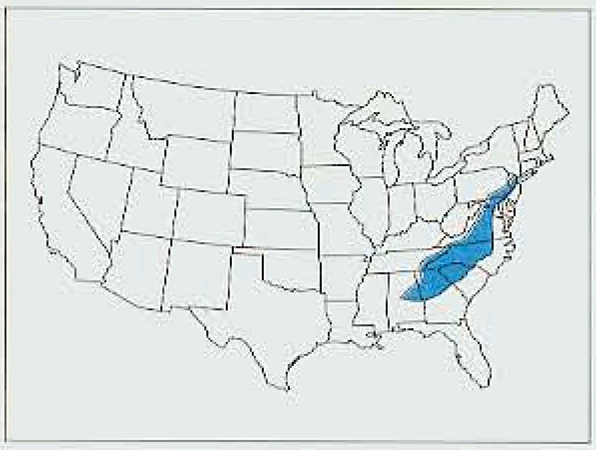
PHYSICAL AND CHEMICAL REQUIREMENTS OF NATURAL AGGREGATE

Most people probably assume that natural aggregate is used chiefly in cement concrete. Much natural aggregate, however, is unsuited for such use. We all have seen crumbling driveways and bridges or cracks in sidewalks and patios. Concrete deterioration has many causes, but unsuitable aggregate, containing deleterious ingredients, can be a primary or secondary cause of the problem.

Natural aggregate varies widely in quality, depending on the source. To ensure that aggregate is suited for particular uses, testing laboratories compare aggregate properties with predetermined standards. The most generally used national guidelines for specifications and testing procedures are those of the American Society for Testing and Materials (ASTM). National specifications must be broad, and at best they serve as general guidelines. Local specifications need to reflect specific uses, availability and quality of local aggregates, and local climatic conditions.

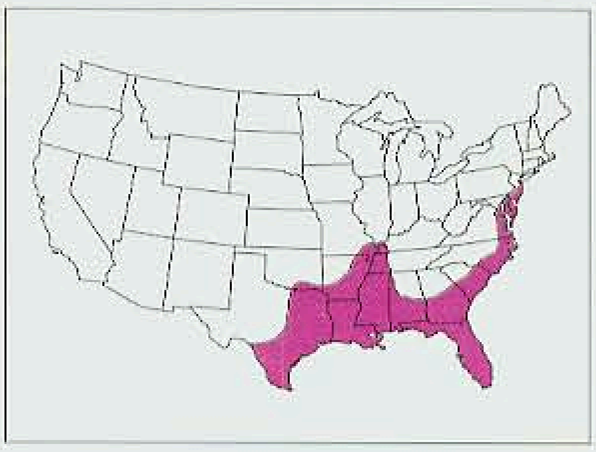
Suitable aggregate consists of clean, uncoated particles of proper size and gradation, shape, physical soundness, hardness and strength, and chemical properties. The final use of the aggregate determines the specific properties sought. Generally, specifications for aggregate used in cement concrete or bituminous mixes are more stringent than are those for other construction-related uses.

Mechanical sieving or screening is used to grade, or sort to size, aggregate. In general, aggregate for cement concrete should be well graded throughout the sand and gravel range of particle sizes, although gap grading (aggregate with specific particle sizes missing) may be used and may be necessary for some products. Specifications for bituminous mixes are dependent on the pavement design, and therefore no general statement can be made regarding the sizes of aggregate used.



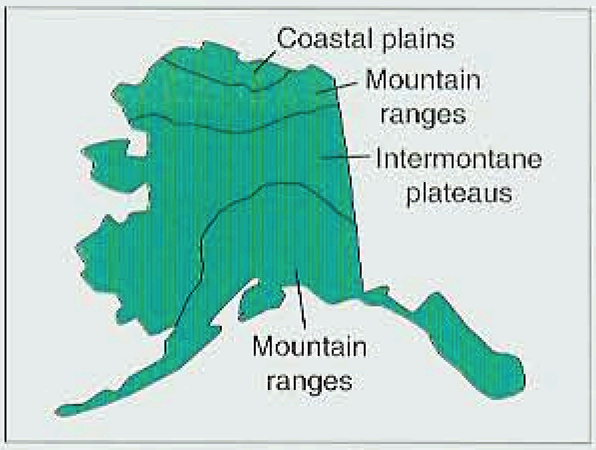
Piedmont Blue Ridge Region

The topography of this region is varied and consists of low, rounded hills, long rolling ridges, and mountains, and contains the highest peaks east of the Mississippi River.



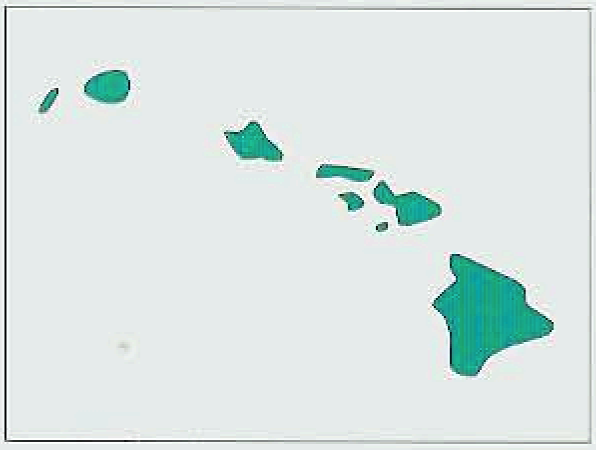
Atlantic and Gulf Coastal Plain

The topography ranges from extensive, flat, coastal swamps and marshes occurring near sea level, to rolling uplands occurring near the inner margin of the region.



Alaska

A complex area consisting of coastal plains, mountain ranges, and intermontane plateaus.



