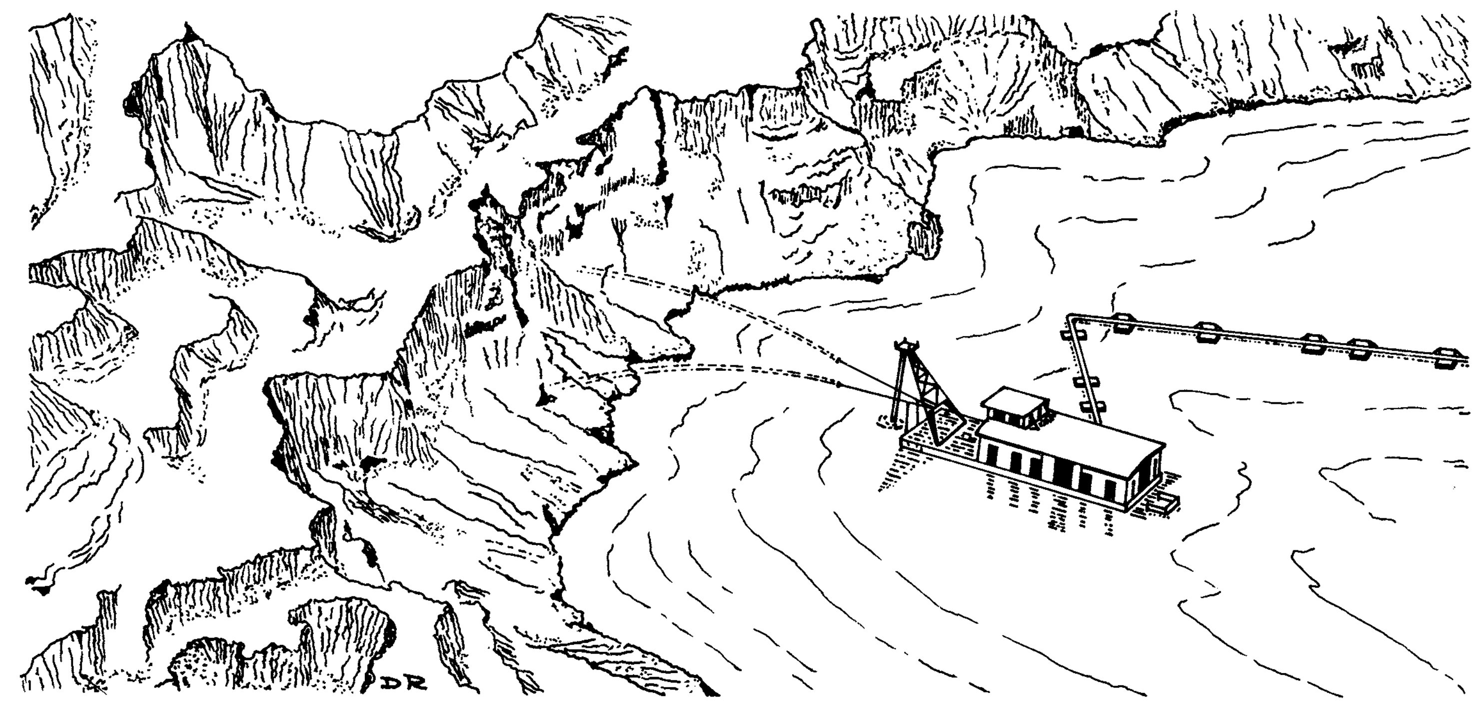
# AN ECONOMIC STUDY OF COASTAL SAND DUNE MINING IN MICHIGAN



REPORT OF INVESTIGATION 20

Geological Survey Division
Michigan Department of Natural Resources 1978

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# AN ECONOMIC STUDY OF COASTAL SAND DUNE MINING IN MICHIGAN

by

Ayres, Lewis, Norris and May, Inc.
and
Michael J. Chapman

Lansing, Michigan
1978

Published by authority of State of Michigan CL '70 s.321.6
Printed by Reproduction Services Section, Office Services Division,
Department of Management and Budget

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## PREFACE

The Sand Dune Protection and Management Act (Act No. 222, Public Acts of 1976; M.C.L. 281.651-281.664) was enacted in July of 1976. The program responsibilities were assigned to the Geological Survey Division of the Department of Natural Resources.

To fulfill one of the study requirements stipulated in the Act, a contract was let to Ayers, Lewis, Norris & May, Inc. to examine and document economics of the sand mining industry in Michigan.

The gathering of preliminary information for this report was initiated by the Geological Survey. Questionnaires which addressed many areas of interest and concern were developed and sent to sand producers in the State and potential consumers listed in the Standard Industrial Classification Code. The data was compiled by the Survey and forwarded to the contractors for inclusion in their report.

The contractors, meanwhile, initiated a review of the literature concerning Michigan's mining industry, particularly the sand mining industry. Utilizing the data obtained from the questionnaires, they compiled the report and submitted the required copies to the Geological Survey for review. Geological Survey Division personnel performed further research as deemed necessary, made some adjustments in the report and finalized it for publication.

Acknowledgement is given to the interested persons in the Geological Survey Division who contributed many constructive thoughts and criticisms during the compilation of this report. Thanks are extended to Beverly L. Champion for editing the manuscript, to Steven E. Wilson for general layout and graphics coordination, to Susan Hetzel for revising the original graphics, to Gregory A. Wilson for final drafting and to Lois J. DeClaire for typing the manuscript. My appreciation is also extended to the contractors, who worked closely with us in preparing this report.

Michael J. Chapman
Environmental & Planning Analyst
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AN ECONOMIC STUDY OF COASTAL SAND DUNE MINING IN MICHIGAN

By

Ayres, Lewis, Norris and May, Inc.[1]
and
Michael J. Chapman[2]

*Abstract*

*Utilization and development of mineral resources have always been important to Michigan's economy. Although the importance of mining has been overshadowed in recent years by growth in manufacturing, the Michigan mineral industry remains a viable economic activity. Compared to other Michigan mineral production such as iron ore, petroleum, natural salines and cement, the value of industrial sand may appear insignificant. However, Michigan leads the nation in industrial sand production.*

*The mining of coastal dune sand is an important component of the industrial sand mining industry. The ten sand dune mining firms which currently operate in Michigan accounted for sixty-eight percent of the total industrial sand production in the State for 1976. These operators reported land holdings of 5,703 acres at 26 sites. Sand is being mined at 14 of the sites while 12 are presently inactive.*

*Dune sand is mined by the open pit method. After the sand is mined and stockpiled, it is processed by screening, washing, drying and beneficiation. The degree of processing is a function of the needs and specifications of various consumers. For example, the glass industry requires sand high in silica and low in impurities, whereas the foundry industry, although requiring high silica content, can tolerate somewhat higher levels of impurities.*

*The future demand for dune sand is highly dependent upon the activities of consuming industries. Forty-one percent of the industries expect their needs for dune sand to remain stable, while fifty-three percent expect needs to increase.*

*Projections of future demand for industrial sand are based on three potential trends. A projection based on current trends shows that recoverable reserves currently owned by dune mining operators may be depleted by the year 2006. Projection of a probable increase in demand indicates depletion by the year 2000, whereas a possible decrease in demand may deplete recoverable reserves by 2010.*

*Some of the factors which will influence the future use of dune sand include the use of casting materials which are more heat resistant than dune sand, and technological advances in recycling and in manufacturing. The demand for sand by glass producers will be affected by the increased use of glass for construction purposes and the the issue of disposable versus returnable containers.*

[1] Ann Arbor, Michigan, contracted by U. S. Army Corps of Engineers, Detroit Engineering District for the Michigan Department of Natural Resources, Geological Survey Division.

[2] Geological Survey Division, Department of Natural Resources



*Although future consumption may be affected by the use of substitutes for dune sand, consumer recognition of potential substitutes is not substantial. Many consuming industries believe that a change in the source of sand would affect not only present costs, but also quality of the finished product and availability of supply.*

## INTRODUCTION

### Authority

The preparation of this report was made possible through Section 22 of the Federal Water Resources Development Act of 1974. Section 22 authorizes the Secretary of the Army, acting through the Chief of Engineers, to cooperate with any state in the preparation of comprehensive plans for the development, utilization and conservation of water and related resources of drainage basins located within the boundaries of such state.

### Purpose of Study

The Michigan "Sand Dune Protection and Management Act" (Act No. 222, Public Acts of 1976) provides for the protection, management, and reclamation of Michigan sand dune areas. As a prerequisite to making recommendations for the protection and management of sand dune areas, the Michigan Department of Natural Resources is charged with conducting a comprehensive study and inventory of Michigan sand dunes.

This report provides background information regarding the production and consumption of Michigan coastal dune sand which will aid in assessing the economic impact of the future application of the Michigan "Sand Dune Protection and Management Act". An overview of the role of mineral production and industrial sand production in the Michigan economy is presented.

### Study Methodology

The first part of the report is devoted to a general discussion of the Michigan mining industry. Information for this section was collected through a literature review.

