MICHIGAN'S INDUSTRIAL SAND RESOURCES

Circular 11

Geological Survey Division
Lansing, Michigan,

Geological Survey Division

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by Jerry D. Lewis

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Preface

Time resurgence of interest in Michigan's mineral industry attests to time esteem that is reserved for the quality, accessibility, and mineability of the diverse mineral commodities found in this state. The number of state, national, and international agencies and mining companies, and the general public, seeking information on Michigan's mineral resources has increased many fold in the past few years.

This commodity report was compiled to answer some of these questions. Included is a general overview of the location and extent of a mineral resource, its mining and processing methods, its major uses, and the relation of all these factors to the economics of the local and state scene.

This particular report on Michigan's industrial sand industry was prepared from Geological Survey Division files, selected references, and a generous input of information and knowledge from sand mining companies operating throughout the state. The author wishes to thank the staff of the Mining and Economic Geology Unit of the Geological Survey Division for their helpful assistance and suggestions in the preparation of this report. The editorial staff of the General Geology Unit provided invaluable assistance. Appreciation is also extended to the staffs of the following sand mining companies for their help and cooperation: Construction Aggregate Corporation; Great Lakes Foundry Sand Company; Manley Brothers of Indiana, Incorporated; Industrial Sand Division, Martin Marietta Corporation; McCormick Sand Corporation; Nugent Sand Company, Incorporated; Standard Sand Company; Michigan Division, Ottawa Silica Company; Sargent Sand Company, and Chevrolet Nodular Foundry.

November 26, 1975,
Jerry D. Lewis, Lansing, Michigan

Abstract

Limited resources of certain Michigan sands and sandstones having high chemical purity and/or well-rounded similarly sized grains constitute an important industrial mineral resource for the state's economic well-being. The economic aspects of the sand mining industry are directly related to the geologic origin, location, and extent of the state `s glacially derived sands and older sandstone deposits. These unique sands, when selectively mined and processed, are ideally suited to the exacting specifications required for foundry and glassmaking uses. A handful of industrial sand mining operations in the state supply a predominant share of this country's industrial foundry and core sand. Alternatives to present mining locations and practices to protect local ecosystems will cause future dislocations and economic adjustments for the production of this important industrial raw material.

Introduction

Sand is a mineral resource that is often taken for granted. Nature has been at work for a long period of geological time to develop vast quantities of this resource. Such vast quantities of sand cloud our perceptions regarding sand as a resource, as only select types of sand are suitable for most industrial uses.

Industrial sand is one of the more select types of sand found in Michigan. This type of sand is needed because of its high chemical purity, grain size, shape, and distribution. Sand and sandstone meeting these specifications are used in metal casting and glassmaking. Some sand is also used as a scouring agent, traction sand in rail transportation, lining for high-temperature furnaces, and in the manufacture of metallurgical alloys.

The physical and chemical aspects of industrial sand and its economic implications to the state and local communities reinforce a need for a closer analysis and understanding of the resource. Analysis and understanding can allow us to better grasp the economic and environmental implications regarding this resource as well as provide possible future policy alternatives for its role in the economic development of the state.

Sands and the Geological Processes

The ice age began over one million years in northeastern Canada. Ice-sheet glaciers formed at this time advanced southward from Canada through the Great Lakes Region as far south as the Ohio and Missouri River Valleys. As the glaciers moved southward, they wore away the underlying rock surface picking up rock fragments and particles. These materials, in turn, were tumbled, reduced in size, and mixed throughout the glacier, only to be deposited later as hills, ridges, knolls, and irregular plains of clay, silt, sand, gravel, and boulders, or mixtures thereof, as the ice front melted.

Stream valleys and channels in softer rock material were widened and deepened by the glaciers as they followed the paths of least resistance. Later, many of these valleys were completely filled by deposits from the glacier. Today, little or no surface evidence exists to indicate the presence of these valleys. Other features, such as the large basins containing the present day Great Lakes, were part of major pre-glacial drainage systems and natural channels for the advancing ice and were only partially filled by deposits from the retreating glaciers (Dorr & Eschman 1970, Hough 1958).

Four major advances and withdrawals of glaciers took place over what is now the State of Michigan. Each major advance and withdrawal was characterized, locally, by innumerable minor advances and retreats -- fluctuations of the ice front. The last major glacial advance and withdrawal played a most important role in the development of the state's present day landscape and consequently its industrial sand deposits.

As the climate changed, the last major glacial advancement ended and the withdrawal of the ice sheet from the southern Great Lakes region began. The receding glacier melted and deposited its rock fragments and particles, building and shaping the landscape which, in some instances, still exists today with little change. On occasion, the ice front would fluctuate due to minor readvances and withdrawals and larger accumulations of glacial deposits would build up. These took the form of a series of parallel hilly ridges extending for several miles and rising above the surrounding landscape. Such features, referred to as end moraines, tended to divert the drainage of meltwaters emerging from the ice front and at times acted as dams which held back the melting water and created pro-glacial ponds or lakes.

Continued withdrawal of the ice sheet eventually exposed parts of deeply eroded basins which in turn filled with glacial meltwater and with rock and mineral material released by the glacial ice, thus creating the ancestral Great Lakes (Hough 1958). These earlier Great Lakes were generally larger in size and experienced higher water levels because of the damming effect of end moraines. With time, water overflow from these dammed impoundments lowered the lake outlets, or the receding ice uncovered previously blocked lower water outlets, and the lake levels assumed relatively lower elevations. Thus, in the 15,000 years since their inception, the levels and sizes of the lakes occupying the Great Lakes basins have varied as much as several hundred feet. Levels in the Lake Michigan basin have been as high as 640 feet and as low as 230 feet above sea level as compared to the present elevation of 579 feet (Kelly and Farrand, 1967).

Along with changes in lake levels, wave and wind action slowly reworked the material deposited by the glacier. The lighter particles were carried away by wave and current action to be deposited in the quieter, deeper offshore waters while heavier particles were left behind. Wave action continued to modify particles by grinding off the edges and rounding them. While this process was taking place the wind dried the beaches and carried small sand grains inland. Again, the larger sized particles could not be transported and were left behind. Boulders and vegetation created obstacles to this movement resulting in modifications along the shoreline (Olson, 1958). Examination of dunes formed in the manner described above will reveal that the larger sand grains are found on the lake or windward side of the dune and the somewhat smaller grains on the leeward or inland side.

Over a period of several thousand years, dunes eventually migrated in the direction of prevailing winds. As vegetative covers became established, dune movement was stabilized. Dunes remain fairly stable until overgrowth is removed by natural or artificial forces. This process is still at work today.