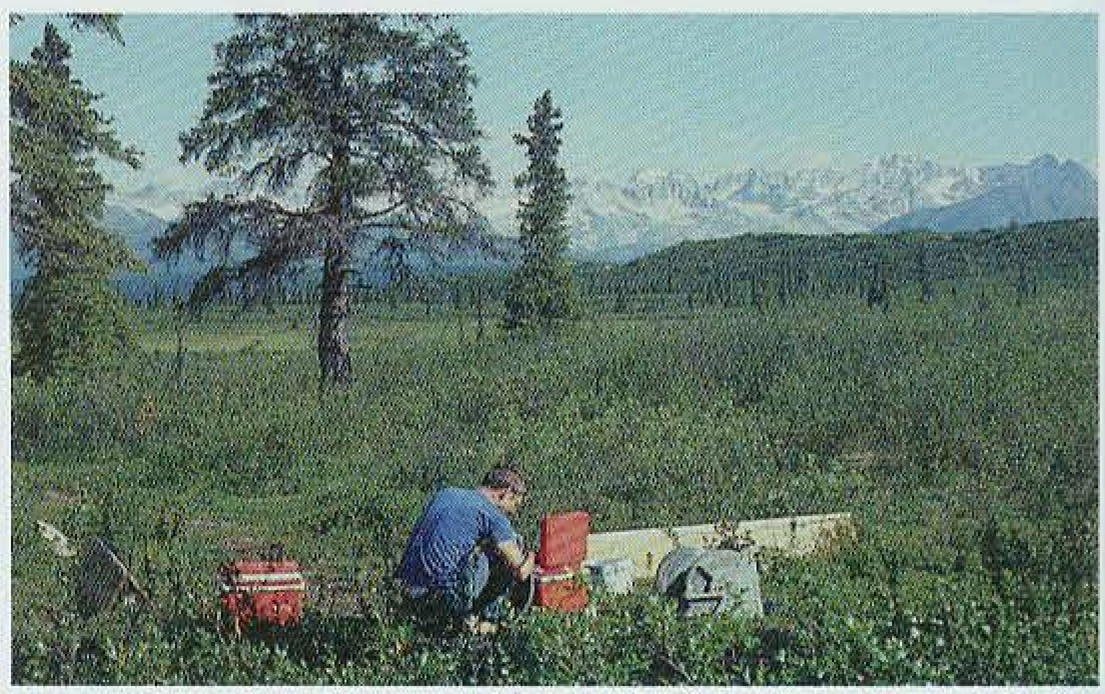
Hawaiian Islands

Islands formed by lava that issued from one or more volcanic eruption centers. The islands have a hilly appearance resulting from erosion that has carved valleys into the volcanoes and built relatively narrow plains along parts of the coastal areas.

CRUSHED STONE RESOURCES	SAND AND GRAVEL RESOURCES
Bedrock consists of igneous and metamorphosed sedimentary and igneous rocks including granite, gneiss, schist, quartzite, slate, marble, and phyllite. Granite and gneiss are commonly used as crushed stone, whereas schist, slate, and phyllite are commonly avoided. Potential sources of good-quality crushed stone are generally available.	The mountains are bordered by low-gradient streams flowing in relatively narrow valleys. The land surface is underlain by saprolite, which is clay-rich, unconsolidated material developed in place primarily from the chemical weathering of the underlying bedrock. The valleys are underlain by relatively thin, moderately sorted alluvium. Stream-channel and terrace deposits are the source of sand and gravel throughout the region. Quality problems tend to be localized.
Consolidated bedrock generally is inaccessible in the Coastal Plain region, except near the inner margin, and in southeastern Florida, which is underlain by semiconsolidated limestones that are of marginal use as aggregate.	The region is underlain with extensive deposits of semiconsolidated sand, silt, clay, and gravel, with sand being the predominant surficial material. Most gravel deposits occur near the inner edge of the Coastal Plain and occur as stream-channel and terrace deposits. These deposits are limited in occurrence and are the primary source of natural aggregate in the region. Isolated deposits of beach and terrace gravels are scattered throughout the area. The quality of the gravels depends on the parent material. The gravels in the Atlantic coastal area tend to be high in quartz and other silica minerals, whereas those in the Gulf coastal area are calcareous. Coarse materials are so limited in this region that shells are commonly substituted for gravel. Sand and gravel occur in parts of the Mississippi embayment as isolated terraces. Sand and gravel also occurs at depth under the alluvial clays of the Mississippi River floodplain.
Underlain by a diverse assemblage of rocks. The principal mountain ranges have cores of igneous and metamorphic rocks. These are overlain and flanked by sedimentary and igneous rocks. The sedimentary rocks include carbonate rocks, sandstone, and shale.	Approximately half of the region, including the mountain ranges and adjacent parts of the lowlands, was covered by glaciers. Glaciofluvial deposits in these areas commonly contain sand and gravel. In the intermontane plateaus, sand and gravel commonly is mined from stream channels, terrace deposits, and placer-mine tailings. The Arctic Coastal Plain consists of silt, sand, and gravel, with the northeastern part having moderate to high potential for sand and gravel. Much of the aggregate is frozen to some degree, and excavation requires drilling and blasting.
Each of the Hawaiian Islands is underlain by lava flows. Andesite and basalt flows are commonly used as a source of crushed stone. In addition, clinker from the tops of lava flows and cinders from cinder cones are also used as stone aggregate.	In some areas alluvium of older and modern terraces and alluvial fans contain poorly sorted sand and gravel of variable quality. In coastal areas a thin layer of coral and shell fragments, volcanic debris, and clay form discontinuous beach deposits, which may be used as aggregate if they meet the required specifications.

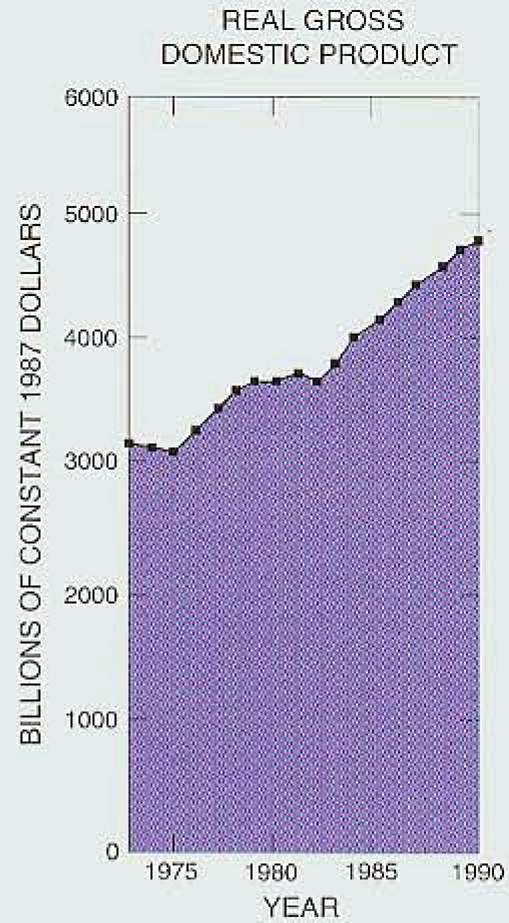
Preliminary investigations may be followed by detailed studies involving aerial photography, geophysical studies, and field reconnaissance studies (as shown in the photographs at right) of the target areas to more accurately define the limits of the potential sources of aggregate. These field studies focus on natural exposures such as stream cuts, cliffs, and other natural outcrops, and on artificial exposures such as highway and railroad cuts and abandoned or active pits and quarries. These studies commonly are augmented by the use of hand-sampling techniques and portable power-auger or coring equipment. Also important are rough estimates of the areal extent and volumes of the deposits, as well as specific physical or chemical properties of the materials. Laboratory analyses provide additional information about the physical and chemical properties of specific samples. Field observations should include information related to mineralogy and texture of the materials, thickness of overburden, water availability, and road access to the area.

