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Wisconsin Sand and Gravel Mining:
From 19th Century Gravel Pits to 21st Century Frac Sand Mines
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Thomas Rademacher

Metallic mining has a more flamboyant and colorful history than nonmetallic mining because it inspires images of lawless boom towns, men who strike it rich searching for gold, and environmental damage. The metallic mining rushes and disastrous working conditions of coal mines are in the collective consciousness of many citizens of the United States. Every high school student in the U.S. is familiar with the California Gold Rush, the mining towns of the old West, and the environmental damage that can result from irresponsible mining practices. Furthermore, most people knowledgeable of Wisconsin history have heard about the lead and zinc mining region of the southwestern part of the state or the iron mining in the north. It may be true that metallic mining and mining for fuel have played an integral part in shaping the settlement of the U.S. and the knowledge of its citizens, but it is also true that nonmetallic resources have shaped the U.S. in equal proportions. The impact of materials such as sand and gravel is much less well known than that of metals because they do not inspire the same imagery. Sand and gravel mining never influenced settlement patterns and typically does not have boom or bust periods. Its production is methodical, mundane, and consistent. A relentless demand for new roads, bridges, dams, and buildings drives its production.

The tendency for people to ignore aggregate materials and focus on metallic resources is exemplified in the scholarship surrounding the mining industry of Wisconsin. Very little has been written about sand and gravel, and few people seem to appreciate humanity's dependence on it for developing society's infrastructure. Sand and gravel has been the most valuable mineral resource in Wisconsin for at least the past 60 years. Nonmetallic resources are the cornerstone of mining in Wisconsin. According to the United States Bureau of Mines & United States

Geological Survey's Mineral Yearbooks, from 1952-2013 sand and gravel was the most valuable material mined in Wisconsin 36 of the 62 years. Furthermore, from 1952 to 1981 sand and gravel held the top spot 26 of the 30 years. It has been surpassed by stone 26 times. Although this may seem like a lot, this number is inflated due to a change in classifications in 1981. This change split sand and gravel into construction and industrial materials and made sand and gravel appear to be less valuable than stone. If these categories are recombined sand and gravel continues its consistent dominance as the most valuable mined material in Wisconsin from 1952-2013. In terms of Wisconsin's metallic resources, no metal has ever been the most valuable material mined in Wisconsin from 1952 onward.[1]

Although sand and gravel have generally been neglected, author Lawrence A. Roe included a chapter focused on these materials in his book *A History of Wisconsin Mining*. He began by including a quote from James D. Cooper of the U.S. Bureau of Mines that stated, "The importance of sand and gravel in the United States is illustrated by the fact that quantitative demand for these commodities is greater than the combined demand for the rest of the nonfuel nonmetallic minerals." Roe went on to explain that construction sand and gravel is the only mineral produced in all 50 states. Therefore, the demand for aggregate resources is at least equal to that of metals. Despite his acknowledgement of sand and gravel's importance, Roe also stated that "the history of industrial mineral production is not nearly as exciting as the story of the metal mining industry."[2] Roe describes sand and gravel as an important resource, but then down plays it to metallic mining even though there is evidence to suggest that it is as influential as metals. In fact, most concretes, plasters, and mortars require sand as a component, gravel is

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[1] United States Bureau of Mines & United States Geological Survey, *Mineral Yearbooks: Statistical Summary*, 1952-2013.
[2] Lawrence A Roe, *A History of Wisconsin Mining*, (Madison, WI: ROECO, 1991), 55.

needed for railroad ballast, and few, if any materials, can replace sand and gravel for construction.[3]

Despite sand and gravel's long standing presence as a mineral resource it is rarely discussed in Wisconsin's mining literature. Author of *Law and Mineral Wealth: The Legal Profile of the Wisconsin Mining Industry*, James A. Lake wrote that non-metallic resources were often ignored when calculating Wisconsin's mineral wealth despite their greater contribution than lead, zinc, and iron. Ironically, Lake then proceeded to also ignore these non-metallic resources in the rest of his book to focus on the metallic minerals.[4] Furthermore, in *Wisconsin History: An Annotated Bibliography*, the authors made no reference to the sand and gravel mining industry and explained in their annotation of Lake's book that there was little mining being done in the state in the mid-20th century.[5] Although this may be true of metallic resources, this is not the case with sand and gravel, which has been continuously mined in Wisconsin since the late 1800s. Sand and gravel was further undervalued in Robert C. Nesbit's *Wisconsin: A History*, where he did not mention sand or gravel resources.[6] When taking into consideration the abundant nature of aggregate materials in Wisconsin and the imagery that metallic mining creates, it is somewhat understandable that researchers have focused on the flashier metallic minerals. The excitement generated by metallic resources is attention that sand and gravel has historically not been able to create.

The lack of research conducted on the sand and gravel mining industry in Wisconsin has not been a serious issue until recently. With technological advancements to hydraulic fracturing,

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[3] Ibid.
[4] James A. Lake, *Law and Mineral Wealth: The Legal Profile of the Wisconsin Mining Industry* (Madison, WI: The University of Wisconsin Press, 1962), 13-14.
[5] Barbara Dotts Paul and Justus F. Paul, *Wisconsin History: An Annotated Bibliography* (Westport, CT: Greenwood Press, 1999), 147.
[6] Robert C Nesbit, *Wisconsin: A History*, 2nd ed. (Madison, WI: The University of Wisconsin Press, 1989).

a technique used by the energy industry to improve the productivity of deep oil and natural gas wells, the demand for Wisconsin sand has skyrocketed. Wisconsin sand is ideal for fracking, and is used to keep wells open to allow oil or natural gas to flow freely out of them. In 1984, Wisconsin produced over 1 million short tons of industrial sand valued at $11.8 million dollars. In the next twenty-six years Wisconsin's production increased to 3.6 million short tons in 2010 with a value that had skyrocketed to $156 million dollars.[7] If this is not astounding enough, Wisconsin's production of industrial sand and gravel in 2014 reached 38 million short tons valued at a whopping $3.1 billion dollars.[8] Just as land rushes and boom periods have drawn attention to metallic resources, the frac sand boom has drawn attention to Wisconsin's sand mining industry. It is now impossible to continue to ignore the state's rich nonmetallic mineral deposits.

To uncover the sand and gravel mining industry in Wisconsin, it is critical to consider a variety of sources that include publications on Wisconsin geology, landscape, and mining. This necessarily includes publications by the Wisconsin Department of Natural Resources and the Wisconsin Geological and Natural History Survey, as well as the United States Bureau of Mines and the United States Geological Survey. It is also these latter two organizations that published the Mineral Yearbooks, a yearly compilation of industry statistics on every type of mining across the United States. These yearbooks include production levels, value amounts, and usages of sand and gravel from 1931 to 2015. Additionally, when analyzing frac sand mining, it is essential to know about hydraulic fracturing technology, the condition of the oil and natural gas industries, and the infrastructure developed to handle its production and transportation. Therefore, it is

[7] United States Geological Survey, "The Mineral Industry of Wisconsin," *Mineral yearbooks area reports 1984 & 2010.*

[8] United States Geological Survey, "2014 Minerals Yearbook: Advance Release," *Silica*, October 2016.

important to examine newspaper and journal articles with various other publications related to the industry. Specifically, the Wisconsin Center for Investigative Journalism published an in-depth series on frac sand mining in Wisconsin that provides important insights. Lastly, Google Earth imagery can be viewed to see the physical impact that sand and gravel mining has made on the Wisconsin landscape.

Sand and gravel has progressed from a late 19th and early 20th century road building material to a 21st century component in hydraulic fracturing. Because of its various implementations and connection to the energy industry, it is potentially very lucrative while remaining relevant to today's society. A basic understanding of the history of this material is essential for handling the recent rush on the state's frac sand reserves. Moreover, sand and gravel mining permanently changes the natural landscape through its extraction, but also with its applications for features such as roads that alter the built environment of the state. This all means that sand and gravel can no longer be left out of Wisconsin's mining literature. With rich aggregate reserves and a tradition of quarrying and mining embedded in the state's culture, Wisconsin sand and gravel mining has a history deserving of being told and an industry worthy of being better understood. Sand and gravel mining in Wisconsin is a historic, versatile, and lucrative business that helped build the state's early roads, is used in several industrial applications, brings in millions of dollars every year, and permanently changes the environment. Furthermore, it has the potential to advance the state's economy and infrastructure, but only if citizens and policy makers choose to prioritize and embrace the industry.

Geological Foundations of Wisconsin Sand and Gravel

To understand mining, it is first necessary to know about geology. Mining, no matter what resource is being extracted, is completely dependent on geological formations. Wisconsin's

wealth in sand and gravel is due to its unique geology. Wisconsin does not have many metallic mineral deposits and those that it does are scattered throughout the state. Wisconsin has typically been renowned for things that reside on top of its landscape like dairy farms, lakes, breweries, and rolling hills. It's not so much known for what resides within or beneath its landscape like sand and gravel, glacial till, or other aggregates. Despite this, humans have always depended on materials that are taken out of the ground, whether it is crops like corn, wheat, or hops, or minerals like iron, copper, or sand and gravel. The quarries and pits of Wisconsin where sand and gravel is excavated, extend downward to take advantage of the resources below. Therefore, a discussion about mining cannot go very far without first considering geology.

Many of the sand deposits in the state are due to shallow seas that covered Wisconsin hundreds of millions of years ago. In the late Precambrian and early Cambrian time, North America had been eroded into a flat, sandy landscape. By about 500 million years ago, an encroaching sea covered Wisconsin. This sea deposited sand that had been eroded into tiny spherical balls by wind for over 100 million years. The sea was no deeper than 100 feet and would occasionally drain, leaving the sands exposed for a million years. Coarse sands and fine pebbles are the oldest Cambrian sediments to be preserved.[9] When the sea rose, about 490 million years ago, it spread far beyond Wisconsin with the start of the Ordovician period. By this time, the sea was about 20-30 feet deep, sand supplies had been well used up, and limestone was abundant. About 480 million years ago, the sea level fell, exposed the continent, and a new layer of quartz sand covered the land from the redepositing of Cambrian sand.[10] Much of this sand is still in Wisconsin today. The Cambrian and Ordovician formations contain excellent deposits

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[9] Robert H. Dott, Jr. and John W. Attig, *Roadside Geology of Wisconsin*, (Missoula, MT: Mountain Press Publishing Company, 2004), 10-12.
[10] Ibid, 14 & 17.

that can be used for industrial processes, like molding and filtering, and are sought after for their nearly pure silica content, uniformity, and accessibility. Furthermore, it was these depositions of sand millions of years ago that endowed Wisconsin with its valuable frac sand reserves.[11] This is the sand that the energy industry needs for hydraulic fracturing because Wisconsin "has some of the best frac sand in the country."[12] [See Figures 1 and 2 below for diagrams of Wisconsin's frac sand potential]

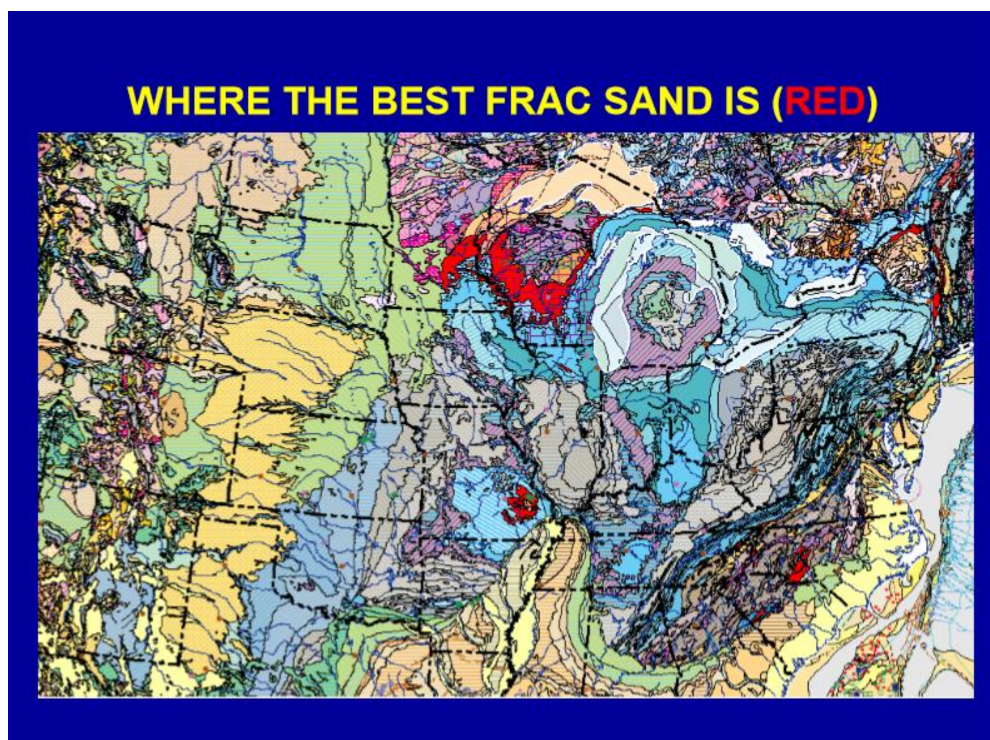

*Figure 1 "*Where the Best Frac Sand is (Red)." The majority of the best frac sand deposits reside within Wisconsin's borders and coincide with the Cambrian sandstones shown above. Bruce A. Brown, "Gold, Iron, Copper, Zinc, and Sand; What's Driving the New Interest in Mining and Mineral Resources in Wisconsin" (Madison, WI: Wisconsin Geological and Natural History Survey), 19, http://www.wisctowns.com/uploads/ckfiles/files/WTA_102511%20Frac%20Sand.pdf.

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[11] Sarah Karon, "Explainer: What Is Fracking?" *WisconsinWatch.org*, accessed September 26, 2016, http://wisconsinwatch.org/2011/07/explainer-what-is-fracking/.
[12] "Wisconsin Geological & Natural History Survey » Mining: Frac Sand," accessed September 26, 2016, https://wgnhs.uwex.edu/wisconsin-geology/frac-sand-mining/.

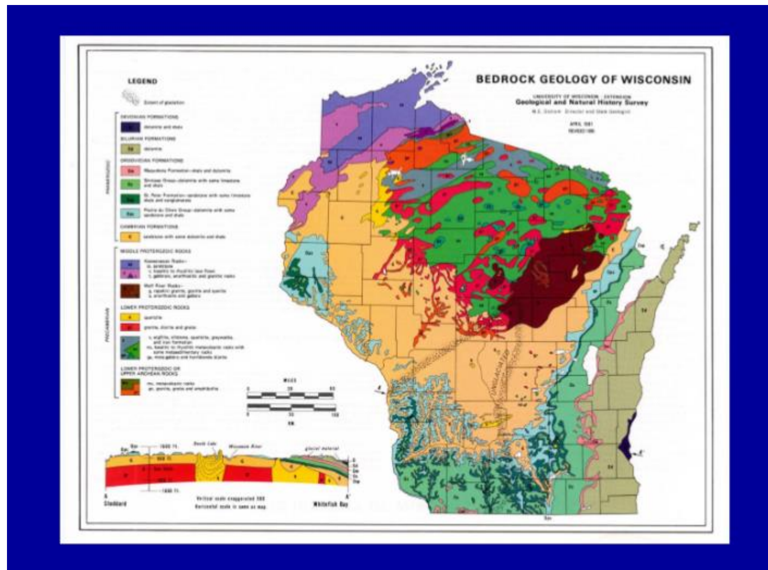

Figure 2 "Bedrock Geology of Wisconsin." The Cambrian Formation in Wisconsin colored in beige, coincides with the location of the best frac sand in the United States. Bruce A. Brown, "Gold, Iron, Copper, Zinc, and Sand; What's Driving the New Interest in Mining and Mineral Resources in Wisconsin" (Madison, WI: Wisconsin Geological and Natural History Survey), 4, http://www.wisctowns.com/uploads/ckfiles/files/WTA_102511%20Frac%20Sand.pdf.