Dune sand in Michigan exhibits unique, inherent properties not found in most other common glacial sand. Dune sand is composed almost entirely of the silica mineral called quartz. Silica content may reach 97 percent in some sand dunes as opposed to 50 percent or less in some of the more common sand found in other parts of the state. Other minerals sometimes found in the sand deposits include magnetite, garnet, zircon, and ilmenite. Dune sand grains generally are similar in size, shape, and composition and it is these characteristics which make dune sand important as a mineral resource.

Sand Types and Their Location

In Michigan, there are three important dune areas where industrial sand is mined. These are 1) inland dunes, 2) coastal dunes, and 3) coastal sand strips (Kelly, 1971). A mineral resource with similar characteristics to dune sand is sandstone. This Paleozoic Sylvania sandstone is mined in only one very limited area of the state (Sherzer, 1911; Ehlers et al., 1951).

Inland dunes are sometimes located up to thirty miles or more from the present day Great Lakes shore. These are older dunes that were formed by wind action during higher lake stages some 8,000 years ago. Inland dunes usually exist in the form of ridges, small hills, and knolls found on ancestral lake beds and outwash plains. The best developed inland dunes may be 30 to 40 feet in height and are found predominantly in the eastern Northern Peninsula and the Saginaw Bay area. Inland dune sand usually has slightly higher silt and clay content, smaller, more angular grains, and a slightly differing chemical composition than coastal dune sand. In addition, being much older and not subject to as much wind and wave action as the coastal variety, these sand features are usually well stabilized with protective vegetative cover.

Coastal dunes are found predominantly along the eastern shoreline of Lake Michigan from the Indiana state line to the Straits of Mackinac. Additional dunes are found along the Great Lakes shoreline in eastern Saint Clair, Alger, Luce, and Houghton Counties. Coastal dune sand is generally free of silt and clay, has a common range of grain sizes, and is generally more rounded than other types of sand deposits. Coastal dunes usually reach a height of over 100 feet above the surrounding terrain and form prominent knolls, peaks, mounds, and ridges. When not stabilized by vegetation, they are extremely unstable and migrate in the direction of the prevailing winds. Good examples of coastal dunes may be found at Silver Lake State Park in Oceana County, Warren Dunes State Park in Berrien County, and in the Sleeping Bear National Lakeshore in Benzie and Leelanau Counties.

Coastal sand strips can be found along all of Michigan's Great Lakes shoreline. They frequently occur with very low, wind-formed ridges near present shorelines. In some places, however, this shore type may extend inland and are the most recently formed type of dune formation. Coastal sands are generally free of clay and silt and physically resemble sands found in the dunes. However, the sand usually has a higher proportion of carbonates, such as limestone and dolomite. Some people consider coastal sand strips to be the beginning stages of dune development.

The only sandstone deposit in the state presently used for industrial sand purposes -- the Sylvania sandstone -- is located in southeastern Wayne County. This unique white sandstone consists of small grains of silica, smaller than those of dune sand. Very few impurities are present. This sandstone deposit is important since Sylvania sand is used principally by the glass industry in making a variety of special glass products.

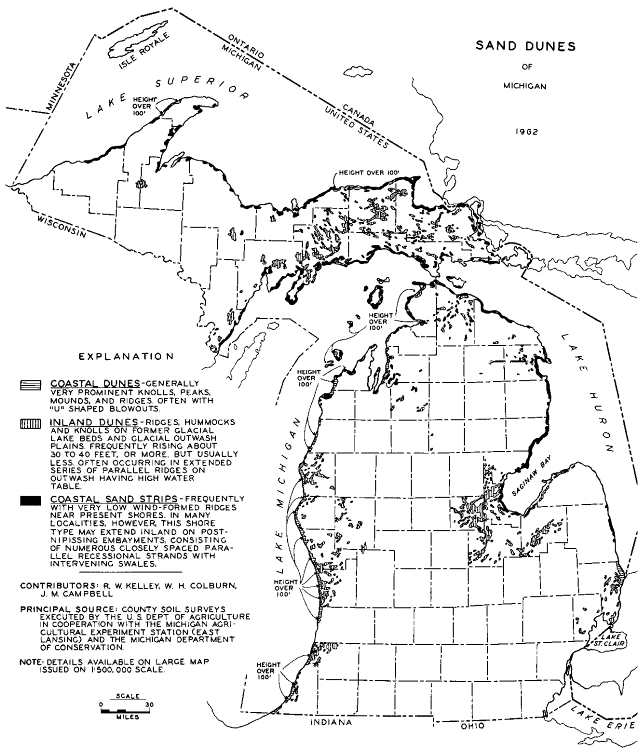

Figure 1 Dune sand areas of Michigan (after Kelly, 1971)

The mainland shore of Michigan is over 2,200 miles in length. Approximately 280 miles, or 13 percent, of this shoreline qualifies as coastal dunes and coastal sand strips. Most of the dunes are on the Lake Michigan side of the state. Included in this western shoreland are approximately 130 miles of high dunes (50 feet or higher) and 50 miles of low dunes (under 50 feet). Coastal dunes and sandstrips encompass a total of 67,645 acres. Public ownership accounts for 19,431 acres, or 29 percent, of the dune lands with the remainder in private ownership. Approximately 5 percent of the dunelands, consisting of privately owned sand dune property, are owned outright or leased by sand mining companies (Hotaling, 1974). One third of this land is being actively mined at the present time and has a calculated reserve life of 30 years. Therefore, at the present mining rate the sand companies have an estimated 100 years of minable reserves. Figure 1 shows the location of the coastal dunes and sandstrlps as well as the inland dunes mentioned earlier.

Sand Economics

Both mineral and sand mining industries have been on the Michigan scene for over a hundred years. Presently, industrial extraction of mineral products amounts to over $1 billion annually. Sand and gravel sold for construction purposes in 1973 had a value of over $65 million while sand for industrial uses amounted to over $14 million. Table 1 provides a further breakdown of the production and value of sand for industrial uses.