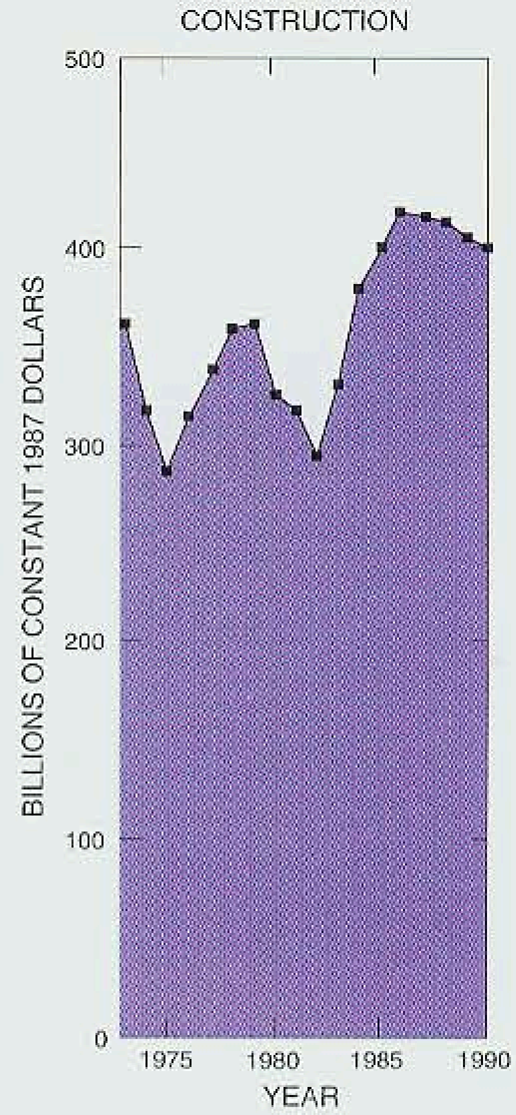
Detailed exploration of an identified source of aggregate may vary depending on the nature of and intended uses of the aggregate. Bulldozers, loaders, or backhoes are used to collect bulk samples; bulk sampling of bedrock may require drilling or blasting. Truck-mounted power augers or drill rigs can be used to collect deeper underground samples. In addition, seismic refraction may be used to determine the thickness of overburden and thickness of desired material, and electrical resistivity may be used to determine gross textural changes within the deposit, such as changes from gravel to sand or shale to sandstone.

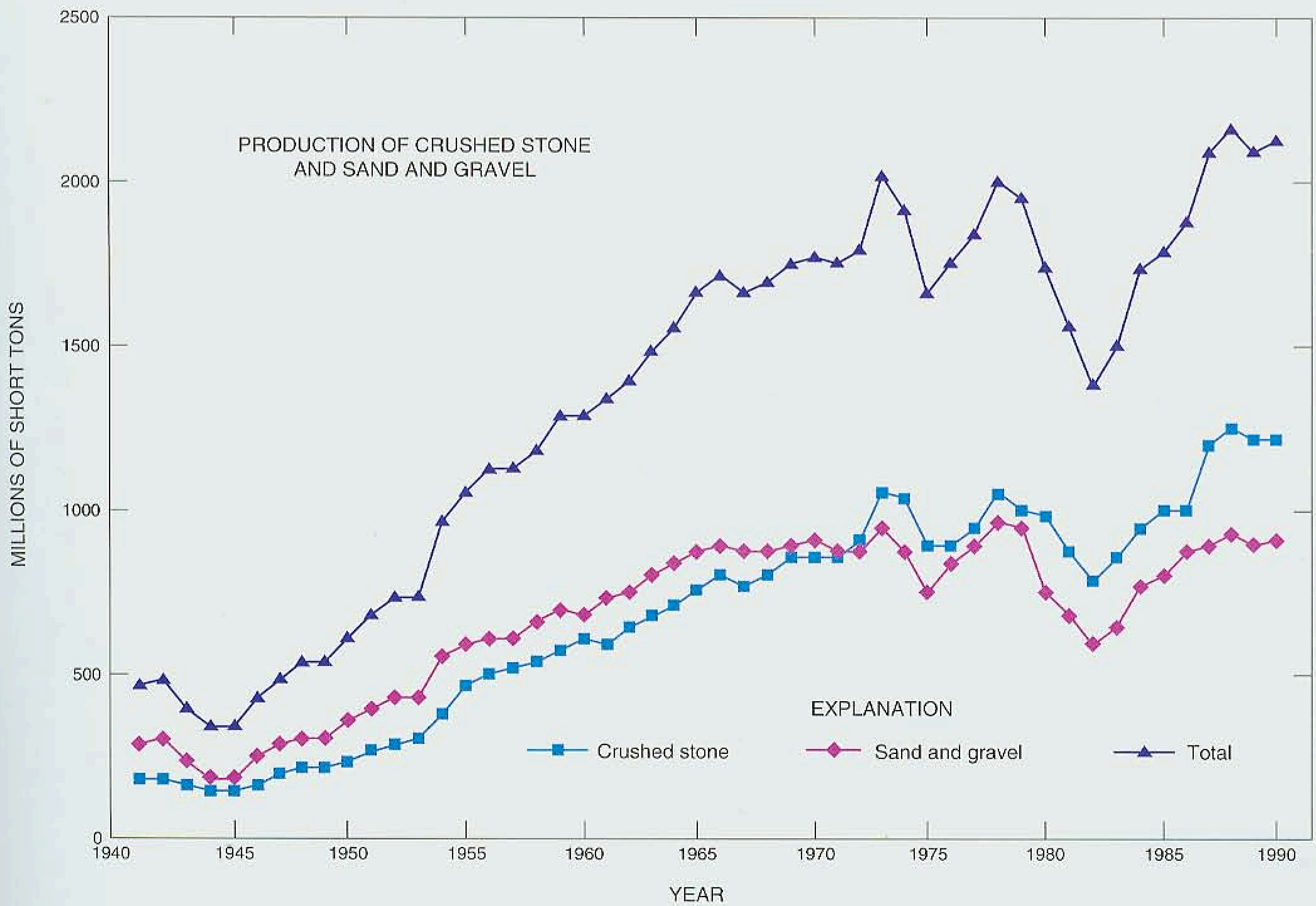


ESTIMATING DEMAND

The U.S. Bureau of Mines and State and local agencies monitor the production of natural aggregate. One purpose of this monitoring is to provide data that can be used to project future needs. The production of aggregate, by itself, is relatively meaningless as a predictive tool. To improve forecasting techniques, a contingency analysis of the factors that could cause the demand to deviate from its current trend commonly is performed. Because crushed stone and sand and gravel are used mostly in the construction industry, reasonable estimates of the future demand for natural aggregate are based on predictions of future construction, such as the number of residential and nonresidential buildings, highway award contracts, and public construction products. Other factors commonly used to predict future aggregate production include population, employment, personal income, mortgage rates, and State or National gross domestic product. These factors can be compared, singly or in combination, to past and present aggregate production to determine if correlations exist. The objective is to find a socioeconomic factor that is predictable, and then to use it as a surrogate for predicting future aggregate production.



