THE PERILS OF EFFICIENCY: AN ANALYSIS OF AN UNEXPECTED CLOSURE OF THE POE LOCK AND ITS IMPACT

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EXECUTIVE SUMMARY

One of the Nation's most economically vital systems, the iron mining - integrated steel production - manufacturing supply chain is potentially one of the least resilient to disruption. The Poe Lock at the Soo Locks connecting Lakes Huron and Superior is a potential single point of failure in this supply chain. An unexpected 6-month closure of the locks would have devastating consequences for industries dependent on this supply chain, particularly the automobile manufacturing industry, and the National economy.

The iron ore extracted from mines located in Minnesota and Michigan is used by steel mills along the Great Lakes to make steel for the appliance, automobile, construction, farm, and mining equipment manufacturers, railcar production and other industries. These steel mills make various grades of steel to supply different markets and different categories within markets. Almost every steel mill makes some type of steel for the automotive industry, the market that dominates the steel industry.

The iron ore shipped from Lake Superior to the Great Lakes steel mills transits the Soo Locks, a set of locks owned and operated by the United States Army Corps of Engineers (USACE). An unanticipated closure of the Poe Lock, the only lock large enough at the Soo Locks to allow passage of the Lake Carriers carrying iron ore, would be catastrophic for the Nation. Depending on what time of year the closure occurred, approximately 75 percent of the U.S. integrated steel production would cease within 2–6 weeks after the closure of the Poe Lock. Approximately 80 percent of iron ore mining operations, and nearly 100 percent of the North American appliances, automobile, construction equipment, farm equipment, mining equipment, and railcar production would shut down. The shutdowns in production of these products would begin slowly and then increase quickly as the stress grows in the iron mining – integrated steel production – manufacturing supply chains. Almost 11 million people in the United States and potentially millions more in Canada and Mexico would become unemployed due to the production stoppage, and the economy would enter a severe recession. There are no plans or solutions that could mitigate the damage to the manufacturing industries dependent on this supply chain.

This report, developed by the Office of Cyber and Infrastructure Analysis' (OCIA) National Infrastructure Simulation and Analysis Center (NISAC) describes the iron mining – integrated steel production – manufacturing supply chain and its history and presents analysis of the impacts of an unanticipated closure and the challenges facing various potential mitigation strategies. OCIA stresses that there is no plan for closing the Soo Locks and no specific reason to believe that the Soo Locks would close. The intent of this report is to highlight the dependency of the North American economy on this set of locks, particularly the Poe Lock. The Poe Lock has been called the Achilles' heel of the Great Lakes navigation system, though it more aptly may be described as the Achilles' heel of the North American industrial economy. The report concludes with some potential mitigation strategies for further analysis, but no single strategy is sufficient to mitigate the disruption.

KEY FINDINGS

- **One the Nation's most economically vital systems, the iron mining - integrated steel production - manufacturing supply chain, is also potentially the least resilient.**
- **A disruption of the Poe Lock likely will cause an almost complete shutdown of Great Lakes steel production.**
- **A shutdown of Great Lakes steel production likely will cause almost all North American appliances, automobile, construction equipment, farm equipment, mining equipment, and railcar production to cease within weeks.**
- **The disruption would likely result in widespread bankruptcies and dislocations throughout the economy. Almost 11 million people would likely be unemployed because of the impact and the North American economies would likely enter a severe recession.**

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BACKGROUND

MINES TO PORTS

FIGURE 1—IRON ORE MINES AND PORTS

One the Nation's most economically vital systems, the iron mining—integrated steel production—manufacturing supply chain, is also potentially one of the least resilient. [1,2,3] The iron ore, extracted from mines located primarily in Minnesota (see Figure 1), and to a lesser extent in Michigan, is used by steel mills, generally located along the Great Lakes (see Appendix A for a listing of the iron ore mines; see Figure 2 for a map of the Great Lakes). The three largest steel mills, which account for about half of the domestic integrated steel capacity, are located at the southern tip of Lake Michigan, around Gary, Indiana: Indiana Harbor (ArcelorMittal), Gary Works (U.S. Steel), and Burns Harbor (ArcelorMittal). Appendix B provides a complete list of U.S. steel mills.

[1] While the term 'iron ore' is used throughout the paper, technically the product is taconite. The iron ore mined in the Mesabi Range, MN was depleted during World War II; during the extraction of the iron ore, the taconite, which was considered a waste product, was discarded. Later, a process was developed to crush the taconite and to use a magnet to extract the iron ore.
[2] The terms 'steel' and 'integrated steel' are used interchangeably throughout this report, but refer to the same type of steel.
[3] Iron ore, which is the primary focus of this report, is the predominant commodity transiting the Soo Locks. Coal, which is the second largest commodity, is discussed in the Lightering Section and in Appendix E. Grains, which is the third largest commodity group transported through the Soo Locks, is the only commodity primarily destined for the export market.

FIGURE 2—THE GREAT LAKES

Iron ore pellets are extremely heavy and the mines use specialized railroad cars, called iron ore jennies, which are less than one-half the size of a standard railcar, to move the iron ore from the mines to the iron ore ports (see Figure 1 and Table 1).[4] Each of the iron ore jennies carries about 85 net or short tons of iron ore the average 70 miles from the mines to the iron ore docks.[5]

TABLE 1—IRON ORE DOCKS[6]

Dock Name	Location	Owner	Storage Capacity (tons)	Load Speed (tons per hour)	Rail Served
Hallet Dock #5	Duluth, MN	Hallet Dock Company	800,000	N/A	BNSF, CN
DMIR Dock #6	Duluth, MN	CN Railway	3,000,000	10,000	CN
CN Ore Dock	Escanaba, Michigan	CN Railway	2,000,000	4,000	CN
Northshore Mining	Silver Bay, Minnesota	Cliffs Natural Resources	3,000,000	6,000	CN
BNSF Dock #5	Superior, Wisconsin	BNSF Railroad	3,500,000	6,000	BNSF
Two Harbors	Two Harbors, Minnesota	CN Railway	2,500,000	10,000	CN
Presque Isle	Marquette, Michigan	CN Railway	57,000	3,500	CN

Most of the iron ore extracted in Minnesota and Michigan must be processed, prior to use, in pelletizing plants located near the iron ore mines. The iron ore must go through a beneficiation process of crushing and grinding to separate and remove waste material. The iron ore may then be mixed with limestone (which is shipped east to west through the Soo Locks) and other chemicals to make iron ore pellets.[7,8] There are many different grades and

[4] Taconite has a density of about 2800 kilograms/cubic meters, which is more than double the density of coal (1350 kilograms/cubic meters) and more than triple the density of grains (2800 kilograms/cubic meters) two other products commonly transported by vessel and rail (see SI Metric at http://www.simetric.co.uk/si_materials.htm, accessed May 10, 2015).
[5] Different industries within this supply chain use different definitions of what constitutes a ton. To simplify the analysis, long tons and metric tons were converted into short tons or net tons, which are the same.
[6] The data for this table comes from two sources, the USACE Navigation Data Center (http://www.navigationdatacenter.us/ports/ports.htm) and Greenwood's Guide to Great Lakes Shipping 2015 (Harbor House Publishers: Boynce City, Michigan).
[7] Technically, the limestone is calcite or dolomite. The calcite is lower in magnesium and the mills mix calcite and dolomite to get a specific percentage of magnesium. Calcite is more commonly shipped to the iron ore mines for pelletizing.

sizes of iron ore pellets and they are not interchangeable. Since the early twentieth century, chemists would take samples of iron ore from railcars that were *en route* from mines to iron ore docks and telegraph or telephone the chemical make-up to the facilities at the docks, so that comparable grades of iron ore could be combined for shipment to a particular steel mill.[9] The use of a different pellet could affect steel quality and the blast furnace lining.[10] This process continues today and iron ore pellets, which are about 63 percent iron ore, are shipped by freighter through the Soo Locks.[11]

[8] When extracted, the taconite may have an iron ore content of 30 percent. The taconite is crushed and ground at taconite processing plants, which are located either at the mines, between the mines and the ports, or at the ports. The taconite must be ground to a fine size so that the iron ore can be extracted by magnetic separate or flotation resulting in production of an iron concentrate. This iron ore concentrate is pelletized into what is called a standard (or acid) pellet or a flux pellet. Both acid and flux pellets have iron content of approximately 65 percent, with flux pellets containing approximately 10 percent limestone or dolomite. The pellets are sized according to the specs of the particular blast furnace to which they will be shipped.

[9] Joachim, George J., "Iron Fleet: The Great Lakes in World War II," Wayne State University Press: Detroit, 1994.

[10] A blast furnace converts the iron ore pellets into liquid iron called 'hot metal' that goes to the basic oxygen furnace to be made into a steel slab (see American Steel and Iron Institute, "The Basic Oxygen Steelmaking Process" at https://www.steel.org/Making%20Steel/How%20Its%20Made/Processes/Processes%20Info/The%20Basic%20Oxygen%20Steelmaking%20Process.aspx?siteLocation=88e232e1-d52b-4048-9b8a-f687fbd5cdcb, accessed April 29, 12015.

[11] U.S. Environmental Protection Agency, "Taconite Ore Processing," at http://www.epa.gov/ttnchie1/ap42/ch11/final/c11s23.pdf, accessed February 5, 2015, and Minnesota Department of Natural Resources, "Taconite," http://www.dnr.state.mn.us/education/geology/digging/taconite.html, accessed February 5, 2015. An alternative method still used as some facilities is called sintering. Sintering takes fine grains of purified low-grade ore into larger shapes with the source of the ore coming from a region outside of Lake Superior. (see Rogers, Robert P., "An Economic History of the American Steel Industry," Routledge Exploration in Economic History).

PORTS TO MILLS

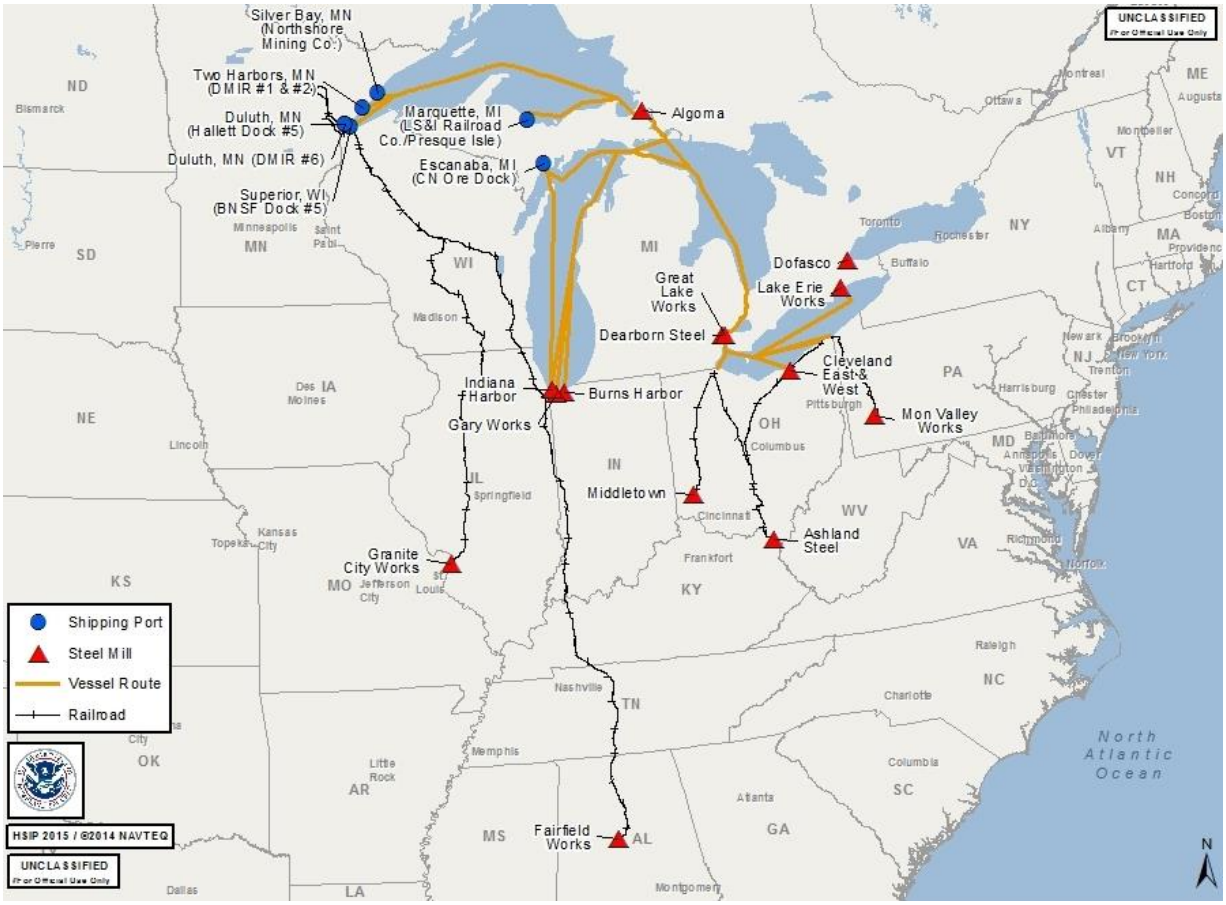

FIGURE 3—PORTS TO STEEL MILLS

There are 13 integrated steel mills in North America. About 50 percent of the iron ore used by the integrated steel mills is shipped directly from the iron ore docks to the mills through the Poe Lock at the Soo Locks. All of the steel mills in Indiana and Michigan, and Lake Erie Works (U.S. Steel) in Ontario receive their iron ore by this pathway (see Figure 3). Another 20 percent of the iron ore used by the integrated steel mills is shipped through the Soo Locks to a Lake Erie port for trans-shipment to a steel mill. In the case of Cleveland East and West (ArcelorMittal), the trans-shipment is onto a smaller vessel that can transit the Cuyahoga River. In the other cases, the trans-shipment is by rail to the final destination. The remaining steel mills either receive their iron ore directly from Minnesota by rail or from sources that do not require shipping through the Poe Lock.

Turning the iron ore pellets into steel is a two-stage process. In the first stage, the pellets are melted into liquid iron in a blast furnace, using oxygen, coking coal, natural gas, and other chemicals while ensuring the proper balance of silicon, sulfur, manganese, and phosphorus. The liquid iron is poured into a basic oxygen furnace along with some scrap steel; oxygen is injected into the mix at supersonic speeds to burn away excess carbon and other impurities. Limestone is then added to gather the impurities into a 'slag' that is discarded. The liquid steel is sent to a treatment facility where the final chemistry and quality is achieved prior to being sent to a caster facility or slab casting area to be processed into a slab. Slabs, which can weigh up to 40 tons, can be 2–7 feet wide, 32 feet long, and up to 1 foot thick (see Figure 4). Slabs can be stored outdoors for specific customers, and, when needed, rolled in the hot rolling and cold rolling facilities to be made into a steel coil (see Figure 4).

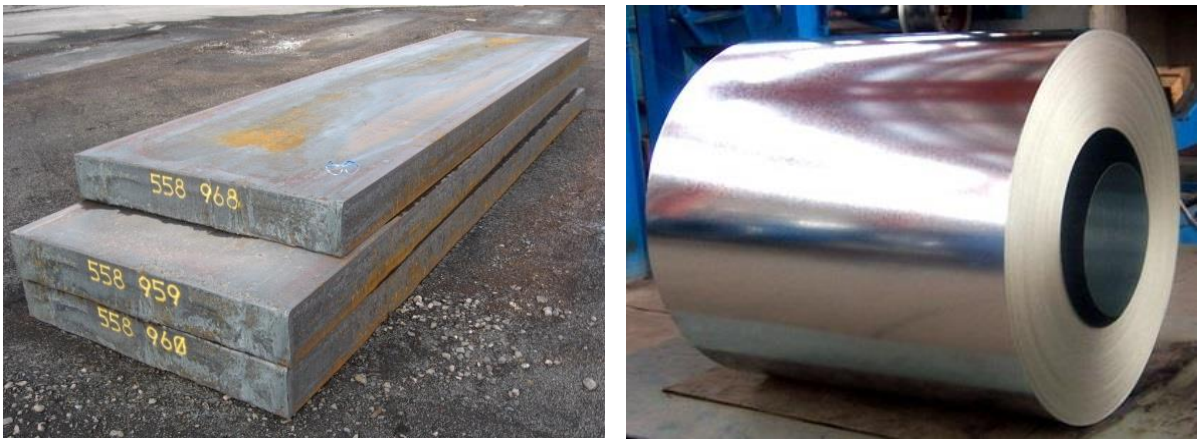

FIGURE 4—STEEL SLAB AND COIL[12]

TYPES OF STEEL PRODUCED IN NORTH AMERICA

In this report, steel refers to steel made in a basic oxygen furnace (BOF), which converts iron ore into steel. BOF steel plants have historically been referred to as integrated steel mills and were the large steel mills located between Illinois and Pennsylvania. Most steel today—about 60 percent of the approximately 120 million ton domestic capacity—is made in an electric arc furnace (EAF), and more commonly referred to as a 'mini-mill'. Mini-mills convert scrap steel into steel using electricity. As their names suggest, mini-mills are typically far smaller than the traditional integrated steel mills. They generally produce steel for specific markets or geographic areas. EAF mills generally have lower cost structures associated with non-union labor, lack of legacy pension plans, and geographic flexibility.

BOF steel has the properties of 'high strength', 'low weight', and 'formability', which means that the steel can be pressed to a thin layer and formed to meet certain shapes and strengths, such as those for an automobile body or frame. EAF steel is used for its strength, particularly in the construction field, as structural steel or rebar. BOF steel and EAF steel are not interchangeable. As one industry expert said, "Mini-Mills are not an option either.[13] They do not produce many of the types of steel that the auto industry requires such as Advanced High Strength Steels or expose quality sheet for outer vehicle panels. Their material could be used for perhaps 50 percent or 60 percent of the components used to build a vehicle. But a vehicle cannot be produced with 60 percent of the parts, it needs every single component." Another industry expert maintained that mini-mills could only supply about 15 percent of the necessary steel, while others said that they cannot use any products coming out of mini-mills. The amount of steel that could be supplied by mini-mills varies by auto manufacturer, but in no case can a car be manufactured using just EAF steel. One of the main drivers for the use of Advanced High Strength steels is the Corporate Average Fuel Economy (CAFE) standards that mandate increasingly high fuel economy for new cars. A car made just from EAF steel would weigh far more than a car made from BOF steel and would not meet the CAFE standards.

[12] Wikipedia, "Semi-finished casting products" at http://upload.wikimedia.org/wikipedia/commons/d/df/Slabs_stack.jpg, accessed May 10, 2015.
[13] Much of the information obtained for this report came from people associated with the broader supply chain. Everyone we spoke with provided very candid and open assessments, for which we are extremely grateful, and we agreed that we would not disclose any identifying information. Any reference to "industry executive" in this report covers these frank discussions.

FIGURE 5—COKE BATTERY SHOWING THE SIDE-BY-SIDE OVENS AND A RAILROAD CAR OF INCANDESCENT COKE[14]

Coking coal is one of the ingredients that helps convert the iron ore pellets into liquid iron. Coking coal is made in coke batteries that concentrate the carbon from coal to make an almost pure form of carbon. Coking coal is also referred to as 'coke' or 'metallurgical coal'.[15] Coking coal is an essential ingredient in steelmaking while thermal coal is used in electric power generators to produce electricity.[16] The coke battery is a series of high-temperature ovens stacked in a row, as shown in Figure 5. These ovens heat coal to 1,100°C in an oxygen-deficient atmosphere to produce coke with low impurities and high-energy content.

[14] American Iron and Steel Institute, "Steelworks: the Online Resource for Steel" Web page "Coke Production for Blast Furnace Ironmaking,"2015, at www.steel.org/Making%20Steel/How%20Its%20Made/Processes/Processes%20Info/Coke%20Production%20For%20Blast%20Furnace%20Ironmaking.aspx, accessed May 18, 2015.
[15] For more information about the process, see World Coal Association, "Coal and Steel," at http://www.worldcoal.org/coal/uses-of-coal/coal-steel/, accessed April 27, 2015.
[16] Ibid.

VESSEL TRANSPORTATION

ONE THOUSAND FOOTERS AND OTHER LAKERS

FIGURE 6—THE LAKER "EDWIN H. GOTT"[17]

Iron ore is moved from mines to one of six ports on Lake Superior or one small port on Lake Michigan. Most of the iron ore is loaded onto one of 13 Class X bulk freight Lake Carriers, more commonly known as 'One Thousand Footers', or 'Footers' (see Figure 6). [18] The One Thousand Footers are about the length of four 747 aircraft nose to tail. They each carry approximately 70,000 tons of iron ore, which is about the equivalent of seven trains with 100 rail cars each or about 3,000 trucks.[19,20] Another 35 vessels carry iron ore, coal, grain, limestone and other products on the Great Lakes and those vessels, together with the One Thousand Footers, are commonly called 'Lakers.' The smaller Lakers that carry iron ore generally do so for specialized trade. For instance, a One Thousand Footer cannot unload iron ore at the Cleveland steel mill; rather a One Thousand Footer unloads iron ore at the Cleveland Bulk Terminal and the iron ore is placed onto smaller Lakers that can transit the Cuyahoga River. The Rouge River in Detroit poses a similar challenge.

The Lakers are self-unloading vessels that require no on-shore equipment to unload iron ore. A Laker can dock at a steel mill and unload their cargo in about 10–12 hours with a crew of about 20 people. While iron ore ports worldwide unload vessels at the rate of about 3,000 tons per hour, the Great Lakes Lakers can unload at rates of up to 10,000 tons per hour. The Great Lakes fleet remains almost the only fleet that uses self-unloading technology.[21] For more information about the Great Lakes fleet, see Appendix C.

[17] From the private collection of Dr. Craig S. Gordon.
[18] USACE designates a Class based on the length of the vessel. Class X refers to vessels from 950 to 1,099 feet. For a complete description, see Appendix C.
[19] The term 'Lakers' may also refer to other classes of Lake Freighters, both American and Canadian, that are smaller, but still carry bulk commodities. Some of these smaller vessels can transit from Lake Superior to the Atlantic Ocean. The vessels that do enter the Atlantic Ocean are referred to as 'Salties.'
[20] The 70,000-ton figure is an approximation depending on water levels in the Great Lakes and the current depth of the Poe Lock. The design capacity of the vessels may be closer to 80,000 tons if St. Marys River was dredged deeper and the Poe Lock had a deeper lakebed elevation.
[21] Thompson, Mark L. "Steamboats & Sailors of the Great Lakes," Wayne State University Press: Detroit, 1991.

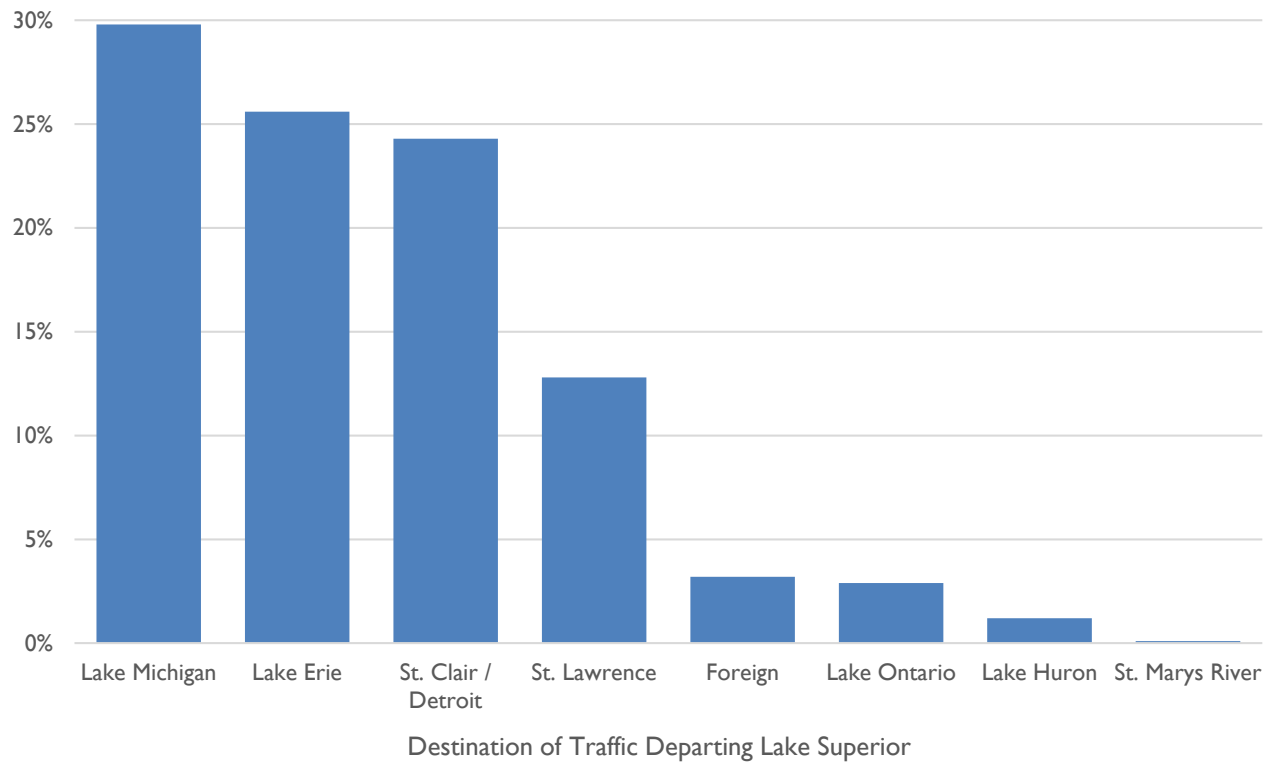

FIGURE 7—EASTBOUND TRAFFIC FROM LAKE SUPERIOR THROUGH THE SOO LOCKS[22]

Figure 7 shows the termination point for all commodities that originates in Lake Superior. About 30 percent of the traffic goes from Lake Superior to Lake Michigan and over 25 percent of the traffic goes from Lake Superior to Lake Erie. Both of these routes are likely only iron ore, while the traffic to St. Clair and Detroit is likely a mix of coal and iron ore. Wheat and oilseed dominate the remaining locations for Lake Superior-originating traffic; much of this moves on Canadian-flagged Lakers. The westbound trade into Lake Superior is about one-ninth of the eastbound trade; limestone dominates the westbound traffic.

[22] USACE, "Statistical Report of Lake Commerce Passing through St. Marys Falls Canal, Sault Ste. Marie, Michigan During the 2013 Navigation Season." Copies from 2004-2012 were also accessed.

SOO LOCKS

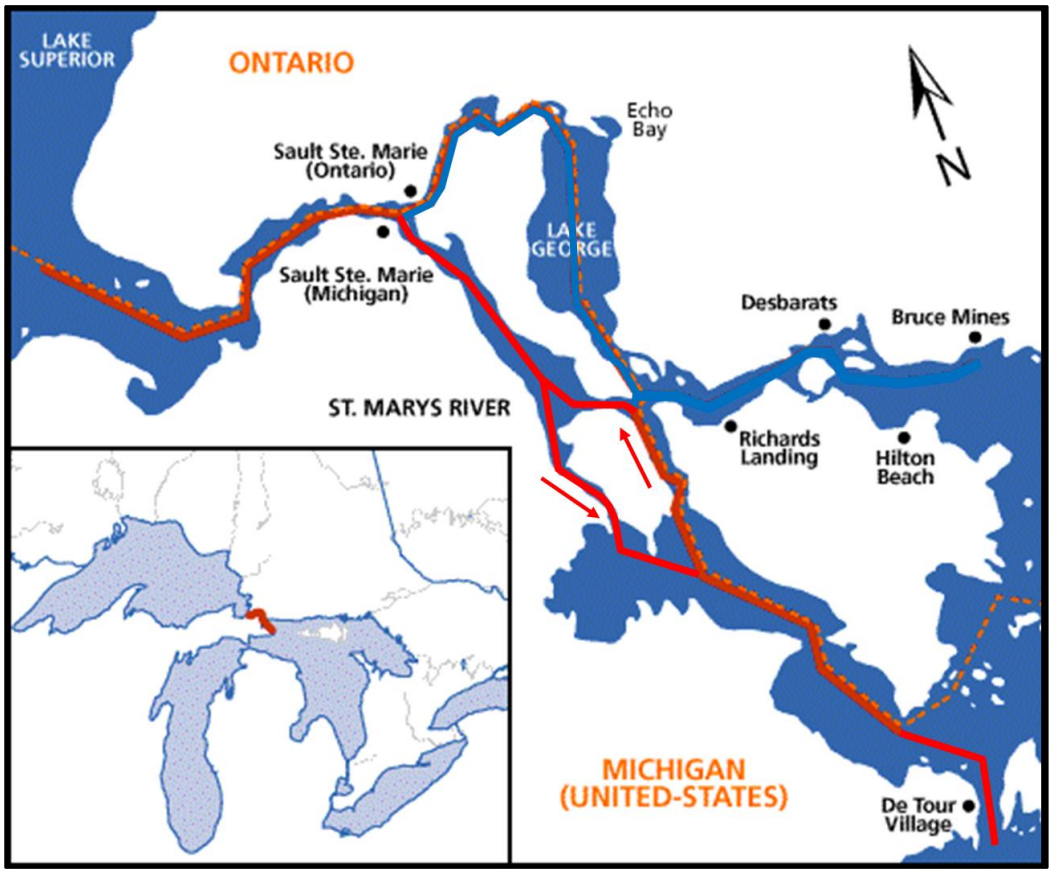

FIGURE 8—ST. MARYS RIVER[23]

From Lake Superior, the iron ore moves to Lake Huron through St. Marys River (see Figure 8), a 63-mile long narrow stretch that defines the Michigan-Canada border.[24] The St. Marys River has been described as not so much a river as a series of lake-connected canals.[25] Between Sault Ste. Marie, Ontario and Sault Ste. Marie, MI, the river drops 21 feet in a three-quarter-mile stretch.[26] To manage the rapids, a group of locks were created, now known as the Soo Locks.[27] Once the Lakers transit St. Marys River, about 43.5 million tons of iron ore are delivered to steel mills located around Gary, IN or Detroit, or to Ohio ports in Ashtabula, Cleveland, Conneaut, and Toledo, a portion of which is transported by rail to steel mills in Pennsylvania, Ohio, and Kentucky. [28,29,30]

[23] Adapted from the Canadian Heritage Rivers System Web page, "St. Marys River" 2011, at www.chrs.ca/Rivers/StMarys/StMarys-M_e.php, accessed May 18, 2015.
[24] Lake Superior is so named not because it is the largest of the Great Lakes, but because it is the highest.
[25] Bowlus, W. Bruce, "Iron Ore Transport on the Great Lakes," McFarland: Freemont, OH, 2009.
[26] USACE, "Soo Locks History," at www.lre.usace.army.mil/Missions/Recreation/SooLocksVisitorCenter/SooLocksHistory.aspx, accessed January 2, 2015.
[27] The names of the Soo Locks, Sault Ste. Marie, MI and Sault Ste. Marie, Ontario derive from the rapids; Sault is the old French word for rapids and Soo is an anglicized derivation of Sault.
[28] USACE, "Statistical Report of Lake Commerce Passing through St. Marys Falls Canal, Sault Ste. Marie, Michigan During the 2013 Navigation Season." Copies from 2004-2012 were also accessed.
[29] After removing the anomalous year of 2009.
[30] Two smaller steel mills, Granite City Works (U.S. Steel) in Granite City, IL and Fairfield Works (U.S. Steel) in Fairfield, AL receive iron ore directly by rail from Minnesota.