The next sections, on production and consumption of dune sand, were prepared by summarizing and analyzing information gathered from questionnaires sent to producers and potential consumers. This information was gathered by the Department of Natural Resources and forwarded via the original questionnaires. Copies of the questionnaires can be found in Appendix I.

The producer questionnaire was sent to the nine operators known to be sand mining (as defined in the statute) in coastal sand dunes. A tenth operator was later surveyed by phone to obtain the needed information. The questionnaire sought information regarding quantity and value of production, mode of transportation, method used to mine sand, employment, land holdings and amount of sand reserves.

The consumer questionnaire was sent out to 4,211 potential users of Michigan dune sand. Potential consumer industries were identified from the Standard Industrial Classification Code for the Great Lakes States (Indiana, Illinois, Michigan, New York, Ohio, Pennsylvania, Wisconsin) and the Province of Ontario, Canada. Responses to this questionnaire totaled 2,139. The questionnaire sought information regarding suppliers of dune sand, use of dune sand in their industry, annual consumption, cost, sand specifications, mode of transportation and associated cost, and alternatives to dune sand.

Much of the information requested from the producers was considered confidential. In some instances, no information was forwarded. To contend with the confidentiality, information has been reported in general terms. Conclusions drawn from the data will not necessarily reflect the total industry. Some indication has been given as to the number of responses used in drawing conclusions.

## MICHIGAN'S MINERAL INDUSTRY

A segment of the Michigan economy has always been tied to the utilization and development of the State's natural resources. In the early 1900's mining, along with agriculture and forestry, was a leading industry in the economy of Michigan. In recent years, manufacturing activities have dwarfed other economic enterprises in terms of total employment and personal income. Although not a substantial employer, Michigan's mineral industry remains a viable economic activity due to the type of minerals produced.

As illustrated in Figure I the value of Michigan's mineral production, which includes fuels, metallics and nonmetallics, totaled $1,488,249,000 in 1976. Of this total, fuel production accounted for 32 percent, metallic minerals 31 percent and nonmetallic minerals 38 percent. The value of annual production has shown a substantial increase of 118 percent from 1970 to 1976, due primarily to production value increases in fuels of 798

| Mineral | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976[p] |
|---|---|---|---|---|---|---|---|
| NONMETALLIC | | | | | | | |
| Industrial Sand | 9,247 | 10,479 | 10,984 | 14,217 | 16,483 | 21,189 | 20,198 |
| Sand & Gravel[a] | 45,529 | 52,650 | 43,461 | 60,014 | 66,227 | 52,208 | 54,679 |
| Cement | 110,513 | 109,833 | 117,368 | 129,627 | 146,823 | 138,357 | 169,600 |
| Stone[b] | 32,998 | 33,131 | 32,770 | 40,768 | 47,625 | 46,461 | NA |
| Lime | 21,355 | 20,117 | 22,647 | 26,055 | 30,036 | 36,540 | 36,735 |
| Natural Salines[c] | 103,294 | 93,150 | 104,672 | 121,086 | 112,350 | 116,876 | NA |
| Salt | 49,963 | 49,007 | 50,761 | 53,732 | 62,055 | 67,240 | 69,051 |
| Gypsum (crude) | 5,061 | 5,585 | 7,267 | 8,538 | 7,258 | 5,936 | 8,078 |
| Clay & Shale[d] | 2,887 | 3,366 | 3,715 | 3,304 | 4,074 | 3,580 | 4,584 |
| Peat | 1,896 | 2,454 | 2,190 | 2,172 | 3,810 | 3,206 | 2,690 |
| Marl | 141 | 111 | 81 | 79 | 258 | 153 | NA |
| Subtotal | 382,884 | 379,883 | 395,736 | 459,592 | 496,999 | 491,746 | 365,615 |
| METALLIC | | | | | | | |
| Iron Ore | 169,808 | 167,015 | 165,370 | 180,158 | 257,944 | 338,635 | 402,619 |
| Copper | 77,945 | 58,321 | 66,783 | 94,193 | 108,761 | 83,771 | 63,322 |
| Silver | e | e | e | e | e | 2,795 | 1,336 |
| Subtotal | 249,332 | 226,325 | 233,331 | 276,526 | 369,225 | 425,201 | 467,277 |
| FUEL | | | | | | | |
| Petroleum | 36,250 | 38,891 | 41,568 | 59,573 | 154,952 | 262,352 | 331,530 |
| Natural Gas | 10,598 | 6,742 | 12,420 | 17,306 | 35,182 | 65,104 | 104,705 |
| Nat. Gas Liquids[f] | 4,478 | 3,659 | 3,859 | 3,314 | f | f | g |
| Subtotal | 51,326 | 49,292 | 57,847 | 80,193 | 190,134 | 327,456 | 460,785 |
| MISCELLANEOUS | 2,154 | 1,271 | 1,595 | 2,811 | 3,463 | 949 | NA |
| TOTAL | 685,696 | 656,771 | 688,509 | 819,123 | 1,059,821 | 1,245,352 | 1,293,677 |

[a] Excludes industrial sand
[b] Excludes limestone used in the manufacturer of cement
[c] Bromine, magnesium compounds, calcium-magnesium chloride, potash and iodine
[d] Tile brick, pottery, clay used for cement, lightweight aggregate, and miscellaneous
[e] Included in miscellaneous
[f] Included in petroleum and natural gas according to proration unit
[g] Includes liquids stripped from gas delivered via interstate pipeline
[p] Preliminary
NA Not available

Table 1. Value of Michigan mineral production, by product, 1970-1976, expressed in thousands of dollars. Data based on information from "Michigan Mineral Producers".



percent and metallic minerals of 87 percent. However, during this period nonmetallic mineral production value increased by only 46 percent.

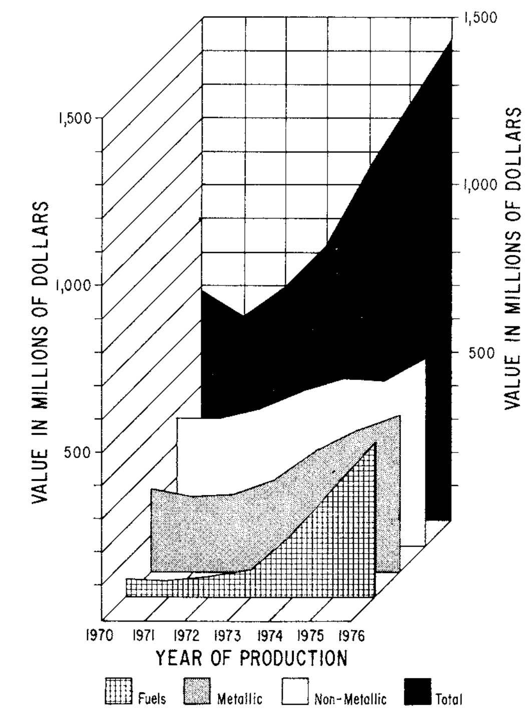


Figure 1. The value of Michigan's mineral production 1970-1976. Data based on information from "Michigan Mineral Producers".

Table I indicates the relative values of each mineral produced in Michigan from 1970 to 1976. Iron ore and petroleum have shown tremendous increases and accounted for 49 percent of the total value of mineral production in 1976. Other significant minerals produced include cement and natural salines. Somewhat less significant are industrial sand and sand and gravel, which account for 1.4 percent and 3.7 percent, respectively, of the total value of mineral production.

Average yearly employment and income in mining compared to other industries is provided in Table 2. Mining accounted for 12,700 employees or 0.4 percent of the total industry employment in Michigan in 1976. Although mining employment increased 7 percent while total employment increased 9 percent from 1970 to 1976, mining's 0.4 percent share of total employment has remained fairly constant. The average income of mining employees in 1976 was $16,500 per employee, well above the average of $15,300 per employee for all other industries. From 1970 to 1976, average yearly income for mining employees increased 60 percent compared to a 53 percent increase for all industry employees. Mining's share of total income earned by all industries has remained approximately 0.4 percent annually from 1970 to 1976.

Perhaps the relatively slow rate of growth in mining industry employment can be explained by increased mechanization and worker productivity. Although it is not an infallible indicator of productivity, output per employee in total value of mineral production has grown at a faster rate than employment. The value of production per employee was $57,489 in 1970. By 1976, the value of production per employee had risen to $117,185, an increase of 105 percent over 1970.

## DUNE SAND PRODUCTION

In Michigan, industrial sand is mined from several sources, for a variety of uses. The major source is the coastal sand dunes located along the western shore of the Lower Peninsula and along some of the shoreland in the Upper Peninsula. The sand found within these dune formations exhibits unique characteristics. These include consistency of grain size which resulted from natural wind sorting. The sorting occurred throughout the thousands of years during which the sand dunes were formed. The grains have also been smoothed and rounded from wind and water action. Additionally, the sand has high place-value because of close proximity to transportation networks. These features, combined with the quantity of sand reserves, make coastal sand dune formations very attractive to sand-mining operators. Inland dunes in Tuscola and Saginaw counties and glacial sand deposits in Wexford County offer substantial sand reserves. These reserves, though, require more processing because of grain size and shape and added impurities; and increased transportation costs due to locations render them less desirable. Sand reserves are present in Saginaw Bay but removal proves to be more expensive because a special dredging technique must be used.