In addition to the deposition by shallow seas, sand and gravel reserves are the result of glacial till (a mix of leftover debris carried by glaciers). One type of this leftover debris is eskers. Eskers are ridges of sand and gravel deposits from rivers that flowed in tunnels within layers of ice toward the glacial margin. When a glacier receded, the sand and gravel from these subglacial rivers and streams was left behind forming eskers.[13] For example, the Kettle Moraine is an accumulation of sand and gravel that was deposited by a river running on top of the ice sheet when the Green Bay and Lake Michigan lobes moved apart.[14] Eskers are easily recognizable and mined. Therefore, they were an early source of sand and gravel in southern Wisconsin where they were used for road and building material. Sand and gravel deposited in this way is a source of aggregate throughout much of the state.[15] In fact, as David Mickelson explained in *Wisconsin:*

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[13] Dott, Jr. and Attig, *Roadside Geology of Wisconsin*, 26.

[14] David M. Mickelson, "Wisconsin's Glacial Landscapes," in *Wisconsin: Land and Life*, ed. Robert C. Ostergren and Thomas R. Vale (Madison, WI: The University of Wisconsin Press, 1997), 42.

[15] Ibid, 46.

Land and Life, “aggregate typically comes from two sources: sand and gravel.”[16] Any concrete or asphalt that is used to build roads, driveways, parking lots, house foundations, or buildings needs large amounts of aggregate. Mickelson went on to explain that Wisconsin’s “roads and buildings are structurally strong in part because of the high-quality aggregate that is often derived from glacial outwash.”[17] With its unique geological formations, Wisconsin has been able to support a successful sand and gravel mining industry for over a century, whose applications are wide ranging and vary from building roads to extracting energy reserves.

Mining in Wisconsin: Lead, Zinc, Iron, and Nonmetallic Minerals

Although Wisconsin has a wealth of nonmetallic materials, the literature on the history of the state’s mining has focused primarily on lead, zinc, and iron. Understanding these materials is essential for contextualizing sand and gravel. The state’s early history was shaped by a demand for mineral resources, particularly lead. Deposits in the southwestern part of the state attracted settlers who founded communities in the region. Miners began arriving in the 1820s. By 1829 there were 4,000 of them who produced 13 million pounds of lead. During this time, lead was in high demand throughout the country for pipes, paint, and ammunition. The deposits in Wisconsin were an important part of the early 19th century United States economy.[18] Robert C. Nesbit, author of *Wisconsin: A History*, explained that lead was “a more effective magnet for American penetration of Wisconsin than either furs or farming.”[19] Thomas Evans described the southwestern part of the state, in the Wisconsin Academy Review, as “the birth place of

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[16] Ibid, 45.
[17] Ibid, 39-40.
[18] “Lead Mining in Southwestern Wisconsin |Turning Points in Wisconsin History | Wisconsin Historical Society,” accessed October 8, 2016, http://www.wisconsinhistory.org/turningpoints/tp-026/?action=more_essay.
[19] Nesbit, *Wisconsin: A History*, 106.

Wisconsin and the principal lead producer for the young United States of America."[20] The lead miners of southwestern Wisconsin helped shape the state's settlement patterns, transportation networks, and economy.

Despite its early success, lead mining peaked in the 1840s as miners exhausted easily accessible deposits and national demand slowed. Cornish miners, who had moved to Wisconsin specifically to mine lead, kept the region productive until around 1860.[21] Even so, as the gold rush took off in 1849, many miners moved out to California. Nesbit claimed that "the framework of the typical American mining camp of the West was laid here," because many experienced Wisconsin miners moved out West to participate in the Gold Rush and took their skills with them. [22] Although lead mining in Wisconsin extended into the 20th century, it was only productive for a relatively short time span. Despite this, it had a lasting symbolic impact on the state. The seal of Wisconsin incorporates a lead miner with a pick, the state's animal is a badger named after the dugouts lead miners made, the state's mineral is galena which is an important source of lead, and New Diggings, and Mineral Point are just a few of Wisconsin's early settlements that took their names from the early lead mining region. As Robert Dott and John Attig mention in Roadside Geology of Wisconsin, the state's first brewery was established in the lead district in Mineral Point in 1835 and the first capitol in Belmont in 1836.[23] There is no doubt that lead mining has had a lasting impact on Wisconsin. However, it has not been mined to any appreciable quantity for decades and has overshadowed other types of mining for too long.

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[20] Thomas J Evans, "Mining in Wisconsin: Where We've Been; Where We're Going," *Wisconsin Academy Review* 28, no. 1 (December 1981), 4.
[21] Nesbit, *Wisconsin: A History,* 116-117.
[22] Ibid, 117.
[23] Dott, Jr. and Attig, *Roadside Geology of Wisconsin*, 131 & 155.

Many miners who stayed in southwestern Wisconsin after the 1840s turned to farming or mining zinc. Zinc was often discarded as a byproduct in early lead mines, but people eventually realized that it could be sold as a commodity to be used in brass and batteries, to coat steel, and for die casting. By 1900, zinc production exceeded that of lead and peaked in the 1910s. Following World War I its production quickly decreased.[24] The last active zinc mine was in Shullsburg and closed in 1978.[25] Zinc mining often gets lumped into conversations about lead mining and the entire southwestern mining region of Wisconsin, but it too played an important role in the state's development. However, as Thomas Evans explained, "the mining heritage of our state is not solely the story of Southwestern Wisconsin." [26] Iron mining in the northern part of the state also played an important role in Wisconsin's growth.

Wisconsin's main iron ranges were the Mayville District, the Baraboo Range, the Black River Falls District, the Menominee Range, and the Gogebic Range. The Mayville District operated from 1892 to 1928 and produced over 2 million tons of ore. In contrast, the Baraboo range in Sauk County was open from 1904 to 1925, but only produced about 550,000 tons of iron ore. The Black River Falls District in Jackson County was mined as early as 1857 with periods of increased activity in the range until it was no longer profitable in 1983. Despite its long-standing operation, it was never able to produce large quantities of iron. The Menominee range was open from 1877 to 1955 and produced over 230 million tons of iron ore. However, most of this was produced in the Upper Peninsula of Michigan, and Wisconsin mines in the range only accounted for 7 million of the total tons produced.[27] The most productive range in

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[24] Roe, *A History of Wisconsin Mining*, 23 & 32.
[25] Bruce A. Brown, "Wisconsin's Mining Industry; Past, Present, and Future" (Madison, WI: Wisconsin Geological and Natural History Survey, 2010 2009), http://static1.1.sqspcdn.com/static/f/1103553/15601564/1323896729620/mining.pdf?token=NwtZer3cZIRcaVrjcqqXeJCT21A%3D.
[26] Evans, "Mining in Wisconsin: Where We've Been; Where We're Going," 4.
[27] Roe, *A History of Wisconsin Mining,* 38 & 40.

Wisconsin was the Gogebic Range that extends into the UP, of which 53 miles are in Wisconsin. The two largest Wisconsin iron mines were in this range and they were the Cary and the Montreal. The Cary mine went down as much as 3,350 feet and the Montreal mine opened in 1886 and produced 44.7 million tons of iron ore. Despite these successes, both mines ceased operations in the 1960s.[28]

The iron mining region in the north boomed in the 1880s following the decline of lead mining. However, Michigan cities in the Upper Peninsula profited more from the iron ore deposits in the Gogebic Range than their Wisconsin counterparts. Furthermore, iron mining in the north was created for the benefit of outside investors in the East who wanted to make quick money.[29] Author Lawrence Roe discussed the land rush in 1884 in northern Wisconsin when 184 mining companies were started. Two years later, only 15 of these companies remained. During this land rush, the town of Hurley was built up and by 1890 it had "58 saloons, 20 hotels, 4 oyster houses, two druggists and a Presbyterian minister."[30] Hurley became known as a stereotypical mining boom town of the West and developed a reputation as Wisconsin's "city of sin."[31] After WWII, the underground iron mining in Wisconsin could not compete with open pits in Minnesota and the last of the Wisconsin iron mines closed.[32] This iron region and the lead and zinc district in the southwest inspired land rushes and boom periods of great excitement. However, Robert Dott and John Attig, explained that "during the past century, lead, zinc, and iron mining have declined and ceased...but geologists continue to locate a variety of essential construction materials. These include stone for buildings, crushed stone as well as sand and

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[28] Roe, *A History of Wisconsin Mining,* 38 & 39.
[29] "Mining in Northern Wisconsin," Wisconsin Historical Society, accessed October 8, 2016, http://www.wisconsinhistory.org/turningpoints/tp-029/?action=more_essay.
[30] Roe, *A History of Wisconsin Mining*, 39.
[31] Dott, Jr. and Attig, *Roadside Geology of Wisconsin,* 77.
[32] Ibid.

gravel for road surfaces and for making concrete."[33] Although important to Wisconsin's early development, lead, zinc, and iron have not played a major role in mining production for over a century, while many nonmetallic materials have.

Gravel Pits of the Late 19th and Early 20th Centuries: Building Wisconsin's Infrastructure

The glacial period in Wisconsin endowed the state with rich geological reserves of aggregate materials that made it possible for people to excavate gravel pits in the late 19th and early 20th centuries. Gravel was an essential material to Wisconsin during this time because it was abundant, cheap, easily accessible, and could be used to improve the state's roads. Today, it is easy to forget how essential good roads are to modern society. However, automobiles and highways were not always as widespread as they are now. In Wisconsin, good roads were only achieved after a hard-fought victory by those who believed in their importance. In the mid-1800s, at the beginning of Wisconsin's statehood, local governments would raise a tax to fund roads. This tax was despised by farmers. Many of them chose to work it off on road crews rather than pay it. Unfortunately, these crews proved to be notoriously ineffective at building roads, and thus, the state's roads remained poor. At the beginning of the 20th century, only 17% of Wisconsin roads were improved with gravel or other similar materials. The majority were poorly built mud or dirt roads that were oftentimes impassible.[34] To understand how gravel played an integral role in building Wisconsin's infrastructure, it is important to understand the Good Roads Movement of the 1890s and the work done by the Wisconsin Geological and Natural History Survey through its road material research.

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[33] Dott, Jr. and Attig, *Roadside Geology of Wisconsin,* 32-33.

[34] Ballard Campbell, "Wisconsin Stories: The Good Roads Movement in Wisconsin, 1890-1911" (Madison, WI: State Historical Society of Wisconsin, 1980), Pamphlet Collection, Wisconsin Historical Society, 1-2.

The Good Roads Movement and the Wisconsin Geological and Natural History Survey (1895-1911)

The Good Roads Movement in Wisconsin began in the 1890s by bicycle enthusiasts who are credited with organizing the first major support for highway improvements in the state. Their activity of cycling was intimately connected with roads, and without decent quality ones, their sport of touring could not exist.[35] In 1895, bicyclists and leading businessmen came together and formed the Wisconsin League for Good Roads. It was "the first statewide highway improvement association in Wisconsin." While bicyclists joined for recreational purposes, businessmen were interested in roads for economic reasons that would mean better transportation of goods and supplies.[36] Farmers were highly skeptical of changes to road policy and protested state aid. It was not until 1901 that the Wisconsin Dairymen's Association officially supported state-financed roads.[37] Also in 1901, the Wisconsin legislature created the Good Roads Commission to find out if country roads needed to be improved. The Commission found that more people favored the idea of state-aid to improve highways.[38] With public opinion beginning to swing in favor of improvements, efforts could be made to locate possible materials and formulate methods of construction. The Wisconsin Geological and Natural History Survey (WGNHS) was at the head of these efforts.

WGNHS was responsible for determining sources for road construction materials during the early 1900s and evaluated gravel pits and quarries for concrete aggregate near new highways. They also evaluated mines and advised bridge and highway projects. In 1896, they published a map of all the quarries in the state that extended from the Wisconsin-Illinois border to the shores

[35] Ibid, 3.; Thomas Rademacher, "The Good Roads Movement in Wisconsin," Wisconsin 101: Our History in Objects, accessed April 29, 2017, http://www.wi101.org/?story=the-good-roads-movement-in-wisconsin.
[36] Campbell, "Wisconsin Stories: The Good Roads Movement in Wisconsin, 1890-1911," 6.
[37] Ibid, 7-8.
[38] Ibid, 11.

of Lake Superior. It identified over 50 in total, and every quarry on the map was on or near a railroad track. This map indicated the importance of transportation networks for these materials.[39] WGNHS also came out with a report in 1903 on highway construction in the state. The report found that eastern and southern Wisconsin had "inexhaustible" supplies of gravel, and that in "all parts of the state, except the southwestern, gravel is very plentiful."[40] The report even mentioned that gravel had been the most used material for improving highways over crushed stone or clays. It was usually the cheapest and applying a generous supply of it could greatly improve the condition of a road. However, the report also said that gravel was rarely a good idea for a permanent solution and was not by itself suited for heavy traffic. Therefore, gravel represented a step in the right direction toward ultimately paving a road.[41]

Although local, state, and national sentiment was moving toward developing networks of roads and highways, improvement efforts of the early 1900s were still minimal. To counteract this, the federal Office of Public Roads (OPR), under the leadership of Logan W. Page, sought "to teach local road supervisors the practical knowledge they needed to sustain effective road-improvement programs after OPR experts left town."[42] OPR helped city officials manage quarries to make use of local materials when building roads. Initiatives like this were underway across the country to ensure better infrastructure for transportation and the rise of the automobile. In fact, the WGNHS report from 1903 prophesized that the automobile could one day lead to the permanent development of roads and highways. It stated:

> There may come a time when the steel rail will be discarded in interurban and rural transportation, and be replaced by a smooth pavement. There may come a

[39] E. R. Buckley, "Map of Wisconsin Showing Location of Quarries" (Wisconsin Geological and Natural History Survey, 1896), https://wgnhs.uwex.edu/publications-home/.
[40] Ernest Robertson Buckley, "Highway Construction in Wisconsin" (Madison, WI: Wisconsin Geological and Natural History Survey, 1903), 32.
[41] Ibid, 89.
[42] Christopher W. Wells, *Car Country: An Environmental History*, Weyerhaeuser Books (Vancouver: University of Washington Press, 2014), 69.

> time when state and even trans-continental highways will be built of smooth, permanent pavements over which the automobile can travel with the same speed that the interurban car travels today.[43]

This declaration, made in 1903 when roads were predominantly gravel, sand, stone, or clay, predicted the rise of interstate highways and interconnected routes of transportation across the country and the state of Wisconsin.

As the Good Roads Movement was gaining steam, WGNHS made serious efforts to test a variety of road materials and to research costs. In 1906, they found that "both gravel and crushed stone may be spread upon a well-drained, well crowned earth road without any further preparation and in time will be beaten down by the traffic into a fairly good surface."[44] Furthermore, they explained that the cost of roads depended on the price of labor and the material, which was largely dependent on the distance it had to be hauled. "A well-constructed gravel road," the report stated, "should be about $300 to $350 per mile."[45] This equals approximately $7,500 and $8,800 today. The closer the material was to the road, the cheaper it would be to build. This meant that widespread reserves of gravel and other aggregates would make it much easier to construct roads throughout the state. In fact, Madison is an example of a city that benefited from widespread aggregates and owned a quarry to help decrease the cost of road building. Benjamin Charles B Tighe, for his PhD dissertation in 1908 at the University of Wisconsin, researched the Madison municipal quarry dating back to the 1890s. Tighe explained that in the 1890s, road material was "badly needed upon the public streets of Madison," and that this ultimately forced the city to purchase the quarry. By 1908, Madison had spent $17,771 on

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[43] Buckley, "Highway Construction in Wisconsin," xiv.
[44] William Otis Hotchkiss, "Rural Highways of Wisconsin" (Madison, WI: Wisconsin Geological and Natural History Survey, 1906), 28, https://wgnhs.uwex.edu/publications-home/.
[45] Ibid, 30-31.

the quarry, which in today's dollars would be $440,457.[46] This quarry supplied Madison with aggregate materials for its roads that helped to spur the city's growth, and illustrated the importance of aggregates to road improvement efforts. A need for public funding to improve and maintain roads was becoming more apparent to Wisconsinites.