Use	1973		1974	
	Production	Value	Production	Value
Molding	4,466,000	10,402,000	3,824,000	11,682,000
Glass	535,000	2,018,000	1,262,000	4,245,000
Traction	295,000	710,000	32,000	103,000
Other*	433,000	1,087,000	231,000	463,000
Total	5,729,000	14,217,000	5,349,000	16,483,000

Production Rounded to nearest thousand tons.
Value Rounded to nearest thousand dollars.
* Includes scouring powder, metallurgical, furnace, and hydrofracing sand.
Source: Department of Natural Resources, Geological Survey Division files

Table 1 Production and use of industrial sand in Michigan

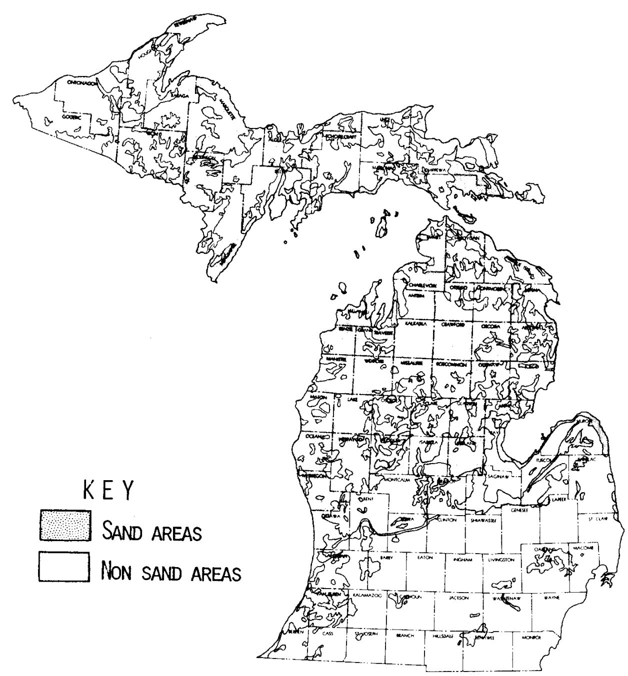

Figure 2 Michigan's major surface sand areas (Source: Abstracted from General Soil Map of Michigan, U. S. Department of Agriculture, Soil Conservation Service, 1972)

The location and extent of common, glacially derived, sandy soils in Michigan are shown in Figure 2. These soils are generally of no economic importance other than limited use as construction material. Their sand grains vary in size, shape, and mineral composition. Comparing Figures 1 and 2 amply illustrates the relatively small reserves of potential industrial-quality sand compared to vast deposits of unsuitable, sandy, glacial soils.

Historically and economically, those industries concerned with specific mineral utilization are located near a minable source of supply of that mineral. The foundry industry, which is dependent upon several mineral commodities, originally followed the coal or lumbering industry for its energy needs. Another consideration for bulk mineral users was proximity to cheap water transportation. Raw materials not found at the site could be imported by water at a better competitive price while at the same time a more economical way to ship bulky finished products was at hand. Limestone and clay for foundry use were often secured locally and brought in by truck or railroad.

As the foundry industry evolved over time, its associated technology placed more stringent requirements on the quality of sand used in its metal casting processes. Early foundry sands often were imported from southeastern Ohio. During the late 1910's and early 1920's, larger and larger quantities of dune sand began to be used in Michigan's foundry industry as machines replaced manual labor and industrial expansion continued apace. New metal casting processes required higher quality sand. At this time, it was found that some Michigan sands could not only withstand the extreme temperatures needed for pouring molten steel but were also more durable, cheaper to mine, and required little or no treatment prior to use in the casting process. Sand with these same characteristics is also preferred by the glassmaking and other minor sand dependent enterprises.

Industry Needs

There are several major characteristics that sand must have for present day industrial uses in Michigan. To be of industrial quality, sand must meet certain prescribed chemical and physical properties, must be located near its market, and must be mined, processed and shipped economically.

From the industrial viewpoint, location of proven sand resources relatively near to market or to transportation facilities is second in importance only to the quality of the sand deposit. Sand, as well as the metallic ores, is a stock resource.① Because this stock resource must be transported to the market, transportation costs are an important economic factor. The product needs to be transported at minimal cost. Long distance hauling cost is minimized by ship and rail transportation. Shorter haulage is usually provided by truck and is more expensive. In many cases, transportation charges are several times more costly than the mined value of the sand itself.

In addition to location, sand must be available in sufficient quantities to assure its long-term availability to the industry. Availability of the resource must also be coupled with reasonable access to the resource itself. Public or private land ownership and local regulations; for example, all affect the industry's capability of mining sand resources.

Mining costs are another important consideration of the industry. The more expensive the extraction process the greater the cost that must be passed on to the consumer of the final product. Included in the cost of mining are blasting, removal of overlying rock and soil (overburden), mechanization, and reclamation of the mined area.

*① **Definition**: Stock Resource; An "in place" resource which must be extracted to have value and which is nonrenewable when the source is depleted.*

The last major consideration of the sand mining industry is ore processing costs. Processing costs, like mining costs, must be kept as low as possible. The final product -- industrial sand -- must be nearly free from deleterious or undesirable minerals. Added treatment costs to remove unwanted material in processing raw sand increases the market price accordingly. Both the foundry and glassmaking industries must adhere to their own particular stringent physical and chemical sand specifications. Changes in processing techniques utilizing less desirable types of sand would require changes in technology with an attendant increase in cost.

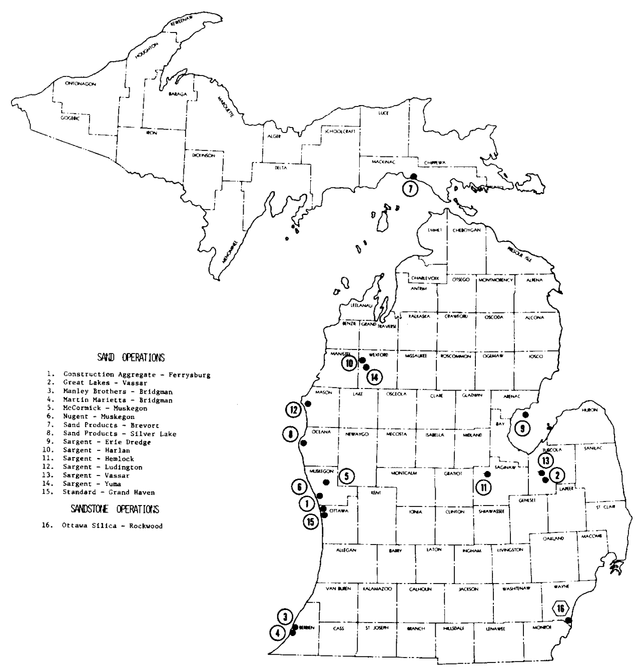

Figure 3 Location of industrial sand producers in Michigan

There are presently ten companies involved in the production of industrial sand in Michigan. The locations of sand producing operations are shown on Figure 3. These companies supply sand to a number of users in the Great Lakes Region. In 1973, they supplied more than 90% of the sand used by foundries associated with the American and Canadian automotive industries. Nationally, they furnished nearly 50 percent of the total sand used by the foundry industry as well as a considerable amount of sand for the manufacture of glass. Michigan leads the nation in the production of industrial sand. Table 2 and Figure 4 show industrial sand production and market value for the years 1958-74.

