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Powering an Industry: The History of the Calumet and Hecla Electrical System and the Environmental Consequences Left Behind

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POWERING AN INDUSTRY: THE HISTORY OF THE CALUMET AND HECLA ELECTRICAL SYSTEM AND THE ENVIRONMENTAL CONSEQUENCES LEFT BEHIND

By

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Abstract

The Calumet and Hecla Copper Mining Company in Houghton County, Michigan, was established in 1865 and closed its doors in 1968. This company was a major contributor in developing secondary copper processing and used these methods to produce copper even when its underground mines were closed. C&H built its own electrical transmission system that could have rivaled many during its time. This allowed the company to have the ability to produce and control its electrical network and expand, but it had major environmental effects. Polychlorinated biphenyl compounds (PCBs), used in transformer oil and other components were produced between about 1930 and the 1970s. They are known to be a carcinogen and to cause other harmful effects to both humans and the environment. This research describes the history of electrical development and maps C&H Torch Lake facilities to further understand how PCBs continue to affect the environment.

Chapter 1 – Introduction

The Calumet and Hecla Copper Mining Company in Houghton County, Michigan, was established in 1865 and closed its doors in 1968. Throughout this time the company played a major role in supplying copper to the United States and helped develop more efficient technologies for processing copper ores. The Calumet & Hecla Copper Mining Company (C&H) developed techniques through experimentation and engineering that enhanced copper production and brought success to the district. Though not the only company working to perfect the processes of copper extraction; they also developed different ways of copper stamping, leaching, flotation, and chemical making that even now are impacting the way copper is processed around the world.

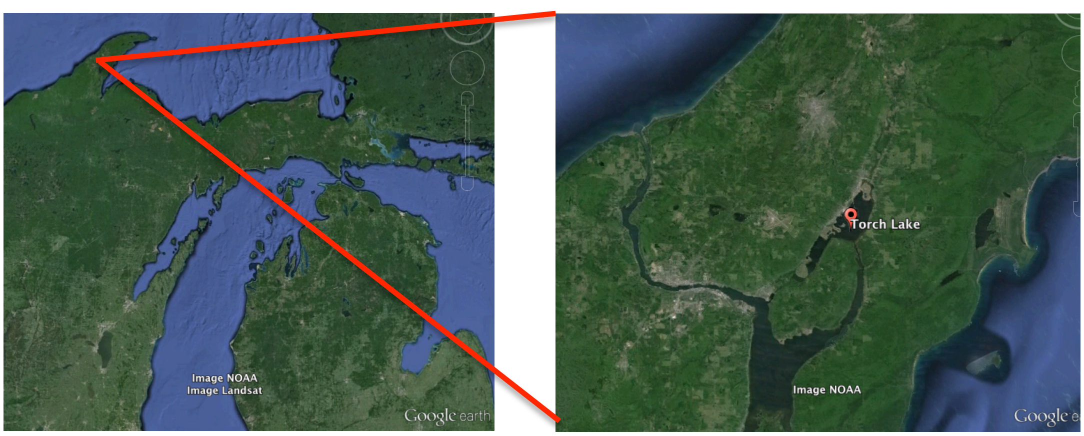

Figure 1: Map of Michigan showing location of Torch Lake in the Upper Peninsula. Source: Google Earth.

As C&H worked to perfect its copper techniques, it also set up an electric transmission system that would rival many industrial companies at the time. With the ability to produce and control its own electrical network, C&H expanded operations

without the need for supplemental power to allow for planning and the ability to efficiently expand its physical plant. This study focuses on the development of the C&H processing facilities, its electrical system between the 1870s and 1960s, and the resulting environmental issues along Torch Lake (seen in Figure 1), especially polychlorinated biphenyl compound (PCB) contamination.

Over this 100-year period, the many C&H facilities had waste streams that led to environmental pollution. The focus since the 1980s is identifying pollution areas and developing remediation plans. One chemical causing environmental issues is the PCB.

This thesis examines the origins of contamination from electrical production along the Torch Lake shoreline where C&H processing facilities were concentrated. It also identifies specific waste streams from the electrical system as well as processing technologies such as leaching, flotation, and copper recovery from scrap metals. PCBs and other pollutants were not identified until the 1980s and later, long after C&H had closed. Records of chemical use in twentieth century processing and the wastes they created had long since been buried in the historical archives, if they existed at all. The goal of this thesis research is to document the development of industrial electric systems in the Lake Superior copper district and provide insight into how this system has introduced hazardous pollution into the landscape.

Government Grants & Research

My project originated from a research investigation at Michigan Technological University (Michigan Tech) that combined historical and environmental investigations into the possible source of PCB and heavy metal contamination at Torch Lake during the copper mining era. The Integrated Assessment of Torch Lake Area of Concern research project (2012-2014), Michigan Sea Grant Number: R/WQ-4 and Contract Number: 3002230000, focused on looking into the C&H processing facilities and the possibility of PCB contamination. As a member of this team, I focused on the history of the electrical system, leaching and flotation technologies, and scrap metal processing. Using data sets already available through past water, sediment, and soil sampling, the research team identified where the highest levels of concentrations were located and mapped them alongside the processing facilities on the western Torch Lake shoreline. We then assessed how the layout of the electrical system, along with the other facilities, may have contributed to the more heavily polluted zones.

A mass balance program was also created which determined if the present PCB contamination could have been caused by known sources, and the result was that it could not all be accounted for. A mass balance program uses the conservation of mass law and calculates what the input should be based on the outputs. If the numbers do not add up, there is a mass that has not yet been found. The research plan was to combine all of the sampling data and map the information using Geographical Information Systems (GIS), as well as map the locations of the electrical system's facilities using GIS. First, a document was created showing all of the sampling data

done by different companies and governmental groups over a span of more than thirty years. At the same time, the C&H electrical distribution system was researched and specific facilities were located along the shores of Torch Lake.

My research project required an investigation into the history of power production, specifically electricity, in order to determine if the PCB contamination came from transformers and other electrical equipment. If it did not correlate with the sampling information, another possible waste stream would need to be identified. Using archival material from the Michigan Technological University Archives and Copper Country Historical Collections (Michigan Tech Archives) including C&H annual reports, company correspondence between C&H or C&H and outside vendors, historic maps of the Keweenaw and C&H specific properties, and measured drawings of C&H facilities, I developed a short history of C&H and its copper processing facilities along Torch Lake. In addition, I utilized early articles from journals such as the *Engineering and Mining Journal* and the *Mining Congress Journal* and histories of electrical production to construct a picture of C&H's electrification of copper processing.

Additional funding by the Keweenaw National Historic Park Heritage Grant allowed students to interview community members who were familiar with the C&H processing facilities. The Michigan Department of Environmental Quality also provided support to continue historical research on PCB sources along Torch Lake. I conducted three interviews that informed me about the slag dumps and scrap burning sites, which provided insight about pollution and waste.

Others have written about Torch Lake and the Calumet & Hecla Mining Company. These topics have been researched for journal articles, books, and theses, but no one has examined the nature of the electrical system or how the company plays a role in current pollution issues. C. Harry Benedict, who worked for C&H and developed early reclamation technologies, provides a first-hand account of early processing history, but does not go in depth about the electrical system or its role in diversification of processing.[1] Historian Larry Lankton also has written three major books on copper mining and social life in the Keweenaw and mentions briefly the change from wood to coal and steam to electricity, and touches on the development of environmental problems in his more recent books.[2]

Torch Lake mining facilities are the subject of three theses from the Industrial Archaeology Program at Michigan Tech, but do not cover the production and transmission of electricity or mining waste pollution. David Vago lays out an interpretive plan for the Calumet and Hecla mill sites in Lake Linden concerning its historical significance and how to preserve them to keep the mining and milling legacy alive in the local area, but do not cover the reclamation plants and the particular workings of the electrical system. Dorothy Quirk covers the history of the

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[1] C. Harry Benedict, 1914. Process of extracting copper. US Patent 1131986 A, filed April 18, 1914; C. Harry Benedict, 1920. Process of treating copper-bearing sands. US

[2] Larry Lankton, *Cradle to Grave: Life, Work, and Death at the Lake Superior Copper Mines* (New York, NY: Oxford University Press, 1991); Larry Lankton, *Keweenaw Copper: Mines, Mills, Smelters, and Communities* (Houghton, MI: Society for Industrial Archeology, 1997); Larry Lankton, *Hollowed Ground: Copper Mining and Community Building on Lake Superior, 1840s-1990s* (Detroit, MI: Wayne State University Press, 2010).

copper reclamation processes along Torch Lake. Finally, Jennifer Bollen writes about the Quincy Mining Company's reclamation history and provides an interpretive plan.[3]

Of more significance to my research is the 2016 thesis in Environmental Engineering by my research partner Ankita Mandelia. She focused on the environmental data and specific research done on Torch Lake itself and the surrounding upland of the western shoreline. Her work on PCB contamination informs my own historical investigation.[4] In combination, Mandelia's review of PCB sampling data and mass balance analysis and my investigation of the electrical system provide an interdisciplinary assessment of pollution production and analysis.

An important factor in my research was that PCBs were only produced in the United States from roughly 1930 to the 1970s and were often used in electrical transformers, although there were other uses for them.[5] As such, my research was focused on the electrical system. I had to find the possible locations on the landscape that could still contain PCBs or that are currently leaching the PCBs into the lake. From this research, I realized that there were no written works specifically looking into this subject on the Keweenaw.

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[3] David Vago, "An Interpretive Plan for the Calumet and Hecla Mill Site" Master's Thesis, Michigan Technological University, 2005; Dorothy Quirk, "Copper from sand : a history of copper reclamation on Torch Lake, Houghton County, Michigan" Master's Thesis, Michigan Technological University, 1999; Jennifer Bollen, "Quincy Mills and Dredge Historic Park Interpretive Plan" Master's Thesis, Michigan Technological University, 1999.

[4] Ankita Mandelia, "Polychlorinated Biphenyl Compound and Metal Contamination and Remediation in Torch Lake, Houghton County, MI" Master's Thesis, Michigan Technological University, 2016.

[5] Interdepartmental Task Force on PCBs, *Polychlorinated Biphenyls and the Environment,* 2.

Once the electrical network and other facilities were mapped along the western shoreline of Torch Lake, the information was then compared with the sampling data. From this map, correlations were made connecting specific buildings or processes with the areas with higher concentrations of PCBs. This led the team to other possible explanations for the PCB contamination and to prove that the electrical system was one cause of the pollution. From this data, more targeted sampling could be planned to locate individual sites of contamination to be remediated and removed from the environment.

As the research progressed for the Michigan Tech investigation, I realized this information was an important part of the Keweenaw copper mining story. The development of the electrical system had not been documented to show what its full potential was. Also, the connection to the environmental story became more and more important because of the impact of the PCBs. I believed that this research should be turned into a history, and therefore chose to write my thesis on this important aspect of the Keweenaw copper story.

Research Question

How did the C&H electrical system develop over time and what were the environmental consequences?

Literature Review

Industrial pollution has increased in popularity in more current literature. Over the past twenty years the US government has focused on cleaning up pollution in the environment and making the land and water safe. One pollutant has gotten a lot of media attention in the past twenty years because of its possible carcinogenic effects. PCBs cause harm to the environment, as they kill benthic, or bottom dwelling, organisms and build up in organic material (humans, fish, etc.).[6] PCBs were an essential part of the electrical infrastructure in the US from about 1930 until the 1970s, after which its production was banned and disposal practices regulated. It is highly probable that C&H used PCBs in its transformers, which were spread along the Torch Lake shoreline, bringing electricity to its various facilities.

An understanding of past literature and a general knowledge about mining and its associated waste was needed before historical research began. During the nineteenth century the US was developing a large mining industry. In the twentieth century, mining was extremely important to other industries in the US because of the raw materials. Copper was found in large amounts in both the Upper Peninsula of Michigan, specifically on the Keweenaw Peninsula, and in the copper sulfide rich land in the west, which included the state of Montana. As copper mining developed from the 1840s to the 1970s, many concerns over waste and pollution arose and the US government became involved in many areas of environmental policy.

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[6] Michigan Department of Environmental Quality, *Biennial Remedial Action Plan Update for the Torch Lake Area of Concern* (Lansing, MI: MDEQ, Oct. 2007), 2 & 8.

As the United States became more industrialized in the late nineteenth century, many people had the attitude of "out-of-sight, out-of-mind."[7] Most cities and companies dumped their waste away from their operations. According to Melosi, this attitude was prevalent throughout industry, small business, and personal life. Industry, since they were interested in the profits, simply discarded their waste the cheapest way possible. As LeCain pointed out, the United States in the 1880s was entering an era of mining characterized by "mass destruction" which was identified by its relation to "mass production."[8] "Mass production mining entailed mass destruction of the environment itself."[9] It was easy to take advantage of the land since there was plenty of land and non-renewable resources. However, once those non-renewable resources ran out, the government had to act to preserve the future of the country.

Everything one could possibly think of when it comes to industry was dumped into the environment: basic garbage, slag, ash, scraps, and many other items.[10] However, out in the wilderness that was the west, the garbage was not a huge problem because the population was not as dense. As the populations increased, so did the worry about contamination from mining behemoths such as the Washoe Smelter and the Anaconda Mining Company, located in Montana. Two of the main waste streams were smoke and tailings. The smoke polluted the air and the tailings polluted the land

[7] Martin Melosi, *Effluent America: Cities, Industry, Energy, and the Environment* (Pittsburgh, PA: University of Pittsburgh Press: 2001), 35.
[8] Timothy LeCain, *Mass Destruction: The Men and Giant Mines That Wired America and Scarred the Planet* (New Brunswick, NJ: Rutgers University Press, 2009), 7 & 135.
[9] LeCain, *Mass Destruction*, 7 & 135.
[10] Melosi, *Effluent America,* 27.

and the water. A large portion of the current pollution examined in copper mining came from the waste tailings. The Environmental Protection Agency (EPA) claims that current US mining produces around two billion tons of waste per year, which adds up to be about 40 percent of the overall solid waste in the US.[11]

Because of this waste, it is common for old mining sites to be investigated for possible toxicity. The EPA has spent millions of dollars trying to clean up areas that were polluted because of mining. One site investigated was the Bingham Pit, located in Utah, where they found several sources of environmental contamination, including sulfates, lead, and arsenic. One particular EPA program, called the Superfund, funds research and sampling to determine if remediation is needed, then they develop and implement a plan to try and improve the environment. According to the EPA, the Superfund program deals with sites as small as individual mining locations, but also as big as entire watersheds, which could contain more than 100 mines.[12]

The EPA listed Torch Lake as a Superfund site and the Michigan Department for Environmental Quality (MDEQ) listed it as an Area of Concern in the Great Lakes region. These listings led to detailed research and sampling of the Torch Lake area and subsequent remediation.

Michigan's Copper Country was home to hundreds of mining companies between 1840 and 1980. The region has certain visible marks left over from its mining

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[11] Melosi, *Effluent America,* 36; Paul White, "Heads, Tails, and Decisions In-Between: The Archaeology of Mining Wastes." *IA: Journal of the Society for Industrial Archeology* 29, no. 2 (2003): 47.
[12] LeCain, *Mass Destruction,* 204-205; White, "Heads, Tails, and Decisions In-Between", 50.

glory. Poor rock from mines (ore with little to no copper content), tailings from stamp mills (stamp sands produced from the stamping and concentrating processes), and the slag from the smelters (waste rock, chemicals, and elements from the refining process) were a few of the discernable wastes left behind. At Torch Lake, tailings are a significant feature. The shorelines by the stamp mills have been moved from their pre-1860 location; the tailings deposits extend into the water and several hundred million metric tons of these sands have filled some of Torch Lake.[13] The new shoreline consists of flat, open terrain where plant life does not easily grow.

In the past decade there has been a significant amount of research and testing done on Torch Lake. The goal of the EPA and the MDEQ was to discover what types of pollution exist and how they can be remediated. Heavy metals and the tailings were the first areas of pollution research, but PCBs were not of interest until the late twentieth century. PCBs are a chemical that were used in the transformer oil as a lubricant. In 1912 we know that the non-PCB containing oil was changed about once per year.[14] As no source could be found contradicting this process after 1930, I have concluded that this was also the practice for the PCB containing oil. There are also no records of how this oil was disposed of, and it is possible that C&H simply discarded

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[13] Charles Kerfoot, et al. "Paleolimnological Study of Copper Mining Around Lake Superior: Artificial Varves from Portage Lake Provide a High Resolution Record," *Limnology and Oceanography* 39.3 (May 1994), 650.

[14] Michigan Department of Environmental Quality, *Biennial Remedial Action Plan Update for the Torch Lake Area of Concern*; John Liston, "Electrical Equipment of the Calumet & Hecla Mining Co., Calumet, Mich," *General Electric Review* 15 no. 8 (Aug. 1912): 527.

it into the lake. This could explain why Torch Lake has a higher concentration of PCBs than surrounding lakes.

It is clear from the other Keweenaw copper histories that electrical systems are overlooked. C&H's system was a significant contributor to the PCB contamination in Torch Lake. The tailings, metals, and other elements that are polluting Torch Lake are a problem, but the discovery of the higher PCB concentrations puts more pressure on environmentalists to act and remediate the problem. Through mapping the electrical system and comparing it with the sampling data already collected, the Michigan Tech team was able to pinpoint exact locations for future sampling, therefore saving time and money.

Conclusion

The remaining chapters discuss the history of electrical production, copper reclamation, and the resulting pollution. Chapter 2 will give a brief background to copper mining in the Keweenaw, with a focus on C&H. It will describe the company from opening to closing, as well as putting it in context with the other mining companies in the Lake Copper District. Chapter 3 will go into detail about the milling, smelting, reclamation, and other secondary copper processing developments by C&H. Chapter 4 will cover the development of power, starting with steam and then incorporating electricity into its power network. Finally, Chapter 5 will deal with the PCB pollution that came from secondary copper processing and the electrical

distribution network. This will include previous and current remediation and thoughts about how to proceed with future environmental sampling.

The Calumet & Hecla power system developed over many years and came in stages. These stages were coupled with technological developments in electrical transmission and copper processing techniques. Because the processes of flotation and leaching were slightly different in the chemicals they used and where they were located on the landscape (near water vs. on a hill), the waste streams and pollution were also different. There were not large amounts of smoke pollution or sulfur like out west. Instead, the Lake Superior Copper District would have other environmental factors and consequences. One of these factors, PCBs, would come from the electrical system, and this research will document how this pollution came to be.

Chapter 2 – The History of the Calumet & Hecla Mining Company

Mining copper in the Keweenaw Peninsula dates back to prehistoric times. There is evidence of Native American mining in the form of pits that littered the copper-rich landscape. Once the land was opened up to Europeans, the realization that this area was rich in copper made it very attractive to settlers. The first copper mine in the Keweenaw to pay dividends, and the most famous early mine, was the Cliff. The Cliff Mine was opened in 1844 and set the standard for copper production from future mines, including C&H.[15]

Historical Background

The Keweenaw Peninsula, located on Michigan's Upper Peninsula, was home to over 140 different copper mines between 1840 and 1970 and over 40 stamp mills to process the rock. This land was unlike any in the world where native, or pure, copper could be mined at an industrial scale, then milled and smelted without using chemicals in order to free the mineral from the rock. The Calumet Mining Company and the Hecla Mining Company were both formed in 1864, when they began mining the Calumet conglomerate lode at what is now Calumet. The Calumet Mining Company built its first stamp mill in Calumet in the 1860s (see Figure 2). The Hecla Mining Company, however, decided to build its stamp mill on Torch Lake. This mill was ready for processing by 1868. When the Calumet and the Hecla mining companies

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[15] Benedict, *Red Metal: The Calumet and Hecla Story*, 20, 5-6.

consolidated in 1870, the Calumet Mill was moved to a new facility on Torch Lake, next to the Hecla Mill.[16]

Calumet mill at Calumet—1867.

Figure 2: Photograph of the original Calumet Stamp Mill. Source: Benedict, *Red Metal: The Calumet and Hecla Story*, 67.

C&H chose Torch Lake because it was convenient for the disposal of waste materials from the copper processes and because it was a deep-water lake where ships going to and from C&H could easily dock and load/unload. Another reason Torch Lake was attractive to the company was because the US government took away the previous dumping site of tailings for many of the Keweenaw mining companies in the Portage Canal Waterway as it was beginning to affect the shipping canal. The first

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[16] Charles Kerfoot, George Lauster, and John A. Robbins, "Paleolimnological Study of Copper Mining Around Lake Superior: Artificial Varves from Portage Lake Provide a High Resolution Record," *Limnology and Oceanography* 39.3 (May 1994), 649; Benedict. *Lake Superior Milling Practice;* Benedict, *Red Metal: The Calumet and Hecla Story*, 33, 41, 66, 71, 83.

smelter C&H was associated with was located on Portage Lake. This smelter was not owned by C&H but used by them and many of the other mining companies in the area. It was built in 1860 and C&H used it until 1886 when it decided to build its own smelter near Hubbell on Torch Lake.[17] The smelter was being built in 1887 and processing shortly after.

By 1905, Torch Lake was home to multiple stamp mills owned by C&H, the Quincy Mining Company, and various other small mining companies. Over a period of fifty years, C&H slowly acquired the smaller mills along the western shoreline of Torch Lake until the company's reach went almost all the way down to the Mason area, which was occupied by the Quincy Mining Company. The expanse of the Torch Lake operations and the northernmost mines can be seen in Figure 3. In total, around 200 million tons of tailings were deposited into Torch Lake during the lives of these multiple mills.[18] Tailings, however, were not the only waste product deposited into or around Torch Lake. As the company developed, other processes and technical developments would lead to waste streams from nearly every type of facility along Torch Lake.

[17] N. Urban, et al, *Integrated Assessment of Torch Lake Area of Concern – Draft 3*, (Houghton, MI), 2-24; J.B. Cooper, "Treatment of Lake Copper," <u>Mines & Minerals</u> 23 (May 1903): 463.
[18] Kerfoot, et al. 1994, 650.

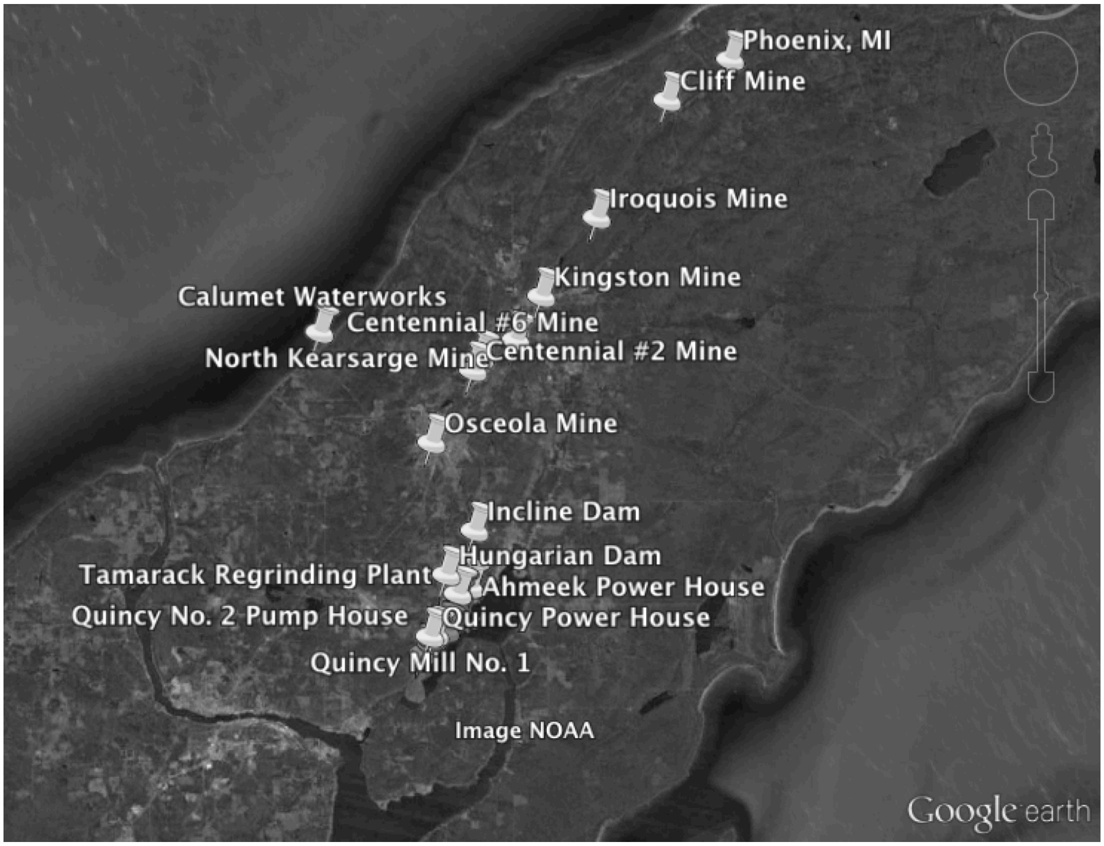

Figure 3: Map of Calumet and Hecla owned facilities between 1870 and 1970. Source: Google Earth, adapted by Author.

C&H had its northernmost mines near Phoenix, MI and its southernmost mills on Torch Lake at Lake Linden, MI. A major part of its success was being able to fully control each part of the mining process: underground mining, transportation, milling, and smelting. By being vertically integrated, C&H was able to know ahead of time how its mills or smelter should be set up in order to handle the specific rock coming from the mines.[19] This vertically integrated setup was extended into the twentieth century and included an electric distribution system.

[19] Robert McIntosh & A.L. Burgan, "Electric Power Generation," *The Mining Congress Journal* 17 (1931): 546; C&H Annual Reports, Michigan Tech Archives and Copper Country Historical Collection (Michigan Tech Archives).

Mining on the Calumet lode provided the ore that was transported by rail to its mills, the Calumet Mill and the Hecla Mill, on the northern end of Torch Lake. This railroad was built in 1867 and was an integral part of copper transportation for C&H (see Figure 4).[20] There the rock was stamped and the copper was separated from the rock, producing stamp sand tailings that were deposited into the lake.

Figure 4: Photograph of Calumet & Hecla Railroad Locomotive. Photograph No. MS003-004-014-02, "C&H Locomotive." Date unknown. Calumet and Hecla Photograph Collection. Michigan Tech Archives & Copper Country Historical Collections. http://digarch.lib.mtu.edu/showbib.aspx?bib_id=688416#. Accessed 7/20/16.

As C&H entered the 1900s, it was already thinking about how it could produce more copper. It began expanding its stamp mills, boiler house, and smelter, along with

[20] Benedict, *Red Metal: The Calumet and Hecla Story*, 162.

building a brand new coal dock at its smelter site. The company also began to add electricity generating equipment to its powerhouses in order to light facilities and to supplement its steam power. By 1910, most of the C&H facilities on Torch Lake had been renovated or expanded. This began a whole new era of experimenting and reprocessing for C&H. Though its mines were producing well, it wanted to make sure that the company was getting the maximum amount of copper out of that rock. C&H opened its first regrinding plant in 1909 and its second in 1914 to reprocess previously stamped tailings.[21]

The next step for C&H was to develop other processes that could help them reclaim even more of the copper than just regrinding it. These new technologies were leaching and flotation. C&H began building its leaching plant in 1914 and it was operating by 1916. The leaching process was first used industrially in two places: Kennecott, Alaska, and Lake Linden, Michigan, beginning in 1916. C&H began experimenting with leaching in 1911 when it took tailings from its recrushing mills and used chemicals to separate the copper from the rock. C&H used cupric ammonium carbonate to make a cuprous compound, coal tar creosotes to leach the cuprous copper, and pyridine oil to act as a ligand in the formation of solid copper.[22]

The leaching process had three steps: separating the copper in concentrate form from the rock, dissolving the copper mineral with the ammonia or another

[21] C&H Annual Reports, Michigan Tech Archives.
[22] C&H Annual Reports, Michigan Tech Archives; Vahid Radmehr, et al, "Ammonia Leaching: A New Approach of Copper Industry in Hydrometallurgical Processes," *Journal of The Institution of Engineers (India)* 94, no. 2 (Oct 2013): 95; C&H Annual Reports (1913), Michigan Tech Archives; Benedict, "Milling at the Calumet & Hecla Consolidated Copper Company." *The Mining Congress Journal:* 523.

solvent, and finally to recapture the copper in the solid form of copper oxide through a distilling process which took place in large stills (see Figure 5). As of 1931 C&H was the only company in the world that was doing copper ammonia leaching.[23]

Figure 5: C&H Reclamation Plant – Leaching Plant. Photograph No. MS003-024-042, "Calumet and Hecla Mills and Reclamation Plant - Leaching Plant." Date unknown. Calumet and Hecla Photograph Collection. Michigan Tech Archives & Copper Country Historical Collections. http://digarch.lib.mtu.edu/showbib.aspx?bib_id=599960#. Accessed 7/20/16.