By 1908, public opinion had moved in favor of state-aid due to WGNHS research and an increase in value for farm products that compelled farmers to want better transportation for their goods. In 1908, by a wide margin of 116,107 to 46,762, Wisconsin residents voted to make it constitutional for the state to provide aid for highway construction.[47] The state aid road law was officially passed three years later in 1911, making it possible for the state government to disperse funds to local municipalities and county governments to fund their road improvement efforts. Major railroads in Wisconsin even offered to haul road materials at reduced rates for state-financed highway construction projects.[48] By 1914, just a few short years after Wisconsin's state aid road law, all of Wisconsin counties were accepting state funding, and by 1918 23% of rural roads were surfaced. The State Aid Road Law marked the beginning of concentrated efforts to construct, improve, and connect road networks throughout the state that have shaped its current infrastructure. From 1907 to 1911, the state gave $10,000 ($243,000 today) a year for state aid, $400,000 ($9.5 million) a year in 1912, over $850,000 ($20.5 million) in 1913, and $1,230,000 ($29.3 million) in 1914.[49] Gravel roads replaced mud, and overtime, concrete, cement, and asphalt replaced pure gravel. The WGNHS survey explained in 1914 that:

> Wisconsin is exceedingly fortunate in having a great abundance of road material. There are few states in the Mississippi Valley which have road material of a

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[46] Benjamin Charles B Tighe, "An Historical and Financial Survey of the Madison Municipal Quarry" (University of Wisconsin-Madison, 1908), Wisconsin Historical Society Archive.
[47] Campbell, "Wisconsin Stories: The Good Roads Movement in Wisconsin, 1890-1911," 16-17.
[48] Ibid, 18.
[49] W. O. Hotchkiss and Edward Steidtmann, "Limestone Road Materials of Wisconsin" (Madison, WI: Wisconsin Geological and Natural History Survey, 1914), 1, https://wgnhs.uwex.edu/publications-home/.

> satisfactory character so widely distributed. Nearly every county in the state has within its boundaries material that will serve for the construction of the major portion of its roads...it is apparent that at present, and always in the future, it will be possible to build roads more cheaply in Wisconsin than in most of the neighboring states where material must be shipped long distances.[50]

The abundance of aggregate materials in Wisconsin had begun to fuel a rise in road improvement across the state.

Transportation Networks, Industry, and the Granite Gravel Company (1911-1934)

The rise in road improvement efforts across the state motivated Wisconsinites to find the most efficient and effective ways to build them. In 1911, the Wisconsin Highway Commission published a report on the cost of county aid roads across the state. A few counties listed were Dane, Columbia, and Brown. The difference in costs depended on charges for freight, crushing, and loading of the material and increased based on how far it had to be hauled. In all cases, roads could be built much cheaper when using gravel rather than crushed stone. The following year in 1912, the Wisconsin Highway Commission came out with a best practices guide on how to build stone and gravel roads. The guide explained proper grading, flushing, trimming, and trench work. It also discussed how to deal with fences and private entrances that might have been in the way, how to build culverts and bridges, and how to lay out subgrades. It emphasized that most of Wisconsin's roads would be built with a stone or gravel subsurface of about nine feet wide, and that from experience, this "has proven to be ample for 90 per cent of even the main traveled roads."[51] This same year, the Highway Commission came out with a list of the crushed stone producers of Wisconsin. It listed 44 total companies with mines across the state. Many, however, had offices in Chicago, suggesting that quarrying and nonmetallic mining in Wisconsin had

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[50] Ibid, 2.
[51] "Suggestions to County Highway Commissioners for Building Stone and Gravel Roads" (Madison, WI: Wisconsin Highway Commission, 1912), 6.

drawn interest from outside investors. People recognized the potential profits from selling construction materials for road improvement efforts. This list of producers also stated every railroad line that each mine was located on.[52] This again illustrated the necessity of having good transportation for heavy, low unit value materials like sand, gravel, and stone.

Further exemplifying the need for rail lines and transportation networks for nonmetallic materials, as well as the extent of business opportunities in Wisconsin's quarrying industry, was the Granite Gravel Company. Incorporated on August 8, 1914 in the Town of Kronenwetter in Marathon County, WI, by members of the 'Wausau Group,' the company hoped "to develop granite gravel for road purposes."[53] It held its first board of directors meeting on October 10, 1916 and maintained correspondence with the state Highway Commission and the Dean of the University of Wisconsin's College of Mechanics and Engineering. Mr. Hirst of the Highway Commission, on January 16, 1917, confirmed that the company's granite gravel was "very valuable for road making purposes," and the Dean of the University of Wisconsin's College of Mechanics and Engineering explained on February 19, 1917, that "this sort of material has been very successfully used for road work."[54] Unfortunately, the good news for the Granite Gravel Company stopped here.

After confirming that their product was valuable, the Granite Gravel Company's second order of business was to acquire a rail line that went to their property. Detailed in a letter from June 14, 1917, the Railway Commission of Wisconsin ordered the Chicago, Milwaukee, and St. Paul Railway to build and maintain a spur track directed toward the gravel pit that would be paid

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[52] "Crushed Stone Producers in Wisconsin" (Madison, WI: The State, 1912).
[53] Granite Gravel Company, "Secretary's Record and Stock Accounts," *A Combined Corporation Record and Stock Holders' Accounts of Granite Gravel Company Principal Office at Wausau Wisconsin*, Wisconsin Historical Society Archive.; "Correspondence, B.F. Wilson President July 9th, 1934."
[54] "Correspondence, Mr. Hirst of Highway Commission, January 16, 1917"; "Correspondence, Dean of the University of Wisconsin's College of Mechanics and Engineering on February 19, 1917."

for by the Granite Gravel Company. The Commission made this decision because the spur track would not exceed three miles, was not unsafe or dangerous, would not negatively impact the public, and was "practically indispensable to the successful operation of the petitioner's industry." A few days later in a letter on June 19, 1917 from C.B. Bird, the company's attorney, to B.F. Wilson, the company's president, Bird explained that it might be a good idea to let the business rest until the Northwestern moved a railroad down to where the mine was. Then, Bird explained, they could negotiate with them exclusively in a position of advantage rather than overpay for the St. Paul.[55] Although it is unclear from existing sources what negotiations were attempted, the result ended badly for the mine. Whatever decisions were ultimately made by the Granite Gravel Company and the railroad lines in their vicinity, no agreements were reached and a rail road track never extended to their gravel pit.

With no access to a rail road, the company had no easy way to get its product to market, and therefore, no way of making any money. Years passed and the gravel pit sat untouched. On May 15, 1924, a decade after its initial incorporation, the secretary of the company said in a letter to the Collector of Internal Revenue that the "corporation has no funds on hand."[56] Two years later, on May 20, 1926, Deputy Tax Collector E.J. Hopkins confirmed that "the Granite Gravel Company owns a potential gravel pit...It was thought at one time that a railroad spur would be built near it. Since this was not done, the pit has never been operated and therefore the company is a liability rather than an asset."[57] More years went by, and with still no rail road line, the gravel pit sat undeveloped and unworkable. B.F. Wilson explained a full 20 years after the company's founding, on July 9th, 1934 that "on account of this material not being used as

[55] "Correspondence, C.B. Bird to B.F. Wilson, June 19, 1917"; "Correspondence, Railway Commission June 14, 1917."
[56] "Correspondence with Collector of Internal Revenue, May 15, 1924."
[57] "Correspondence with Deputy Tax Collector E.J. Hopkins, May 20, 1926."

anticipated, nothing has been done to develop this property. We are simply paying taxes from year to year, hoping something may develop, so that we can make use of this material."[58] The gravel pit had little value, not because of the material itself, but because of its location. With no means of transportation, no money could be made. Finally, and mercifully, after more than 20 years of nothing but paying taxes on a plot of land and holding out hope for a railroad, the company was dissolved on October 8, 1937.[59]

Despite never transacting any business and always lacking a railroad line, the Granite Gravel Company attracted a lot of attention early on in its existence. Throughout 1914, the year Granite Gravel officially incorporated, the company received an onslaught of letters from mining equipment companies throughout the country. Most of the letters were from companies based in Chicago like the J.C. Buckbee Company, Chalmers and Williams disc crushers, and Fairbanks Morse and Co. However, companies from outside of Chicago also contacted them. Some included the Universal Crushers Company from Cedar Rapids, IA, the Schofield-Burkett Construction Co from Macon, Georgia, and the Mertes Machinery Co from Milwaukee. These companies sold excavators, elevators, crushers, screens, conveyors, hoppers, storage units, and other mining equipment. Numerous journals also contacted Granite Gravel with offers to subscribe to their publications. Some examples included the Cement and Engineering News, as well as Rock Products and Building Materials, all from Chicago.[60] The sheer number of people who reached out to Granite Gravel showed the large amount of equipment needed to operate a gravel pit and the extent to which gravel and other nonmetallic materials could be profitable.

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[58] "Correspondence, B.F. Wilson on July 9th, 1934."
[59] "Secretary's Record and Stock Accounts," 35.
[60] "Correspondence," 1914-1915.

The use of sand and gravel as a road building material proved to be essential to Wisconsin's early development of its infrastructure. The sand and gravel mining industry got kick started by the Good Roads Movement and was documented early on by the Wisconsin Geological and Natural History Survey. With improved transportation networks that the industry itself helped create, sand and gravel mining in Wisconsin began to grow throughout the 20th century. Although driven by a demand for road materials, sand and gravel can also be used for much more. Its implementations extend into other industries and sectors as well. Due to its versatility, sand and gravel mining has persisted throughout Wisconsin's history well beyond the Good Roads Movement and after WGNHS stopped researching it. This versatile and persistent quality of sand and gravel make it a reliable and valuable material to this day. With the proper markets and transportation networks, this type of mining can thrive.

Wisconsin's Most Valuable Mineral Resource: Beyond Road Making to Industrial Uses and Resource Management

Sand and gravel has been an indispensable road building material throughout Wisconsin's history. However, it is also used in several other processes. Some of these uses include railroad ballast (the material railroad tracks are laid on), fill for construction projects, snow and ice control, building material, and industrial processes such as filtering and hydraulic fracturing. It is important to think of sand and gravel as more than just a road material. Its versatility makes it a valuable commodity that needs to be properly managed as a finite resource. Although Wisconsin's mineral output ranks far behind other states in the U.S., its vast wealth of sand and gravel ranks in the top ten. Its value and versatility often remain unnoticed, but if used wisely and managed properly, could greatly benefit the state.

Sand and Gravel as a Finite Resource

Despite sand and gravel's abundance in Wisconsin, it is a finite resource like any other naturally occurring substance. From 1931 to the present, the output and value of sand and gravel have risen across the country and in the state. From 1910 to at least 1970, sand and gravel had been the most extracted mineral resource in Wisconsin, and by 1970 there were 440 operators.[61] As the population rose, the demand for sand and gravel to build the necessary infrastructure rose with it. However, as WGNHS explained in 1913:

> In a section where rock or stone is easily obtained people do not appreciate its usefulness. There are parts of our prairie states and parts of foreign countries where a rock or a large stone is not to be found, but must be brought long distances at a considerable cost. The presence of suitable stone near at hand for buildings, for foundations of houses, for making concrete, etc. is a greater advantage than we are likely to think.[62]

This is a commonly held belief about aggregate materials. They often go unnoticed, and people generally don't realize their importance until they no longer have access to them. Benjamin Charles B. Tighe exemplified this in his dissertation on the Madison Municipal Quarry written in 1908 when he referenced several individuals who expressed how plentiful stone was in Madison. Mr. Keyes, a Madison contractor, stated that "there is enough stone within two miles of Madison to build seventeen such cities," and a local geologist explained that the supply was "practically unlimited." Even Mayor Bashford said to the Madison City Council that "the quantity of stone on this land would seem sufficient to last the city fifty years."[63] Despite these men's confidence in the city's stone supply, a study done in 1935 showed that the building stone had all but run out.[64] Far from being unlimited, the supply proved to be finite just like any other natural

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[61] Thomas O Friz, "Mineral Resources, Mining, and Land-Use Planning in Wisconsin," Information Circular (Madison, WI: Geological and Natural History Survey, 1975), 14 & 17.
[62] Ray Hughes Whitbeck, "The Geography and Industries of Wisconsin" (Madison, WI: Wisconsin Geological and Natural History Survey, 1913), 13, https://wgnhs.uwex.edu/publications-home/.
[63]Tighe, "An Historical and Financial Survey of the Madison Municipal Quarry," 3-6.
[64] B. E. Karges, "Location of Quarry Sites in the City of Madison" (Madison, WI: Geological and Natural History Survey, 1935), https://wgnhs.uwex.edu/publications-home/.

resource. In the 1930s, the University of Wisconsin had been using sandstone as its building material and was planning on expanding its campus. However, the 1935 investigation showed that there was not enough good quality stone to support a University building program. Far from being unlimited, the city and University had to learn the hard way that nonmetallic minerals are finite just like any other natural resource.

Resource management is a key tool that should be used for all minerals, even the ones that are plentiful. E.F. Bean, from WGNHS, published a report on the mineral resources of Marinette County in 1941 where he explained that gravel was the most valuable mineral resource of the county because of its implementation for highways and other construction. After this, he explained how he had known of many instances where a county would sell gravel land for a small price only to have to buy it back for much more than what it had sold for when they needed aggregate resources. He emphasized that "gravel land near a railroad should never be sold at a low price per acre."[65] Bean knew of sand and gravel's potential value and advised Marinette County not to make the mistake of underestimating their value or the importance of having good transportation. Bean was exhibiting foresight in his recommendation, because as the population grows, construction materials increase in demand.

The importance of resource management for sand and gravel, that Bean's warnings exemplified, was again illustrated three decades later in a WGNHS report in 1975. In the report, Thomas O. Friz described how gravel deposits in Wisconsin are abundant, but can be difficult to find and utilize close to markets as materials are used up or land is built over.[66] High-volume, low-value products like sand and gravel are of critical local importance. However, with

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[65] E. F. Bean, "Mineral Resources of Marinette County" (Madison, WI: Geological and Natural History Survey, 1941), 4-5.
[66] Friz, "Mineral Resources, Mining, and Land-Use Planning in Wisconsin," 9-12.

increasing urban sprawl, many prime deposits are being built over, making them inaccessible.[67] Following Friz's report, the USGS and WGNHS published material on the mineral and water resources of Wisconsin in 1976 that stated,

> Sand and gravel are high volume, low value commodities, and transportation costs between the source and market areas often make up a large share of the costs to the user...Thus, although the sand and gravel resources of the State as a whole are enormous, there is already a shortage of suitable deposits within reasonable haulage distances of a number of communities in Wisconsin...many very valuable deposits of sand and gravel are being lost through the spread of the communities that such deposits might well have served. When homes and shopping centers are built over the deposits, or when mining is prevented by zoning restrictions, the deposits are for all practical purposes lost.[68]

This sentiment held by the USGS and WGNHS is crucial in understanding that although sand and gravel are abundant because of Wisconsin's glacial history, they are not always accessible. When sand and gravel deposits are built over, they cannot be used for any construction or industrial uses and their effective abundance is substantially diminished.