Year	Quantity**	Value***
1974	5,349,000	16,483,000
1973	5,729,000	14,21 7,000
1972	4,867,000	10,984,000
1971	4,591,000	10,479,000
1970	4,757,000	9,247,000
1969	5,357,000	11,145,000
1968	4,927,000	9,754,000
1967	3,971,000	8,269,000
1966	4,435,000	8,713,000
1965	3,948,000	7,750,000
1964	3,422,000	6,651 ,000
1963	2,851,000	5,577,000
1962	2,004,000	3,468,000
1961	1,693,000	2,498,000
1960	1,699,000	2,719,000
1959	1,919,000	2,849,000
1958	1,792,000	2,321,000

* Includes sand and sandstone.

** Rounded to nearest thousand tons.

*** Rounded to nearest thousand dollars.

Source: Department of Natural Resources, Geological Survey Division files

*Table 2 Industrial sand production in Michigan 1958 to 1974**

In terms of the industry's economic impact, a recent newspaper article stated that there are 1,334 foundries employing 144,000 people that use sand from the Lake Michigan area (Muskegon Chronicle, 1975). The foundry business, which depends upon sand for making cores and molds, is the eighth largest industry in terms of goods and services produced in the United States. In 1974, the ten Michigan companies involved in sand mining employed an estimated 575 employees with a payroll of nearly $8 million. These figures do not include employment taxes paid and other fringe benefits accruing to this labor force.

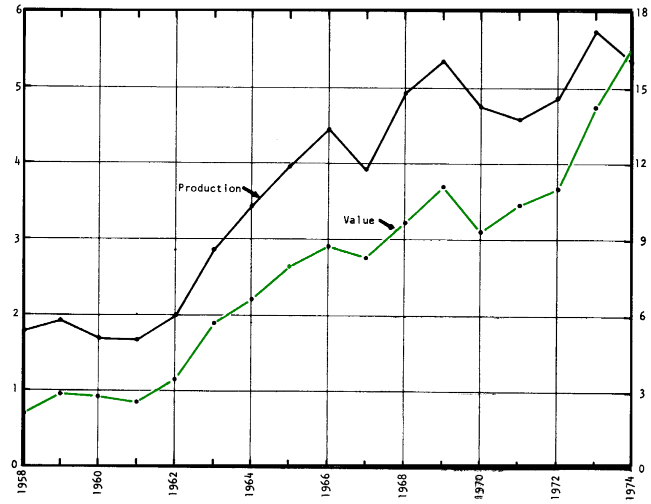

Figure 4 Production and value of industrial sand in Michigan 1958 to 1974.
Production is in million tons (black line), value (green line) in million dollars

Sand casting and glass making are two of the oldest industrial processes known. There is hardly a manufactured product made or an industrial process used that does not utilize some form of these two industrial techniques in its makeup or in its fabrication. The fixtures and tools used to make almost all manufactured products are made from sand castings. The tools to make these tools were made from sand castings -- and so on ad infinitum. Therefore, any decision affecting the cost and availability of industrial sand will have a wide reaching, multiple effect on the cost and availability of almost every manufactured product and its competitive advantage in the market place. The elevated financial position of the foundry industry attests to the economic importance of this prosaic basic product called industrial sand and its total impact on all other industries and the cost of almost all fabricated goods sold.

Table 3 illustrates the relative proportion of sand extracted in Michigan and the nation used in the foundry and glassmaking industries. The requirements for each of these enterprises is somewhat different in that sand used in the glassmaking industry must meet more rigid chemical and physical specifications (Bownocker 1926). These requirements, in turn, determine the quality of the resource that can be mined, the type of sand deposit tapped, and the mining and processing methods employed.

Early foundries removed natural sand from small pockets along river banks and local sand hills as their needs dictated. These sands were a composite mixture of sand, clay, and other materials. Since the early 1900's, industry demands and its associated advancing technology created the need for unbonded sand. Unbonded sand has very little clay or other impurities present. Dune and coastal strip sands and crushed sandstone are the leading sources of unbonded sand. The industrial advantages of unbonded sand are: (I) more uniform grain size, (2) greater tolerance to heat, (3) less bonding material and moisture required (additives), (4) workability, and (5) greater suitability for a variety of foundry uses.

	Glass	
	Tons*	Value**
California	1,.421,000	7,154,000
Illinois	904,000	2,450,000
Michigan	535,000	2,018,000
New Jersey	2,118,000	9,798,000
Other ***	5,593,000	21,724,000
Total	l0,571,000	43,144,000
	Molding	
	Tons*	Value**
California	W	W
Illinois	710,000	2,537,000
Michigan	4,466,000	10,402,000
New Jersey	808,000	3,900,000
Other ***	3,039,000	11,702,000
Total	9,023,000	28,541,000

W Withheld
* Rounded to the nearest thousand tons.
** Rounded to the nearest thousand dollars.
*** Includes remaining 19 producing states and figures.

Source: U. S. Bureau of Mines Yearbook - 1973 and State of Michigan, Department of Natural Resources, Geological Survey Division.

Table 3 Glass and molding sand production of the leading producing states in 1973.

In order to standardize these advantages, a series of specifications have been developed concerning the physical and chemical properties of unbonded sand (McLaws, 1971). Rigid specifications are necessary for both the foundry and glass- making industries to maintain quality control. These specifications must be met by the sand producer. Several of the parameters used in unbonded sand specifications are uniqueness of mineral type, grain shape, similarity of grain size or fineness, and amount of other minerals present. Figure 5 illustrates a variety of washed sand grains from several selected locations in Michigan.

One of the prime indicators of superior sand quality is fineness of grain size. Grain fineness is a measure of the amount of sand passing through screens with specified mesh openings. Table 4 shows the sieve analyses of selected Michigan sands. Coastal dune sands usually have fineness ranging from 46 to 50. Inland dune sands are generally finer and range from 50 to 75. Grain size and shape affect both the escape of hot gases from the molten metal poured into the mold and surface texture of the casting (Dietert, 1966). The finer the sand used the smoother the finish. Generally speaking, the finer grained sands are used on smaller size castings. Extraneous material, such as clay or broken grains, will plug off the pore spaces of the mold causing blistering, pock marks, and possible weakening of the casting. The sand grains themselves must be durable so that the sand may be reclaimed and reused time after time -- up to 25 times or more -- depending on the type of casting and technique employed. The chemical quality of the sand is also important. The sand must contain less than 2 percent calcium or magnesium carbonate. If too much carbonate is present it reacts with acid based binding material and causes the prepared mold to lose requisite strength. Other extraneous minerals such as mica and feldspar cause the mold to react with the molten metal causing abrasions and weakening of the cast. Table 5 shows chemical analyses of some Michigan sands. Special attention should be focused on the high silica contents and the low calcium-magnesium-carbonate content of industrial quality sands.