[23] Benedict, *Red Metal*, 179; C. H. Benedict, "Milling at the Calumet & Hecla Consolidated Copper Company." *The Mining Congress Journal:* 523, 524.

Flotation experiments began at C&H in 1916, though the flotation plant did not open until 1918. Flotation worked by regrinding the tailings to a finer particle size, and then floating the copper particles with a chemical mixture, which induced the copper to adhere to air bubbles introduced into the pulp. A frothing agent, which at C&H was usually pine oil, retained the bubbles on the surface until the copper-laden froth was skimmed off.[24] When flotation was being developed, C&H jumped on the opportunity to reclaim its sands by this method and was doing experimentation and trying to get patents as early as 1915.[25] The chemicals used in the flotation and leaching processes include the xanthates, pine oil, and ammonia, which were some of the waste products emptied into Torch Lake. The regrinding plants, leaching plant, and flotation plant were located in Lake Linden and became the Lake Linden Reclamation Plant. Figure 6 shows the Total Percentage of Michigan Copper Output from 1871 to 1946.

[24] R. Hess, "1952 Industrial Wastes Forum." *Sewage and Industrial Wastes* 25 no. 6 (Jun 1953): 706-728; Arthur Taggart, "Research in Flotation." *American Scientist* 35 no. 1 (Jan 1947): 85-94; Benedict, *Lake Superior Milling Practice*; C&H Annual Reports. Michigan Tech Archives.

[25] "Flotation Process," MS-002, Box 48 Folder 580, Michigan Tech Archives.

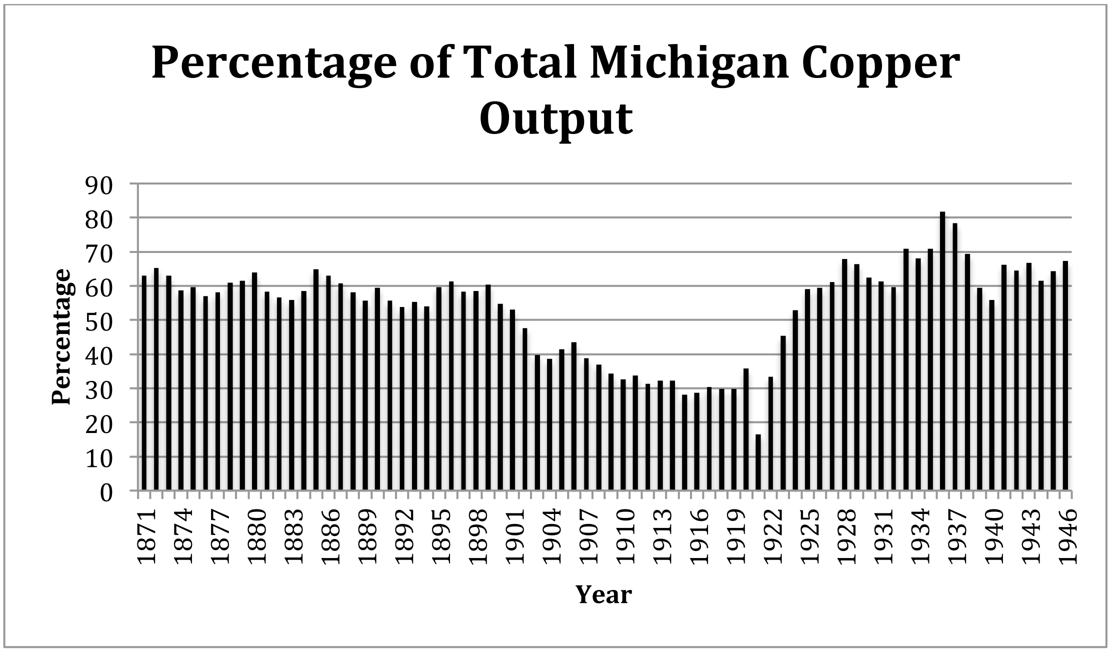

Figure 6: Table showing the percentage of Michigan Copper coming from C&H between 1871 and 1946. Adapted from Michigan Copper and Boston Dollars, 1951 by Gates, page 230.

Though C&H was seeing growth, it still had its struggles. In the mines, workers began to strike, particularly in 1913, because of the working conditions and wages, and this caused a few shutdowns throughout this time period. Also, the large western mines were starting to take over the copper scene by producing more mineral than the Michigan mines. This, combined with the wars and Great Depression, made C&H look to other means of copper acquisition besides what was underground. It knew it needed more copper to produce a profit, and were going to do everything it could to get it.

Before 1920, the venture into secondary copper was still considered risky. C&H believed that it could recover enough copper from the tailings and rock yet to be stamped to make it profitable, but many others were not quite sure. A value of

$4,150,000 was put on the reprocessing of its tailings, according to its first consolidation, and in the end it proved to be much more successful than C&H had thought.[26]

After a few years of successful reprocessing, C&H decided to open up another reclamation plant near the old Tamarack Mill. Opened in 1925, the Tamarack Reclamation plant reprocessed the stamp sands from the Ahmeek, Tamarack, Lake Milling and Smelting, and Osceola mills. C&H had been planning for another reclamation plant located near the old Tamarack Stamp Mill in Hubbell because of its successes in the Lake Linden Reclamation Plant (see Figure 7). In 1920 the foundations were laid and it was processing by 1925.[27]

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[26] "Reclamation Plant Closing After Thirty Years of Operation," *Calumet and Hecla News & Views*, October 1948, 1. Michigan Tech Archives.
[27] C&H Annual Reports, Michigan Tech Archives; C&H Annual Reports (1920 & 1925), Michigan Tech Archives.

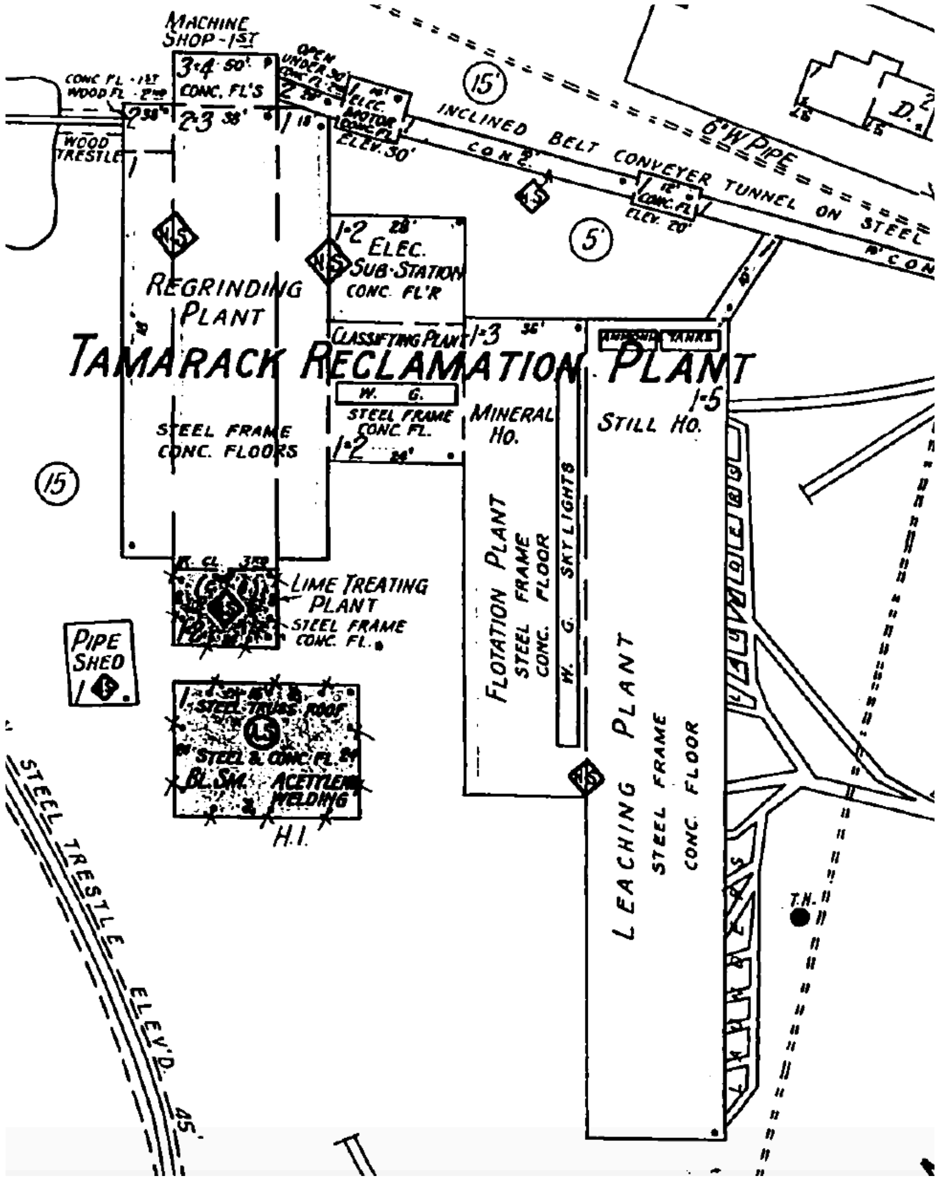

Figure 7: 1935 Sanborn of Lake Linden #14 showing the Tamarack Reclamation Plant. Courtesy Michigan Tech Archives and Copper Country Historical Collections.

These reclamation plants made a significant impact on the amount of copper that C&H produced. Figure 8 shows production numbers for both mining and reclamation roughly every five years, beginning in 1894 and ending in 1959. Though the reclamation plants were closed in 1934 because of the struggles from the Great

Depression, it gives a representation of the significance of reclamation, particularly in 1929 and 1940.[28]

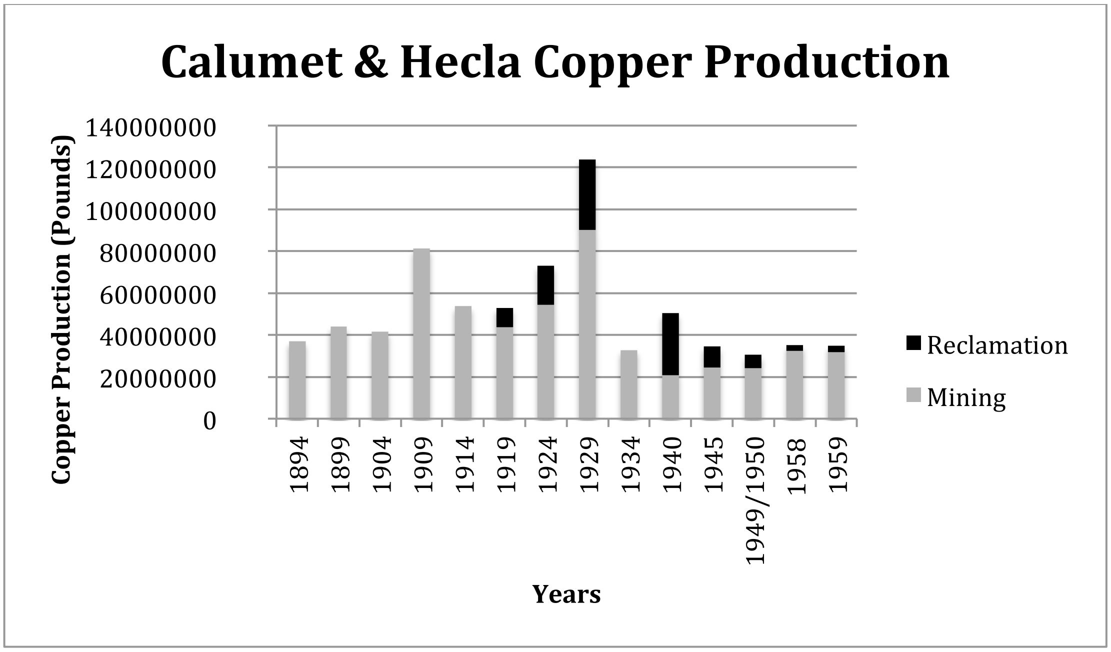

Figure 8: Table showing the C&H copper production in pounds for both underground mining and reclamation. Source: C&H Annual Reports, Michigan Tech Archives.

The Great Depression was starting at the beginning of the 1930s and this would take its toll on the copper industry on the Keweenaw. Most of the smaller mining companies, if they were still around, closed their doors, and Quincy and C&H had to reduce their operations to save money. Copper prices were at rock bottom and C&H was forced to close many facilities. Both reclamation plants were closed from 1931 until the Lake Linden Reclamation Plant reopened in 1935, and the company as a whole closed for a short period in 1931.[29] By 1932, some C&H mines were producing again, but the reclamation facilities were still not in operation. When the

[28] C&H Annual Reports, Michigan Tech Archives.
[29] C&H Annual Report (1931), Michigan Tech Archives.

Lake Linden Reclamation Plant re-opened in 1935, it produced 9,118,000 pounds of copper. Both of the reclamation plants were running by 1937, and the total amount of copper reclaimed that year was 20,398,000 pounds.[30] When the plants were running again and the copper price was leveling out, C&H decided it needed to expand its secondary processing program even further. The next step in the secondary copper story was scrapping copper-containing materials and the making of copper chemicals.

The additions of flotation and leaching, and then scrapping and chemicals, added to the C&H secondary copper repertoire. The secondary copper processes were highly reliant on machines and only needed a few people to supervise the processes, and between 1909 and 1939, employment in the Lake Superior Copper District fell from 19,000 to 3,200. This was because companies were being more selective about the specific rock it mined, and because reclamation could process more copper with less people.[31]

C&H had been experimenting with processing scrap copper and copper chemicals since the early 1930s. Processing scrap was not new, as companies had been scrapping copper since the 1920s.[32] Being able to take scrap materials and separate the copper from other base metals meant that C&H could truck in scrap at a reduced cost, reprocess it by leaching, re-smelt it, and sell it at a lower price than what it would cost if it was to get it through underground mining. C&H trucked in

[30] C&H Annual Report (1937), Michigan Tech Archives.
[31] William Bryam Gates, *Michigan Copper and Boston Dollars* (Cambridge, MA: Harvard University Press, 1951), 145 & 154.
[32] C&H Annual Reports, Michigan Tech Archives; Gates, *Michigan Copper and Boston Dollars*, 147.

Revereware, motors, wires, and various copper-containing items to be scrapped. At C&H, the materials were sorted, the non-copper metals were separated from the copper through leaching, and the copper was re-smelted to make it usable. Another aspect of scrapping was the reuse of material from the old facilities owned by C&H. These included the Osceola Mill (as seen in Figure 9), which was scrapped in 1941, and the Lake Milling, Smelting, & Refining Mill, which was liquidated in 1945.[33]

Figure 9: Photograph of the Osceola Stamp Mill, 1911. Photograph No. MTU Neg 00158, "Osceola Mill." 1911. Roy Drier Photographic Collection. Michigan Tech Archives & Copper Country Historical Collections. http://digarch.lib.mtu.edu/showbib.aspx?bib_id=605365#. Accessed 7/20/16.

[33] C&H Annual Reports, Michigan Tech Archives; "Scrap Drive Continues," *Calumet and Hecla News & Views*, Michigan Tech Archives, June 1943, 4; "Quincy Reclamation Plant at Mason To Be In Production Very Soon," *Calumet and Hecla News & Views*, September 1943, 1; "Tons of Scrap Steel Have Been Salvaged," *Calumet and Hecla News & Views*, October 1943, 4.

Besides scrap processing, C&H also developed copper chemicals. C&H helped found the Lake Chemical Company, which would use copper not suitable for making ingots into chemicals such as copper oxide and copper hydrate (see Figure 10).[34]

The only mill that remained open into the 1950s and beyond was the Ahmeek Stamp Mill, located between the C&H Smelter Complex and the second C&H reclamation plant at Tamarack. In 1951 there were only seven C&H mines in production while both reclamation plants were still operating. Smelter activities decreased along with underground mining, and by 1967 there were only three mines still producing: the Centennial #6, Kingston, and Osceola. To help offset the losses from the lack of underground mining, C&H decided to ship in more copper scrap material to reprocess.[35] These scraps, along with the copper it was receiving from the flotation and leaching, were enough to carry C&H into the 1960s. Its chemical division was able to take low-grade copper and transform it into useable products for a variety of uses.

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[34] "Calumet & Hecla and Cleveland Firm Organize A New Company – Will Manufacture Chemical Products," *Calumet and Hecla News & Views*, October 1945, 1; "New Product, Copper Hydrate, Ready for Production Soon – Percy Rowe Develops Important Process," *Calumet and Hecla News & Views*, June 1945, 1.

[35] C&H Annual Reports, Michigan Tech Archives; C&H Annual Report (1951), Michigan Tech Archives; C&H Annual Report (1967), Michigan Tech Archives; "Smelter Scrap," MS-002, Box 86 Folder 20, Michigan Tech Archives.

Figure 10: Photograph of the Lake Chemical Company storing Copper Hydrate. Photograph No. MS003-002-001-04, "Calumet & Hecla - Lake Chemical Company." Date unknown. Calumet and Hecla Photograph Collection. Michigan Tech Archives & Copper Country Historical Collections. http://digarch.lib.mtu.edu/showbib.aspx?bib_id=686561#. Accessed 7/20/16.

The C&H Lake Linden flotation plant closed in 1953 along with the majority of the other Lake Linden reclamation facilities except the leaching plant. This plant remained open to finish processing any scrap that was still coming in. The C&H Tamarack reclamation plant shut its doors, along with the entire C&H chemical division, in 1956. In 1968 C&H was sold to Universal Oil Products and it became known as the Calumet Division.[36] UOP tried to revamp the facilities but eventually saw it as a losing battle. Very little copper was being produced by the mines and, with

[36] C&H Annual Report (1953), Michigan Tech Archives; C&H Annual Report (1956), Michigan Tech Archives; C&H Annual Report (1968), Michigan Tech Archives.

the reclamation plants already shut down, there was little they could do to keep the division without losing profits. The Lake Linden leaching plant, Ahmeek stamp mill, smelter, Centennial #6 Mine, Kingston Mine, and Osceola Mine were all permanently closed on April 8, 1969.[37] After UOP left and the land sat vacant for a few years, the beginnings of the environmental effect started to be seen, which would lead to years of research and remediation efforts.

C&H was a large part of the Torch Lake landscape for about 80 years until it was finally closed in 1969. The local communities struggled financially as their main source of employment disappeared. The once loud and bustling western shore of Torch Lake turned into an industrial graveyard. Buildings were torn down, machines were packaged up and sold, and the remaining landscape was very much changed from what it had been in the late 1800s (see Figure 11). Almost fifty years later, there are still industrial remains pointing at what the Torch Lake shoreline once was, along with pollution that is affecting the local ecosystems.

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[37] Universal Oil Products Annual Report (1969), Michigan Tech Archives.

Figure 11: Photograph of ruins of the C&H Smelter.

Chapter 3 – Copper Processing
(Milling, Smelting, Reclamation, & Secondary Copper Processing)

Torch Lake became home to not only C&H stamp mills, but also its reclamation plants and secondary copper processing facilities. As C&H began to expand along the Torch Lake waterfront, it bought some of the other stamp mills from smaller mining companies. After being bought C&H closed most of the mills, with the exception being the Ahmeek Stamp Mill. The Ahmeek Mill was used by C&H until its closure in 1969. C&H had two reclamation plants: one at Lake Linden and one at Tamarack. These were an integral part of the C&H story, allowing the company to produce more copper than just relying on its underground mining. When the US entered WWII, the demand for copper quickly increased. C&H responded by developing two means of secondary copper processing: scrap and chemicals. These technological diversifications allowed the company to remain in business even as its mining production waned.

Milling

Beginning in 1880 several copper concentrators operated along the western shoreline of Torch Lake, including (from north to south) the two C&H mills, the Ahmeek Mill, the two Tamarack Mills, the Lake Milling, Smelting and Refining Mill, the Osceola Mill, and the two Quincy Mills. Quincy was the largest company on the lake besides C&H and operated on the southern end of the lake in Mason. North of Mason is Tamarack City where the Lake Milling, the Osceola, the Tamarack, and the

Ahmeek stamp mills were located. The Osceola and Tamarack Mining Companies were eventually purchased by C&H after the turn of the twentieth century.[38]

In total, around 200 million tons of tailings were deposited into Torch Lake during the life of these mills.[39] Tailings were just one type of waste product that was deposited in the lake. Other wastes included slag from the smelter, ash from the boilers, and eventually chemicals that would be used in the reclamation facilities later in the 1900s.

The first Calumet Mill was located in Calumet. It was built during the 1860s. The first Hecla Mill, however, was built at Lake Linden and was processing by 1868. The Calumet and the Hecla mining companies were separate entities until the consolidation of 1870. It was then that the new Calumet & Hecla Mining Company decided to move the old Calumet Mill close to the Hecla Mill, allowing for all stamping to be done in one location (see Figure 12).[40]

[38] C&H Annual Reports, Michigan Tech Archives.
[39] Joel Fett, et al, "Geochemically Fingerprinting Spatial and Temporal Recovery of a Highly Anthropogenically Disturbed Lake: Torch Lake, (Upper Peninsula) Michigan, USA," Michigan State University, 1.
[40] Benedict, *Red Metal: The Calumet and Hecla Story*, 41, 66, 71, 83.

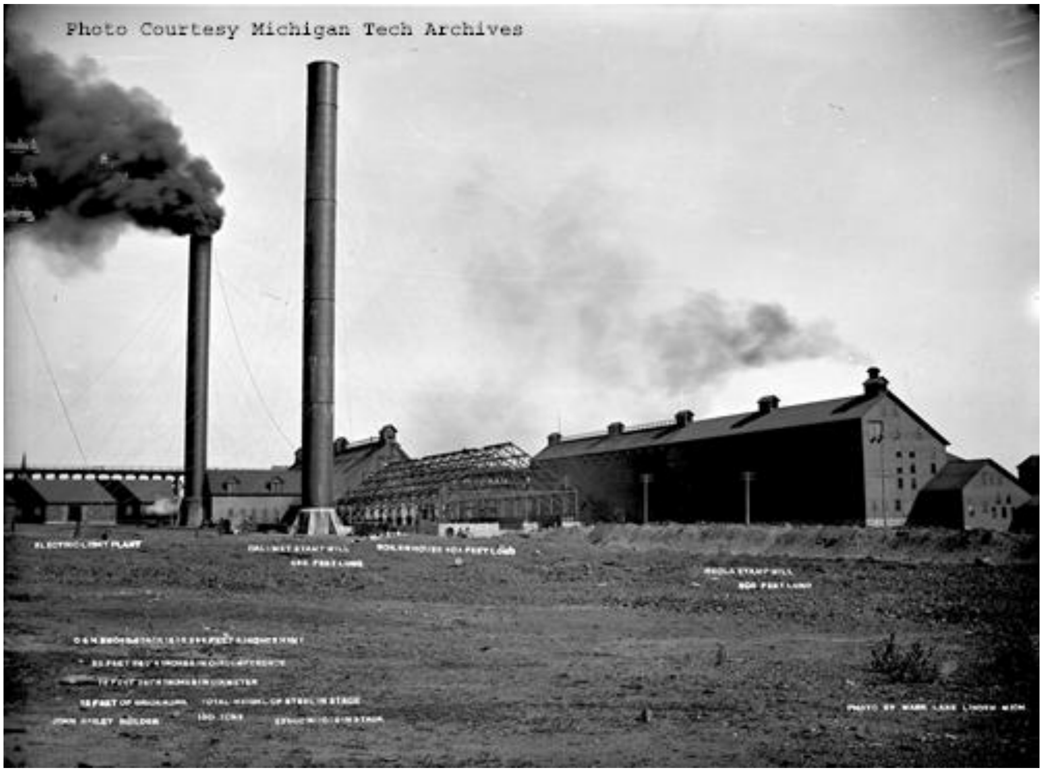

Figure 12: Photograph of the C&H Stamp Mills. Photograph No. MTU Neg 00451, “Mills - C & H Mill.” Date unknown. Roy Drier Photographic Collection. Michigan Tech Archives & Copper Country Historical Collections. http://digarch.lib.mtu.edu/showbib.aspx?bib_id=612748#. Accessed 7/20/16.

The Calumet Stamp Mill ran from the 1870s until 1944 when it was closed. The Hecla Mill ran from 1868 until 1921. The structure was partially dismantled in 1924, with the remaining equipment and structures taken down in 1940. Both of these mills followed the transition of stamp evolution that will be described later in this section.

The Ahmeek Mill was built and began operating around 1910 (see Figure 13). It was bought by C&H in 1923 and operated for more than four decades before it was closed in 1969. In order to improve the mill, C&H did a complete renovation around

1930 and had the mill processing again by 1931.[41] A more thorough history of this mill will follow.

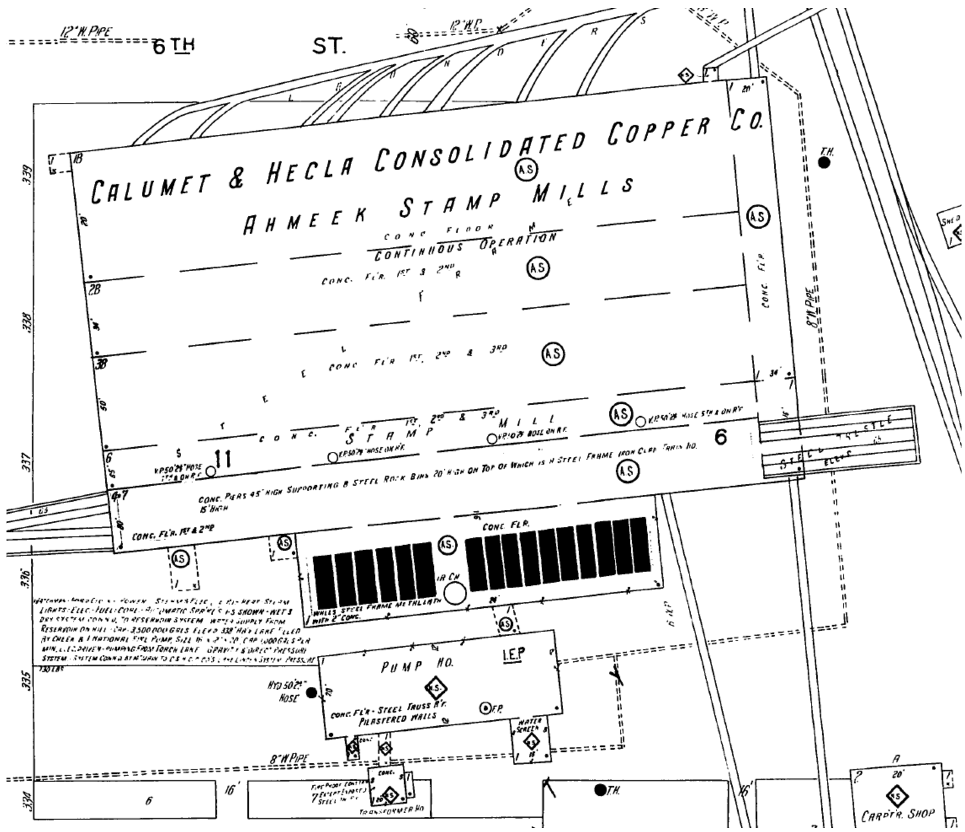

Figure 13: 1928 Sanborn of Lake Linden #13 showing the Ahmeek Stamp Mill facilities. Courtesy Michigan Tech Archives and Copper Country Historical Collections.