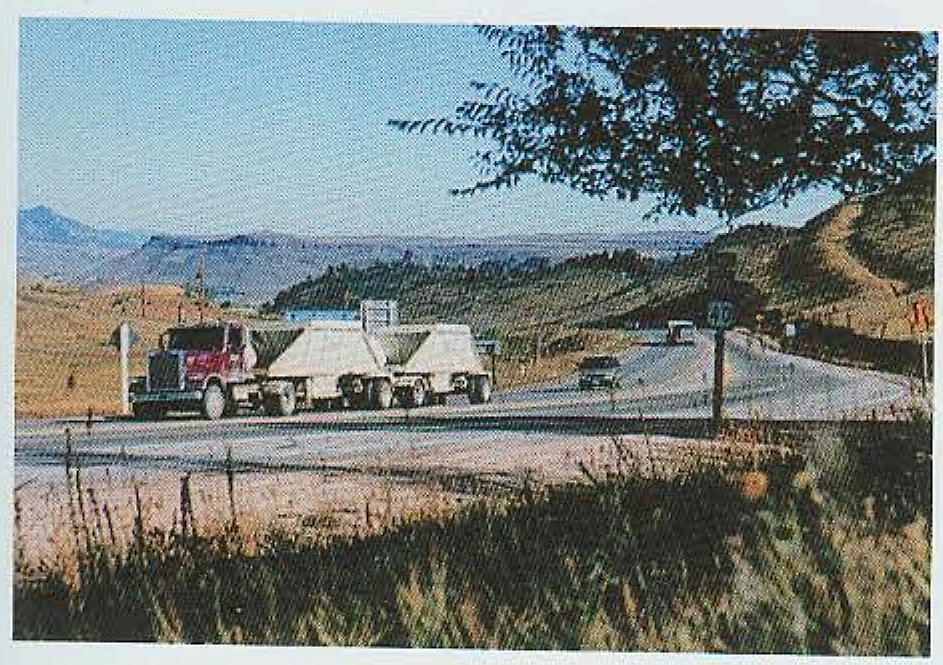




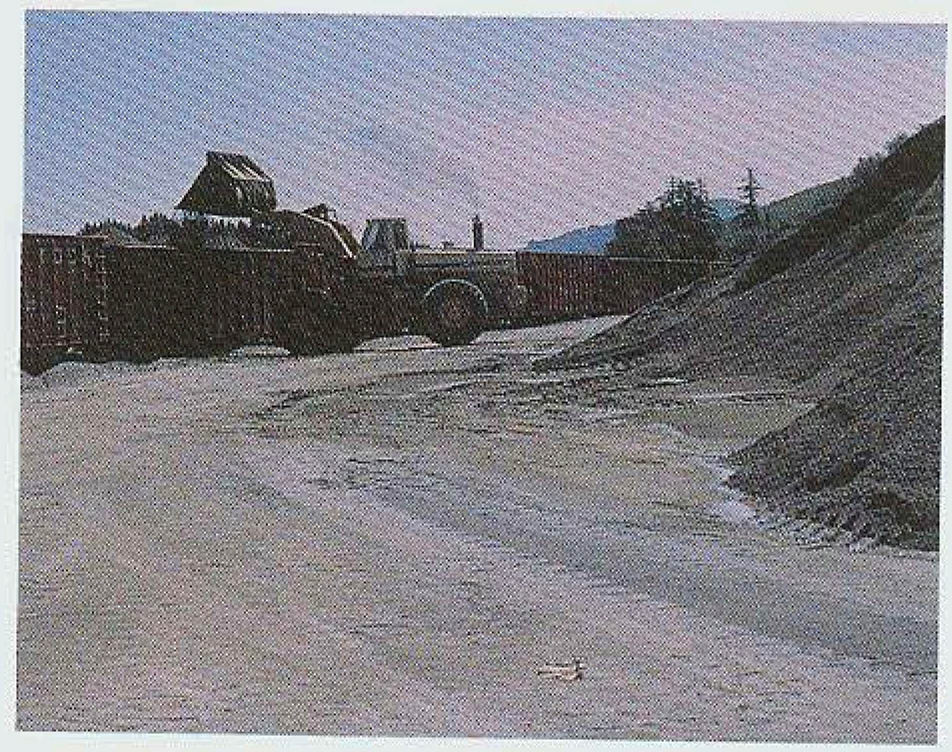
TRANSPORTATION

The three principal types of transportation are road, rail, or water. Aggregate is either used at the site of extraction (such as in cement concrete or bituminous mixes) or is transported to the point of use. The preferred mode of transportation depends on a variety of factors, including delivery-schedule requirements, the distance to be hauled, the volume of material, loading and unloading facilities, and the availability of transportation methods.

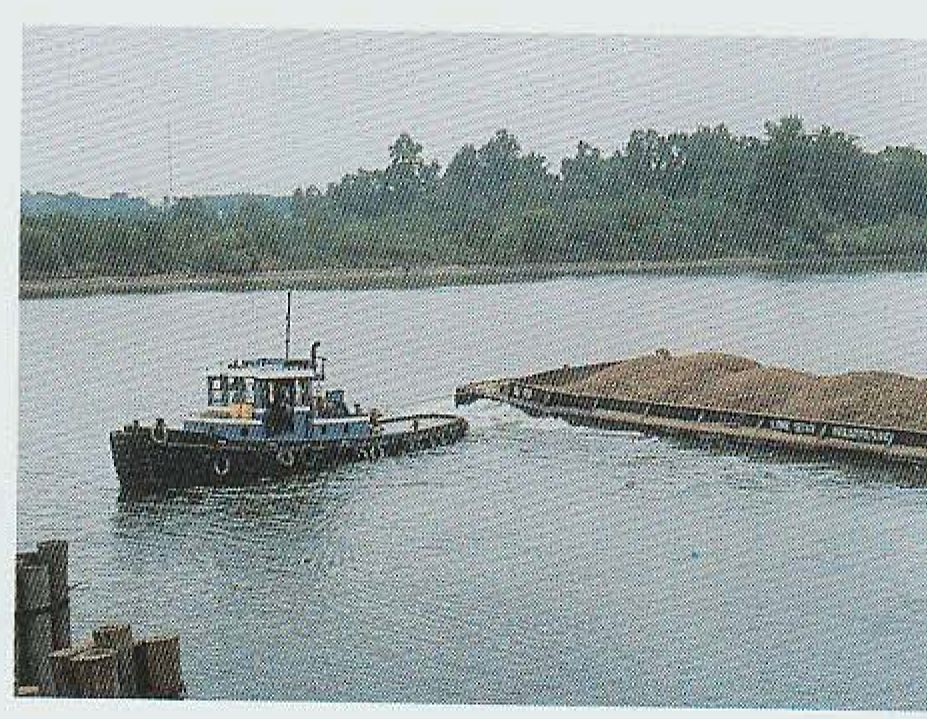
Transport by truck is by far the most common method. Trucks can quickly and simply be loaded at points of origin and can dump or drop their loads unassisted at the destination. They are not restricted to railways or waterways and can deliver practically anywhere there is a road. Trucks from small pickups to rigs that carry 28 tons can be matched to requirements and thus can make deliveries without great economic consequences.