Sand and Gravel's Versatility and the Mineral Yearbooks

The notion that sand and gravel is valuable and requires resource management becomes even more evident when considering its other uses. Beyond a road material, sand and gravel is used for abrasives, glass, refractories, hydraulic fracturing, filtering, and molding. As expanding residential areas are built on top of deposits, not only are they increasing the future costs of road materials, but they are also hurting industrial uses by increasing transportation costs for them as well.[69] As Peter E. McKeever and John Preston of WGNHS explained in 1975, even though cars are "more metallic than nonmetallic, the windows, lights, protective coating, and spark plugs are made of nonmetals." They further emphasized that "the average consumer takes these products

[67] Ibid, 58.
[68] United States Geological Survey and Wisconsin Geological and Natural History Survey, "Mineral and Water Resources of Wisconsin," 1976, 100-101.
[69] Ibid, 103.

for granted and seldom considers that the same processes that furnish the iron and gold of the world are also used to produce these and many other important items."[70] Construction purposes dominate Wisconsin's sand and gravel uses, but these materials go beyond building roads and bridges.

Another one of these uses is as a molding sand in foundries. As far back as 1928, WGNHS published a study on the molding sands of Wisconsin, indicating that even back in the 1920s, sand and gravel had other implementations beyond construction. 323 foundries were spread across the state in 1925 and the average yearly production of molding sand was 84,225 short tons with an average yearly value of $63,000.[71] Most molding sand deposits are in the southeastern part of the state where they were formed from bed rock geology and glacial activity. Most deposits are on or very near rail lines and as the report explained, "proximity to transportation facilities is a requisite of any sand deposit worth developing."[72] Again, transportation and geology are key elements to sand and gravel resource potential.

Molding sands is one example of numerous applications for sand and gravel documented in the Mineral Yearbooks. From 1932 to the present, the United States Bureau of Mines, and later the United States Geological Society, recorded mining data across the country on all types of materials and usages in what is called the Mineral Yearbooks. It is important to note that USGS has changed its classifications of industrial materials over time. Prior to 1959, many of sand's classifications within the Yearbooks had their own categories. For example, engine, molding, and filtering sand had their data separated out from each other. However, from 1959 to

[70] Peter E. McKeever and John Preston, "Mineral Prospecting and Mining Transactions" (Madison, WI: Geological and Natural History Survey, 1975), 89.
[71] David W. Trainer, "Molding Sands of Wisconsin" (Madison, WI: Wisconsin Geological and Natural History Survey, 1928), 7, https://wgnhs.uwex.edu/publications-home/.
[72] Ibid, 11.

the early 1970s, most industrial sand was lumped into a single category. This meant that classifications like engine, molding, and filtering sand were now classified as 'Sand (Other).' From the early 1970s to 1985, this category was relabeled to 'Industrial Sand.' Finally, from 1985 to the present, all industrial uses of sand and gravel were put into the category of 'Industrial Sand and Gravel.'[73] This combining of classifications means that it is impossible to differentiate between different types of industrial usages for sand and gravel with these statistics. It is unclear why USGS chose to do this with the data. Presumably, it was easier for them to collect and combine the statistics in this way. [See Appendix A for in depth statistics of value and production levels for sand and gravel mining in Wisconsin and Appendix B for the United States].

Despite the combination of various statistical categories, it is still possible to identify trends and attribute industry movements to statistical information. The most obvious example is with sand used for hydraulic fracturing. This implementation began as its own category but was added to the 'Sand (Other)' category in 1959, 'Industrial Sand' in the early 1970s, and 'Industrial Sand and Gravel' in 1985. This implementation is currently the driving force for the sand and gravel mining industry and pushed the value of Industrial Sand and Gravel to over $3 billion dollars in 2014. By reaching these new heights, sand and gravel has exceeded even its loftiest potentials with the frac sand boom. Learning about the history and nuances of this one implementation of sand and gravel is critical in understanding the industry as it moves forward further into the 21st century and beyond.

[73] United States Bureau of Mines and United States Geological Survey, *The Mineral Industry of Wisconsin*, 1959-2014.

21st Century Frac Sand Mines and the Frac Sand Frenzy

Today in Wisconsin, sand and gravel deposits are no longer solely used as road, construction, and industrial materials. Due to a recent sand mining boom, huge mines have opened throughout the state to extract this mineral resource. These mines are much larger than 19th century gravel pits and serve a far different purpose. The sand extracted from them is known as frac sand, and unlike materials from local gravel pits, it is shipped far out of state to places like the Permian Basin in Texas or the Bakken and Marcellus shale fields in North Dakota. Once there, the energy industry uses it in oil and natural gas wells. In 2015, the United States Geological Survey published a report on frac sand in the United States. It stated that "a new mineral rush is underway…in Wisconsin and Minnesota, for deposits of high-quality frac sand."[74] The report explained how Wisconsin accounts for almost one-half of the frac sand capacity of the United States because of its "premium sand deposits, railway infrastructure, and long-term presence in the industry."[75] Frac sand has been dubbed the new gold by the Wall Street Journal and, in some ways, even mirrors metallic mining rushes.[76] It has made sand and gravel mining in Wisconsin relevant to thousands of people across the state by drawing increased attention to the industry that it previously could not generate. To understand frac sand mining in Wisconsin and how it has made sand and gravel mining relevant, it is necessary to consider the technology that made the boom possible, the history and scale of industrial sand mining, and the procedures and controversies surrounding it.

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[74] Mary Ellen Benson and Anna B. Wilson, "Frac Sand in the United States—A Geological and Industry Overview" (United States Geological Survey, 2015), 1.
[75] Ibid, 53.
[76] Alison Sider and Kristin Jones, "In Fracking, Sand Is the New Gold," *Wall Street Journal*, December 2, 2013, sec. Business, http://www.wsj.com/articles/SB10001424052702304868404579194250973656942.

Frac Sand Mining Reaches New Heights

The recent frac sand boom in Wisconsin happened on a scale that was never seen before and compelled people to pay attention to the industry. Since mining for frac sand was first recorded in 1959, it has consistently grown in value and production levels.[77] In 1984, Wisconsin produced over 1 million short tons of industrial sand valued at $11.8 million dollars. In the next twenty-six years Wisconsin's production increased to 3.6 million short tons in 2010 with a value that had risen to $156 million dollars. One year later, in 2011, Wisconsin's production increased to 5.5 million short tons with a value that had skyrocketed to $280 million dollars.[78] If this is not astounding enough, Wisconsin's production in 2014 reached 38 million short tons valued at a whopping $3.1 billion dollars.[79] In July 2011, there were a total of 31 sand mines in Wisconsin classified as either active, in development, or proposed.[80] By May 23, 2016, there were 128 total industrial sand facilities.[81] Frac sand is needed in very large volumes and one oil or natural gas well can require 10,000 tons of silica sand.[82] High-grade frac sand can go for $60 to $80 per ton, which is more than five times the price of construction sand and gravel.[83] Because of this, Wisconsin sand is needed in large amounts and can draw high prices. [See Appendix A for value and production levels of Wisconsin industrial sand]

During this frac sand frenzy in Wisconsin, the country was also experiencing a nationwide boom. In the USGS's report on frac sand mining in the U.S. from 2015, the

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[77] United States Bureau of Mines, "The Mineral Industry of Wisconsin," *Minerals yearbook area reports 1959,* (1960).
[78] United States Bureau of Mines, "The Mineral Industry of Wisconsin," *Mineral yearbooks area reports 1984, 2010, 2011.*
[79] United States Geological Survey, "2014 Minerals Yearbook: Advance Release," *Silica*, October 2016.
[80] Kate Golden, "Frac Sand: Wisconsin Sites" (Wisconsin Center for Investigative Journalism, 2011).
[81] "Locations of Industrial Sand Mines and Processing Plants in Wisconsin - Wisconsin DNR," accessed January 5, 2017, http://dnr.wi.gov/topic/Mines/ISMMap.html.
[82] Sally Younger, "Sand Rush: Fracking Boom Spurs Rush on Wisconsin Silica," *National Geographic News*, July 4, 2013, http://news.nationalgeographic.com/news/energy/2013/07/130703-wisconsin-fracking-sand-rush/.
[83] "Silica Sand Mining in Wisconsin" (Wisconsin Department of Natural Resources, January 2012), http://dnr.wi.gov/topic/mines/documents/silicasandminingfinal.pdf, 3;. Steve Glischinski, "The Demand for SAND," *Trains*, May 2013, 50.

researchers explained that in 2003 2.2 million tons of frac sand were sold, a 45% increase from 2002. They attributed this growth to "aggressive horizontal drilling and hydraulic fracturing programs," by the petroleum industry.[84] Total U.S. production further increased to 13 million tons valued at $546 million dollars in 2010, and to 26 million tons valued at $1.33 billion dollars in 2011. By 2014, these totals had reached 81 million short tons valued at over $7 billion dollars.[85] [See Appendix B for production and value levels of US frac sand]

Hydraulic Fracturing and Wisconsin Sand

During the boom, the billions of dollars of Wisconsin sand mined for the energy industry was contingent on a technology known as hydraulic fracturing (also known as fracking, fracturing, or hydrofracking). Developed by Stanolind Oil in 1949, it is a technique used by the energy industry to reach natural gas and oil reserves from deep rock formations.[86] Energy companies use hydraulic fracturing to acquire previously unreachable oil or natural gas reserves. Companies will drill down thousands of feet into deposits, create small cracks in the rocks, and pump a combination of frac sand, water, and chemicals under enormous pressure into the wells to keep the cracks open. This allows the reserves to flow to the surface.[87] Sand is an essential component of this process and functions as a 'proppant,' propping the cracks in the rock open. The earliest fracturing treatments used river or construction sand, however, these deposits are now considered too impure and too angular. With today's advancements, frac sand must now meet specific requirements put in place by the American Petroleum Institute and International Organization for Standards.[88] Sand needs to be homogenous, high in silica content, devoid of

[84] Mary Ellen Benson and Anna B. Wilson, "Frac Sand in the United States—A Geological and Industry Overview" (United States Geological Survey, 2015), 54.
[85] United States Geological Survey, "2014 Minerals Yearbook: Advance Release," *Silica*, October 2016.
[86] "Silica Sand Mining in Wisconsin," 1.
[87] Ibid.
[88] Carl T. Montgomery and Michael B. Smith, "Hydraulic Fracturing: History of an Enduring Technology," *Journal of Petroleum Technology*, December 2010, 26–32.

impurities, spherical, and crush resistant. Ideal deposits are geologically accessible, loose, unconsolidated, close to the surface, and on or near truck and rail networks.[89] Many Wisconsin sand deposits meet all these specifications. Thus, they are desirable and bring in the highest prices. Without Wisconsin sand, hydraulic fracturing would be far less profitable and efficient, and without hydraulic fracturing there would be far less demand for Wisconsin sand. Although many people fear and question hydraulic fracturing because of environmental concerns, it will continue to be used in the foreseeable future.[90]

Frac Sand Mining Procedures

Despite various locations and geological formations across counties, frac sand mining operations all follow the same basic principles and procedures. Once a deposit is located and the proper infrastructure is in place, mines start by removing the overburden and placing it into piles that create a sound and light barrier for neighboring properties. Overburden is the soil that sits between the surface and the deposit. Frac sand in Wisconsin is close to the surface so there is not much to remove. After this, the sand is dug up and excavated.[91] If it is tightly cemented, mines will drill into the deposits and drop explosives into place. Blasting can create noise, vibrations, and dust emissions, and can be dangerous for workers if not done safely. Consequently, the Federal Mine Safety and Health Administration (MSHA) has regulations to limit the emission of dust particles and vibrations. Furthermore, the Wisconsin Department of Safety and Professional Services regulates blasts in SPS 307, Wisconsin Administrative Code, which requires record keeping and the notification of neighbors, while also setting limits on seismic activity. Following blasting, mines crush, process, and transport loosened deposits to separate the grains that meet

[89] Benson and Wilson, “Frac Sand in the United States—A Geological and Industry Overview," 2-8.
[90] Robin Beckwith, “Hydraulic Fracturing: The Fuss, The Facts, The Future,” *Journal of Petroleum Technology*, December 2010, 41; Montgomery and Smith, “Hydraulic Fracturing: History of an Enduring Technology,” 32.
[91] “Silica Sand Mining in Wisconsin," 7.

industry requirements with those that do not.[92] The final step is mine reclamation, regulated by Wisconsin Administrative Code NR 340 that requires operators to provide financial assurances before production.[93] All these procedures listed are like other sand mining operations in the state, and they follow the same principles that have been used for decades in Wisconsin's nonmetallic mining industry. Consequently, Wisconsin has a history of industrial sand mining that has recorded very few problems in over 100 years.[94]

Rules, Regulations, and Concerns

Communities and environmental advocacy groups have raised concerns over air and water quality, groundwater usage, noise and light pollution, safety hazards on roads from trucks moving heavy materials, and wildlife habitat disturbances. To discuss these concerns the Wisconsin Department of Natural Resources published a report in 2012 on sand mining in the state. With regards to air quality, the report explained that most air pollutants are from fugitive dust particles and that it is uncommon for these particles to escape off site unless there are strong winds or very dry conditions. Operators are required to maintain fugitive dust plans, and although emissions could pollute the air, they are "insignificant."[95] A frac sand plant produces less dust than a quarry or gravel pit that crushes its materials, and the Mine Safety and Health Administration (MSHA), the Occupational Safety and Health Administration (OSHA), the Department of Natural Resources (DNR), and the Environmental Protection Agency (EPA) all

[92] Ibid, 8-9.
[93] Ibid, 10-11.
[94] Bruce A. Brown, "Gold, Iron, Copper, Zinc, and Sand; What's Driving the New Interest in Mining and Mineral Resources in Wisconsin" (Madison, WI: Wisconsin Geological and Natural History Survey, n.d.), http://www.wisctowns.com/uploads/ckfiles/files/WTA_102511%20Frac%20Sand.pdf, 29.
[95] "Silica Sand Mining in Wisconsin," 13.

have air standards that apply.[96] Therefore, the WDNR concluded that it expected air quality to be maintained.[97]

The report then analyzed the effects of frac sand mining on water resources. Interestingly, a main use of water at mines is to keep dust down so that air quality standards are met. The report explained that a mine's water usage can range from 700 to 1380 gallons per minute and that water use per day ranges from 420,500 gallons to 2 million.[98] Although this is a lot of water, total withdrawals in Wisconsin in 2014 were 1.952 trillion gallons. Mining only accounted for 0.9% of the state's total surface withdrawals, which was less than cranberry producers (3.6%) and paper manufacturers (5.6%). Additionally, industrial uses (which mining got lumped into) only accounted for 6% of total groundwater withdrawals while agricultural irrigation was at 35%. Non-metallic mines had 301 active withdrawal sources, which put it behind golf courses (418), cranberry producers (413), and agricultural irrigation (3,785).[99] Furthermore, this data was from 2014, the peak boom year for frac sand mining. This means that even at the height of the frac sand boom, Wisconsin mines were not using a significant amount of the state's water. Furthermore, all companies seeking to open a frac sand facility need to apply for a high capacity well permit and a storm water permit. Companies near water or wetlands, and threatened or endangered species also need to meet additional regulations. As Bruce Brown, geologist for WGNHS pointed out, mines and processing plants routinely recycle as much water as possible and limestone quarries or gravel pits have just as much potential for groundwater impact as sand mines.[100]

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[96] Brown, "Gold, Iron, Copper, Zinc, and Sand; What's Driving the New Interest in Mining and Mineral Resources in Wisconsin," 31-33.
[97] "Silica Sand Mining in Wisconsin," 20.
[98] Ibid, 21.
[99] "Wisconsin Water Use: 2014 Withdrawal Summary" (Wisconsin Department of Natural Resources, 2014).
[100] Brown, "Gold, Iron, Copper, Zinc, and Sand; What's Driving the New Interest in Mining and Mineral Resources in Wisconsin," 31-33.