The Tamarack Stamp Mill was built in 1887 and closed in 1919. C&H gained ownership of the mill in 1917 when the Tamarack Mining Company went out of

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[41] C&H Annual Reports, Michigan Tech Archives.

business.[42] C&H decided to close this mill shortly after taking control and instead use the land to build its second reclamation plant.

The Tamarack #2 Stamp Mill, also referred to as the Lake Milling, Smelting & Refining Co. #2 Mill, was built in 1898. It was purchased by C&H in 1923. It was closed by C&H in 1930 and was finally scrapped in 1947.[43] Over this site, C&H built its Lake Chemical Warehouse where it stored copper chemicals, which will be discussed later in this chapter.

The Osceola Stamp Mill was built in 1899. C&H purchased this mill in 1910 and kept it running for ten years.[44] The mill was closed by C&H in 1921 and the structure was scrapped in 1941.

The first basic milling process included breaking up rock into workable pieces by roasting it and then dumping cold water on it. This fractured the rock and made it easier to break apart. The next form of stamping, which happened in the Keweenaw as early as the 1850s at the Cliff Mine, came in the form of gravity stamps. The gravity stamps used a means of energy, human, animal, water, or steam, to lift the stamp heads, which would then be released to fall onto the rock, which broke it up. This was not a very efficient means of stamping, as energy was lost during the fall. [45]

The first Ball steam stamp was used before the C&H merger in 1967 at the Calumet stamp mill, which was much more efficient than the gravity stamp (Figure

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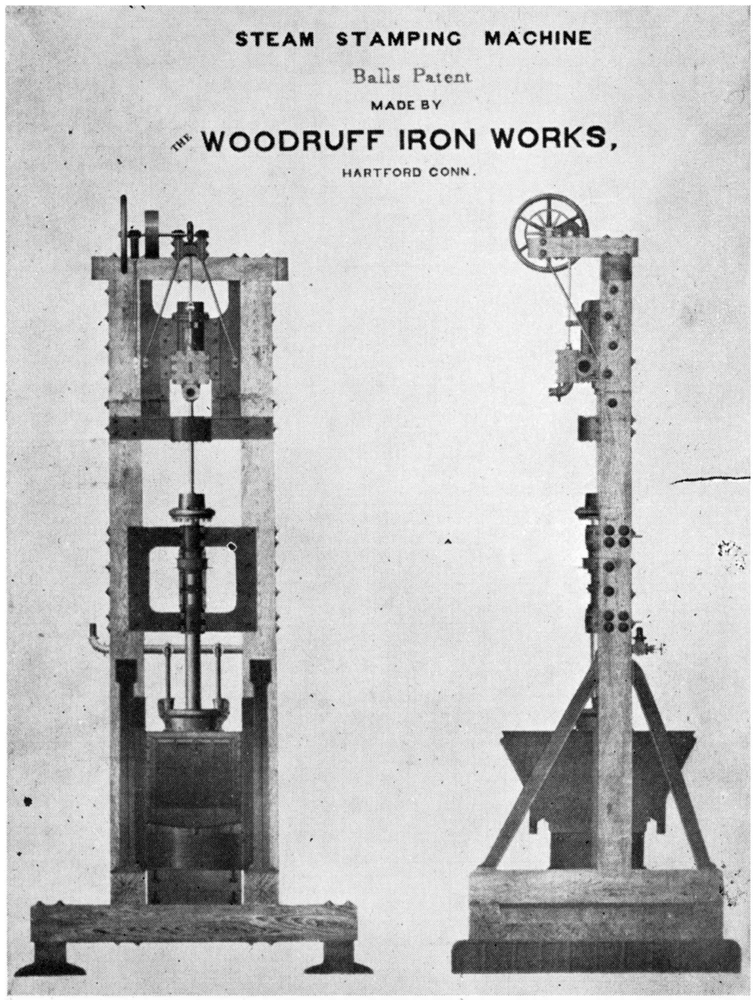
[42] Ibid.
[43] Benedict, *Red Metal: The Calumet and Hecla Story*, 162; C&H Annual Reports, Michigan Tech Archives.
[44] C&H Annual Reports, Michigan Tech Archives.
[45] Benedict, *Red Metal: The Calumet and Hecla Story*, 42.

14).[46] This stamp would not only use power to lift the head up, but also to increase the force of the downward stroke in order to increase the volume of rock that could be broken. These were the stamps originally installed in the Hecla Mill on Torch Lake. A single Ball stamp could crush 100 to 120 tons of conglomerate rock per day.



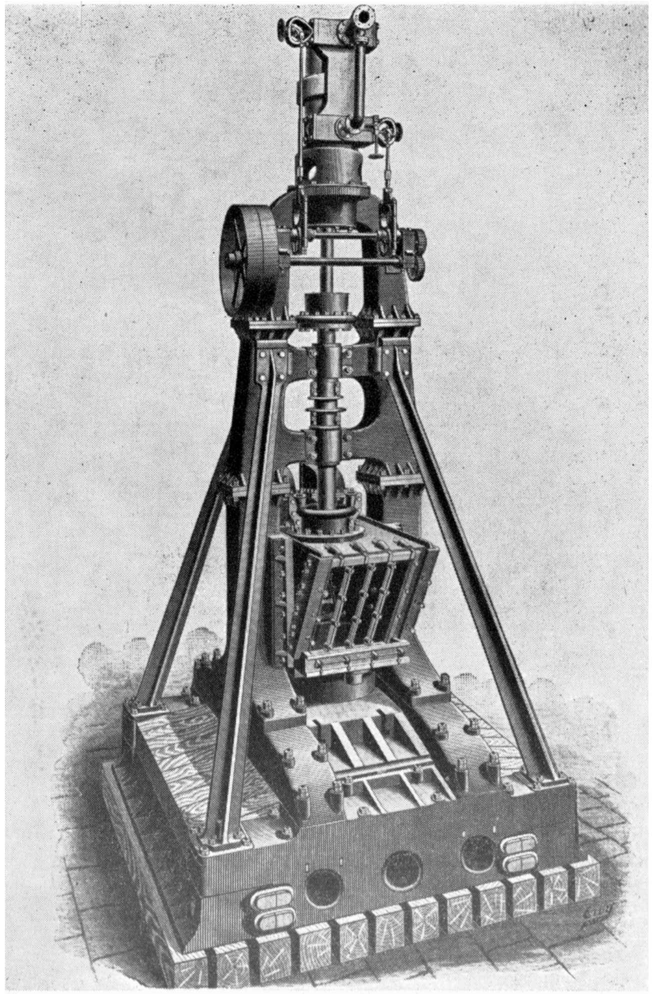
The Ball Stamp (*circa* 1875)

Figure 14: The Ball Steam Stamp. Source: Benedict, Lake Superior Milling Practice, facing page 58.

[46] Ibid*,* 65.

However, by 1900, a new steam stamp would take its place. The Leavitt stamp replaced the Ball stamps at both the Calumet and the Hecla mills on Torch Lake. This increased the capacity of a single stamp to 325 tons of conglomerate rock per day.[47] The next iteration of the steam stamp was the Allis (Figure 15). The Allis steam stamp was used in the Torch Lake mills except the Calumet and the Hecla around 1900.[48] Several machinery companies were producing steam stamps and competed for business. While some mills, like the Calumet and the Hecla, used the Leavitt, some also used the Allis-Chalmers stamps.

[47] Ibid, 83.
[48] Benedict, *Lake Superior Milling Practice*, 60.



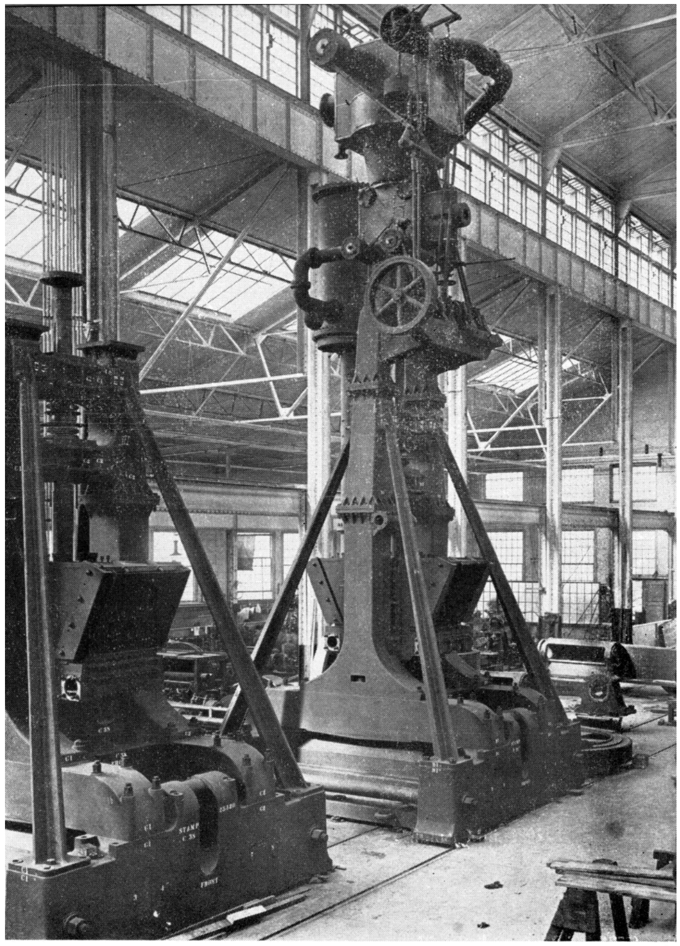
The Allis Stamp (*circa* 1884)

Figure 15: The Allis Steam Stamp, circa 1884. Source: Benedict, Lake Superior Milling Practice, facing page 60.

The most impressive steam stamp in the area was called the Nordberg Compound Steam Stamp (Figure 16). This stamp replaced both the Leavitt stamps in the Calumet and the Hecla and the Allis stamps in the other Torch Lake mills.[49] One important part of the steam stamps is that by 1914, companies had figured out how to

[49] Ibid.

use the steam exhaust. They used this exhaust to turn a low-pressure turbine, which would create a source for power.[50] This subject will be revisited in Chapter 4.



The Nordberg Compound Stamp

Figure 16: The Nordberg Compound Steam Stamp. Source: Benedict, Lake Superior Milling Practice, facing page 61.

Apart from the stamps themselves, other machines were used in the milling process. This pattern is how the copper was separated from the ore at the Calumet Mill in 1907 (see Figure 17). First, the rock was crushed by a series of stamps. Second, it was sorted via classifiers, which did just that: classify the material and separate it by

[50] Ibid, 62.

size. The coarser material would be reground in Chilean mills, which was the mill of choice for C&H for fine grinding. Third, it was run through a series of jigs, which were oscillating sluices that separated the heavier copper from the lighter rock. The fourth and final step was to send the fine copper-bearing material over Wilfley tables. These tables allowed C&H to recover copper from very finely ground material, or slimes. As the slimes flowed across a table, the rock washed off to waste, and fine copper particles settle onto the table.[51] Once the copper was in its most concentrated form, it was then sent via rail to the smelter.

[51] Ibid, 73; Benedict, *Red Metal: The Calumet and Hecla Story*, 85, 49, 51.

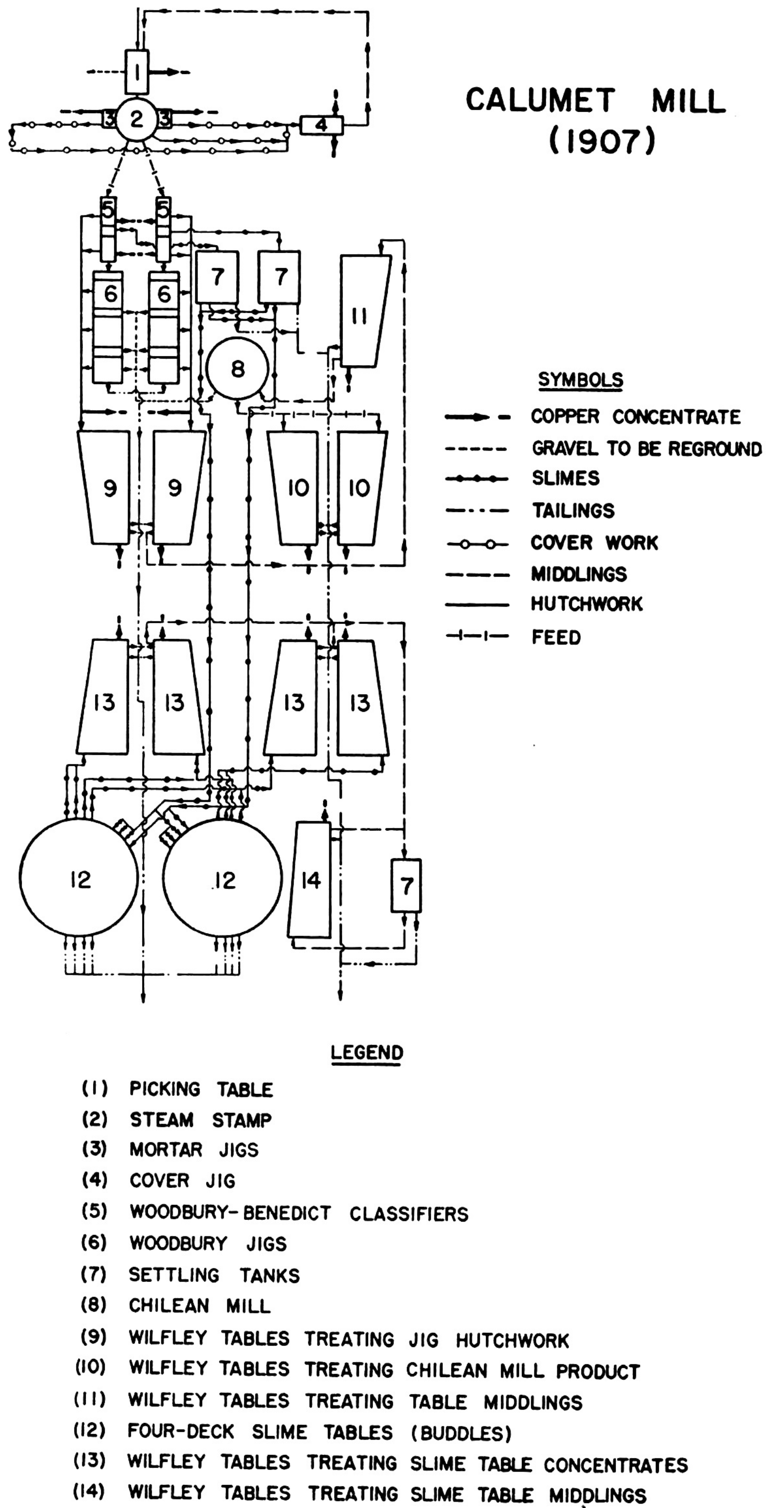


Figure 17: Calumet Mill Flow-Sheet, circa 1907. Source: Benedict, Lake Superior Milling Practice, 50.

The Ahmeek Stamp Mill was the only mill operating after 1944 (see Figure 18). This meant that C&H needed to keep this mill up-to-date on the latest technology. In 1955, the Ahmeek Mill had Nordberg steam stamps. The stamp shoes needed to be replaced every 8 to 12 days as they wore down from 835 pounds to 600 pounds. After being stamped, the rock and copper passed over Dorr classifiers and jigs. The material would then be ground even further with the use of a Ball stamp, then run through a Wilfley table or another Dorr classifier, depending on the size of the slimes. The final process was to use flotation to try and retrieve any remaining copper in the rock.[52] The flotation process will be discussed in more detail later in this chapter.

[52] Benedict, *Red Metal: The Calumet and Hecla Story*, 124, 125.

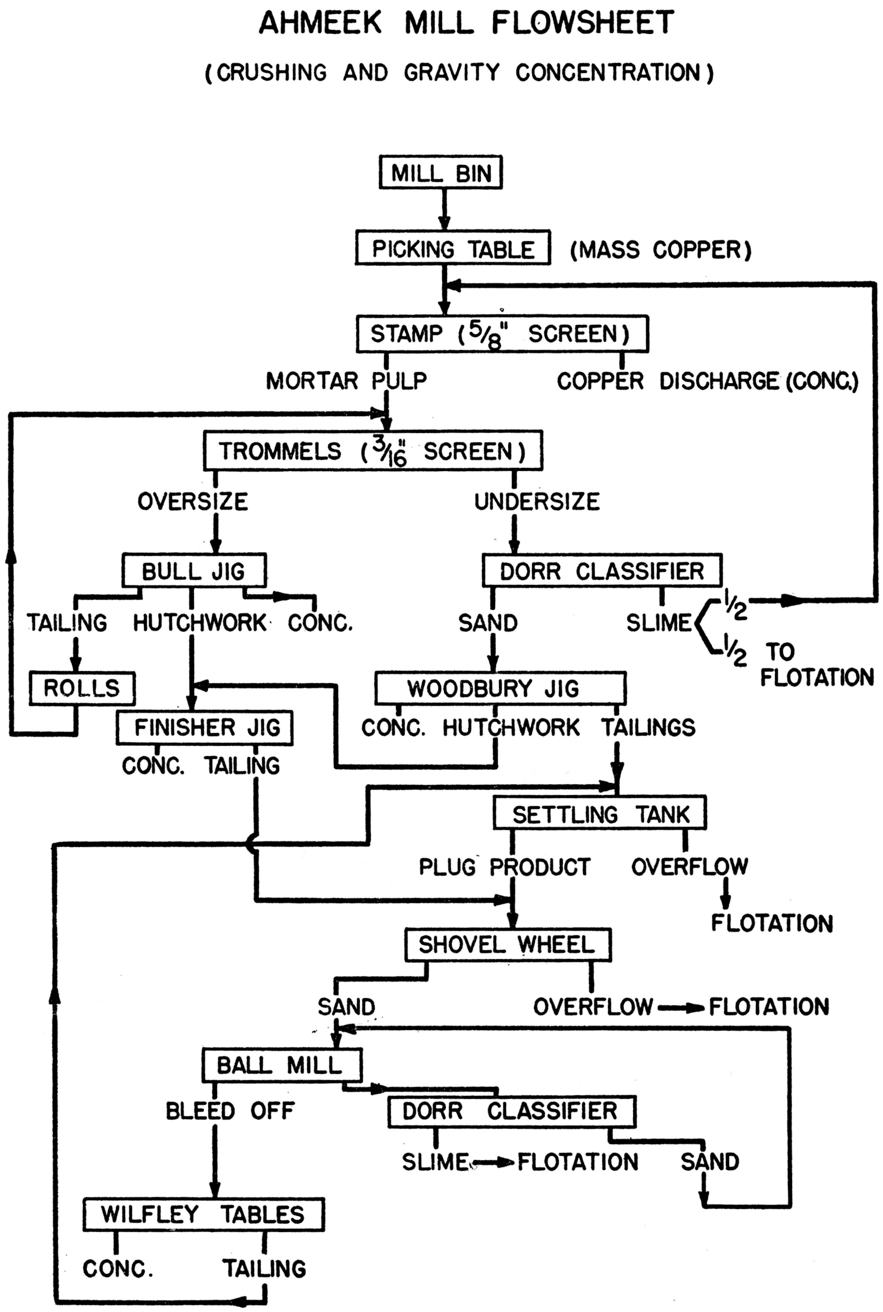


Figure 18: Ahmeek Mill Flow-Sheet. Source: Benedict, Lake Superior Milling Practice, 126.

Milling had its own waste items, of which the main one is stamp sand tailings. However, there were other waste materials coming from the mills. According to a

C&H document, all of the wastes from the milling process were disposed of into Torch Lake, which meant that they did not have to pay for additional disposal costs.[53] This statement, from a 1957 cost study, shows that C&H was trying to be as cost effective as it could in its last years. However, what the company did not quite know at the time was how harmful all of the waste materials could be to the environment. Waste from the stamp mills contained more than just poor rock and copper; many other chemicals can be found in the rock itself, such as arsenic and mercury, as well as chemicals that get added to the stamp sand as it is processed.

Types of Copper in the Lake District

It is important to understand that not all copper-bearing rock is made equal, and in turn, not all copper is found in the same types of rock. There are three distinct types of copper-bearing rock in the Keweenaw Peninsula: mass – where the molten copper seeped into large holes within the rock and formed pure copper chunks (Figure 19);

[53] "Report on Copper Bearing Brick and Ash Residues at Smelter," MS-002, Box 524 Folder 21, Michigan Tech Archives.

Figure 19: Mass copper at the Ahmeek Mine, circa 1915-1916. Photograph No. MS003-25A-129, "Ahmeek Mine." 1915/1916. Calumet and Hecla Photograph Collection. Michigan Tech Archives & Copper Country Historical Collections. http://digarch.lib.mtu.edu/showbib.aspx?bib_id=607698#. Accessed 7/20/16.

amygdaloid – where the copper would form in the little gas bubbles in lava and small, almond-shaped deposits of copper would be left (Figure 20);

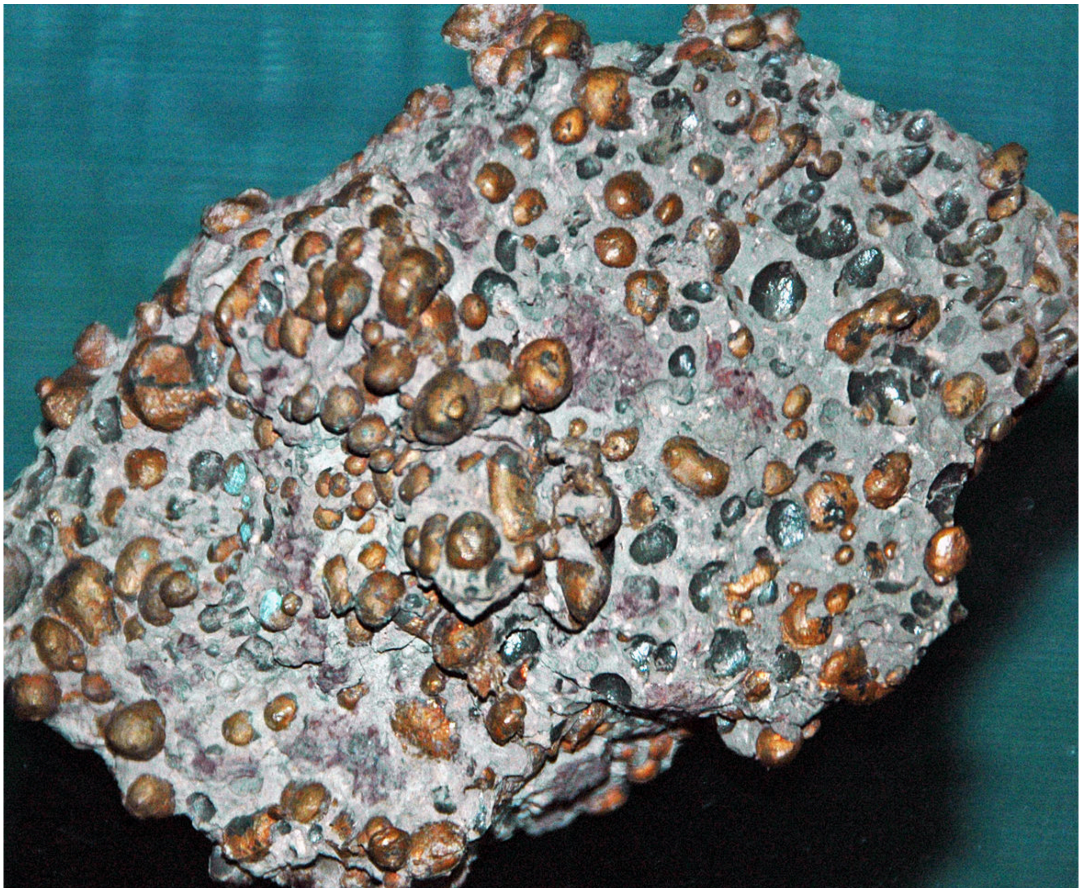


Figure 20: Amygdaloid copper rock. Source: flickr user James St. John: Cupriferous amygdaloidal basalt (Mesoproterozoic, 1.05-1.06 Ga; Wolverine Mine, Kearsarge, Upper Peninsula of Michigan, USA).

and conglomerate – where sedimentary rock, located on top of the earlier lava flows, would form, and the copper would form in the little gaps between the particles (Figure 21).[54]

[54] Lankton, *Cradle to Grave*, 5.

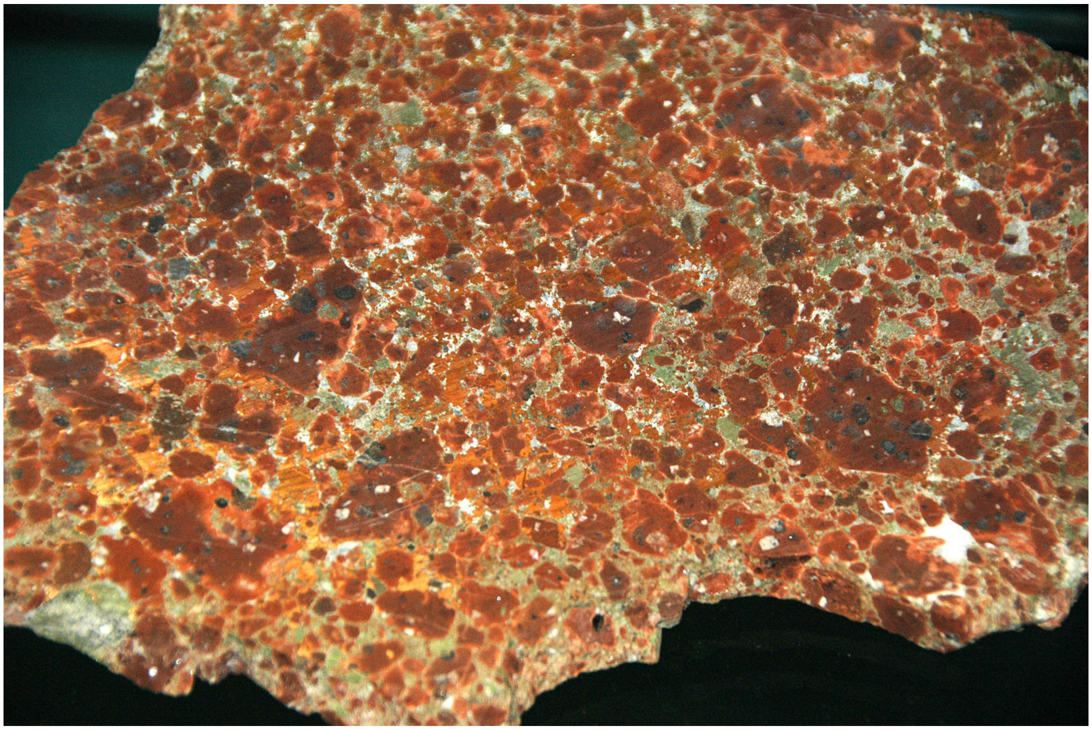


Figure 21: Conglomerate copper rock. Source: flickr user James St. John: Cupriferous felsite conglomerate (Mesoproterozoic; Kingston Mine, Keweenaw County, Michigan, USA).

In order for C&H to be the most efficient, it needed to find out which processes were the most efficient for treating the two types of copper found embedded in its mines' rock: amygdaloid and conglomerate. One such method was adjusting the heights of the stamp shoes so that the pattern they stamped was the best for freeing the copper from the rock.