If pits or quarries have access to railroads, rail delivery may be more economical than truck delivery. The choice depends on two principal variables—the tonnage of aggregate to be moved and the distance it must be hauled. Other factors to be considered are loading and unloading facilities and schedule requirements. If the aggregate shipped annually exceeds 20,000 short tons, or if the aggregate is to be hauled more than 45 miles, rail shipping may be more economical than truck transport. With greater tonnages and distances, the advantages of rail shipment are even greater. Aggregate can be loaded on either 100-ton bottom-dump hopper cars or gondolas and moved in single cars (the most expensive way to ship by rail), or can be joined and moved as multiple cars, by trainloads, or by unit trains (the least expensive way).



The midcontinent of the United States has many navigable rivers that have been modified to permit movement of freight by water. Moving aggregate by hopper or flat deck barges may be economical. Because the movement of aggregate by water is not regulated by government agencies, the rates are established by agreements between the user and the barge line. As with rail transport, economic advantages of shipping by barge increase as the tonnages and



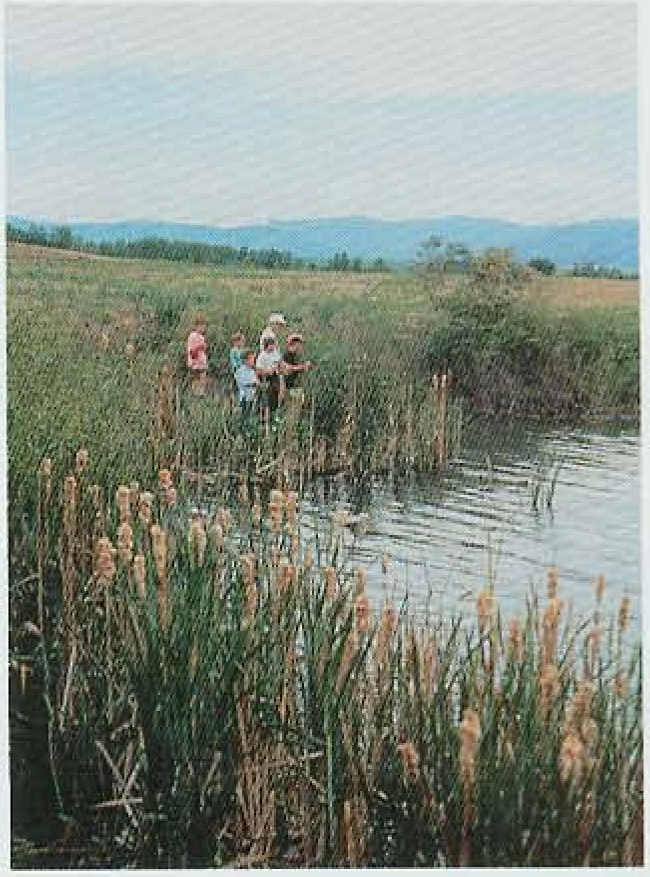
distances of transport increase. Hopper barges commonly hold 1,500 tons of aggregate and can be grouped into tows of 30 to 40 barges, depending on the width and depth of the river to be traveled and the size and horsepower of the tow boat.

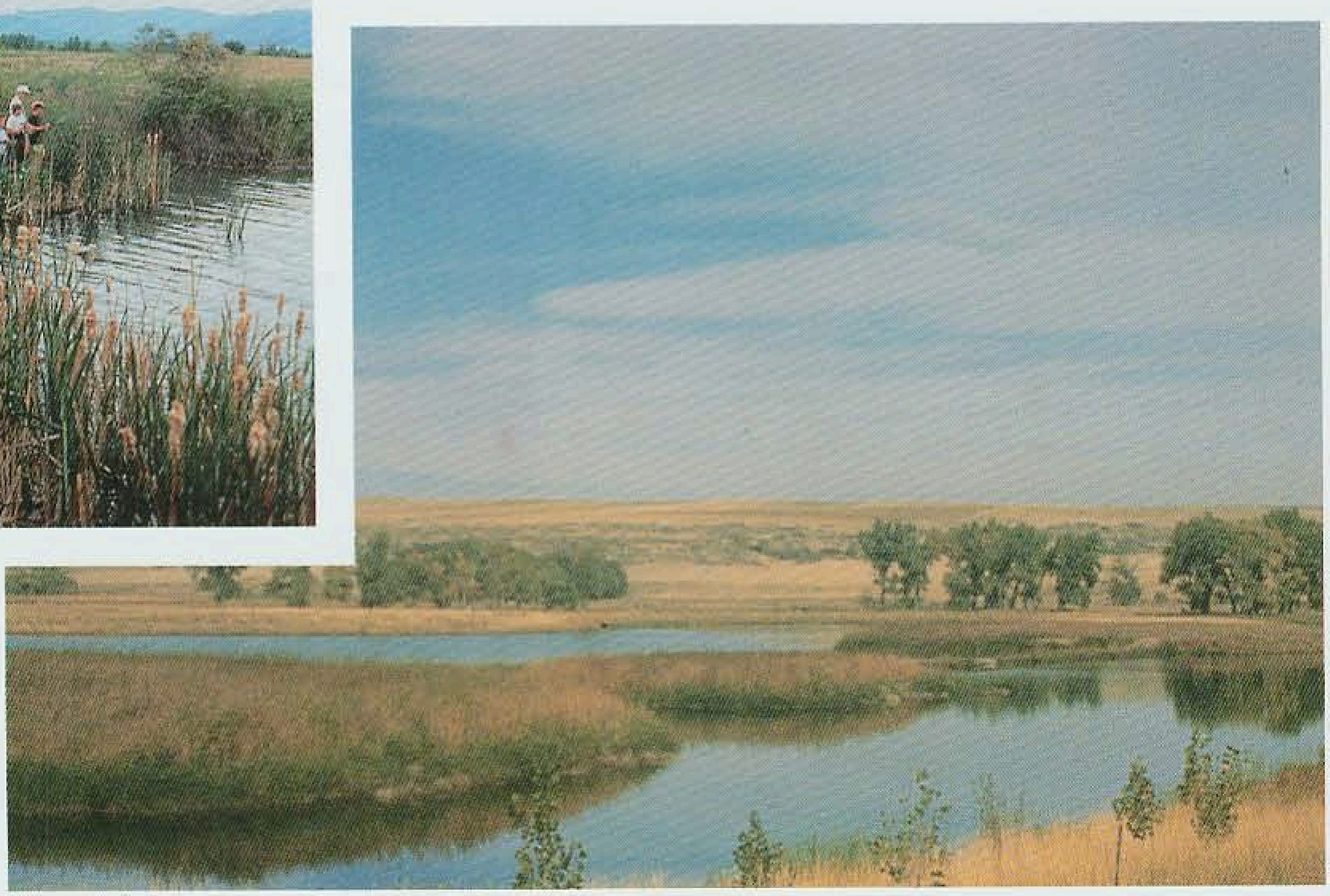
Lake or ocean freighters only recently have become an efficient means to transport aggregate. Along the Atlantic and Gulf Coasts of the United States, where local supplies of good quality aggregate are in short supply, aggregates are imported from Mexico, Scotland, Canada, and other foreign countries. Transportation by ship is possible in part because of back-haul pricing. A commodity other than aggregate moves one way, and pays most of the cost of round-trip shipping. After unloading the initial commodity, the ship is loaded with aggregate for the return voyage. Transporting the aggregate on the return voyage at a low price prevents the vessel from returning to the point of origin with an empty hold.