FIGURE 9—THE FOUR LOCKS OF THE SOO LOCKS

The Soo Locks, which are owned and operated by the United States Army Corps of Engineers (USACE), consists of four locks (see Figure 9).[31] The two primary locks in operation are the Poe Lock, rebuilt in 1968, and the MacArthur Lock, constructed in 1943.[32] The Lakers carrying iron ore use the Poe Lock almost exclusively because the MacArthur Lock is too small to accommodate the larger Lakers; almost 70 percent of the U.S. Laker capacity on the Great Lakes is Poe-restricted, meaning that the Lakers can use only the Poe Lock.[33] Lakers small enough to lock through the MacArthur Lock are referred, herein, as MacArthur-sized. The dependency on the Poe Locks to move the preponderance of the commodities, particularly iron ore, led USACE to call the Poe Lock "the Achilles' heel of the Great Lakes Navigation System. There is currently no redundancy for the Poe Lock."[34] This lock is the weak link in Great Lakes commerce.[35] The Sabin Lock closed in 1989 and the Davis Lock has not been used since 2008. Both of these locks are about 100 years old and are too shallow to permit the transit of bulk carriers. USACE has installed a cofferdam on either side of the Sabin Lock, which sealed the lock in preparation for the permanent dewatering of the lock and the construction of a new lock.[36,37]

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[31] The locks operate as follows. When a vessel enters the locks to "lock down" from the Lake Superior side, the gate on the Lake Huron side of the lock remains closed and the Lake Superior gate closes. A valve on the Lake Huron side opens and water flows out until the water level in the lock is the same as that of Lake Huron. Then, the gate on the Lake Huron side opens and the vessel moves out. The gate on the Lake Huron side then closes. A vessel coming from Lake Huron goes through a similar process; in this case, the valve on the Lake Superior side opens to allow water to enter until the water level is the same as the Lake Superior side.

[32] The original lock was built by the Northwest Fur Company in 1797, and was destroyed during the War of 1812. Because of the increase in iron ore mining needed for the Midwest steel mills, Congress provided a 750,000 acre land grant to the State of Michigan for the purpose of raising funds to build the State Lock which opened in 1855 (see Bowlus, W. Bruce, "Iron Ore Transport on the Great Lakes," McF: Fremont, OH, 2010). As the iron ore trade increased, a new lock was needed, which opened in 1881. The original lock was closed a few years later, when it was widened and re-opened as the Poe Lock in 1896. The Poe Lock locks through about 70 percent of the tonnage that transits the Soo Locks.

[33] According to 33 CFR (Code of Federal Regulations) 207.440, the maximum overall dimensions of vessels that will be permitted to transit MacArthur Lock are 730 feet in length and 75 feet in width. However, whenever the Poe Lock is out of service for a period exceeding 24 hours the District Engineer may allow vessels greater than 730 feet in length, but not exceeding 767 feet in length to navigate the MacArthur Lock.

[34] USACE, "Great Lakes Navigation System: Economic Strength to the Nation," on January 2009 at www.lre.usace.army.mil/Portals/69/docs/Navigation/GLN_Strength%20to%20the%20Nation%20Booklet2013v2_final2w.pdf, accessed February 23, 2015.

[35] USACE/Great Lakes and Ohio River Division, "Supplemental Reconnaissance Report."

[36] A cofferdam is a temporary structure built within or across a dam or lock that allows the lock or dam to be dewatered.

[37] There is a plan to remove the Sabin and Davis Locks and build a new Poe-sized lock. Congress has authorized the project but it has not yet been funded.

MILITARY PRESENCE AT THE SOO LOCKS

During World War II, the Soo Locks were considered so vital to the war effort that the US Army garrisoned up to 20,000 troops there because of concerns about a German attack. The British and Canadians also garrisoned troops on their side of the border.[38] Searchlights dotted the area to protect the locks from an air attack. While an air attack was considered highly unlikely, Charles Lindbergh's crossing of the Atlantic Ocean was still fresh, raising the fear of a potential air assault. The biggest concern was an attack from the north; James Bay on the southern part of Hudson Bay, is only 400 miles from Sault Ste. Marie.

FIGURE 10—KOREAN WAR ERA SEACHLIGHTS

The searchlights were replaced during the Korean War and remain in place today (see Figure 10).[39]

During the Spanish-American War in 1898, parts of the Pennsylvania National Guard were ordered to Michigan to guard the Soo Locks.[40]

The Lakers were designed to make maximum use of the dimensions of the locks. The Poe Lock is 1,200 feet long and 110 feet wide and the One Thousand Footers are about 1,000 feet long and 105 feet wide. Unlike captains of ocean-going vessels, the Great Lakes captains pilot their ships without tugboats through congested rivers, the Soo Locks, or for docking. All vessels enter the locks under their own power, still without using a tugboat.[41]

> *"When you're on a ship coming into the locks, especially a thousand–footer, the lock's 110 feet wide, the ship is 105 feet wide, and from the pilot house, your perspective, it doesn't look like the ship will actually even fit into the lock. So it's kind of a unique experience. It's amazing to watch the skill of the captains when they bring these big ships into such a small area."*[42]

It takes a total of about 60 minutes to transit a lock, from the time a vessel approaches the lock until it leaves the lock. Once the vessel is secure within the locks, it takes 15–20 minutes to either raise or lower the vessel the 21-foot difference between Lake Superior and Lake Huron.[43]

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[38] Lake Superior State University, "Pre-LSSU History: The Story of Fort Brady," at http://www.saultstemarie.com/lake-superior-state-university-405/, accessed March 5, 2015.
[39] From the private collection of Dr. Craig S. Gordon.
[40] Image and information from The National Son, "The 18th Pennsylvania Volunteer Infantry Regiment," Winter 2013, Volume VI, Number 2.
[41] USACE, "Frequently Asked Soo Locks Questions," at http://www.lre.usace.army.mil/Missions/Recreation/SooLocksVisitorCenter/FrequentlyAskedSooLocksQuestions.aspx, accessed March 29, 2015.
[42] Kevin Sprague, USACE Detroit District, "Soo Locks Opens Despite Ice," on March 26, 2015 at http://abc10up.com/soo-locks-open-despite-ice/, accessed March 29, 2015.
[43] USACE, "Frequently Asked Soo Locks Questions," at http://www.lre.usace.army.mil/Missions/Recreation/SooLocksVisitorCenter/FrequentlyAskedSooLocksQuestions.aspx, accessed March 29, 2015.

The Soo Locks are purported to be among the busiest locks in the world.[44] Records from 2004–2013 indicate that the MacArthur Lock handles over 4,100 vessels per year, while the Poe Lock handles about 3,800 vessels.[45] On average, 15.2 vessels per day have 'locked through' the MacArthur Lock over the past 10 years, though over the past 3 years this has dropped to 13.7.[46] On average, 12.7 vessels per day have locked through the Poe Lock over the past 10 years.

U.S.-flagged vessels, which are subject to the Jones Act of 1920, dominate vessel movement through the Soo Locks.[47] Approximately 63 percent of the vessels locking through the MacArthur Lock and approximately 71 percent of the vessels locking through the Poe Lock are U.S.-flagged vessels. Canadian-flagged vessels constitute most of the other vessels. Canadian traffic has increased over the past 3 years because the configuration of the Canadian fleet has changed considerably. In 2010, the Canadian Government lifted a 25-percent tariff on Canadian-flagged vessels not built in Canada, which led to new orders and deliveries of vessels.[48] In 2011, the first new Canadian Lakers entered the fleet.[49] The new Lakers are Welland Canal-sized vessels, which are slightly too large for the MacArthur Lock.[50] This has led to a 25 percent decrease in the Canadian traffic through the MacArthur Lock as traffic shifted to the Poe Lock, a trend that is likely to continue as new Lakers enter the fleet.

FIGURE 11—THE SOO LOCKS

In addition to the four USACE locks, there is one Canadian Lock used for recreational vessels, located near the top of the graphic in Figure 11. Further, the Soo Locks complex houses two hydroelectric plants, the Sault Ste. Marie International Bridge that connects Sault Ste. Marie, Ontario to Sault Ste. Marie, Michigan, and a rail bridge. The hydroelectric plants provide all of the power needs of the Soo Locks complex and can provide black-start

[44] Michigan State University, "The Soo Locks," at http://geo.msu.edu/extra/geogmich/SOOLOCK.html, accessed January 2, 2015.
[45] USACE, "Statistical Report of Lake Commerce Passing through St. Marys Falls Canal, Sault Ste. Marie, Michigan During the 2013 Navigation Season." Copies from 2004-2012 were also accessed.
[46] After dropping the anomalous year of 2010. Including 2010 would raise the figure to 16.7.
[47] The Jones Act, technically called the Merchant Marine Act of 1920 (P.L. 66-261), requires that all goods transported by water between U.S. ports be carried on U.S.-flagged ships, constructed in the U.S., owned by U.S. citizens (including corporations such as the Great Lakes Fleet, Inc. which is one of the 3 largest carriers on the Great Lakes and indirectly owned by Canadian National Railway), and crewed by U.S. citizens or residents.
[48] The Bay Observer, "Removal of Tariff Unleashes $1 Billion Renewal of Great Lakes Fleet" on June 21, 2013 at http://bayobserver.ca/removal-of-tariff-unleashes-1-billion-renewal-of-great-lakes-fleet/, accessed May 8, 2015.
[49] Boat Nerd, "Baie St. Paul (2)" at http://www.boatnerd.com/pictures/fleet/baiestpaul.htm, accessed May 8, 2015.
[50] The Welland Canal is a series of 15 locks that connect Lake Erie and Lake Ontario with access thereafter to the Saint Lawrence Seaway and then the Atlantic Ocean.

capabilities in the event of a power outage in parts of the Upper Peninsula of Michigan.[51] Algoma Steel (Essar Steel) is located on the Lake Superior side of the Soo Locks on the Canadian side of the border.

STEEL MILLS – AUTOMOBILE MANUFACTURING

The relationship between the mills and the auto assembly plants is complex. Steel mills make various grades of steel to supply different markets and different categories within markets (see Appendix D for a list of products made with steel).[52] However, almost every steel mill makes some type of steel for the automotive industry, the market that dominates the steel industry.[53]

Automotive companies order specific grades of steel from specific mills for specific car parts. The resulting steel is then processed at a number of automotive parts manufacturers.[54] Industry executives reported that there are some 1,500 different recipes of steel for the automotive industry. Almost every part of a car made from steel uses a different type of steel. Industry executives explained that to certify steel for a particular use, automotive manufacturers may require one year to qualify, not just a particular grade of steel, but the path used to process the steel. Each steel mill manufactures steel for multiple cars and each car has steel from multiple plants. For these reasons, there is not a simple linear relationship from mine to mill to manufacturer.

[51] Black start is the procedure to recover from a total or partial shutdown of generation capacity supplying the transmission network. Many power stations require off-site power to restart operations, but black start facilities can be started without it. Each region of the U.S. has detailed black start plans and designated black start facilities. If there is a failure of the transmission network, resulting in widespread generation shutdowns, the black start power stations will be started and reconnected to the network first , so that other plants can be gradually brought back on line to form an interconnected system again (see Morris, Lindsay, Power Engineering Magazine, "Black Start Preparedness for Any Situation," July 1, 2011, at www.power-eng.com/articles/print/volume-115/issue-7/features/black-start-preparedness-for-any-situation.html, accessed June 22, 2015.)

[52] Steel making is a multi-phased process beginning with the combining iron ore with various other materials that include limestone, coking coal, and oxygen in a blast furnace. At temperatures in excess of 3000 degrees, the blast furnace produces molten iron. The molten iron moves to a basic oxygen furnace that combines the molten iron with oxygen, some scrap steel, and other chemicals to make molten steel. The slab casting facility takes the molten steel and turns it into a slab, which is a rectangular-shaped block more than 6 inches thick. The slabs generally go to one or more rolling facilities that turns the slab into a thin coil of steel ranging from 1/16th inch to 1/2 inch thick though the slabs could go to a plate mill to make steel plates.

[53] The primary steel market is for automobiles, followed by construction, machinery and equipment, pipelines to move energy products, packaging containers, appliances, and national defense. A large percentage of steel is sold to steel distribution centers that sell to smaller manufacturers, contractors, and local governments.

[54] The parts of the car typically made out of steel include auto body (except the hood on some cars that is made of aluminum), chassis, suspension modules, engine block (this could be aluminum on some cars), drive shafts, rails for seats, underneath crash pad, door beam, and the steering column.

HISTORY OF THE SOO LOCKS

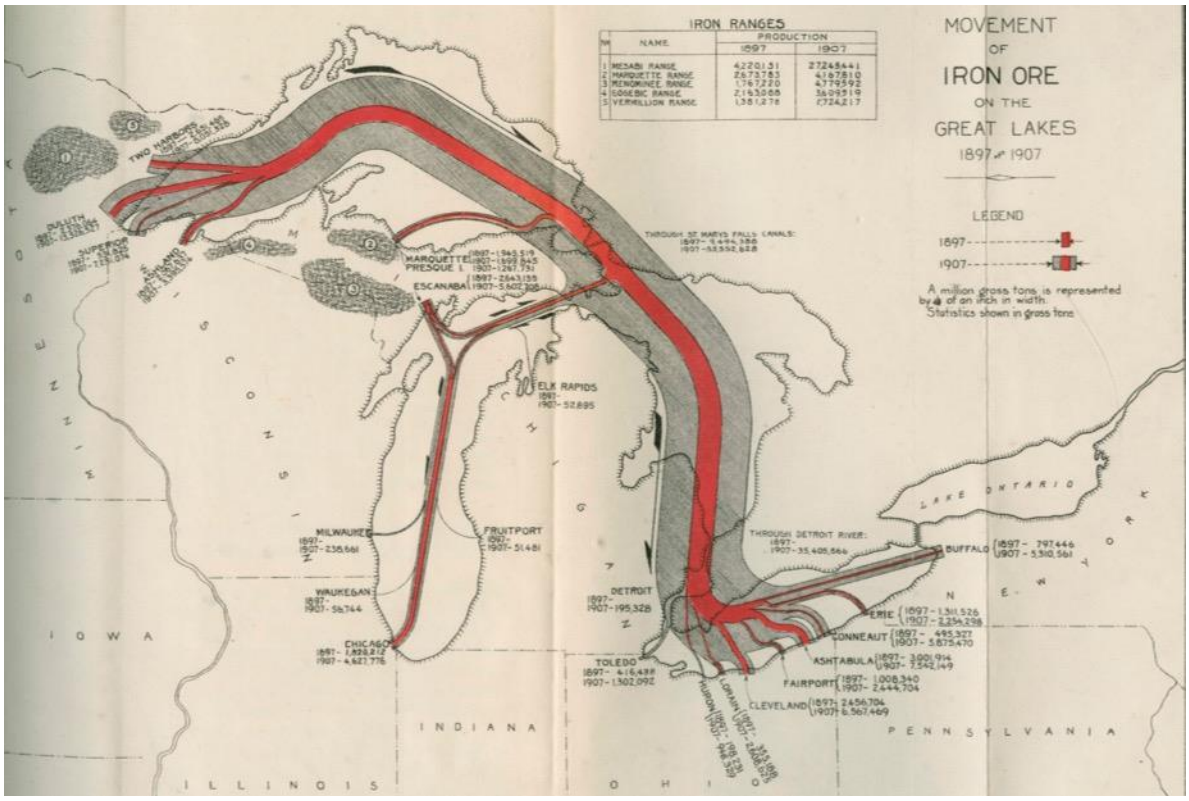

FIGURE 12—HISTORICAL DOCUMENT SHOWING MOVEMENT OF IRON ORE IN 1897 AND 1907[55]

The iron ore-steel-manufacturing supply chain that passes through the Soo Locks has operated essentially uninterrupted and unchanged for 160 years and may account for both its efficiency and lack of resilience. On August 17, 1855, the two-masted brigantine Columbia, left Marquette, MI on Lake Superior, sailed down Saint Marys River, locked through the new State Lock at the Soo Locks, transited Lake Huron, and docked in Cleveland. From Cleveland, the Columbia's cargo of 132 tons of iron ore went by rail to an iron smelter near Pittsburgh. This was the first shipment of iron ore to pass through the Soo Locks.

Figures 12 and 13 show historical maps to illustrate how stable these routes have been over time. The red line in Figure 12 shows the routes and the relative amount of iron ore shipped through the Great Lakes in 1897. The grey line in Figure 12 shows the increased volume of iron ore moved along these routes in 1907. Figure 13 shows the movement of commodities in 1940 (iron ore is shown in orange). Only two significant changes to the supply chain exist today. The Wisconsin iron ore ports (other than the port in Superior, WI) migrated to Minnesota, and the destination for the iron ore has generally moved west from Lake Erie to Lake Michigan. As one industry executive explained, the rationalization of the steel industry during the period 1970-2000 impacted the steel mills on Lake Erie to a greater extent; the likelihood that a steel mill would close was directly proportional to its distance from Minnesota. [56]

[55] Map reproduced from "Report of the Commissioner of Corporations on Transportation by Water in the United States," Volume 2, 1909, opposite p. 156, via Nekola Peter and Dugre, Neal, The Newberry: Digital Collections for the Classroom, Web page "Commodities and the Transformation of the American Landscape," 2014, at http://dcc.newberry.org/collections/commodities-and-the-transformation-of-the-american-landscape, accessed May 18, 2015.

[56] Much of the information obtained for this report came from people associated with the broader supply chain. Everyone we spoke with provided very candid and open assessments, for which we are extremely grateful, and we agreed that we would not disclose any identifying information. Any reference to 'industry executive' in this report covers these frank discussions.

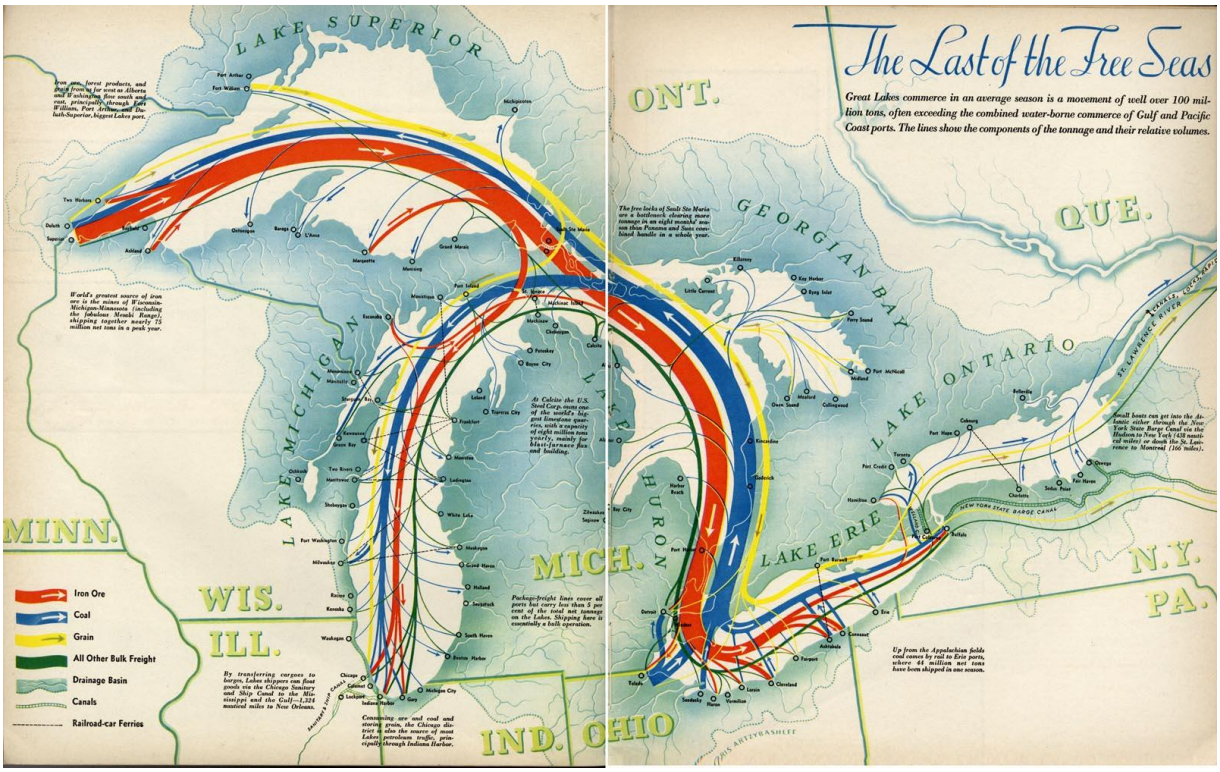

FIGURE 13—HISTORICAL DOCUMENT SHOWING MOVEMENT OF IRON ORE IN 1940[57]

From the time of the Columbia's first shipment, through the explosion of industrialization around the Great Lakes, the amount of iron ore moving by water increased rapidly, as the cost of waterborne transportation dropped in comparison to the cost of shipping by rail. In 1884, about 2.3 million tons of iron ore were shipped from Lake Superior iron ore docks to the Great Lakes steel mills.[58] By 1898, the volume had increased almost 6-fold. Vessel rates, which started at about $3 per ton to move iron ore in 1856 dropped 83 percent to $0.50 by 1897.[59] During the same period, rail rates decreased, but not nearly by the same degree or same rate. By 1907, moving iron ore by vessel saved the steel mills $173 million over moving iron ore by rail; iron ore could be shipped from Lake Superior to Lake Erie at one-seventh the cost of the shipping iron ore from Lake Erie to Pittsburgh.[60,61] As the February 6, 1902 Marine Review stated, "the cost of water carriage by the introduction of larger vessels… has been greatly reduced, while that by rail has not been lessened materially. The savings is, therefore, greater than ever."[62]

About half of the integrated steel mills that make automotive quality steel today were built during this period of industrialization.[63] These steel mills, and others built as late as the mid-1960s, were constructed without an ability to receive iron ore by rail. The cost differential between rail and vessel was such that a rail option was not considered necessary.

The decision to forgo a rail option meant that the supply chain relied on the Soo Locks to operate, without fail. There has never been a long-term failure of the Soo Locks, which has led to an assumption that the Soo Locks will operate indefinitely without a major failure. As one industry executive put it, users expect that "the Soo Locks will operate just as the sun rises every day." One reason for the 160 years of uninterrupted service may be that new

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[57] Artyzbasheff, Boris, "The Last of the Free Seas," Fortune Magazine, July 1940, via "Visual Telling of Stories" Web site, at http://www.fulltable.com/VTS/f/fortune/xa/75.jpg, accessed May 12, 2015.
[58] Mansfield, J.B., "History of the Great Lakes," Chicago: J.H. Beers & Co. 1899.
[59] Ibid.
[60] Curwood, James O., "The Great Lakes: The Vessels that Plough Them: Their Owners, Their Sailors, and Their Cargoes. New York: G.P. Putnam, 1909.
[61] The $173 million dollar figure comes from the above referenced book written in 1909.
[62] Bowlus, W. Bruce, "Iron Ore Transport on the Great Lakes," McFarland: Freemont, OH, 2009.
[63] Rouge Steel (now AK Steel Dearborn) was built in 1915, Indiana Harbor in 1901, Gary Works in 1906, Great Lake Works in 1902, and Cleveland in the 1880s.

locks were added at regular intervals from the initial building of the Soo Locks through the rebuilding of the Poe Lock in 1968. As Table 2 shows, from the time that the State Lock opened in 1855 through the rebuilding of the Poe Lock, a lock was built or rebuilt every 19 years, on average. During this period, the longest span without a lock addition or replacement was the 26 years between the building of the State Lock (1855) and the building of the Weitzel Lock (1881). Since the rebuilding of the Poe Lock (1968), 47 years have elapsed without a new lock or a lock rebuild, almost twice as long as the previous longest gap.

TABLE 2—THE HISTORICAL LOCKS AT THE SOO LOCKS[64]

Lock	Year Opened	Measurements	Depth	Year Closed	Years in Service	Years Since Last Lock Construction
State Lock	1855	350' x 70'	12'	1888	33	-
Weitzel Lock	1881	515' x 80'	18'	1943	28[65]	26
Poe Lock	1896	800' x 100'	21'	1954	23[66]	15
Davis Lock	1914	1350' x 80'	24'	2008	94[67]	18
Sabin Lock	1919	1350' x 80'	24'	1989	70	5
MacArthur Lock	1943	800' x 80'	29 ½'	-	72+	24
Poe Lock (rebuilt)	1968	1200' x 110'	32'	-	47+	25

GREAT LAKES NAVIGATION SEASON

FIGURE 14—THE GREAT LAKES TRANSPORT DURING THE WINTER[68]

The Locks close during the winter due to the harsh weather conditions (see Figure 14), which allows for maintenance and repairs to both the locks and the Lakers. Traditionally, the Soo Locks navigation season has been from approximately March 25–January 15, lasting about 297 days.[69] Since at least 2004, the MacArthur Lock navigation season has, on average, shortened by about 3 days per year. Since at least 2004, the MacArthur Lock has delayed its opening until about April 9 and has closed earlier than the Poe Lock, generally around December 23.[70] The MacArthur Lock navigation season is now about 252 days long, or about 1.5 months shorter than Poe Lock's navigation season.

There are important differences in shipping patterns between Poe-restricted Lakers and the MacArthur-sized Lakers. On average, there are roughly 16 passages per day through the MacArthur Lock, compared to fewer than

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[64] USACE, "Soo Locks History," at http://www.lre.usace.army.mil/Missions/Recreation/SooLocksVisitorCenter/SooLocksHistory.aspx, accessed April 26, 2015.
[65] While the Weitzel Lock did not formally close until the building of the MacArthur Lock in 1943, after 1919, the lock was rarely used.
[66] While the original Poe Lock remained until 1954, suggesting 58 years of service, the USACE reported that, after the opening of the Sabin Lock in 1919, "no significant tonnage passed the old Poe Lock (email, June 7, 2015 at 1:28p)."
[67] The Davis Lock is technically still operational, but has not been used since 2008.
[68] Photo source U.S. Coast Guard, January 9, 2014, via Phys.org Web page "Great Lakes Become Nearly Covered with Ice," February 15, 2014, at http://phys.org/news/2014-02-great-lakes-ice.html, accessed May 18, 2015.
[69] The information herein comes from the 2004-2012 Traffic Statements, St. Marys Falls Canal, Sault Ste. Marie, Michigan.
[70] The average opening day excludes a significantly later opening in 2009. This delay may have been due to the economic downturn that decreased the number of vessels transiting the Soo Locks and allowed USACE to extend its maintenance season.

13 per day through the Poe Lock, even though there are 40 percent more Lakers that must use the Poe Lock than can use the MacArthur Lock (see Appendix C). This is because the Poe-restricted Lakers each make about 50 long trips per year, from Lake Superior to steel mills and coal-fired electric power generation facilities along Lake Michigan, Lake Erie, and Detroit. In contrast, the MacArthur-sized Lakers may each make about 85 shorter trips per year, carrying a wider variety of commodities downstream through the Soo Locks and limestone upstream.

The three most critical months for shipping iron ore are May, June, and July. Total shipments during these months are almost 18 percent higher than for the three-month period October through December. The May–July period has better weather and higher water levels.[71,72] Water in the Great Lakes is highest from June through August, meaning that ships can be more fully loaded. At this time of year, water levels average about 22 inches above the chart datum of 577.5 feet on Lakes Michigan and Huron.[73] Thereafter, the water levels drop by about 2 inches per month before reaching their lowest levels in February. Each inch of draft lost by the largest Lakers decreases the cargo that the vessel can move by about 200 tons.[74,75]

Seasonal ice, winds, and storms affect shipping on the Great Lakes. Before May, shipping can be difficult due to ice conditions, as exemplified during March–April 2014 when almost all of the Great Lakes froze. (In March 2014, 92 percent of the Great Lakes froze, the second highest total on record.[76] In April 2014, nearly 67 percent of the Great Lakes remained frozen.) Starting in September, the winds become challenging, slowing the shipping process. In late October, the weather cools significantly and the storms become more severe.

November is a particularly bad month for weather with some of the fiercest storms occurring including the two worst ever recorded, the Great Storm of 1913 and the Armistice Day Storm in 1940.[77] The sinking of the Edmund Fitzgerald, made famous in popular music, occurred during a storm in November 1975.[78]

Inventories on each side of the locks rise and fall in a seasonal pattern, as the iron mines, shippers, and steel mills plan and work around the winter closure of the locks. During the seasonal closure of the locks, the iron mines continue to extract iron ore and move it to the docks, where they build inventory until the navigation season recommences. At full capacity, the iron ore docks hold about 15 million tons. By the time the navigation season closes, all of this iron ore should have been moved from the docks to the mills, building up the excess inventory at the mills.

During the winter, while the iron ore mines are building up inventory at the docks, the steel mills are drawing down their on-site inventory built during the previous navigation season.[79] When the locks reopen, the steel mills may have only a few weeks' worth of inventory remaining. The relatively low levels of inventory remaining after the winter closure of the Soo Locks was demonstrated in April 2014, when remaining ice from the severe winter effectively delayed the Soo Locks opening by 2 weeks.[80] Gary Works (U.S. Steel) had to curtail production during the first week of April due to a lack of iron ore.[81]

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[71] Escanaba's shipping season is almost diametrically opposite. The high season for shipping out of Escanaba is December – January and the low season is August – September. The large vessels generally will not visit Escanaba when the Soo Locks is open and Escanaba can continue to ship when conditions on Lake Superior and Lake Huron are more difficult.
[72] Trying to extend the shipping season is problematic as the ice can damage the vessels and potentially have negative environmental impacts.
[73] USACE, "Lakes Michigan-Huron Water Levels – June 2015," on June 5, 2015 at http://w3.lre.usace.army.mil/hh/ForecastData/MBOGLWL-mich_hrn.pdf, accessed June 8, 2015.
[74] Lake Carriers Association, "Dredging Crisis," on April 23, 2013 at http://www.lcaships.com/2013/04/23/dredging-crisis/, accessed June 8, 2015.
[75] Thompson, Mark L. "Steamboats & Sailors of the Great Lakes," Wayne State University Press: Detroit, 1991.
[76] NOAA, "National Overview – March 2014 Great Lakes Ice," at https://www.ncdc.noaa.gov/sotc/national/2014/3/supplemental/page-4/, accessed June 22, 2015.
[77] Joachim, George J., "Iron Fleet: The Great Lakes in World War II," Wayne State University Press: Detroit, 1994.
[78] Gordon Lightfoot, "Wreck of The Edmund Fitzgerald - Gordon Lightfoot Song Lyrics," at http://gordonlightfoot.com/wreckoftheedmundfitzgerald.shtml, accessed June 24, 2015.
[79] Typically, the taconite is pelletized at the mines before being transported to the docks. None of the iron ore is stored at the mines as there is no economic benefit to maintaining inventory there. At the docks, iron ore may be segregated by grade and destination, some of which may be interchangeable between steel mills.
[80] The Locks did open on time, but the vessels could not operate due to the icy conditions. The Lakers, which generally take 2 1/2 days to transit Lake Superior, were at sea for 9 days in Lake Superior following two icebreakers (see Figure 13).
[81] The Times, "Steelmaking idled at Gary Works," on April 4, 2014, at www.nwitimes.com/business/local/steelmaking-idled-at-gary-works/article_089e0dcf-c395-5d95-b151-457d90c23839.html?print=true&cid=print, accessed January 2, 2014.

Supply disruptions can occur for reasons other than weather. Also in April 2014, Great Lakes Works (U.S. Steel) declared force majeure related to a crane collapse involving repair work.[82] Reports indicated that, "at least one automaker has reportedly started to examine possible [supply] shortages related to the U.S. Steel situation."[83] To restore normal production required two months from the time that Great Lakes Works restarted full operations.

[82] Found in most commercial contracts, force majeure frees either party from liability in the event there are circumstances beyond ones control (e.g., fire destroying a manufacturing plant so that products cannot be manufactured and supplied).
[83] Platts, "Force Majeure Events at US Steel's Great Lakes Works Could Disrupt Supply," on April 11, 2014 at http://www.platts.com/latest-news/metals/pittsburgh/force-majeure-events-at-us-steels-great-lakes-21470889, accessed March 11, 2015.