Smelting

The C&H smelter was opened on Torch Lake in 1887 and closed in 1969. According to C&H Annual Reports, the smelter covered about thirty acres by 1893

(see Figure 22).[55] The C&H smelter had a reverberatory furnace building, which had its own brick stack. Inside this main building were four separate furnaces made from brick and fireclay, which would withstand the high heat produced in the furnace. The heat was produced by burning coal in a firebox, which was sectioned off from the mineral melting area so the coal would not contaminate the copper.[56]

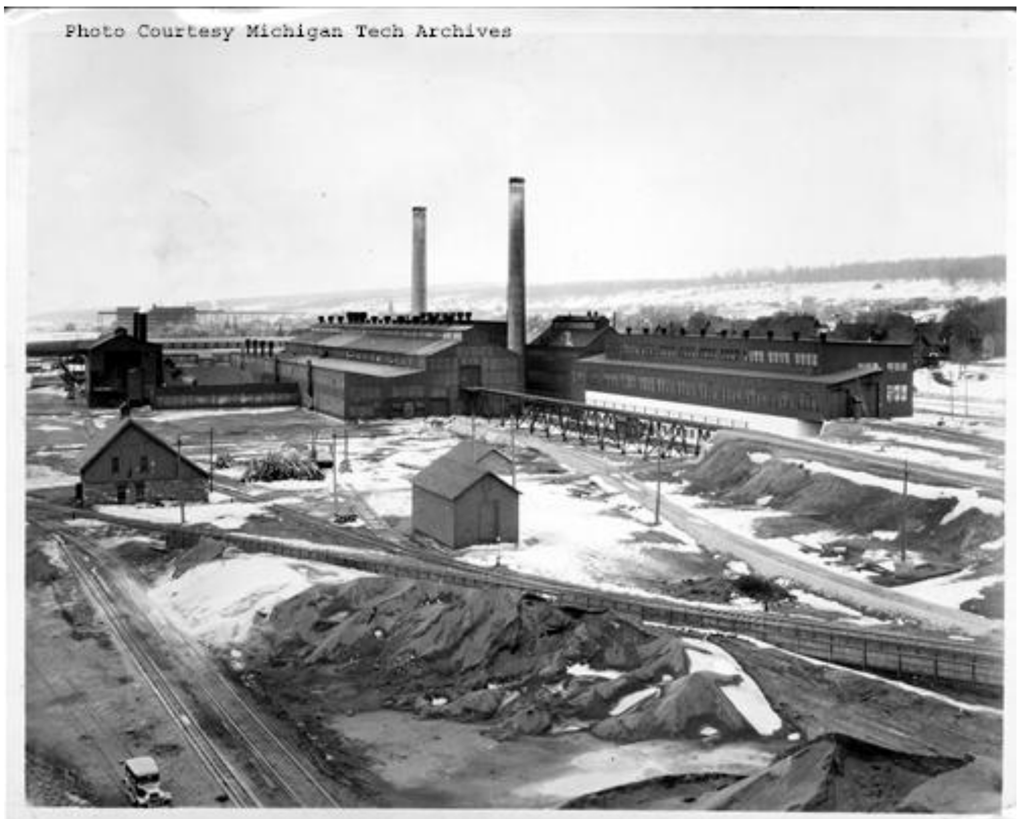


Figure 22: Photograph of the C&H Smelter. Photograph No. MS003-001-006-003, "Calumet & Hecla Smelter." Date unknown. Calumet and Hecla Photograph Collection. Michigan Tech Archives & Copper Country Historical Collections. http://digarch.lib.mtu.edu/showbib.aspx?bib_id=620702#. Accessed 7/20/16.

Smelting in the Keweenaw did not have to take apart copper compounds as it did in the case of copper sulfide ores. This meant that the Keweenaw copper was

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[55] C&H Annual Reports, Michigan Tech Archives.
[56] Lankton, *Cradle to Grave*, 12.

smelted by merely melting the material in order to separate the pure copper from the small pieces of rock that still mechanically adhered to the copper. Keweenaw copper was put into the furnaces to be heated to its melting point when the slag, or impure material, was skimmed off the surface and discarded. The molten copper was then stirred to allow any further impurities to oxidize. Adding hardwood poles into the copper then eliminated this oxygen. The wood would burn and the carbon, combined with the extra oxygen, would escape through the stacks. Slag was skimmed off one more time before the copper was hand-ladled into casts, where it was allowed to cool to a solid form. The copper was mainly formed into ingots and cakes before being shipped out to manufacturers across the country.[57]

By the 1920s, new smelting technologies changed the layout of the furnace building. Instead of four smaller furnaces, it now housed two larger ones; one furnace was used for melting the copper and completing the first slag skim, where it would then enter the other furnace where it would be stirred and refined before being mechanically ladled into the ingot or cake casts.[58]

The slag produced by the smelting process would be dumped near the smelter site or taken away by slag cars to a waste slag dump near the lake.[59] Because C&H produced so much slag, there were many slag dumps and remnants scattered across the landscape. One of its slag dumps is still located on Trap Rock Road and the other

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[57] Ibid, 12.
[58] Ibid, 250.
[59] "Smelter Flow Sheets," MS-002, Box 86 Folder 22, Michigan Tech Archives.

between the smelter and a local beach (see Figure 23).[60] In 1925 C&H was disposing about 130 tons of waste slag per day. Some of the elements released into the environment with the slag included calcium, silicon, copper, aluminum, and lead.[61]

Figure 23: Photograph of Smelter Slag at the Trap Rock Road dumpsite.

The slag located near the Hubbell smelter was of interest to many people for about a decade after the company closed. Companies as well as Michigan Technological University did experiments in the 1980s not to test the toxicity of the slag, but to see if it would be possible to leach any further copper out of the slag.[62]

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[60] Jean Butler (Hubbell resident), in discussion with the author, May 2014.
[61] "Slag-Disposal," MS-002, Box 127 Folder 30, Michigan Tech Archives; "Project # 1920 (Copper Recovery from Slag and Tailings)," MS-002, Box 164 Folder 3, Michigan Tech Archives.
[62] "Slag Leaching Process," MS-002, Box 571 Folder 6, Michigan Tech Archives.

This continued into the 1980s and onward at a company located in the old C&H electrolytic plant, which was named Peninsula Copper Industries (PCI), in which Michigan Tech acquired stock in 1983.[63] Workers would leach the slag and other copper-bearing material in order to collect any copper that may remain.

Reclamation

By 1900, many of the smaller copper mines in the Keweenaw had closed. Those that remained would need to have efficient operations in order to succeed. C&H and Quincy were already established by the turn of the twentieth century, and the Copper Range Mining Company would soon become the third great mining company in the Keweenaw. These three companies would make it through World War I, the Great Depression, and World War II. Of these, C&H saw the most prosperity and used more new technologies and processes than the other Keweenaw mining companies to change the way it acquired copper. Before 1930, the beginning date for the appearance of PCBs, C&H had opened a flotation plant, leaching plant, regrinding plants, and a coal pulverization plant.[64]

Not only did it open its own facilities, but it also bought other mining companies and added their facilities to its own. These would include the Ahmeek, Tamarack, and Osceola. It bought Tamarack in 1910 and remodeled the stamp mill, but decided to close the mill in 1919. However, C&H did take advantage of the Tamarack property and began erecting a reclamation plant next to the abandoned mill,

[63] "Michigan Tech Ventures," Copper Country Vertical File, Michigan Tech Archives.
[64] C&H Annual Reports, Michigan Tech Archives.

which became operational in 1925 (see Figure 24). C&H purchased Ahmeek in 1923 as well and over the next few years C&H would upgrade the milling equipment. Finally, C&H bought Osceola in 1923 and operated the mill until the late 1930s.[65]

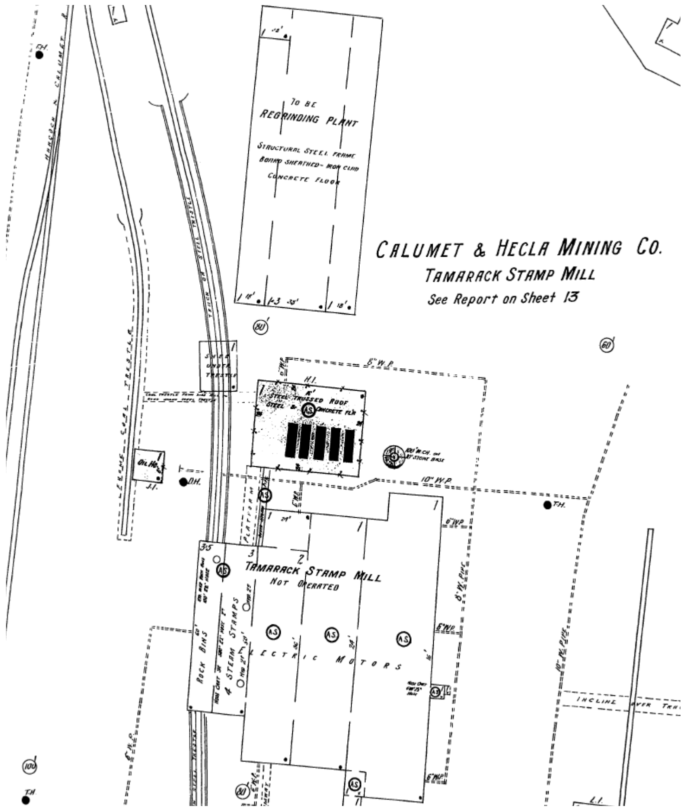

Figure 24: 1917 Sanborn of Lake Linden #12 showing the Tamarack Stamp Mill and future reclamation area. Courtesy Michigan Tech Archives and Copper Country Historical Collections.

New facilities added to C&H at Torch Lake after 1905 and before 1930 included the regrinding, leaching, and flotation plants, which would become known as the Lake Linden reclamation plant. This reclamation plant dredged the stamp sands that had been deposited over the years, pumped them up to the regrinding plant, ran them through chemicals in the leaching plant, where some copper would be dissolved,

[65] "Tamarack Regrinding Plant-Misc," MS-002, Box 42 Folder 10, Michigan Tech Archives; C&H Annual Reports, Michigan Tech Archives.

and then to the still house for the mixture to be distilled, or send them to the flotation plant to separate the remaining copper from the other materials.[66] These processes not only needed different chemicals, but an extensive amount of energy as well. The C&H power system will be described in Chapter 4. The development of the reclamation plant helped C&H into the second half of the twentieth century, after most of its mines had closed.

The C&H reclamation plant consisted of five separate units: the dredge, the shore-plant pump house or classifying house, the regrinding and table treatment plant, the leaching plant, and the flotation plant. The dredge was similar to a vacuum in that the stamp sands were sucked up via a 20-inch pipe and sent to the classifying house. The dredge would send 10,000 tons of tailings a day to the classifying house. The classifying house had large tanks that could hold enough tailings for the regrinding plant to be busy for 48 hours.[67] The regrinding plant would reprocess the sands through stamps, and then through the various classifying machines.

Reclamation was extremely important to the mining companies and the local communities because it meant that the mining companies would stay open for a longer period of time and this brought economic stability to the area. Lankton goes on to state "reclamation turned Torch Lake into one of the region's biggest 'mines' in the twentieth century."[68]

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[66] "Meet the Folks Who Operate the C. & H. Lake Linden Reclamation Plant," *Calumet and Hecla News & Views*, July 1944, 4.
[67] Benedict, *Lake Superior Milling Practice*; C&H Annual Reports (1966), Michigan Tech Archives; C&H Annual Reports (1915), Michigan Tech Archives.
[68] Lankton, "Keweenaw Copper: Mines, Mills, Smelters, and Communities," 51.

Regrinding technology was developed in order to re-grind stamp sands previously discarded or to grind up milled rock even further to extract more copper. Reground material could be coarse (1/4 inch) to fine (sand-like) depending on the way of stamping, a dark grey color, and contain a small percentage of copper that the mills had not been able to collect. By grinding the stamp sands up into finer particles and re-running them through stamp mill equipment and classifying machines at regrinding plants, C&H was able to regain some of the copper previously lost due to low efficiency. Its first regrinding plant was taking shape in 1907 and began operating in 1909. The second regrinding plant began producing in 1912, just in time to help support the copper needed for WWI.[69]

By 1915 C&H had installed a dredge to pump previously discarded stamp sands back to the classifying house and then into its regrinding plant to be processed once again. In 1914 C&H began building a leaching plant to help separate the copper from the rock, and this was completed in 1916. Its flotation plant was added to the reclamation plant in 1919.[70]

By the 1910s, leaching and regrinding became more common. In fact, flotation is noted as one of the most important changes in mining that took place during the early reclamation period. C&H had the benefit of an in-house researcher, C. H.

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[69] C&H Annual Reports (1906/1907 & 1909/1910), Michigan Tech Archives; C&H Annual Reports, Michigan Tech Archives.

[70] Benedict, *Red Metal: The Calumet and Hecla Story*, 191; C&H Annual Reports, Michigan Tech Archives; "Operations at Calumet Division Suspend May 1," *Calumet and Hecla News & Views*, April 1949, 4.

Benedict. Benedict engineered new techniques and processes associated with leaching and flotation and filed many patents to keep the C&H processes protected by law.[71]

C. H. Benedict was a substantial researcher in the field of leaching. He gave C&H the license to use his process and he would spend many more years at C&H perfecting the reclamation process. As a researcher for C&H, Benedict wrote several books on the subject of copper processing and patented multiple copper processing techniques, including ammonia leaching, which were of great help in my research and are still looked at as a leading source for copper mining studies. The last technology to be added to the C&H Lake Linden reclamation plant was flotation. The Lake Linden Reclamation Plant went into commission in 1915, although it did not reach its full potential until December.[72]

The Anaconda Copper Mining Company began using flotation in 1915, and this was roughly the same time that C&H installed its facilities. The Keweenaw copper did not have sulphide to react with the flotation chemicals that were used, so C&H experimented and discovered that xanthates would help them to form bubbles and have the copper float to the top of tanks so that it could be extracted.[73] Flotation allowed copper companies to see that their previous waste tailings could be profitable.

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[71] Fredric Quivik, "Of Tailings, Superfund Litigation, and Historians as Experts: U.S. v. Asarco, et al. (the Bunker Hill Case in Idaho)." *The Public Historian* 26 no. 1 (Winter 2004): 91; "Leaching Process," MS-002, Box 47 Folder 524, Michigan Tech Archives.
[72] "Reclamation Plant Closing After Thirty Years of Operation," *Calumet and Hecla News & Views*, October 1948, 1; C&H Annual Reports (1915), Michigan Tech Archives.
[73] Thomas Arthur Rickard, *The Flotation Process* (San Francisco, CA: Mining and Scientific Press, 1916), 31; Benedict, *Lake Superior Milling Practice*, 99 & 102.

The tailings would be reground, and then floated with a chemical mixture because the copper would adhere to the air bubbles. A frothing agent helped the bubbles persist when they reached the surface, much like the head on a glass of beer, and at C&H this frothing agent was usually pine oil.[74] The froth, with the copper particles, could then be skimmed from the surface.

The US Bureau of Mines was doing experiments on flotation in the 1910s, as were other laboratories. In 1928, A.W. Fahrenwald discovered that flotation could lead to the recovery of copper that would otherwise be deposited into the lake. C&H took these experiments seriously and, apart from upgrading its reclamation facilities almost every year, the new technologies influenced them into installing a new flotation plant in the Ahmeek stamp mill to try and reclaim any remaining copper directly from the milling process instead of through dredging.[75] Both the stamp mill and the flotation plant helped to recover thousands of pounds of copper until the Ahmeek complex closed with the end of the company in 1967 (see Figure 25).

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[74] Hess, “1952 Industrial Wastes Forum." *Sewage and Industrial Wastes:* 706-728; Arthur F. Taggart, "Research in Flotation." *American Scientist* 35 no. 1 (Jan 1947): 85-94; Benedict, *Lake Superior Milling Practice*; C&H Annual Reports, Michigan Tech Archives.

[75] C&H Annual Reports (1928), Michigan Tech Archives.

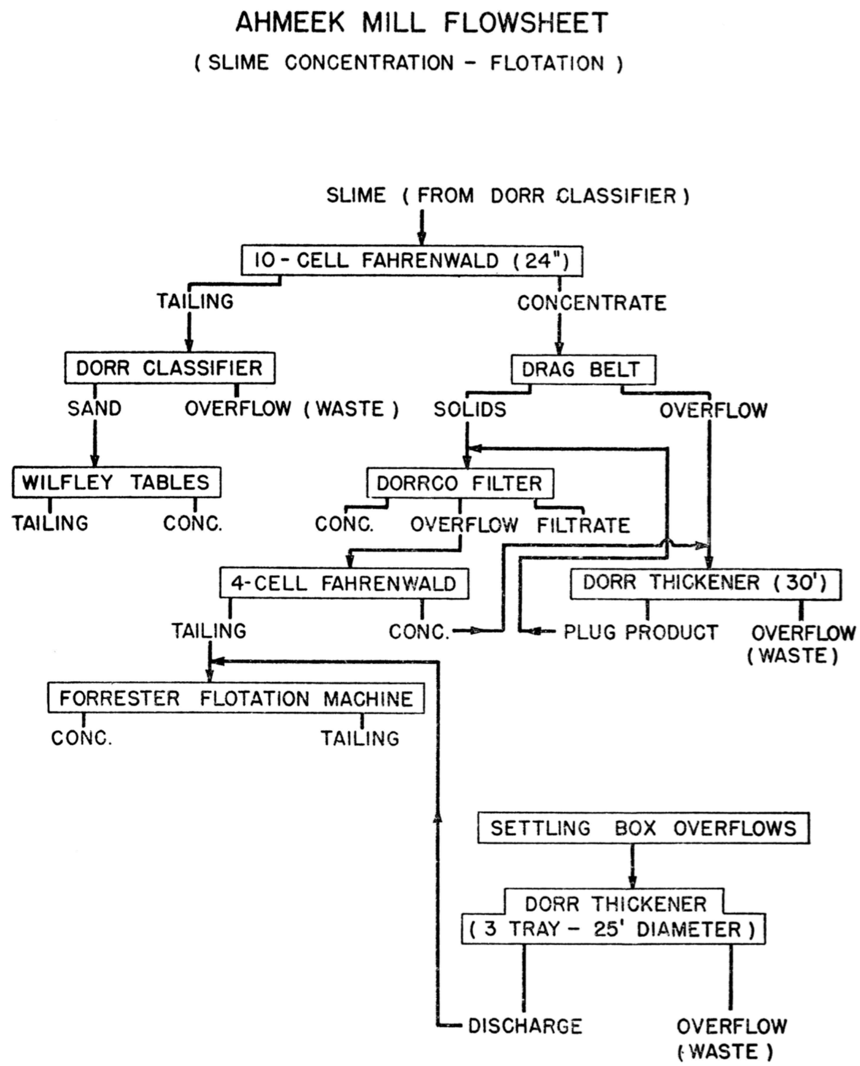

Figure 25: Flow Sheet of the Ahmeek Flotation Plant. Source: Benedict. *Lake Superior Milling Practice,* 128.

New chemicals were introduced in and around Torch Lake through the leaching and flotation plants first opened in the 1910s. During the 1960s, C&H became aware of other waste streams besides their tailings and tried to reuse what it could to save money. The chemicals used in the flotation and leaching processes include the xanthates, pine oil, and ammonia. These chemicals would play a role in the

environmental story, which will be discussed in Chapter 5, but will take a backseat compared to other concerns, especially PCBs.

Before 1930, many technological advances allowed the reclamation processes to become cheaper and more productive. In 1915, the mines produced 71,030,320 pounds of copper while the Lake Linden Reclamation Plant produced 1,582,802 pounds. Just one year later in 1916, the reclamation number was up to 5,412, 649 pounds. By 1918, a total of 9,245,388 pounds of copper were produced, and by 1920 a substantial 14,138,240 pounds were recovered. This period of growth saw increased metallurgical efficiency and a decrease in reclamation costs.[76] This allowed C&H to push forward and develop more resources for its secondary copper movement. The Lake Linden Reclamation Facilities can be seen in Figure 26 and the Lake Linden Leaching Plant flow sheet can be seen in Figure 27.

[76] C&H Annual Reports (1915), Michigan Tech Archives; C&H Annual Reports (1916), Michigan Tech Archives; C&H Annual Reports (1918 & 1920), Michigan Tech Archives; C&H Annual Reports (1927), Michigan Tech Archives.

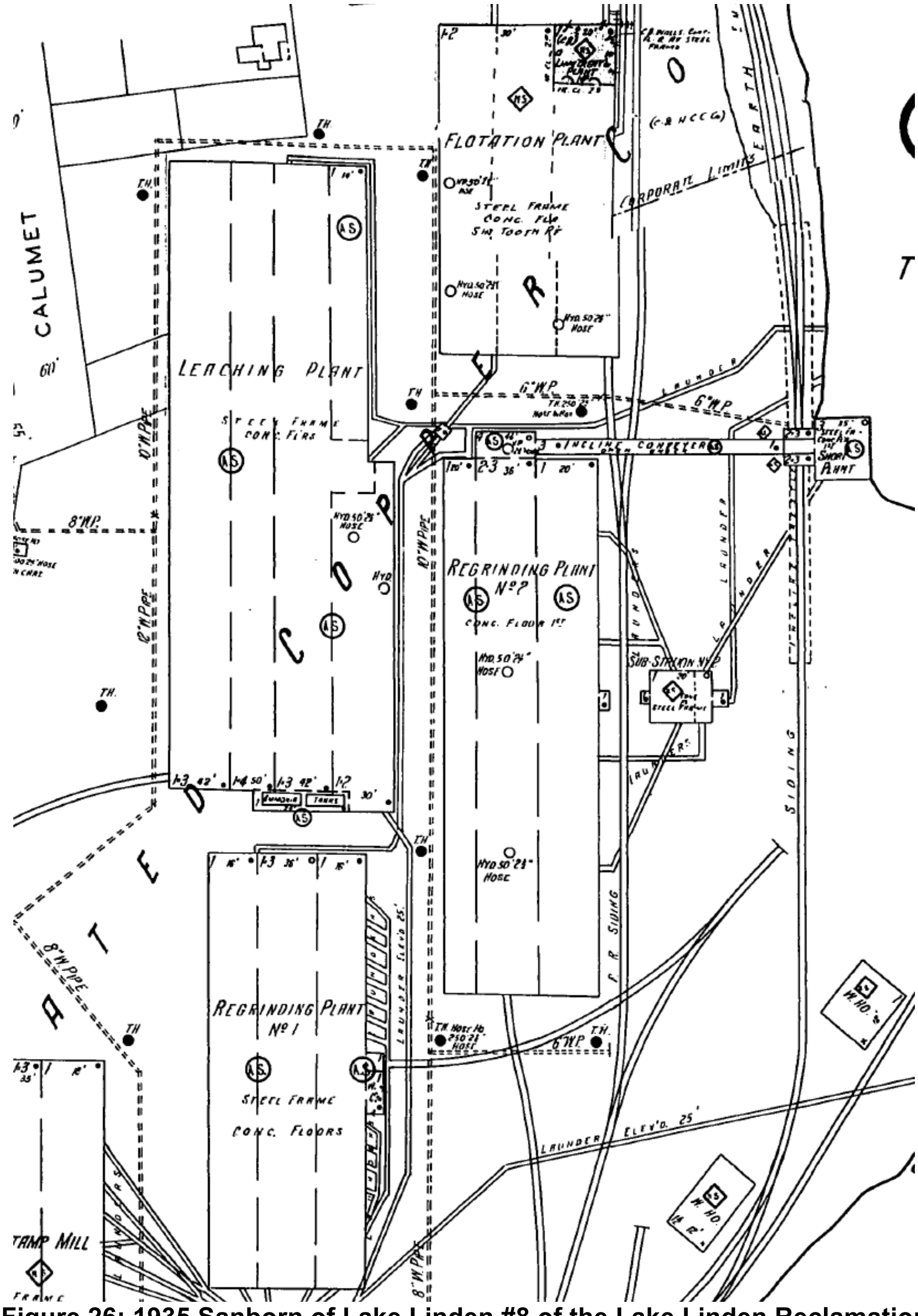

Figure 26: 1935 Sanborn of Lake Linden #8 of the Lake Linden Reclamation Facilities. Courtesy Michigan Tech Archives and Copper Country Historical Collections.

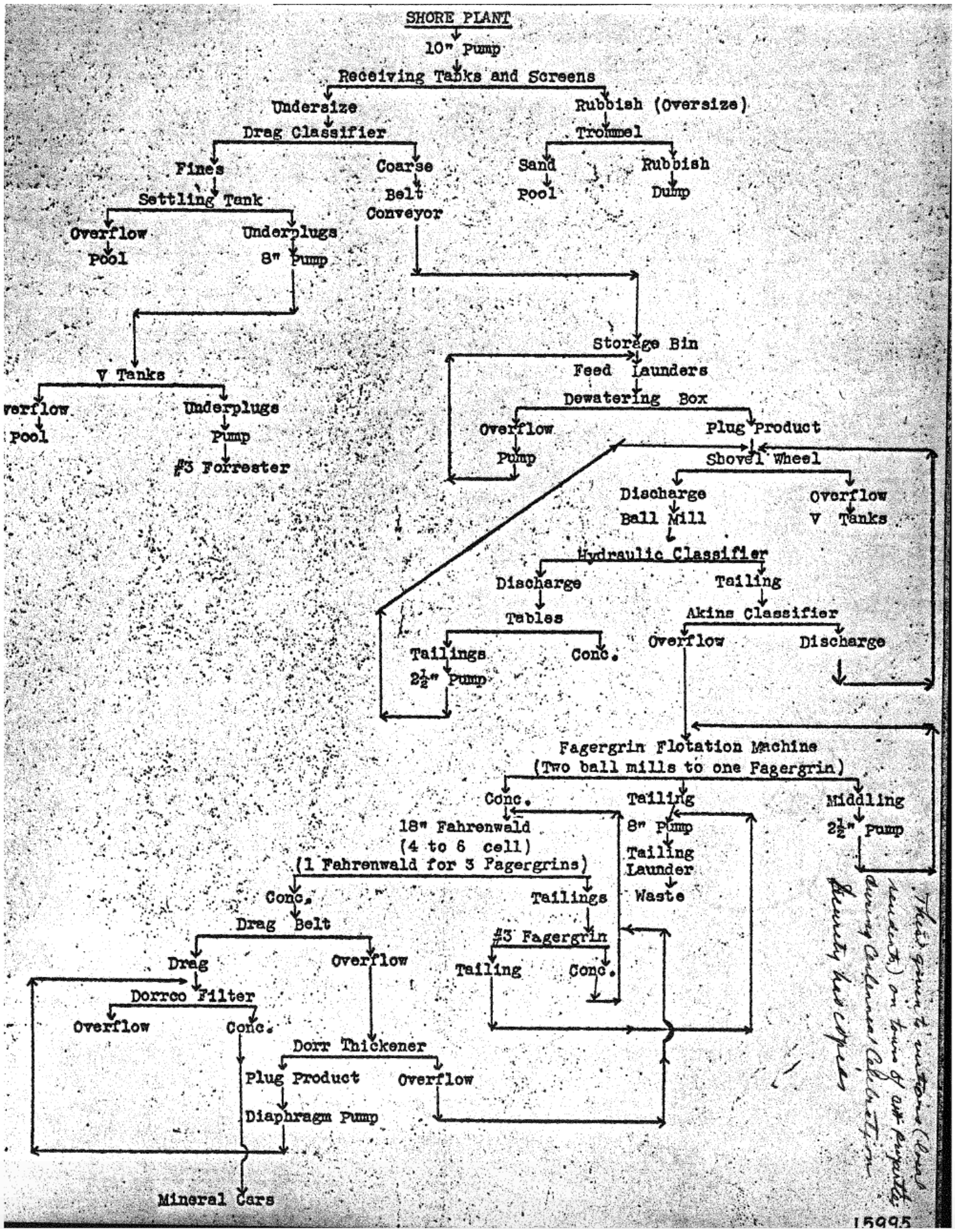

Figure 27: Tamarack Reclamation Plant Flow Sheet – Leaching Plant. Courtesy Michigan Tech Archives and Copper Country Historical Collections. MS-002 Box 87 Folder 3.