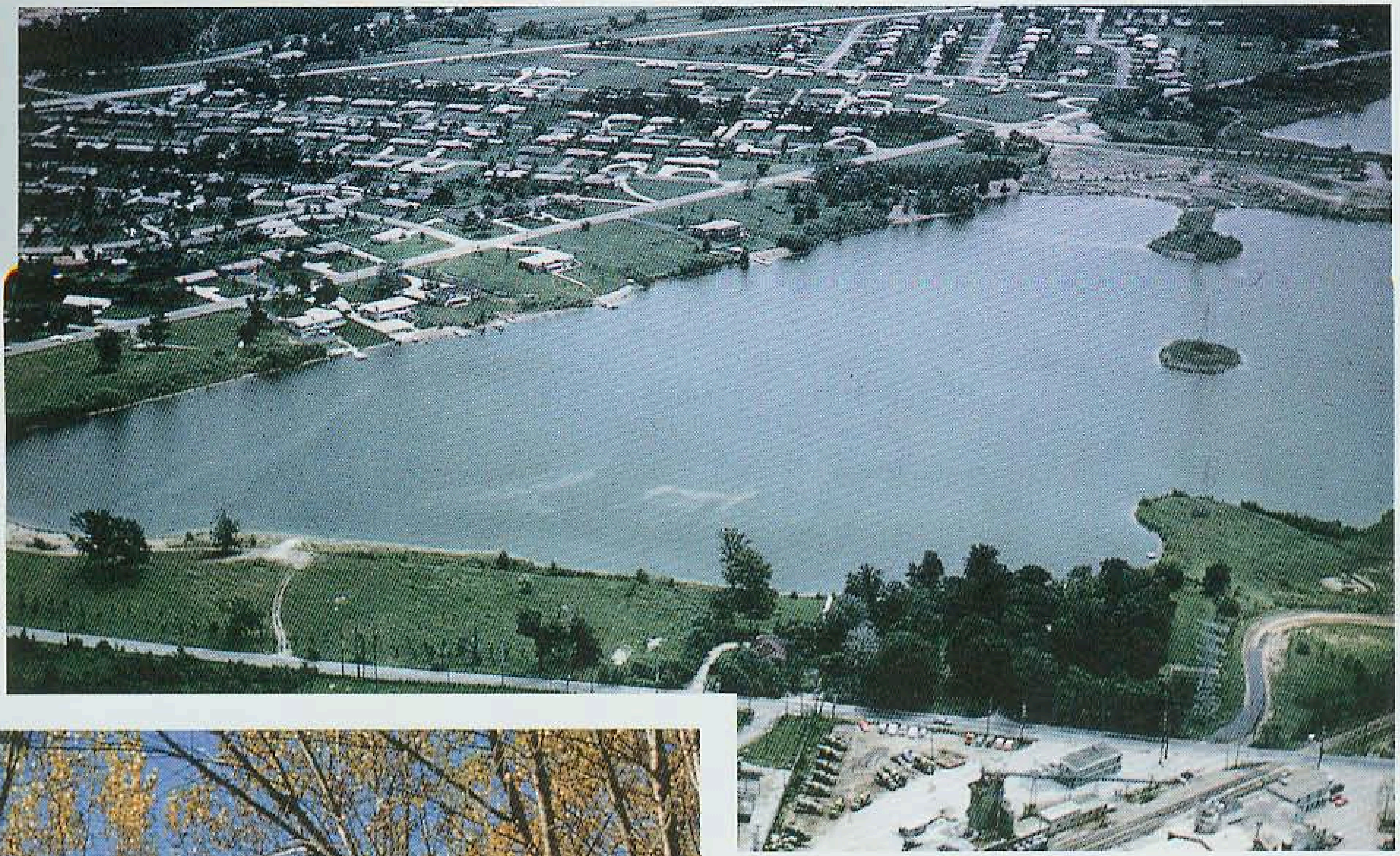
RECLAMATION

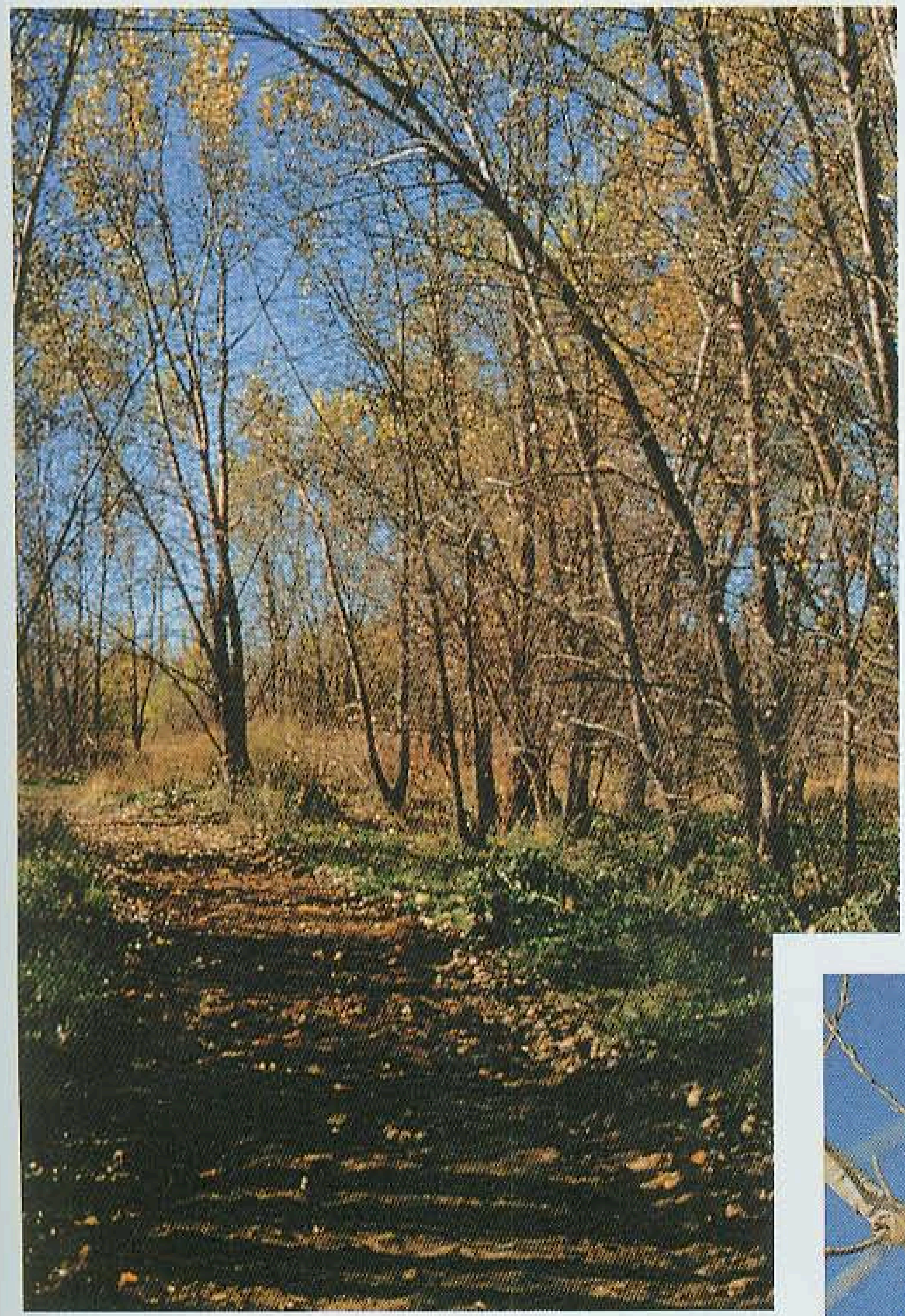
Reclamation of a mined-out area is highly important to communities near aggregate operations because residents do not want a scarred landscape near their property. The most acceptable method for the community, and commonly the most economical for the producer, is to plan reclamation before the aggregate is extracted. Aggregate can be mined with the final land-surface contours in mind, equipment can be used for both mining and reclamation, and mined-out areas can be reclaimed concurrent with extraction in other parts of the operation.