A sandstone formation known as the Sylvania Sandstone located at or near the surface in Wayne and Monroe counties contains high silica, uncontaminated sand grains. Mining sandstone involves different techniques (i. e., blasting, crushing, etc.) and the process is more expensive. However, the requirements of the glassmaking industry for high-silica sand with negligible contaminants motivate the operators to mine the sandstone, even at greater expense.

Presently, ten operators are producing industrial sand mined from coastal sand dune areas. The names and addresses were compiled

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976[a] |
|---|---|---|---|---|---|---|---|
| Mining | | | | | | | |
| No. of Employees | 11.9 | 11.2 | 12.1 | 12.9 | 13.4 | 13.5 | 12.7 |
| Income Earned($) | 123,055 | 114,829 | 132,151 | 152,080 | 176,444 | 202,235 | 209,624 |
| Average Yearly Income/ Employees($) | 10.3 | 10.3 | 10.9 | 11.8 | 13.2 | 15.0 | 16.5 |
| All Industries | | | | | | | |
| No. of Employees | 3,004.9 | 2,977.3 | 3,113.9 | 3,279.1 | 3,270.9 | 3,123.8 | 3,264.3 |
| Income Earned($) | 30,092,690 | 32,584,897 | 36,245,709 | 40,884,525 | 42,766,515 | 43,695,732 | 50,071,918 |
| Average Yearly Income/ Employees($) | 10.0 | 10.9 | 11.6 | 12.5 | 13.1 | 14.0 | 15.3 |
| Percentage Mining vs. All Industries | | | | | | | |
| No. of Employees | 0.40% | 0.38% | 0.39% | 0.39% | 0.41% | 0.43% | 0.39% |
| Income Earned($) | 0.41% | 0.35% | 0.36% | 0.37% | 0.41% | 0.46% | 0.42% |

[a] Preliminary

Table 2. Average yearly employment and income in Michigan, mining versus all industries for 1970-1976. Data based on information from "Michigan Statistical Abstracts".

with the aid of the Michigan Industrial Sand Producers Association and the Michigan Department of Natural Resources. Also, a list of active mining sites was assembled and is presented in Figure 2. The sites are located by township and reference is made to the operator and number of sites being mined within each township.

Names and Addresses

Auto Specialty Mfg. Company
643 Graves Street
St. Joseph, Michigan 49085

Construction Aggregate Corporation
P. O. Box 6380
Ferrysburg, Michigan 49409

Hart Packing Company
P. O. Box 28
Hart, Michigan 49420

Manley Brothers of Indiana, Inc.
P. O. Box 67
Chesterton, Indiana 46304

Martin Marietta Corporation
Industrial Sand Division
110 East Main Street
Rockton, Illinois 61072

Nugent Sand Company, Inc.
P. O. Box 506
Muskegon, Michigan 49443

Sand Products Corporation
2489 First National Building
Detroit, Michigan 48226

Sargent Sand Company
2840 Bay Road
Saginaw, Michigan 48603

Standard Sand Company
P. O. Box 290
Grand Haven, Michigan 49417

C.W.C. Textron
2672 Henry Street
Muskegon, Michigan 49441




Figure 2. Map showing the location, operators' names and number of sites of sand dune mining in Michigan.

Size of Operation

The operators identified were classified as small, medium or large producers according to the following class sizes:

Small ..... annual production less than 100,000 tons
Medium .... annual production between 100,000 and 500,000 tons
Large ..... annual production exceeding 500,000 tons

The data necessary to make this determination was obtained through the producer questionnaire. Accordingly, three operators were classified as small, two operators as medium and the remaining five operators were categorized as large.

Mining Methods

The sand mining industry in Michigan uses the open pit method to remove the resource. (2, p. 19-25) For some operators, this limits the time schedule by which their operation remains active. Snow and cold weather make the sand mining more difficult; and transporting the resource is also complicated by winter conditions. Six operators reported engaging

| Year | Quantity[a] (tons) | Value[b] (dollars) | Value per Ton[c] (dollars) |
|---|---|---|---|
| 1976 | 5,336,398 | 20,198,262 | 3.78 |
| 1975 | 5,493,000 | 21,189,000 | 3.86 |
| 1974 | 5,349,000 | 16,483,000 | 3.08 |
| 1973 | 5,729,000 | 14,217,000 | 2.48 |
| 1972 | 4,867,000 | 10,984,000 | 2.26 |
| 1971 | 4,591,000 | 10,479,000 | 2.28 |
| 1970 | 4,757,000 | 9,247,000 | 1.94 |
| 1969 | 5,357,000 | 11,145,000 | 2.08 |
| 1968 | 4,927,000 | 9,754,000 | 1.98 |
| 1967 | 3,971,000 | 8,269,000 | 2.08 |
| 1966 | 4,435,000 | 8,713,000 | 1.96 |
| 1965 | 3,948,000 | 7,750,000 | 1.96 |
| 1964 | 3,422,000 | 6,651,000 | 1.94 |
| 1963 | 2,851,000 | 5,577,000 | 1.96 |
| 1962 | 2,004,000 | 3,468,000 | 1.73 |
| 1961 | 1,693,000 | 2,498,000 | 1.48 |
| 1960 | 1,699,000 | 2,719,000 | 1.60 |
| 1959 | 1,919,000 | 2,849,000 | 1.48 |
| 1958 | 1,792,000 | 2,321,000 | 1.30 |

[a] Rounded to nearest thousand tons
[b] Rounded to nearest thousand dollars
[c] Rounded to nearest cent

Table 3. Industrial sand production in Michigan 1958-1976. Data based on information from "Michigan Industrial Sand Resources", and U. S. Bureau of Mines.

in active mining during twelve months while the remaining four operators indicated actively mining during eight or nine months of the year.

The open pit method of mining used by the ten operators previously listed involves a variety of techniques. The most common and economic means of removing sand is by the use of a front-end loader. In some instances, the front-end loader is replaced by a crane and clamshell. Both types of operation remove sand from the base of a sand dune and unload it into a nearby hopper. The sand drops through a rough screen where debris and foreign elements are trapped, allowing the sand to be funneled onto a conveyor belt. The conveyor transports the sand to the plant site where it is stockpiled for processing at a later time. When the plant site is a considerable distance away from the mining site, the sand can be hauled by truck and stockpiled.

Other methods of mining sand include dredging and hydraulic mining. Oftentimes more expensive operations, these methods offer unique advantages. With hydraulic mining, water is jetted under high pressure against a dune bank, washing the sand into a small holding pond. The slurry (sand and water) is then sucked up and transported through a pipeline, to be stockpiled and dried. The water is drained off and pumped back to the unit for re-use. When a dredge is used, the method of operation is somewhat different. Dredging removes sand below the water table, creating a sizable water feature. The advantage of dredging is the capability to remove sand up to fifty feet in depth. The sand is transported in a slurry through a pipeline and stockpiled. Excess water is drained off and channeled back to the water source. Hydraulics (jetting the water against a sand bank) may be combined with the dredge in removing the sand.

Processing Methods

The stockpiled sand, whether delivered by conveyor, truck or pipeline will require some means of processing. At a minimum, washing and drying the sand is necessary. If the sand is to be transported by Great Lakes vessel, the washing and drying process is usually done at the destination terminal. For sands that are unusually high in iron or calcium carbonates, beneficiation is necessary. This process utilizes magnetic and float separation to remove impurities. After the sand has been washed and dried and contaminants have been removed, it is screened. In this process, sand is separated according to grain size and stockpiled for future blending.

The many uses for sand demand different specifications, many of which require specific percentages of sized grains. This is known as grain fineness. Fineness is determined by pouring a premeasured amount of sand through sieves graduated and numbered according to mesh opening. The percent of sand on each sieve is calculated by weight to determine the grain fineness of the sand mixture. The mesh openings are graduated in U.S. Standard Sieve Numbers. (See Figure 7 for numbers.)

Production

Annually, the Bureau of Mines releases figures on total industrial sand mined in Michigan (Table 3). For 1976, the total quantity of industrial sand produced was 5,461,398 short tons having a market value, free on board (F.O.B.), of $20,198,262. This translates to $3.78 per ton. These figures represent sand mined from coastal dunes, inland dunes, inland sand deposits, Saginaw Bay and sandstone deposits in Wayne County. In order to isolate industrial sand mined from coastal dune areas, figures were computed from questionnaires which were sent to operators mining sand in these areas.

Ten operators reported a total of 3,616,606 tons of sand sold in 1976. Only three operators reported a F.O.B. value for the product sold. They reported selling 1,137,526 tons of sand in 1976 having a F.O.B value of $5,440,446. This translates to $4.78 per ton.



The Bureau of Mines reports that Michigan is the leading producer of industrial sand, followed by Illinois, New Jersey, and California. (5) Table 4 compares industrial sand production in the United States to Michigan from 1970 to 1976. Reasons for Michigan's high production output of industrial sand are: 1) the availability of abundant sand reserves of very high quality; 2) accessibility to transportation networks; and 3) the ability to maintain a fair market price.