POTENTIAL IMPACTS DUE TO A CLOSURE SCENARIO

The impact to the iron mining—integrated steel production— automobile manufacturing supply chain would occur quickly if the Poe Lock were to remain closed at the start of the new navigation season due to an event that lasted about 6 months.[84,85] The scenario closure used in this analysis lasts from March 25– September 25. In order to determine the impacts of a potential closure scenario, OCIA-NISAC reviewed the supply chains for each of the iron ore mines and steel mills to determine which mines and mills were likely to operate and at what level, and confirmed the general assessment with industry executives. The assessments herein are based on reasonable assumptions about what would likely happen; in the event of a real unanticipated closure, the actual impacts are likely to differ.[86,87]

[84] All industry experts expressed concern about a potential longer-term failure of the Soo Locks. Some indicated that they awake each day and cross their fingers that the Soo Locks will operate that day. It should be noted that the Soo Locks has consistently and reliably operated.
[85] While the scenario discussed herein is a 6-month closure, major disruptions would occur even with a significantly shorter disruption.
[86] The 6-month closure scenario was selected as a plausible length of time that is long enough to have significant impacts. No specific damage is assumed. Steel mill closures of less than 1 month do cause some minor disruptions and some automobile manufacturers may have to curtail production for short periods. However, the impact to the U.S. economy would likely not be noticeable. A closure of 1 year or more would cause far more dramatic economic impacts than estimated here. Longer outages would likely force the various industries involved in this supply chain to make lasting operational changes, which are outside the scope of this analysis.
[87] The original assumption was that a 6-month closure at the start of the shipping season would be the worst possible timing. Therefore, this scenario was selected to establish the upper bound of consequences. However, subsequent research suggests that a closure at the start of the navigation season may not be the worst case. The analysis herein suggests that a 6-month closure scenario at the start of the navigation season on March 25 would lead to production stopping around April 15 and re-starting around December 15. This would allow steel mills to have enough iron ore on hand to get through the winter. This implies a steel shutdown of about 244 days. On the other hand, later in the shipping season, around September 1, may represent the "best" time for closure. At this point, the integrated steel mills would have built up their winter supply; shipments that arrive between September 1 and January 15 generally meet current demand. As the steel mills have about 2 months of supply on hand, the September 1 shutdown would mean a closure of the mills around November 1. No iron ore would start arriving at the steel mills until March 25, when the Soo Locks would normally re-open for the new navigation season. Our assumption in this case is that, by May 1, there would be sufficient inventory at the steel mills to re-start production. This implies a steel shutdown of about 182 days. The worst-case scenario likely would be a closure that started between May 1 and July 15, because there would be no way for steel mills to restock before the winter closure. For example, if the Locks closed on June 1, there would be the beginnings of extra inventory from shipments delivered between March 25 and June 1. Our assumption is that, on June 1, there would be a 35-day inventory, which means that, if the Soo Locks closed on June 1, steel production would end around July 4. The problem is at the other end. A June 1 shutdown would mean a December 1 re-open; however, there is no way to get enough iron ore to the steel mills before the winter closure of the Soo Locks to allow production to recommence. Our estimate is that there would not be sufficient inventory until about April 15, which implies a 284 day closure. Still, a "best case scenario" would have significant unemployment impacts as described in the section entitled, "Potential Economic Impacts," though the GDP impacts would be less severe due to the shorter disruption period.

IRON ORE MINING ASSUMPTIONS

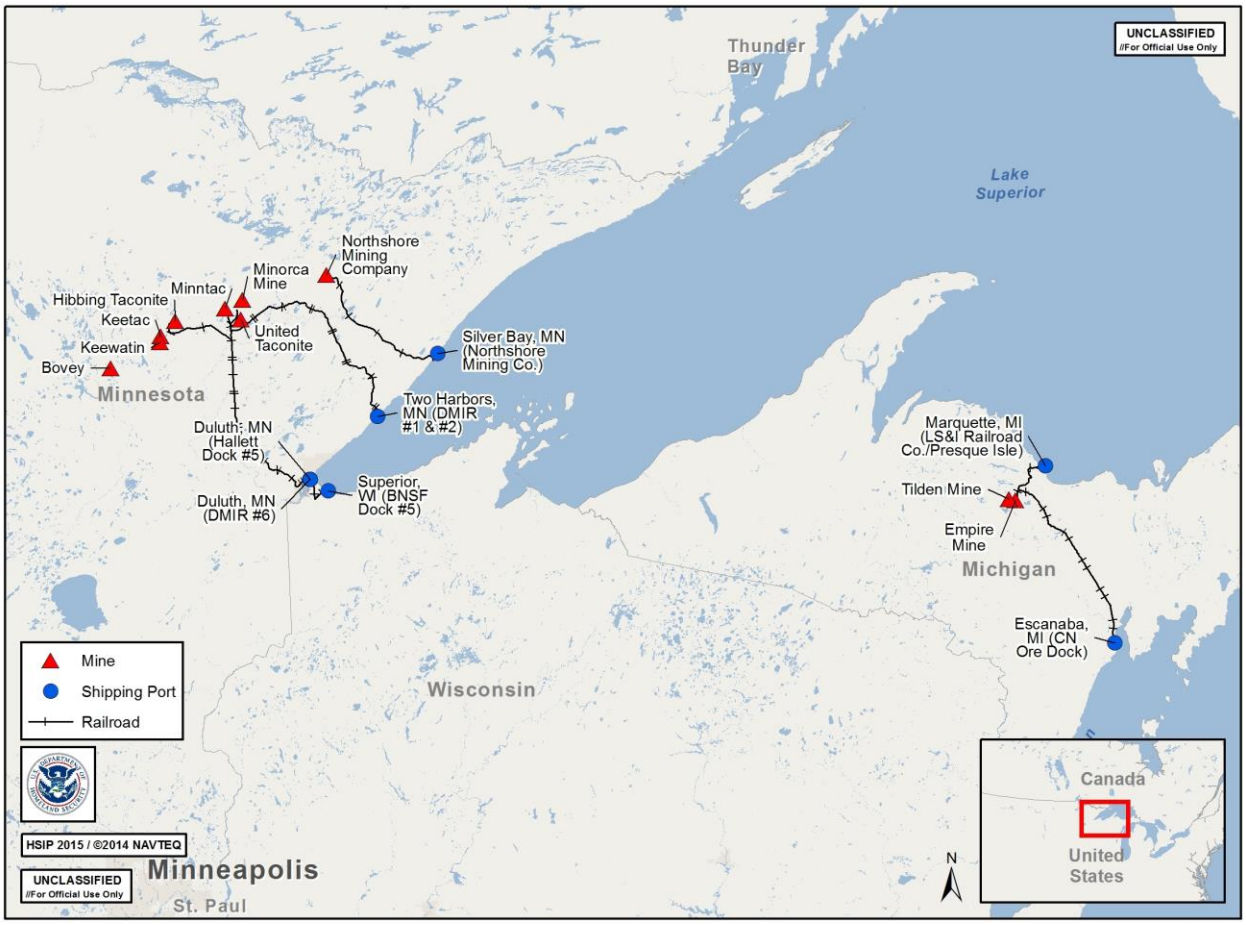

FIGURE 15—IRON ORE MINES AND PORTS

Overall, about 78 percent of the domestic iron ore capacity is expected to shutter for the duration of the scenario.[88]

Some mining operations would likely continue in both Michigan and Minnesota under a lock closure scenario. Forty-six percent of the 15.2 million tons of the rated iron ore mining capacity in Michigan would remain operational in a closure scenario (see Figure 15 for the locations of the iron ore mines).[89] This calculation is based on the assumptions that the Empire Mine could continue to operate through the Port of Escanaba, as it currently does, and that the Tilden Mine would operate at a level to support the Algoma Steel Mill (Essar Steel), which is the only steel mill on Lake Superior and to meet the surge capabilities at the Port of Escanaba. Likewise, 16 percent of the 48.5 million tons of annual capacity in Minnesota would remain operational in a closure scenario, based on the assumption that iron ore that currently moves by rail to steel mills could continue to be mined and transported (see Table 3 for a list of operational and non-operational mines).

[88] Iron ore is mined throughout the winter and moved to the ports for transportation when the new navigation season begins. Once the pellets have been moved to the docks, they become stranded. The docks are designed to receive iron ore by rail or truck and to move the iron ore out by vessel. There is no equipment at the docks to load iron ore onto rail for further movement. If one could move the pellets out, then new mining activity would drop to 0 as there is likely a sufficient stock of pellets at the mines to meet the demand of the steel mills remaining in operation.

[89] These figures assume that, unless otherwise specified, rated capacity and production are assumed to be the same. The operating mines, quarries, mills, and factories generally are operating at full capacity under the current economic conditions. However, as will be discussed, the two mines in Michigan are not operating at their rated capacities.

TABLE 3—IRON MINE EXPECTED OPERATING STATUS

Operating Mines			Non-operating Mines or Portions of Mines not Operating		
State	Mine	Capacity (mm tons)	State	Mine	Capacity (mm tons)
Michigan	Empire Mine	2.5	Michigan	Empire Mine	3.7[90]
	Tilden Mine[91,92]	4.5		Tilden Mine	4.5[93]
Michigan Total		7.0			8.2
Minnesota	Bovey[94]	1.2	Minnesota	Hibbing Taconite	9.0
	Keewatin[95]	0.4		Minntac	16.0
	Keetac[96]	6.0		United Taconite	5.9
				Minorca Mine	3.1
				Northshore Mining	6.9
Minnesota Totals		7.6			40.9

All of the iron ore pellets that had been extracted, pelletized, and moved to the iron ore ports in Minnesota in preparation for the March 25 opening of the navigation season would likely be orphaned if the Poe Lock was not operating.[97] There is no feasible way to move this iron ore out of the iron ore docks by any means other than by Laker. While the Duluth-Superior docks evidently have limited capacity to load rail cars, the terrain surrounding Duluth-Superior, Two Harbors, and Silver Bay makes it impractical to move iron ore by rail out of the port facilities. The challenge is that all of the mines are in the mountainous parts of Minnesota, with the decline most pronounced near the ports. Within a couple of miles of the docks, the elevation changes more than 500 feet. Locomotives could only pull up a few railcars of iron ore at any one time. Therefore, any steel mills still in operation after the scenario closure would require new production from the mines. However, the Minnesota mines still in operation could be hampered by a lack of limestone moving upstream through the Soo Locks, if the MacArthur Lock were also closed. This limestone is necessary for the pelletizing of iron ore.[98]

Limestone deliveries could continue if only the Poe Lock closed. Far less limestone is required to move upstream, as the iron ore-to-limestone ratio is about 9:1.[99] Further, limestone is far less dense than iron ore and there are more options to deliver limestone to the pelletizing plants. In the event of a MacArthur Lock closure, limestone could be dropped in Green Bay, Wisconsin, Manitowoc, Wisconsin, or Cleveland, Wisconsin and railed to the pelletizing plant. There may be some capacity to rail limestone directly from Port Inland, Michigan, a major limestone quarry, to pelletizing plants.

[90] Empire Mine's rated capacity is 6.2 million tons, but is nearing the end of its productive life and produces at far lower rates (per Industry Executive). Therefore, the 3.7 million tons listed as "Non-operating" may not be available.
[91] The Tilden Mine (Cliffs Natural Resources, US Steel) could also ship out of Escanaba.
[92] Tilden Mine supports Algoma Steel (Essar Steel), which is located on the upbound side of the Soo Locks and Tilden Mine could continue to ship iron ore from the Port of Presque Isle/Marquette to Algoma. Data reviewed by OCIA-NISAC suggests that Algoma receives about 1.5 million tons of iron ore from Tilden Mine and an additional 3.0 million tons could be mined and shipped through Escanaba. This would represent a rate equal to the surge capacity.
[93] Tilden Mine's rated capacity is 8.0 million tons, but has been producing at lower levels (per Industry Executive). Therefore, not all of the 4.5 million tons listed as "Non-operating" may be available.
[94] The owner of the Bovey and Keewatin mines filed for bankruptcy on May 6, 2015. Keewatin's operations were idled previously and A.K. Steel, the part owner of the Magnetation operations and the sole customer was reported to have announced that it will limit its relationship with Magnetation and investigate other iron ore sources because of Magnetation's "near-term liquidity issues." This suggests that Magnetation's ability to survive bankruptcy may be challenging. (see Forum News Services, "Grand Rapids-based Magnetation mining files for bankruptcy" on May 6, 2015 at http://www.twincities.com/business/ci_28052217/grand-rapids-based-magnetation-mining-files-bankruptcy, accessed May 6, 2015.
[95] See previous footnote.
[96] Keetac will be idled in May 2015 due to a glut of iron ore and steel.
[97] There would be no orphaned iron ore in Michigan. The Port of Escanaba could still operate and the Port in Marquette, Michigan does not have any storage facilities.
[98] A number of the steel mills have sinter plants that can take iron ore particles and convert them into usable products at the steel mill. However, sinter generally is used for a relatively small amount of the iron ore, possibly about 5 percent.
[99] For making flux pellets.

STEEL MANUFACTURING ASSUMPTIONS

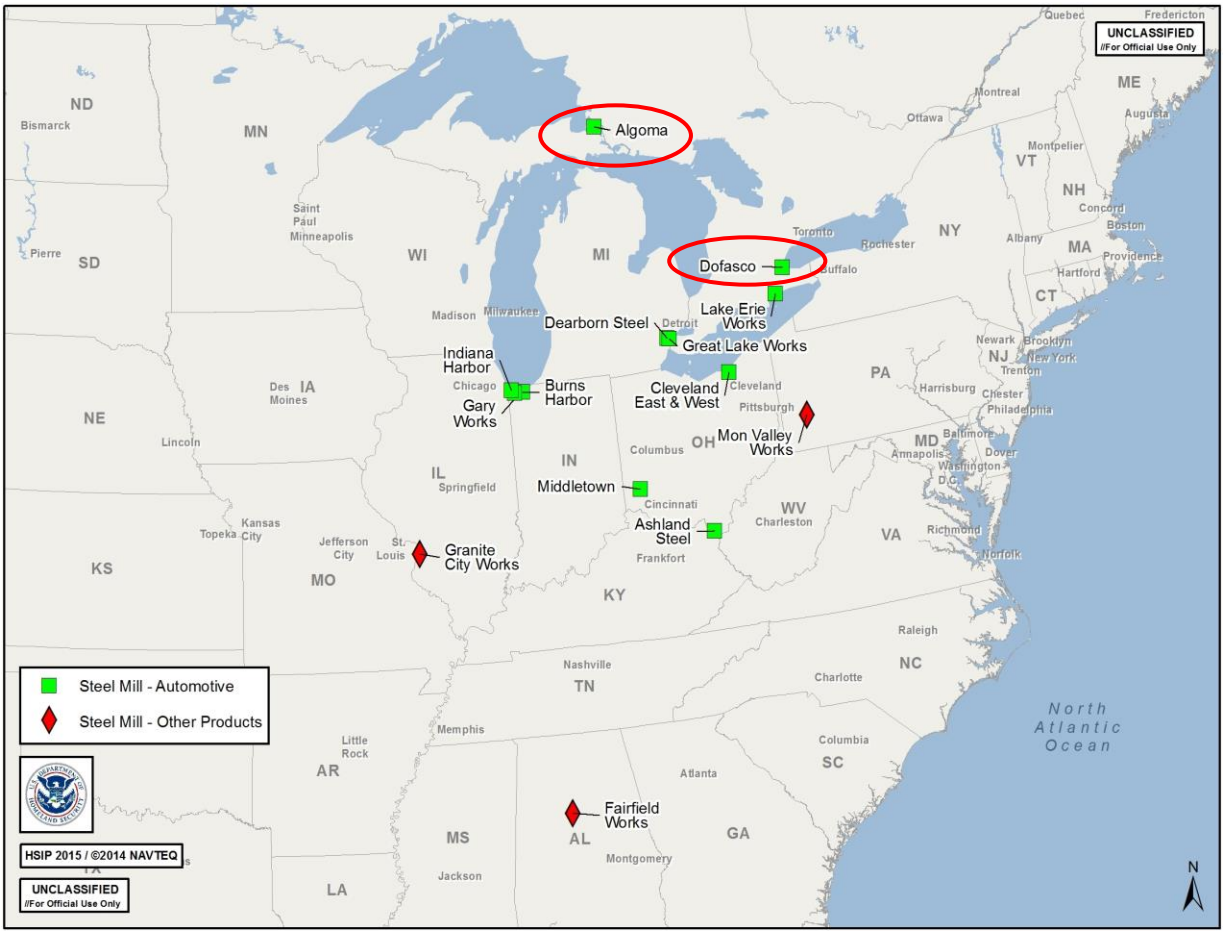

FIGURE 16—STEEL MILLS

The estimated total integrated steel production in North America is 57.5 million tons. Table 4 shows which steel mills OCIA-NISAC believes could continue to operate and which are likely not to operate due to a lack of iron ore (see Figure 16 for a map of the steel mills). In this Soo Locks closure scenario, 74 percent of the integrated steel production will shut down. More concerning, the steel mills that would shut down are, as a whole, more critical in the manufacturing of appliances, automobiles, construction, farming, and mining equipment, and railcar manufacturing than the steel mills that could continue to operate. Among the steel mills that could continue to operate, Fairfield Works (U.S. Steel) produces steel for the construction and tubular markets, Granite City Works (U.S. Steel) for the tubular market, and Algoma (Essar Steel), while it produces steel for the automotive market, does not produce the high strength—low weight steel most in demand.[100] Fairfield Works and Granite City Works receive their iron ore, by rail, directly from Minnesota, while Algoma is the only steel mill on Lake Superior. Therefore, the iron ore does not need to transit the Soo Locks.

[100] Fairfield Works (U.S. Steel) is also installing an electric arc furnace where the existing blast furnace is located (P.R. Newswire, "U. S. Steel Announces Construction Of Electric Arc Furnace And Tubular Products Coupling Facility In Jefferson County, Alabama," on March 19, 2015 at http://www.prnewswire.com/news-releases/u-s-steel-announces-construction-of-electric-arc-furnace-and-tubular-products-coupling-facility-in-jefferson-county-alabama-300053140.html, accessed June 15, 2015.

TABLE 4—STEEL MILL OPERATING STATUS DURING A POE LOCK CLOSURE

Operating Steel Mills			Non-operating Steel Mills		
State / Province	Mine	Capacity (mm tons)	State / Province	Mine	Capacity (mm tons)
Alabama	Fairfield Works[101]	2.4			
Illinois	Granite City Works[102]	2.8			
			Indiana	Burns Harbor	5.0
				Gary Works	7.5
				Indiana Harbor[103]	9.5
			Kentucky	Ashland	2.6
			Michigan	Dearborn	2.5
				Great Lake Works	3.8
Ohio			Ohio	Cleveland	3.8
	Middletown[104]	2.4		Middletown	0.5
Ontario	Algoma	2.8	Ontario	Lake Erie Works	3.7
	Dofasco	4.5			
			Pennsylvania	Mon Valley Works	2.9

To make the full complement of car models available in North America today, all of the steel mills listed as "Non-operating Steel Mills" in Table 4 must be operating, other than Mon Valley Works (U.S. Steel), which primarily makes steel for the appliance industry.[105] In Figure 16, the steel mills that produce steel for the automotive industry are marked by green boxes. The two steel mills that would still operate, Algoma (Essar Steel) in Sault Ste. Marie, Ontario and Dofasco (ArcelorMittal) in Hamilton, Ontario are indicated by a red circle. As discussed in the Background section, the integrated steel – automotive supply chain is complicated, and most steel mills produce steel for parts of most automotive lines. Based on discussions with industry executives, to make any automobiles in North America, the three Indiana steel mills must be operational and some combination of three of the remaining six steel mills. If one steel mill is not operational, some automotive *lines* are not likely to be functioning; if two steel mills are not operational, some automotive *companies* may not be able to make automobiles.

Table 5 provides the per-State estimate for steel production remaining after the closure scenario, which is the proxy used for employment.

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[101] U.S. Steel announced that it plans to close Fairfield Works and re-open it as a mini-mill (see NPR, "U.S. Steel to End Operations at Alabama's Fairfield Works Mill," on August 18, 2015 at www.npr.org/2015/08/18/432683704/u-s-steel-to-end-operations-at-alabamas-fairfield-works-mill, accessed October 13, 2015).
[102] Granite City Works (U.S. Steel) has been temporarily idled due to lack of demand for tubular products because of the decrease in petroleum prices. Our analysis assumes a 'normal' economic environment where Granite City would be operational. Granite City sources its iron ore from Keetac. Further, the REMI Model used to calculate the economic impact is based on an environment where Granite City Works was not idled.
[103] Indiana Harbor receives the majority of the iron ore shipped out of Escanaba, which means that it could operate. However, the amount of iron ore shipped out of Escanaba is not likely sufficient to operate. Industry analysts and management consultants suggest that steel mills will not operate at less than 70-85 percent capacity utilization as it is not profitable below that level (see The Globe and Mail, "U.S. Steel Shutting Hamilton Mill," on October 1, 2010, at www.theglobeandmail.com/report-on-business/us-steel-shutting-hamilton-mill/article4329666/, accessed January 27, 2015 and Boston Consulting Group, "Flexibility: Streamlining Production," at www.bcgperspectives.com/content/articles/metals_mining_sourcing_procurement_flexibility_innovation_todays_imperatives_steel/?chapter=2, accessed January 15, 2015.) One industry executive stated that it is "technically impossible for a blast furnace to run at less than 70 percent," which would be the case.
[104] Based on our analysis of the Middletown supply chain, OCIA-NISAC estimates that Middletown could only receive 82 percent of its needs from the Magnetation mines (see footnote 90) and from Escanaba.
[105] In order to make appliances in North America, Mon Valley Works (U.S. Steel) must be operational.

TABLE 5—STEEL PRODUCTION BY STATE

State or Province	Steel Manufacturing Still Operational
Alabama	100.0%
Illinois	100.0%
Indiana	0.0%
Kentucky	0.0%
Michigan	0.0%
Ohio	35.8%
Ontario	70.4%
Pennsylvania	0.0%

The supply chain challenge is more complex than just moving iron ore to the integrated steel mills. For example, if steel mills could accept new sources of iron ore, disruptions to other supply chains could result. Blast furnaces are configured to take a specific iron ore pellet of a particular size that is either a standard or a flux pellet, mixed with a particular calcite/dolomite blend of limestone, trace elements and other chemicals, and metallurgical coal from a particular mine. Changing the iron ore pellets may require obtaining new limestone, trace elements and chemicals, or metallurgical coal products from new suppliers and testing the final products to ensure compatibility to the needs of the firm purchasing the steel.

AUTOMOTIVE MANUFACTURING ASSUMPTIONS

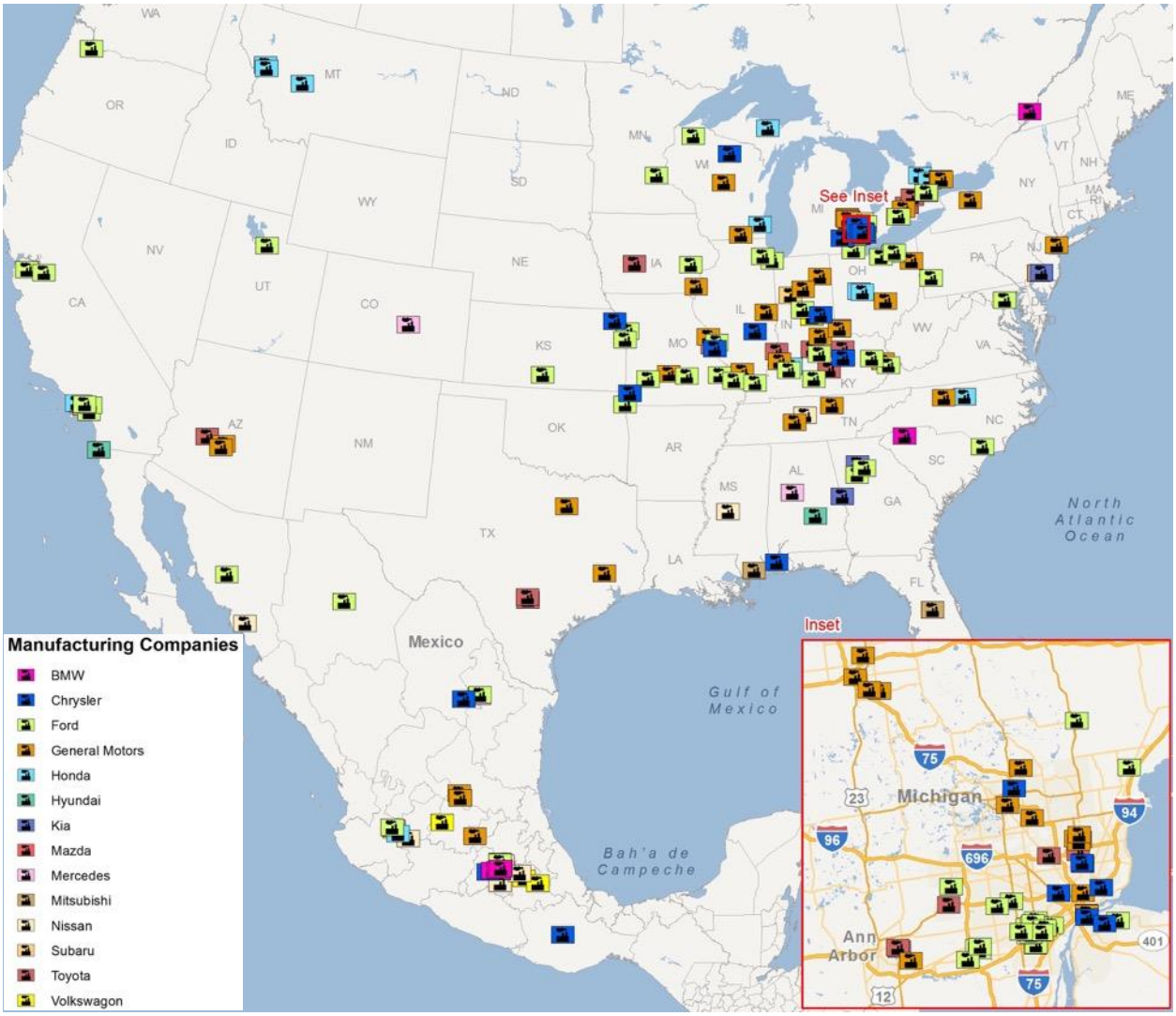

FIGURE 17—LOCATION OF AUTOMOTIVE MANUFACTURING PLANTS

An extended closure of the Poe Lock, which OCIA-NISAC assumes to be 6-months, would be extremely detrimental to the North American automotive industry including Canada and Mexico. Almost all North American automobile production would cease, and, in addition to the automotive industry, other industries that depend on steel including farm, mining, and construction equipment manufacturing, railroad locomotive and railcar production, and appliances.[106,107] As Figure 17 shows, most of the automotive manufacturing plants are located between Michigan and Ontario, Canada and south to Alabama. There are plants located in various other parts of the United States. Further, many automotive firms have plants in Mexico, most of which have supply chains highly integrated with the Canadian-United States supply chains.[108] According to industry executives, all of the

[106] An automotive expert stated, "[automobile] operations would shut down once the ore supplies were depleted and the normal steel and part buffers were exhausted. This would happen on a part-by-part basis and we do not have a good estimate of that timing. Our best guess is that it would happen within a few weeks. Yes, we would look to other non-domestic supply, but would be highly unlikely that we could secure enough material in the right specifications and quantities to support our volumes. This will impact all operations in North America and some operations across the globe." The global impacts of a potential shutdown have not been considered in this analysis.

[107] The construction industry would not likely be impacted. Most steel used in construction comes from EAF mills and, to the extent that the BOF mills operate, they will likely have to sell their steel into the construction and tubular markets.

[108] While OCIA-NISAC did not estimate an impact to the Mexican economy, published reports suggest that the automotive sector may account for about 3.25 percent of their economy, which is approximately the same percentage that the auto industry is in the U.S. economy, and higher than the auto industry contribution

automotive plants shown on Figure 17 use steel from at least one of the nine steel mills that make automotive quality steel.

Only a small percentage of North American auto manufacturing may be able to continue production after the disruption scenario. Some industry executives reported that one Volkswagen plant and one Nissan plant in Mexico sources its steel in Mexico. These plants would be able to maintain operations only if they source all other auto parts requiring steel from sources outside of North America, which is not likely. The BMW and Mercedes Benz plants located in the southeastern United States may be less impacted, if they can import all parts from Europe and only assemble automobiles in the United States. The disruption scenario will affect all other automotive plants.

According to industry experts, short-term disruptions of a single steel mill can cause disruptions throughout the North American supply chain. Firms must scramble to find alternative suppliers and to begin managing the process, part-by-part, to extend production times for at least some of their lines. Eventually, keeping the system going becomes impossible and lines shut down due to the lack of a single component. It could take more than 2 months to resupply the supply chain with enough steel-based product to restart production from the loss of a single steel mill. Lead times for many automotive parts are typically 8 – 14 weeks. However, regarding the current scenario, one industry expert said, "it's all done if all of the steel mills shut down."

The average age of automobiles on the road today is about 11.4 years.[109] This is consistent with average ages over the past few years and expectations over the next three years. A disruption scenario would lead to an increase in the average age based on the dearth of new vehicles, and a likely decrease in the scrapping of older automobiles. In contrast, the need for repair work will increase, though parts requiring steel may become scarce.

OTHER INDUSTRY IMPACTS

Based on the scenario and assumptions discussed, OCIA-NISAC analysts estimated production levels, after the scenario event, for the 6-digit North American Industrial Classification System (NAICS) codes. As an example, NAICS codes 212210 (Iron Ore Mining) and 331110 (Iron and Steel Mills and Ferroalloy Manufacturing) were set to the values found in Tables 3 and 4, respectively, while 336111 (Automobile Manufacturing) and 336112 (Light Truck and Utility Vehicle Manufacturing) were set to 0. The full list of impacted NAICS codes that OCIA-NISAC anticipates will be affected by the disruption scenario can be found in Appendix F.

CONSIDERATIONS REGARDING THE RE-OPENING OF THE POE LOCK AFTER THE CLOSURE SCENARIO

A 6-month closure, from about March 25 to September 25 does not mean that steel production could begin shortly thereafter. First, blast furnaces, which presumably have been hot idled or kept warm during the closure, would have to be re-inspected.[110,111] Extended hot idling can damage or destroy a blast furnace, incurring lengthy repairs times and costs well in excess of $100 million each, though processes have improved that could mitigate

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to the Canadian economy, which is closer to 2 percent. Mexico is the largest exporter of auto parts into North America and should be expected to be impacted by the scenario. See Wall Street Journal, "U.S. Car-Making Boom? Not for Auto-Industry Workers," on March 23, 2015; Canadian Vehicle Manufacturers' Association, "Key Facts" at http://www.cvma.ca/eng/industry/importantfacts.asp, accessed May 6, 2015; U.S. Department of Commerce, "The Automotive Industry in the United States", at http://selectusa.commerce.gov/industry-snapshots/automotive-industry-united-states, accessed May 6, 2015.

[109] IHS, Inc., "Average Age of Vehicles on the Road Remains Steady at 11.4 years, According to IHS Automotive," on June 9, 2014 at http://press.ihs.com/press-release/automotive/average-age-vehicles-road-remains-steady-114-years-according-ihs-automotive, accessed April 27, 2015.

[110] Blast furnaces generally operate continuously for about 15 years between significant maintenance periods. If a blast furnace is not going to be operated, it must be kept warm by keeping coking coal heated, but not adding in iron ore, limestone and enriched oxygen that make steel. Hot idling, the term to denote this process of keeping the furnace warm is usually not done for periods longer than a few weeks (see Platts, "Platts Steel Glossary," at www.steelbb.com/steelglossary/#term_206, accessed January 17, 2015). Anything longer than a few weeks is considered, herein, to be an extended period.

[111] Pittsburgh Business Times, "'Unprecedented' Ice Conditions Cause U.S. Steel Curtailments," on April 4, 2015 at http://www.bizjournals.com/pittsburgh/blog/innovation/2014/04/unprecedented-ice-conditions-cause-u-s-steel.html?page=all, accessed March 29, 2015.

this risk.[112,113,114] A significant problem with hot-idling a blast furnace is the cooling water. [115] Hot idling a blast furnace during the winter may lead to the freezing of the cooling water and damage to the blast furnace.

More problematic than re-starting the blast furnace is restarting the coke batteries. As mentioned in the Background Section, coke batteries concentrate the carbon from coal to make coke, which is an essential ingredient in steelmaking. Industry executives reported that the coke battery must be operated continuously or hot-idled properly to prevent damage. The coke battery is far more likely than the blast furnace to become damaged in this unanticipated outage scenario.