In 1942, the Quincy Mining Company began the process of building its own reclamation plant to reclaim the sands from both of its mills. Quincy's Reclamation Plant, plus the remnants of its two stamp mills at the south end of Torch Lake in Mason, was the only part of the western shoreline not owned by C&H. However, Quincy entered into a contract in 1942 with C&H to build the plant and the Metals Reserve Company for the financing and operation of its new reclamation plant. The Metals Reserve Co. gave Quincy a loan of $1,150,000 for its reclamation plant, showing that it was important for the government to have enough copper to meet wartime demand.[77]

The Quincy Reclamation Plant, which was processing by 1943, was built by C&H in order to increase the amount of overall copper to benefit the war effort (see Figure 28).[78] Talking to students and locals, I have realized that this plant was a relatively unknown facility in the Keweenaw compared to the underground mining, milling, and smelting done by Quincy, possibly because it was opened so late and many people assume the company had closed because its mines had. Though the dredge in Mason is a known landmark for the community, many of those that I have conversed with do not know what it was used for. For the first years of the Quincy reclamation plant operation, the federal government was subsidizing the price of copper. Once the government stopped subsidizing in 1945, the Quincy mine shut down but the reclamation plant continued to process. This statement about the Quincy

[77] "Power," MS-001, Box 372, Folder 69, Michigan Tech Archives; "Michigan," *Engineering & Mining Journal*, 143 (August 1942): 147.
[78] Quincy Mining Company Annual Reports, Michigan Tech Archives.

mine closing misleads many people, including statements from tour guides at the Quincy mine, into thinking that the entire company shut down, but in fact, the reclamation plant was still going strong.[79]

Figure 28: Quincy Reclamation Plant, post-1943. Photograph No. MS003-002-004-07, "Quincy Reclamation Plant." Date unknown. Calumet and Hecla Photograph Collection. Michigan Tech Archives & Copper Country Historical Collections. http://digarch.lib.mtu.edu/showbib.aspx?bib_id=686590#. Accessed 7/20/16.

After WWII the mines of the Keweenaw were still producing, but not on the level that the western mines were. The underground mines in the Keweenaw were seeing lower profits than in pre-war years, and this meant that C&H was running their

[79] "Michigan," *Engineering & Mining Journal*, 146 (October 1945): 120, 143.

business well in trying to diversify with reclamation, copper chemicals, and scrap processing.[80]

The Ahmeek Stamp Mill had been upgraded to include leaching and flotation in order to reclaim as much copper from the rock being stamped there as possible (see Figure 29). On November 5, 1958, a report entitled 'Report on The Leaching of Ahmeek Mill Concentrates' by L.C. Klein, attempted to give answers to questions about leaching Ahmeek Mill concentrates for production of copper powder. It covers capacities of present leaching and distillation facilities; changes in leaching and distillation equipment necessary to adapt this equipment to the leaching of concentrates and distillation of the rich solutions produced; material handling; changes in leaching techniques; leaching solution control; types of concentrates that can be leached; and the control of impurities in the oxide produced. It also includes a rough estimate for the capital expenditures that were necessary and the cost of the oxide production. It also mentions what Torch Lake water had in it because tests of the water were done to see how it would react with the chemicals in the leaching process. Torch Lake water had high concentrations of chlorides, calcium, and magnesium, and, though arsenic was used in the leaching process, this report states that all of the arsenic remained in the plant and was recycled for future use.[81]

[80] "Revere Copper & Brass," MS-002, Box 75 Folder 74, Michigan Tech Archives.
[81] "Leaching of Concentrates," MS-002 Box 85, Folder 15, Michigan Tech Archives.

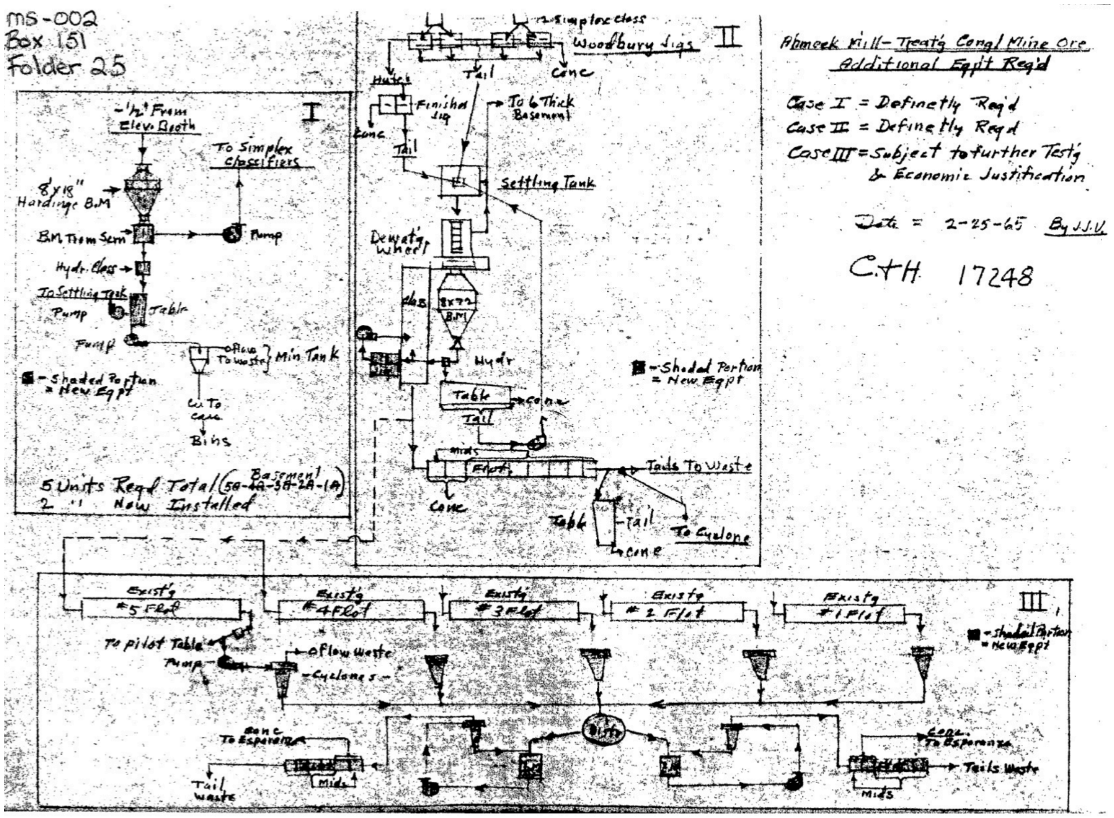

Figure 29: Ahmeek Stamp Mill Flow-Sheet, circa 1965. Courtesy Michigan Tech Archives and Copper Country Historical Collections. MS-002 Box 151 Folder 25.

Between 1959 and 1968 the Ahmeek Mill was also recovering copper from slag, tailings, and brick from the smelter furnaces, apart from processing ore from the C&H mines. This allowed the mill to stay alive when it would otherwise have been forced to shut down for a period of time. Between 1965 and 1966 there were pushes to increase the overall efficiency at the Ahmeek Mill and C&H reached the point of planning out the phases, but this project never went to fruition.[82] A close-up photograph of slag can be seen in Figure 30.

[82] "Mill Return & Mill Yields," MS-002 Box 151, Folder 19, Michigan Tech Archives; "Conversion of Mill Circuits for Increased Capacity and Proc. of Con. Ore," MS-002 Box 151, Folder 25, Michigan Tech Archives.

Figure 30: Photograph of copper slag from the C&H Smelter.

L. C. Klein prepared an R&D Study on Sampling & Effluent Handling at the Ahmeek Mill on April 14, 1967. It describes where the waste streams came from and what different types of wastes could be. The report was meant to become a project to take multiple outputs and narrow them down to just one, but this all ended when UOP

bought C&H and then closed the Calumet Division.[83] The Ahmeek Stamp Mill was the perfect one to remain open into this late period because, though the other stamp mills had already closed down, this one was separated from the reclamation plants that needed space to work, and it also had extra technology that the other mills did not have.

Secondary Processing

The first new development in secondary processing was scrap. C&H and the War Production Board worked together in 1942 to recover the copper from small-arms shells and other war material that was not being used or had defects. The new facility used ammonia leaching, similar to the tailings leaching process, in order to separate the copper from the other materials. This was needed in order to help support the war effort.[84] In 1943 a news post stated:

> Treatment of steel clad with brass is now being successfully carried on at the Lake Linden Reclamation Plant. This material is the scrap which results from operations in the manufacture of small calibre jacketed bullets. Scrap is rolling into Lake Linden from all parts of the United States, from steel mills, ammunition makers and from Government ordnance plants. After the copper and zinc are leached off, the resulting steel is sold to steel makers. The zinc is lost but the copper is refined at the Calumet and Hecla smelter and soon finds its way back to war plants.[85]

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[83] "Ahmeek Mill Sampling and Effluent Handling," MS-002 Box 151, Folder 27, Michigan Tech Archives; C&H Annual Report, 1969, Michigan Tech Archives.
[84] "Reclaim Vital Metal in Leaching Process," *Calumet and Hecla News & Views*, November 1942, 1; Benedict 1955, 121; A. Fletcher, "Review Lecture: Metal Recycling from Scrap and Waste Materials," *Proceedings of the Royal Society of London. Series A, Mathematical and Physical Sciences* 351 no. 1665 (Oct. 1976): 151.
[85] "May Expand Lake War Work Plant," *Calumet and Hecla News & Views*, February 1943, 1.

C&H formed the Secondary Department in 1944 in order to handle the scrap processing. The leaching process was slightly altered to process the scrap. The tanks were originally built to process fine sands, but as they had a diameter of 54 feet, they could easily hold up to 200 pounds of scrap. The scrap (which contained some iron) was picked up from piles using large magnets, then set into the tanks where the leaching process would take place. Over the course of the War Production Board Scrap Contract, "65,000 tons of scrap yielding 20,800,000 pounds of copper and 40,000 long tons of steel were produced."[86] This scrap leaching was an important part of the war effort and allowed C&H to produce more copper than just mining and reclamation.[87]

The copper wires brought in needed to be freed from the plastic outer casing, and the easiest way to do this was by burning it off. A piece of open land near the smelter and coal dock was used to pile the wires, then C&H burned them until the outer coating simply fell off the copper.[88]

The second development in secondary processing was turning copper, which was not quite pure enough to be smelted, into chemicals. Chemicals were used for a variety of uses, including paint for the bottom of boats, to help fabrics resist mildew, and as fertilizers. This chemical phase was a part of the diversification of C&H and

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[86] "New Department is Formed," *Calumet and Hecla News & Views*, November 1944, 7; Benedict, *Lake Superior Milling Practice*, 122.
[87] Benedict, *Red Metal: The Calumet and Hecla Story*, 182; Benedict, *Lake Superior Milling Practice*, 121-122.
[88] Tauno Kilpela (retired C&H employee), in discussion with the author, July 2013; Benedict, *Lake Superior Milling Practice*, 122.

this was done in tandem with the Lake Chemical Company, which was a company jointly founded by C&H and the Harshaw Chemical Company of Cleveland, Ohio. The purpose of the Lake Chemical Company was "engaging in the manufacture and sale of Copper Oxychloride Sulphate and Cupric Hydroxide, and such other copper chemicals as may be determined upon at a later date."[89] This new company was housed in a section of the Tamarack Reclamation Plant and continued to produce copper hydrate and copper oxide, but also began producing copper hydroxide and oxychloride sulfate, and in 1947 cupric oxide as well.[90] A flow sheet of the copper oxychloride sulfate plant can be seen in Figure 31.

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[89] "Calumet & Hecla and Cleveland Firm Organize A New Company – Will Manufacture Chemical Products," *Calumet and Hecla News & Views*, October 1945, 1; "Lake Chemical Co. Minutes of Meetings (1945)," MS-002 Box 22 Folder 1, Michigan Tech Archives.

[90] "Calumet & Hecla and Cleveland Firm Organize A New Company – Will Manufacture Chemical Products," *Calumet and Hecla News & Views*, October 1945, 1; "Cupric Oxide; New Product of C. & H.," *Calumet and Hecla News & Views*, August 1947, 1.

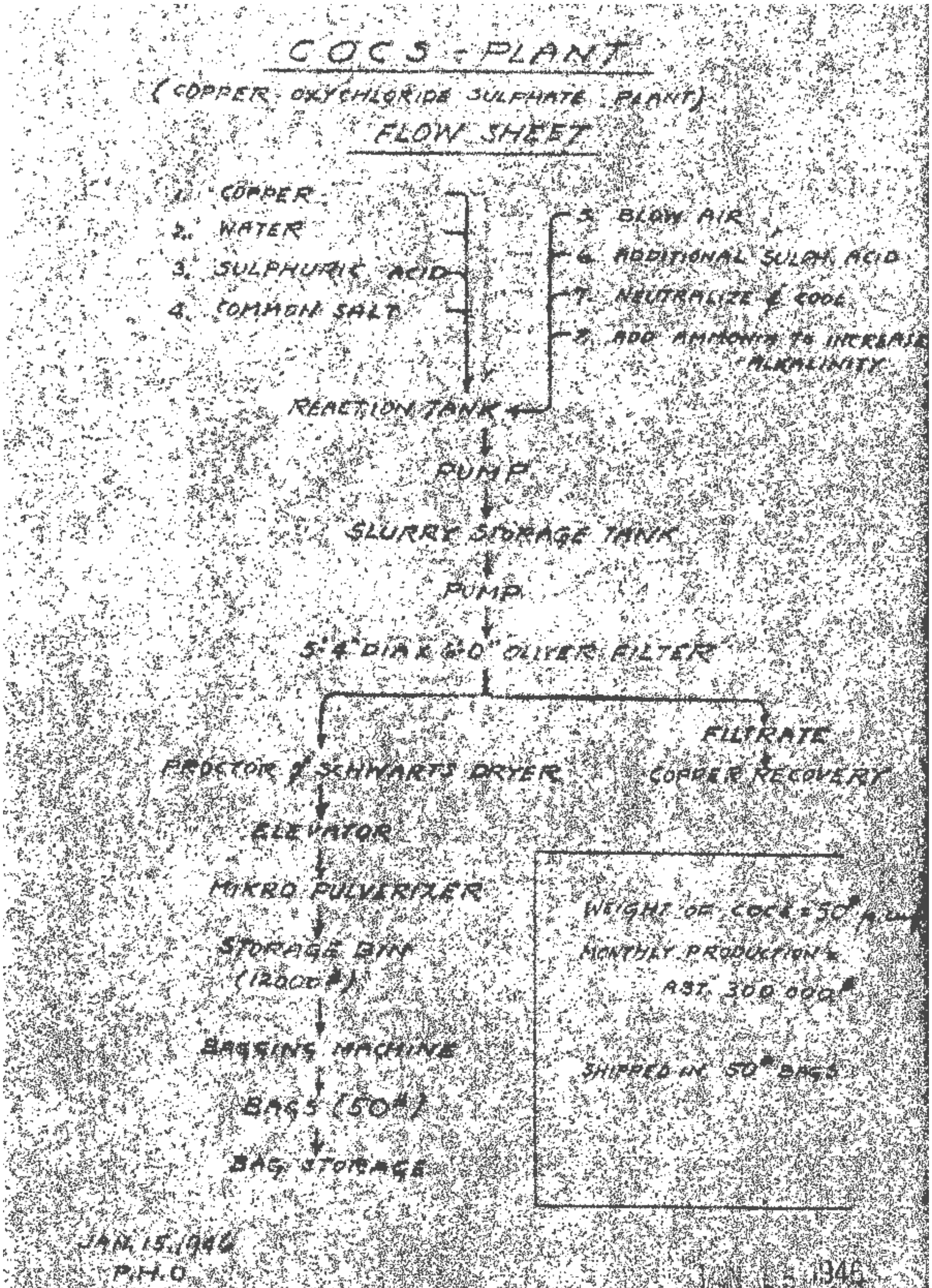

Figure 31: Flow Sheet of the Lake Chemical Company at the Tamarack Facility. Courtesy Michigan Tech Archives and Copper Country Historical Collections. MS-002 Box 60 Folder 4.

Copper chemicals, such as copper oxide, were being produced at the Lake Linden Leaching Plant and Still House for the war effort as well. One report stated that 3,264 tons of scrap was treated at the Lake Linden Reclamation Plant, which produced 1,174,831 pounds of copper oxide.[91]

C&H continued to produce copper oxide as well as experiment with other types of copper chemicals. Because of this, and the continuation of scrap processing, the Secondary Department was formed to take care of the purchasing, processing, treatment, and selling of the copper containing material. Copper oxide was especially helpful to the US Navy. The copper chemical would be infused into paint, which would be used to coat the bottoms of naval ships. Because copper is a biocide, barnacles and algae could not grow on it, making the ships less likely to grow barnacles and algae.[92]

Another chemical, copper hydrate, was developed at the Tamarack Reclamation Plant as a component in copper naphtenate (see Figure 32). This is used to help reduce mildew on fabrics, and it was mainly supplied for the Army.[93]

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[91] "Leaching," *Calumet and Hecla & Views*, April 1944, 1.
[92] "New Department if Formed," *Calumet and Hecla News & Views*, November 1944, 7; "Steam Plant Dismantled," *Calumet and Hecla News & Views*, December 1944, 1.
[93] "New Product, Copper Hydrate, Ready for Production Soon – Percy Rowe Develops Important Process," *Calumet and Hecla News & Views*, June 1945, 1.

Figure 32: Photograph of Copper Hydrate at the Lake Chemical Plant. Photograph No. MS003-002-001-03, "Calumet & Hecla - Lake Chemical Company." Date unknown. Calumet and Hecla Photograph Collection. Michigan Tech Archives & Copper Country Historical Collections. http://digarch.lib.mtu.edu/showbib.aspx?bib_id=686560#. Accessed 7/20/16.

Even with the chemical division running well, C&H knew it needed to make more money to keep the company alive. It began selling off slag to companies who would use it to aid in the insulating of homes, pipes, and industrial machines and buildings, as well as its ashes to companies such as the American Smelting & Refining Co., because the slag retained a small percentage of copper. This copper, although not enough to be processed at the smelter, could be used for these other

purposes. C&H did all it could to seek out who could use its copper in order for the company to make a profit. It also experimented with the recovery of copper from the flue dust produced in the smelter to see if it could make that process economical. Even with these, C&H was running out of copper and money. The smelter division tried to make small changes to each step of the scrap handling and smelting to see if it could find an area where it could gain copper, but this experimentation did not work.[94] In the end, all of these experiments, contracts with outside companies, or small changes could not save C&H from the realization that Keweenaw copper could not compete with the large western mining companies. The Lake Chemical Company shut down in 1956.

[94] "Slag Utilization," MS-002, Box 201 Folder 21, Michigan Tech Archives; "Copper Slag Agreements & Contracts," MS-002, Box 181 Folder 6, Michigan Tech Archives; "Soot Removers," MS-002, Box 201 Folder 25, Michigan Tech Archives; "Smelter Secondary Projects," MS-002, Box 138 Folder 3, Michigan Tech Archives.

Chapter 4 – The Development and Use of Power

Power is crucial to every industry. When copper mining began in the Lake Superior District in the 1840s, the mining companies were using rudimentary means of power. It would not even take fifty years before steam and electrical distribution became an important part of copper mining. The Keweenaw's largest mining company, C&H, developed a power network that combined steam power and electricity to advance its copper processing facilities. The electrical transmission system is the main focus of this chapter, as the PCBs found in the transformer oil is the contaminant of focus in this thesis.

Early Fuel

Before larger power facilities were built and steam and electricity could be harnessed for energy, rudimentary means of power such as manpower and then animal power were the standard (see Figure 33). By the 1850s, steam technology was developed on a national level and able to be harnessed on a large scale. Steam engines provided mechanical energy through boilers at individual locations, mainly near industrial operations. C&H, by the 1880s, largely used the steam energy for lighting purposes at its Torch Lake facilities, before the system was expanded to help with the hoisting and stamping at the mills.[95]

[95] Lankton, *Cradle to Grave*, 46.

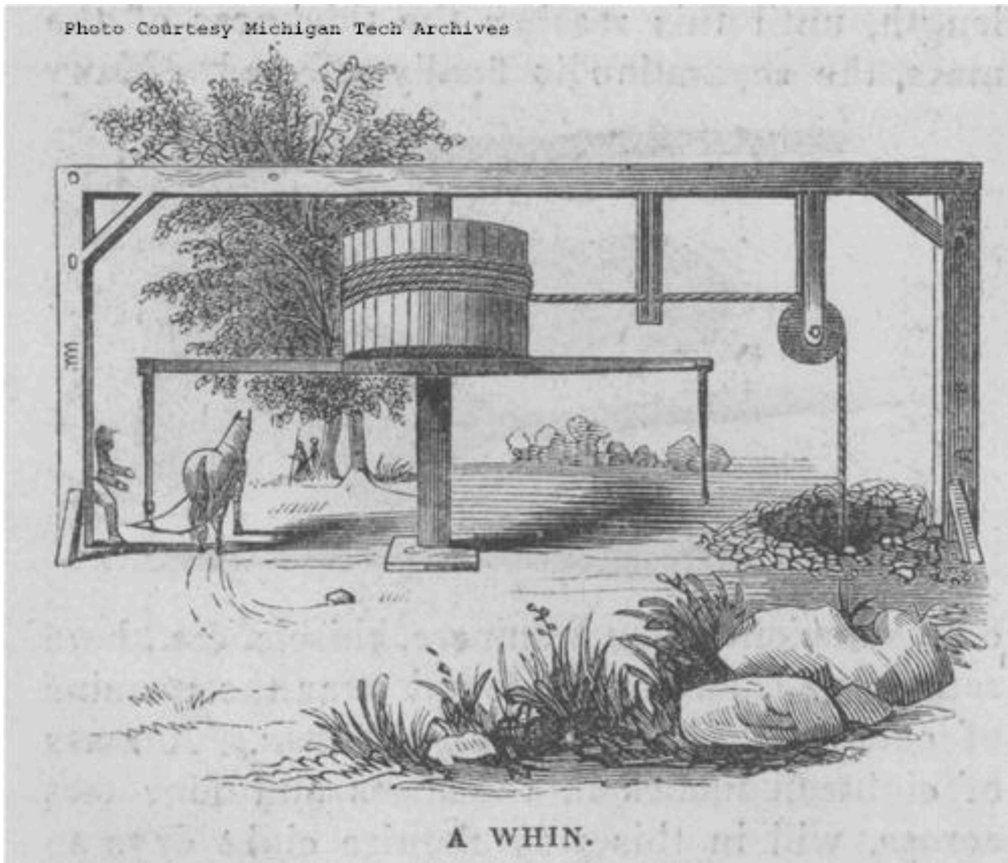

Figure 33: Example of a horse whim. Photograph No. Book-AP2H2v6-578-B, "A whin [or horse whim]." April 1853. Book Collection. Michigan Tech Archives & Copper Country Historical Collections. http://digarch.lib.mtu.edu/showbib.aspx?bib_id=619233#. Accessed 7/20/16.

At first, wood was the best and cheapest fuel in the U.S. to fire the boilers. The large forests of the United States were an invaluable resource for fuel by the early to mid-1800s, and were used for cooking on small farms as well as large-scale agricultural processes such as making charcoal.[96] In 1850, 90 percent of the heat energy was still being produced by wood. By 1900, 71.4 percent of the heat energy was provided by bituminous and anthracite coal. This transition is closely tied to the

[96] Louis Hunter, *A History of Industrial Power in the United States, 1780-1930: Volume I – Water Power* (Charlottesville, VA: University Press of Virginia, 1979), 163.

change from water transportation to railroads, as coal could now be shipped via rail for a lower cost.[97]

The Keweenaw had an abundance of timber, and the local mining companies used it to their advantage until the once thick forests were large expanses of stumps (see Figure 34). Companies used plots of land closest to their locations and hired woodchoppers to supply the fuel. Once the land was cleared, they would move to land that was further away and took what they wanted. Because of these large forests, there was plenty of wood available to power the steam engines. The Keweenaw does not posses coal resources. Before the Soo Locks opened in 1855, it was very difficult and expensive to deliver coal to the Upper Peninsula.[98]

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[97] Louis Hunter, *A History of Industrial Power in the United States, 1780-1930: Volume II – Steam Power* (Charlottesville, VA: University Press of Virginia, 1985), 393.

[98] Benedict, *Red Metal*, 87; Benedict, *Lake Superior Milling Practice*, 55; Lankton, *Cradle to Grave*, 42-43.

Figure 34: Logged-Out Area. Photograph No. Nara 42-214, "Logged-out Area." Date unknown. Nara Photographic Collection. Michigan Tech Archives & Copper Country Historical Collections. http://digarch.lib.mtu.edu/showbib.aspx?bib_id=603459#. Accessed 7/20/16.

Beginning around 1870, steam was becoming the main source of energy in the U.S. Between 1870 and 1900, the trend toward steam power was highly visible. In 1870, industries used 1.13 million HP of waterpower and 1.22 million HP of steam power. By 1900, industries were using 8.7 million HP of steam power, but only slightly more waterpower at 1.7 million HP. The transition from water to steam was especially important to the iron industry. By 1870, about ten percent of the iron industry had not employed steam power, and in 1880, the percentage went down to four percent.[99]

[99] Louis C. Hunter, *A History of Industrial Power in the United States, 1780-1930: Volume I – Water Power*, 493.

In the Keweenaw, steam was the energy of choice. Steam power had a huge impact on the hoisting and the breaking of the rock. According to Lankton, steam power was a main factor in allowing the Keweenaw copper mines to develop to the depths they did. Steam engines worked by using a boiler fueled first by wood and then by coal to heat the water until it turned into a gas at high pressure, which then drove reciprocating steam engines that produced mechanical power.[100] In the twentieth century these reciprocating engines became turbines. This use of steam power allowed the Lake Superior Copper District to grow and develop into a copper-producing region. Stamping was one of the most important steam applications. An example of a Keweenaw boiler house is shown in Figure 35.

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[100] Lankton, *Cradle to Grave*, 46; Hunter & Bryant, *A History of Industrial Power in the United States, 1780-1930: Volume III – The Transmission of Power*, 53.

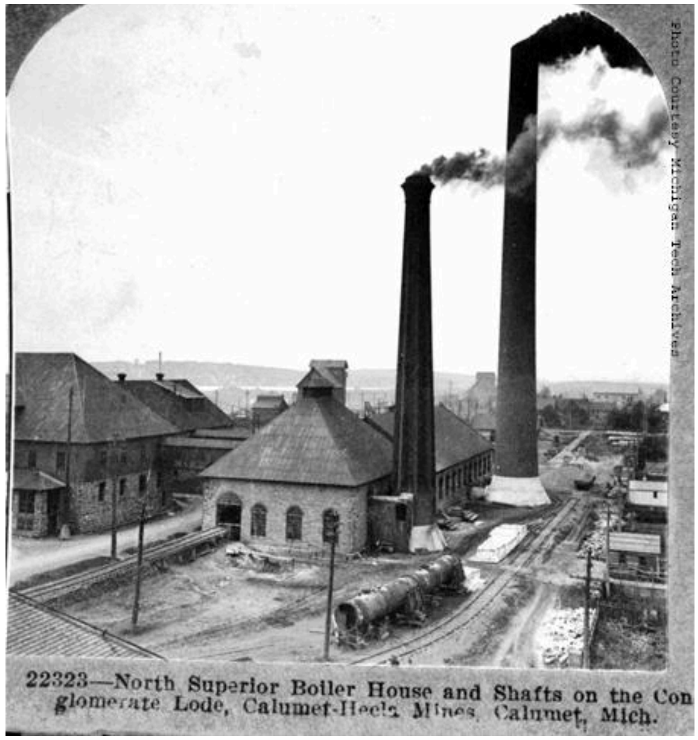

Figure 35: C&H Boiler House in Calumet. Photograph No. MTU Neg 05766; MS003-032B-25-116, "Copper Mines & Mining Companies - Calumet & Hecla." Date unknown. Copper Country Vertical Photograph File. Michigan Tech Archives & Copper Country Historical Collections. http://digarch.lib.mtu.edu/showbib.aspx?bib_id=641741#. Accessed 7/20/16.