Table 5 summarizes land holdings and sand reserves of the dune-mining operators. Ten operators identified land holdings totaling 5,803 acres in 26 sites. The sites ranged in size from 8.3 acres with 400,000 tons of recoverable reserves to 1,552 acres with 50,000,000 tons of recoverable reserves. There were 14 active sites identified containing a total of 189,700,000 tons of recoverable reserves and 12 inactive sites containing 67,065,000 tons of recoverable reserves. The total recoverable reserves presently identified by 10 operators are 256,765,000 tons and the total nonrecoverable reserves are 19,050,000 tons for the same areas.

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 |
|---|---|---|---|---|---|---|---|
| United States[a] | | | | | | | |
| Quantity | 29,145 | 26,161 | 29,530 | 28,974[c] | 28,024[c] | 26,723 | 29,669 |
| Value | 101,191 | 91,371 | 112,386 | 110,065[c] | 135,357[c] | 146,982 | 169,161 |
| Michigan[b] | | | | | | | |
| Quantity | 4,757 | 4,591 | 4,867 | 5,729 | 5,349 | 5,493 | 5,336 |
| Value | 9,247 | 10,479 | 10,984 | 14,217 | 16,483 | 21,189 | 20,198 |
| Percent Share[d] Michigan vs. United States | | | | | | | |
| Quantity | 16% | 18% | 16% | 20% | 19% | 21% | 18% |
| Value | 9% | 11% | 10% | 12% | 12% | 14% | 12% |

[a] U.S. Bureau of Mines
[b] "Michigan's Industrial Sand Resources"
[c] Data not directly comparable to previous years because of changes in statistical reporting. However, data utilized here to present broad industry trends.
[d] Rounded to nearest percentile.

Table 4. Industrial sand production for the United States and Michigan 1970-1976.

Land Holdings and Sand Reserves

By means of a questionnaire producers were asked to identify active and inactive mining sites, the number of acres in each and the amount of sand reserves within each site. Reserves are known sand deposits of a desired grade, which may be recoverable or nonrecoverable. Recoverable reserves are those which can be extracted and processed economically. It does not infer that every ton of every acre is extractable. The sand which is considered unsatisfactory because of coarseness, excessive impurities or location on site are known as nonrecoverable reserves. Many times mining must stop within certain distances from the property line to allow a buffer zone for necessary grading or screening purposes. This sand is calculated as nonrecoverable and is left on site.

Production Cost

Due to confidentiality and competitiveness among the operators the question dealing with production costs was left unanswered by all.

Reclamation

Dune areas that have been stripped of vegetation and left exposed are very susceptible to the erosive forces of wind and water. Act No. 222 of the Public Acts of 1976 requires sand dune mining operators to reclaim disturbed areas. To meet Department of Natural Resources specifications, areas which

| | Operational Status | | |
|---|---|---|---|
| | Active | Inactive | Total |
| Number of Sites | 14 | 12 | 26 |
| Number of Acres | 4,163 | 1,540 | 5,703 |
| Recoverable Resources (1000 tons) | 189,700 | 67,065 | 256,765 |
| Non-recoverable Reserves (1000 tons) | 19,000 | 50 | 19,050 |

Table 5. Land holdings and sand reserves in Michigan. Data based on information from Dune Sand Consumers Questionnaire, 1976.

are disturbed by mining must be regraded to a desired slope and revegetated. Buffer zones, consisting of vegetation and/or berms, can be used for screening the operation and reducing noise. Combined with an end land-use plan, reclamation can restore the landscape to a pleasing, stable, useful tract of land.

As reported in the producer questionnaire, six out of ten operators surveyed indicated they were actively engaging in some type of reclamation program. The range of funds expended per year was $1,500 to $20,000, with the total equaling $51,000.

## DUNE SAND CONSUMPTION

### Consuming Industries

Results from the questionnaires sent to potential producers and consumers confirm that the majority of Michigan dune sand is consumed by the foundry industry for use in making cores and casting molds. Another identified user of Michigan dune sand is the glass manufacturing industry. Although consumption by the glass industry is not as great as by the foundry industry, strict specifications demanding a high-silica, low-impurity sand make dune sand ideally suited for the industry. Other miscellaneous minor consumers of dune sand use it for such purposes as abrasives, engine traction and sandblasting.

Figure 3 illustrates the percentages of dune sand devoted to each type of use as identified by both producers and consumers. As noted earlier in this report dune sand producers sold 3,616,106 tons of dune sand. Of this total 3,501,306 tons or 96.8 percent was purchased by foundries, 70,000 tons or 1.9 percent was purchased by glass manufacturers and 44,800 tons or 1.3 percent was sold for other uses.

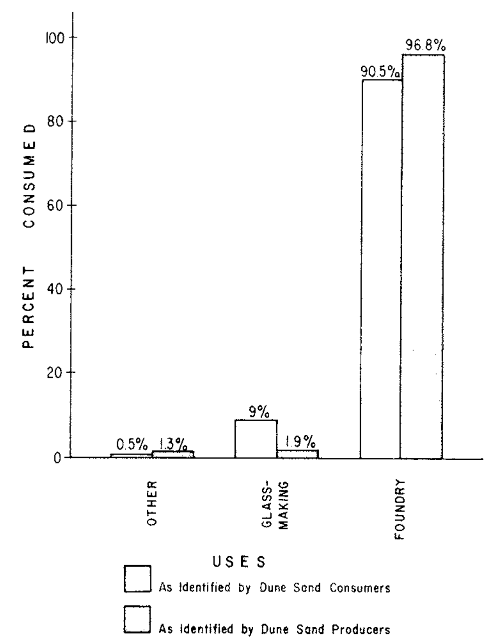


Figure 3. Dune sand consuming industries in Michigan, 1976.

There were 4,211 questionnaires sent out to potential consumers, and 2,139 responses were received. Of these responses 135 indicated that they did use Michigan dune sand. All of the others indicated they obtained sand from other sources. Of the affirmative response group, 123 were received from foundries, 4 from glass manufacturers and 8 were received from miscellaneous industries.

It should be noted that there is difficulty in establishing trends or patterns based solely on the information gathered from these questionnaires. The data was compiled and will be used to represent the consuming industries answering the questionnaire.

The consumers who responded to the questionnaire indicated purchases of 1,444,817 tons of dune sand. Foundries purchased 1,311,088 tons, or 90.5 percent of the total amount. The four glass manufacturers indicated purchasing 131,863 tons, or 9.0 percent of the total and the remaining 1,900 tons or 0.5 percent was purchased by other industries for miscellaneous uses.

The consumer questionnaires were sent to potential consumers located in seven states and the Province of Ontario. Consumption of



Michigan dune sand is distributed throughout these areas. Particularly, the largest consumers are located in Michigan and Ohio, followed by Ontario, Illinois, Indiana and Pennsylvania. The states consuming the least amount of sand were New York and Wisconsin. Figure 4 illustrates the amount of sand distributed in 1976 to these states and the Province.

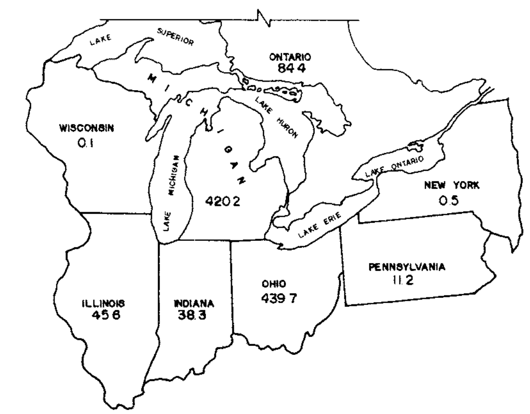


Figure 4. Reported Michigan dune sand consumption by State or Province in 1976.

According to published reports, Michigan industrial sand producers supplied more than 90 percent of the sand used by foundries associated with the American and Canadian automotive industries in 1973. (2, p. 10) The association of foundries utilizing dune sand and the automotive industry was not revealed by the questionnaire results. However, correspondence with a representative from one of the three major automobile companies has provided pertinent information regarding their use of Michigan dune sand. This particular automobile company operates two foundries in Michigan, one in the Province of Ontario, one in Ohio, and one in Arkansas. The Arkansas foundry is supplied by sand mined in Oklahoma. The remaining foundries annually consume 2,285,000 tons of Michigan industrial sand. Until the early 1970's, over 75 percent of this company's annual sand consumption was supplied by Michigan coastal dune operations. Currently, about 55 percent originates from Michigan coastal dunes and the remaining amount from inland sand deposits. The reduction of coastal dune sand consumption is attributed to problems arising from processing and transportation.

Although not evidenced by the questionnaire results, silica sand of the quality and composition of Michigan dune sand is an essential material in a variety of other manufacturing processes, including chemical and metallurgical processing, abrasives, locomotive traction and filters. (4, p. 935-936) The use of dune sand for these purposes is mentioned here to correct any potential oversight caused by lack of responses to the questionnaires.