OCIA-NISAC analysts believe that the steel mills will not re-commence mill operations until about mid-December, in order to secure sufficient inventory of iron ore to last through the normal winter closure of the Soo Locks.[116] This assessment is based on the assumption that extending the idling of the steel mills until mid-December would be preferable to a second shutdown due to insufficient iron ore inventory during the normal winter closure. Automotive parts manufacturers could then begin operations in mid-January, but the first cars are not likely to come off production lines until early April.[117,118]

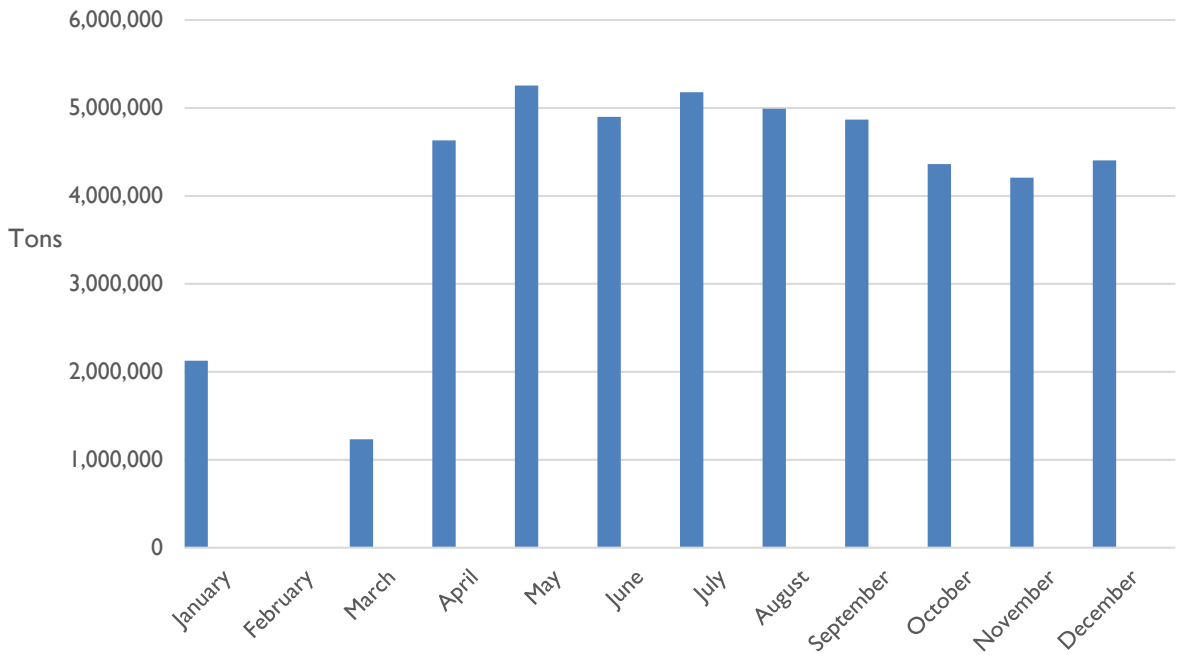

FIGURE 18—AVERAGE MONTHLY SHIPMENT OF IRON ORE OUT OF LAKE SUPERIOR, 2010-2013[119]

Under the scenario, the idled iron ore mines are not likely to restart operations until the first week of December. If the closure were to occur at the start of the navigation season, the iron ore docks along Lake Superior would be at their capacity, around 15 million tons of iron ore. This approximately matches the 15.5 million tons of iron ore that is normally shipped from September 25 through January 15 (the remaining navigation season after the Poe Lock would re-open under this scenario). The average capacity, as seen in Figure 18, should be considered the

[112] Boston Consulting Group, "Flexibility: Streamlining Production," at www.bcgperspectives.com/content/articles/metals_mining_sourcing_procurement_flexibility_innovation_todays_imperatives_steel/?chapter=2, accessed January 15, 2015.
[113] Reuters, "Update 2- U.S. Steel CEO says Mulling another Electric Arc Furnace," at http://www.reuters.com/article/2014/03/25/ussteel-furnace-idUSL1N0MM16820140325, accessed January 15, 2015.
[114] An industry executive reported the improved processes to OCIA-NISAC.
[115] This is also known as 'banking' a blast furnace.
[116] An industry executive confirmed this assumption.
[117] Industry experts believe that it would take closer to 120 days to have enough supply in the supply lines to start the assembly plants. This would mean that the first cars would not roll off the assembly lines until possibly mid-April.
[118] The OCIA-NISAC analysis suggests a similar re-starting date for the appliance, construction, farm, and mining equipment, and railcar manufacturers.
[119] Lake Carriers' Association, "Cargo Reports," at http://www.lcaships.com/reports/, accessed May 6, 2015.

maximum capacity because weather plays a significant role in how much product can actually be moved during these 4 months.[120,121] Additionally, inventory levels at the iron ore docks must be near zero on January 15, so that the iron ore mines can extract at their average monthly production levels and have space to store the iron ore.[122] OCIA-NISAC assumes that the first 11 million tons of iron ore shipped through the Poe Lock will be held in storage to get the steel mills through the normal winter closure of the Soo Locks. This leaves about 4.5 million tons of iron ore that could be extracted, pelletized and moved prior to the winter closing of the Soo Locks. The iron mines extract at a rate of about 3.8 million tons per month, meaning that it would take about 5 weeks to produce the 4.5 million tons.

[120] The average annual shipment of iron ore from Lake Superior through the Soo Locks is about 46.2 million tons.
[121] This is net after taking out shipments from Marquette to Algoma Steel (Essar Steel).
[122] An industry executive reported that the last shipments of the navigation season come out of production, off the railcars, and onto the waiting vessels just before the Soo Locks closes.

POTENTIAL ECONOMIC IMPACTS

The scenario closure would have catastrophic impacts on the regional and National economy. Economic modeling based on the assumptions described in the preceding section shows that approximately $1.1 trillion in economic output, as measured by the Gross Domestic Product (GDP), and over 10.9 million jobs would be lost in the first year following the disruption. The impacts described here are more severe than those predicted in prior studies because this analysis took a comprehensive view of the supply chain and its relationship to the National economy. One previous study of the impacts of a hypothetical closure of the Soo Locks concluded that a 30-day closure would have an economic impact to industry of $160 million.[123,124]

One challenge in properly determining the impact of a supply chain disruption is that each step of the process holds some inventory, even if operating under the "just-in-time" framework.[125] Depending on when a disruption occurs, steel mills would have anywhere from 2 weeks to 3 months of iron ore inventory. Each of the automotive suppliers also holds a certain level of inventory, which may be an additional 2 to 3 weeks. Therefore, a 30-day study would only capture the beginning of the disruption when some steel mills, other automotive tier 1 suppliers and certain automotive lines would only start to face severe shortages.[126]

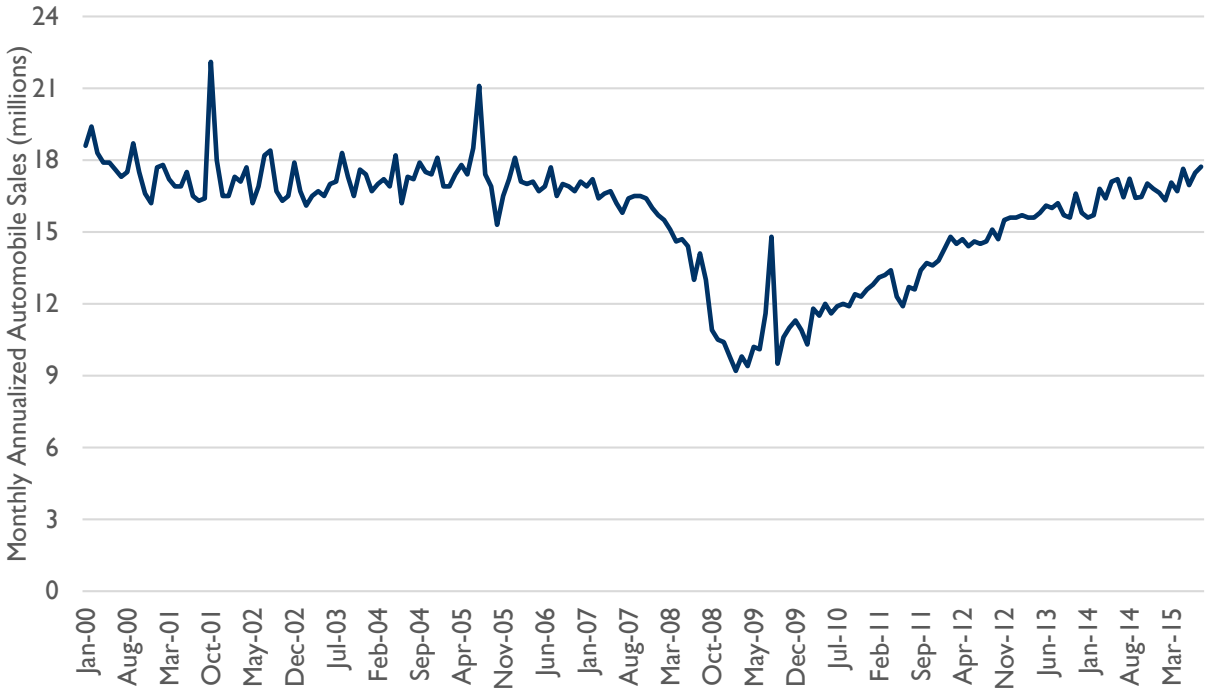

FIGURE 19—ANNUALIZED AUTOMOBILE SALES

A 6-month closure of the Poe Lock, at the start of the navigation season, would be expected to halt all automobile production and the sales of cars manufactured in North America completely for almost 10 months, from about June 1 to April 1. That is, no automobiles would be produced in North America. By comparison, during the 2009 recession, two of the three major automotive companies required bailouts from the United States Government

[123] USACE, "Great Lakes Navigation System: Economic Strength to the Nation," on January 2009 at www.lre.usace.army.mil/Portals/69/docs/Navigation/GLN_Strength%20to%20the%20Nation%20Booklet2013v2_final2w.pdf, accessed February 23, 2015.
[124] Transport Canada, USACE, US Department of Transportation, The St. Lawrence Seaway Management Corporation, Saint Lawrence Seaway Development Corporation, Environment Canada, US Fish and Wildlife Service, "Great Lakes St. Lawrence Seaway Study," in Fall 2007, at http://www.seaway.dot.gov/publications/great-lakes-st-lawrence-seaway-study-0, accessed January 12, 2015.
[125] Just-in-time inventory controls means that each supplier in a supply chain holds only the necessary amount of inventory to maintain operations. This frees up working capital for purposes other than for purchasing inventory.
[126] OCIA-NISAC estimates that, based on likely levels of inventory held throughout the supply chain, catastrophic failure would likely occur around 42 days after a closure of the Poe Lock. This estimate has not been reviewed by any industry executives.

when annualized sales of new automobiles had dropped from the typical 16–18 million units to about 9 million units (see Figure 19).[127]

Initial conversations with the automotive industry confirm that the loss of Great Lakes steel would be catastrophic to the industry. Industry officials reported that:

- "The loss of the integrated mill steel supply for 180 days would be catastrophic to the North American Auto Industry including its tier one suppliers…There is no contingency plan, stockpile or off shore sourcing action that could come close to mitigating the situation."
- "[The Firm] does not have long-term contingency plans for a disruption in normal steel supply. We have limited ability to purchase small amounts of some types of steel on the open market, but it would be unlikely to support full production of all required parts for even a single product line."
- "There are no contingency plans in place to respond to a disruption of normal steel supplies."

UNEMPLOYMENT IMPACTS

In support of OCIA-NISAC, Sandia National Laboratories used the Regional Economic Models, Inc. (REMI) model to estimate the impacts of an unanticipated Poe Lock closure on economic productivity and employment.[128] Analysts conducted the REMI analysis in two steps: first, a baseline forecast was computed, in which there was no change to the economy; and second, an alternative forecast was generated, in which a set of simulation variables model a change in the economy. For the Poe Lock scenario, the assumptions described in the prior section of this report, and, in detail, in Appendix F, with respect to the disruptions to the iron mining, steel production, automotive manufacturing industries, and other industries, formed the parameters for the simulation.

At the National level, the model predicts that the Poe Lock closure scenario would add 5.8 percentage points to the unemployment rate, currently at 5.5 percent.[129] This would bring the National unemployment rate under the closure scenario to 11.3 percent. This would exceed the highest level of National unemployment recorded during the 2008-2009 recession, which peaked at 10.0 percent in October 2009.[130]

[127] Federal Reserve Bank of St. Louis, "Light Weight Vehicle Sales: Autos & Light Trucks," on June 28, 2015 at research.stlouisfed.org/fred2/series/ALTSALES/, accessed June 28, 2015.
[128] Regional Economic Models, Inc. The REMI model is a commercially available dynamic economic forecasting model, and incorporates region-specific descriptions of inter-industry relationships. As a result, the model captures the industry structure of a particular region, as well as transactions between industries. For more information, see REMI Web page, "The REMI Model," 2015, at www.remi.com/the-remi-model, accessed May 18, 2015.
[129] Bureau of Labor Statistics, "The Employment Situation -- May 2015," on June 5, 2015 at http://www.bls.gov/news.release/empsit.nr0.htm, accessed June 11, 2015.
[130] Bureau of Labor Statistics, "Labor Force Statistics from the Current Population Survey," at http://data.bls.gov/timeseries/LNS14000000, accessed June 11, 2015.

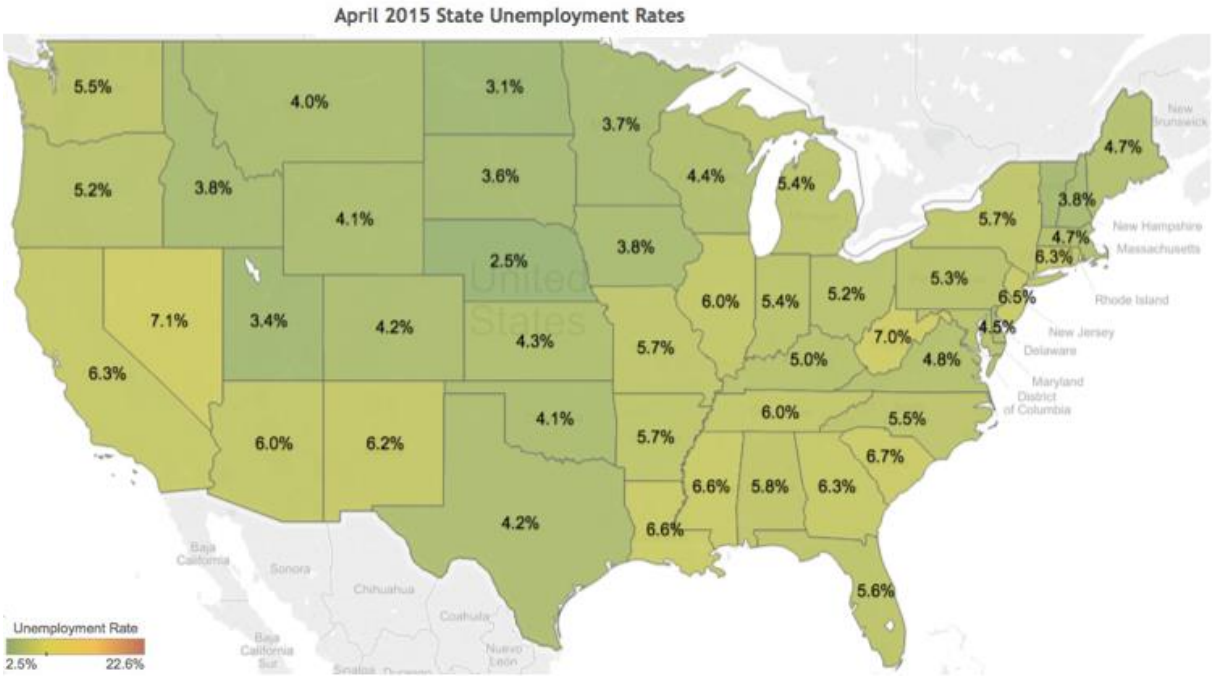

FIGURE 20—APRIL 2015 STATE UNEMPLOYMENT RATES[131]

Figure 20 displays State-level unemployment rates for April 2015 (the most recent available), as determined by the U.S. Department of Labor's Bureau of Labor Statistics. Nebraska has the lowest unemployment rate at 2.5 percent and Nevada has the highest at 7.1 percent. Figure 20 is used as the baseline with the unemployment impacts from the Poe Lock closure scenario added to this baseline.

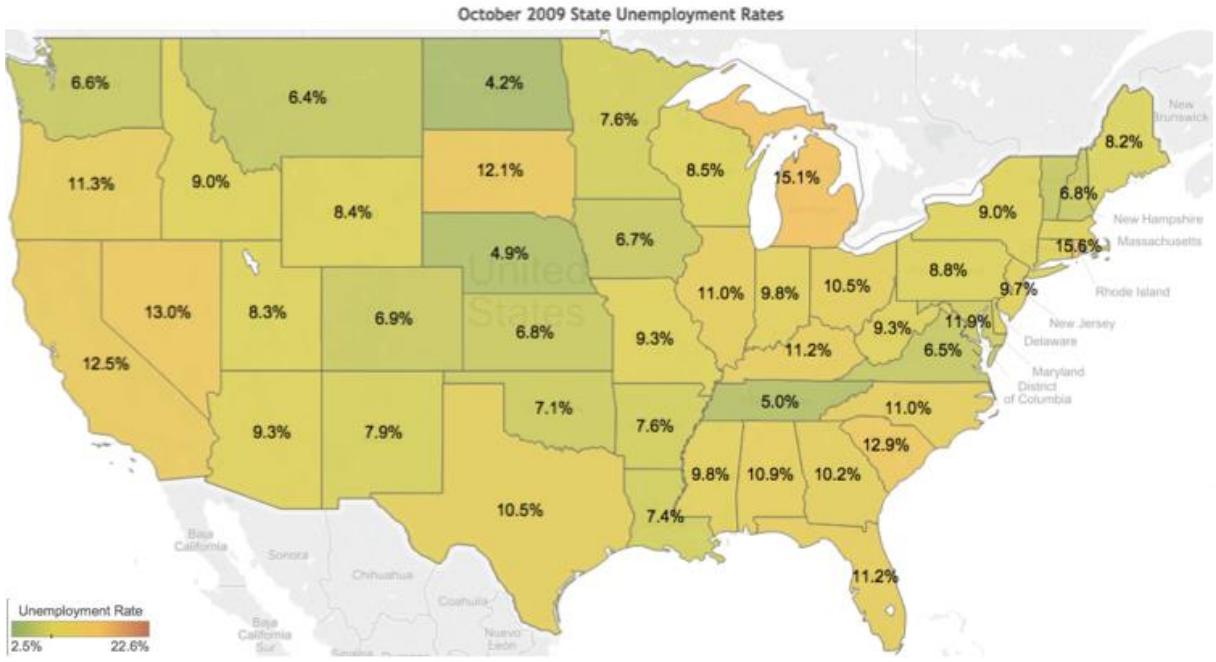

FIGURE 21—OCTOBER 2009 STATE UNEMPLOYMENT RATES[132]

[131] Bureau of Labor Statistics, "Unemployment Rates for States," on May 27, 2015 at http://www.bls.gov/web/laus/laumstrk.htm, accessed May 31, 2015.

For perspective, Figure 21 shows unemployment levels from the height of the 2008–2009 recession. At its peak in October 2009, unemployment was high across the Nation, particularly in California and Nevada in the west, South Dakota and Michigan in the Midwest and north, and Rhode Island in the east. The color scale is the same for Figures 20 and 21: green represents the lowest level of unemployment (generally below 7 percent), and yellow and orange represent the highest levels of unemployment experienced during the 2009 recession. North Dakota had the lowest unemployment rate at 4.2 percent and Rhode Island had the highest at 15.6 percent.

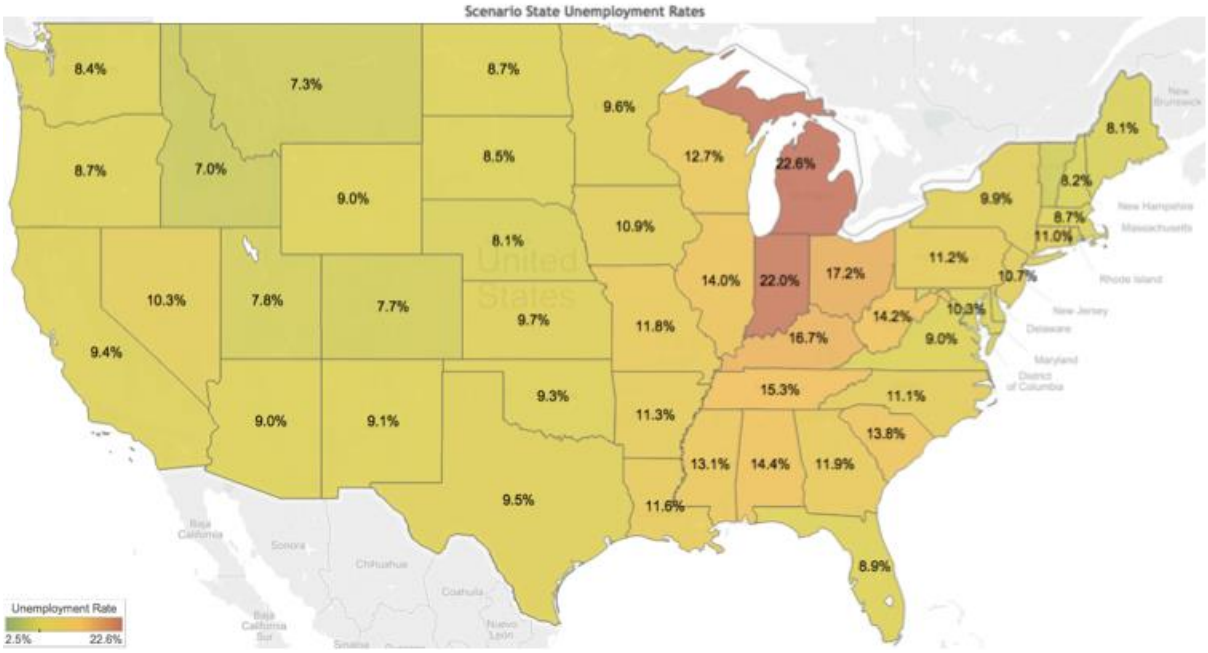

FIGURE 22—POE LOCK CLOSURE SCENARIO STATE UNEMPLOYMENT RATES

Economic modeling suggests that the Poe Lock closure scenario would result in 10.9 million people out of work in the United States, with additional losses in Canada and Mexico.[133] Figure 22 displays the potential State-level unemployment rates under the Poe Lock closure scenario. The Figure reflects changes in unemployment due to the Poe Lock closure (see Figure 23) overlaid on the baseline unemployment rates found in Figure 20. The color scale in Figure 22 remains consistent with that in Figures 20 and 21, so that green represents the lowest level of unemployment (generally below 7 percent); yellow and orange represent the highest levels of unemployment experienced during the 2009 recession; and red the highest levels of unemployment, which occurs under the closure scenario. Under the Poe Lock closure scenario, exceptionally high rates of unemployment occur along the Great Lakes and south. Unemployment rates in Indiana and Michigan would reach or exceed 22 percent and all of the Great Lakes States, except for Minnesota and New York, have unemployment rates that would exceed 10 percent.

[132] U.S. Bureau of Labor Statistics, "Local Area Unemployment Statistics for October 2009, on December 19, 2014 at http://www.bls.gov/web/laus/laumstrk.htm, accessed January 2, 2015.

[133] The lost economic output would be mitigated by government policy responses, both automatic (e.g., unemployment insurance) and considered. The Regional Economic Models, Inc. (REMI Model) used to estimate the economic impacts did not consider consumer response to this type of event (e.g., purchase a vehicle from an off-shore manufacturer [most foreign cars in the United States are made domestically], buy a used car, or maintain the existing car), employment losses at new car dealerships, and impacts to other industries (e.g., railcar and locomotive manufacturing).

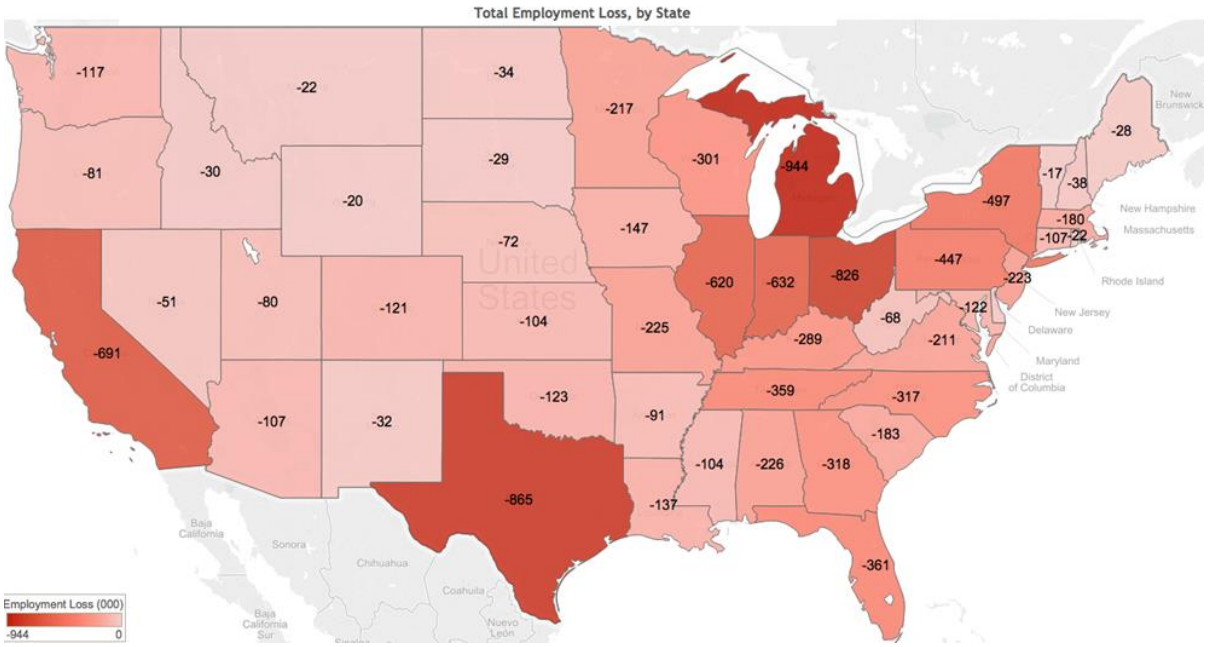

FIGURE 23—POE LOCK CLOSURE SCENARIO, STATE EMPLOYMENT CHANGES

Three States (Michigan, Texas, and Ohio) would experience job losses in excess of 800,000 people due to an unanticipated closure of the Poe Lock (see Figure 23). Another four States (California, Indiana, Illinois, and New York) would experience job losses that about equal or exceed 500,000 people due to the closure. Job losses in the Mountain States and Northern Plains would be relatively small, as there are few automobile assembly plants in these areas (see Figure 17).

Table 6 compares the unemployment rates of the six most affected States to that which occurred in October 2009. In every case, the State unemployment rate is projected to be higher than it was during the 2008-2009 recession; in most cases, the expected unemployment rate would be substantially higher.

TABLE 6—COMPARISON OF UNEMPLOYMENT RATES BETWEEN 2009 AND CLOSURE SCENARIO FOR SELECTED STATES

State	October 2009 Unemployment Rate	Closure Scenario Unemployment Rate
Alabama	7.4%	14.4%
Indiana	9.8%	22.0%
Kentucky	11.2%	16.7%
Michigan	15.1%	22.6%
Ohio	10.5%	17.2%
Tennessee	5.0%	15.3%

The ability to recover after the 6-month scenario closure may be predicated on the skilled labor remaining in the affected area. Many of the jobs associated with the iron mining - integrated steel production - manufacturing supply chain require highly skilled labor. If, over the course of the 6-10 month disruption, these people move elsewhere, the labor needed to mine, mill, or manufacture the output may not be available. Hiring and training new labor will take a significant investment and may significantly delay restarting production. These considerations have not been included in the model as the movement of labor is speculative.

ECONOMIC OUTPUT IMPACTS

The decrease in GDP attributable to a Poe Locks closure scenario is expected to be about $1.1 trillion, which is roughly a 6-percent decrease. Although not directly comparable, it may be useful to recall that during the worst six month period during the 2008-2009 recession, the GDP fell at a 7 percent annualized rate.[134,135] The National GDP growth rate since the first quarter of 2009 has been approximately 2.2 percent, per year.[136] This would suggest, that if the U.S. continues this rate of expansion, the annualized decease in the GDP after the closure scenario would be approximately 4 percent for the full year.[137]

A recession brought about by an unexpected closure of the Poe Lock would be categorically different from historical recessions. Recessions are usually caused by falling aggregate demand, credit contractions, or oil supply shocks, for which government fiscal or monetary policy can mitigate the length or severity of the recession. A supply shock as contemplated herein may be unprecedented. The closest example may be recession following the 1973-1974 Arab Oil Embargo. In that case, however, oil was available in the United States, but not in sufficient supply to meet demand. The dust bowl in the 1930s resulted in a lack of arable land in the Midwest, which led to the largest population migration in the United States.[138] In the Poe Lock closure scenario, there is no plan, policy, or remedy that could restart automobile production. Government policy would be generally limited to transfer payments to those individuals directly impacted by the event.

Given the size of the economic impact, it is illustrative to consider the economic value of a single Laker trip. A 1000-footer, carrying a cargo of 70,000 short tons, has a commodity replacement value of about $4.0 million. The iron ore grade shipped on the Great Lakes has a per ton value of about $57 multiplied by the 70,000 tons.[139] The REMI GDP estimate of a $1.1 trillion impact is based on the inability to ship 46.2 million tons of iron ore, which is the four-year average from 2010-2013. This suggests that, in the closure scenario, each ton of iron ore contributes about $23,800 of economic value; a Laker carrying 70,000 tons represents a loss of $1.7 billion to the U.S. economy and potentially another $340 million to the Canadian and Mexican economies.[140,141]

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[134] Federal Reserve Bank of St. Louis, "Real Gross Domestic Product" at https://research.stlouisfed.org/fred2/series/GDPC1#, accessed June 11, 2015.
[135] There are a number of factors that make the GDP numbers not comparable. For instance, the Poe Lock closure scenario does not account for transfer payments and government policy responses that could lessen the GDP impacts.
[136] Federal Reserve Bank of St. Louis, "Real Gross Domestic Product" at https://research.stlouisfed.org/fred2/series/GDPC1#, accessed June 11, 2015.
[137] This is estimated by subtracting the 6 percentage point loss from the estimated 2.2 percent increase.
[138] Public Broadcasting Service, "American Experience: Mass Exodus from the Plains", at http://www.pbs.org/wgbh/americanexperience/features/general-article/dustbowl-mass-exodus-plains/, accessed April 22, 2015.
[139] Bloomberg Business, "Iron Ore Price Outlook Cut by World Bank as Supplies to Expand" on April 22, 2015 at http://www.bloomberg.com/news/articles/2015-04-22/iron-ore-price-outlook-cut-by-world-bank-as-supplies-to-expand, accessed May 6, 2015.
[140] The term 'economic value' is not the same as profits. The concept here is that automobile lines shut down due to the lack of a single part. If the iron ore is not shipped through the Poe Lock, automotive steel cannot be made, and therefore, an automobile cannot be assembled. For this illustrative purpose, OCIA-NISAC is attributing the total value added in the supply chain to the iron ore shipments.
[141] OCIA-NISAC reviewed the significant commodity groups transporting goods on the U.S. waterways (USACE, "Waterborne Commerce of the United States: Calendar Year 2012," at http://www.navigationdatacenter.us/wcsc/pdf/wcusnatl12.pdf, accessed May 6, 2015). Petroleum is the largest group, with about 41 percent of all commerce, but most of this group represents crude oil imported into the Gulf Coast. The second largest group is coal. An article prepared for The Center for Energy and Economic Development, Inc. by Pennsylvania State University (Rose, Adam and Dan Wei, "The Economic Impacts of Coal Utilization and Displacement in the Continental United States, 2015," in July 2006) estimated that coal will contribute $1 trillion to the U.S. economy. Assuming that this estimate is accurate and further assuming that all coal, at some point, is shipped on the waterways and captured by the USACE data, then the per ton contribution to the U.S. economy is slightly over $3000 per ton, or less than a quarter of the per ton contribution of iron ore. Further, there are both transportation alternatives to moving coal on the waterway, the use of the more expensive rail routes, and alternative fuel sources for electric power generation, the use of natural gas. The other major product categories moving on the waterways are: Crude Materials (e.g., limestone, sand, wood), Food and Farm Products, and Chemical and Related Products). Most of these products are either low value, abundant in multiple locations throughout North America, are for export and therefore do not have an additional multiplier effect within North America, or has multiple alternative sources of transportation (e.g., rail, truck). Manufactured equipment, which may constitute the highest valued products moving on the waterways, are made up of machinery, vehicles, and electrical machinery, which, in most cases, uses iron ore as the first stage of development.