Following its discussion on water resources, the report described the potential impacts of sand mining on the recreational experience of adjacent properties as well as impacts on historic sites and wildlife habitats. The increased truck traffic alone has raised concerns about noise, safety, dust, and road conditions. Although these concerns are valid and there is no easy way to fix this, it is ironic that the industry responsible for supplying Wisconsin with its road materials is now being criticized for using them. To combat historic site or habitat problems, state agencies cooperate with the Wisconsin Historical Society to ensure no historic sites will be disrupted and the WDNR requires an Endangered Resources Review as part of the permit process. The final measure to limit these problems is reclamation plans themselves. These plans typically return mined areas to agricultural use or go on to provide habitat for wildlife.[101] The WDNR concluded its report by stating that "current nonmetallic mining regulations implemented at the county level, as well as the various environmental regulations implemented by the department are adequate to ensure that permits for individual sand mining operations and processing facilities are protective of public health and the environment." The report went on to state that "most sand mine siting is controlled through local zoning decisions," and that public concerns have focused on impacts that the state does not have the authority to regulate.[102] This means that it is the responsibility of the counties to implement the tools they have to protect their environments and quality of life.

In 2012, the same year as the WDNR report, The Center for Land Use Education at the University of Wisconsin-Madison conducted two studies to determine how prepared the state's 72 counties were for handling the frac sand mining influx. The first study was on comprehensive plans, which are tools for counties to address natural resource planning. Results showed that 31

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[101] "Silica Sand Mining in Wisconsin," 30-33.
[102] Ibid, 41.

counties included goals or objectives for nonmetallic resources, 26 included only policies, and 26 did not mention any goals, objectives, or policies at all. Within the frac sand mining area of the state, 7 counties didn't have plans or had plans that could not be located. For example, Trempealeau county, which has several frac sand operations, only had a map. The results showed that very few counties were taking advantage of the tools they had to manage their resources.[103]

The researchers then looked at zoning ordinances, and unfortunately, their findings were not any better. Zoning standards can include a list of safety precautions, lighting, air blast prevention, explosive storage, maximum size, proximity to market, and much more. [104] Therefore, zoning ordinances can severely limit what mines do. However, based on the findings, 32 of the 72 counties in the state did not even have any type of nonmetallic mining zoning ordinances. 18 of these 32 without nonmetallic mining zoning ordinances were counties with frac sand potential. For example, Monroe County had no zoning ordinances but several frac sand operations and Trempealeau county had very few standards but many frac sand facilities. This study again showed that few counties were taking advantage of available tools to manage their resources.[105] A lack of understanding of the value and rich history of nonmetallic minerals within Wisconsin has contributed to counties being overwhelmed by the demand for frac sand.

The League of Conservation Voters has expressed concerns over the effects frac sand mines have on groundwater, air quality, wildlife, and overall quality of life near the mines. They have stated that "if you are at all concerned about the booming, polluting, unregulated hydraulic

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[103] Anna Haines and William Risse, "Evaluating Nonmetallic Mining: County Comprehensive Plans" (University of Wisconsin-Extension, Center for Land Use Education, August 2012).
[104] Zoning standards can include: a list of safety precautions, lighting, air blast prevention, explosive storage, maximum size, proximity to market, fuel placement, odors, test data, setback from roads, water required, structure placement, roads used, noise level, topography alteration, hours of operation, dust, permit length, operations plan, erosion control, landscaping, equipment list, water quality, and other setbacks.
[105] Anna Haines and William Risse, "Evaluating Nonmetallic Mining: County Zoning Ordinances" (University of Wisconsin-Extension, Center for Land Use Education, August 2012).

fracking practices occurring across the United States, you should definitely be concerned about the booming, polluting, unregulated frac sand mining practices happening right here in Wisconsin."[106] Although it is true that frac sand mines were booming when this statement came out, based on the WDNR's Silica Sand Mining in Wisconsin report, they were not polluting.[107] And furthermore, they were only unregulated due to the lack of understanding at the county level of nonmetallic minerals. In 2016, the DNR published an updated report on its 2012 study that reiterated, confirmed, and expanded on, many of its previous findings.[108] In terms of the regulations, Roberta Walls, the Environmental Assistance Coordinator and industrial sand mine contact at the DNR, explained that the regulations for sand and gravel mining in Wisconsin are well suited for the industry. The DNR follows strict scientific findings when determining regulations and many concerns the public had were on issues that were not appropriate for the industry.[109] Regardless, the sheer scale of the industry and the procedures and concerns surrounding it were enough to attract the attention of Wisconsinites who may not have otherwise known about the state's nonmetallic mining industry.

Pros and Cons of Frac Sand Mining

Although sand mining in Wisconsin is a controversial topic that often divides citizens between pro-economy and pro-environment arguments, it does have many advantages. Some of these include providing local jobs and stimulating economic growth.[110] For example, Unimin Corp.'s Tunnel City silica extraction center has paid Greenfield $222,019, which Clerk Susie

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[106] "Frac Sand Mining," *Wisconsin League of Conservation Voters*, accessed September 26, 2016, http://conservationvoters.org/issues/frac-sand-mining/.
[107] "Silica Sand Mining in Wisconsin" (Wisconsin Department of Natural Resources, January 2012), http://dnr.wi.gov/topic/mines/documents/silicasandminingfinal.pdf.
[108] "Industrial Sand Mining in Wisconsin: Strategic Analysis for Public Review" (Wisconsin Department of Natural Resources, June 2016).
[109] Roberta Walls, Conversation with Roberta Walls, Phone, February 17, 2017.
[110] Brown, "Gold, Iron, Copper, Zinc, and Sand; What's Driving the New Interest in Mining and Mineral Resources in Wisconsin," 29.

Zillmer explained in 2015 as a "gift from heaven."[111] The Wisconsin Economic Development Corporation estimated that the average processing plant requires an initial investment of between "$20-$40 million dollars for equipment, buildings, and infrastructure" and that 50 to 80 new jobs will be created. New mines are estimated to create 10 new jobs and moreover, there is also a need for workers to transport the sand, build the facilities, and sell heavy equipment.[112] The Wisconsin Center for Investigative Journalism estimated in 2013 that approximately 3,000 jobs could have been generated by the frac sand mining activity in the state if all the current operations had been working at capacity.[113]

Additionally, the railroad industry has perhaps benefited the most from increased frac sand production because rail is the preferred mode of transportation for frac sand. It is the most economical and does not damage existing road ways. Therefore, most sand facilities are located at or near them. Transportation is key for sand and gravel's profitability, and is a trend that follows from the gravel pits of the late 19th and early 20th centuries. As of May 2014, there were 125 permitted mines, most of which were clustered along rail lines.[114] Rail is four times more fuel efficient than a highway truck, and Dave Fellon of Progressive Rail explained that, "you can move a ton of freight over 435 miles on just one gallon of fuel." [115] From 2002 to 2012, there was a 63% increase in freight rail revenue in Wisconsin.[116] Examples of fortunate rail companies that have benefited from increased sand transport are the Canadian Pacific and the Wisconsin

[111] "Wisconsin Towns Worry Frac Sand Boom Will Dry up," *Midwest Energy News*, June 3, 2015, http://midwestenergynews.com/2015/06/03/wisconsin-towns-worry-frac-sand-boom-will-dry-up/.
[112] "Silica Sand Mining in Wisconsin," 33.
[113] Eggleston, "This Sand Is Your Sand, This Sand Is My Sand."
[114] Taylor Chase, "As Rail Moves Frac Sand across Wisconsin Landscape, New Conflicts Emerge," *WisconsinWatch.org*, July 13, 2014, http://wisconsinwatch.org/2014/07/as-rail-moves-frac-sand-across-wisconsin-landscape-new-conflicts-emerge/;. "Silica Sand Mining in Wisconsin," 34.
[115] Chase, "As Rail Moves Frac Sand across Wisconsin Landscape, New Conflicts Emerge."
[116] Taylor Chase, "As Rail Moves Frac Sand across Wisconsin Landscape, New Conflicts Emerge," *WisconsinWatch.org*, July 13, 2014, http://wisconsinwatch.org/2014/07/as-rail-moves-frac-sand-across-wisconsin-landscape-new-conflicts-emerge/;.

Northern. The Canadian Pacific can haul sand to the Bakken and Marcellus shale fields and the Alberta oilfields to the west of Wisconsin. Because of this business opportunity, it has rebuilt its dormant 44-mile track from Ladysmith to Poskin, WI to serve Superior Silica's new frac sand mine in Barron, WI.[117] For the Wisconsin Northern, it only moved 1,600 carloads in 2005, but in 2012 it moved 28,500, most of which was frac sand shipments. Wisconsin Northern's first contract was with EOG Resources in Chippewa Falls which opened in December 2011. Following EOG Resources, Chippewa Valley Sands, Chieftain Sand and Proppant, and Great Northern Sand all came on-line within two years along Wisconsin Northern's tracks.

Despite these benefits of frac sand mining, there are many issues as well. Environmental and community concerns are two examples, however, the WDNR and Center for Land Use Education have shown that these are minimal and preventable problems. The exceptions to this are increased truck traffic and increased rail transportation. Although these can be viewed as a good thing, it means that tracks are at capacity, which can lead to traffic delays, noise, and safety concerns. In some instances, trains can be stuck on tracks for hours causing traffic delays if they extend into roads. Even so, there have been no increases in car-train accidents and derailments are down.[118] Beyond rail traffic, a final issue is economic uncertainty. Frac sand is tied to international markets and subject to trends in the price of oil and natural gas. As a result, boom and bust periods can and do impact the industry resulting in employment fluctuations and stagnant mines.

Frac Sand Volatility: Supply Meets Demand

Many cranberry growers in Wisconsin are in the central part of the state where deposits of frac sand are located. Because of this, some cranberry growers sold frac sand located on their

[117] Steve Glischinski, "The Demand for SAND," *Trains*, May 2013, 53-54.
[118] Chase, "As Rail Moves Frac Sand across Wisconsin Landscape, New Conflicts Emerge."

properties.[119] Despite some growers' successes, most small companies or operators have struggled. Transportation can account for 50% of sand costs and for small operators not located on rail lines, it can be extremely difficult to get the sand to market. Claude Riglemon, a real estate appraiser and cranberry operator in Tomah, WI made a deal with a mining company that they could have rights to his sand if they would build him a new reservoir. The reservoir was built in 2011, but the sand sat on his property for over a year with no buyer because of challenges transporting it. Rigleman explained that transportation costs and the permit process push small operators out because they can't profit. Although he supports the industry, the permit process cost him $6000 and he explained that he wouldn't do it again if given the chance. As Rigleman stated in 2012: "Right now, it might be a little Wild West, but in a couple of years, the quick-buck operators will wash out. The boom will subside. The big guys will provide the market with what they need."[120] His statement proved to be prophetic.

The frac sand downturn began around Thanksgiving of 2014.[121] Supply quickly caught up to demand and with lower prices the advantage shifted to larger companies who had the infrastructure, experience, and cash on-hand to deal with the downturn. In June 2015, Wisconsin had 58 inactive frac sand sites and only 63 active.[122] The market was not sustainable, and when it crashed, some company stocks plummeted more than 90%. For example, Hi-Crush Proppants stock plummeted 98%.[123] Roberta Walls explained that the frac sand industry is dependent on

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[119] "Silica Sand Mining in Wisconsin," 26.

[120] Kate Prengaman, "As Supply Meets Demand, Wisconsin's Frac Sand Rush Slows," *WisconsinWatch.org*, December 15, 2012, http://wisconsinwatch.org/2012/12/frac-sand-rush-slows/.

[121] Caleb Brown, "Frac Sand Not Likely to Boom in near Future," *La Crosse Tribune*, December 15, 2015, http://lacrossetribune.com/news/frac-sand-not-likely-to-boom-in-near-future/article_baaa01c6-8c7f-5972-820d-d48b3671acce.html.

[122] "Wisconsin Towns Worry Frac Sand Boom Will Dry up."; WisconsinWatch, "October Update: Wisconsin's Frac Sand Industry Map," *WisconsinWatch.org*, October 18, 2013, http://wisconsinwatch.org/2013/10/october-update-wisconsins-frac-sand-industry-map/.

[123] Rich Kremer, "Frac Sand Company Stocks Recovering After Huge Industry Slowdown," *Wisconsin Public Radio*, June 24, 2016, http://www.wpr.org/frac-sand-company-stocks-recovering-after-huge-industry-slowdown.

how much hydraulic fracturing is being done. More fracturing means more sand, less fracturing means less sand.[124] Hydraulic fracturing is a more expensive type of fossil fuel extraction method and is only profitable in times of high prices for oil. In May 2016, a barrel of crude oil from U.S. West Texas Intermediate was $44.66, down 25% from 2015 and down over 50% from 2014. Pumping more sand down a well increases the wells cost, but has the potential to double its output. Therefore, when prices are high, operators can afford to buy more sand from Wisconsin to pump down their wells. When prices are low, they have a tougher time making a profit and thus won't buy as much sand.[125] With this fall in prices, the demand for Wisconsin sand dropped.

Because of this decrease in demand and a fall in prices, many companies were forced to lay off workers to ride out the storm. Job loss has impacted not only mining facilities, but also the operations that supplied goods and services to the mines. Badger Mining Co. opted not to restart its industrial sand mine in Alma Center. The President, Marty Lehman, explained that laying off employees is a painful decision, but one that needed to be made to ride out the slow down.[126] A large company like Unimin Corp. has other products for its sand including glass, ceramics, and paints, which helped it fend off the market fluctuations for the price of oil. U.S. Silica, another large company, was set to lay off 30 employees in 2015 and hoped to buy up closing operations to be a consolidator in the industry.[127] Frac sand companies are aware of the boom and bust cycles that circulate through extraction industries. Thus, they plan for them in their economic models and have experience dealing with downturns.

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[124] Conversation with Roberta Walls
[125] Sider and Jones, "In Fracking, Sand Is the New Gold."
[126] Eric Lindquist, "Silent Sandbox: Once Booming Frac Sand Industry Continues Major Downturn," *Leader-Telegram*, May 8, 2016, http://www.leadertelegram.com/News/Front-Page/2016/05/08/Silentsandbox.html.
[127] "Wisconsin Towns Worry Frac Sand Boom Will Dry up."

Although frac sand may be valuable, it is a volatile commodity because it has a very specific application in an industry that is known for its market fluctuations. With over 2500 quarries and pits in the state and just over 100 industrial sand operations, frac sand is only one part of a much larger and historic industry in Wisconsin.[128] Boom and bust periods like the one in Wisconsin's frac sand industry, can create economic uncertainty and turmoil. Thankfully, most mines in Wisconsin didn't have a significant share of local economies yet, so the downturn didn't dramatically affect most town revenues. Permanent economic prosperity from mining will probably not be found with frac sand alone, but it could be found with mining for frac sand in conjunction with other nonmetallic resources and aggregate materials. Despite a slow-down, frac sand officials are confident that the market will recover in the future. Forecasts predict a rebound in 2017 and more substantially in 2018. Large investments in infrastructure means that companies aren't likely to abandon Wisconsin any time soon. Barring any major, long-term changes to the petroleum industry, Wisconsin will remain the largest supplier of frac sand for the foreseeable future.[129]

Frac sand mining in Wisconsin is a complex and nuanced topic that is more than a pro-job versus pro-environment debate. Any discussion of mining will create environmental, quality of life, and health concerns. However, the reality of sand mining in Wisconsin is that it is not very damaging to public health or the environment. In fact, this is one of the very reasons why it has not garnered much attention in the past. It has been around for over a century with very few problems. As far as mining is concerned, frac sand mining is as environmentally friendly as it gets. The frac sand boom has drawn attention to the sand and gravel mining industry that it previously could not generate. It also caused many citizens to consider how the mines would

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[128] Conversation with Roberta Walls.
[129] Benson and Wilson, "Frac Sand in the United States—A Geological and Industry Overview," 10.

impact their communities. UW–Stout Professor Thomas Pearson explained that frac sand mines "can disrupt the visual connections to a once familiar place," and "fuel objections to a proposed mine well before environmental or health considerations are even discussed."[130] Therefore, it is important to consider how mining in Wisconsin has changed the landscape and reflect on its significance to the state.