As an abrasive, silica sand is used in glass grinding, stone sawing, sandpaper and scouring compounds and polishes. In metallurgical processing of base metal ores, silica sand is used as a flux to facilitate fusion at a lower temperature than normal. The chemical industry includes silica sand in the manufacture of such products as sodium silicate, silica gel, silicon carbide, silicon tetrachloride and a wide variety of silicones. Railroads use silica sand to increase the traction of locomotive wheels on the rails. Silica sand also provides a filtering medium used in treating municipal water supplies, sewage treatment, water conditioning equipment, and purifying swimming pools.

### Purchasing and Transportation Costs

The responses from the consumers of Michigan dune sand were significant enough to determine an average price for a ton of sand. Based on an average for each producer, the purchasing price for a ton of sand was determined to be $5.15. The highest figure reported was $7.75 and the lowest was $3.10. Figure 5 illustrates, by state or province, the average transport and purchase costs.

Upon examination of the consumer questionnaire, it appeared that certain elements affected the purchase price. Particularly, the intended use and the resultant specifications had some affect on the price. The amount of sand purchased also appeared to affect the price. It was clearly evident that a standard price for a ton of sand does not exist.

The mode of transportation and the associated cost to the consumer was also addressed in the consumer questionnaire. The modes of transportation included truck, rail and water. The majority of sand is transported by truck, but some is carried by rail and a smaller amount by water.

Truck transportation costs were reported by both in-state and out-of-state consumers. In-state, the average cost to transport sand via truck was $5.50 a ton. Out-of-state, the average cost was $9.54 a ton. Using all figures reported for truck transportation costs, an average of $8.83 per ton of sand is obtained.

Rail transportation is used by at least one producer to ship sand in-state, yet no consumers reported such costs. Rail transportation costs, though, were reported by a significant number of out-of-state consumers. Based on reported figures from these consumers, an average cost for transporting a ton of sand via rail was $11.32.

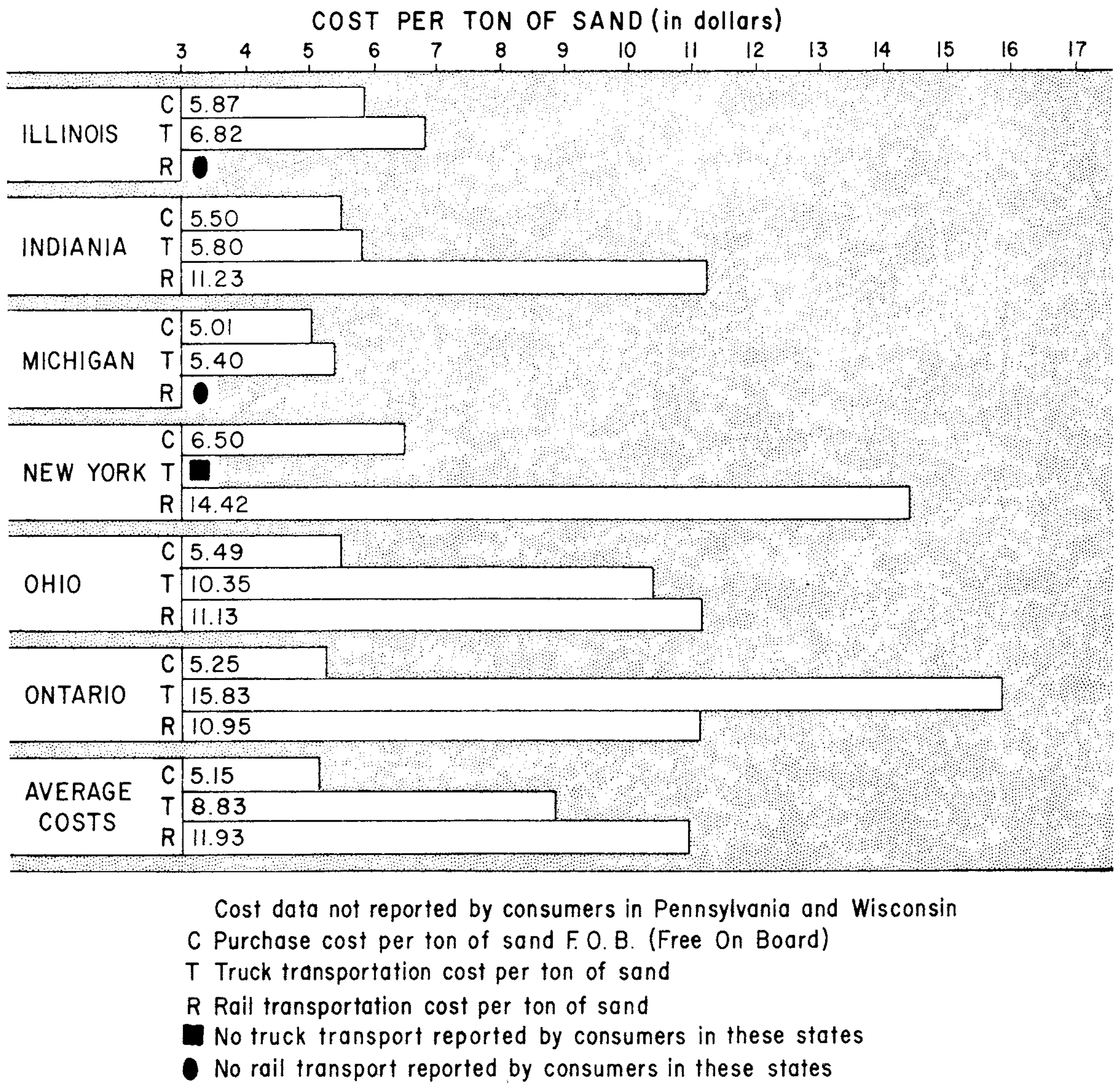


Figure 5. Average costs for purchase and transportation of dune sand, 1976.

Although some consumers reported that the sand was transported by water, no cost for this mode of transportation was available.

For all consumers reporting, 974,152 tons were transported by truck, 413,540 tons by rail and 57,125 tons by water. Figure 6 depicts the mode of transportation from producer to consumer by state and province.

Physical and Chemical Specifications

Sand is defined as grains of mineral material ranging in size from 0.625 to 2 millimeters and consisting primarily of silica. (4, p. 935) Industrial sand must meet rigid specifications regarding size gradation, shape and other physical and chemical properties. These specifications vary according to the type of industry using the sand and are discussed in that manner.

Foundries

The general properties which determine the value of sand for foundry use are: 1) grain shape, 2) grain size, 3) bond or cohesiveness, 4) refractoriness, 5) durability, and 6) chemical composition. (3, p. 21-25; 7, p. 96-108) Grain shape is important because



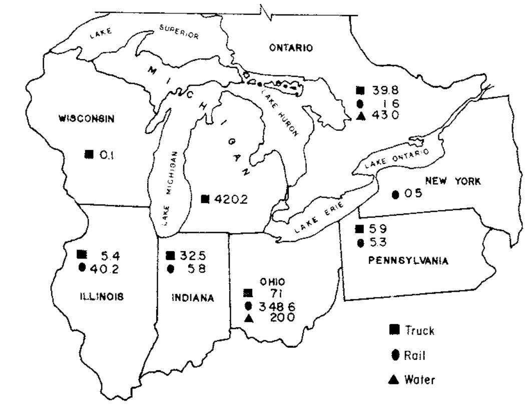


Figure 6. Modes of transportation for dune sand by State or Province in 1976.

it is a determinant of the permeability of the sand. Permeable sand will allow gases and steam to escape through the mold, thus lessening the dangers of a defective casting. The best permeability is obtained from sub-angular or rounded sand grains. Angular grains tend to pack more tightly, thus reducing permeability.

Questionnaire results tend to support the use of sub-angular or round grain shapes in foundries. Although forty-one foundries indicated no grain-shape specifications, forty-nine specified sub-angular, nineteen specified round, and twenty-three specified angular grain shapes.

Grain size affects permeability as well as the desired finish of the casting. Finer grains in a mold import a smoother finish to the casting, but there is a tendency for permeability to be reduced. Large castings which generate more gas require coarser sand for greater permeability.

Grain size is expressed by the percent of a sample retained by screens with mesh openings specified by a U.S. Standard Sieve Number. The U.S. Standard Sieve Number corresponds to the size of the opening in the screen mesh.

Foundries surveyed were asked to indicate their specifications for the percent of sand retained under the 30, 40, 50, 70, 100, 140, 200 and pan U.S. Standard Sieve Numbers. Figure 7 illustrates the average value determined from questionnaire responses. Although a small range of grain sizes may appear to be optimum to attain the desired surface finish and permeability, generally a range of sieve sizes from 50 to 200 was specified by the various industries. Silica undergoes an increase in volume at a certain temperature. If all grains were to reach this temperature and expand

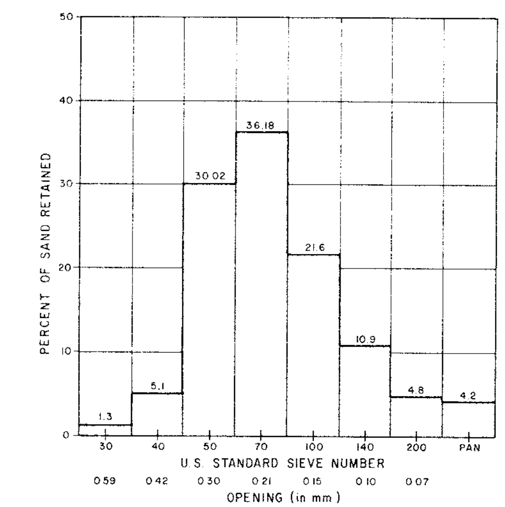


Figure 7. Grain size requirements of dune sand users.

simultaneously, serious defects could occur in the casting. Since different size grains reach this temperature at different times, a range of grain sizes is desirable.