The primary goal of reclamation is to return the land to a beneficial use. Residential developments are a popular use for reclaimed sites. The natural setting provided by rock outcrops and water fulfill a demand for scenic, lake-front property. Reclaimed pits or quarries have also been converted to industrial and commercial properties or to office parks, golf courses, parks and recreation areas, storm-water management, farmland, and landfills.









Reclamation procedures depend on the configuration and character of the mined-out area. Progressive reclamation typically involves the following steps: (1) terracing the pit or face walls during or after extraction, (2) final shaping of the worked out area by replacing and recontouring the overburden, and (3) landscaping. Reclamation plans are most effective if operators and planners select a strategy that satisfies the land use needs of the community and at the same time provides an economic incentive for the operator.

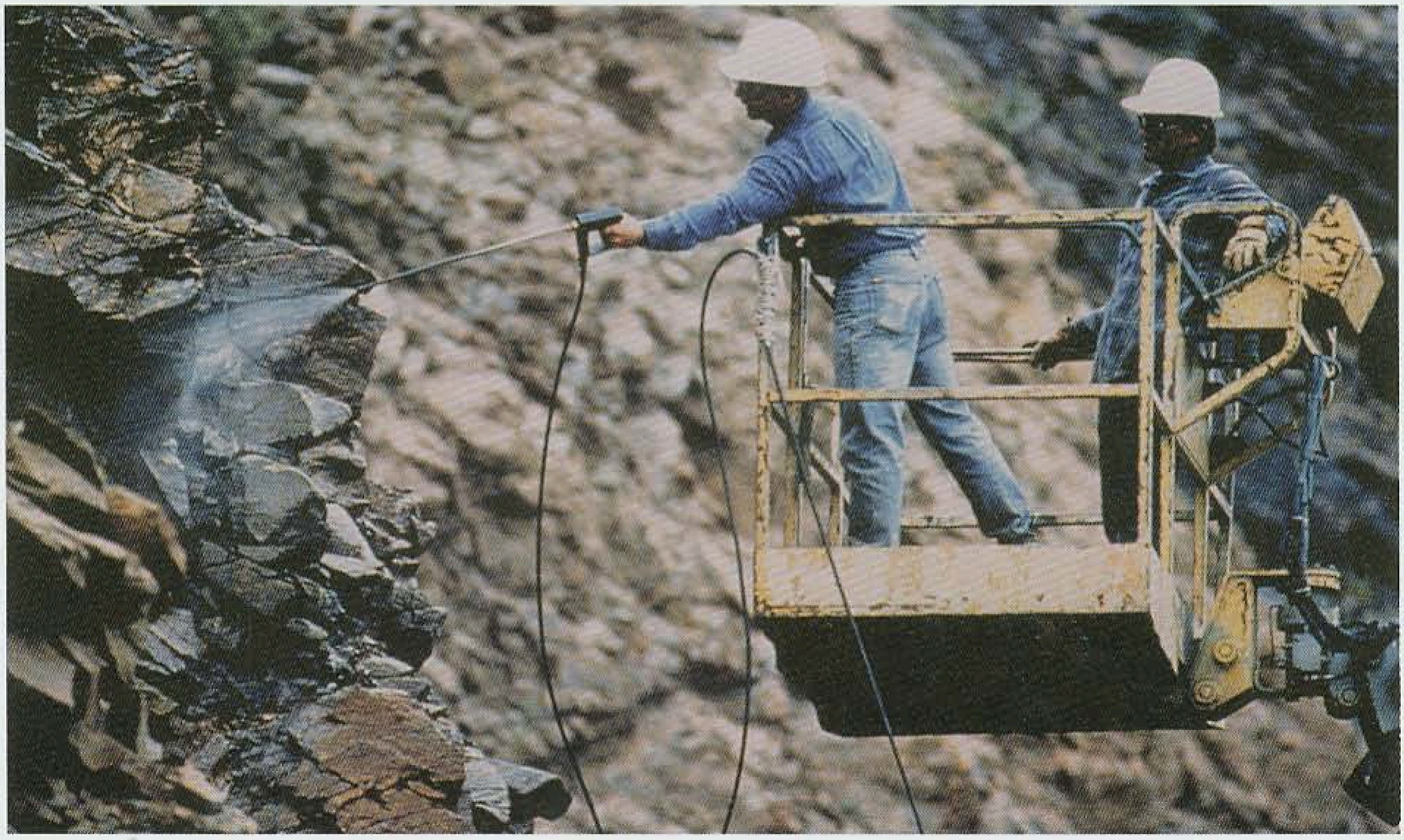
Living with Aggregate Operations

To design guidelines or regulations for crushed stone or sand and gravel operations, it is necessary to predict what effects such operations may have on the surrounding communities and environment. Regulations should set minimum operational standards to control impacts such as noise, traffic, dust, pollution of streams and water supplies, and erosion. The task for planners is to balance the needs of the operators with the public's right to minimum nuisance resulting from the extraction. Aggregate operators generally wish to be good neighbors and are willing to cooperate if cooperative efforts lead to a more smoothly operating facility. In fact, many innovative actions taken to decrease environmental impacts have been conceived and voluntarily implemented by aggregate operators.

Planning efforts such as those described above help to limit public exposure to the impacts of aggregate mining and processing. Buffer zones, in particular, help mitigate impacts. Regulations or permits should set minimum standards for buffer-zone widths. Buffer zones shield adjacent residents and land owners from mining operations and at the same time protect mining operations from intrusion or adjacent land-use conflicts. Berms, fences, screens, dense tree plantings, or other barriers contribute to public safety and provide aesthetic controls that help to screen objectionable views. Newly exposed rock faces can be treated to match adjoining naturally weathered surfaces.