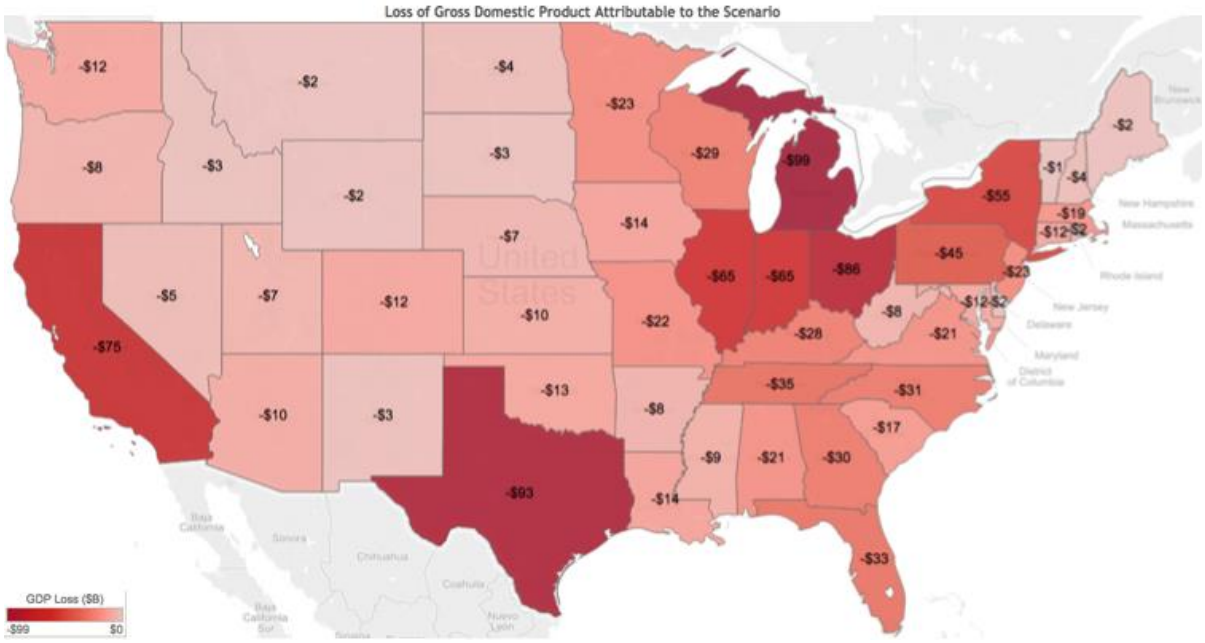

FIGURE 24—POE LOCK CLOSURE SCENARIO GROSS DOMESTIC PRODUCT CHANGES

The closure scenario could cost Michigan and Texas close to $100 billion of GDP each (see Figure 24).[142] Another five States (California, Illinois, Indiana, New York and Ohio) could lose between $55 billion - $86 billion in GDP each. Together, these seven States account for about 50 percent of the total GDP loss caused by the scenario disruption.

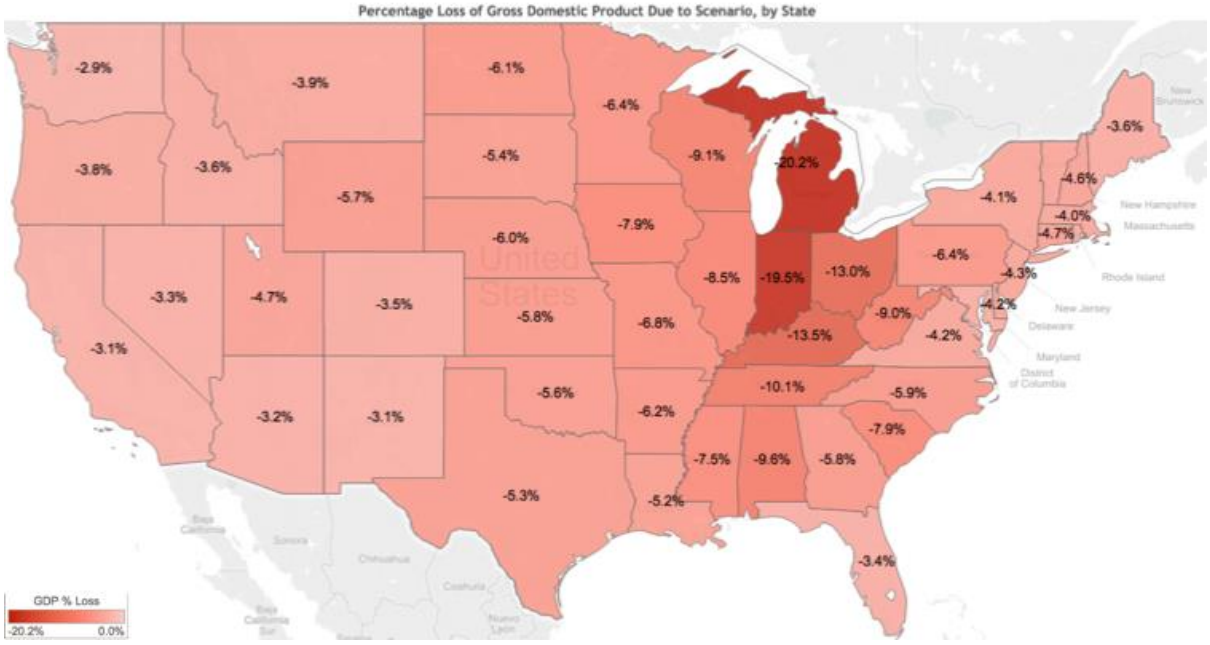

FIGURE 25—POE LOCK CLOSURE SCENARIO, GROSS DOMESTIC PRODUCT PERCENTAGE CHANGE

[142] Technically, the economic output at the State level is measured as the Gross State Product. For simplicity sake, we refer to the State-level economic output as GDP with the meaning of the State's contribution to the National GDP.

Figure 25 shows the estimated percentage change in GDP, by State. Michigan and Indiana would feel the most severe impacts, as their economies could lose approximately 20 percent of economic activity. Economic activity in Kentucky, Ohio, and Tennessee could contract between 10 and 13 percent, each. Another three States, Alabama, West Virginia, and Wisconsin could each lose about 9 percent of economic activity due to the scenario closure. The States just to the east of the Mississippi River would contract more than the States just to the west of the Mississippi River or in the Southeast. The Western States would contract by about 3 percent, which depending on their growth rates at the time of the scenario closure, could mean that they continue to grow, though at a slower rate. As an example, Colorado grew at a 4.7 percent rate in 2014, and the scenario closure results projects a 3.5 percent decrease in economic activity. [143] Colorado would still grow at a better than 1 percent rate for the year of the closure. New England and the Mid-Atlantic States would see contractions in the 4 to 6 percent range.

[143] Bureau of Economic Analysis, "Percent Change in Real GDP by State, 2014," on June 10, 2015 at https://www.bea.gov/newsreleases/regional/gdp_state/gsp_newsrelease.htm, accessed June 12, 2015.

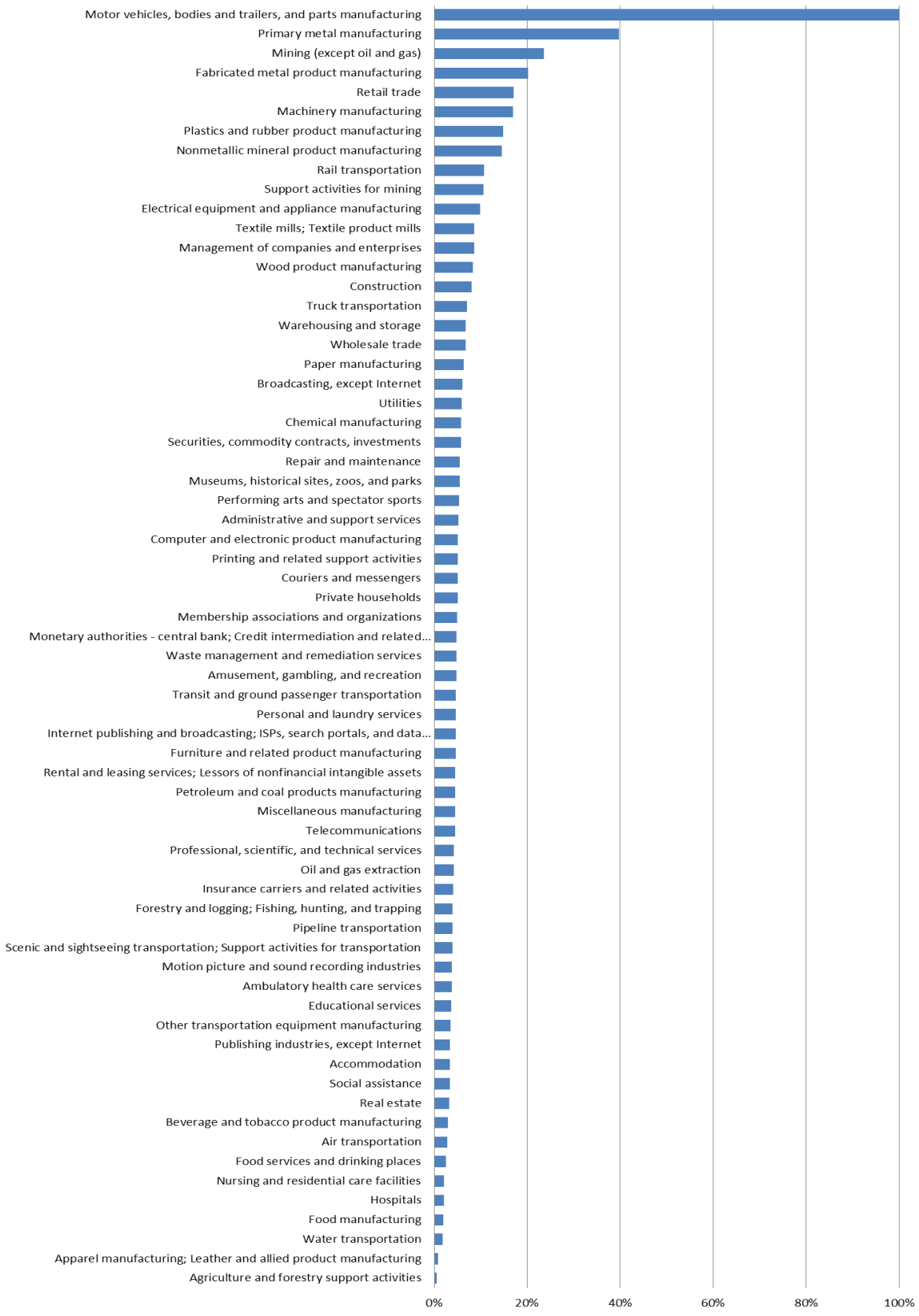

FIGURE 26—GDP PERCENT CHANGE, BY INDUSTRY

The industry category most impacted by the Poe Lock closure scenario is motor vehicles, bodies and trailers, and parts manufacturing industry (see Figure 26). This was not surprising, as this parameter in the model represented the system shock from the Poe Lock closure scenario. Analysts programmed the motor vehicles category to contract by 100 percent, in order to represent the cessation of automobile manufacturing under the scenario, for all of the reasons described in the Assumptions sections. Primary metal manufacturing (which captures the contraction in the integrated steel industry), mining (which captures the contraction in the iron ore mining), and fabricated metal manufacturing all are anticipated to contract between 20 and 40 percent, respectively. Retail trade, which captures, among other direct and indirect effects, new car sales, is anticipated to contract by about 17 percent.

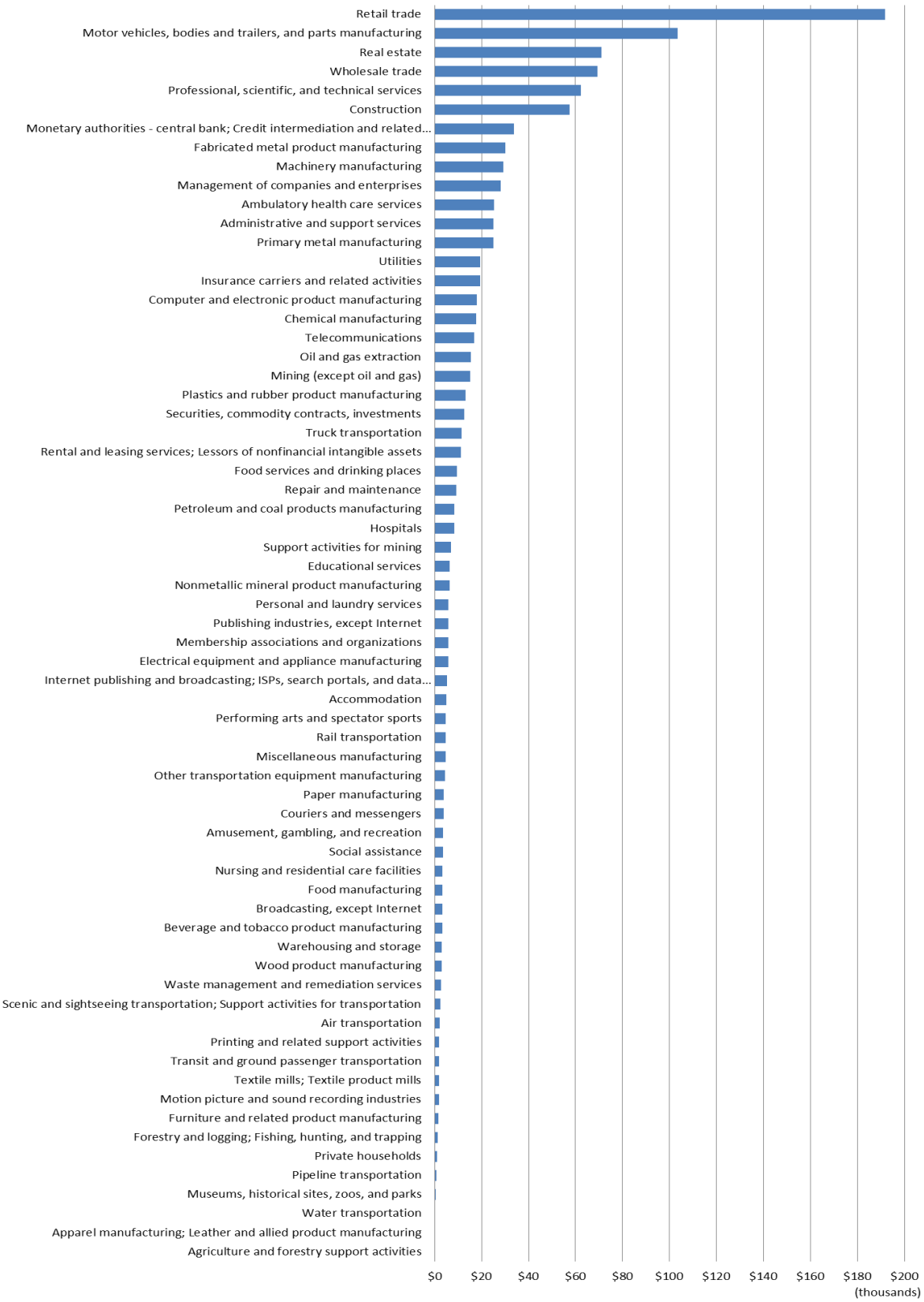

FIGURE 27—DECREASE IN GDP, BY INDUSTRY

In absolute terms, the retail trade industry sector is the most affected by the closure scenario (see Figure 27). The REMI model predicts a $192 billion contraction, primarily due to a lack of new cars to sell. The number also includes a decrease in appliance and auto part sales. Real estate and construction, combined, would be the second largest impact at a $129 billion contraction. This is mainly a second-order effect reflecting decreased demand. The contraction in the motor vehicles, bodies and trailers, and parts manufacturing industry is roughly $103 billion.

ALTERNATIVE STRATEGIES CONSIDERED

The serious impacts of this scenario are due to the history of the iron mining - integrated steel production - manufacturing supply chain, which has evolved over the last 160 years to maximize efficiency. The resulting system has permitted these industries to survive in increasingly competitive markets, but has fostered neither resilience nor flexibility. In the event of an unanticipated 6-month closure, most steel mills, including the steel mills most critical to significant aspects of the Nation's economy, would have no way to receive iron ore.

OCIA-NISAC assessed a number of possible mitigation strategies, including:

- Moving iron ore by rail,
- Moving iron ore by truck,
- Shipping from the Port of Escanaba, Michigan,
- Lightering on smaller Lakers which can transit the MacArthur Lock,
- Obtaining steel or iron ore from foreign sources,
- Stockpiling ore at the steel mills, and
- Switching automotive production to use aluminum for some parts.

None of these strategies employed singly would significantly alleviate the issues. Even if a mitigation strategy is identified and employed, any option would increase cost and decrease competitiveness for the firms involved.

MOVING IRON ORE BY RAIL

Moving iron ore from the mines to the mills is not a viable mitigation; as one industry executive put it, "it's not even in the realm of the possible; it's just not going to happen." Even if the steel mills could accept iron ore from rail transportation, congested rail lines and the lack of equipment would make the use of rail impractical.

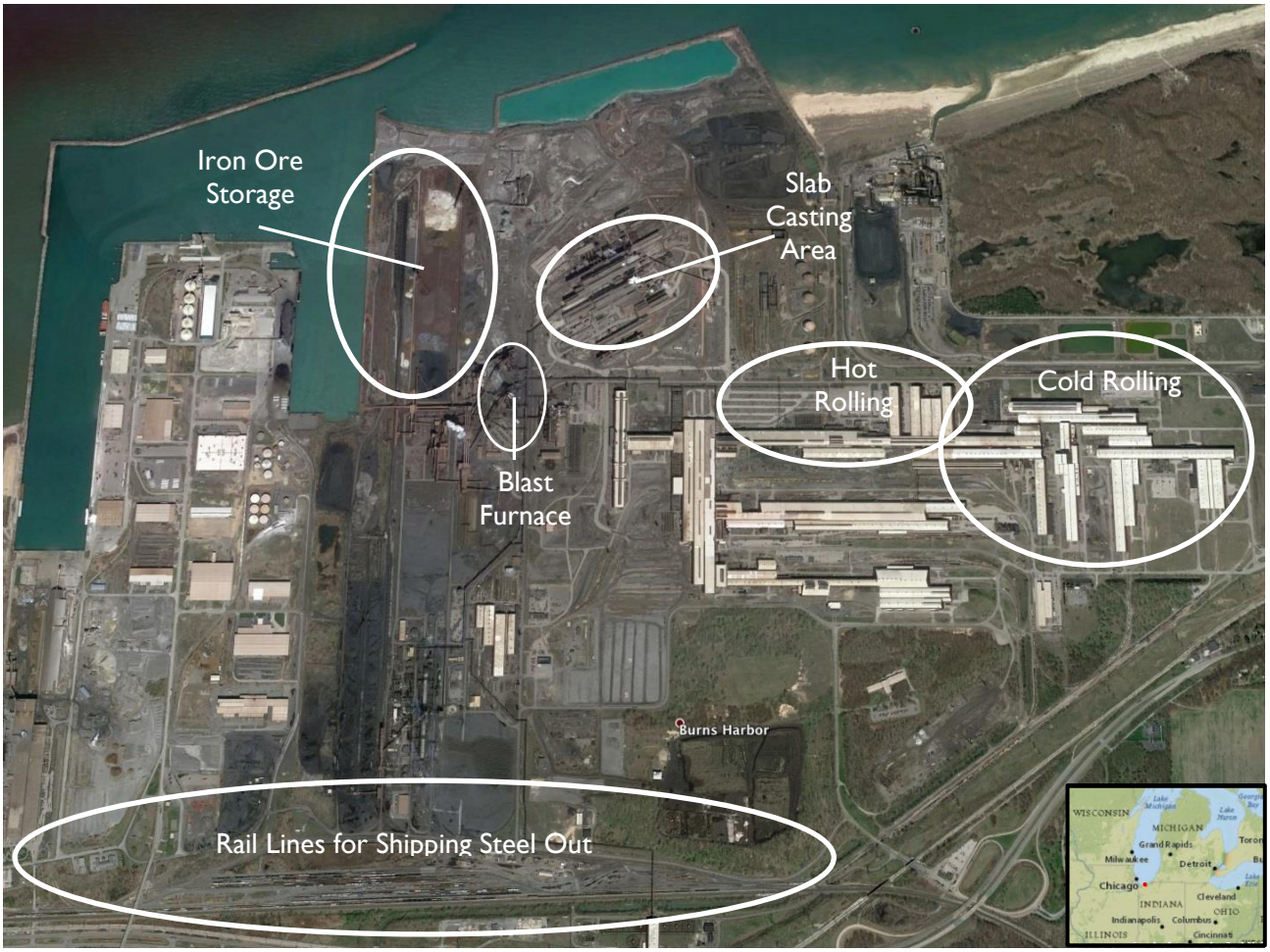

FIGURE 28—BURNS HARBOR STEEL MILL

For 160 years, the steel mills along the Great Lakes have received their iron ore via Lake Carrier; the mills are designed to receive iron ore by water and there is logistically no way to receive iron ore by rail.[144,145] One steel mill, Lake Erie Works (U.S. Steel) does not have a rail line at its mill; other steel mills such as Indiana Harbor (ArcelorMittal) and Burns Harbor (ArcelorMittal) do not have the infrastructure to receive iron ore by rail; while another steel mill, Great Lakes Works (U.S. Steel) on Zug Island, could potentially receive iron ore by rail for one of its two blast furnaces.[146] As shown in Figure 28, the Great Lakes steel mills are built with the iron ore inventory facing the water and the rail lines on the other side of the mills inland for truck or rail shipment of steel out. Figure 28 is an image of Burns Harbor, but it is representative of the majority of Great Lakes steel mills.

[144] The mill, now called Indiana Harbor (ArcelorMittal), was built in 1901, while Gary Works (U.S. Steel) was built in 1906 (Encyclopedia of Chicago, "Iron and Steel" at www.encyclopedia.chicagohistory.org/pages/653.html, accessed January 2, 2015.) However, prior to their development, earlier Great Lakes steel mills have been receiving iron ore by barge since 1855 (Michigan State University, "Iron Ore/Taconite Shipping," at http://web2.geo.msu.edu/geogmich/iron_ore__taconite.html, accessed January 2, 2015.)

[145] Industry officials indicated that Gary Works (U.S. Steel) has the ability to take in 1-2 unit trains per week, and did do so up until 5 - 10 years ago, until Chicago became too congested (see next page). However, 2 trains per week would only provide about 1/8th of Gary Works' iron ore requirements.

[146] Technically, Great Lakes Works was a peninsula that Henry Ford or Samuel Zug converted into an island (Crains Detroit, "Beyond the Shores," on August 19, 2012 at www.crainsdetroit.com/article/20120819/FREE01/308199988/beyond-the-shores, accessed January 2, 2015.

NORTH AMERICAN RAIL CARRIERS

In the United States, the vast majority of rail shipment is provided by the Class I railroads. The North American Class I freight railroads are Burlington Northern and Santa Fe Railway (BNSF), Canadian National Railway (CN), Canadian Pacific Railway, CSX Transportation (CSX), Kansas City Southern Railway, Norfolk Southern Railway (NS) and the Union Pacific Railroad. BNSF and CN are the primary rail companies operating within Minnesota and Michigan and between Minnesota, Michigan, and Chicago. Chicago is the central rail point in the United States. CN, CSX, and NS are the primary carriers of products, equipment and supplies, from Chicago east to the steel mills.

There are an insufficient number of locomotives and railcars to move the iron ore, even if the steel mills could receive iron ore by rail. A 2012 Sandia National Laboratories study for OCIA-NISAC estimated that 1670 railcars per day would be necessary to move the iron ore, while an industry expert believed that 2500 railcars per day would be necessary.[147] This number of railcars and the locomotives are not believed to exist.[148] The current supply of rail cars that could carry iron ore "would perhaps be best described as zero to extremely limited."[149] Further, "there are many additional potential constraints that must be taken into account in assessing capacity. This includes hiring and training personnel to operate the trains, locomotive supply, and additional yard tracks to land the trains and fuel the locomotives."[150]

The Northern and Midwest States already face heavy rail congestion, due in part to the movement of Bakken shale oil by rail, which would preclude any large-scale movement of iron ore by rail.[151] Industry executives have also indicated that some of the congestion is due to issues on other North American rail lines, which has forced the traffic onto the lines that would be needed to move iron ore. OCIA-NISAC estimates that the volume of railcars between Duluth, MN and Minneapolis/St. Paul would increase by 200 percent, from Minneapolis/St. Paul to Milwaukee would increase by about 40 percent, and the Milwaukee to Chicago lines would face volume increases of over 35 percent.[152] One industry executive stated that the infrastructure does not exist "to support the level of traffic [conceived under the disruption scenario] without major investment in infrastructure and the time to construct." This industry executive speculated that, at most, one to two unit trains a week could move from Minnesota to the steel mills, assuming that Bakken Crude movements do not increase.[153] This would not come close to the 20 unit trains per day that would be required to move sufficient quantities of iron ore from Minnesota and Michigan to the Great Lakes steel mills.[154]

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[147] OCIA-NISAC, "Modeling the Impacts of a Prolonged Closure of the Soo Locks: Phase I," February 2012.
[148] Further, the railcars used to move the iron ore must be able to transport iron ore. Only standard gondolas, without rotary coupling systems used to dump coal quickly, can be used to move iron ore. The mass of the iron ore can damage other types of rail cars. The standard gondolas can only be filled about 1/3rd full before it reaches its weight limits.
[149] Email from industry executive.
[150] Email from industry executive.
[151] MPR News, "Solution to Congested Rail Lines May be Years Away," September 30, 2014 at www.mprnews.org/story/2014/09/30/unclogging-rail-traffic, accessed January 3, 2015.
[152] OCIA-NISAC, "Modeling the Impacts of a Prolonged Closure of the Soo Locks: Phase I," February 2012.
[153] The Bakken shale oil trains do not share rail cars or facilities with the iron ore trade.
[154] Bakken Crude is the oil play located in North Dakota and Montana. 700 railcars a day are traveling from North Dakota, through Minnesota and Wisconsin, to Chicago, up from close to 0 in 2011.

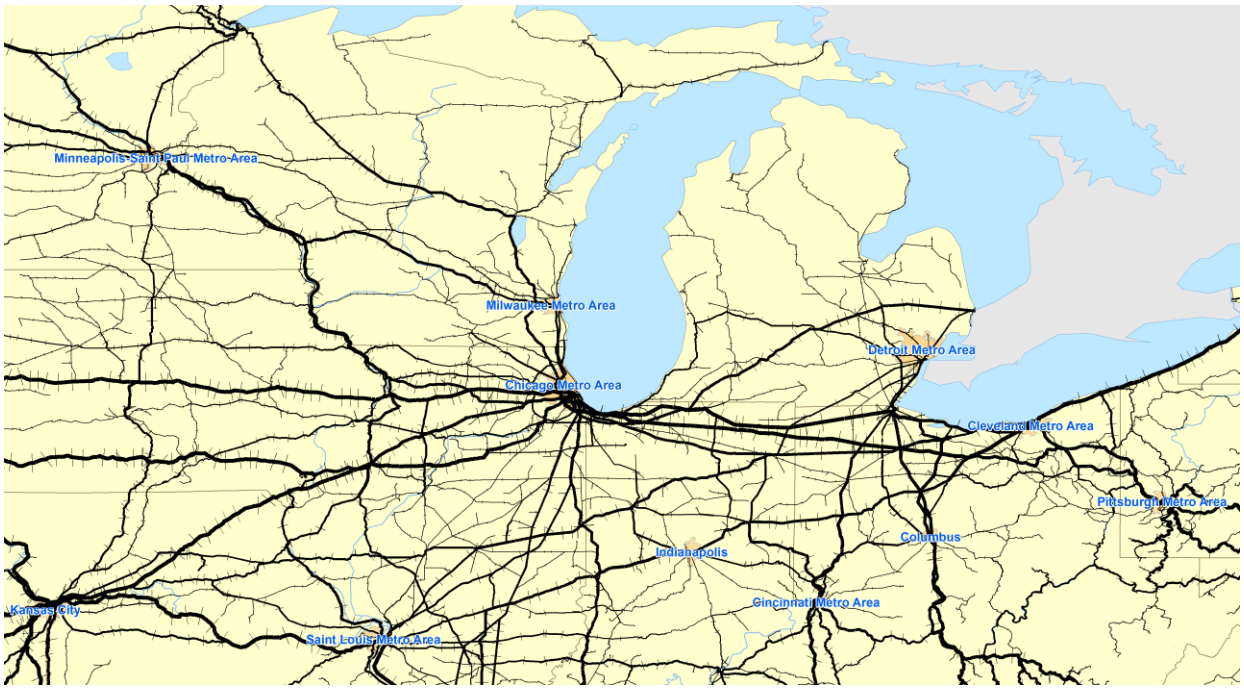

FIGURE 29—MAP OF MIDWEST RAIL LINES, THICKNESS OF LINE REPRESENTS DENSITY OF USE[155]

Moreover, any increase in rail traffic would be on some of the most heavily congested rail lines in the Nation (see Figure 29). Chicago, through which a quarter of all freight rail traffic in the Nation passes, is the most congested area in the Nation; shippers report that they can move goods two-thirds the way from Chicago to Los Angeles in the time it takes to traverse Chicago.[156] The three largest steel mills in the Nation are located about 25 miles southeast of Chicago within 10 miles of Gary, Indiana.

Some commodity types such as coal, iron ore, intermodal containers, and motor vehicles, are not required to pass through rail yards *en route* to their destination—they are allowed to bypass the rail yards by means of bypass rail links. These types of commodities are moved in "unit trains," which move directly from an origin to a destination because there is sufficient volume between the specific origin and destination to support an entire train. Because of this, the travel times of these shipments may be less affected by rail yard congestion, though they still must travel on congested railways, enter rail yards for inspection and maintenance, and not all rail yards have bypass rail links. Most unit trains designed to carry iron ore would be unloaded and returned to their origination point empty because the commodities tend to flow in one direction.

The existing congestion is such that, in 2014, utilities and grain producers petitioned the U.S. Government to impose a timetable on BNSF to alleviate the difficulties.[157] The Surface Transportation Board of the Department of Transportation (DOT) issued a decision that BNSF was "to publicly file their plans to timely resolve their backlog of grain car orders, as well as weekly status reports pertaining to grain car service."[158] Cliffs Natural Resources, the leading iron ore mining company, reported on October 10, 2014, "that due to ongoing insufficient rail service [Cliffs] will immediately begin utilizing trucks to transport iron ore pellets [the 82 miles] to the Duluth-Superior Harbor."[159] However, since that time, Cliffs has returned to rail for this leg of transportation.

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[155] DOT/Federal Railroad Administration, "Freight Rail Today," at http://www.fra.dot.gov/Page/P0362, accessed February 4, 2015.
[156] New York Times, "Freight Train Late? Blame Chicago," at http://www.nytimes.com/2012/05/08/us/chicago-train-congestion-slows-whole-country.html?_r=0, accessed February 4, 2015. The article further stated that some trains go across Chicago at "about a quarter the pace of many electric wheelchairs." This description was confirmed by industry executives.
[157] Wall Street Journal, "Utilities Press Railroad to Speed Coal Deliveries," on November 23, 2014 at www.wsj.com/articles/utilities-press-railroad-to-speed-coal-deliveries-1416786948?cb=logged0.04710544156841934, accessed January 3, 2015.
[158] Surface Transportation Board, "Docket No. EP 724 (Sub-No. 2) United States Rail Service Issues-Grain," on June 20, 2014 at www.stb.dot.gov/decisions/readingroom.nsf/UNID/F8F5F23979674DB485257CFD007024F0/$file/43842.pdf, accessed January 3, 2015.
[159] Cliffs Natural Resources, "News Release: Hibbing Taconite Begins Transporting Iron Ore Pellets by Truck," on October 10, 2014.