The binding capability of sand used by foundries is an important characteristic. Naturally bonded sand, commonly called bank sand, contains enough clay, loam, or other material to bond the grains together when tamped into a mold. Dune sand does not contain natural binding materials and often a natural or synthetic binder must be added.

Refractoriness is the ability of a material to resist alteration by heat. It is measured by determining the temperature at which the grains begin to melt or fuse together. Because the range of fusion for silica is similar to the casting temperature of iron and steel (1350°C to 1700°C) slight differences in the fusing temperature of sand are crucial.

The temperature of fusion depends upon the sand's composition. Sands high in silica content, such as dune sand, are the most refractory. Sand used for high-temperature steel casting usually contains more than 96 percent silica, before the addition of a chemical binder. Aluminum or brass casting can be done at lower temperatures, allowing for the use of sands which are naturally bonded and composed of 75 to 90 percent silica.

Correspondence with two of the three major automobile manufacturers indicates that refractoriness is an important characteristic. One manufacturer specifies a fusion point of

1650°C while the other specifies 1723°C. Therefore, sands high in silica content, such as dune sand, should be the most suitable to meet this specification.

The durability of sand is judged by its physical alteration after reuse. Sand is durable if the average grain size and shape does not change after successive cycles of reuse. The least durable grains are angular with fracture planes passing through them.

As mentioned throughout this discussion, silica content appears to be critical for foundry use of sand. However, the level of other chemical constituents of the sand is also important. A high content of impurities can cause defects in the casting.

In the consumers questionnaire industries were asked to provide specifications for maximum impurity limits in the sand. Figure 8 provides a summary of chemical impurity limits specified by foundries. Although somewhat higher levels of aluminum oxide and calcium oxide (lime) are tolerated, limits for all other chemical impurities are kept well below 1.0 percent.

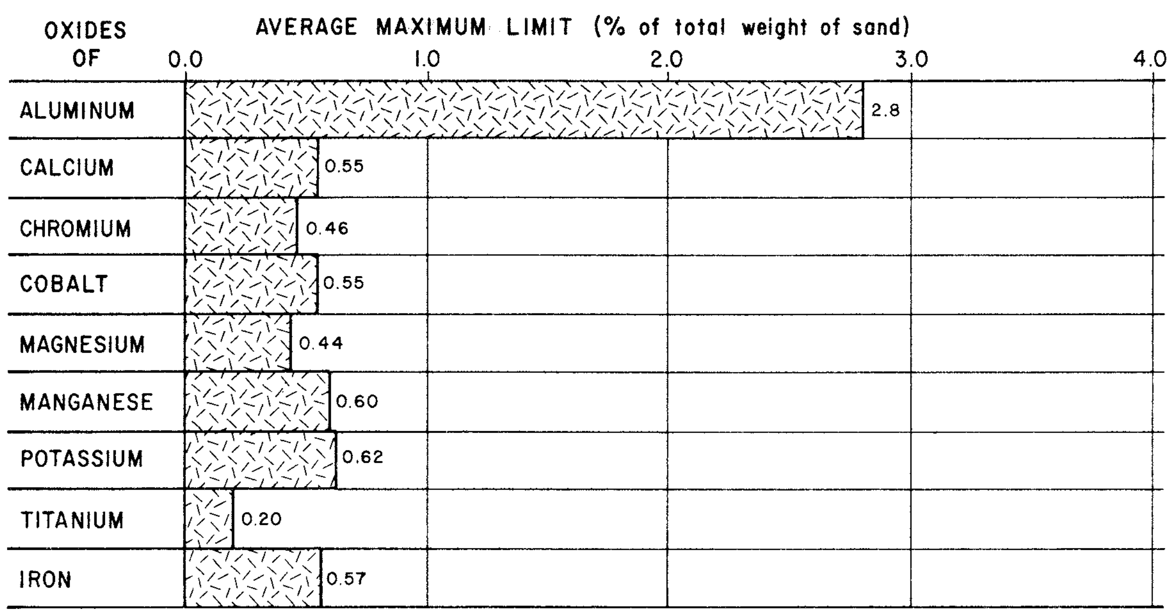


Figure 8. Limits of chemical impurity of sand acceptable for foundry use.

Glass Manufacturer

The physical and chemical quality of sand purchased by glass manufacturers depends on the type of glass produced. (7, p. 96-108) For better grades of glass where tint and light transmission are important, the sand must have a silica content of 99 percent or higher and be relatively free of other impurities.

Iron oxide in the ferric state of oxidation ($Fe_2O_3$) is the most common impurity that imparts a tint to glass. As the need for crystal clarity diminishes, e. g., in window glass and in amber and green bottles, successively larger amounts of total iron content are allowed.

Aluminum oxide ($Al_2O_3$) was formerly considered an objectionable impurity, but is now intentionally added to some types of glass to increase durability and diminish expansion. High concentrations of calcium oxide (CaO) and titanium dioxide ($TiO_2$) are avoided. Magnesium oxide (MgO), when present in amounts less than one percent, improves the resistance of glass to devitrification (crystallization).

Questionnaire results regarding glass manufacturing specifications for maximum impurity limits are summarized in Figure 9. While aluminum oxide concentration averaged above three percent, concentrations of the oxides of magnesium, manganese, titanium and iron remained below one percent.

The physical properties of sand used for glassmaking seem to be less important than chemical characteristics. No particular grain shape or size distribution were specified by glass manufacturers responding to the survey. While grain size and shape may be important physical properties, glassmaking furnaces can be modified to accomodate the available sands



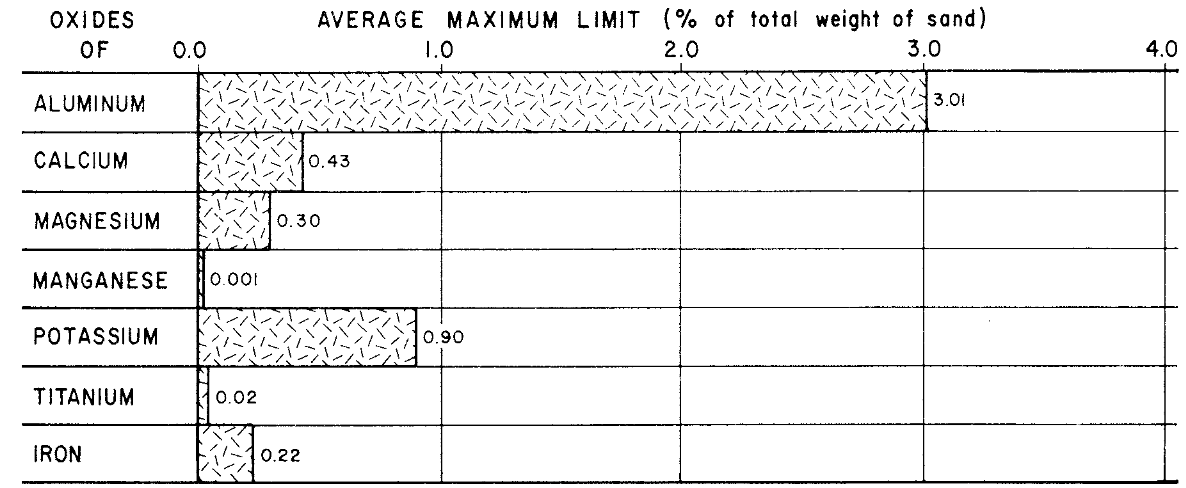


Figure 9. Limits of chemical impurity of sand acceptable for glassmaking.

Grain sizes on the extreme ends of the U.S. Standard Sieve Number scale are generally avoided. Fine grains tend to carry impurities and are believed to cause blisters in the glass. Coarse grains fuse less easily and this tends to lower output and increases the amount of energy required by the glassmaking furnaces.

Other Industries

Questionnaire results were inconclusive regarding the use of dune sand by other industries. However, the literature sources consulted in the course of this study provide physical and chemical specifications sought by other industries utilizing sand of a quality similar to dune sand.

For abrasive uses, sand should be free of adhering clay or coating of iron oxide and have a silica content ranging from 80 to 99 percent. (7, p. 138). Purity specifications vary with the type of abrasive action required. Angular sand grains are used when a fast cutting action is desired, while round grains are used to produce a smooth finish.

For locomotive traction, specifications call for a clean, hard sand of uniform grain size and an absence of clay and moisture. (3, p. 30) These qualities insure a rapid and steady flow through a pipe directed at the rails in front of the locomotive wheels. Subangular or angular grains are preferred because round grains do not remain on the track.