Mine Altered Landscapes of Wisconsin and Reflections on Sand and Gravel Mining

All mining practices have the potential to dramatically alter the landscape, making it unrecognizable to what it once was. However, society depends on resources that are mined and unless something changes in the way civilizations are built, there will continue to be a need for resource extraction. Nonmetallic mines typically have localized impacts on their surrounding environment, however the materials excavated from them can make profound changes to the land across a far greater region. Clarence W. Olmstead in *Wisconsin: Land and Life* explained that "landscapes are part of the everyday lives of people, yet they challenge scholars both to define exactly what they are and to understand how they develop and change." He went on to say that landscapes are "a record of ourselves-who and what we are, what we have created, what we value."[131] The Wisconsin landscape is often associated with an abundance of lakes, farms, and rolling hills that are quintessential to rural Wisconsin. However, the state is also dotted with quarries and pits that create marks on the earth different from anything else in the region. The non-metallic mines spread out across the state provide materials for road construction, bridges, buildings, and the oil industry.[132] As Christopher Wells explained in Car Country, "gravel

[130] Eggleston, "This Sand Is Your Sand, This Sand Is My Sand."
[131] Clarence W. Olmstead, "Changing Technology, Values, and Rural Landscapes," in *Wisconsin Land and Life*, ed. Robert C. Ostergren and Thomas R. Vale (Madison, WI: University of Wisconsin Press, 1997), 355–356.
[132] Wisconsin Department of Natural Resources, "Nonmetallic Mining Overview," accessed September 25, 2016, http://dnr.wi.gov/topic/Mines/Nonmetallic.html.

pits…bear less obvious connections to the forces that called them into being and require some specialized knowledge to see the connections clearly."[133] Society needs, creates, and values these structures and resources, and the evidence to prove it is right out in the open at a local quarry.

Quarries and pits are so prevalent throughout the state that six of them can be easily identified from one Google Earth image of Madison, WI from June 12, 2014 [Figures 3-9]. These six quarries are on the fringes of the city between the urban/suburban and rural countryside division in the landscape. They are surrounded by suburbs or farmland, are a considerable distance away from downtown, and supply their surrounding area with important materials. Additional quarries just like these are scattered all over the state near other cities. Three examples include Red Granite, White Lake, and New Auburn. In Red Granite, there is an abandoned quarry filled with water that is now used as a local swimming hole [See Figure 10], in White Lake, there is a small pit near the Wolf River [See Figure 11], and finally, in New Auburn, there is a huge frac sand mine in the countryside [See Figure 12].

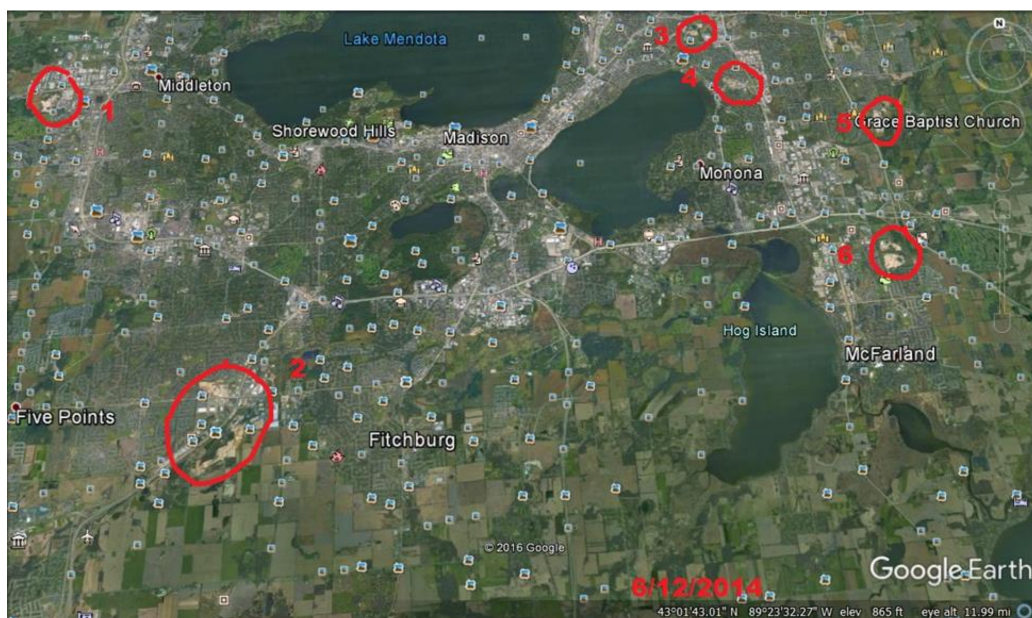


Figure 3 Google Earth Satellite Image of Madison, WI (6/12/2014). Six quarries in the greater Madison area, all of which are on the fringes between the urban/suburban landscape and the rural countryside.

[133] Wells, Car Country, 227

Figure 4 Quarry 1 (6/12/14) A quarry is shown here to the west of Middleton with a golf course to the south, farmland to the west, and a hospital to the east.

Figure 5 Quarry 2 (6/12/14) This quarry is next to Quarry Ridge, a popular Madison mountain biking destination, and Military Ridge bike path. Farmland is to the south and east and suburbs are to the west.

Figure 6 Quarry 3 (6/12/14) Located north of Lake Monona and east of Lake Mendota, this quarry is surrounded mainly by a residential area and has a retention pond at its center.

Figure 7 Quarry 4 (6/12/14) Just east of Lake Monona, the quarry pictured here is surrounded by suburbs. Not far east of here, the area becomes much less populated.

Figure 8 Quarry 5 (6/12/14) The above quarry has suburbs to the north and west, but a much more lightly populated area to its south and east where farmland begins to become more prevalent.

Figure 9 Quarry 6 (6/12/14) Small neighborhoods to the west and south bump against this quarry with farmland near to the east.

Figure 10 (10/7/2013) Abandoned quarry in the heart of Red Granite, WI that is now filled with water and used as a local place to swim.

Figure 11 (9/2/2013) Small pit near the rural town of White Lake, WI and the Wolf River.

Figure 12 (9/29/2015) Frac sand mine spread out across the rural countryside of New Auburn, WI.

Each of these three mines highlight interesting aspects of quarrying. Red Granite illustrates that eventually quarries will outlive their initial usefulness and remain as a mark on the land for many years after production stops. The small pit in White Lake highlights that even small, rural towns need supplies of aggregate. Finally, the frac sand mine in New Auburn connects Wisconsin mining to the larger economic sphere of the energy industry. This mine is particularly interesting because a short five years earlier, the landscape it now resides on was an expanse of farm land. The mine has grown rapidly because of the increased demand for frac sand during the recent boom years, and now dominates the surrounding area. What was once farm land is now an expansive sand mine [Figures 13 and 14]. Each of these mines served a different purpose, but all of them will remain on the landscape as marks of past Wisconsinites' activities.

Figure 13 (9/29/2015) Close-up of the southern section of the New Auburn frac sand mine.

Figure 14: Compare the Left with Figure 12. Compare the Right with Figure 13. These images were taken on October 2, 2011 and are the same area as the prior figures they correspond to. What is now a large frac sand mine was once rural farmland only six years ago.

Other marks indicating the past activities of Wisconsinites are the structures with which the excavated sand and gravel have been used to build. Wisconsinites have used sand and gravel resources to alter the state's landscape and built environment for over a century. It can alter the landscape in dramatic ways because it is needed in large quantities to create massive structures like railroads, highways, bridges, roads, and buildings. The thousands of quarries, pits, roads, railways, and buildings spread out across Wisconsin make significant impressions on the earth that will last for decades after production ceases or people stop using them. Below are visual examples of how sand and gravel has helped to permanently alter the built environment of Wisconsin through its implementation in highways and airports [Figure 15].

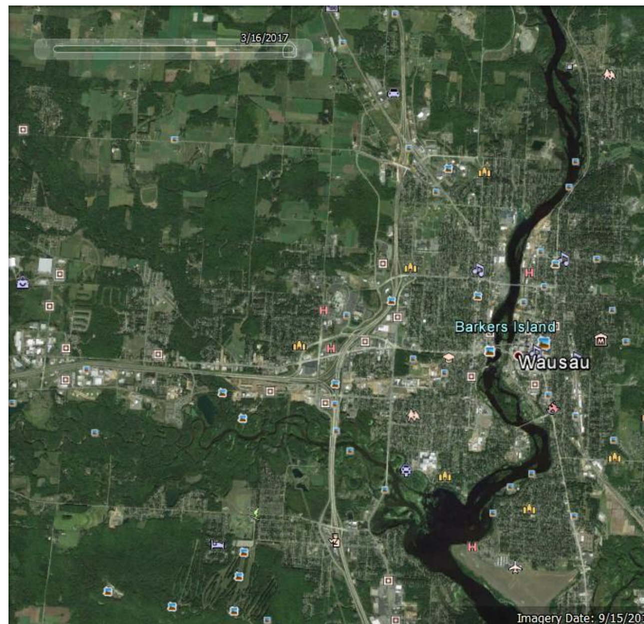


Figure 15. Above Left: Madison Airport and quarry to its north from 6/12/2014. Above Right: Image of Wausau Wisconsin's highway network from 9/15/2013. Right: Milwaukee freeways from 6/18/2015.

All these images provide visual evidence that even if a mine is reclaimed or a road demolished, the place where it was located will never go back to what it was like prior to the opening of the mine or the building of the road. Although this may be disconcerting for some worried about the long-term effects on Wisconsin's environment, Thomas Friz from WGNHS has explained that, "Pits are the easiest form of surface mine to reclaim." Topsoil can be replaced, the land can be graded, and plants can be regrown. Oftentimes, pits and quarries can be reclaimed into lakes or made into other uses like sanitary landfills. Once their usefulness runs out as an extraction site, neighborhoods and shopping centers can even be built over them as well. Property values can actually increase after mines close if they are reclaimed properly, and communities are able to benefit from previous sites if they plan accordingly.[134]

Sand and gravel is Wisconsin's most valuable and heavily mined mineral resource. Despite this, it has been largely ignored or downplayed in the historical writings of the state. Although it is not as flashy of a material as lead, zinc, iron, or other metals, its impact on society is of equal proportions. Sand and gravel made it possible for Wisconsinites in the late 19th and early 20th centuries to build better roads, construct highways, and improve transportation networks. It can be applied to construction efforts and several industrial applications including as a molding sand and for filtering. In the 21st century its most lucrative implementation is in the energy industry as a proppant for hydraulic fracturing, and it is this segment of the market that Wisconsin dominates all other states. Despite Wisconsin's position as the leading supplier of frac sand in the country, the recent boom years caught many county governments and citizens off guard. It is for these reasons and more that it is important to study sand and gravel and its history within the state. An understanding of all the natural resources available is a prerequisite to

[134] Friz, "Mineral Resources, Mining, and Land-Use Planning," 33.

creating a sustainable society. This includes even the ones like sand and gravel that appear to be ubiquitous and are used in more mundane fashions.

Formed after millions of years of geological activity, shallow seas, and glaciers, sand and gravel in Wisconsin is an abundant resource that has geological and historic value. It is a versatile material with multiple applications and a lucrative business that brings in millions of dollars every year. It holds contemporary significance by creating jobs, helping to build infrastructure, facilitating the extraction of other resources, and permanently altering the state's landscape. Although Lawrence Roe stated that "the history of industrial mineral production is not nearly as exciting as the story of the metal mining industry," and authors like James A Lake and Robert C Nesbit did not discuss sand and gravel when describing Wisconsin's mineral resources, it is an essential material to the state both historically and presently.[135] Nonmetallic mining in Wisconsin is widespread, and sand and gravel is leading the charge. Sand and gravel has more potential than any other mineral in the state to advance Wisconsin's economy and infrastructure. However, it can only do this if citizens and policy makers take the initiative to learn about the natural resources and environment that make up Wisconsin.

[135] Roe, *A History of Wisconsin Mining*, 55.; Lake, *Law and Mineral Wealth: The Legal Profile of the Wisconsin Mining Industry*, 13-14.; Nesbit, *Wisconsin: A History*.

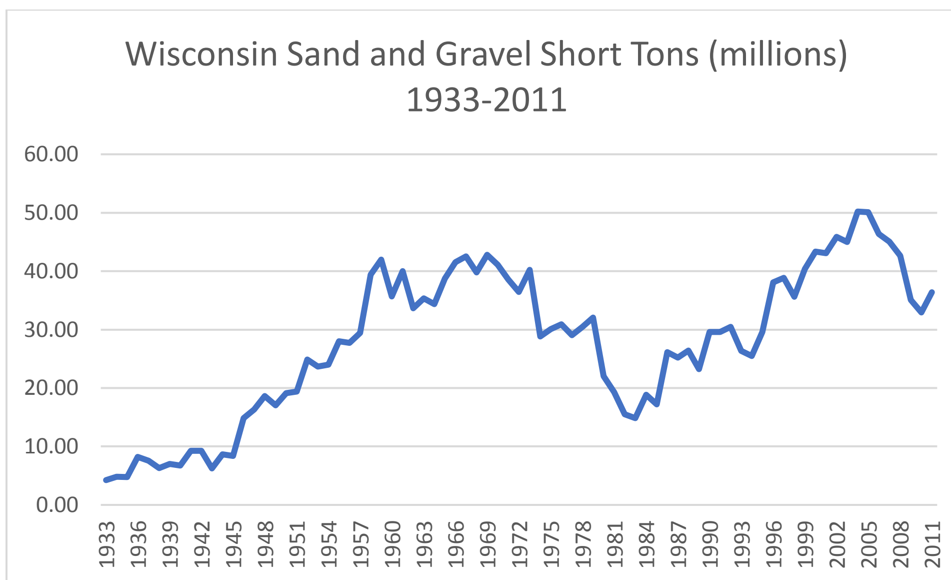
Appendix A: Wisconsin Mineral Yearbook Statistics

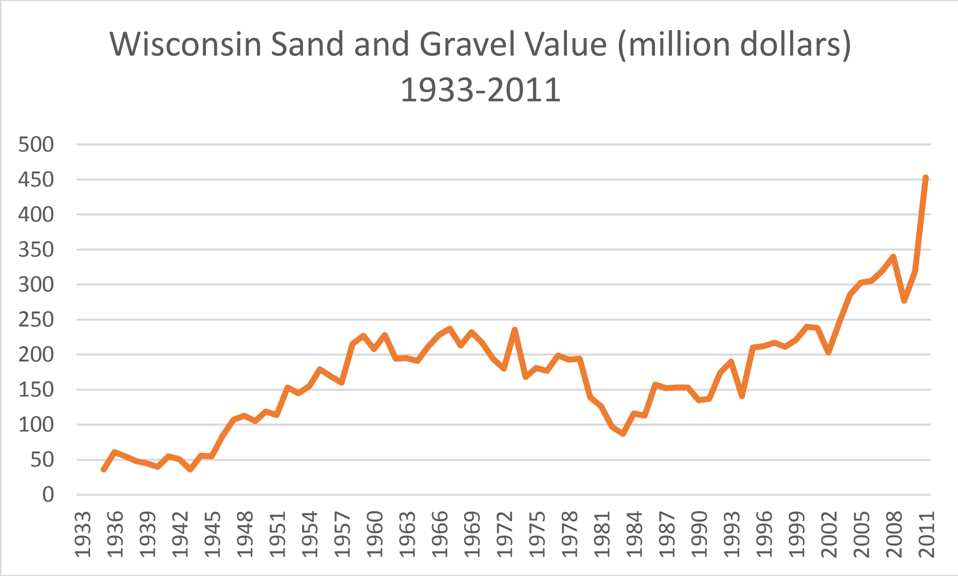
All values adjusted for inflation and obtained from the US Bureau of Mines and USGS Mineral Yearbooks.