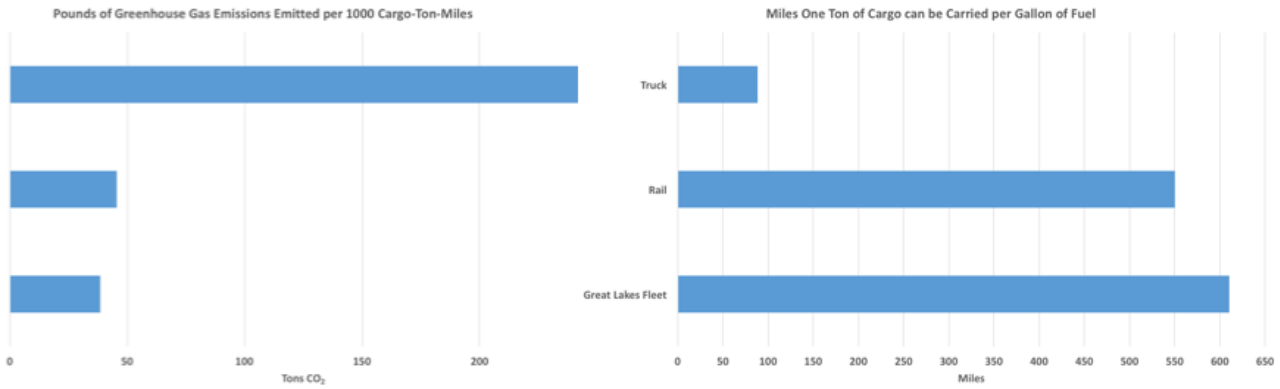

FIGURE 30—CARBON DIOXIDE (CO^2) EMISSIONS AND GALLONS OF FUEL USED TO MOVE CARGO

The Lakers are a highly efficient and safe mode of transportation in comparison to rail transportation. The DOT reports that fatality rates are 23 times higher and injury rates 125 times higher in the rail industry than the Laker industry.[160] Similarly, the USACE and DOT estimated that the Lakers are more fuel-efficient and produce less carbon dioxide than any other mode of transportation (see Figure 30).[161] Rail produces about 20 percent more carbon dioxide, and are about 13 percent less fuel efficient, than Lakers.

MOVING IRON ORE BY TRUCK

There are not enough trucks, or drivers, in the Nation to move the iron ore from the mines to the mills.[162] Each One Thousand Footer Lake Carrier carries approximately 70,000 tons of iron ore, which is equivalent to about 3,000 trucks. The mills use the 70,000 tons about every five days, which means that 600 trucks per day--1 truck every 2.4 minutes--would have to enter a steel mill, drop its load and leave. To bring trucks to 7 mills would mean that, for every point on the Interstate Highway System between Minnesota and Indiana, there would be a truck loaded with iron ore passing every 20 seconds on one side of the road and one truck returning empty on the other side of the road. The Interstate Highway System would have to be shut down to all traffic except for the iron ore trucks and no road maintenance could occur.

As stated earlier, most steel mills are designed to receive iron ore by Lake Carriers and cannot accept iron ore by truck. At some mills, there is no means to get a truck to the area where the iron ore is stored. Trucks are used extensively to move finished products from the mills; one steel mill reported that 400 - 500 trucks a day transport products to customers.

Lakers are a more efficient and safer mode of transportation than trucks. DOT reports that fatality rates are 155 times higher and injury rates are 2172 times higher transporting cargo by truck than by Laker.[163] The Lakers are more fuel-efficient and produce less carbon dioxide (CO_2) than trucks.[164] Trucks produce about 11 times as much CO_2 and uses about 10 times as much fuel to move cargo compared to Lakers.

Finally, OCIA-NISAC estimates that the cost of moving iron ore by truck is approximately four times the value of the iron ore itself and would likely be cost-prohibitive in addition to impractical.

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[160] U.S. Department of Transpiration/Maritime Administration, "Waterways: Working for America," at http://www.marad.dot.gov/documents/water_works_REV.pdf, accessed February 5, 2015.
[161] USACE, "Great Lakes Navigation System: Economic Strength to the Nation," at http://www.lre.usace.army.mil/Portals/69/docs/Navigation/GLN_Strength%20to%20the%20Nation%20Booklet2013v2_final2w.pdf, accessed February 6, 2015.
[162] Under current economic conditions, trucking companies face a dearth of truck drivers (see, Journal of Commerce, "The Driver Shortage," on June 24, 2015 at http://www.joc.com/special-topics/driver-shortage, accessed June 24, 2015).
[163] U.S. Department of Transportation/Maritime Administration, "Waterways: Working for America," at http://www.marad.dot.gov/documents/water_works_REV.pdf, accessed February 5, 2015.
[164] USACE, "Great Lakes Navigation System: Economic Strength to the Nation," at http://www.lre.usace.army.mil/Portals/69/docs/Navigation/GLN_Strength%20to%20the%20Nation%20Booklet2013v2_final2w.pdf, accessed February 6, 2015.

SHIPPING IRON ORE THROUGH THE PORT OF ESCANABA

FIGURE 31—CN ORE DOCK AT ESCANABA, MICHIGAN

Currently, the Port of Escanaba could provide only limited mitigation during a closure scenario. The CN Railway Ore Dock in Escanaba, Michigan is the only port downbound of the Soo Locks that is able to load iron ore (see Figure 31). However, the Port of Escanaba is the smallest iron ore port in Minnesota or Michigan; it is about 20 percent smaller than the next smallest port (Silver Bay, Minnesota) and 20 percent the size of the largest port (Two Harbors, Minnesota). Escanaba currently ships about 7 percent of the iron ore mined, a number that has been stable since at least World War II.[165] Escanaba is too far from the mining centers to compete in cost with the Lake Superior iron ore docks. As an example, the rail distance from Minntac to Duluth is about 70 miles; from Minntac to Escanaba is about 350 miles. The extra rail distance means additional shipping costs at rail rates, which are higher, on a ton per mile basis, than the waterborne rates.

The infrastructure at Escanaba has not been maintained and the capacity of Escanaba continues to decline. Most of the iron ore that transits Escanaba originates out of the Empire Mine in Michigan. The Empire Mine has been expected to close for a number of years, most recently in 2014. However, ArcelorMittal and Cliffs Natural Resources agreed to extend the life of the Empire Mine until at least January 2017.[166] Without a long-term customer, CN Railway is not expected to invest significant resources at the Port of Escanaba.

Even if it surges to maximum capacity, in its current state, Escanaba could handle only about 10 percent of the total annual iron ore requirements of the Great Lakes steel mills. Essentially all of the iron ore that transits the

[165] Morgan, John P. "The Domestic Mining Industry of the United States in World War II," Government Printing Office: Washington, 1949.
[166] UpperMichigansSource.com, "Empire Mine Avoids Closure through New Ore Deal," on February 27, 2014 at http://www.uppermichiganssource.com/news/story.aspx?id=1012772#.VXY0R2BiXJQ, accessed June 2, 2015.

Port of Escanaba goes to Indiana Harbor (ArcelorMittal) and Middletown (AK Steel). An insufficient amount of iron ore could move through Escanaba to operate Indiana Harbor efficiently. While it is possible that enough iron ore could be moved to operate one of the three blast furnaces at Indiana Harbor, the overall capacity utilization of Indiana Harbor would be about 33 percent. Iron ore would likely continue to move through Escanaba to Middletown (see Table 4).

LIGHTERING

FIGURE 32—LIGHTERING EXAMPLE

Lightering is the process of transferring cargo (in this case, iron ore) from a Poe-sized Laker to a MacArthur-sized Laker for transit through the MacArthur Lock and then from a MacArthur-sized Laker to a Poe-sized Laker for transit to the steel mills (see Figure 32). Lightering occurs periodically on the Great Lakes. The most common occurrence is when a Laker is disabled and the iron ore must be off-loaded onto another Laker. Lightering may also occur if iron ore is being sold onto the seaborne market and the commodity must be moved onto a smaller Laker that can transit the Welland Canal through the Saint Lawrence Seaway.

However, a significant number of logistical issues would challenge the ability to undertake lightering successfully:

- The Poe and MacArthur Locks are among the busiest in the world, so to move all traffic through a single lock would cause significant congestion;

- Beginning in September the weather turns unfavorable, making lightering past August questionable.
- Lightering can only occur if wave heights are forecast to be less than 1 meter during the off-loading and on-loading period.[167] To off-load and on-load a Poe-restricted Laker onto 2-3 MacArthur-sized Lakers and from the MacArthur-sized Lakers to a Poe-restricted Laker could take more than 24 hours;[168]
- Loading from a MacArthur-sized Laker to a Poe-restricted Laker requires specialized equipment that does not exist in sufficient capacity. The Poe-restricted Lakers are significantly higher off the water and the self-unloading structures on the MacArthur-sized Lakers cannot properly align; and
- Under current use, the 70-year-old MacArthur Lock closes for a number of hours each month for repair. Constant usage is likely to increase the need for repair and unanticipated closures. Currently, the MacArthur Lock does not open for at least 2 weeks after the Poe Lock opens. Reliance on the MacArthur Lock would entail a delay.

Lightering could also be encumbered by a number of contractual obstacles regarding:

- Which iron mines have priority to ship;
- Which steel mills would have priority for receipt;
- How the grain and coal that would normally move on the displaced Class VIII Lakers would get to their destination and identifying the responsible party to pay for the transportation price differential.

To address the concern about whether coal shipments are necessary, OCIA-NISAC analyzed a potential disruption of coal deliveries to the major coal-fired generation facilities on the southeastern portion of Michigan. Although transporting coal by freighter is more cost-effective, there does not appear to be a logistical requirement to use freighters over rail transportation. Currently, coal is currently railed from Wyoming to Wisconsin and then placed on a Laker. If the coal had to be moved the full distance on rail lines, about 400 additional rail cars (4 unit trains) a day would be needed to move the longer distance.

Even if additional rail cars cannot be located or congestion in the Chicago area inhibits the ability to move 4 unit trains a day, coal may not be critical to maintain Michigan automobile production, provided that iron ore was being delivered. The Los Alamos National Laboratory contingency analysis on behalf of OCIA-NISAC suggests that other generators in Michigan and neighboring regions can make up the lost generation. The analysis indicated that this shift in generation would cause no major overloads or voltage problems within the regional transmission system. The regional operators could also reduce demand by implementing interruptible contracts during peak load periods. The loss of coal movements through the Soo Locks does not appear to affect the ability of Michigan automobile manufacturers to continue their operations. For a more complete discussion, please see Appendix G.

IMPORTING FOREIGN ORE

Using imported iron ore from Canada or another country is not considered possible. Industry experts indicate that iron ore pellets are not interchangeable; steel mills are designed to receive specific types of pellets from specific mines in order to meet customer specifications. Different iron ore grades from different mines affect the grade of steel produced at a mill.[169] Therefore, imported iron ore would require additional testing, materials, and time to ascertain how to convert the seaborne iron ore into specified steel products.

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[167] This corresponds generally to a wind speed of less than 12 miles per hour (University of North Carolina, "Beaufort Scales (Wind Speed), on May 31, 2001 at https://www.unc.edu/~rowlett/units/scales/beaufort.html, accessed February 26, 2015, though wave height also depend on bathymetry (underwater topography) and fetch (the distance over water that wind blows in a single direction).

[168] The lightering estimates were based on analysis done by USACE for an Expert Elicitation Workshop on lightering.

[169] Footnote 1 describes the process of creating the taconite pellets. As part of the process, various chemicals can be added to the extracted iron ore to make taconite pellets. Depending on the type of steel to be made, different chemicals are added. Therefore, the processed taconite pellets have been developed for a specific mill to make a specific type of steel. These taconite pellets are not interchangeable. Further, seaborne iron ore from Australia and Brazil is actually iron ore and taconite. The U.S. blast furnaces are not configured to accept iron ore without changing processes, which could result in a significant amount of testing, up to a year as previously stated, to determine that the steel is manufactured to the exact same specifications.

In any case, only a limited amount of iron ore, possibly 1 to 2 million tons, could be moved through Canada's St. Lawrence Valley, far less than the 45 million tons shipped out from Minnesota and Michigan.[170] Additionally, the price of seaborne iron ore (typically from Brazil or Australia) can diverge significantly, higher or lower, from Minnesota iron ore prices. This does not include the substantial transportation cost differentials and other logistical challenges. For instance, the transit time from the iron ore Port of Tubarao in Brazil to Gary, Indiana is four times the transit time from Duluth, Minnesota to Gary, Indiana. Further, the size of the Welland Canal restricts traffic on that portion of the St. Lawrence Seaway to Lakers having far smaller capacity than the Lakers that carry iron ore. The locks in the Saint Lawrence Seaway can handle Lakers that are only slightly larger than MacArthur-sized Lakers, meaning that each Laker would hold about 30 percent less iron ore than the typical Laker. However, one of the biggest hindrances may be the unique nature of the Great Lakes shipping fleet. According to a review of the Lloyds Registry of shipping vessels, there are almost no self-unloading vessels outside of the Great Lakes.[171,172] The ports and mills along the Great Lakes have limited capabilities to unload the type of traditional bulk carrier used elsewhere in the world.

Almost all steel mills today are part of vertically integrated corporations that include ownership interests in iron ore mines, dating back to 1900 in some cases.[173] ArcelorMittal and U.S. Steel directly own iron ore mines and steel mills, while A.K. Steel owns an equity interest in an iron ore company in addition to their steel mills. Essar Steel, which owns the Algoma Steel Mill in Sault Ste. Marie, Ontario and Cliffs Natural Resources, which owns iron ore mines but not steel mills, are the only companies that are not vertically integrated. Many of the steel mills that went bankrupt in the 1970-2000s were firms that imported iron ore and could not withstand the volatile cost differentials between Great Lakes iron ore and seaborne iron ore.[174]

IMPORTING STEEL

The first action many firms will take is to obtain, or attempt to obtain, appropriate steel slabs from overseas. This is more likely to be possible for automobile parts less reliant on specialized steel. This would be a short-term solution designed to keep automobile lines going for as long as possible. At best, industry executives believe that this would keep some lines going for a couple of weeks and is a means of extending the use of the existing steel supply. It is conceivable that cargo planes would be used to carry steel slabs or steel coils, a very expensive proposition. Industry executives stated that cargo planes have been used in the past during other disruption events. Subaru, which accounts for about 3 percent of the North American automobiles sales, reported that it spent $60 million a month flying in auto parts due to the labor difficulties at the Ports of Los Angeles/Long Beach in the first quarter of 2015.[175] Other, larger Asian automobile firms, reportedly spent far more to keep their production lines operational.

For a disruption of 6 months or longer, industry executives are divided on whether steel slabs can be imported. Automotive quality steel is available in Japan, in Europe, from POSCO in South Korea, and from Boasteel in China. However, there are a number of limits on the ability to import steel from these locations:

- Changing the types of steel used in automotive production requires significant trials, validation, and inspections;

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[170] Baird/URS, "Soo Locks Partial Benefits Analysis: Foreign Sourcing Alternative," undated.
[171] From a meeting with the USACE, February 19. 2015. The foreign self-unloading vessels are too large to transit the Welland Canal and therefore cannot enter the Great Lakes.
[172] Self-unloading vessels first appeared on the Great Lakes in 1908 though they did not become widespread until the 1970s (see DOT/Maritime Administration, "Status of the U.S. Flag Great Lakes: Water Transportation Industry," on February 2013 at www.marad.dot.gov/documents/US-Flag_Great_Lakes_Water_Transportation_Industry_Final_Report_2013.pdf, accessed March 10, 2015). They are not in use outside of the Great Lakes because of the differences in use. Vessels in the Great Lakes fleet pick up their cargo and drop it off 2 days later, returning to pick up more cargo. Thus, shortening the time in port is critical. Conversely, seaborne freighters travel for weeks from origination to destination and a few additional hours in port is not worth the loss of capacity or increased weight associated with the self-unloading equipment.
[173] Rogers, Robert, "An Economic History of the American Steel Industry," Routledge: New York, 2009.
[174] AK Steel holds equity interests in the Bovey Mine and the Keewatin Mine. ArcelorMittal owns the Minorca Mine and holds equity interests in the Hibbing Mine and the Empire Mine. U.S. Steel owns the Keetac Mine and the Minntac Mine and holds equity interests in the Tilden Mine and the Hibbing Mine. Cliffs Natural Resources is the only independent iron ore firm, which owns the Northshore Mine and United Taconite. Cliffs also holds equity interests in the Hibbing Mine and the Empire Mine.
[175] Reuters, "Japan Automakers Hit Production Snags as U.S. Port Dispute Drags On," on February 6, 2015 at http://www.reuters.com/article/2015/02/06/us-usa-ports-japan-idUSKBN0LA0MR20150206?feedType=RSS&feedName=businessNews, accessed June 22, 2015.

- The lack of infrastructure in domestic ports, and the lack of availability of ships, trucks and drivers, railcars, locomotives, and crew, are limiting factors. To illustrate this point, approximately 41.8 million tons of steel can be made by the steel mills listed as Non-Operating Steel Mills because of the disruption (see Table 4). Each steel coil weighs about 30 to 40 tons; for purposes of simplicity, will be assumed to weigh 33.33 tons. Therefore, to make up for the 41.8 million tons in lost capacity under this scenario, 1.25 million slabs would have to be transported from a port to a steel-rolling facility. One truck could carry one slab, which means it would take 1.25 million truck trips, or over 24,000 truck trips a week. One train could take three slabs per railcar. For a unit trail of 100 cars, this would be 300 slabs per train on 80 unit trains a week. Industry experts stated that the amount of infrastructure necessary to move this amount of slabs does not exist;
- Even if a manufacturer could import steel coils, there are additional logistics challenges. Steel coils are delivered to customers either by railcar or truck depending on the preferences of the purchaser. The preferences can be so specific as to designate how the steel coils are placed on a truck so as to line up properly with the receiving dock. If steel coils were imported through a port, which would have to be either along the Eastern Seaboard or at some unidentified point on the Gulf Coast, the steel coils would have to move from rail or barge to truck. Moving these 30 to 40 ton steel coils without damaging them in the transfer may be problematic;
- Foreign steel companies are not in the business of selling steel slabs, which is a lower profit venture. If the slabs could be rolled overseas, the coils would likely degrade during shipment to North America;[176]
- In 'normal' economic times, it is highly unlikely that sufficient excess supply of steel would be available, particularly of the steel quality needed for automotive production. For instance, a number of industry executives stated that they would look to Boasteel of China and POSCO of South Korea as potential alternative sources of steel. Boasteel produces about 44 million tons of steel[177] and Posco about 38 million tons.[178] The North American demand for automotive steel is likely around one-half of the combined output of these two companies, if one assumed that their entire output was automotive quality steel, which it is not. While there is insufficient information to do a complete analysis, the spare automotive steel capacity of these two firms is probably fairly small;
- To obtain sufficient quantities of steel, if even available, would take at least 3-4 months, and likely significantly longer;
- Some industry executives reported that there may be legal or contractual restrictions that would inhibit the ability to import foreign steel slabs; and
- The cost of importing steel slabs would be significantly higher than the current price of steel. While the price differential has not been estimated, the cost of cars would either have to rise significantly to cover the price differential, or firms involved in the supply chain would have to cover the costs out of their available capital, which is not sustainable.

It has been suggested that foreign automobile companies are more likely to have overseas sources that could produce steel slabs manufactured to the correct specifications and moved to the United States. Industry executives have stated that these firms generally manufacture automobiles to similar specifications in their home markets in Asia or Europe and in the North American markets. However, most foreign automobile manufacturers have moved their supply chains to the local markets, leaving little excess production capacity in their home market. As an example, the Japanese automotive companies make almost all of their cars for the North American market in North America. As the Japanese economy has restructured over the past 30 years, few cars are made in Japan for export into the North American market.

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[176] According to at least one industry executive, slabs cannot be rolled overseas for transportation to the United States due to environmental issues that would cause the coils to degrade.
[177] Boasteel, "Brief Introduction," at http://www.baosteel.com/group_en/contents/2880/39991.html, accessed June 15, 2015.
[178] POSCO, "2015 Investor Forum," on February 5, 2015 at http://www.posco.com/homepage/docs/eng3/dn/invest/archive/2015_investors_forum_eng.pdf, accessed June 15, 2015.

INCREASE IRON ORE INVENTORY AT STEEL MILLS

Maintaining a 6-month inventory of iron ore at the steel mills could mitigate the impacts of a closure. However, some steel mills do not have the storage capacity to maintain this type of inventory and no company likely has the available capital to tie up in precautionary inventory for an event that has never occurred.

INCREASE STEEL INVENTORY IN THE AUTOMOTIVE SUPPLY CHAIN

Maintaining a precautionary supply of steel in the automotive supply chain is not considered feasible. Almost every part of an automobile has a unique steel coil that consists of a different recipe, dimension, and elasticity. Environmental issues and age degrade the quality of the steel coil, some of which degrade to the point that, within 90 days, they may not be usable.[179] Different types of steel coil cannot be substituted without extensive analysis and new crash tests, which have very long process times. Something seemingly as simple as painting the steel body requires testing because different types of paints adhere to the different types of steel differently. In fact, automotive manufacturers do not select paints because the paints adhere to the steel; rather, they select steel because the steel adheres to the paint.

CHANGING AUTOMOBILE PRODUCTION FROM STEEL TO ALUMINUM

It would be not be feasible for the automotive manufacturers to switch from steel to aluminum under the closure scenario. As an illustration, Ford Motor Company started production of a new F-150 truck with an aluminum body replacing the traditional steel body.[180] While the body is made with aluminum, the frame and other parts are still made with steel. In addition, the retooling of the Dearborn truck factory cost over $840 million and shut down production for over 2 months, even with extensive advance planning. Because of higher production costs, the sticker price of the aluminum F-150 is about $3000 per vehicle higher than the truck with the traditional steel body.[181] The production of an aluminum body is more complicated than that of the traditional steel production; "many steps are jammed into the same amount of time it takes to make a steel body assembly."[182] As one industry executive put it, aluminum stamping and welding is more akin to aviation production than automobile production.

In any case, there is an insufficient amount of aluminum production capacity to meet additional automotive needs.[183] Domestically, five companies operate 10 aluminum smelters with annual production capacity of approximately 2.7 million tons, compared to the estimated 30.0 million tons of steel used annually in automotive production. Worldwide capacity of aluminum is approximately 61.9 million tons with about 16.0 million tons of idle capacity.

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[179] Steel is coiled to make it easier to transport, with each coil averaging about 30 - 40 tons (see Figure 4). Stamping plants will take the coil, unroll them, and then cut and form the particular automotive parts.
[180] Automotive News, "Inside Ford's Retooled F-150 Plant," November 16, 2014, at www.autonews.com/article/20141116/OEM01/311179981/inside-fords-retooled-f-150-plant, accessed January 9, 2015.
[181] Tech Times, "Ford Retooling Plant for Aluminum F-150, Assembly Line Shuttering for Two Months," August 26, 2014, at www.techtimes.com/articles/14089/20140826/ford-retools-production-plant-build-new-f150.htm, accessed January 9, 2015.
[182] Automotive News, "How will Ford Build the Aluminum F-150?" April 28, 2014 at www.autonews.com/article/20140428/OEM01/304289997/how-will-ford-build-the-aluminum-f-150, accessed January 9, 2015.
[183] An independent economist reported that all available aluminum capacity was purchased to make the Ford F-150.

POTENTIAL MITIGATION STRATEGIES

A combination of strategies will likely be required to mitigate the disruptions caused by an unexpected closure of the Poe Lock. While OCIA does not have a specific set of recommendations, the following are suggestions for further analysis.

TWINNING AND UPGRADING THE POE LOCK

The creation of a second Poe-sized lock—"twinning the Poe Lock"—would mitigate most failure scenarios.[184] USACE has developed a plan, awaiting Congressional funding, to construct a second Poe-sized lock by combining the shuttered Sabin and Davis Locks. According to USACE, the current working estimate for construction of the entire project is $580 million, last updated in 2009, and will take 10 years to complete.[185,186] This project would mitigate the impact of situations in which only the Poe Lock is disrupted. The second Poe-sized lock must be built to the same specifications as the existing Poe Lock; building a lock with larger dimensions would lead shippers to build larger Lakers, causing the same single point of failure situation that exists currently. This is a cycle that has repeatedly occurred in the past; each time a new, larger lock was built, the dimensions of new ships were stretched to make the most of the new dimensions.[187]

USACE estimates of the remaining cost of upgrading at around $87 million, according to its asset renewal plan for the Soo Locks.[188] This plan shows that some of the infrastructure to be updated either has failed or is in the process of failing. Examples include the electrical system for the MacArthur Lock, which was built in 1943; leaking valve bulkheads on the MacArthur Lock; the Poe Lock hydraulic system; gate anchorages, a new set of gates for the Poe Lock, and miter and quoin block rehabilitation for the Poe Lock. Other significant infrastructure is listed as inadequate or poor. A full upgrade of the Poe Lock could require its complete shutdown for 6 to12 months, which could only be done if there were a twin lock.

A STRATEGY TO IMPROVE RESILIENCE

To ensure resilience, feasible strategies must be developed that do not rely on passage through the Soo Locks, even with a second Poe-sized lock. With only 400 feet between the Poe Lock and the to-be-constructed lock, many failures or event scenarios could affect both locks, disrupting the supply chain.

There is no single strategy to bypass the Soo Locks. OCIA-NISAC analysts suggest a series of considerations for further study. A set of strategies agreed-to ahead of a disruption event, with proper authorities and buy-in from all parties, is necessary to maintain a sufficient supply of iron ore to the integrated steel mills.

SUGGESTIONS TO MITIGATE AN IRON ORE SHORTFALL

About 49.6 million tons of iron ore move through the Great Lakes over the course of the navigation year, from March 25 through January 15 for the Soo Locks, and year-round for the Port of Escanaba. This represents the average amount of iron ore shipped over the past four years. Based on conversations with industry executives and OCIA-NISAC analysis, the following is a suggested path to meeting this goal of 49.6 million tons shipped:

- Once the Poe Lock re-opens on September 25, approximately 16.1 million tons could be shipped during the remainder of the navigation season.

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[184] Lake Carriers Association, Second Poe-Sized Lock," on April 17, 2013 at http://www.lcaships.com/2013/04/17/second-poe-sized-lock/, accessed March 28, 2015.
[185] USACE, "Great Lakes Navigation System: Economic Strength to the Nation," at http://www.lre.usace.army.mil/Portals/69/docs/Navigation/GLN_Strength%20to%20the%20Nation%20Booklet2013v2_final2w.pdf, accessed January 1, 2015.
[186] One of the concerns about the 10-year time horizon for constructing a new lock regards a prior discussion of steel. There, the analysis points out that BOF steel and EAF steel are not interchangeable because BOF steel has the property of formability. The metallurgy can be controlled to a far greater degree when one starts with iron ore and not scrap steel. However, EAF steel continues to improve and could get to a point where mini-mills could provide the necessary steel to automotive companies, particularly in a crisis.
[187] Thompson, Mark L. "Steamboats & Sailors of the Great Lakes," Wayne State University Press: Detroit, 1991.
[188] USACE, "Soo Locks Asset Renewal Plan," on February 2012.

- While the Port of Escanaba is the smallest of the iron ore docks, there is room to expand operations there significantly. A number of industry executives stated that the Port of Escanaba could be renovated and enlarged to handle 15.0 million tons of iron ore. These 15 million tons would far exceed both the current shipments through Escanaba and the anticipated surge level of about 5.5 million tons. In addition to the port renovation, significant upgrades to the rail system in the area would be necessary.[189] There is historical precedent to consider the Port of Escanaba as part of a mitigation strategy. The Soo Locks was recognized as a single point of failure during WWII. In December 1940, President Roosevelt ordered an engineering study to consider an 'overland ship railway' that would allow fully loaded iron ore carriers to be hoisted out of the water, placed on trains, and sent, by rail, around Saint Marys River.[190,191] While that plan was not technically feasible, a new plan emerged in August 1942. Under this plan, Escanaba, being the only port downstream of the Soo Locks, would be expanded to 60 million tons.[192] This was seen then as merely an emergency backup for the Soo Locks. After the initial phases of construction, lumber shortages and a re-assessment of the German threat led to the termination of the project. The docks that had been constructed were razed and the material used for other purposes.
- There are six steel mills that are in Table 4 as a Non-Operating Steel Mill that either have some rail access or could, with relatively minor modifications, receive some iron ore by rail. Excluding Middletown (AK Steel) that is anticipated to operate at 82 percent, the other five are: Ashland (AK Steel), Cleveland (ArcelorMittal), Gary Works (U.S. Steel), Great Lakes Works (U.S. Steel), and Mon Valley Works (US Steel). Ashland (AK Steel) and Mon Valley Works (U.S. Steel) currently receive steel by rail, after it has been trans-shipped at a Lake Erie dock.[193] Gary Works (US Steel) and Great Lakes Works (U.S. Steel) have very limited capability to receive iron ore by rail, and probably have not done so in years to decades.[194] Given the rail constraints discussed previously, rail, en masse, is not a likely course of action. However, a smaller use of rail may be feasible. If two unit trains a week made deliveries to two of the six previously mentioned steel mills, over the course of the year, approximately 1.0 million tons of iron ore could be delivered. In order to undertake this, four unit trains would probably be necessary as well as some degree of upgrading to the rail infrastructure at the steel mills. Plans to mitigate rail congestion between Minnesota and Indiana, and in particular, the Chicago area, would be necessary.
- Many of the integrated steel mills along the Great Lakes have space to store significant amounts of iron ore. However, companies are unlikely to tie up significant working capital in preventive inventory for an event that has not occurred. Still, the U.S. Government should explore avenues that may make the storing of a preventive inventory palatable. A strategic iron ore stockpile that could provide a six-month supply of iron ore may be warranted. Even if a closure were to extend beyond 6 months, the 6-month supply would provide time to develop alternatives.[195] To meet the 49.6 million ton requirement, 16.5 million tons of storage would be necessary after taking into consideration other mitigation strategies.[196] Initial OCIA-NISAC analysis, and discussions with industry executives, suggest that this is logistically feasible. The iron ore pellets generally are not subject to environmental degradation. One industry executive reported that when iron ore supplies ran short in April 2014, they used a pile of iron ore pellets that had been sitting in a rejected pile since 2000. Another executive stated that iron ore pellets have been dredged from lake bottoms after being submerged for 20 years and used.
- The three Northern Indiana plants—Burns Harbor (ArcelorMittal), Gary Works (U.S. Steel), and Indiana Harbor (ArcelorMittal)—each have a functioning sinter plant. This means that they could receive

[189] There may be locations along the Lake Superior side of the Soo Locks where iron ore could be dumped and then railed to Escanaba. This alternative would permit Lakers to carry iron ore to the dumping site and then it may be a shorter route to Escanaba There is no specific site considered. Any options may require the purchasing or condemnation of existing property and the completion of environmental impact statements.
[190] Escanaba Daily Press, "History of Escanaba and Lake Superior Railroad," on December 27, 1950 at http://www.michiganrailroads.com/RRHX/Stories/E&LSHistory.htm, accessed April 26, 2015.
[191] Joachim, George J., "Iron Fleet: The Great Lakes in World War II," Wayne State University Press: Detroit, 1994.
[192] Ibid.
[193] Cleveland (ArcelorMittal) receives its iron ore at the Cleveland Bulk Terminal (CBT). While CBT does not have current capacity to receive iron ore by rail, industry executives believe that, logistically, it could be done.
[194] OCIA-NISAC has no information on the rail accessibility of Dearborn (AK Steel).
[195] Storage facilities would need to maintain various mixes of different types of iron ore. Depending on economic conditions, the iron ore may be secured from either domestic or foreign sources.
[196] OCIA-NISAC would suggest some additional amount of iron ore by stockpiled in order to control for some possible degrading of iron ore, and to keep a broader mix of pellet types.

seaborne iron ore. Industry executives suggest that 5 percent of the iron ore needs could be met with sinter. This could provide about a 1-million-ton cushion.

OTHER CONSIDERATIONS

OCIA-NISAC is uncertain as to whether all relevant stakeholders have been engaged regarding the legal and logistical challenges facing a successful lightering process. Lightering would reduce disruptions to the automotive, appliance, farm equipment, and construction and mining machinery industries, but the contractual challenges must be considered.

A designated place or places must be predetermined to receive limestone, which would only be required if MacArthur Lock was also closed. Some possibilities include Green Bay, Wisconsin, Manitowoc, Wisconsin, or Cleveland, Wisconsin. The limestone would then be railed to the pelletizing plant. A significant percentage of the iron ore pellets production depends on the availability of limestone.