In metallurgical processing, silica sand is used as a flux in smelting ores of base metals. (3, p. 34) A flux is material which facilitates fusion at lower temperatures than normal. The silica content of sand used as a flux should be high, but iron, aluminum and basic oxide impurities are not objectionable.

Sand used as a filtering medium must consist of uniform grain size, be of high chemical purity and be free of clay and organic matter. (3, p. 31) It should not contain either iron or manganese, for these would react with chemicals used in the water treatment process. Sand with good permeability is preferred.

Sand used by the chemical industry in the manufacture of a number of products must be as pure as that used for glassmaking, or 99.0 percent silica. (3, p. 28) Permissible trace impurities vary according to use.

Recycling

Foundries are one of the few industries that use sand without consuming it in the manufacturing process. Thus, foundries have an opportunity to recycle the sand as well as the problem of eventual disposal.

Sand used in the formation of casting molds and cores can be recycled until it becomes unusable through agglomeration or excessive coating of deleterious materials. Sand recycling technology has been advanced in recent years by the development of methods of cleaning and recovering sand particles.

A representative of one of the major automobile companies who was contacted in the course of this study maintains that recycling is still not economically feasible for foundries manufacturing automobile components. The cost of recycling one ton of sand exceeds the purchase price by 2½ times; and the cost of disposal amounts to less than one-half of the purchase price. The company representative acknowledges that increasing environmental awareness, concern for resource depletion, and opportunities to reduce costs and increase quality serve as incentives to continue research in sand recycling.

Results of the survey of foundries using dune sand seem to support the feasibility of recycling. Nearly 50 percent of the foundries responding to the survey employed recycling in their operation. These foundries recycled the same sand an average of 7.5 times. The necessity for treatment prior to recycling was verified by 77 percent of these foundries.

Nearly all foundries reported discarding the sand in an undisclosed manner when it is no longer usable. Only two foundries reported that they sell the sand after use, while six use the sand as landfill.

## Future Demand and Potential Substitutes

Consuming industries generally expected an increase in future demand for dune sand. When asked to project their future needs, 53 percent of the industries expected their requirements to be greater while 41 percent felt they would remain stable. Only 6 percent predicted a lesser need in the future.

Figure 10 presents three projections of future demand for Michigan Industrial sand. Projections were made for sand from all sources because historical data is not available for coastal dune sand alone. However, as a major source of the industrial sand supply in Michigan, coastal dunes will be greatly affected by increased future demand.

Curve A in Figure 10 was determined by extrapolating 1958 to 1976 production trends to the year 2030, with the assumption that production will equal demand if supply is not constrained. On the basis of this extrapolation, demand will increase by 258,450 tons annually. Total demand will increase to 12,480,000 tons by the year 2000 and 20,234,000 tons by 2030. Curves B and C utilize national industrial sand demand projections prepared by the U.S. Bureau of Mines. (4, p. 943) The Bureau of Mines projections forecast high, probable, and low demand. Curves B and C were based on the probable and low demand projections. The future demand for Michigan industrial sand was determined by extrapolating the current share of the national industrial sand production supplied by Michigan at the same rate as the probable and low demand projections forecast by the U.S. Bureau of Mines.

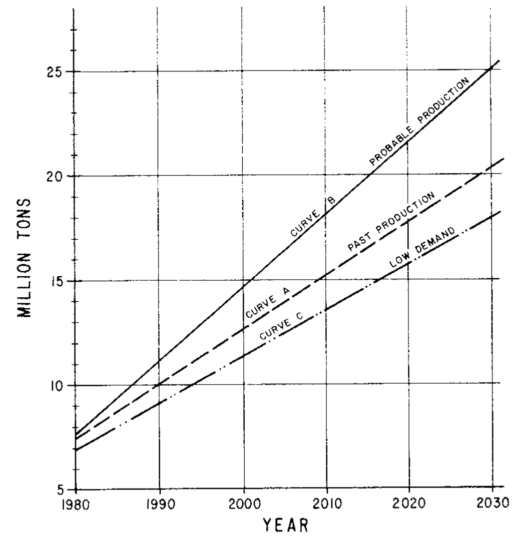


Figure 10. Projected use of Michigan dune sand, 1980-2030.

Based on Curve B, demand will increase by 340,000 tons annually to 14,380,000 tons by 2000 and over 25,000,000 tons by 2030. Curve C shows a projected demand of 11,275,000 tons by 2000 and 17,875,000 tons by 2030.

As reported previously, dune mining operators hold an estimated recoverable reserve of 256,765,000 tons from both active and inactive sites. Based on demand figures in Curve A, the estimated recoverable reserves will be depleted by the year 2006. Recoverable reserves will be depleted by 2000 based on Curve B and by 2010 based on Curve C. These figures must be viewed with some caution since Curves A, B and C are based on industrial sand production from all sources. Depending on the relative share of total industrial sand production supplied by coastal dunes, depletion of reserves could be postponed for a number of years.

A number of factors will ultimately affect future demand for dune sand. The U.S. Bureau of Mines reports that the trend in casting appears to be toward favoring use of molding materials which are more heat resistant than silica sand and use of permanent molds made of high temperature ceramics. (4, p. 944) Advances in recycling technology have potential for decreasing demand for sand by foundries. Changes in the automobile industry, as dictated by the national energy situation, will undoubtedly have an impact on dune sand consumption. Smaller engines and the increasing use of plastics and other light-weight materials in automobiles may curtail demand for dune sand used in casting.



The future demand for dune sand in glassmaking is tied to the use of glass for building materials and glass containers. Expansion of use for construction purposes is possible if glass is further improved in strength, thereby making it adequate for structural support. The greatest unknown factor affecting the glassmaking industry is the issue of disposable versus returnable containers. As this matter reaches resolution, the impact on the glassmaking industry and its consumption of dune sand will become clearer.

A final factor affecting future consumption is the use of substitutes for dune sand. Of the consuming industries surveyed, 30 percent said there were potential substitutes, 35 percent said there were none, and 35 percent did not know of any possible substitutes.

Those foundry industries which recognized possible substitutes mentioned olivine, bank sand and silica sand from sources other than Michigan dunes. Other potential substitutes include zircon and chromite.

Olivine is a mineral composed of iron and magnesium in solid solution with silica. The composition varies between iron-rich and high magnesium content. Forsterite, the magnesium-rich variety of olivine, is the only one with sufficient refractoriness to be usable as a foundry material. Forsterite fuses at 1810°C. It can be used in producing stainless steel castings because it is not attacked by manganese oxide which is associated with the process. In Sweden, olivine sands have displaced silica sand for all types of casting, and in Great Britain every effort is being made to convert to the use of zircon, chromite, and olivine. (3, p. 27)

Zircon sand is composed of grains of almost pure zirconium silicate. This material is used because of high refractoriness (fuses at 2010°C), good thermal expansion properties, and higher heat conductivity which promotes more rapid chilling of the castings.

Chromite is effective in casting stainless steel. It has good chilling properties, does not combine chemically with molten metal and is more resistant to metal penetration than either silica or zircon, thereby producing smoother surface finishes.

Over 53 percent of the foundries surveyed felt that a change in the source of sand supply would affect their operation, while 21 percent were unsure of the affect. The foundries expressed concern most frequently that transportation and purchase costs might rise, quality and finish of castings might deteriorate and supplies might not be readily available. Several foundries indicated that the physical and chemical properties of dune sand are best suited for their operation.

The essential consideration in selection of substitutes for dune sand in glassmaking is the silica content of the sand. Several glass manufacturers mentioned that alternative sources of sand with lower silica content were available from Ohio and Ontario. However, a change from dune sand to a sand with less silica would lower the quality of the finished product.

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# APPENDIX

SAND USER SURVEY

State of Michigan
Michigan Department of Natural Resources
Division of Geology

The Michigan Department of Natural Resources is required by Act No. 222, P.A. 1976, "Sand Dune Protection and Management Act", to make "an economic study of the current and projected coastal sand dune mining practices in the state showing where the sand is marketed, its uses and the amount of sand reserves." This survey is a vital component for gathering much of the needed information. Please take some time, answer the following questions and return as soon as possible. Your cooperation is needed and will be greatly appreciated.

1. Do you use Michigan dune sand in your operation?

   Yes _____ No _____ (If no, it is not necessary to answer remaining questions. Please return survey immediately.)