The quality of sand used for glassmaking is much more restrictive. Specifications for glass sands generally require a specific range of grain sizes which produce even melting. Chemically, the sands must be over 98 percent pure silica and contain practically no impurities, especially metallic oxides. As little as .001 percent of certain metallic oxides will impart color to glass. Other included minerals with high melting temperatures, such as garnet, will cause "stones" or spots to appear in the finished glass. Most glass companies prefer to have nearly pure silica sand (99.5 percent or greater purity) to which they will add their own desired special ingredients. This is particularly true in the case of optical glass. Table 5 shows the chemical analysis of sandstone mined near Rockwood which is the major source of glass sand in Michigan. Note the very high silica and very low metal oxide content. Some fiberglass and amber colored glass bottles are made from processed sand from Bridgman and Muskegon.

Mining, Processing, and Reclamation

As previously mentioned, sand mining in Michigan is concentrated along the Lake Michigan shoreline with some mining taking place at inland locations. Seven companies operating along the shoreline produce more than 90 percent of the total industrial sand used by foundries in Michigan and neighboring Great Lakes states. Four companies are mining sand and sandstone in the interior of the state for local usage. These ten companies mine sand by one or more standard methods including: (1) surface mining, (2) dredging, and (3) hydraulicing (4) drilling and blasting.

Surface mining is the most common method of sand extraction. In this process, a front-end loader or crane with a clam shell is used to move sand (see Figures 6A and 60). Sand is removed from the dune and loaded directly into a hopper where it is rough screened. After screening it is either loaded into trucks or onto conveyor belts and transported to a storage stockpile.

Michigan locality	U. S. Standard sieve number			Company

	30	40	50	70	100	140	200	Pan	GN	%Clay	
	Opening in millimeters (mm)										
	0.59	0.42	0.30	0.21	0.15	0.10	.07				
Bridgman [c]	N.A.	2.8	19.4	54.4	17.2	0.8	0.2	0.2	50	0.3	Manley Brothers of Ind., Inc.
Bridgman [c]	0.3	2.9	28.3	51.8	16.0	0.6	0.1	0	50	0	Martin-Marietta Corp.
Ferrysburg [c]	0.3	4.0	28.2	50.6	16.6	0. 3	-	T	47-51	0.2	Construction Aggregate Corp.
Muskegon [c]	1.9	9.8	34.I	37.5	15.0	1.4	.2	0.1	48	0.025	Nugent sand Company, Inc.
Silver Lake [c]	0.2	4.4	28.4	43.8	22.8	0.4	0.0	0.0	51	N.A.	Anonymous [3]
Ludlngton [c]	0.2	5.5	39.8	48. 7	5.4	0. 3	0.0	0.0	46	0.0	Sargent Sand Company
Manistee [c]	0.6	10.4	55.8	32.2	2.6	0. 2	0.0	0.0	43	0.0	Sargent Sand Company [2]
Cross Village [c]	0.5	2.5	78.9	17.7	0.4	0.0	0.0	0.0	42	N.A.	Anonymous [3]
Saginaw Bay [b]	1.9	6.9	28.3	46. 3	14.5	1.4	0.1	0.0	49	0.0	Sargent Sand Company
Bridgman [i]	0.2	1.2	5.4	20.2	36.4	27.2	8.6	0.62	79	0.7	Manley Brothers of Ind., Inc.
Muskegon [i]	0.1	0.5	5.6	22.0	43. 1	20.3	7.6	0.8	75	0.015	McCormick Sand Corp.
Vassar [i]	0.0	0.3	0.8	11.1	45.5	27.8	11.1	2.5	90	1.0	Great Lakes Foundry Sand Co.
Yuma [i]	2.2	11.0	30.5	34.8	16.5	4.3	0.6	T	50	0.0	Sargent Sand Company
Rockwood [s]	-	4.2	30.7	32.8	33.3	8.4	0.5	0.0	55	0.0	Ottawa Silica Company
Rockwood [s]	-	0.5	5.2	20.4	47.2	24.1	2.1	0.0	73	0.0	Ottawa Silica Company

b - Saginaw Bay sand	I - Inland dune sand	1 - Percent retained on sieve	GN - Grain size fineness number
c - Coastal dune sand	S - Sylvania Sandstone	2 - Data supplied from field analysis	T - Trace
	N. A. - Not available	3 - Operatlon no longer in existence	

Table 4 Grain size analysis of some typical Michigan industrial sands

Michigan locality	SiO_2	Fe_2O_3	Al_2O_3	TiO_2	MgO	CaO	Na_2O	K_2O	Loss on ignition	Company
Ferrysburg [c]	93.47	0.70	3.65	0.09	0.39	0.67	N. A.	N. A.	0.49	Construction Aggregate Corp.
Muskegon [c]	94.41	0.51	3.22	0.06	0.09	0.14	0.42	0.91	0.32	Nugent Sand Company
Ludlngton [c]	96 62	1.90	0.3	0.15	0.03	0.8	0.20	N. A.	N. A.	Sargent Sand Company
Saginaw Bay [b]	96 90	1.40	0.4	0.11	0.05	1.0	0.10	N. A.	N. A.	Sargent Sand Company
Bridgman [i]	92 70	0.49	3.96	0.09	0.10	0.22	0.44	1.62	0.42	Manley Brothers of Indiana
Muskegon [i]	92 00	0.57	5.02	N. A.	N. A.	N. A.	0.52	2.05	0.31	McCormick Sand Corp.
Vassar [i]	90.16	1.18	4.66	0.25	0.10	0.21	2.79 t		0.65	Great Lakes Foundry Sand Co.
Yuma [i]	96.16	1.80	0.5	0.1	0.8	1.0	0.35	N. A.	N. A.	Sargent Sand Company
Rockwood [s]	98 95	0.10	0.04	0.01	0.24	0.26	N. A.	N. A.	0.49	Ottawa Silica Company

b - Saginaw Bay sand	i - Inland dune sand	t – total Na_2O + K_2O
c - Coastal dune sand	s - Sylvania Sandstone	N.A. - Not available

Table 5 Chemical analysis of some typical Michigan industrial sands (chemical composition in percent)

Figure 5 A ***Coastal dune sand***
from Hamlin Township, in Mason County has smooth, well rounded, uniformly sized grains that are free of contaminants. This sand meets the most exacting standards of the foundry industry and is widely used.

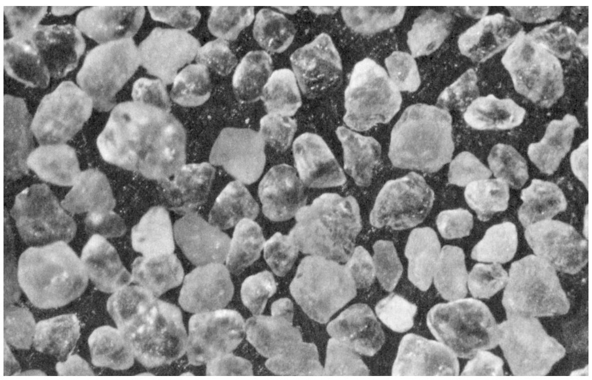

Figure 5 B ***Inland dune sand***
from Covert Township in Berrien County has similar characteristics but finer grain size. This sand is used in making fiberglass and amber glass and is sometimes blended with coastal sand for various foundry uses.