One of the most important things that industrialists and engineers were looking for in power was a cheap way to transmit it, not just how to produce it.[101] Electrical distribution was what was developed to solve this issue. First used as a means for lighting, the application of electricity was adapted for other copper processing facilities. With the use of steam and electricity, C&H could not only power its stamps and smelter with steam, but use electricity, by means of electric motors, to help power the other facilities as well.

[101] Hunter & Bryant, *A History of Industrial Power in the United States, 1780-1930: Volume III – The Transmission of Power*, 115.

Lake Linden Power Plant

By the 1890s, the transition from steam to electricity and steam was still taking place. With steam power, there were joints in the steam pipes that would let the energy escape, and when pipes broke all of that energy pumped into them would be lost. This made steam power very inefficient and costly compared to the electricity that mostly replaced it. Electricity was to have a major impact on industry.[102]

C&H chose to build its powerhouse on Torch Lake to be closer to the mills and smelter. It produced steam to power the stamps at the mills. The original C&H powerhouse was built in Lake Linden in 1878 and mainly consisted of steam engines, with an electrical apparatus used for lighting purposes.

> The first electrical apparatus consisted of an alternating current arc lamp outfit, which was installed in 1878 and constituted the initial commercial arc lighting system in the United States. It comprised a Siemens & Halske arc generator and twenty lamps, and was imported from Germany by the late Alexander Agassiz, who was at that time president of the company. These lamps were utilized at the mills at Lake Linden, five miles from the mine, where the main generating station was later established. The only prior arc lighting in the United States consisted of a similar set which was shown at the Philadelphia Exposition in 1876, and another installed at Cornell University in the same year.[103]

In 1891, the earliest incandescent lights were installed at C&H. By 1893 both mills and the docks at Torch Lake were lighted from the plant in Lake Linden, and plans were being made to have a separate plant for electric lighting and a new one for

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102 Ibid, 188; Hunter, *A History of Industrial Power in the United States, 1780-1930: Volume II – Steam Power*, 434.
103 Liston, "Electrical Equipment of the Calumet & Hecla Mining Co., Calumet, Mich," *General Electric Review,* 521.

electric transmission. In 1895 an iron building for a steam fire engine and the electric lighting was built and was producing by 1896. In 1901 a new addition to the stamp mills, for the non-stamping operations, was installed to run on electricity and a brand new power plant was planned for installation near the mills. In order to distribute the electricity to the mills, electric cables were run underground from the powerhouse to the mills.[104]

The first non-lighting application of electricity at C&H was to dewater mines. In 1892 it was documented that the first use of electricity, besides lighting, was at the number 11 shaft and involved two 80 HP, 1250-volt DC motors that were used to drive pumps for dewatering the mine.[105] C&H also installed AC generators at the power plant in 1892 to serve incandescent lighting by connecting to multiple transformers. According to an article written in 1944, C&H claimed that it was "one of the first users of electric power in this country."[106]

Calumet and Hecla spent more money on equipment than any other mining company on the Keweenaw, because it was the largest operator. Alexander Agassiz, the president of C&H at the time, understood the importance of a centralized power system, in which multiple steam engines and the majority of the electric generating

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[104] Ibid; C&H Annual Reports (1892/1893), Michigan Tech Archives; C&H Annual Reports (1894/1895 & 1895-1896), Michigan Tech Archives; C&H Annual Reports (1900/1901), Michigan Tech Archives; C&H Annual Reports (1901/1902), Michigan Tech Archives.

[105] Hunter, *A History of Industrial Power in the United States, 1780-1930: Volume II – Steam Power*, 2; "Jim Breth Tells of Early Days of C. & H. Electrical Department," *Calumet and Hecla News & Views*, January 1949, 7.

[106] Liston, "Electrical Equipment of the Calumet & Hecla Mining Co., Calumet, Mich," *General Electric Review,* 521; "Calumet and Hecla Electrical Department Keeps Plant in Production," *Calumet and Hecla News & Views*, May 1944, 4.

units were all in one place.[107] These units worked together to provide power to the multiple Torch Lake facilities and allowed upgrades to maintenance to occur in one location. Steam engines remained at other facilities to provide a more local source of power, such as at the mines for hoisting.

As the company expanded, eventually it needed to expand its power system. By 1899 there were over fifty steam engines spread out powering the mines, mills, and the smelter. Together, these engines produced around 50,000 HP, which, comparing the production and consumption, would have been equivalent to a city of 200,000 people.[108]

As 1900 approached, technological developments in copper processing, power, and many other areas led to changes for C&H. One such change was in electrical generation and this led to C&H using more electrical energy. Steam engines were replaced with electric motors, and electrical lines were soon being extended from the Lake Linden power plant to the other C&H locations. Though steam engines were a staple up to this point, it became the era of electricity and electric driven motors became increasingly important (see Figure 36).[109]

Other Keweenaw mining companies had steam engines, but not a steam and electrical network like C&H had. The Quincy Mining Company, another large mining company in the region, did not have a centralized power plant. It did, however, have a

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[107] Lankton, *Cradle to Grave*, 43-44.
[108] Lankton, *Hollowed Ground*, 94-95.
[109] Ibid, 129; Benedict, *Red Metal*, 121-122; Benedict, *Lake Superior Milling Practice*, 133.

small power plant that was built between its two stamp mills on Torch Lake around the turn of the twentieth century, but was disconnected from its mine.[110]

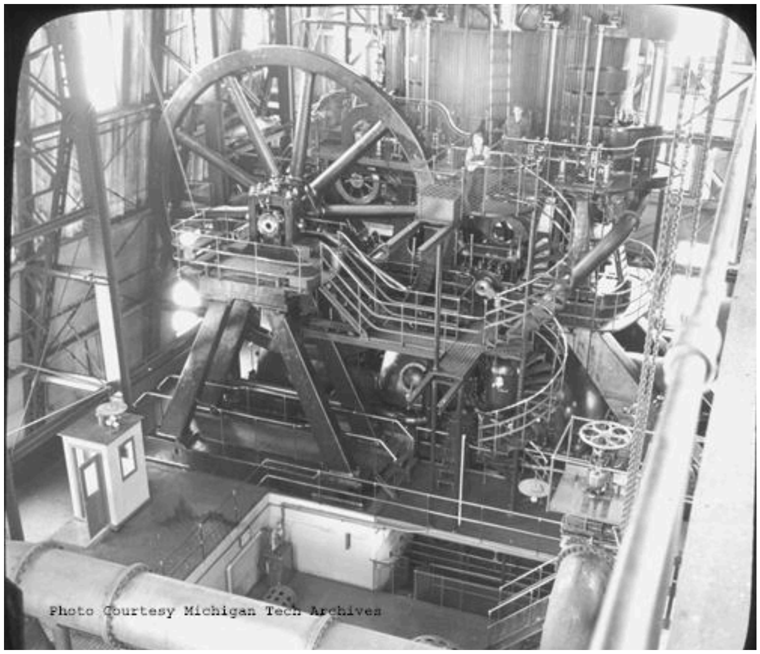

Figure 36: Photograph of Calumet & Hecla Steam Pump. Photograph No. MS003-024-001, "Calumet and Hecla Mills and Reclamation Plant - Steam Pump." Date unknown. Calumet and Hecla Photograph Collection. Michigan Tech Archives & Copper Country Historical Collections. http://digarch.lib.mtu.edu/showbib.aspx?bib_id=599200#. Accessed 7/20/16.

A large transformation to the power industry would happen beginning in 1900. C&H, as well as other Keweenaw mines, were on par with other mining districts when it came to steam and electricity. As of 1902, only half of the metal mining industry used steam or electricity in their mines.[111]

In 1902, C&H decided to build another powerhouse next to the old one at Torch Lake and in 1903 it went into commission with an AC system that had two

[110] Quincy Mining Company Annual Reports, Michigan Tech Archives.
[111] Hunter & Bryant, *A History of Industrial Power in the United States, 1780-1930: Volume III – The Transmission of* Power, 444.

generators and a 1,000 KW, 440 volt capacity. Shortly after, the power plant was expanded with three 2,000 KW generators and electricity was extended via transmission lines all the way to the mines in Calumet. At the mines it was used for dewatering purposes, electrical lighting of mining operations, and in rock crushing and tramming.[112]

The powerhouse facility from 1902 was remarkably efficient and C&H purposely made it to be larger than the current need so it could house additional generators as demand for electricity grew. The power plant at this time supplied current to roughly 325 motors and had the capacity to serve many more. Before electrification, C&H lost a lot of steam through the long pipes running from facility to facility, and thus lost efficiency. To power the new reclamation facilities would have taken a lot of steam and it would have been less economical.[113]

In 1905, C&H added three large engines and the electrical system was expanded up to the mines, and in 1907, C&H added three generators to generate potential energy at 13,200 volts. By 1906 it had a capacity of 9000 HP and by 1907 it generated 6000 KW and the frequency also had changed to 60 cycles to provide the lighting for the facilities. In 1906 C&H upgraded its stamp mills, and it was noted that

[112] "Calumet and Hecla Electrical Department Keeps Plant in Production," *Calumet and Hecla News & Views*, May 1944, 4; "Modernization of Lake Linden Power Plant Is Approved By Directors – Two years required to complete job," *Calumet and Hecla News & Views*, March 1947, 3; Benedict, *Red Metal*, 121; C&H Annual Reports (1904/1905), Michigan Tech Archives.
[113] Liston, "Electrical Equipment of the Calumet & Hecla Mining Co., Calumet, Mich," *General Electric Review,* 521, 522; Carl Fichtel, "Electric Power at the Calumet & Hecla," *The Engineering and Mining Journal* 84 (27 July, 1907): 157.

additional electrical equipment needed to be installed in order to power the non-stamping operations.[114]

Another expansion took place in 1907. The power facilities on Torch Lake were connected to the Calumet area and this allowed C&H to electrify its entire infrastructure, including the Lake Linden mills and smelter to the Calumet Waterworks Pumping facilities to the most northern mines up near Phoenix, from its one powerhouse. C&H also built its new boiler house in 1907, right next to the powerhouse in Lake Linden "to provide steam for the twenty-eight steam stamps at the Lake Linden mills, as well as for the increased electrical system." This boiler house contained twenty-four Babcock and Wilcox boilers, each rated at 20,000 pounds of steam per hour, and provided pressure at 180 pounds per square inch for the stamps in the stamp mills and the steam engine-driven electrical units in the powerhouse.[115] Without the boilers there would not have been steam. This means that the boiler houses are just as important as the steam engines themselves in providing power. The Lake Linden facilities after the 1907 update can be seen in Figure 37.

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[114] Liston, "Electrical Equipment of the Calumet & Hecla Mining Co., Calumet, Mich," *General Electric Review,* 521; "Electrical Department Turns Out A Tremendous Amount of Power – Output is four and one half times demand of whole district," *Calumet and Hecla News & Views*, January 1947, 1; "Electrical Department Turns Out A Tremendous Amount of Power – Output is four and one half times demand of whole district," *Calumet and Hecla News & Views*, January 1947, 1; Benedict, *Red Metal*, 188.

[115] "Modernization of Lake Linden Power Plant Is Approved By Directors – Two years required to complete job," *Calumet and Hecla News & Views*, March 1947, 3.

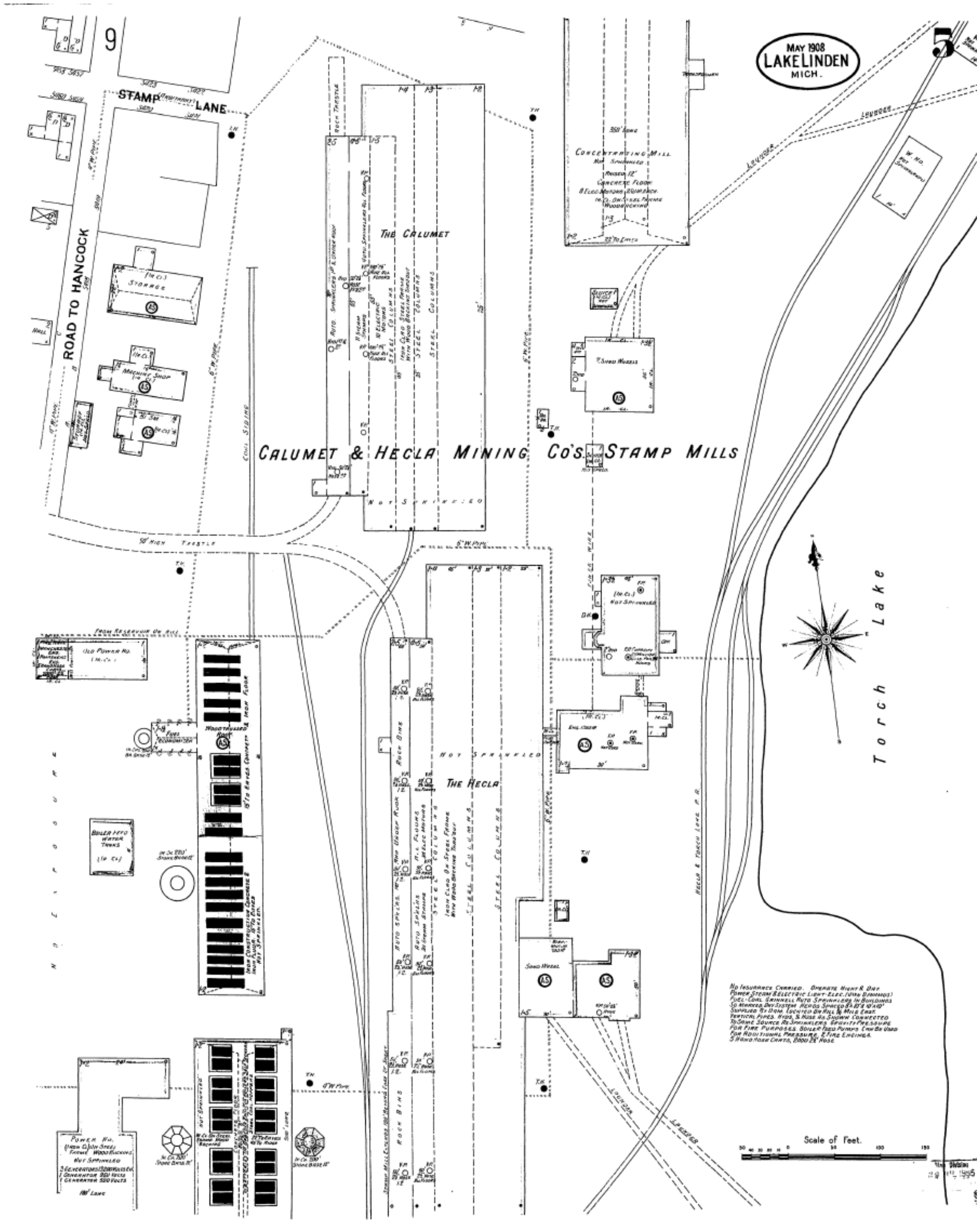

Figure 37: 1908 Sanborn of Lake Linden #5 showing the Lake Linden facilities. Courtesy Michigan Tech Archives and Copper Country Historical Collections.

By 1908 the Calumet stamp mill was run by electricity and part of the Hecla Stamp Mill had been converted, except for the steam stamps themselves. In 1909

C&H erected an electrical line all the way to the Calumet Waterworks to drive the electric pump to deliver 3,000,000 gallons a day to the mill boilers at Lake Linden. Experiments were run to see if it was economical to install a steam turbine to power an electric generator. The steam exhaust drove the turbine from the stamp mills. C&H found it to be very economical and installed equipment to produce 7,500 KW.[116] As C&H electrified its milling operations, the stamps were still driven by steam. The rest of the milling operations, however, were slowly converted from steam engines to being driven by electric motors.

In the 1910s C&H began to expand its copper processing to include reclamation. This process worked to reclaim some of the copper previously with the stamp sands into Torch Lake. This meant that C&H, which had already been milling on Torch Lake for a couple of decades, needed to find a way to not only pump the stamp sands back up into processing facilities, but also rerun it through more intensive processes and back out again to the lake.

The updates to the powerhouse in the 1910s increased the generating capacity in order for C&H to build more milling facilities on the northern end of Torch Lake. Low-pressure units were planned in 1911 to use the exhaust steam from the stamp mills to make electricity. As of 1912 there was a 13,200-volt line from the power plant to the new regrinding plants, and then another circuit (high tension), to supply the smelter. The majority of the rest of the electricity went to the underground mining

[116] C&H Annual Reports (1907/1908), Michigan Tech Archives; C&H Annual Reports (1908/1909), Michigan Tech Archives; C&H Annual Reports (1911), Michigan Tech Archives.

operations. Besides the mine operations, the mills, and the smelter, electricity was also provided to the machine shop, carpenter shop, pattern shop, and foundry.[117]

The first of the turbine driven units was installed at the C&H power plant in 1913 in order to use the steam exhaust from the mills. This one was a 7,500 kw, mixed pressure turbine. In 1916, a 10,000 kW turbine was installed at the Lake Linden power plant and a 2,000 kW turbine was installed at the Ahmeek Mill power plant, but the expanding C&H needed the ability to produce more energy. C&H decided to rebuild the Ahmeek Mill, including the on-site power facilities, to power the mill, the flotation unit, and the Tamarack reclamation plant and related facilities.[118]

In 1916, C&H decided to install a 10,000 KW turbine, which allowed the powerhouse to have the capacity of 22,500 KW. This permitted the company to expand its secondary processing without power concerns. The success of the Lake Linden Reclamation Plant caused the company to invest in another reclamation plant, this time just north of the Tamarack mills. Along with these two reclamation plants, C&H also had to electrify all of its underground mining operations, transportation lines, the smelter, the Ahmeek mill, and other miscellaneous buildings running experiments and other chemical projects.

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[117] “Turbo Generator,” MS-002, Box 48 Folder 532, Michigan Tech Archives; "Modernization of Lake Linden Power Plant Is Approved By Directors – Two years required to complete job," *Calumet and Hecla News & Views*, March 1947, 3; Liston, “Electrical Equipment of the Calumet & Hecla Mining Co., Calumet, Mich,” *General Electric Review,* 523, 527.

[118] "Calumet and Hecla Electrical Department Keeps Plant in Production," *Calumet and Hecla News & Views*, May 1944, 4, 5, 8; "Modernization of Lake Linden Power Plant Is Approved By Directors – Two years required to complete job," *Calumet and Hecla News & Views*, March 1947, 3; Benedict, *Lake Superior Milling Practice*, 127.

During the 1930s and 1940s, when the chemical phase was beginning to grow, C&H made changes in its electrical plant and sub-plants in order to be prepared for any further electrical needs. By 1931 the main electrical network was in place; it ran from Lake Linden to the Calumet Waterworks and from Tamarack to Phoenix. Pulverized coal, which we will discuss later in this chapter, was the main fuel. The Torch Lake facilities can be seen on Figure 38, which is adapted from a 1931 issue of the *Mining Congress Journal*.[119] It shows the connected facilities on Torch Lake and the equipment they contained related to the transmission and distribution of electricity.

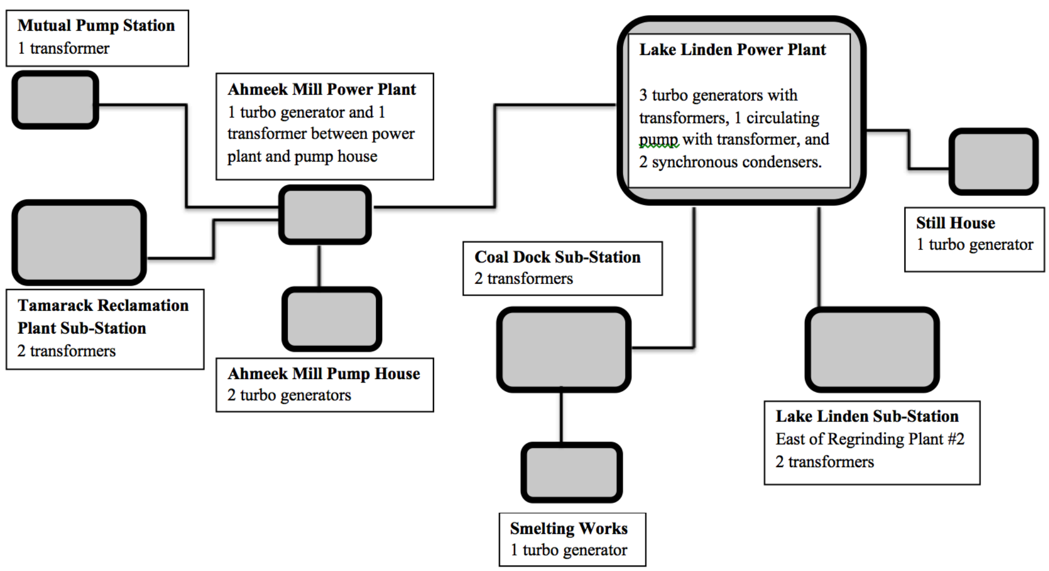

Figure 38: C&H Consolidated Copper Company Electric Distribution System adapted from *The Mining Congress Journal*, October 1931, page 546.

After the US entered World War II, the Metals Reserve Company commissioned C&H to build a reclamation plant for Quincy, the company whose

[119] Robert McIntosh & A.L. Burgan, "Electric Power Generation," *The Mining Congress Journal* 17 (1931), 546.

mills occupied the southern end of the lake.[120] The war created a demand for copper and copper products, and to increase the supply Quincy was going to operate its own reclamation plant to reprocess the sands from its two stamp mills.

Quincy decided to buy its electricity from C&H instead of investing in a new, or updating its old, electrical system. This meant that the C&H power plant in Lake Linden, along with the Ahmeek, would need to be able to provide electricity to many different buildings spanning almost the entire north to south length of Torch Lake. Quincy started buying its electricity from C&H in November 1943 so it could focus on its reclamation plant and did not have to worry about its aging electrical system. Quincy eventually sold off its electrical equipment to the highest bidders in order to recuperate some of the money it had invested into the system. In 1944, Allis-Chalmers sent a message to the Quincy Mining Company saying that C&H would always have enough electricity and that Quincy should have no problem buying its electricity from them.[121]

By 1944 the electrical system had a capacity to generate about 50,000 H.P. The Lake Linden power plant had twenty four 512 H.P. Babcock and Wilcox boilers supplying steam to equipment which could generate 175 pounds per square inch gauge

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[120] C&H Annual Report (1942), Michigan Tech Archives.
[121] "Correspondence - President (W. P. Todd), General Manager (C. J. McKie) and Businesses January 1948-May 1949," MS-001, Box 372 Folder 2, Michigan Tech Archives; "Electrical Department," MS-002, Box 59 Folder 39, Michigan Tech Archives; "Electrical Equipment," MS-001, Box 364 Folder 91, Michigan Tech Archives; "Power," MS-001, Box 364 Folder 42, Michigan Tech Archives.

pressure, which was replaced in 1949 by a new pulverized coal boiler which could generate 850 pounds per square inch of pressure.[122]

Because the electrical network extended all the way to Mason to power the Quincy Reclamation Plant, there may have been additions and updates to the Lake Linden power plant, lines, and substations. Reclamation facilities use a lot of power, and this also could have meant that C&H's network needed boosting on the southern end. By 1947, the electrical and steam power was being used as follows: mines – 17%, mills – 23%, smelter – 8%, reclamation – 38%, and other – 14% (see Figure 39).[123] There is evidence of a Quincy booster plant about 1,000 ft. from the reclamation plant, but no remains have been found and it has also not been found on any maps.[124] One important thing to realize is that underground mining was at its end and the reclamation activities were processing at a high level. This meant that the majority of the electrical and steam power during the 1950s and beyond was going to reclamation, with smelting coming in second.

[122] "Calumet and Hecla Electrical Department Keeps Plant in Production," *Calumet and Hecla News & Views*, May 1944, 1; "Jim Breth Tells of Early Days of C. & H. Electrical Department," *Calumet and Hecla News & Views*, January 1949, 7.
[123] "Jim Breth Tells of Early Days of C. & H. Electrical Department," *Calumet and Hecla News & Views*, January 1949, 8.
[124] "Single Line Diagram," MS-005, Drawing 12307, Michigan Tech Archives.

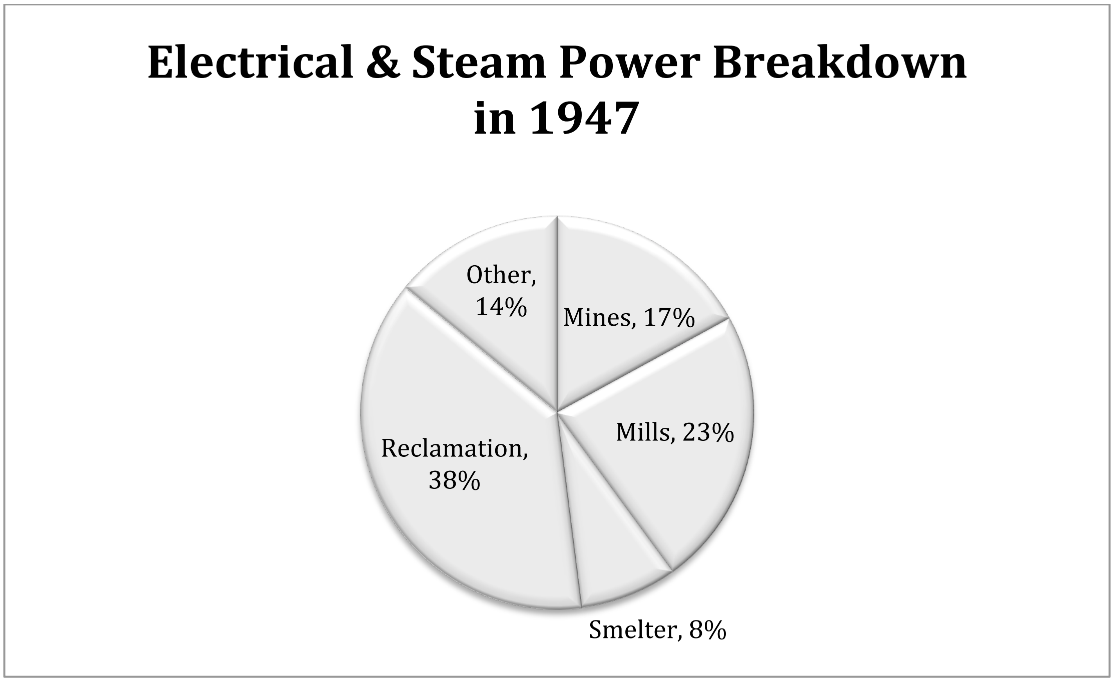

Figure 39: Chart of the Electrical & Steam Power Breakdown by Percent in 1947. Source: "Jim Breth Tells of Early Days of C. & H. Electrical Department," Michigan Tech Archives.

In 1949 there was an upgrade to the C&H power plant.[125] Quincy's Annual Reports claimed that due to the new power plant of C&H going into operation in November, there had been some reduction in the cost of electricity per KWH.

Ahmeek Power Plant

When C&H purchased the Ahmeek Mining Company in 1923, it kept the stamp mill open and used it to process some of its rock. This mill kept producing until 1933 when it was shut down due to the plummeting price of copper, then reopened in 1936 as the Great Depression eased.[126] It remained the last stamp mill the company

[125] C&H Annual Reports (1949), Michigan Tech Archives.
[126] C&H Annual Reports (1923, 1933, 1936), Michigan Tech Archives.

had and was sold to UOP in 1968 when it was officially closed. C&H's electrical system continued to grow into the 1940s and C&H wanted to expand their electrical system along the lake. Though the Ahmeek mill already had a small power plant in place, C&H decided to start from scratch and build a system that could not only power the Ahmeek, but the Tamarack Reclamation Plant facilities as well.