Wisconsin Sand and Gravel Totals

WI Sand and Gravel 1935-2011		
	Short Tons	Value
1935	4,776,637	$2,066,516
1940	6,742,882	$2,304,197
1945	8,384,279	$4,111,282
1950	19,117,115	$11,959,012
1955	27,978,335	$19,958,450
1960	35,681,000	$25,648,000
1965	38,751,000	$27,707,000
1970	41,103,000	$35,107,000
1975	30,057,000	$40,580,000
1980	22,014,000	$47,565,000
1985	17,197,000	$50,624,000
1990	29,572,000	$73,750,000
1995	29,601,438	$133,400,000
2000	43,353,903	$172,000,000
2005	50,100,049	$246,700,000
2010	32,926,038	$290,000,000
2011	36,387,296	$425,000,000

WI Sand and Gravel 2000-2011		
	Short Tons	Value
2000	43,353,903	$172,000,000
2001	43,100,372	$175,600,000
2002	45,867,173	$152,000,000
2003	45,018,393	$188,700,000
2004	50,199,257	$225,000,000
2005	50,100,049	$246,700,000
2006	46,352,190	$256,100,000
2007	45,029,417	$276,100,000
2008	42,648,424	$305,000,000
2009	35,086,569	$248,000,000
2010	32,926,038	$290,000,000
2011	36,387,296	$425,000,000





Wisconsin Hydraulic Fracturing Sand

Oil/hydrafrac 1959-1975		
	Short tons	Value
1959	See Sand: Other	
1960	See Sand: Other	
1961	See Sand: Other	
1962	See Sand: Other	
1963	30,000	187,000
1964	14,000	69,000
1965	3,000	15,000
1966	0	0
1967	See Sand: Other	
1968	See Sand: Other	
1969	See Sand: Other	
1970	See Sand: Other	
1971	See Sand: Other	
1972	0	0
1973	no data	no data
1974	no data	no data
1975	See Industrial Sand	

Sand: Other (engine, blast, filter, oil/hydrafrac) 1959-1971		
	Short tons	Value
1959	122,000	$239,000
1960	205,000	$276,000
1961	282,000	$303,000
1962	208,000	$550,000
1965	351,000	$301,000
1967	160,000	$202,000
1968	102,000	$153,000
1969	145,000	$349,000
1970	240,000	$588,000
1971	267,000	$726,000
1975	See Industrial Sand	

	Sand: Molding	
	Short tons	Value
1935	62,944	$43,524
1940	78,886	$54,603
1945	Undistributed	
1950	Undistributed	
1955	860,504	$1,567,675
1960	83,000	$178,000
1965	879,000	$2,251,000
1970	782,000	$2,190,000
1975	See Industrial Sand	

Industrial Sand 1975-1984		
	Short tons	Value
1975	1,304,000	$6,165,000
1976	1,249,000	$6,251,000
1977	866,000	$5,034,000
1978	1,222,000	$6,291,000
1979	1,166,000	$7,752,000
1980	872,000	$8,887,000
1981	1,100,000	$13,180,000
1982	788,000	$9,662,000
1983	621,000	$7,208,000
1984	1,060,000	$11,821,000
1985	See Industrial Sand and Gravel	

Industrial Sand and Gravel 1985-2014		
	Short tons	Value
1985	1,197,000	$14,624,000
1986	1,194,000	$12,399,000
1987	1,314,000	$15,168,000
1988	1,351,000	$15,458,000
1989	1,514,000	$22,399,000
1990	Omitted	Omitted
1991	Omitted	Omitted
1992	1,374,000	$24,639,000
1993	1,630,318	$31,399,000
1994	1,796,767	$32,400,000
1995	1,796,767	$32,400,000
1996	1,840,859	$33,300,000
1997	1,884,952	$33,800,000
1998	1,929,044	$34,500,000
1999	1,929,044	$34,300,000
2000	1,906,998	$32,000,000
2001	1,884,952	Omitted
2002	1,918,021	$32,700,000
2003	1,918,021	$32,700,000
2004	2,358,946	$47,000,000
2005	2,480,200	$55,700,000
2006	2,700,662	$74,100,000
2007	2,921,124	$90,100,000
2008	3,626,604	$120,000,000
2009	3,229,772	$116,000,000
2010	4,045,482	$156,000,000
2011	6,073,735	$280,000,000
2012	10,700,000	$611,000,000
2013	19,800,000	$1,210,000,000
2014	38,300,000	$3,150,000,000

Wisconsin Sand and Gravel Usages

Sand: Building		
	Short tons	Value
1935	469,733	$184,233
1940	837,402	$303,172
1945	992,001	$449,674
1950	2,730,763	$1,812,948
1955	2,500,203	$1,920,510
1960	3,071,000	$2,711,000
1965	6,954,000	$4,619,000
1970	3,640,000	$3,439,000

Gravel: Building		
	Short tons	Value
1935	604,107	$343,029
1940	1,207,607	$440,494
1945	1,222,718	$693,998
1950	2,348,259	$1,856,976
1955	3,929,117	$3,071,799
1960	3,409,000	$3,198,000
1965	3,507,000	$2,986,000
1970	4,292,000	$4,402,000

Sand: Paving		
	Short tons	Value
1935	389,675	$153,656
1940	663,773	$234,237
1945	275,180	$105,551
1950	2,260,689	$1,079,291
1955	5,477,832	$2,564,109
1960	8,553,000	$5,106,000
1965	2,915,000	$2,183,000
1970	4,810,000	$3,221,000

Gravel: Paving		
	Short tons	Value
1935	2,681,645	$1,147,299
1940	2,858,799	$946,257
1945	4,105,238	$1,742,572
1950	10,095,780	$5,897,900
1955	12,959,416	$9,535,793
1960	16,613,000	$11,817,000
1965	20,502,000	$13,657,000
1970	22,925,000	$18,614,000

Sand: Railroad Ballast		
	Short tons	Value
1935	71,902	$17,821
1940	25,898	$7,833
1945	7,698	$6,233
1950	18,881	$9,684
1955	13,525	$7,345
1960	105,000	$84,000
1965	other	other
1970	other	other

Gravel: Railroad Ballast		
	Short tons	Value
1935	401,155	$82,609
1940	734,627	$167,651
1945	1,185,433	$339,321
1950	856,615	$272,741
1955	984,750	$465,116
1960	503,000	$365,000
1965	196,000	$111,000
1970	158,000	$99,000

Gravel: Fill		
	Short tons	Value
1935	19,257	$6,965
1940	225,861	$47,304
1945	46,484	$27,925
1950	601,059	$201,987
1955	410,598	$319,903
1960	927,000	$436,000
1965	1,957,000	$804,000
1970	1,907,000	$1,028,000
1975	Fill (Total)	

Sand: Fill		
	Short tons	Value
1935	no data	no data
1940	no data	no data
1945	0	0
1950	0	0
1955	4,065	$2,033
1960	1,159,000	$564,000
1965	1,816,000	$775,000
1970	2,087,000	1,152,000
1975	Fill (Total)	

Fill (Total)		
	Short tons	Value
1975	3,485,000	$3,056,000
1980	3,064,000	$4,737,000
1986	2,719,000	$4,205,000
1990	1,948,000	$2,760,000
1995	1,433,004	$2,280,000
2000	1,829,836	$4,840,000
2005	2,083,368	$5,620,000
2010	1,089,083	$3,350,000

Concrete Products (cement blocks, bricks, pipes)		
	Short tons	Value
1975	1,808,000	$2,436,000
1980	667,000	$1,667,000
1986	163,000	$387,000
1990	213,000	$686,000
1995	317,465	$1,330,000
2000	244,713	$914,000
2005	255,736	$1,130,000
2010	100,310	$395,000

Asphaltic Concrete/Bituminous Paving		
	Short tons	Value
1975	4,122,000	$5,958,000
1980	2,777,000	$4,814,000
1986	1,658,000	$3,607,000
1990	1,457,000	$3,335,000
1995	1,774,721	$4,980,000
2000	2,590,431	$7,970,000
2005	1,388,912	$4,950,000
2010	1,433,004	$8,400,000

Roadbase and subbase		
	Short tons	Value
1975	11,478,000	$11,055,000
1980	7,591,000	$12,372,000
1986	5,485,000	$11,186,000
1990	5,000,000	$11,313,000
1995	4,982,447	$11,200,000
2000	7,330,370	$21,100,000
2005	6,470,567	$22,400,000
2010	4,188,782	$17,300,000

Concrete Aggregate (Residential, Highways and Bridges, Dams, Airports, Waterworks)		
	Short tons	Value
1975	7,639,000	$11,698,000
1980	6,520,000	$14,057,000
1986	5,980,000	$16,317,000
1990	4,913,000	$14,593,000
1995	7,881,525	$26,900,000
2000	7,925,618	$30,100,000
2005	6,591,821	$28,700,000
2010	3,626,604	$18,200,000

Construction Sand and Gravel		
	Short tons	Value
1980	21,143,000	$38,678,000
1985	16,000,000	$36,000,000
1990	29,572,000	$73,750,000
1995	34,171,000	$101,000,000
2000	41,446,905	$140,000,000
2005	47,619,848	$191,000,000
2010	28,880,556	$134,000,000

Snow/ice control		
	Short tons	Value
1978	103,000	$127,000
1980	152,000	$262,000
1986	258,000	$684,000
1990	156,000	$492,000
1995	148,812	$471,000
2000	214,950	$625,000
2005	243,610	$1,050,000
2010	244,713	$969,000

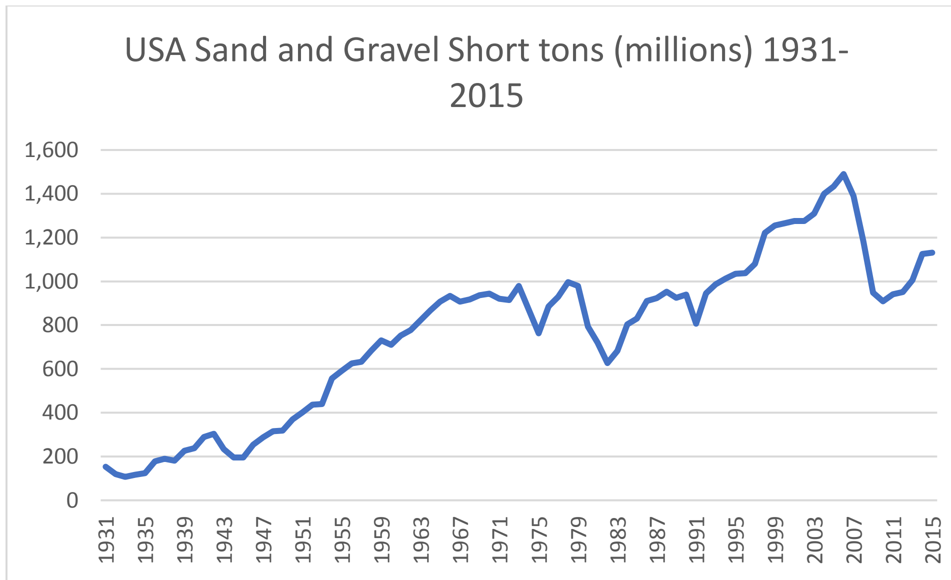
Appendix B: United States Mineral Yearbook Statistics

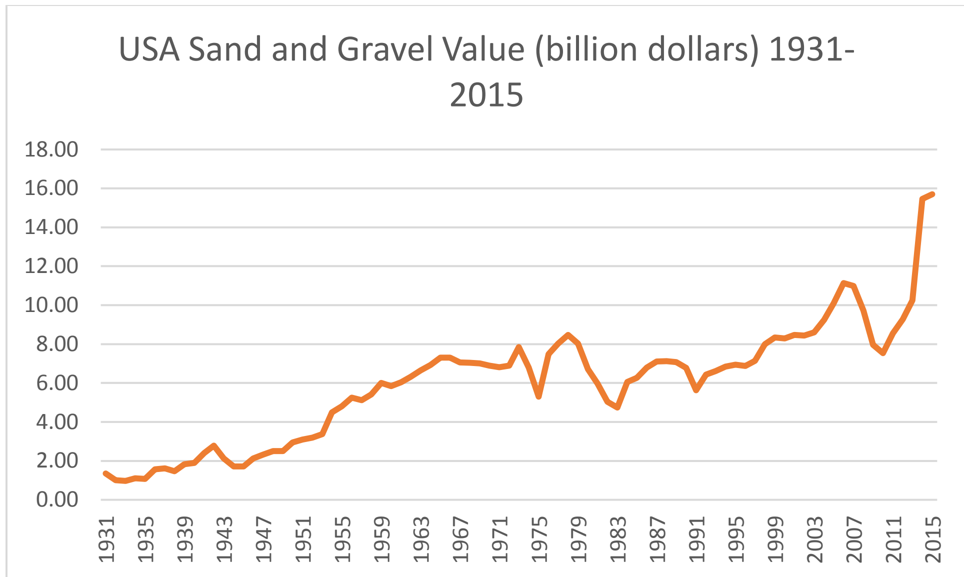
All values adjusted for inflation and obtained from the US Bureau of Mines and USGS Mineral Yearbooks.