Figure 5 C ***Coastal sand***
from Saginaw Bay off Arenac County also has a uniformity of grain size and shape and is generally free of contaminants. The grains are not very well rounded and are only fairly smooth. This sand has limited foundry use.

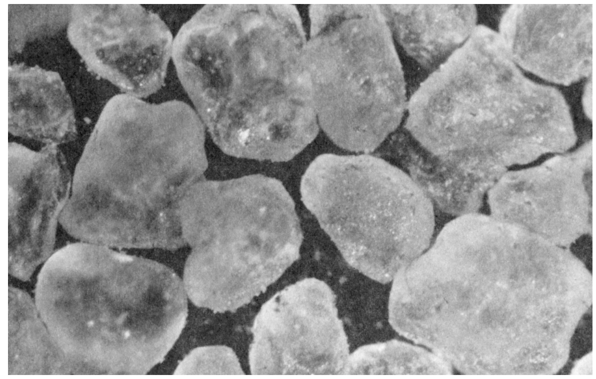

Figure 5 D ***Old coastal beach sand***
from Little Traverse Township, Emmet County has large, uniformly sized, sub-rounded grains. The sugary appearance of the grains is caused by pitting and coating. This sand is unsuitable for industrial use.

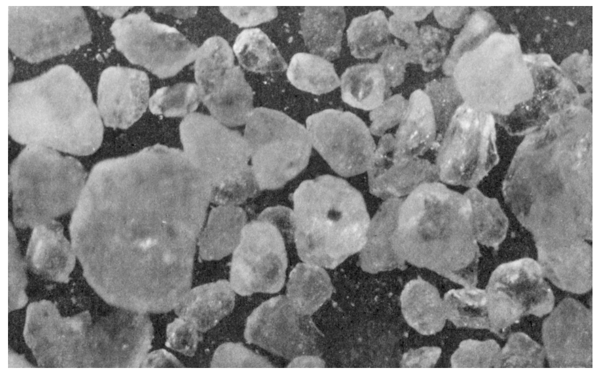

Figure 5 E ***Glacial outwash sand****,*
Hamburg Township, Livingston County is made up of assorted grain sizes, shapes and roundness. The pits and fractures contain clay. Although free from deleterious minerals, this sand is undesirable for industrial use.

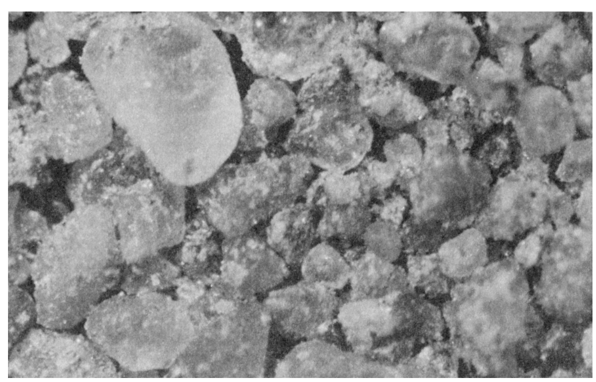

Figure 5 F ***Glacial outwash sand****,*
Stephenson Township, Menominee County is typical of most inland sand. The pitted and fractured grains vary in size and shape and are coated with carbonate, clay, and silt. This sand is undesirable for industrial use.

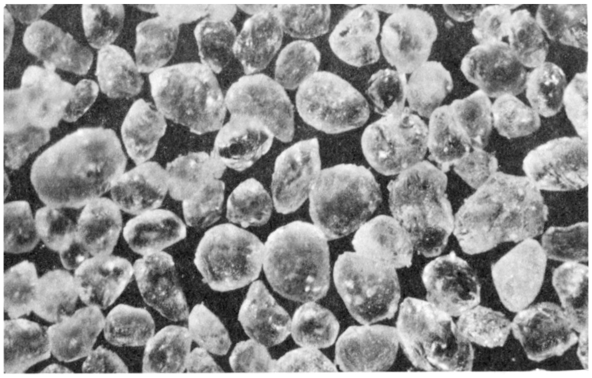

Figure 5 G ***Sylvania Sandstone***
from Brownstone Township in Wayne County is considered high purity silica and is made of well rounded grains of uniform size and shape. This clean, uncontaminated sand is highly desirable for glassmaking.

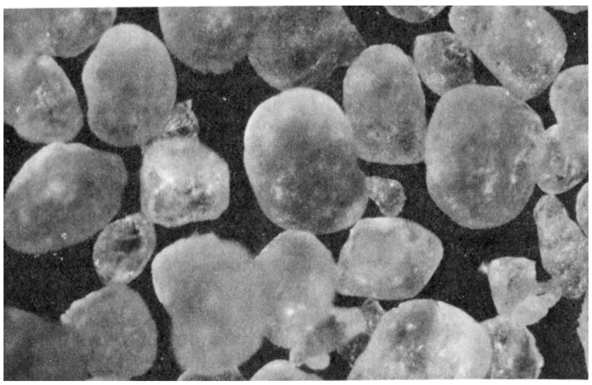

Figure 5 H ***Prairie Du Chien Sandstone***

from well in Stephenson Township, Menominee County, indicates potential high-purity industrial sand. The smooth, well rounded, uncontaminated sand grams may require sieving to achieve uniformity in size.

Figure 5 5 A through 5H - Sand grains from selected areas in Michigan. Photographs represent approximately 40 magnifications (40X)