A February 1930 report from Stone & Webster to C&H reported that the old power and boiler houses were not as efficient as they needed to be and that new ones should be built. This report included cost estimates and drawings of where the old buildings were and where the new ones should go. Because of this report and possibly others, the entire Ahmeek Mill and related power generating facilities were renovated in 1930 by C&H, who contracted the work on the power plant to Stone & Webster Engineering Company. At the recommendation of Stone & Webster, C&H went about upgrading the Ahmeek stamp mill, the electrical and steam generating facilities, and also incorporated an ash disposal system for the fly ash waste from the power plant (see Figure 40).[127] With all of the reclamation facilities back on-line after the worst of the Depression, the power plant had to be ready for maximum capacity.

The new Ahmeek power and boiler houses went into commission in January 1931 and ran smoothly for the next few years.[128] The Ahmeek facilities again had an update in 1937 when the fire protection system was updated to provide ample protection for the buildings and equipment. In 1938 the Ahmeek Stamp Mill housed

[127] "Stone & Webster-Ahmeek Mill Power Plant," MS-002 Box 73 Folder 51b or 52, 1 of 2, Michigan Tech Archives; "Power Plant-Memorandum of Contract," MS-002 Box 151, Folders 5-18, Michigan Tech Archives.
[128] C&H Annual Report (1931), Michigan Tech Archives.

eight stamps that could process 900 tons of material per day. The Ahmeek mill area was becoming a center for not only stamping but also for electrical generation. In 1941 the Ahmeek boiler plant began providing the steam needed at the Tamarack Reclamation Plant, because C&H decommissioned the Tamarack boiler plant.[129]

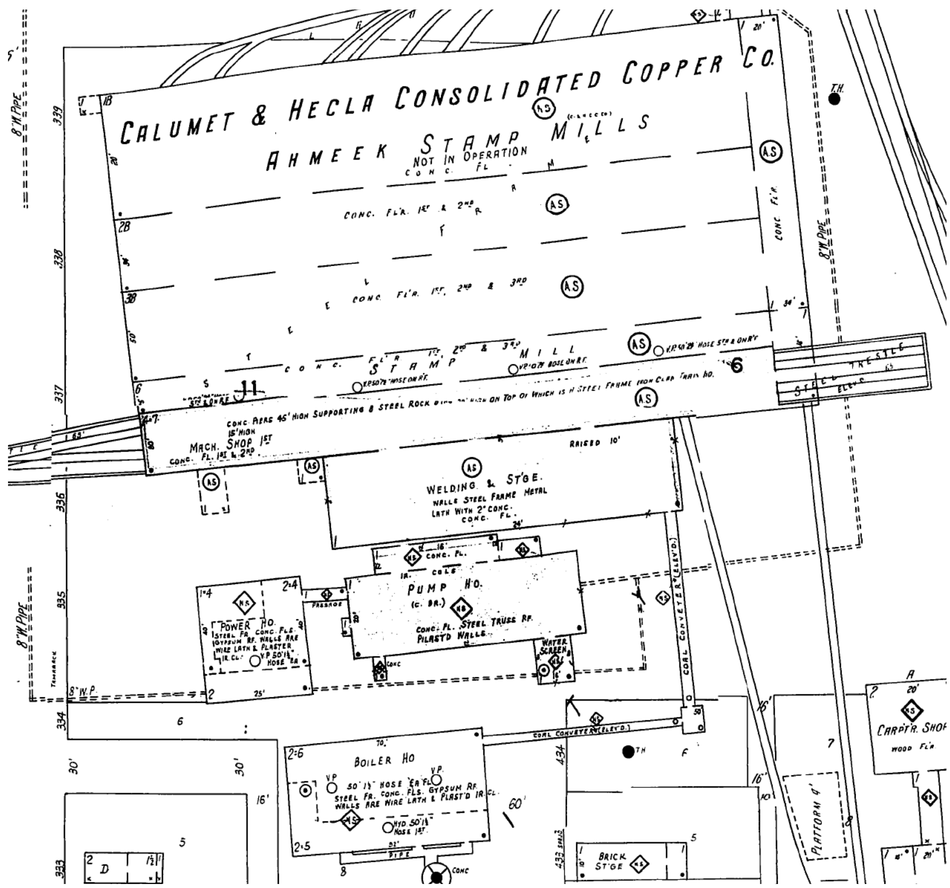

Figure 40: 1935 Update of the 1928 Sanborn of Lake Linden #13 after the update of the Ahmeek Stamp Mill complex. Courtesy Michigan Tech Archives and Copper Country Historical Collections.

The Ahmeek powerhouse was important to the chemical processing at the Tamarack. It allowed for steam to be produced at the Ahmeek Mill for mill use, as

[129] "Tamarack-Osceola-Ahmeek Fire Protection," MS-002 Box 38, Folder 9, Michigan Tech Archives; Benedict, "Steam Stamps hold their ground at Ahmeek Mill", *The Engineering and Mining Journal*, 139, no. 12 (1938), 53-56; C&H Annual Report (1941), Michigan Tech Archives.

well as for use at the Lake Chemical division at the Tamarack Reclamation Plant. It can be argued that C&H's need for steam power in multiple locations (because of the stamp mills), led to its decision to generate electricity in those locations, such as at the Ahmeek mill. For the next few years, there was not much that changed in the Ahmeek. It continued to stamp and use the flotation equipment installed in 1928 and produced well for the company. In January 1946 the Ahmeek Mill power plant turbines were repaired and machinery in the boiler house was modernized. The Lake Linden power plant produced 40,000 kva while the Ahmeek produced 13,375 kva.[130] This shows that C&H drew electricity from both of its major steam-producing centers.

Repairs were done to the Ahmeek Mill power plant turbines in 1946, which led to higher efficiency.[131] In 1946, when there was a coal shortage, C&H had to tap into the local electrical grid. One report states:

> Electric power from other sources in the district is 60 cycles. Consequently while the power distributed by Houghton County Electric Light Company is generated by water power, advantage could not be taken of this source. Fortunately [C&H] was able to secure a second-hand frequency changer of 1000 Kw. capacity which was purchased and installed in the Lake Linden power plant ready to meet another such contingency. This machine can operate either from a 60 cycle source and deliver 25 cycles, or from a 25 cycle source and deliver 60 cycles, and provides a means to have an interconnection

[130] "Vern E. Alden Co., Re: Power Plant, etc," MS-002, Box 59 Folder 24, Michigan Tech Archives; C&H Annual Report (1928), Michigan Tech Archives; "Turbines are Repaired," *Calumet & Hecla News & Views*, January 1946, 7; "Jim Breth Tells of Early Days of C. & H. Electrical Department," *Calumet and Hecla News & Views*, January 1949, 7.

[131] "Jim Breth Tells of Early Days of C. & H. Electrical Department," *Calumet and Hecla News & Views*, January 1949, 7.

> between the company's electric system and the local utility system for a limited amount of power.[132]

In 1949 the Ahmeek Mill power plant had three Babcock and Wilcox boilers with turbine driven fans, which supplied 180,000 pounds of 650-degree Fahrenheit steam at a pressure of 140 pounds per square inch and a total capacity of 13,375 kva.[133] This power facility remained open until the closing of the Calumet Division in 1969.

After the 1931 renovation C&H was able to send electricity to the Tamarack, which would prove necessary for the reclamation plant and later for the chemical production. It also prepared the facilities for the upcoming war, when copper became a strategic natural resource. However, once the war ended, C&H was one of the only copper mining companies left in the Keweenaw, and its extensive electrical system allowed it to focus on recycling, reprocessing, and making copper chemicals. C&H was therefore able to remain open for about 25 more years. This new power plant created a decrease in the cost of electricity as well as the capacity to allow the mines and reclamation plants to resume their work after the effects of the Depression were over.[134]

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132 "Electrical Department Turns Out A Tremendous Amount of Power – Output is four and one half times demand of whole district," *Calumet and Hecla News & Views*, January 1947, 1.

133 "Jim Breth Tells of Early Days of C. & H. Electrical Department," *Calumet and Hecla News & Views*, January 1949, 7.

134 C&H Annual Reports (1941), Michigan Tech Archives; C&H Annual Report (1930), Michigan Tech Archives.

Smelter Power Plant

The C&H Smelter had a small electrical generating facility. There is little recorded about this facility. In 1929 the facility, which was in the southeast corner of the furnace building, contained an 800 kw. turbo generator. A 1931 report later states that steam is produced at the smelter and used to run the 800 kw. turbine generator (generating electricity) as well as for "other miscellaneous steam-driven equipment and also for heating the buildings in winter."[135] The waste heat from the smelting process was also recycled as steam, which was also used to generate electricity and heat the building. This shows that C&H was conserving all of the energy it could in order to cut costs.

C&H Power

Figure 41 shows the breakdown of where the C&H electricity was produced in 1931. These areas of electrical production could also be where the pollution has been or is still coming from.

[135] "C&H Smelting Works Furnace Building and Extensions Plan and Section, 1929," MS-005, Drawing 9003, Michigan Tech Archives; Endicott R. Lovell & Herman C. Kenny. "Present Smelting Practice," *The Mining Congress Journal* 17 (1931), 538.

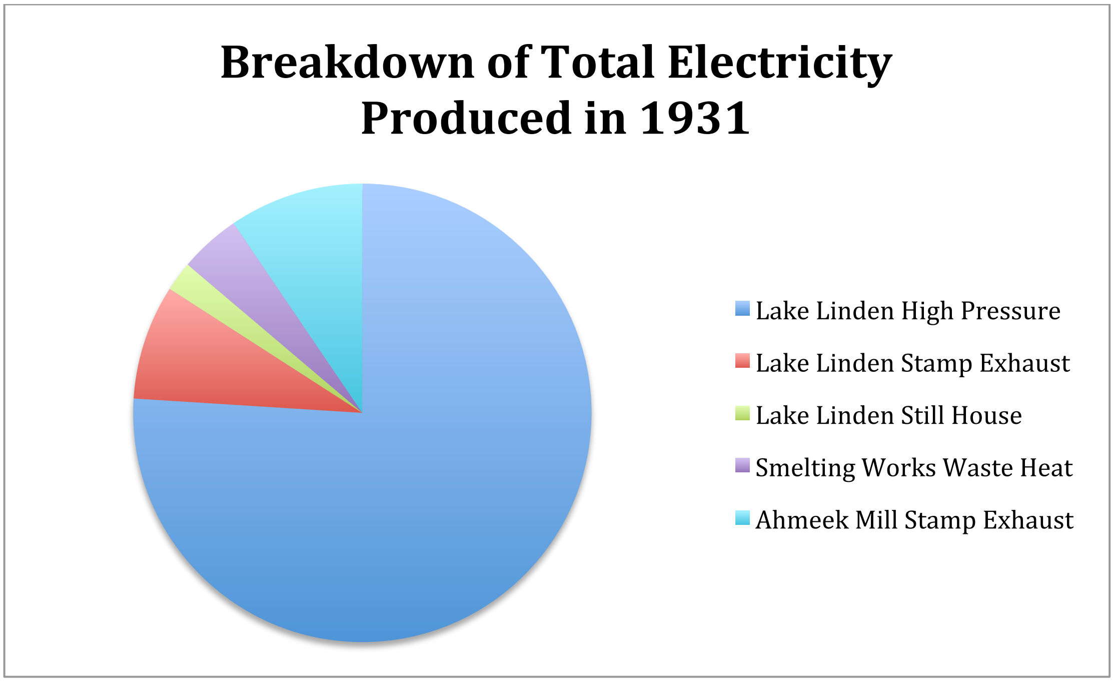

Figure 41: Breakdown of Total Electricity Produced in 1931. Source: McIntosh, Robert & A.L. Burgan. "Electric Power Generation," 541.

The waste stream of focus from the electrical distribution system is the PCB. PCBs had been in production as C&H was operating and renovating its electrical system. These chemicals were used in the transformer oil, and in 1912 the non-PCB containing oil was changed at least once a year.[136] Since there are no documents mentioning the frequency of oil changes after PCBs were introduced, I have hypothesized that the PCB containing oil was also changed about once per year. There are no records specifically stating where this oil went, but when comparing to the other waste streams, it is very plausible that this oil was also dumped into Torch Lake or used to help reduce dust in parking lots or other dirt areas.

[136] Liston, "Electrical Equipment of the Calumet & Hecla Mining Co., Calumet, Mich," *General Electric Review,* 527.

Pulverized Coal

The coal that powered the facility came via ship and rail. Its destination was the smelter coal dock or railroad depot. C&H became aware that burning pulverized coal would get them more efficiency than burning whole coal. The coal was then sent through the Coal Pulverization Plant, which was being planned in 1923, in order for it to be pulverized and then sent via rail to the powerhouse.[137] The Coal Pulverization Plant can be seen in Figure 42. Before 1923 the coal was not pulverized and burned whole. Coal was the main source of fuel, which was burned to produce steam. This steam turned turbines that drove generators, which produced electricity.

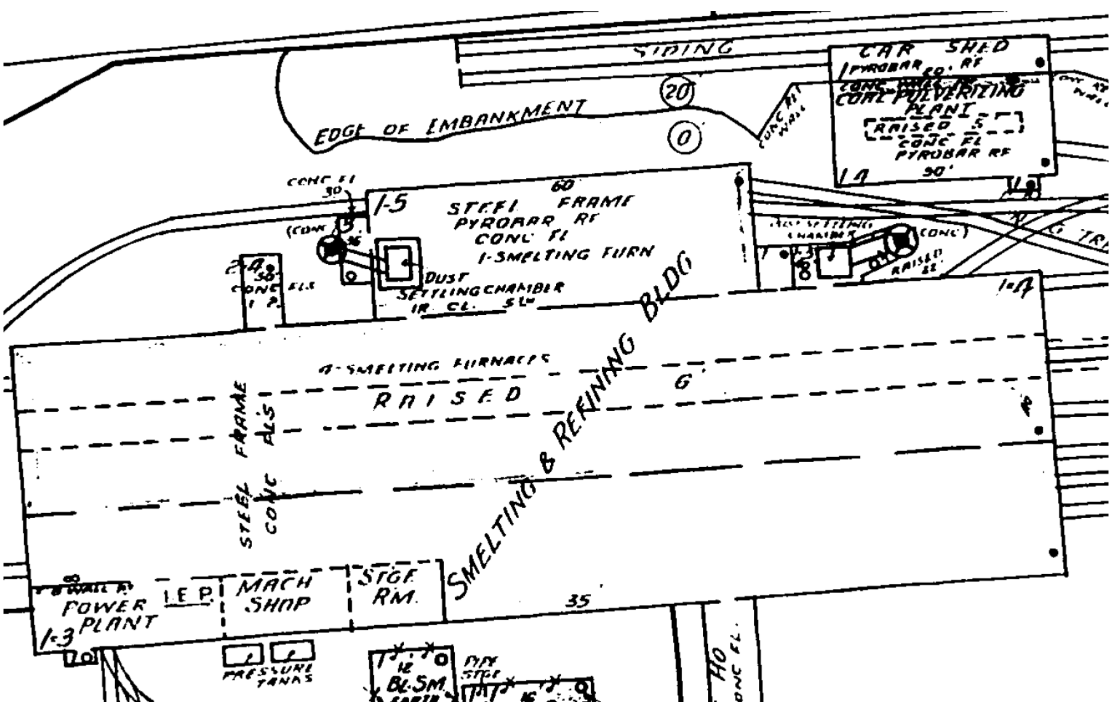

Figure 42: 1928 Sanborn of Lake Linden #9 showing the smelter and coal pulverizing plant. Courtesy Michigan Tech Archives and Copper Country Historical Collections.

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137 "Coal Pulverized Pit -& Blueprints, Drawings, Telegrams, etc," MS-002, Box 127 Folder 1, Michigan Tech Archives; "Coal Pulverized Pit -& Blueprints, Drawings, Telegrams, etc," MS-002, Box 126 Folder 14, Michigan Tech Archives.

According to a report made in the *C&H News & Views*, the most important factor involved with generating steam and electrical energy was the cost of coal. C&H was pushing for a more efficient power plant to make the most out of the coal it could afford. It was discovered that installing a pulverized coal boiler and building a new pulverizing plant could save the company about $300,000 a year. This new coal pulverizer was installed near the smelter in August 1947 and was much more efficient than the previous.[138]

Fly ash was the main waste stream from the boilers. It was the residue left behind after the coal had been burned. At first this waste was discarded into Torch Lake like many of the other wastes, but as C&H became more aware of the success of the copper chemical market, it realized it could benefit from this particular waste. C&H used fly ash as an additive in the fertilizer produced at Lake Chemical, which increased profit.[139]

[138] "Modernization of Lake Linden Power Plant Is Approved By Directors – Two years required to complete job," *Calumet and Hecla News & Views*, March 1947, 3; "Smelter Has Been Modernized With New Equipment – New Coal Pulverizer and a Furnace Placed in Operation," *Calumet and Hecla News & Views*, September 1947, 1.
[139] "Fly Ash," MS-002, Box 199 Folder 20, Michigan Tech Archives.

Chapter 5 – Environmental Issues – PCBs

Waste products from C&H were deposited onto the landscape and eventually led to harm coming to the environment. Tailings were milling waste, and the tailings from the various stamp mills stretched out into Torch Lake. C&H, in their copper extracting processes and waste tailings, deposited remaining copper and other chemicals found in the rock into the water and even the soil. Another waste product was from the flotation process, which usually consisted of pine oil and xanthates, which mixed with the tailings and were disposed of into the lake. Although these chemicals are dangerous to the environment and have been found in Torch Lake, they are not the focus of this thesis.

The most dangerous chemical, PCBs, were commonly found in the mineral oil inside transformers, specifically in the dielectric liquid, because PCBs were efficient insulators. This means that the PCBs were directly in relation to the electrical system. In 1912 the insulating oil was normally changed in transformers about once a year, and since no records have been found about the procedures after 1930, I have hypothesized that the PCB containing insulating oil was also changed once per year. This oil could have possibly been dumped right into Torch Lake, or onto roads or parking lots in order to keep the dust down. PCBs were also found in the plastic insulation around copper wires, and C&H burned off this material in their scrapping process in order to reclaim the copper content.[140] PCBs would cause a lot of problems

[140] United States Environmental Protection Agency, *Polychlorinated Biphenyls 1929-1979: Final Report* (Washington DC: Office of Toxic Substances, 1979), ii, 3; Liston,

after the company closed, but it was not discovered as harmful until about the time C&H closed.

History of PCBs

When discovered in 1881, PCBs were seen as something new and wonderful that would benefit the world by providing a synthetic insulation compound. They were finally ready to be introduced, after extensive testing and experimentation, to the industrial world in 1929 by Swann Research, Inc., located in Anniston, AL, which became Monsanto Chemicals in 1935. Monsanto classified PCBs as Aroclors. PCBs were made out of benzene from coal tar and were hailed for their heat resistance.[141] Because of this, PCBs became important in electrical systems for their insulator use in the mineral oil in transformers. Monsanto had a monopoly on PCBs once it bought Swann Research. Monsanto opened up another plant in Sauget, Illinois, to produce PCBs.

Polychlorinated biphenyl compounds are synthetic organic chemicals containing chlorinated biphenyl rings (see Figure 43). PCBs are particularly dangerous because most varieties of the Aroclor are semi-volatile and persistent, and therefore

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"Electrical Equipment of the Calumet & Hecla Mining Co., Calumet, Mich," *General Electric Review,* 527.

[141] United States Environmental Protection Agency, *Polychlorinated Biphenyls 1929-1979: Final Report*, 1-2; Ellen Griffith Spears, *Baptized in PCBs: Race, Pollution, and Justice in an All-American Town* (Chapel Hill, NC: University of North Carolina Press, 2014), 1, 54-55.

remain in the environment without degradation. These molecules are attracted to organic material, meaning that humans and fish absorb them.[142]

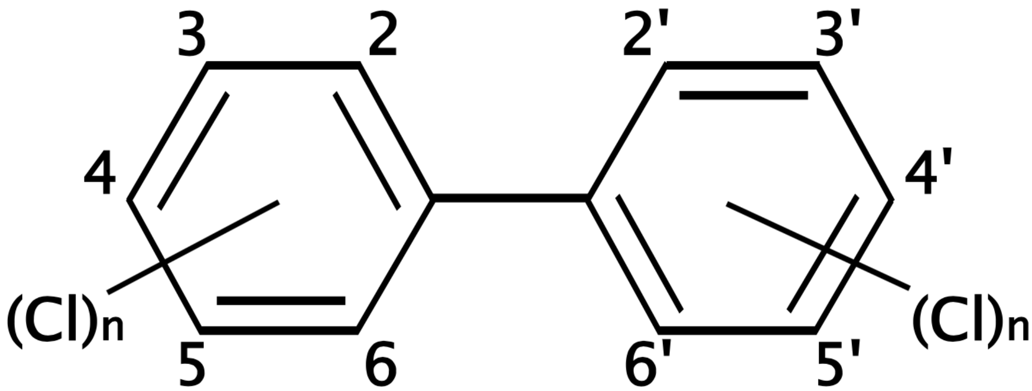

Figure 43: Chemical Structure of PCBs. Source: By D.328 07:28, 13 August 2006 (UTC) - drawn by D.328, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=1048994.

As early as 1931, PCBs were discovered to have bad effects on humans, specifically skin problems. New techniques were developed to help researchers document the effect of toxic chemicals like PCBs, but this information was not widely circulated or known.[143] However, Monsanto, even when brought to court, largely overlooked these reports. The company tried to hide the fact that PCBs were dangerous, even as more reports of their toxicity were brought to light. As toxicity research developed, Monsanto could no longer avoid facing the evidence that the workers and environment at their Anniston plant were unhealthy. Their first means of solving the issue was to replace all of the workers so that the PCB levels would not

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142 U.S. Department of Health and Human Services, *Toxicological Profile for Polychlorinated Biphenyls (PCBs)* (Atlanta, GA: Agency for Toxic Substances and Disease Registry, 2000), 1-2.
143 United States Environmental Protection Agency, *Polychlorinated Biphenyls 1929-1979: Final Report*, 3; Spears, *Baptized in PCBs: Race, Pollution, and Justice in an All-American Town*, 61, 67, 72, 77.

build up. This, however, was not a solution but a temporary fix. In 1934 researchers were aware that PCBs were causing skin irritations, but in 1937 it was decided that PCBs would still be produced. The electrical industry found PCBs to be vital to their equipment, plus federal regulations mandated that any transformer inside a building had to consist of nonflammable insulating oil, which meant PCBs.[144]

PCBs are considered a carcinogen, meaning that there have been studies shown to link them to the development of cancer. They can also negatively affect the immune system, reproductive system, nervous system, and endocrine system (see Figure 44). They were only produced in the US from about 1930 until the 1970s, but this was enough time to damage the environment and leave behind a contaminated landscape.[145]

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[144] Spears, *Baptized in PCBs: Race, Pollution, and Justice in an All-American Town*, 61, 67, 72, 77.

[145] "Learn about Polychlorinated Biphenyls (PCBs)," *U.S. Environmental Protection Agency,* https://www.epa.gov/pcbs/learn-about-polychlorinated-biphenyls-pcbs; United States Environmental Protection Agency, *Polychlorinated Biphenyls 1929-1979: Final Report*, ii.

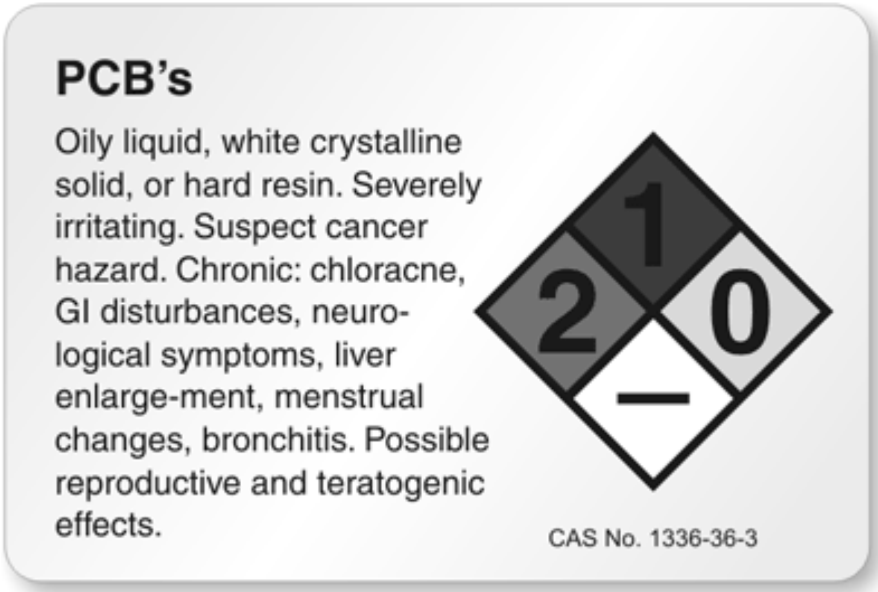

Figure 44: National Fire Protection Association panel for PCBs. Source: Sott.net – Health & Wellness, High Levels of PCBs Tied to Defective Sperm in Infertile Men (http://sott.net/en242254).

One of the final blows to PCBs came in 1968, when PCB contaminated cooking oil seriously affected 1,000 people in Yusho, Japan. This, followed by other PCB contamination in the US, finally brought an end to the production of PCBs. Between 1969 and 1971, the United States Food and Drug Administration (FDA) established safe levels of PCBs allowed in food, though no formal limit was enforced. Also in 1971, a ruling from the Council on Environmental Quality identified PCBs as a major problem. Following these two decisions, the FDA placed a formal limit on the amount of PCBs allowed in food and animal feed, finally enforcing their earlier ruling.[146]

[146] United States Environmental Protection Agency, *Polychlorinated Biphenyls 1929-1979: Final Report*, 5; Interdepartmental Task Force on PCBs, *Polychlorinated Biphenyls and the Environment*, 6.

PCBs were cut from production at Monsanto's Anniston plant in 1966. In 1970 they limited overall PCB sales to closed electrical equipment with the recommendation that the PCB-containing oil be replaced with a non-PCB formula. Monsanto finally closed its Anniston plant in 1973.[147] The environment in Anniston, both natural and social, is still one of pollution, controversy, and law. *Baptized in PCBs: Race, Pollution, and Justice in an All-American Town*, by Ellen Spears, documents the historical and present climate in Anniston that has resulted from the production of PCBs.

The final ban of PCBs came in the Toxic Substances Control Act of 1976, though it was not officially introduced until 1979 when congress passed the act. Monsanto's other plant, in Sauget, stopped producing PCBs in 1977, two years before the U.S. ban was implemented.[148]

PCBs at Torch Lake

Because PCBs were used in equipment such as transformers and capacitors, other electrical equipment including voltage regulators, switches, reclosers, bushings, and electromagnetics, oil used in motors and hydraulic systems, and many more, it is highly plausible that C&H was using PCBs in its equipment. When C&H bought new transformers in the 1930s when it renovated the electrical system, PCBs were most

[147] Spears, *Baptized in PCBs: Race, Pollution, and Justice in an All-American Town*, 2, 5; United States Environmental Protection Agency, *Polychlorinated Biphenyls 1929-1979: Final Report*, 5.

[148] United States Environmental Protection Agency, *Polychlorinated Biphenyls 1929-1979: Final Report*, ii; Spears, *Baptized in PCBs: Race, Pollution, and Justice in an All-American Town*, 275.

likely introduced to the environment around Torch Lake.[149] The destructive nature of PCBs was not discovered until after C&H closed. Since the transformers were an integral part of the electrical system and most likely contained PCB oil, they became a focus for the cleanup of PCBs. Only later would it become known that the plastic insulators on copper wire also contained PCBs and they should be a significant focus of PCB research as well.