USA Sand and Gravel Totals

USA Sand and Gravel 1931-2015		
	Short tons	Value
1931	153,479,044	$86,280,320
1935	123,923,923	$61,977,379
1940	238,308,000	$110,688,000
1945	195,524,000	$128,837,000
1950	370,455,000	$295,040,000
1955	592,153,000	$536,236,200
1960	709,792,000	$720,432,000
1965	908,049,000	$957,416,000
1970	943,941,000	$1,115,705,000
1975	762,153,000	$1,190,341,000
1980	794,400,000	$2,302,000,000
1985	829,530,000	$2,812,070,000
1990	939,006,000	$3,685,600,000
1995	1,034,188,000	$4,412,000,000
2000	1,265,894,309	$5,946,000,000
2005	1,433,666,090	$8,212,000,000
2010	909,296,600	$6,840,000,000
2015	1,130,861,173	$15,500,000,000

USA Sand and Gravel 2000-2015		
	Short tons	Value
2000	1,265,894,309	$8,287,349,721
2001	1,276,366,266	$8,469,399,559
2002	1,275,704,880	$8,435,599,005
2003	1,308,994,681	$8,607,642,353
2004	1,399,604,671	$9,243,255,293
2005	1,433,666,090	$8,212,000,000
2006	1,489,994,198	$9,347,000,000
2007	1,388,912,251	$9,499,000,000
2008	1,179,914,027	$8,717,000,000
2009	948,649,114	$7,113,000,000
2010	909,296,600	$6,840,000,000
2011	941,043,166	$8,020,000,000
2012	950,963,967	$8,880,000,000
2013	1,005,418,146	$9,940,000,000
2014	1,125,459,848	$15,250,000,000
2015	1,130,861,173	$15,500,000,000

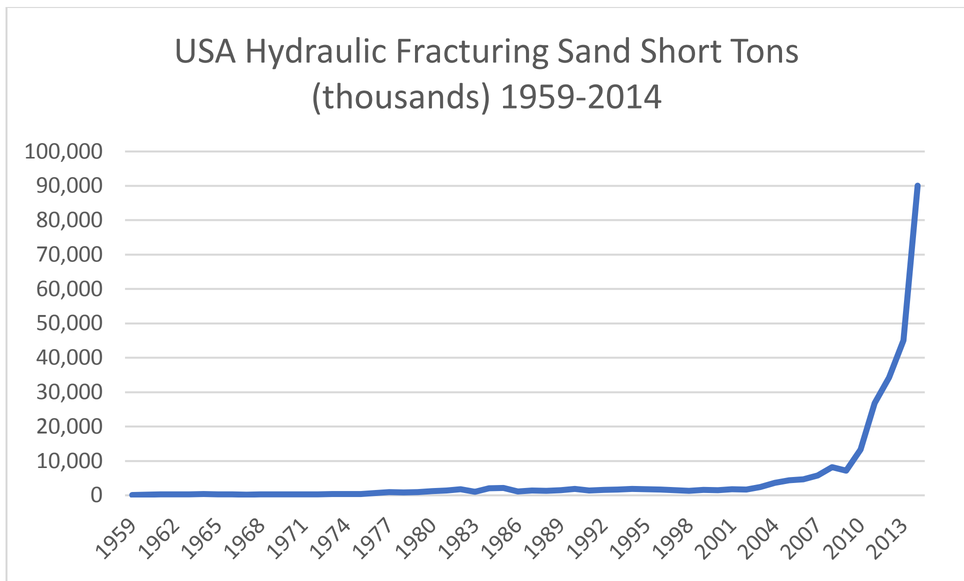


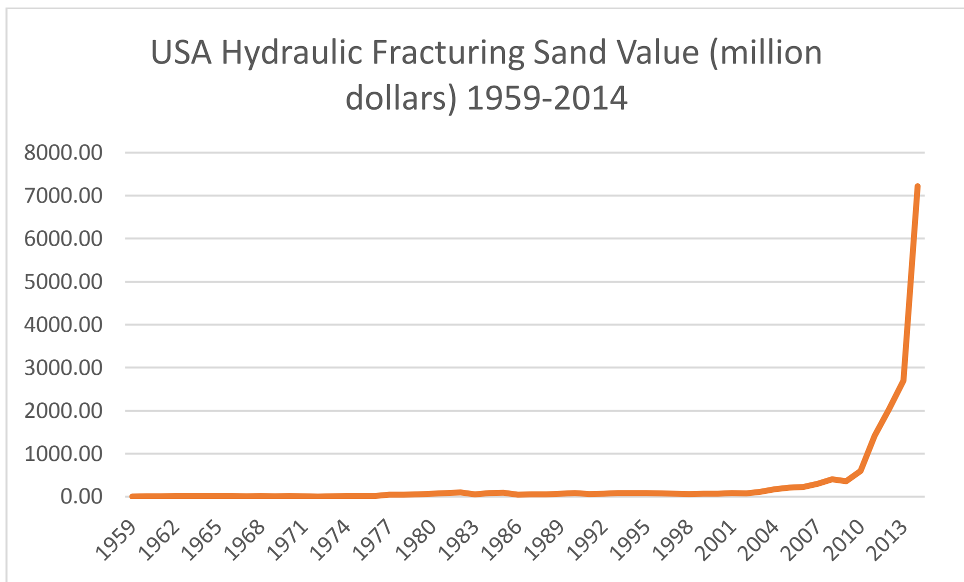


USA Hydraulic Fracturing Sand

USA Hydraulic Fracturing Sand 1959-2014		
	Short tons	Value
1959	85,000	$360,000
1960	153,000	$939,000
1965	259,000	$1,830,000
1970	296,000	$2,360,000
1975	371,000	$4,279,000
1980	1,176,000	$24,000,000
1985	2,102,000	$42,417,000
1990	1,839,000	$46,655,000
1995	1,741,651	$53,000,000
2000	1,510,166	$47,500,000
2005	4,420,268	$174,000,000
2010	13,337,966	$546,000,000
2014	90,058,834	$7,120,000,000

USA Hydraulic Fracturing Sand 2000-2014		
	Short Tons	Value
2000	1,510,166	$47,500,000
2001	1,763,698	$64,800,000
2002	1,631,420	$59,200,000
2003	2,380,992	$87,900,000
2004	3,615,581	$135,000,000
2005	4,420,268	$174,000,000
2006	4,640,730	$187,000,000
2007	5,798,157	$261,000,000
2008	8,146,080	$365,000,000
2009	7,198,092	$319,000,000
2010	13,337,966	$546,000,000
2011	26,786,164	$1,330,000,000
2012	34,281,881	$1,950,000,000
2013	45,084,532	$2,620,000,000
2014	90,058,834	$7,120,000,000





Works Cited

Bean, E. F. "Mineral Resources of Marinette County." Madison, WI: Geological and Natural History Survey, 1941.

Beckwith, Robin. "Hydraulic Fracturing: The Fuss, The Facts, The Future." *Journal of Petroleum Technology*, December 2010.

Benson, Mary Ellen and Wilson, Anna B. "Frac Sand in the United States—A Geological and Industry Overview." United States Geological Survey, 2015.

Brown, Bruce A. "Gold, Iron, Copper, Zinc, and Sand; What's Driving the New Interest in Mining and Mineral Resources in Wisconsin." Madison, WI: Wisconsin Geological and

Natural History Survey. http://www.wisctowns.com/uploads/ckfiles/files/WTA_102511%20Frac%20Sand.pdf.

———. "Wisconsin's Mining Industry; Past, Present, and Future." Madison, WI: Wisconsin Geological and Natural History Survey, 2009-2010 http://static1.1.sqspcdn.com/static/f/1103553/15601564/1323896729620/mining.pdf?token=NwtZer3cZIRcaVrjcqqXeJCT21A%3D.

Brown, Caleb. "Frac Sand Not Likely to Boom in near Future." *La Crosse Tribune*, December 15, 2015. http://lacrossetribune.com/news/frac-sand-not-likely-to-boom-in-near-future/article_baaa01c6-8c7f-5972-820d-d48b3671acce.html.

Buckley, Ernest Robertson. "Map of Wisconsin Showing Location of Quarries." Wisconsin Geological and Natural History Survey, 1896. https://wgnhs.uwex.edu/publications-home/.

———. "Highway Construction in Wisconsin." Madison, WI: Wisconsin Geological and Natural History Survey, 1903.

Campbell, Ballard. "Wisconsin Stories: The Good Roads Movement in Wisconsin, 1890-1911." Madison, WI: State Historical Society of Wisconsin, 1980. Pamphlet Collection, Wisconsin Historical Society.

Chase, Taylor. "As Rail Moves Frac Sand across Wisconsin Landscape, New Conflicts Emerge." *WisconsinWatch.org*, July 13, 2014. http://wisconsinwatch.org/2014/07/as-rail-moves-frac-sand-across-wisconsin-landscape-new-conflicts-emerge/.

"Crushed Stone Producers in Wisconsin." Madison, WI: The State, 1912. Wisconsin Historical Society Pamphlet Collection.

Dott, Jr., Robert H. and Attig, John W. *Roadside Geology of Wisconsin*. Missoula, MT: Mountain Press Publishing Company, 2004.

Evans, Thomas J. "Mining in Wisconsin: Where We've Been; Where We're Going." *Wisconsin Academy Review* 28 (December 1981).

"Frac Sand Mining." *Wisconsin League of Conservation Voters*. Accessed September 26, 2016. http://conservationvoters.org/issues/frac-sand-mining/.

Friz, Thomas O. "Mineral Resources, Mining, and Land-Use Planning in Wisconsin." Madison, WI: Geological and Natural History Survey, 1975.

Glischinski, Steve. "The Demand for SAND," *Trains*, May 2013.

Golden, Kate. "Frac Sand: Wisconsin Sites." Wisconsin Center for Investigative Journalism, 2011.

Granite Gravel Company. *A Combined Corporation Record and Stock Holders' Accounts of Granite Gravel Company Principal Office at Wausau Wisconsin*. Wisconsin Historical Society Archive.

Haines, Anna and Risse, William. "Evaluating Nonmetallic Mining: County Comprehensive Plans." University of Wisconsin-Extension, Center for Land Use Education, August 2012.

———. "Evaluating Nonmetallic Mining: County Zoning Ordinances." University of Wisconsin-Extension, Center for Land Use Education, August 2012.

Hotchkiss, William Otis. "Rural Highways of Wisconsin." Madison, WI: Wisconsin Geological and Natural History Survey, 1906. https://wgnhs.uwex.edu/publications-home/.

Hotchkiss, W. O. and Steidtmann, Edward. "Limestone Road Materials of Wisconsin." Madison, WI: Wisconsin Geological and Natural History Survey, 1914). https://wgnhs.uwex.edu/publications-home/.

"Industrial Sand Mining in Wisconsin: Strategic Analysis for Public Review." Wisconsin Department of Natural Resources, June 2016.

Karges, B.E. "Location of Quarry Sites in the City of Madison." Madison, WI: Geological and Natural History Survey, 1935, https://wgnhs.uwex.edu/publications-home/.

Karon, Sarah. "Explainer: What Is Fracking?" *WisconsinWatch.org*, Accessed September 26, 2016, http://wisconsinwatch.org/2011/07/explainer-what-is-fracking/.

Kremer, Rich. "Frac Sand Company Stocks Recovering After Huge Industry Slowdown." *Wisconsin Public Radio*, June 24, 2016. http://www.wpr.org/frac-sand-company-stocks-recovering-after-huge-industry-slowdown.

Lake, James A. *Law and Mineral Wealth: The Legal Profile of the Wisconsin Mining Industry*. Madison, WI: The University of Wisconsin Press, 1962.

Lindquist, Eric. "Silent Sandbox: Once Booming Frac Sand Industry Continues Major Downturn." *Leader-Telegram*, May 8, 2016. http://www.leadertelegram.com/News/Front-Page/2016/05/08/Silentsandbox.html.

"Locations of Industrial Sand Mines and Processing Plants in Wisconsin - Wisconsin DNR." Accessed January 5, 2017. http://dnr.wi.gov/topic/Mines/ISMMap.html.

McKeever, Peter E. and Preston, John. "Mineral Prospecting and Mining Transactions." Madison, WI: Geological and Natural History Survey, 1975.

Mickelson, David M. "Wisconsin's Glacial Landscapes." In *Wisconsin: Land and Life*, edited by Robert C. Ostergren and Thomas R. Vale, 35-48. Madison, WI: The University of Wisconsin Press, 1997.

Montgomery, Carl T. and Smith, Michael B. "Hydraulic Fracturing: History of an Enduring Technology." *Journal of Petroleum Technology*, December 2010.

Nesbit, Robert C. *Wisconsin: A History*, 2nd ed. Madison, WI: The University of Wisconsin Press, 1989.

Olmstead, Clarence W. "Changing Technology, Values, and Rural Landscapes." In *Wisconsin Land and Life*, edited by Robert C. Ostergren and Thomas R. Vale, 355-375. Madison, WI: University of Wisconsin Press, 1997.

Paul, Barbara Dotts and Paul, Justus F. *Wisconsin History: An Annotated Bibliography.* Westport, CT: Greenwood Press, 1999.

Prengaman, Kate. "As Supply Meets Demand, Wisconsin's Frac Sand Rush Slows." *WisconsinWatch.org*, December 15, 2012. http://wisconsinwatch.org/2012/12/frac-sand-rush-slows/.

Rademacher, Thomas. Wisconsin 101: Our History in Objects. "The Good Roads Movement in Wisconsin," Accessed April 29, 2017. http://www.wi101.org/?story=the-good-roads-movement-in-wisconsin.

Roe, Lawrence A. *A History of Wisconsin Mining*. Madison, WI: ROECO, 1991.

Sider, Alison and Jones, Kristin. "In Fracking, Sand Is the New Gold." *Wall Street Journal*, December 2, 2013, http://www.wsj.com/articles/SB10001424052702304868404579194250973656942.

"Silica Sand Mining in Wisconsin." Wisconsin Department of Natural Resources, January 2012. http://dnr.wi.gov/topic/mines/documents/silicasandminingfinal.pdf.

"Suggestions to County Highway Commissioners for Building Stone and Gravel Roads." Madison, WI: Wisconsin Highway Commission, 1912. Wisconsin Historical Society Pamphlet Collection.

Tighe, Benjamin Charles B. "An Historical and Financial Survey of the Madison Municipal Quarry." University of Wisconsin-Madison, 1908. Wisconsin Historical Society Archive.

Trainer, David W. "Molding Sands of Wisconsin." Madison, WI: Wisconsin Geological and Natural History Survey, 1928. https://wgnhs.uwex.edu/publications-home/.

United States Bureau of Mines. "The Mineral Industry of Wisconsin." *Minerals yearbook area reports 1959,* (1960).

———. "The Mineral Industry of Wisconsin." *Mineral yearbooks area reports 1984, 2010, 2011.*

United States Bureau of Mines and United States Geological Survey. *Mineral Yearbooks: Statistical Summary*, 1952-2013.

———. *The Mineral Industry of Wisconsin*. 1959-2014.

United States Geological Survey. "2014 Minerals Yearbook: Advance Release." *Silica*, October 2016.

———. "The Mineral Industry of Wisconsin." *Mineral yearbooks area reports 1984 & 2010.* United States Geological Survey. "2014 Minerals Yearbook: Advance Release." *Silica*, October 2016.

United States Geological Survey and Wisconsin Geological and Natural History Survey. "Mineral and Water Resources of Wisconsin." 1976.

Walls, Roberta. Conversation with Roberta Walls. Phone. February 17, 2017.

Wells, Christopher W. *Car Country: An Environmental History*. Vancouver: University of Washington Press, 2014.

Whitbeck, Ray Hughes. "The Geography and Industries of Wisconsin." Madison, WI: Wisconsin Geological and Natural History Survey, 1913. https://wgnhs.uwex.edu/publications-home/.

Wisconsin Department of Natural Resources. "Nonmetallic Mining Overview." Accessed September 25, 2016, http://dnr.wi.gov/topic/Mines/Nonmetallic.html.

"Wisconsin Geological and Natural History Survey - Mining: Frac Sand." Accessed September 26, 2016, https://wgnhs.uwex.edu/wisconsin-geology/frac-sand-mining/.

Wisconsin Historical Society. "Lead Mining in Southwestern Wisconsin." Accessed October 8, 2016. http://www.wisconsinhistory.org/turningpoints/tp-026/?action=more_essay.

———. "Mining in Northern Wisconsin." Accessed October 8, 2016. http://www.wisconsinhistory.org/turningpoints/tp-029/?action=more_essay.

"Wisconsin Towns Worry Frac Sand Boom Will Dry up." *Midwest Energy News*, June 3, 2015. http://midwestenergynews.com/2015/06/03/wisconsin-towns-worry-frac-sand-boom-will-dry-up/.

Wisconsin Watch. "October Update: Wisconsin's Frac Sand Industry Map." *WisconsinWatch.org*, October 18, 2013. http://wisconsinwatch.org/2013/10/october-update-wisconsins-frac-sand-industry-map/.

"Wisconsin Water Use: 2014 Withdrawal Summary." Wisconsin Department of Natural Resources, 2014.

Younger, Sally. "Sand Rush: Fracking Boom Spurs Rush on Wisconsin Silica." *National Geographic News*, July 4, 2013. http://news.nationalgeographic.com/news/energy/2013/07/130703-wisconsin-fracking-sand-rush/.