Figure 6 A Sand mining methods - crane & clam shell

Figure 6 B Sand mining methods - front-end loader

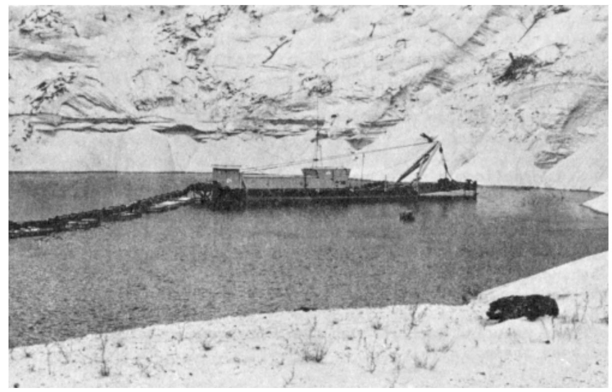

Figure 6 C Sand mining methods - dredge

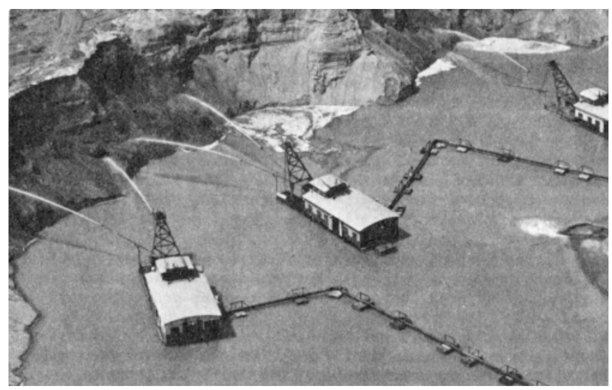

Figure 6 D Sand mining methods - hydraulic

The dredging method of sand mining is somewhat more costly and requires more elaborate equipment (Figure 6C). The principle of this operation is to jet water under high pressure against the dune bank or pond bottom making sand slurry. This slurry of riled sand is then sucked up by another pipeline and transported to a surge tank or storage pile. The water transporting the sand is recovered and returned to the pond. A dredge can mine sand to a depth of 50 to 60 feet below the water surface.

Hydraulic mining is very similar to dredging except the operation is conducted from a portable stand rather than from a dredge (Figure 6D). Water is ejected under several hundred pounds pressure from a swivel nozzle which is mounted on the stand. The pressurized water stream is aimed at a dune bank, washing it down into a small holding pond. From this point, the sand is pumped through a pipeline to a surge pile. Once the sand slurry reaches the surge pile, the water is drained off and recycled back through the high-pressure water line to be used again.

Unlike sand, loosely cemented sandstone usually requires drilling and blasting before it can be mined. After overlying soil and unwanted rock have been removed holes are drilled and explosive charges are placed in them and detonated. The rock is broken into pieces that are small enough to be handled by front-vend loaders. These pieces are loaded into trucks and transported to the plant for crushing and screening.

After the sand has been stockpiled, it is loaded onto a conveyor system and moved to a drying plant. Here, it is fed into a slightly tilted 6 to 8 foot diameter rotating drying cylinder. An oil or gas fired flame is jetted through the cylinder drying the sand. After leaving the low end of the cylinder, the sand is conveyed past blowers to cool. The sand is then removed to screening plants where it is sized and placed in storage silos. It is removed from the silo and blended according to specifications of the purchasing company before being shipped by rail or truck. Companies that utilize boat transportation usually ship directly without drying or screening. When the sand reaches its distribution point, it is then put through the drying and screening process before being used. Sand recovered from dredging and hydraulic operations are usually stockpiled to dry before further processing. Figure 7 shows a simplified schematic drawing of a typical sand producing operation.

Sands which are unusually high in calcium carbonate, such as inland dune and coastal beach sands, or sand mined below the water table are given a primary flotation treatment to remove some of the unwanted minerals. After flotation treatment they are conveyed to storage stockpiles, ready for processing.

For some companies, such as those that produce fiberglass, iron minerals are removed by passing the grains through magnetic separators prior to screening. Screening is then employed to classify the different sizes of sand which are later blended to meet the exacting specifications required by the purchasing company.

In the past, once sand was mined and processed, site reclamation was not considered important. Companies, when finished with the extraction of the resource, concerned themselves very little with what they left behind. Open pits, scarred unsloped banks, trash and unwanted equipment were all grim reminders that some type of extraction industry had come and gone. These vestiges of an industry concerned only with the extraction of a stock resource are rapidly disappearing. Unlike the past, extractive industries today are well aware of environmental degradation of the landscape. Recently proposed land use and environmental legislation, combined with an increasing awareness of many individuals, groups, and governmental bodies, has brought about this change in industry practices.

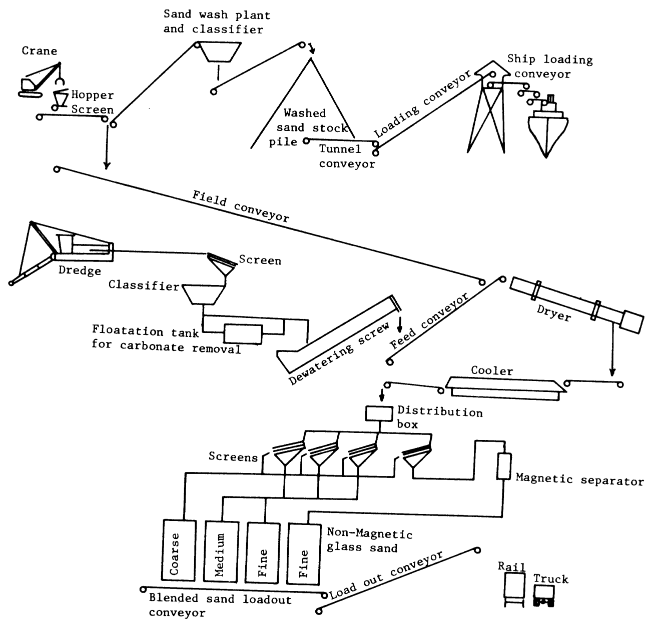

Figure 7 Simplified schematic drawing of a typical sand producing operation

Companies currently extracting minerals, such as sand, are progressively subjected to increasingly stringent governmental regulations. This, in turn, has fostered more concern by the industry in terms of both multiple and long-range use of the land they will leave behind. Professional consultants are available to examine and evaluate future alternative uses of an area, including revegetation and reclamation of the land surface for recreational, suburban, industrial, or other uses. While a disturbed area, where minerals have been mined, can never be totally restored to its preexisting condition, reclamation can, under the right conditions, provide alternative relevant uses that, in the past, were not properly considered.

Alternatives

The mineral resources of Michigan have in the past, and will continue in the future, to contribute to the growth and dynamics of the state and national economies. Michigan is an industrial state. Manufacturing is our number one industry in terms of total employment and monetary value. In 1973, Michigan ranked fourth in the value of metallic and nonmetallic minerals produced, fossil fuels not included. The industrial use of sand is a key component of the manufacturing industry. Molds made of sand are used to make metal castings used in nearly all other manufacturing processes. A wide variety of glass products are also made of Michigan dune sand.

Any stock resource, such as industrial sand, must, by necessity, be mined in place. Axiomatically, the further the resource is located from the market, the higher the transportation costs. Quality and demand also affect the price that a consumer must pay. Several possible alternative sources of molding and glassmaking material may now exist but with each alternative material utilized the cost of a marketable product will increase considerably. Demand for quality molding and glassmaking material by Industrial consumers continues to increase as the state's population and economy grow apace.