CONCLUSIONS

In terms of an impact to the North American economy, it is hard to conceive of a single asset more consequential than the Poe Lock. As outlined in the report, 10.9 million jobs in the United States, and possibly upwards of 13 million jobs in North America, are likely dependent on the functioning of the Poe Lock. An unprecedented supply shock could affect North America if the closure scenario were to occur. The United States has historical knowledge of how to respond to shocks caused by financial crises, oil prices or availability, or falling aggregate demand. There is no similar guide for responding to a supply shock that incapacitates a large set of industries.

As documented in this report, the iron mining - integrated steel production - manufacturing, particularly automobile manufacturing, supply chain, is not only consequential, but potentially one of the least resilient supply chain in North America. The relationship between the steel mills and the auto assembly plants is complex. There is a different steel coil for just about every part of an automobile made with steel, and collectively, there are reportedly some 1500 different recipes of steel for the automotive industry. Without the steady stream of iron ore coming from Lake Superior through the Poe Lock, many or all of these 1500 different steel recipes cannot be made. The inability to make just one recipe could stop production of a particular automobile; the inability to make a couple of recipes could stop production for a particular automotive company; and the inability to make a few recipes could stop production of all North American automotive production. Historically, the lack of a single part has caused automobile production to shut down.

The current lack of resilience does not mean that measures cannot be taken to mitigate a potential closure scenario. Engagement and planning among the relevant stakeholders may allow for the iron mining - integrated steel production - manufacturing supply chain to remain viable even in the face of a prolonged closure of the Poe Lock. The actions taken and considered during World War II suggest a course of action. This report documented three steps that were taken: a new lock, the MacArthur Lock, was constructed; the building out of the rail infrastructure to the Port of Escanaba coupled with the expanding of the port was considered; and a large contingent of troops were garrisoned. While the latter action was in response to the perceived overt threat, the two prior actions could do much to improve resilience. In addition to the other actions suggested in the Potential Mitigation Strategies section, resilience could be built into the system.

However, the critical aspect must be the focus on a plan to deal with a potential Poe Lock failure. As one industry expert put it, "the game plan needs to be in the book, because everyone will be scrambling."

APPENDIX A: IRON ORE MINES

TABLE 7—IRON ORE MINES

Name	Location	Owner	Capacity (M tons)[197,198]
Bovey	Bovey, MN	Magnetation 100 percent[199]	1.2
Keewatin	Keewatin, MN	Magnetation 100 percent	0.4
Keetac	Keewatin, MN	U.S. Steel 100 percent	6.0
Hibbing Taconite	Hibbing, MN	ArcelorMittal 62 percent Cliffs Natural Resources 23 percent U.S. Steel 15 percent	9.0
Minntac	Mt. Iron, MN	U.S. Steel 100 percent	16.0
United Taconite	Eveleth, MN	Cliffs Natural Resources 100 percent	5.9
Minorca Mine	Virginia, MN	ArcelorMittal 100 percent	3.1
Northshore Mining	Babbitt, MN	Cliffs Natural Resources 100 percent	6.9
Empire Mine	Negaunee, MI	Cliffs Natural Resources 79 percent ArcelorMittal 21 percent	6.2
Tilden Mine	Tilden, MI	Cliffs Natural Resources 85 percent U.S. Steel 15 percent	9.0
Minnesota Taconite Operation[200]	Hibbing, MN	Essar Steel 100 percent	Under development (7.7 when complete)

[197] Iron mines report capacity and production in long tons or metric tons while freighters and steel mills report in short tons. Therefore, to make comparisons more direct, iron ore capacities were converted into short tons.
[198] A number of mines do not operate at their rated capacity as discussed in the section entitled, "Iron Ore Mining Assumptions."
[199] Magnetation LLC owns 100% of the Bovey and Keewatin operations. A.K. Steel is a 49.9 percent owner of Magnetation LLC.
[200] Essar Steel's mine is expected to be operational in 2016 and will likely supply both the Algoma Steel Mill (Essar Steel) and replace the Empire Mine's shipment of iron ore to Indiana Harbor (ArcelorMittal). As the Empire Mine will close in 2016-2017, Indiana Harbor's purchase of iron ore from Essar Steel will increase the dependency on the Soo Locks as the Empire Mine shipped out of Escanaba. (see Essar, "Essar Steel Minnesota LLC Signs a Landmark Iron Ore Pellet off Take Agreement with ArcelorMittal USA) on February 11, 2013 at http://www.essar.com/article.aspx?cont_id=LOiyw6+Hl40=, accessed April 11, 2015. However, industry executives have said that Essar has not secured any means to ship the iron ore out of Minnesota. All available space at the Lake Superior iron ore docks are fully committed. This project has faced numerous delays and there is some skepticism whether the mine will open.

APPENDIX B: NORTH AMERICAN INTEGRATED STEEL MILLS

TABLE 8—STEEL MILLS

Name	Location	Owner	Steel Products	Capacity (M tons)
Algoma	Sault Ste. Marie, ON	Essar Steel	Automotive, construction, energy, manufacturing, mining, shipbuilding,	2.8
Ashland	Ashland, KY	A.K. Steel	Automotive, electrical steel, stainless steel, service centers	2.6
Burns Harbor	Burns Harbor, IN	ArcelorMittal	Appliances, automotive, construction, office furniture and rail cars	5.0
Cleveland	Cleveland, OH	ArcelorMittal	Automotive, service centers, converters, plate slabs and tubular applications	3.8
Dearborn	Dearborn, MI	A.K. Steel	Automotive	2.5
Dofasco	Hamilton, ON	ArcelorMittal	Automotive, appliances, construction, container, tubular	4.5
Fairfield Works	Birmingham, AL	U.S. Steel	Construction, tubular, metal building, automotive, appliance	2.4
Gary Works	Gary, IN	U.S. Steel	Automobile, appliance, container, metal building, home construction	7.5
Granite City Works	Granite City, IL	U.S. Steel	Tubular, construction, container, automotive	2.8
Great Lakes Works	Ecorse, MI	U.S. Steel	Automotive, container	3.8
Indiana Harbor	East Chicago, IN	ArcelorMittal	Automotive, appliance, office furniture, agricultural, construction, pipe and tube, electrical/motor lamination, converters and steel service centers	9.5
Lake Erie Works	Nanticoke, ON	U.S. Steel	automotive, construction, infrastructure, appliance, manufacturing and pipe and tube industries	3.7
Middletown	Middletown, OH	A.K. Steel	Automotive, electrical steel, stainless steel, service centers	2.9
Mon Valley Works	Braddock, PA	U.S. Steel	Appliance, construction	2.9

APPENDIX C: THE GREAT LAKES FLEET

The U.S. Great Lakes bulk carrier shipping fleet consists of 48 Lakers. Slightly over one-half of the fleet is Poe-restricted, meaning that it can only transit the Soo Locks through the Poe Lock. Twenty Lakers can use either the Poe or the MacArthur Lock. However, the Poe-restricted Lakers are significantly larger, with an average capacity of over 51,000 net tons compared to less than 25,000 net tons for the smaller Lakers. Approximately three-quarters of the carrying capacity is on Poe-restricted Lakers.

The Poe-restricted and the MacArthur-sized Lakers have significantly different functions. Poe-restricted Lakers, particularly the 13 one-thousand footers that make up 46 percent of the total Great Lakes Laker carrying capacity and 62 percent of the Poe-restricted carrying capacity, are almost exclusively used for long haul trips from Lake Superior to the three Northern Indiana integrated steel mills, Detroit, and most of the Ohio iron ore docks. The commodities are almost exclusively one-way deliveries of iron ore or coal with no pick up of commodities to transit upstream through the Poe Lock. The MacArthur-sized Lakers generally work shorter trips carrying a variety of commodities to various ports. These trips may include carrying grain downstream for foreign export or iron ore to steel mills that cannot accept the larger Lakers (i.e., AK Steel Dearborn, ArcelorMittal Cleveland). However, unlike the Poe-restricted Lakers, the MacArthur-sized Lakers may carry products, particularly limestone, upstream through the Soo Locks.

Industry executives assert that many, if not most, Lakers are under long-term charter at the beginning of the shipping season.

USACE designates a 'Class' rank based on the length of the vessels (Table 9).

TABLE 9—USAC CLASS RANK FOR GREAT LAKES VESSELS[201]

Class	Length
I	400 feet or less
II	400 – 499 feet
III	500 – 549 feet
IV	550 – 599 feet
V	600 – 649 feet
VI	650 – 699 feet
VII	700 – 730 feet
VIII	731 – 849 feet
IX	850 – 949 feet
X	950 – 1099 feet

Table 10 provides a brief description the Great Lakes "Laker" Fleet.

[201] Greenwood's Guide to Great Lakes Shipping, 2015, Harbor House Publishers: Boyce, Michigan.

TABLE 10—THE U.S. GREAT LAKES 'LAKER' FLEET[202]

Class	Vessel Name	Owner	Built	Length (Feet)	Beam (Feet)	Mid-Summer Draft (Feet)	Mid-Summer Capacity (Tons)	Estimated Practical Capacity (Tons)	Likely Cargo	McArthur – sized
Class VI	Adam E. Cornelius	American Steamship	1973	680	78	28.58	29,200	29,108	iron ore , coal, stone, limestone, grain	No
Class X	American Century	American Steamship	1981	1,000	105	34.08	80,900	64,223	Coal, stone, iron ore, Loads coal at Midwest Energy Resources	No
Class V	American Courage	American Steamship	1979	636	68	28.00	24,300	24,300	iron ore, coal, limestone, sand, grain	Yes
Class X	American Integrity	American Steamship	1978	1,000	105	34.08	80,900	64,223	Coal, iron, stone. Two Harbors to Zug Island, Midwestern Energy Resources	No
Class VII	American Mariner	American Steamship	1980	730	78	30.92	37,300	34,099	iron ore , coal, limestone, grain	No
Class X	American Spirit	American Steamship	1978	1,004	105	28.92	62,400	61,131	iron ore, coal, stone	No
Class VIII	American Valor	American Steamship	1974	767	70	27.00	26,200	26,200	iron ore , coal, limestone, grain	Yes
Class VII	American Victory	American Steamship	1942	730	75	39.25	26,700	12,481	iron ore , coal, stone, limestone, grain	Yes
Class VIII	Arthur M. Anderson	Great Lakes Fleet	1952	767	70	27.00	25,300	25,300	iron ore, coal, limestone, salt, stone	Yes
Class V	Buffalo	American Steamship	1978	635	68	27.33	24,300	24,300	Iron ore, coal, limestone, gypsum	Yes

[202] The information herein comes primarily from the following sources: Lake Carriers Association (http://www.lcaships.com/members/), the web pages of the vessel owners, and Boat Nerd (http://www.boatnerd.com/).

Class	Vessel Name	Owner	Built	Length (Feet)	Beam (Feet)	Mid-Summer Draft (Feet)	Mid-Summer Capacity (Tons)	Estimated Practical Capacity (Tons)	Likely Cargo	McArthur – sized
Class X	Burns Harbor	American Steamship	1980	1,000	105	34.08	80,900	64,223	Almost exclusively Superior to Indiana Harbor or Burns Harbor	No
Class V	Calumet	Grand River Navigation	1929	630	68	26.00	19,650	19,650	limestone, stone, aggregates, coal, sand, and salt	Yes
Class VIII	Cason J. Callaway	Great Lakes Fleet	1952	767	70	27.00	25,300	25,300	iron ore, coal, limestone, salt, stone	Yes
Class VII	Defiance / Ashtabula	Grand River Navigation	1982	702	78		30,700	30,700	iron ore, stone, sand	No
Class VI	Dorothy Ann / Pathfinder	Interlake Steamship Co.	1953	699	70	26.25	26,700	26,700	mainly grain, some iron ore, stone	Yes
Class X	Edgar B. Speer	Great Lakes Fleet	1980	1,004	105	32.08	73,700	62,879	iron ore only and only to Gary, IN and Conneaut, OH	No
Class VII	Edward L. Ryerson (not self-unloading)	Central Marine Logistics	1959	730	75	28.33	27,500	27,500	iron ore for Dofasco as it is not self-unloading; Superior to Hamilton	Yes
Class X	Edwin H. Gott	Great Lakes Fleet	1978	1,004	105	32.08	74,100	63,279	iron ore only and only to Gary, IN and Conneaut, OH	No
Class V	Great Republic	Great Lakes Fleet	1981	635	68	28.33	25,600	25,600	iron ore, stone, coal, it was built to go on the Cuyahoga River	Yes
Class VII	H. Lee White	American Steamship	1974	704	78	30.63	35,400	32,787	iron ore , coal, limestone, grain	No
Class VI	Herbert C. Jackson	Interlake Steamship Co.	1959	690	75	27.71	24,800	24,800	Grain, coal, iron ore, stone	Yes

Class	Vessel Name	Owner	Built	Length (Feet)	Beam (Feet)	Mid-Summer Draft (Feet)	Mid-Summer Capacity (Tons)	Estimated Practical Capacity (Tons)	Likely Cargo	McArthur – sized
Class VIII	Hon. James L Oberstar	Interlake Steamship Co.	1959	806	75	28.50	31,000	31,000	iron ore, stone, coal	No
Class X	Indiana Harbor	American Steamship	1979	1,000	105	34.08	80,900	64,223	Iron ore, stone, coal	No
Class X	James R. Barker	Interlake Steamship Co.	1976	1,004	105	29.08	63,300	61,547	iron ore, coal	No
Class VIII	John G. Munson	Great Lakes Fleet	1952	768	72	27.33	25,550	25,550	iron ore, coal, limestone, salt, stone	No
Class VI	John J. Boland	American Steamship	1973	680	78	30.58	34,000	31,611	iron ore , coal, stone, limestone, grain	No
Class VIII	John Sherwin	Interlake Steamship Co.	1957	806	75		35,280	35,280	it is not self-unloading; grain storage only	No
Class VII	Joseph L. Block	Central Marine Logistics	1976	728	78	30.92	37,200	34,018	iron ore, stone, coal	No
Class VII	Joseph Thompson Jr. / Joseph Thompson	VanEnkevort Tug & Barge	1944	707	72	27.33	21,200	21,200	stone, aggregates, limestone and coal	Yes
Class VIII	Joyce Vanenkevort / Great Lakes Trader	VanEnkevort Tug & Barge	2000	845	78	30.83	39,600	35,214	iron ore, stone	No
Class VIII	Kaye E. Barker	Interlake Steamship Co.	1952	767	70	27.00	25,900	25,900	iron ore, coal, stone	Yes
Class VIII	Ken Boothe St / Lakes Contender	American Steamship	2012	740	78	30.00	38,500	36,456	iron ore , coal, limestone, grain	No
Class VIII	Lee A. Tregurtha	Interlake Steamship Co.	1942	826	75	28.08	29,300	29,300	iron ore, coal, stone	No
Class V	Manistee	Grand River Navigation	1943	621	60	24.50	14,900	14,900	stone, sand, salt, limestone and coal	Yes
Class V	Manitowoc	Grand River Navigation	1973	630	68	26.00	19,650	19,650	iron ore, stone and coal	Yes

Class	Vessel Name	Owner	Built	Length (Feet)	Beam (Feet)	Mid-Summer Draft (Feet)	Mid-Summer Capacity (Tons)	Estimated Practical Capacity (Tons)	Likely Cargo	McArthur – sized
Class X	Mesabi Miner	Interlake Steamship Co.	1977	1,004	105	29.08	63,300	61,547	iron ore, coal	No
Class VII	Olive L. Moore / Lewis J. Kuber	Grand River Navigation	1952	728	70	26.92	22,300	22,300	stone, aggregates, limestone and coal	Yes
Class X	Paul R. Tregurtha	Interlake Steamship Co.	1981	1,014	105	30.08	68,000	63,089	iron ore, coal	No
Class VIII	Philip R. Clarke	Great Lakes Fleet	1951	767	70	27.00	25,300	25,300	Iron ore, salt, stone, coal	Yes
Class X	Presque Isle	Great Lakes Fleet	1972	1,000	105	28.58	57,500	57,261	iron ore, coal, stone	No
Class IX	Roger Blough	Great Lakes Fleet	1968	858	105	27.92	43,900	43,900	iron ore, limestone, stone	No
Class V	Sam Laud	American Steamship	1975	635	68	28.00	24,300	24,300	Iron ore, coal, limestone, stone	Yes
Class VIII	St. Clair	American Steamship	1975	770	92	30.08	44,800	42,442	iron ore, coal, limestone, grain, stone	No
Class X	Stewart J. Cort	Interlake Steamship Co.	1972	1,000	105	27.92	58,000	58,000	iron ore mainly Superior to Burns Harbor due to boat configuration	No
Class II	Undaunted / Pere Marquette 41	Pere Marquette Shipping	1940	494	58	19.50	5,750	5,750	mainly stone, other various	Yes
Class VIII	Victory / James L. Kuber	Grand River Navigation	1953	807	70	27.00	25,500	25,500	iron ore, stone, aggregates, limestone and coal	No
Class X	Walter J. McCarthy Jr.	American Steamship	1977	1,000	105	34.08	80,900	64,223	iron ore , coal, limestone, grain	No
Class VI	Wilfred Sykes	Central Marine Logistics	1949	678	70	27.67	21,500	21,500	iron ore, limestone, coal, stone	Yes

APPENDIX D: SELECTED PRODUCTS MADE OUT OF STEEL

The following products are likely made, in part or in whole, with steel produced at one or more of the integrated steel mills discussed in this report.[203]

Agricultural Equipment
Air Conditioners
Air Ducts
Automotive [Trailers & Vehicles]
Automotive Parts
Bicycles – Bikes
Cans – Lids – Crown Corks
Chains
Chimneys – Chimney Caps
Chutes
Cladding – Roofing
Cranes
Cutlery
Doors – Gates – Windows
Electric Cables + Accessories
Electric Equipment
Elevators
Fencing
Fire Fighting Equipment
Furnaces – Incinerators
Furniture
Grilles
Hardware – Tools
Household Appliances
Kitchen Sinks
Kitchens
Kitchenware
Motors – Engines
Ovens – Burners – Stoves
Pumps
Radiators For Heating
Railway & Train
Ropes – Stranded Wire – Cables
Safes
Transformers
Trolleys – Handcarts
Tires – Steel Reinforced
Valves – Fittings
Water Coolers
Water Heaters

[203] Mesteel, "Fabricated Steel, and Products Made Out of Steel," at http://www.mesteel.com/cgi-bin/w3-msql/goto.htm?url=http://www.mesteel.com/products/fabricatedsteelproducts.htm, accessed March 24, 2015.

APPENDIX E: IMPACTED NAICS CODES

TABLE 11—NAICS CODES IMPACTED BY SCENARIO

NAICS Code	Industry	Anticipated Production Levels
212210	Iron ore mining	See Table 3
327215	Glass product manufacturing made of purchased glass	20.0%
331110	Iron and steel mills and ferroalloy manufacturing[204]	See Table 4
331221	Rolled steel shape manufacturing	See Table 4
331513	Steel foundries	See Table 4
332111	Iron and steel forging	See Table 4
332322	Sheet metal work manufacturing	50.0%
332510	Hardware manufacturing	0.0%
332613	Spring manufacturing	0.0%
332618	Other fabricated wire product manufacturing	0.0%
333111	Farm machinery and equipment manufacturing	0.0%
333120	Construction machinery manufacturing	0.0%
333131	Mining machinery and equipment manufacturing	0.0%
333132	Oil and gas field equipment machinery and equipment manufacturing	0.0%
333414	Heating equipment	50.0%
333415	Air conditioning and warm air heating equipment and commercial	50.0%
333924	Industrial truck, tractor, trailer, and stacker machinery manufacturing	0.0%
334290	Other communications equipment manufacturing	33.3%
334416	Capacitor, resistor, coil, transformer, and other inductor manufacturing	80.0%
334512	Automatic environmental control manufacturing for residential, commercial	50.0%
335210	Small electrical appliance manufacturing	0.0%
335221	Household cooking appliance manufacturing	0.0%
335222	Household refrigerator and home freezer manufacturing	0.0%
335224	Household laundry equipment manufacturing	0.0%
335228	Other major appliance manufacturing	0.0%
336111	Automobile manufacturing	0.0%
336112	Light truck and utility vehicle manufacturing	0.0%
336120	Heavy duty truck manufacturing	0.0%
336211	Motor vehicle body manufacturing	0.0%
336212	Truck trailer manufacturing	0.0%
336212	Truck Trailer Manufacturing	0.0%
336214	Travel Trailer and Camper Manufacturer	0.0%
336310	Motor vehicle gasoline engine and engine parts manufacturing	0.0%
336320	Motor vehicle electrical and electronic equipment manufacturing	10.0%
336330	Motor vehicle steering and suspension components	10.0%
336340	Motor vehicle brake system manufacturing	10.0%
336350	Motor vehicle transmission and power train parts manufacturing	0.0%
336360	Motor vehicle seating and interior trim manufacturing	0.0%
336370	Motor vehicle metal stamping	0.0%
336390	Other motor vehicle parts manufacturing	50.0%
336510	Railroad rolling stock manufacturing	50.0%
336999	All other transportation equipment manufacturing	0.0%
337124	Metal household furniture manufacturing	0.0%

[204] Integrated steel mills only.

NAICS Code	Industry	Anticipated Production Levels
423110	Automobile and other motor vehicle merchant wholesalers	10.0%
423120	Motor vehicle supplies and new parts merchant wholesalers	25.0%
423620	Household appliances, electric housewares, and consumer electronics wholesale	50.0%
423810	Construction and mining machinery and equipment merchant wholesalers	50.0%
423820	Farm and garden machinery and equipment merchant wholesalers	25.0%
423830	Industrial machinery and equipment merchant wholesalers	10.0%
441110	New car dealers	10.0%
441120	Used car dealers	120.0%
441310	Automotive parts and accessories stores	50.0%
483113	Coastal and Great Lakes Freight Transportation	TBD
488320	Marine cargo handling	TBD

APPENDIX F: LIGHTERING CALCULATIONS

Based on the redacted assumptions, OCIA-NISAC estimates that a Laker can make a round trip from Two Harbors, Minnesota to Gary, Indiana and return in about 5.48 days. Over the course of 26 days, the Laker could load at Two Harbors, Minnesota and unloaded at Gary, Indiana 5 times. Therefore, the 13 1000 footers could, collectively, unload 65 times at Gary, Indiana.

Over the course of 26 days, OCIA-NISAC estimates that a Laker could go from Sault Ste. Marie, MI to Gary, IN and unload 7 times. The reason for more unloadings is the that travel time through the Soo Locks and to and from Two Harbors, MN to Sault Ste. Marie, MI is longer than the time it would take to lighter a Laker. However, the constraint is that only 4 One Thousand Footers would be able to make these trips. Therefore, the 4 One Thousand Footers could, collectively, unload 28 times at Gary, IN.

The number of unloadings under normal conditions is estimated to be 65. The number of lightering unloadings is estimated to be 28, which is about 43 percent of the normal unloadings. The weather constraints outlined in the assumptions means that lightering could only take place about two-thirds of the time. Therefore, the amount of iron ore that could be lightered is 29 percent (43 percent multiplied by 66 percent).[205]

[205] The actual equation is, .431*.663 that does equals .29.

Time in hours between major ports	TWO HARBORS	TORONTO	TOLEDO	THUNDER BAY	SOO LOCKS	SILVER BAY	QUEBEC CITY	PORT WELLER	PORT HURON	PORT COLBORNE	MONTREAL	MILWAUKEE	MARQUETTE	MAC BRIDGE	LORAIN	KEEWEENAW	HOLLAND	GREEN BAY	GRAND HAVEN	ESCANABA	DULUTH	DETROIT	CONNEAUT	CLEVELAND	CHICAGO-GARY	BUFFALO
ASHTABULA	59	17	8	51	34	55	58	15	16	7	45	49	45	33	5	55	52	42	50	43	59	10	1	4	57	7
BUFFALO	66	11	15	58	41	62	53	10	23	2	40	56	52	40	13	62	58	49	57	50	66	17	3	5	64	
CHICAGO/GARY	54	74	53	46	29	50	110	72	41	64	97	7	40	24	54	46	7	18 12		19	54	47	58	55		
CLEVELAND	56	19	6	49	32	53	60	17	14	9	47	47	43	31	1	53	49	40	48	41	57	8				
CONNEAUT	60	16	9	52	35	56	57	14	17	6	44	50	46	34	6	56	52	43	51	44	60	11				
DETROIT	49	27	6	41	24	45	63	25	6	17	50	39	35	23	7	47	41	32	40	33	55					
DULUTH	2	77	56	13	25	4	118	73	44	65	105	48	36	32	56	10	50	41	49	42						
ESCANABA	40	58	39	32	15	36	96	58	27	50	83	13	26	10	40	32	8									
GRAND HAVEN	50	68	46	42	25	46	103	65	34	57	90	6	36	17	47	39	2									
GREEN BAY	43	59	38	35	18	39	95	57	26	49	82	12	29	9	39	31	13									
HOLLAND	50	68	47	42	25	46	104	66	35	58	91		36	18	48	40	2									
COPPER HBR.	10	67	46	7	15	10	110	54	34	46	97	38	9	22	52											
LORAIN	56	20	5	48	31	52	61	18	13	10	48	46	42	30												
MACKINAW BRIDGE	27	50	29	34	7	28	86	48	17	40	73	16	18													
MARQUETTE	16	63	42	11	11	16	98	60	30	52	85	34														
MILWAUKEE	48	66	45	40	23	44	102	64	33	56	89															
MONTREAL	96	20	53	88	71	92	13	30	66	38																
PORT COLBORNE	66	10	15	58	41	62	53	8	23																	
PORT HURON	44	33	12	36	19	40	69	31																		
PORT WELLER	74	2	23	66	49	70	45																			
QUEBEC CITY	109	43	68	101	84	105																				
SILVER BAY		73	52	10	21																					
SOO LOCKS	25	52	31	17																						
THUNDER BAY		69	47																							
TOLEDO	55	25																								
TORONTO	76																									

Times on this page are an estimate based on:

- Welland Canal estimated at 8 hours.
- Soo Locks estimated at 30 minutes.
- Detroit, St. Clair and St. Marys Rivers estimated at restricted speed.
- Estimates are based on open lake speed of 15 mph.
- Modern vessels may average between 12 mph and 18+mph in open water.
- Estimates exclude Fuel Stops and Abnormal Locks Delays.

FIGURE 33—GREAT LAKES AND SAINT LAWRENCE SEAWAY TRAVEL TIMES[206]

[206] Boat Nerd, "Great Lakes and Saint Lawrence Seaway Travel Times" at http://boatnerd.com/facts-figures/travel_times-lakes.htm, accessed March 2, 2015.

APPENDIX G: ANALYSIS OF THE IMPACT OF A DISRUPTION IN COAL SHIPMENTS TO MICHIGAN ELECTRIC POWER GENERATION

BACKGROUND

Two types of coal are transported on the Great Lakes. The significantly smaller portion is metallurgical or coking coal, which is an essential ingredient in steel manufacturing. Most of the coal shipped on the Great Lakes is thermal coal, which is used for electric power generation, particularly in Michigan. The coal used in Michigan's coal-fueled power plants mixes western coal, which has low sulfur content, with eastern coal, which has a higher heat content.[207] The Western coal is railed from the Powder River Basin in Wyoming and Montana to DTE Energy's Midwest Energy Resource Co. docks at the Port of Duluth-Superior. The coal then moves, via a Lake Carrier, through the Soo Locks to Michigan. The Eastern coal is shipped by rail from West Virginia and the surrounding States to Michigan.

The question regarding the need for western coal results from a scenario whereby a sufficient supply of iron ore is transported, but there is no capacity to move coal by Lake Carrier. [208] Can a sufficient supply of coal be transported to Michigan via alternative routes, such as rail, or is the coal even necessary to support manufacturing production?

COAL-FIRED PLANTS IN MICHIGAN

TABLE 12—TOP COAL-FIRED POWER PLANTS IN MICHIGAN

Plant	Nameplate Capacity (MW)	Summer Capacity (MW)	2013 Summer Model Generation (MW)	2014 Electricity Generation (MWHr)
Monroe	3,280	2,930	3,090	14,572,303
J H Campbell	1,586	1,440	1,440	8,574,687
Belle River	1,395	1,284	1,233	7,564,057
St Clair	1,547	1,374	1,367	5,339,461
Trenton Channel	776	713	700	2,524,496
River Rouge	651	527	519	2,125,977
Dan E Karn	544	515	515	2,011,851
Presque Isle	450	344	344	1,887,006
B C Cobb	313	312	312	1,862,030
J R Whiting	345	325	323	1,813,193
J C Weadock	313	310	310	1,705,975
Eckert Station	375	299	180	547,163
TES Filer City Station	70	60	60	368,881

Coal is the base load fuel for Michigan's electric power generation, meaning that the coal-fired electric power generation provides electric power to meet the minimum level of electric power demand. Table 12 shows Michigan's largest coal-fired power plants. Most of the generation facilities are located in the southeastern part of

[207] Union of Concerned Scientists, "How Coal Works," www.ucsusa.org/clean_energy/coalvswind/brief_coal.html#.VP8whGO9F5o, accessed March 11, 2015.
[208] The analysis in Appendix F was conducted by Los Alamos National Laboratory in support of OCIA-NISAC.

Michigan where these facilities supply electric power in the area of significant automobile manufacturing.[209] The table includes the nameplate or rated capacity of the generator, the summer capacity, the estimate of generation in the 2013 summer-peak model, and the total 2014-generation for each plant.[210] The summer capacity is essentially equivalent to the 2013 summer model generation, which shows that these generation facilities are for base load generation, as they are in almost constant use.

Coal-fired plants account for nearly 40 percent of Michigan's summer generation capacity and 54 percent of Michigan's net annual electricity generation.[211,212] An unexpected closure of the Poe Lock could, similar to the disruption of the iron ore trade, disrupt the coal trade. In many cases, the same Lakers used to move iron ore also move coal so the transport of both would stop. However, if iron ore cannot be moved to the Great Lakes steel mills, then the coal likely is not a critical issue, as electric power demand from Michigan's manufacturing base would be severely diminished. The coal is used as a fuel source for the electric power generators that most directly support Michigan's manufacturing base. The reduction in electric power demand resulting from the Poe Lock closure scenario implies a reduced need for coal to maintain reliable electricity in Michigan.

The reduced demand for coal is borne out by an analysis of the 2009 recession. Table 13 shows a comparison of GDP change, from 2008 to 2009 and from 2009 to 2010, to electric power demand change. This loss of generation is roughly equivalent to the generation provided by Monroe, which is the largest generation facility (see Table 12). While the OCIA did not calculate an equivalent GDP impact for the Soo Locks scenario, the decrease in annual automobile sales is informative. From 2008 to 2009, the decline in automobile sales was 21.2 percent. Under the Poe Lock closure scenario, automotive sales would likely decline by about 75 percent. [213,214] The corresponding decrease in electric power demand may be roughly equivalent to the output of the next three largest generators- JH Campbell, Belle River, and St. Clair.

TABLE 13—CHANGE IN MICHIGAN GDP AND ELECTRIC POWER DEMAND FROM 2008-2010

Period	Michigan GDP Change[215]	Michigan Electric Power Demand Change[216]
2008-2009	-8.3%	-10.3%
2009-2010	+5.3%	+8.2%

ANALYSIS 1: MOVING COAL BY RAIL

Coal makes up about a quarter of the shipments going through the Soo Locks.[217] The majority of western coal is sent to the Ports of Duluth-Superior, where it is loaded on ships and sent through the Soo Locks (see Figure 34). A smaller portion is railed to Chicago, and then shipped up-bound to coal-fired generators in Michigan.

OCIA-NISAC used the OCIA-NISAC R-NAS model to model potential impacts to the rail industry. The rail routes displayed in Figure 34 only include segments with more than 24 cars per day.