2. Please list below, the name and addresses of suppliers from which you have purchased Michigan dune sand since 1976. Mark present suppliers with an asterick.

| Supplier Name | Address | Tons Purchased (1976 calendar year) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

R-7525

-2-

3. For what purpose do you use Michigan dune sand?

   ☐ moiding/foundry ☐ glass ☐ fire/furnace
   ☐ traction (locomotive) ☐ blast ☐ other _____ (specify)

4. How much Michigan dune sand do you purchase annually?

   _______tons/year

5. How much does it cost for a ton of sand 'Free on Board' (F.O.B.)?

   $_____/ton

6. How many times can the same sand be used in your operation?

   _______time(s)

7. Is treatment necessary to recycle sand for the same use?

   Yes _______ No _______

8. What happens to the sand when it can no longer be used in your operation?

   ☐ discard ☐ sell ☐ other _____ (specify)

9. What are the sand specifications necessary for your particular needs?

   a) Grain Shape

   ☐ Angular ☐ Sub-Angular ☐ Round

   ☐ No Grain Shape Specifications

   b) Grain Size Distribution - please insert under each indicated U.S. sieve #, the % of sand that should be retained in order to meet your size specifications.

| U. S. Standard Sieve Number | | | | | | | |
|---|---|---|---|---|---|---|---|
| 30 | 40 | 50 | 70 | 100 | 140 | 200 | Pan |
| ___% | ___% | ___% | ___% | ___% | ___% | ___% | ___% |

☐ No Grain Size Specifications

-3-

c) Critical Control Limits for Impurities - please indicate maximum impurity limits (Weight % of metal oxide) for which you have specifications.

| Metal Oxide | Max. Limit (%) | Metal Oxide | Max. Limit (%) |
|---|---|---|---|
| Aluminum ($Al_2O_3$) | | Manganese ($MnO_2$) | |
| Calcia (CaO) | | Potassium ($K_2O$) | |
| Chromium ($Cr_2O_3$) | | Titanium ($TiO_2$) | |
| Cobalt ($Co_3O_4$) | | Total Iron ($Fe_2O_3$) | |
| Magnesia (MgO) | | ☐ No Impurity Specifications | |

10. How is Michigan industrial sand transported to your site of operation?

| Item | Tons | Transportation cost/ton |
|---|---|---|
| Truck | | |
| Rail | | |
| Water | | |
| Other _____ (Specify) | | |

11. Are there any substitutes/alternatives for dune sand, should your present supply be depleted?

    Yes _____ (If yes, please list them) No _____ Don't know _____

12. What do you expect your future (30 yrs.) need will be for the supply of sand?

    Less ___ Stable ___ Greater ___

13. Would a change in source from which you receive sand affect your operation?

    Yes ___ No ___ Don't know ___

    If yes, in what way?

Ind. Sand Quest. page #1

DEPARTMENT OF NATURAL RESOURCES
Division of Geology

Industrial Sand Questionnaire

Background

1. On attached property description form we have attempted to list and describe all properties containing sand reserves within 2 miles of the Great Lakes coastal shoreline that you own or have under lease. Please check for accuracy and answer associated questions. If there are additional properties which have not been listed, please include them on the extra enclosed property description forms.

2. On attached user form, list major sand customers and indicate how many tons they purchase per year.

Operational

Transportation

3. Method of transportation leaving plant to customer or site of use.

| Item | | Quantity (tons) |
|---|---|---|
| Truck | Owned by your Co. | |
| | Private | |
| Railroad | | |
| Waterway | | |
| Other | | |



Ind. Sand Quest. pg #2

4. Estimate the distance and percent of industrial sand transported to point of sale or site of use.

   _____ 0 - 25 miles _____%
   _____ 26 - 50 miles _____%
   _____ 51 - 100 miles _____%
   _____ 101 - 200 miles _____%
   _____ 201 or more miles _____%

   a) What percent of sand is distributed to other states? _____%to Canada?_____%

5. Industrial sand sold in 1976 for the following uses:

| Use | Quantity | Your cost to Produce* | Value ($) F.O.B. |
|---|---|---|---|
| Foundry | | | |
| Glass | | | |
| Blast | | | |
| Fire or Furnace | | | |
| Engine (traction) | | | |
| Other _____ | | | |

* Cost to produce product includes fixed and variable costs.

6. What processing methods are utilized to prepare the sand for market?

   _____ Washing _____ Drying _____ Other
   _____ Screening _____ Beneficiation

   a) If beneficiation is used, what type? __________

7. What percent of the total sand processed is considered waste or reject?

8. Do you have an active reclamation program? Yes_____ No_____

   a) If yes, what do you estimate as the amount spent on reclamation activities? $ __________ per year

Ind. Sand Quest. pg #3

9. Type of operation: check one

   _____ This is only an industrial sand operation.

   _____ This is an industrial sand operation supplying raw material to a parent company in the business of producing industrial sand products.

   _____ This is a subsidiary of a company which is in other type of business not related to industrial sand products.

10. Check type of method(s) used to mine the sand reserves.

    _____ Clamshell _____ Hydraulic _____ Other
    _____ Front-end loader _____ Dredge

11. What do you anticipate your customers' future (30 years) needs to be?

    _____ Less _____ Stable _____ Greater

Economics

12. Employment

    (a) Total number of full time employees __________.
    (b) Total number of part time employees __________.
    (c) Total man hours per week __________.
    (d) Total payroll for 1976 __________.

13. How many months during the year is your operation actively mining? _______months

14. Tax Information

    a) Your Business is an important economic contributor to local, state and federal governments through taxes. Please specify amounts paid to the following:

    Local taxes _______ State taxes _______ Federal taxes_______

Property Description Form

a) Number of acres: __________ acres.
b) If now active, how many years has the property been operational?
   __________years.
d) Estimate of sand reserves: recoverable __________ tons.
   non-recoverable__________ tons.
d) Is this property also the location of the plant and product distribution?
   Yes_____ No_____
e) Number of tons removed from this site per year: __________ tons.
f) Number of months per year that sand is mined from this property.
   __________ month(s).
g) Number of acres newly affected per year __________ acres.

Property Description Form

a) Number of acres: __________ acres
b) If now active, how many years has the property been operational?
   __________years.
c) Estimate of sand reserves: recoverable __________ tons.
   non-recoverable__________ tons.
d) Is this property also the location of the plant and product distribution?
   Yes_____ No_____
e) Number of tons removed from this site per year: __________ tons.
f) Number of months per year that sand is mined from this property.
   __________ month(s).
g) Number of acres newly affected per year __________ acres.

User Form

| Customer Name | Address | Tons Purchased (1976 calendar year) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
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| | | |

Factors for converting from METRIC to U. S. Customary and U. S. CUSTOMARY to Metric

| When You Know | (Symbol) | | Multiply By | | To Find | (Symbol) |
|---|---|---|---|---|---|---|
| **LENGTH** | | | | | | |
| millimeters | (mm) | x | 0.039 | = | inches | (in.) |
| centimeters | (cm) | x | 0.394 | = | inches | (in.) |
| meters | (m) | x | 3.281 | = | feet | (ft.) |
| meters | (m) | x | 1.094 | = | yards | (yd.) |
| kilometers | (km) | x | 0.621 | = | miles | (mi.) |
| inches | (in.) | x | 2.540 | = | centimeters | (cm) |
| feet | (ft.) | x | 30.480 | = | centimeters | (cm) |
| yards | (yd.) | x | 0.914 | = | meters | (m) |
| miles | (mi.) | x | 1.609 | = | kilometers | (km) |
| **AREA** | | | | | | |
| square centimeters | ($cm^2$) | x | 0.155 | = | square inches | ($in.^2$) |
| square meters | ($m^2$) | x | 10.764 | = | square feet | ($ft.^2$) |
| square meters | ($m^2$) | x | 1.196 | = | square yards | ($yd.^2$) |
| square kilometers | ($km^2$) | x | 0.386 | = | square miles | ($mi.^2$) |
| square inches | ($in.^2$) | x | 6.452 | = | square centimeters | ($cm^2$) |
| square feet | ($ft.^2$) | x | 0.093 | = | square meters | ($m^2$) |
| square yards | ($yd.^2$) | x | 0.836 | = | square meters | ($m^2$) |
| square miles | ($mi.^2$) | x | 2.590 | = | square kilometers | ($km^2$) |
| **MASS (weight)** | | | | | | |
| grams | (g) | x | 0.035 | = | ounces | (oz.) |
| kilograms | (kg) | x | 2.210 | = | pounds | (lb.) |
| ounces | (oz.) | x | 28.350 | = | grams | (g) |
| pounds | (lb.) | x | 0.454 | = | kilograms | (kg) |
| **VOLUME** | | | | | | |
| milliliters | (ml) | x | 0.0352 | = | fluid ounces | (fl. oz.) |
| liters | (l) | x | 2.113 | = | pints | (pt.) |
| liters | (l) | x | 1.057 | = | quarts | (qt.) |
| liters | (l) | x | 0.264 | = | gallons | (gal.) |
| cubic meters | ($m^3$) | x | 35.314 | = | cubic feet | ($ft.^3$) |
| fluid ounces | (fl. oz.) | x | 28.383 | = | milliliters | (ml) |
| pints | (pt.) | x | 0.473 | = | liters | (l) |
| quarts | (qt.) | x | 0.946 | = | liters | (l) |
| gallons | (gal.) | x | 3.785 | = | liters | (l) |
| gallons | (gal.) | x | 0.0283 | = | cubic meters | ($m^3$) |
| **TEMPERATURE** | | | | | | |
| Fahrenheit | ($^oF$) | | ($^oF$-32)/1.8 | = | Centrigrade | ($^oC$) |
| Centigrade | ($^oC$) | | (1.8$^oC$+32) | = | Fahrenheit | ($^oF$) |

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