The first future alternative material for industrial use may include common sand which is of less desirable quality. These sands usually contain in excess of thirty percent clay and other undesirable mineral matter (Ries and Rosen, 1906; Brown, 1936). It is presently estimated that only 50 to 75 percent of common minable sand may be suitable for industrial use after additional upgrading. This sand will probably not be utilized in the near future because of high processing costs and the large amount of waste that would be generated because of its mineralogical make-up. In addition, the use of thin, low quality sand deposits will make it necessary to disturb proportionately greater land areas, with attendant environmental dislocations, in order to produce an equal amount of usable

A second alternative is to find comparable substitutes for dune sand for industrial uses. Presently, crushed quartz and quartzite might be considered as alternatives. However, the crushed fragments would be sharp and angular, consist of a variety of sizes and shapes, and contain a large amount of unwanted material. Therefore, at the present time, this can not be considered a viable alternative. The vast majority of massive quartz and quartzite reserves in Michigan are located in the western half of the Northern Peninsula. Even if they could meet industrial requirements, transportation costs would be exorbitant. Another source of sand is sandstone. In Michigan, there is only one sandstone formation presently being mined that would be partially suited for industrial use -- the Sylvania Sandstone in southeastern Wayne County. The cost of mining this sandstone is at least three times as much, if not more, then the cost of mining dune sand. The sandstone is of high quality and is used principally for the manufacture of glass. As high quality glass sands are fast becoming short in supply, the use of this sand by foundries will be severely limited. Other suitable sandstone resources might be found in the Northern Peninsula. Because these deposits are located at a considerable distance from the industrial market their suitability and marketability have not been thoroughly explored.

Some sands could be imported from outside the state (Jaster, 1957). At this time the only suitable sand available is the Saint Peter Sandstone mined in Illinois and Wisconsin (Ostrom, 1971). This is an extremely high purity sandstone used mainly for glass and metallurgical purposes. If the foundry industry is willing to pay the higher price and the additional cost of transportation, this sand would be entirely suitable. Other potential industrial sand deposits might be found in Indiana and other nearby states (Carr, 1971; Olson, 1970). Better, high-quality, high-temperature sands, such as zircon, are found in Australia (Miles and Stephens, 1950). These sands could conceivably be imported but would be even less of a feasible alternative because of their high cost.

Dredging off the Great Lakes shorelines might be considered as the most promising alternative at the present time. As with other sands, only certain areas could be dredged because of the physical and chemical properties of the sand and the relatively greater amount of impurities present, such as clay and silt. In addition, the producer must invest considerable capital in a large seagoing dredge thereby adding to his mining costs and subsequently the value of the marketable product.

The last major alternative to be considered would be a change in technology by those industries involved in the manufacture of cast-metal products. Obviously, this would entail a great capital expenditure of both time and research which would directly affect not only industry alternatives but marketability as well. This alternative, along with the importation of sands from outside national borders, cannot be considered viable substitutes for Michigan dune sands because of their relatively high cost.

The opinions expressed in the Conclusion section are those of the author and do not necessarily reflect the views or policy of either the Michigan Department of Natural Resources (DEQ) or the Geological Survey.

Conclusion

Today, the industrial sand mining industry faces an uncertain future. This industry, like many other extractive industries, is being subjected to increasing public and governmental pressure to severely limit or stop its sand mining operations, especially along Lake Michigan's shoreline areas.

Dune sand is preferred by industrial consumers because of its chemical and physical properties, ready availability, and agreeable price. Sand mining operators prefer to quarry dune sand because it is found in large volumes and is relatively free from excessive contamination and overburden. Compared to other sand sources it requires less processing, is more easily mined, and is close to bulk transportation facilities. The mining of thinner inland sand deposits usually require additional processing, more handling, and the disturbance of larger land areas. The additional consumption of time and energy to carry out all of these operations contributes to the increased cost of this basic raw material.

Current dune sand mining operations have an average estimated life of 30 years on lands now in production. Mining companies own, or have under lease, approximately 3,500 acres, or 5 percent, of Michigan's dunelands. Roughly one third of this land is presently being mined with the remainder reserved for future use.

With the increased concern about sand mining in Michigan we are now forced to make a decision: 1) Should all dune sand mining be halted along the Great Lakes shorelands; 2) Should dune sand mining be allowed to continue unabated as in the past; or 3) Should we seek a compromise to these opposing posit ions?

The elimination of sand mining within the Great Lakes shorelands is supported by growing numbers of ecologically minded citizens. They contend that the dunes and their fragile ecosystems should not be destroyed as they are vital to the ecology of the area and invaluable educational and recreational assets that should be preserved intact for future generations to study and enjoy.

The continuation of present mining practices is supported by equally concerned industrial opponents. They contend that Michigan is an industrial state and that industrial sand is the backbone of all basic industrial manufacturing in the state. Without dune sand our automotive and associated manufacturing industries would be forced to shut down or seek more costly alternatives.

The debate has been carried to the state legislature in attempting to work out a compromise solution in the form of House Bill 4038. The purpose of the bill is to provide for the protection of Great Lakes sand dunes by requiring permits for all sand extraction operations, to set up a responsible regulatory agency, and to provide penalties. If enacted, this law will require dune sand mining companies to file an environmental impact statement including (1) the effect of mining on the local economy, (2) the effect ?of sand extraction on surface and ground-water movement, (3) the effect of sand extractions on other surface resources, and (4) plans for reclamation of the area after mining has ceased. The operator will also be required to justify selection of the proposed mining site with alternative locations given. A fee would be assessed to finance state surveillance and regulation of mining activities after a permit is issued.

Many sand mining companies are actively engaged in vigorous exploration programs in Michigan and adjoining states to find additional or alternative sources of Industrial quality sand. Minor reserves of potential industrial quality sand and sandstone have been found. However, most of these sand resources at present are either less desirable chemically or less accessible to markets and bulk transportation facilities, and therefore cannot compete in the market place with Michigan dune sand at the present time. Encroaching urbanization and restrictive zoning regulations have made other large reserves of sand inaccessible for industrial use.

The consumptive user of industrial sand have adopted special technologies that are very selective in the types of sand that can be utilized. Given enough time and generous capital resources, they may be able to adjust their technologies to the use of more costly but less desirable sand from less environmentally sensitive areas.

Several questions arise concerning the overall aspects of sand mining that require an intelligent solution. Will the resultant added cost of consumer goods amidst deteriorating state and national economic conditions be justified in order to save every sand dune in the state? Does the preservation of these total sand dune ecosystems have a higher priority than suburban or commercial development or the production of dune sand for industrial purposes? We are faced with these and other choices

which will require a high level of tolerance and understanding by all special interest groups involved.. Let us hope that the wisdom of our choice of solutions will serve as a model for the many future decisions that will have to be made regarding environmental protection versus development and use of our basic non renewable raw materials.

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