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[209] Technically, electric power generated by an individual station or multiple stations does not directly supply industrial needs. Rather, the generation is added to the bulk power system and is directed by Balancing Authorities and local distribution companies to specific end-users. However, the loss of significant amounts of generation in an area of high demand lower the reliability levels and makes the area more susceptible to cascading failures.
[210] Capacities from U.S. Energy Information Administration (EIA)-860; total generation from EIA-923.
[211] Energy Information Administration, "EIA-860, Annual Electric Generator Report," www.eia.gov/electricity/data/eia860/, accessed March 11, 2015.
[212] Energy Information Administration, "Michigan State Profile and Energy Estimates," www.eia.gov/state/?sid=MI, accessed March 11, 2015.
[213] Federal Reserve Bank of St. Louis, "Light Weight Vehicle Sales: Autos & Light Trucks," at https://research.stlouisfed.org/fred2/series/ALTSALES/#, accessed March 27, 2015.
[214] Some automotive sales would occur in the first one-third of the month and there may be some foreign manufacturers who continue to produce cars.
[215] Federal Reserve Bank of St. Louis, "Real Total Gross Domestic Product by State for Michigan," at http://research.stlouisfed.org/fred2/series/MIRGSP#, accessed March 27, 2015.
[216] US Energy Information Administration, "Michigan Electricity Profile: 2012, Table 10" at http://www.eia.gov/electricity/state/michigan/, accessed March 27, 2015.
[217] Lake Carriers Association, "U.S. Flag Shipments of Dry-Bulk Cargos on the Great Lakes: Calendar Years 2008-2013 and 5-Year Average," at www.lcaships.com/wp-content/uploads/2014/07/60005_60005-LCA_p1-4.pdf, accessed March 15, 2015.

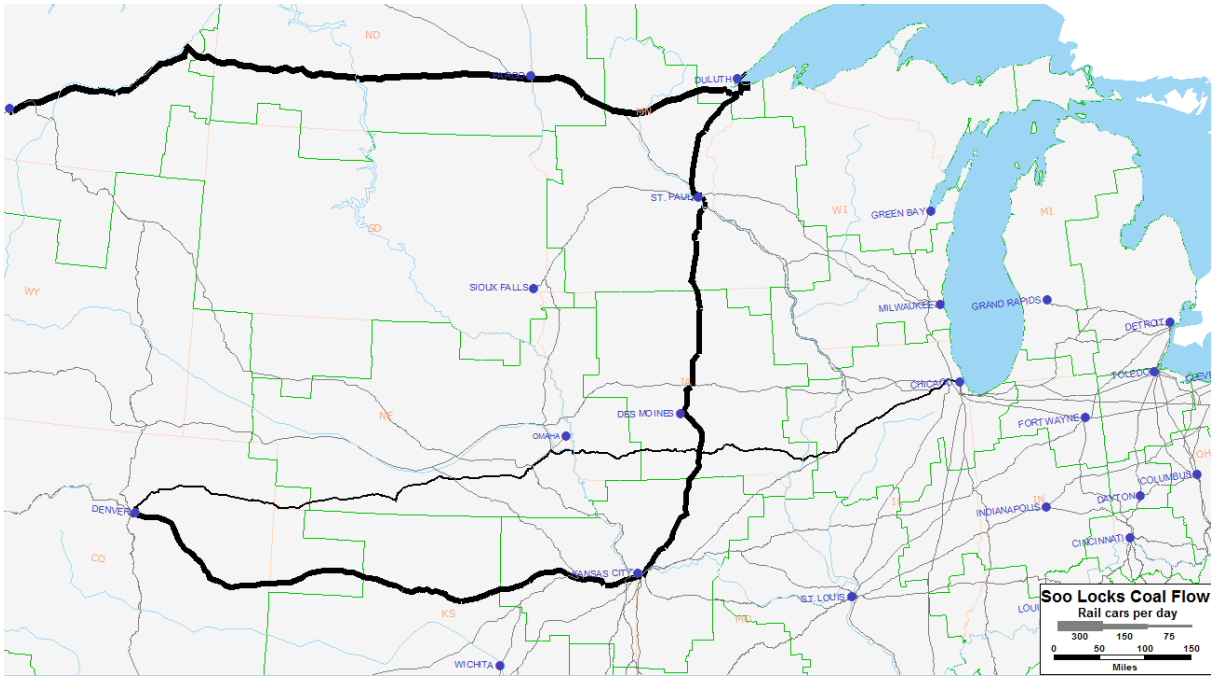

FIGURE 34—RAIL TRAFFIC FOR COAL PRIOR TO A POE LOCK SCENARIO CLOSURE

OCIA-NISAC estimated the impact to the rail network after a Poe Lock closure scenario. Figure 35 shows flow of western coal on the rail network after an unanticipated closure, using the same scale for line thickness as Figure 34 The thickest lines in both figures represent flow volumes of about 380 cars per day, equivalent to about 4 unit trains. The disruption scenario shows the coal flowing through Chicago and then on to Michigan and Ohio.

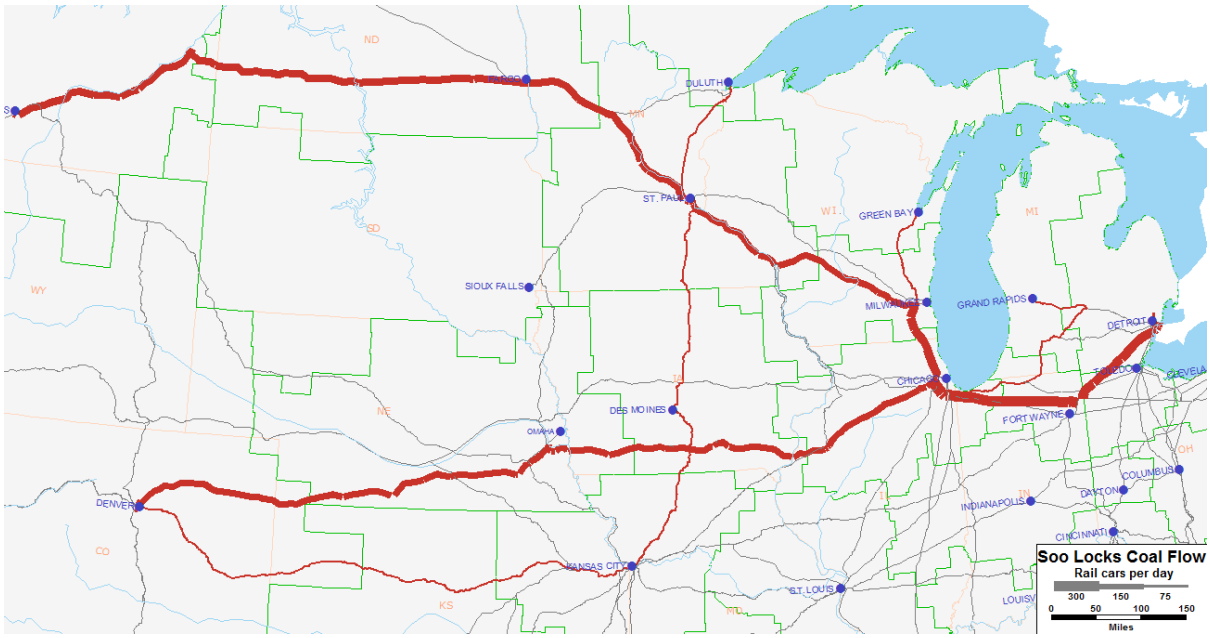

FIGURE 35—SOO LOCKS RAIL TRAFFIC FOR COAL DURING POE LOCK SCENARIO CLOSURE

OCIA-NISAC estimates that there is about a 41 percent increase in railcar-miles after the disruption, based on the additional mileage necessary to move the coal to eastern Michigan instead of the Port of Duluth-Superior.[218] However, because of the decrease in coal shipments (see Figure 36) due to the closing of some coal-fired generation facilities and the increased transportation of crude oil that has usurped coal shipments, the infrastructure likely exists to move the 4 unit trains a day necessary to provide Michigan with Powder River Basin coal.[219,220] Further, an industry executive confirmed that capacity exists to move a limited number of additional trains. Most of this coal is already transported partway by rail; in the post-disruption scenario, it must now travel longer distances, across or around Chicago by rail, to reach its destination in Michigan.[221]

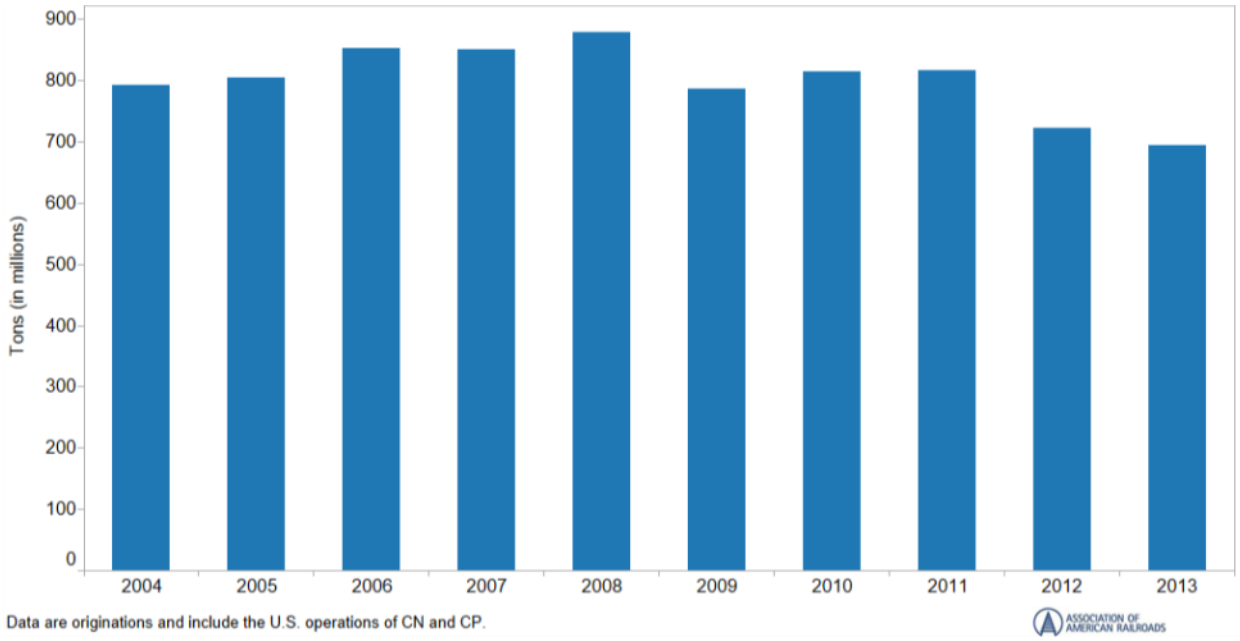

FIGURE 36—ANNUAL SHIPMENTS OF COAL (MILLIONS OF TONS)[222]

ANALYSIS 2: CONTINGENCY ANALYSIS OF MICHIGAN'S BULK ELECTRIC POWER SYSTEM

OCIA-NISAC's contingency study examines a specific scenario whereby all coal-fired generation in Table 12 is taken offline because of an inability to transport coal, but iron ore is available and steel production continues. This is to address the question of whether a lightering policy needs to consider the shipment of coal. Because steel production continues, automobile production is not impacted and an adequate supply of electricity is required for Michigan manufacturers. The sum of the lost generation in Table 12 totals 9.2 gigawatts (GW) in the spring and 10.4 GW in the summer, which is roughly equivalent to the amount of power needed to power 8 million homes.

OCIA-NISAC analysts determined that there are three potential sources of generation available to replace the lost coal-fired generation. First, in the summer-peaking model, which analyzes the ability of the bulk power system to supply adequate electricity for the hour of highest demand, the "peak hour" or "peak conditions," there is over 5 GW of available excess generation capacity at other facilities in Michigan, mostly natural gas-fired plants. Second, the Midwest Independent System Operator (MISO), which is responsible for coordinating the bulk power system

[218] For the purposes of analysis, it is assumed that once a shipment is interrupted by the Soo Locks it can only use rail to reach its final destination, it will not be routed to an alternative port and then send on water.
[219] Wall Street Journal, "Surge in Rail Shipments of Oil Sidetracks Other Industries," on March 13, 2014, www.wsj.com/articles/SB10001424052702304914904579437680173044774, accessed March 16, 2015.
[220] A unit train, also called a block train or a trainload service, is a train in which all cars carry the same commodity and is shipped from the same origin to the same destination, without being split up or stored *en route*.
[221] This analysis only considers physical and logistical constraints, not potential cost differentials that may affect business decisions.
[222] U) Association of American Railroads, "Annual Rail Traffic Data: Coal," at www.aar.org/data-center/rail-traffic-data , accessed March 16, 2015.

in much of the Midwest, has a reserve capacity of between 5 and 15 GW of excess generation available. The higher range of excess generation assumes that temperatures and generator outage rates are normal for the summer, while the lower range of excess generation assumes that temperatures are high and generator outage rates, called forced outage rates, match historical highs. That reserve capacity is composed of on-hand excess generation, net firm imports, behind-the-meter generation, and demand response.[223,224,225,226,227] Finally, the Ontario Independent Electricity System Operator (IESO), the equivalent to MISO in Ontario, has between 6 and 12 GW of excess generation capacity at the time of its summer peak customer demand.[228,229]

Based on the availability of between 11 and 27 GW of excess generation capacity in MISO and IESO, there is adequate generation available in spring and summer to offset the loss of coal-fired generation. However, this supplemental generation may or may not be available for extended periods. The continued use of these generators for extended periods would likely increase the risk of forced outages of these facilities. Generating companies may not be willing to run their generation plants if, by doing so, it would put the plants at risk for unplanned outages. Maintenance schedules for these plants are not known to OCIA-NISAC.

While there appears to be sufficient generation available to compensate for the loss of coal-fired plants, this does not imply that the transmission system is capable of moving this power to the areas where it is needed. The contingency analysis determines whether the transmission system can withstand the transfer of this power into Michigan without experiencing overloaded transmission lines or areas of low voltage or voltage collapse. Indiscriminate shifting of large quantities of generation in an electric power flow model can lead to instabilities and, ultimately, to loss of electric power in an area. However, the contingency analysis does not consider reducing load, meaning decreasing electric power demand, either by executing interruptible contracts, through other load management programs, such as air conditioner interruption programs, or by requests for customers to conserve electric power, activities that may all take place if generation reserves fall to low levels.[230,231]

Preliminary analysis indicated that other electric power generators in Michigan and neighboring regions could cover the generation shortfall of 9.2 GW in the spring. The shift in generation was accomplished without resulting in overloaded transmission lines or regions of low voltage. Approximately half this generation was picked up within the State of Michigan, while the other half came from utilities in Indiana, Illinois, Ohio, and Canada.

The contingency analysis indicated that the generation shortfall of 10.4 GW in the summer could not be covered by other electric power generators in Michigan and neighboring regions without stressing the system. The model suggested other generation in Michigan or the surrounding States or Provinces could provide about 72 percent of the required power without causing any overloaded transmission lines or regions of low voltage. However, attempting to move the remaining 28 percent of typical summertime requirements caused the model to fail.[232] It is likely that, under summer peak conditions, utilities might have to exercise interruptible contracts and demand response, or even impose rolling blackouts, to make up for the nearly 3 GW shortfall in generation. This would only be necessary for periods of very high customer demand, which generally occurs for a few hours per day and

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[223] On-hand excess generation is generation remaining after demand has been met. Operators have scheduled it as available before the time of the summer peak. It is nameplate minus derates minus inoperables minus scheduled outages.
[224] Net firm imports are the total expected firm (contracted) power flow into the MISO region (from other NERC entities – PJM, SERC, SPP and IESO) at the time of the summer peak.
[225] Behind the meter generations is generation operated under the control of the customer (hence behind the meter; i.e., the customer's electric meter).
[226] Demand response is the ability of a "utility" (or "marketing participant", balancing authority, or anyone who sends electricity to customers) to reduce its electric consumption in response to an instruction received from an Independent System Operator.
[227] Midwest Independent System Operator, "MISO 2014 Summer Resource Assessment," www.misoenergy.org/Library/Repository/Study/Seasonal%20Assessments/2014%20Summer%20Resource%20Assessment.pdf, accessed March 11, 2015.
[228] Independent Electricity System Operator, "Ontario's Electricity System," www.ieso.ca/ontarioenergymap/index.html, accessed March 11, 2015. Generation capacity equals 33,771 MW. Summer peak demand was 27,005 on August 1, 2006, but only 21,363 MW in 2014. www.ieso.ca/Pages/Power-Data/2014-Electricity-Production-Consumption-and-Price-Data.aspx, accessed March 16, 2015.
[229] The bulk power grid in Canada, the United States, and parts of Mexico is operated without respect to political boundaries. The North American Electric Reliability Corporation is responsible for the bulk power grid reliability across the three countries and electric power moves across the borders as needed.
[230] Some utility customers agree to have their electric power delivery terminated, if needed, in order to reduce electric power demand when the system is unstable. In return, the customers are charged lower rates.
[231] MISO could reduce demand by executing interruptible contracts. In MISO, there were at least 4.5 GW of interruptible contracts in the summer of 2014. Load-reduction activities begin if reserves drop below 2,400 MW. See "MISO 2014 Summer Resource Assessment," www.misoenergy.org/Library/Repository/Study/Seasonal%20Assessments/2014%20Summer%20Resource%20Assessment.pdf, accessed March 11, 2015.
[232] More extensive analysis would be required to determine the cause of the divergence and whether it is due to numerical limitations of the modelling software or physical limitations of the electrical system in wheeling this much power into Michigan.

for a few days during the year. This result suggests that it would be prudent to keep at least 3 GW of the 10.4-GW coal-fired generation that was lost due to the closing of the Soo Locks, in service for summer peak. This point will be addressed further in Analysis 3.

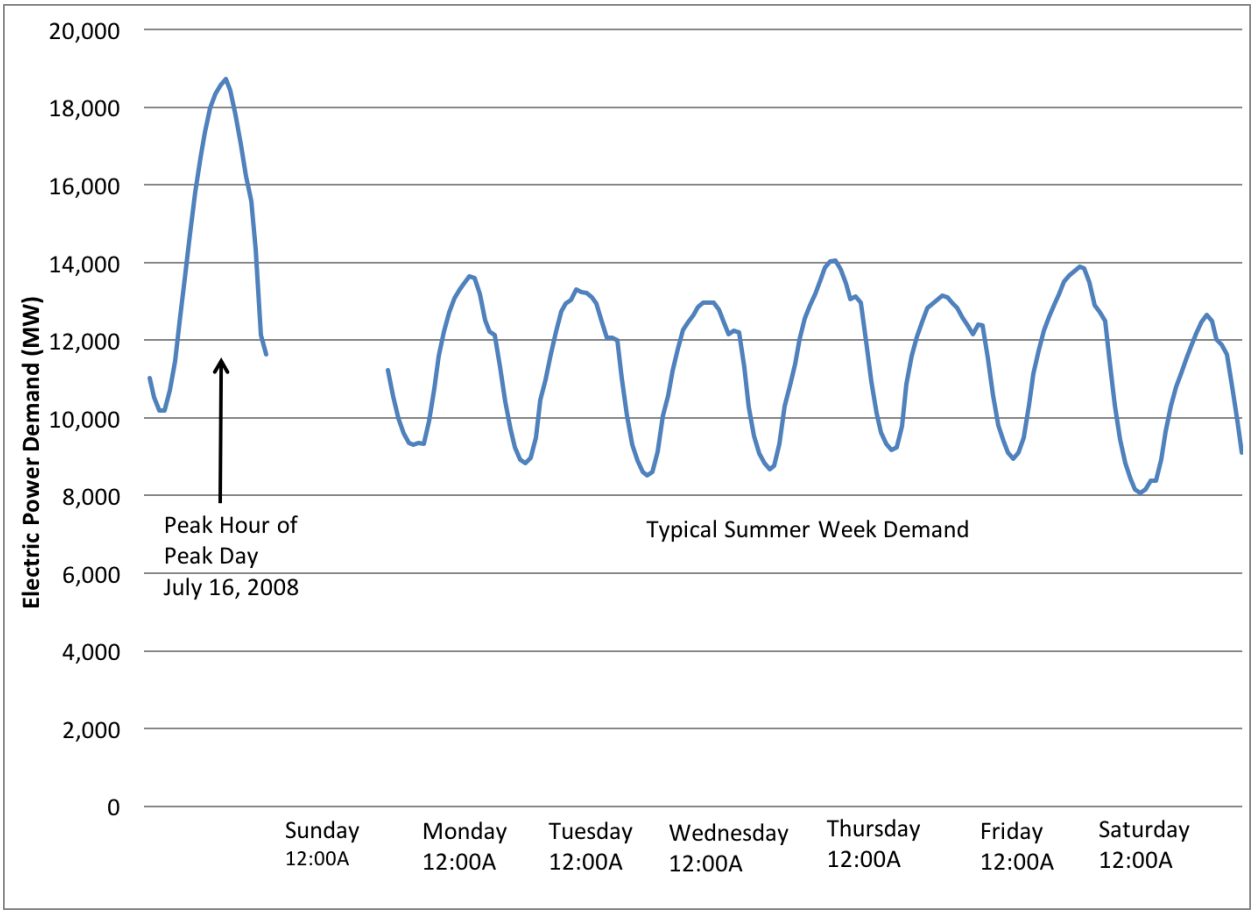

FIGURE 37—HOURLY LOAD CURVES FOR THE PEAK SUMMER DAY WITH THE HIGHEST ELECTRICAL USAGE AND DAILY LOAD CURVES DURING A REPRESENTATIVE SUMMER WEEK IN MICHIGAN IN 2008.

It should be noted that it is unlikely that MISO, or any regional operator, would actually operate the transmission system as suggested by the contingency model because increasing the use of other generation facilities would greatly reduce the reserve margin.[233] Without ample generation reserves, the bulk power system would be at increased risk if additional transmission or generation assets suddenly tripped out of service. However, this should only be a problem when the bulk power demand approaches its peak loading conditions, which only occurs for a limited number of hours during the year. This is demonstrated in Figure 37, where the state of Michigan's summer-peak demand of 18,700 MW, which occurred at 4:00 P.M. on July 16, 2008, is much greater than the daily peak demands that occurred during the average week that summer.[234] The daily peak loading conditions only occur for a few hours a day. It is further demonstrated in Figure 38, which depicts a load-duration curve for the Michigan utilities. The load duration curve expresses how many hours during the year that the system experiences demands above a particular value. For example, the demand in Michigan exceeded 16,000 MW for 140 hours in 2008. From the figure, the Michigan electrical system experienced demands within 2.9 GW of its yearly peak, the amount of power shortfall indicated by the earlier analysis showing that 72 percent of electric power demand could be met without stressing the system, for 155 hours in 2008.

[233] The entities responsible for the bulk power grid stability and reliability must keep a certain percentage of their generation capacity in reserve in the event of unforeseen circumstances such as plant outages, extreme weather, or other disruptions.
[234] Data obtained from FERC Form 714. Demand data for Michigan is the sum of demand data for Detroit Edison and demand data for Consumers Energy. Hourly demand data for the individual utilities is not available after 2008, See FERC www.ferc.gov/docs-filing/forms/form-714/data.asp, accessed March 15, 2015.

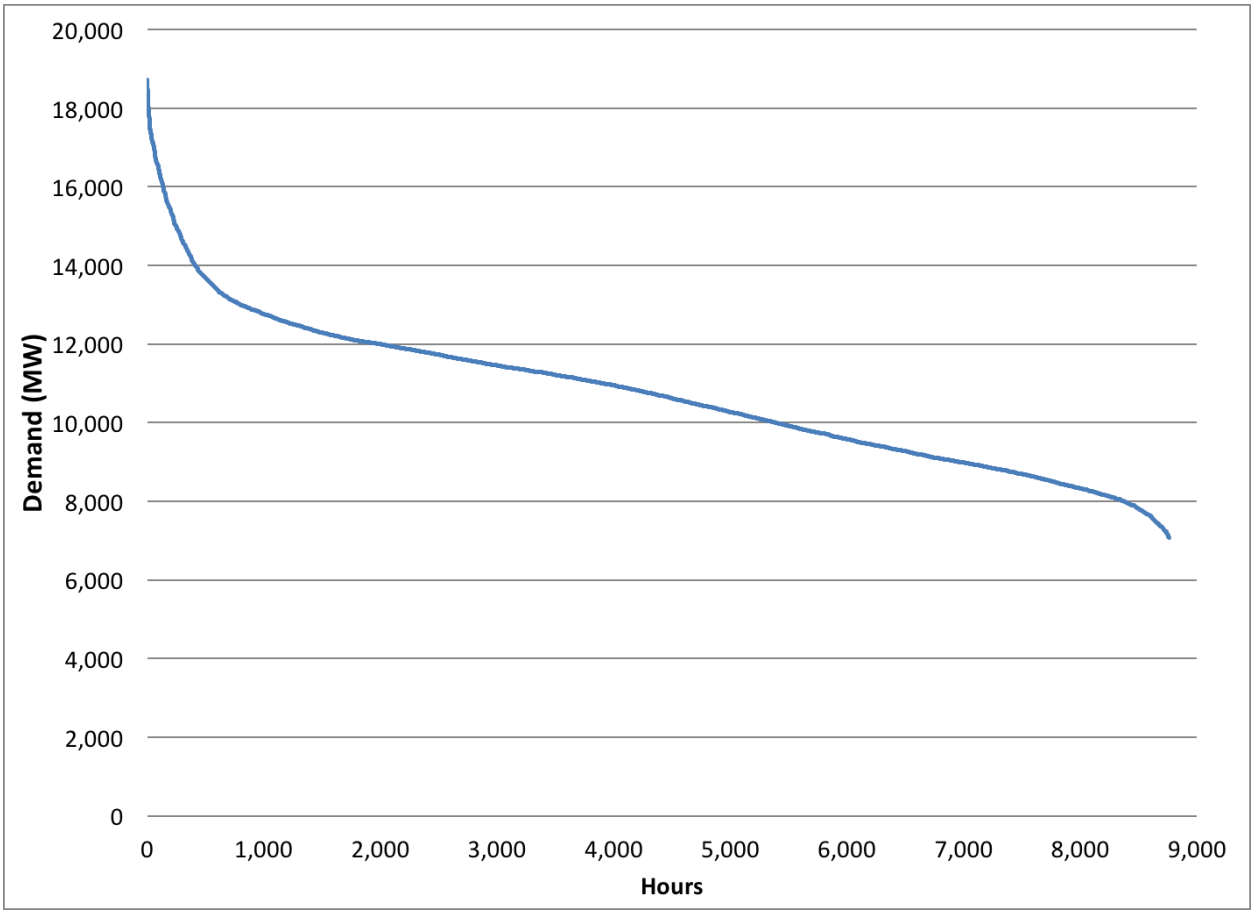

FIGURE 38—LOAD DURATION CURVE FOR MICHIGAN UTILITIES FOR THE YEAR 2008. THE LOAD DURATION CURVE EXPRESSES HOW MANY HOURS DURING THE YEAR THAT THE SYSTEM EXPERIENCED DEMANDS ABOVE A PARTICULAR VALUE.

ANALYSIS 3: RELYING ON EXISTING COAL STOCKS

Coal-fired electric power generators generally keep a 1- to 3-month stockpile of coal onsite. Table 14 shows the annual coal deliveries in 2013 to 2014 to the Power Plants identified in Table 12. Monroe, the largest coal-fired plant in Michigan, receives about 680,000 short tons of coal per month. Monroe has a port on Lake Erie, which may aid the year-round delivery of coal. Table 14 provides the information necessary to determine how much electricity can be generated by one net ton of coal. At Monroe, 1.9-megawatt hours (MWHr) of electricity is produced for every short ton of coal consumed. The average electricity production for all coal-fired plants in Michigan is about 1.8 MWHr per short-ton.

TABLE 14—COAL DELIVERED AND CONSUMED; ELECTRICITY GENERATED AT MICHIGAN COAL-FIRED PLANTS

Plant	2014			2013		
	Tons Delivered	Tons Consumed	Electricity MWHr	Tons Delivered	Tons Consumed	Electricity MWHr
Monroe	8,131,739	7,532,913	14,572,303	7,784,949	8,309,642	15,961,902
J H Campbell	5,093,476	4,764,741	8,574,687	4,225,854	4,884,102	8,591,976
Belle River*	0	4,258,122	7,564,057	0	4,262,341	7,589,031
BRSC Shared Storage*	6,804,878			6,902,859		
St Clair*	528,234	3,050,976	5,339,461	246,541	3,647,138	6,178,063
Trenton Channel	1,551,801	1,499,598	2,524,496	1,825,724	1,979,362	3,406,770
Presque Isle	1,299,897	1,248,815	1,887,006	1,326,481	1,236,463	1,882,904
Dan E Karn	1,066,546	1,136,524	2,011,851	1,381,856	1,494,265	2,544,690
J R Whiting	1,094,451	1,093,830	1,813,193	982,449	1,012,394	1,653,060
River Rouge	1,173,310	1,091,641	2,125,977	1,126,273	1,246,692	2,254,911
B C Cobb	1,031,570	1,079,788	1,862,030	902,610	1,046,423	1,783,115
J C Weadock	1,144,452	959,112	1,705,975	989,164	920,629	1,627,591
Eckert Station	388,426	365,774	547,163	408,274	358,481	508,998
TES Filer City Station	248,893	212,791	368,881	171,538	188,499	310,484
Escanaba Paper Company	102,847	48,184	81,155	110,288	47,553	79,807
T B Simon Power Plant	69,755	19,132	78,818	57,533	22,359	93,569
Wyandotte	19,533	17,770	21,984	7,188	17,552	12,255

* Belle River and St Clair share storage of coal (BRSC Shared Storage)

In 2014, Michigan coal-fired plants produce an average of 4.26 million MWHr of electricity production per month (EIA-923 data), which corresponds to the amount of electricity that would be generated from 2.37 million short tons of coal. Therefore, the amount of coal on hand in Michigan at any given time is enough to produce about 1 to 3 months of electricity. However, at the time that the Soo Locks navigation season commences at the end of March, stocks are generally at their season lows of 1 to 2 months' worth of stock.

On average, at the end of March, the time corresponding to the Soo Locks closure scenario, there is about 4.63 million short tons of coal in stock.[235] The 4.63 million short tons of coal could generate about 8.33 MWHr using the ratio of 1.8MWHr per short ton of coal. The 8.33 MWHr of generation using the stock could produce about 2777 hours of electricity from 3 GW of electric power generation. However, the previous analysis suggested that, in a typical year, there are only 155 hours that would require 2.9 GW of additional electric power generation suggesting that the coal stocks could be maintained to meet peak conditions.

CONCLUSION OF COAL ANALYSIS

The analysis suggests that the loss of coal shipments on the Great Lakes would not cause a cessation of manufacturing in Michigan in the specific case that iron ore is shipped, but coal is not. First, there should be sufficient ability to move up to four unit trains of coal per day from the Powder River Basin to Michigan, making it likely that enough coal could be moved to Michigan to maintain electric power for manufacturing needs. Second, other existing non-coal-fired electric power generators and interruptible contracts are likely to be sufficient to cover generation shortfalls, except during peak periods during the summer. Third, there should be a 1- to 2-month supply of coal stocks remaining in Michigan at the time of the closure. By combining the second and third point, there should be sufficient reserve capacity and coal stockpiles to meet peak summer conditions. Finally, what is not

[235] This is an average of the 2010-2014 after tossing out the highest and lowest figures that may be aberrant.

known is whether Michigan imports western coal due to economics or regulatory requirements or because of the physical characteristics of the generators. If the cause is economics or environmental, then logistically, it is likely fairly easy to move additional coal from West Virginia and the surrounding environs to Michigan. The movement of coal is not a necessary component of a strategy to mitigate a Soo Locks closure.

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Who knew that a senior economist at the Federal Reserve Bank of Chicago would have written a piece about a trip that he took on a Laker going through the Soo Locks? But finding that piece led us to meet the author, William Strauss, who reviewed and commented extensively on the work, directed us on avenues to consider, and introduced us to many of the industry people. Bill has been a tremendous resource and a great guide.

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- U.S. Department of Transportation / U.S. Maritime Administration: Great Lakes Gateway Office
- U.S. Department of Transportation/ Federal Highway Administration
- U.S. Department of Transportation / U.S. Maritime Administration
- U.S. Department of Transportation / Pipeline and Hazardous Materials Safety Administration
- U.S. Department of Transportation / Office of the Secretary
- U.S. Army Corps of Engineers: Great Lakes and Ohio River Division
- U.S. Army Corps of Engineers: Detroit District
- U.S. Army Corps of Engineers: Soo Field Office
- U.S. Coast Guard

The following Canadian Government Agencies reviewed the report:

- Public Safety Canada
- Industry Canada

In addition, the Saint Lawrence Seaway Development Corporation provided a review.

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