Excavation of sand and gravel below the water table can affect aquifers. Regulations may prohibit penetration of the aquifer or may allow penetration of the aquifer only if operations will not adversely affect water supplies. If such excavations are to be refilled, the filling should meet water-pollution-control standards.

The impact of noise depends on adjacent land use; noise can be mitigated through the use of buffer zones, berms, and muffling



equipment. Noise-generating equipment (such as the primary crusher shown in the photograph to the right) can be placed near the middle of the site, in pits below grade, in sound-insulated buildings, or away from residential areas. Haul roads can be kept away from property lines, and the use of conveyor belts can minimize traffic within the site.

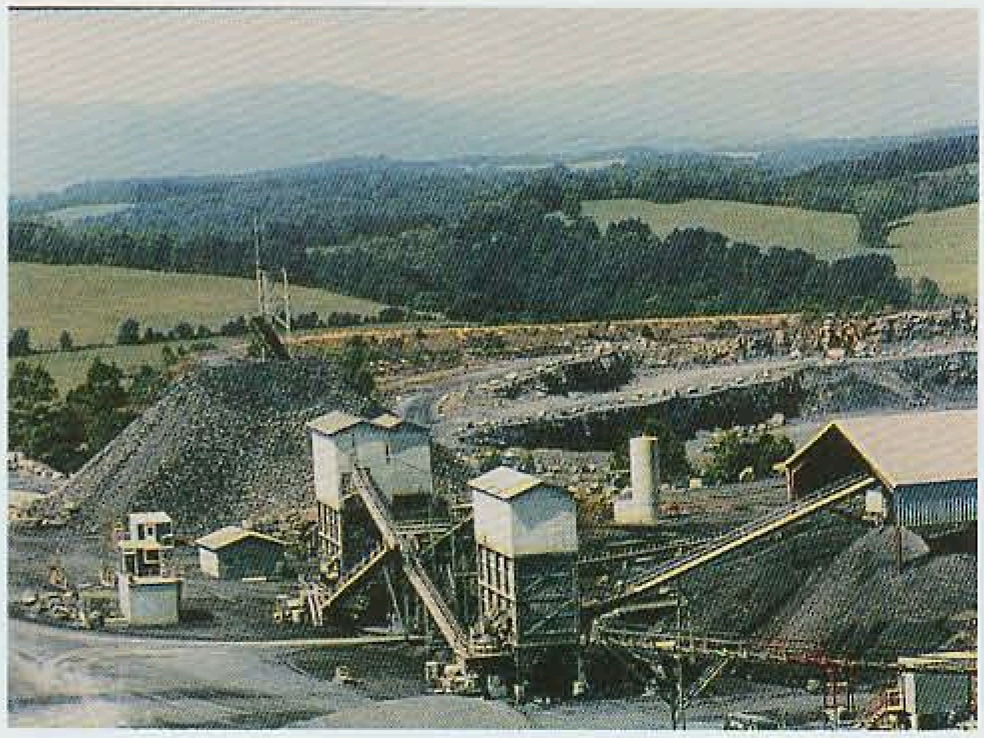
Truck traffic is one of the most serious problems associated with aggregate development. Some traffic can be mitigated at the site. Operators can be required to provide acceleration and deceleration strips on both sides of all entrances and exits to the operations. Paving and limiting the number

of entrances and exits and wheel washing procedures can minimize the amount of dirt deposited by trucks on adjacent highways. The most serious problems associated with truck traffic—noise and safety problems—are on public rights-of-way. Conveyors constructed to carry aggregate under highways, reduced speed limits, restriction of routes for truck traffic, and restriction of hours of operation all can help minimize traffic problems.

Dust can be reduced by minimizing the amount of area mined at any time, by planting vegetation or constructing other wind breaks, by using wet or chemical dust suppression systems, and by enclosing dust-generating equipment in vacuum-equipped buildings (such as those shown in the photograph below). Erosion can be controlled through techniques such as settling ponds and revegetation.

Reclamation plans can require the land to be left as originally contoured, or they can provide for acceptable final uses of the land. Performance bonds can be required to ensure that reclamation takes place according to plan. Contemporaneous mining and reclamation can reduce the impact of mining, accelerate revegetation, and allow incremental bond release to the operator.

Cooperative planning by developers, government, and citizens is the key to successful protection and utilization of aggregate resources.



SUMMARY

Present annual aggregate use in the United States is about 9 short tons for every person. This tonnage will increase as the aging infrastructure requires repair or replacement. Coupled with the demand for the resource, there also is an increasing demand for increased economy in large construction projects and for decreased cost in housing development.

Provisions for uninterrupted future supplies of aggregate should be made. Even though potential aggregate sources are widely distributed throughout the United States, some areas lack quality aggregate, or potential aggregate may be covered by overburden so thick that surface mining is impractical. Economic factors require that pits and quarries be near population centers. However, citizens and regulatory agencies in residential communities commonly desire that mining operations be conducted far from their boundaries. Furthermore, citizens commonly do not support mining because they do not recognize the community dependence on natural aggregate. They purchase little, if any, aggregate and do not recognize that aggregate mining is a necessary land use.

Proper long-range planning can help assure adequate supplies of aggregate, while simultaneously protecting the public from the unwanted effects of mining. Long-range plans should incorporate a multiple land-use program that includes identification and protection of natural resources, strategies that will permit development of resources in relation to future market needs and environmental considerations, and a beneficial use of mined-out areas.

Geologic maps and surveys provide useful information about potential aggregate sources. Judicious use of these sources is critical in areas where reserves are small or where urban pressures preempt their use. By using geologic information to identify resources near the sites of use, operators can provide the most economical resource for the consumer. Advance planning of haulage routes and conveyor distribution can minimize undesired impacts of transportation of aggregate, and application of advanced technology can alleviate many other inconveniences of aggregate mining.

A projected mine plan can diagram stages of an operation over a period of time. Adequately planned reclamation can be accomplished concurrent with mining. Predetermined uses for the reclaimed land can be mandated so that the final use will be beneficial to the community. As land is backfilled and recontoured, it can be converted to office parks, public parks, or wildlife habitats for the benefit of people living in the area. If land for housing is scarce or expensive, reclamation can provide additional home sites, some with lakefront access.

Mining operators, public officials, consumers, and community residents no longer can remain independent of one another. All groups and individuals must work together to ensure adequate community and environmental protection from the nuisances of mining, while at the same time ensuring low-cost construction and maintenance of the infrastructure.

As we progress into the 21st century, the view of aggregate production must be changed from one of a scarred landscape to one of protection of a valuable resource. Although natural processes move gravel from one section of a river to another, new detrital material is added at an imperceptible rate. Bedrock being formed by geologic processes today will not be available for use as aggregate for thousands of years. Aggregate mining must be seen as an interim use of the land, not the final use.