Oil in these transformers was changed at least once a year in 1912, and it is plausible that this was also the practice after 1930. It is also possible that this oil could have been dumped straight into Torch Lake, recycled in some way, or even spread out on dirt parking lots to help control dust, though there is no record of what exactly happened to this waste product. Figure 45 shows the transformation of transformer oil over its lifetime, with the middle vial being treated with hydrodechlorination, which was being used by 2004, in order to destroy PCB molecules.[150]

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[149] "Learn about Polychlorinated Biphenyls (PCBs)," *U.S. Environmental Protection Agency,* https://www.epa.gov/pcbs/learn-about-polychlorinated-biphenyls-pcbs; C&H Annual Reports, Michigan Tech Archives.

[150] Liston, "Electrical Equipment of the Calumet & Hecla Mining Co., Calumet, Mich," *General Electric Review,* 527; "Hydrodec – good oil on electricity," *CSIROpedia,* https://csiropedia.csiro.au/hydrodec-good-oil-on-electricity/.

Figure 45: Photograph of transformer oil over the course of its usefulness. Source: "Hydrodec – good oil on electricity," CSIROpedia, https://csiropedia.csiro.au/hydrodec-good-oil-on-electricity/.

Another way PCBs entered the environment at Torch Lake was through scrap processing. Copper wires were brought in by the truckload, but in order to get at the copper interior, the outside insulating plastic had to be removed. This plastic also contained insulating PCBs. C&H removed this plastic by burning the wire, therefore allowing the PCBs to escape into the soil and possibly into the water.

PCBs were not discovered in Torch Lake fish until 1971, but researchers have suggested that it was a problem by 1964 if not before. This information, however, came too late to help Torch Lake as C&H was already closed by this time. The EPA

announced methods for the safe disposal of PCBs in 1978 and the final ban in the US came in 1979, but the damage had already been done in the Keweenaw.[151]

Fish Consumption Advisories

All of the different elements and chemicals used in the Keweenaw (copper, mercury, lead, arsenic, ammonia, etc.), including PCBs, created a source of environmental concern. In the case of Torch Lake, tumors were discovered on sauger and walleye in 1973, and in 1983 the Michigan Department of Health issued fish consumption advisories for these species of fish in Torch Lake. This meant that the fish were considered unsafe to eat. By 1986 Torch Lake was put on the National Priority List (NPL) by the EPA as the tumors were of concern.[152] Figure 46 shows the current fish advisory for Torch Lake. For example, an average adult should only eat a 20" bass caught out of Torch Lake once per year, at the risk of consuming too much mercury and PCBs.

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[151] United States Environmental Protection Agency, *Polychlorinated Biphenyls 1929-1979: Final Report*, 3; Interdepartmental Task Force on PCBs, *Polychlorinated Biphenyls and the Environment*, 6; Michigan Department of Environmental Quality, *Remedial Action Plan Update for the Torch Lake Area of Concern*, 44.

[152] N. Urban, et al, *Integrated Assessment of Torch Lake Area of Concern – Draft 3*, 3-56.

Torch Lake

Type of Fish	Chemicals of Concern	Size of Fish (length in inches)	MI Servings per Month*
Largemouth Bass	PCBs & Mercury	Under 18”	2
		Over 18”	1
Northern Pike	PCBs	Any	2[2x]
Smallmouth Bass	PCBs & Mercury	Under 18”	2
		Over 18”	1
Suckers	PCBs & Mercury	Under 16”	12
	Mercury	Over 16”	4
Walleye	PCBs & Mercury	Under 22”	1
		Over 22”	6 Per Year

Figure 46: Chart of fish on the 2015 Fish Consumption Advisory, Specifically in Torch Lake. Source: Michigan Department of Health and Human Services’ Eat Safe Fish Guide, Upper Peninsula 2015, page 44, http://www.michigan.gov/documents/mdch/MDCH_EAT_SAFE_FISH_GUIDE_-_UPPER_PENINSULA_WEB_455361_7.pdf.

The discovery of the fish tumors led to multiple surveys in the 1970s by the EPA and DEQ that looked into the tumor issue and found that some of the walleye and sauger had liver tumors, which are associated with organic chemicals. 1986 saw an end to the tumor investigations. Researchers concluded that the tumors were caused by higher concentrations of the xanthates and creosotes that were used by C&H in its copper processing facilities.[153] They had all but ruled out heavy metal and PCB toxicity.

The 1983 fish consumption advisory was removed in 1993 since there were no sauger in Torch Lake and the walleye no longer exhibited tumors. A new fish

[153] Ibid, 3-62.

consumption advisory was issued in 1998, which focused on mercury and PCBs, although a statewide mercury advisory was in effect between 1993 and 1998.[154]

Area of Concern

The initial listing of Torch Lake as an Area of Concern came in 1983 when it was designated one by the International Joint Commission. The Michigan Department of Natural Resources (MDNR) published the first Remedial Action Plan (RAP) in 1987. Researchers and government officials used it to clearly state what they had discovered and how they planned to move forward. One was published in 1987 as the project was just beginning, and a second was published in 2007, summing up the recent activity and drawing the project to a close. [155]

The RAP identified three Beneficial Use Impairments (BUIs) in Torch Lake for the AOC to be remediated. The three BUIs were: "fish tumors or other deformities, restrictions on fish consumption, and degradation of benthos.[156] In 1997 a Public Advisory Council (PAC) was organized by the MDEQ in order to begin looking at ways to delist the BUIs. Ten years later, in 2007, the fish tumors or other deformities BUI was delisted.[157] The other two BUIs are still a work in progress. Once the

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[154] Ibid, 1-10.
[155] United States Environmental Protection Agency, *Five-Year Review Report for Torch Lake Superfund Site Houghton County, Michigan* (Chicago, IL: EPA, 2013), 13.
[156] Ibid, 3.
[157] N. Urban, et al, *Integrated Assessment of Torch Lake Area of Concern – Draft 3,* 3-70; United States Environmental Protection Agency, *Five-Year Review Report for Torch Lake Superfund Site Houghton County, Michigan* (Chicago, IL: EPA, 2013), 24.

remaining BUIs are delisted, the site will no longer be characterized as an Area of Concern.

The AOC was focused on getting the water clean. There were not only problems with the fish, but sediments as well. As one of the BUIs stated, there were no benthic, or bottom-dwelling, organisms in Torch Lake. This was cause for concern as benthic organisms relate to the health of a lake. If there are no benthic organisms, it means that they could not live in the environment. The Contaminants of Concern in the RAP were wood and coal tar creosotes, xanthates, and fish contaminants, which consisted of heavy metals and other possibly toxic chemicals, including heavy metals and PCBs.[158] The 2007 RAP update explained the delisting of the fish tumors or other deformities BUI as Torch Lake fish no longer exhibited these qualities.

Superfund

The Torch Lake Superfund was formally listed on the National Priorities List in 1986, just as the fish consumption advisories were put into action. The Superfund program came to Torch Lake because of the fish tumor issues and they were concerned that leaching from stamp sands was causing the tumors. The EPA believed that a listing on the National Priorities List (NPL) would help bring an end to the tumors because they could remediate the stamp sands.[159] The copper mining companies had deposited 178.5 million metric tons of copper-bearing stamp sand

[158] Michigan Department of Environmental Quality, *Biennial Remedial Action Plan Update for the Torch Lake Area of Concern*, 8, 44.
[159] N. Urban, et al, *Integrated Assessment of Torch Lake Area of Concern – Draft 3,* 3-65 & 3-66.

tailings into Torch Lake.[160] This meant that, even though they had been stamped and most had been reprocessed, some copper still remained. This could leach out into the lake from the tailings over time.

The EPA believed copper to be a main contributor to the fish tumors, and they set up a process for capping the tailings. They called each area an Operating Unit (OU). There were three total units. "Operable Unit 1 includes the stamp sands, water quenched slags and other mining wastes deposited along the Torch Lake shoreline", "Operable Unit 2 includes ground water, surface water and submerged stamp sands and sediments in Torch Lake, Portage Lake, the Keweenaw Waterway/Portage Ship Canal, and the Lake Superior Shoreline from south of the North Entry to Freda/Red Ridge, Boston Pond and Calumet Lake," and "Operable Unit 3 includes stamp sands and water quenched slag deposits along the Lake Superior shoreline, Keweenaw Waterway/Portage Ship Canal, Michigan Smelter, Quincy Smelter, Isle Royal, Calumet Lake, Boston Pond and Grosse Point/Point Mills."[161]

Each of these OUs had Remedial Investigation/Feasibility Studies (RI/FS) done to determine what steps to take to solve the contamination problem. The Record of Decision (ROD) for OU II, released in 1994 determined that the sediments were indeed contaminated, but that dredging the lake and disposing of the sediments properly would be impractical. OU II was eventually delisted from the NPL in 2002

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[160] Kerfoot, et al, "Paleolimnological Study of Copper Mining Around Lake Superior: Artificial Varves from Portage Lake Provide a High Resolution Record," *Limnology and Oceanography* 1994, 650.
[161] Michigan Department of Environmental Quality, *Biennial Remedial Action Plan Update for the Torch Lake Area of Concern*, 13.

while OUs I and III still had work that needed to be done. The RODs for OU I and III allowed the EPA to move forward with their plan to cap the tailings with soil and vegetation.[162]

The first phase for OU I consisted of removing potentially toxic barrels from the shoreline and water. However, only about 80 barrels were removed and some 800 still remain at the bottom of the lake, and it is possible that these barrels may contain PCBs. The second phase was to cap the tailings piles. Lake Linden was capped in 1999, Hubbell/Tamarack in 2000, and Mason in 2001. The capping consisted of adding topsoil and vegetation to the tailings, where they would grow and help the sands to stop eroding.[163] OU III was also being worked on as other tailings piles across the Keweenaw were also capped.

New Sampling

The recent discovery of PCBs in Torch Lake and the Keweenaw waterways led to an investigation in Torch Lake and the surrounding water bodies. Semipermeable membrane devises (SPMDs) were a new piece of technology which served as "passive samplers that concentrate trace levels of hydrophobic organic compounds in the water column," essentially acting like a fish over time and soaking up the same chemicals, including PCBs (see Figure 47). Using the results from fish

[162] Ibid, 13-15.
[163] N. Urban, et al, *Integrated Assessment of Torch Lake Area of Concern – Draft 3*, 3-71.

sampling, sediment sampling, and the SPMDs, a research team from Michigan Technological University mapped the sampling data for Torch Lake.[164]

Figure 47: Semipermeable Membrane Device. Source: NOAA, Technology – Observing Systems and Sensors: Semipermeable Membrane Devices. http://oceanexplorer.noaa.gov/technology/tools/spmds/spmds.html

One site in particular, the C&H powerhouse in Lake Linden, was identified as a source of PCB contamination in 2010, under CERCLA's emergency response clause. This was considered an emergency because the levels of copper, asbestos, arsenic, lead, and PCBs posed a threat to those living around the area. The structure was razed and the area was remediated by August 2013.[165]

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164 Larry Brown, et al, "Urban streams across the USA: lessons learned from studies in 9 metropolitan areas," *Journal of the North American Benthological Society* 28, no. 4 (2009), 1056; N. Urban, et al, *Integrated Assessment of Torch Lake Area of Concern – Draft 3*.

165 U.S. Environmental Protection Agency, *Community Involvement Plan - Calumet & Hecla Power Plant Site* (Lake Linden, MI: May 2013), 1; N. Urban, et al, *Integrated Assessment of Torch Lake Area of Concern – Draft 3*, 3-76; U.S. Environmental

Michigan Sea Grant

Funding for this project, from Michigan Sea Grant, was used to create an Integrated Assessment of the Torch Lake area. There were three objectives: "1) to gather and summarize existing information regarding conditions in the AOC; 2) to communicate with stakeholders about the status of the site as well as stakeholders' ideas for and visions of future conditions in the AOC; and 3) to identify and to begin to evaluate potential remedial actions that could mitigate any remaining undesirable conditions."[166] For the first objective, it was important to collect all of the previous sampling data and combine the findings into one comprehensive product. This part of the Torch Lake story can be found in a thesis written by my research partner on the Integrated Assessment, Ankita Mandelia. The end result was that Torch Lake had a much higher concentration of PCBs in the fish and sediment samples than the Portage Waterway and Lake Superior.[167]

The second objective was conducted through the primary investigators, Dr. Noel Urban, Dr. Judith Perlinger, and Dr. Carol MacLennan. They put together informational material and attended and presented at public meetings in order to help

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Protection Agency, *Pollution/Situation Report – C&H Power Plant-Removal Polrep* (Lake Linden, MI: Nov 2012), 2; U.S. Environmental Protection Agency, *EPA Ends Cleanup at Former Power Plant Facility* (Lake Linden, MI: Oct 2014), 2.

[166] N. Urban, et al, *Integrated Assessment of Torch Lake Area of Concern – Draft 3*, 1-3.

[167] Mandelia, "Polychlorinated Biphenyl Compound and Metal Contamination and Remediation in Torch Lake, Houghton County, MI;" Michigan Department of Environmental Quality, *Biennial Remedial Action Plan Update for the Torch Lake Area of Concern*, 1.

communicate with the stakeholders. The third objective, to identify and evaluate areas of possible contamination, was my focus.

As the first step, we combined all of the sampling information from the different research groups and deduced the most important samples from all of this information. Next we plotted them all on a map of Torch Lake to see where the highest concentrations of PCBs were located. We conducted this research in tandem with the historical investigation of the facilities along the Torch Lake waterfront, particularly the electrical facilities. We then mapped the Torch Lake electrical facilities from Lake Linden to Mason combined with the SPMD, sediment, and soil PCB data (see Figure 48). Subsequent sampling of soil and shoreline sediments by the MDEQ began in 2014 and continues to this date in the search for possible PCB sources that may continue to contaminate Torch Lake.

Figure 49 was the result of historical research and the combination of the sampling data. There is a clear correlation between the major electrical sites, as well as the burning of the PCB containing scrap wire, and the sampling data received. This relationship suggests that there is a relationship between the electrical equipment and the PCB contamination in the environment.

As of the summer of 2016, the MDEQ has sampled the Lake Linden area (summer 2014) and the Hubbell/Tamarack area (summer 2015). The MDEQ plans to conduct additional sampling in the Hubbell/Tamarack area during the summer of 2016 and then at the Mason/Quincy area in 2017.

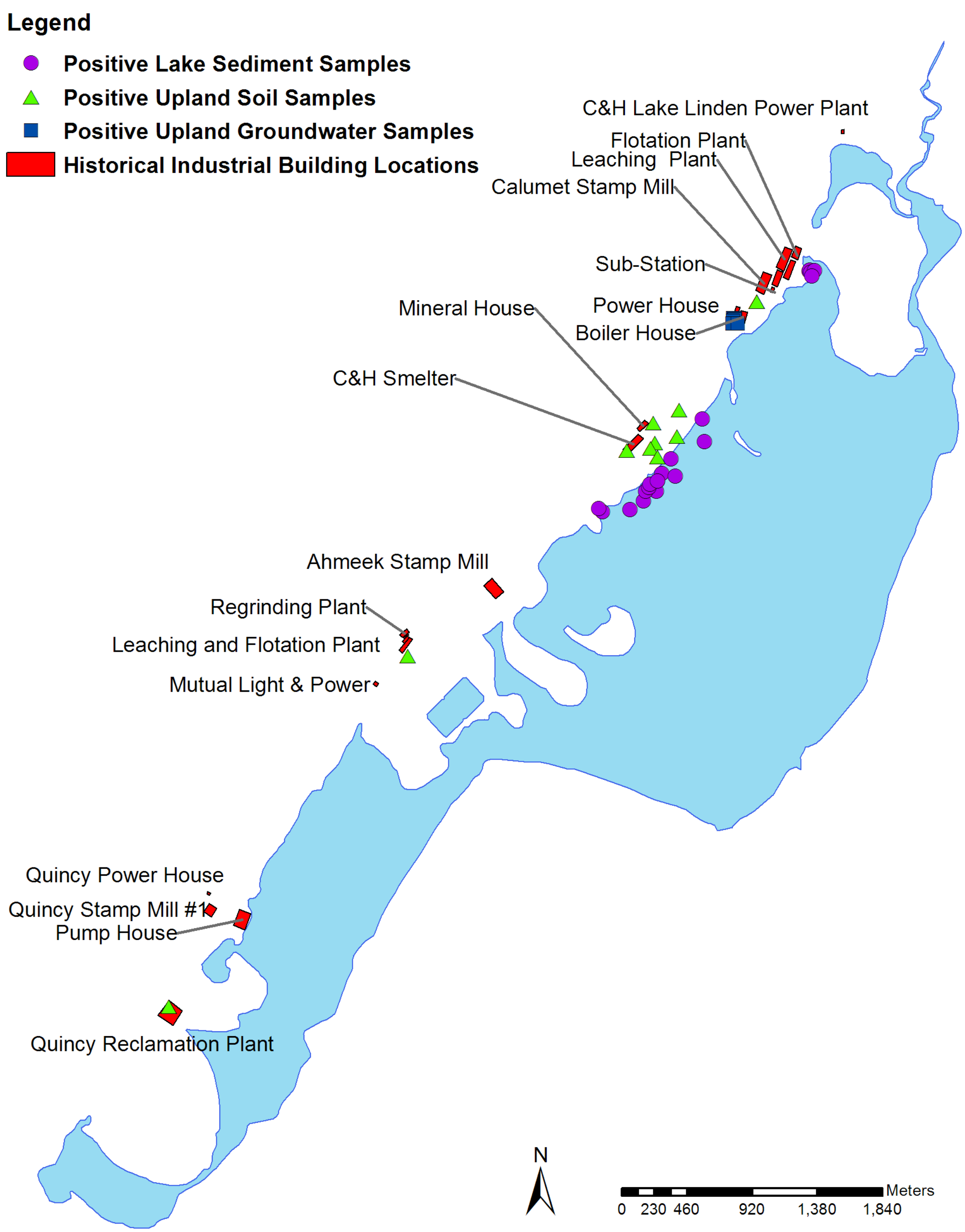

Figure 48: Map of Torch Lake: Correlation between Buildings and Testing. Source: Mandelia, "Polychlorinated Biphenyl Compound and Metal Contamination and Remediation in Torch Lake, Houghton County, MI".

Chapter 6 – Conclusion

The Calumet and Hecla Mining Company, and various other companies, took advantage of Torch Lake for almost an entire century. It bought nearly every mining property from Lake Linden down to Tamarack, and only Mason remained out of its control. It owned multiple stamp mills and opened two reclamation plants to reclaim lost copper. C&H diversified not only through flotation and leaching, but also by processing scrap metal and making copper chemicals.[168] This allowed the company to remain open even when its underground mines were failing, and prolonged the existence of copper mining in the Keweenaw.

My research question was: How did the C&H electrical system develop over time and what were the environmental consequences? When PCBs were introduced to the electrical industry they became an important part of transformers. These transformers were commonplace in industrial settings in order to step down electricity, including at C&H. As C&H's electrical system expanded, more transformers were used. Some of the PCBs in the transformers were introduced into the environment, causing pollution that bio-accumulates instead of breaking down. This pollution has been the focus of research in the past decade and will continue to impact the Torch Lake waterfront.

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[168] "Copper Paint in Demand," *Calumet and Hecla News & Views*, Dec. 1944, 8; "Calumet & Hecla and Cleveland Firm Organize A New Company, Will Manufacture Chemical Products," *Calumet and Hecla News & Views*, Oct. 1945, 1.

The Calumet Mining Company and the Hecla Mining Company both had existing steam power systems in place to operate their facilities before the merger took place in 1870, creating C&H. Steam power was crucial to running the mine hoists, the steam stamps, and the smelter. In the early 1900s, electricity came to use an increasing share of that steam. As additional facilities were added to the Lake Linden landscape, more power was needed.[169] Some of the power needs were met with electrical apparatuses. Electricity allowed for energy to be transmitted to these facilities without the loss of efficiency that would have occurred with steam.

Power left the Lake Linden power plant at 13,600 volts and had to be stepped down to 2,300 volts for use. In order to accomplish this, transformers were installed to lower the voltage. These transformers are believed to be the main source of PCB contamination. The insulating mineral oil used in most transformers between 1930 and the 1970s contained PCBs.[170] Since the C&H transformers were replaced over time, it is highly probable that these transformers did contain the PCB oil. This oil may have been discarded into Torch Lake with the rest of the waste. There is no record of what exactly happened to this oil. However, it has been discovered that PCBs also entered the environment through the burning of scrap. This is a new development that is currently being investigated (summer 2016).

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[169] Benedict, *Red Metal*, 71; C&H Annual Reports, Michigan Tech Archives.
[170] Liston, "Electrical Equipment of the Calumet & Hecla Mining Co., Calumet, Mich," *General Electric Review*, 522; Frederick N. Bosson, "Electric Power Distribution," *The Mining Congress Journal* 17 (1931), 547; Interdepartmental Task Force on PCBs, *Polychlorinated Biphenyls and the Environment,* 2.

PCB contamination is a serious environmental issue. PCBs are considered carcinogens, and they also include disruption of the immune, reproductive, nervous, and endocrine systems in humans.[171] As humans eat the fish, the PCBs build up in their system, causing the harmful effects previously stated. Being able to find and remediate PCB sources may help reduce the concentration of PCBs in the fish, allowing them to once again become a part of the diet of the local communities.

All of the C&H Torch Lake facilities, with the addition of all the mines and water pumping stations, needed power. The transformation from wood to coal to pulverized coal, and from motive to steam to electricity, allowed an expansion that may not have happened otherwise. Between 1878 and 1969, C&H built multiple generations of its powerhouse in Lake Linden, each time adding new, more efficient equipment.[172] A photograph showing the inside of the Lake Linden power plant can be seen in Figure 49. However, this also meant the spread of PCBs began around 1930.

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[171] "Learn about Polychlorinated Biphenyls (PCBs)," *U.S. Environmental Protection Agency,* https://www.epa.gov/pcbs/learn-about-polychlorinated-biphenyls-pcbs.
[172] "Jim Breth Tells of Early Days of C. & H. Electrical Department," *Calumet and Hecla News & Views*, January 1949, 7.

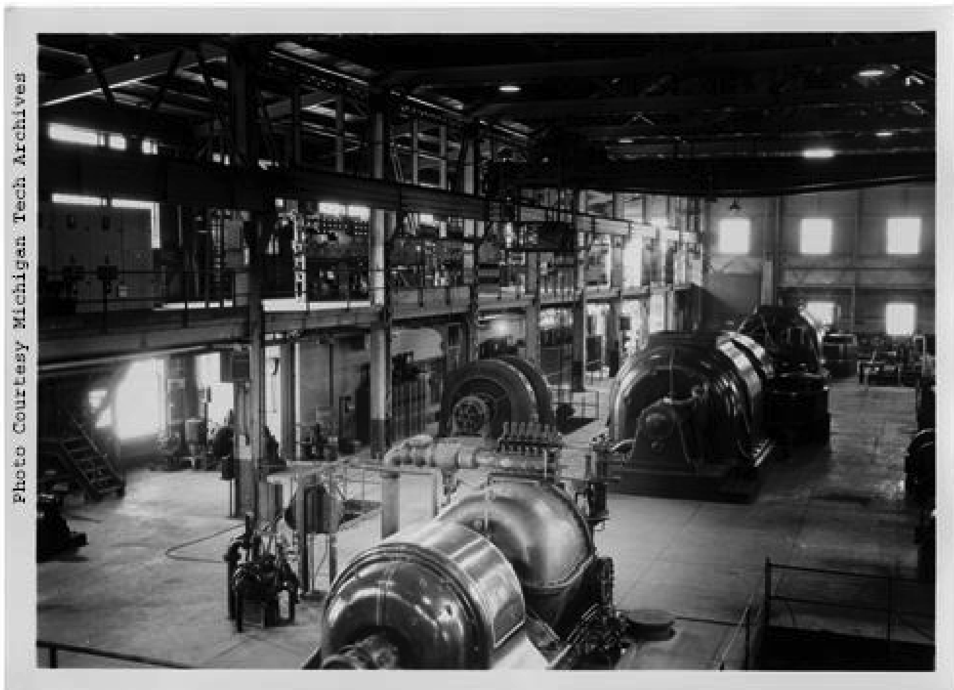

Figure 49: Photograph of the C&H Lake Linden Power Plant. Photograph No. MS003-004-011-02, "Calumet and Hecla Power Plant." 1949. Calumet and Hecla Photograph Collection. Michigan Tech Archives & Copper Country Historical Collections. http://digarch.lib.mtu.edu/showbib.aspx?bib_id=688407#. Accessed 7/20/16.

By 1931, the Ahmeek power plant was also generating 13,600 volts in parallel with the Lake Linden power plant. The Ahmeek power plant also had transformers onsite that contained the PCB enriched oil. The Tamarack Reclamation Plant was the recipient of electricity from this distribution system, and therefore had multiple transformers to step down the voltage.[173] These areas have not had proper sampling, and this should be done on the soils and possible outlets into Torch Lake.

By the 1950s, C&H was faced with the fact that its mines were no longer producing and its mills no longer needed. However, because of the secondary scrap

[173] Bosson, "Electric Power Distribution," *The Mining Congress Journal,* 547; Benedict, *Lake Superior Milling Practice*, 127.

and chemical process unique to C&H, it was able to stay open for almost two more decades. However, the end finally came in 1969 when it was sold and closed, leaving behind an industrial waste landscape that is still affecting the local communities.

Other mining areas had waste streams that affected the environment. Places like the Berkeley Pit and the Bingham Canyon show how damaging copper mining can be. Compared to the Keweenaw, these areas look worse as there is a physical scar on the landscape. Torch Lake has pollutants that do not visually show environmental damage like the western strip mines. Instead it hides the truth about the processes that once took place.

The research team from Michigan Technological University that was mentioned in Chapter 1 mapped the sampling data for Torch Lake.[174] This data was gathered over a span of more that thirty years and consisted of sediment, soil, and fish samples. Once compiled, the data was compared against the map made of the electrical system to see if there was any correlation between the areas of higher concentration and the historical electrical sites. This information was built on the Superfund and Area of Concern reports and investigations that had previously taken place.

This thesis stresses the importance of waste in industrial processes, specifically copper mining. When the attitude about waste is "out-of-sight, out-of-mind," consequences are bound to arise. If waste is not identified from the beginning, it is a very lengthy and costly task of connecting environmental pollutants with their original

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[174] N. Urban, et al, *Integrated Assessment of Torch Lake Area of Concern – Draft 3*.

function and location. Finding the causes of pollution and understanding why the company did what it did is just one step towards stopping environmental damage all together.

The cost of sampling the entire western coast of Torch Lake would be staggering. Because we have located specific areas of possible PCB contamination, sampling can now be done in an effective manner by concentrating around locations known to have PCBs. The testing I have suggested near the Ahmeek Stamp Mill and the Tamarack Reclamation Plant are just two areas that need further attention. There were other sub-stations along Torch Lake that may also have PCB contamination near them. One was located near the Lake Linden Reclamation Plant right on the shoreline, another just north of the smelter, and another north of the Quincy Reclamation Plant.[175] These sub-stations all had transformers at one point between 1930 and 1969 and should not be ignored just because they were not a large power facility like the Lake Linden powerhouse.

The other possible source of PCB contamination, the insulating plastic from wires, should also be further examined. As of this date, the only known area where this insulation was burned off at was the smelter yard.[176] If there were other locations where this wire was burned, that should also be tested for PCB contamination.

When exploring environmental pollutants such as PCBs, it is equally important to understand where they could have been used, and therefore discharged to the

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[175] "13KV System to Quincy, TL, & Mines," MS-005, Drawing 11461, Michigan Tech Archives.

[176] Tauno Kilpela (retired C&H employee), in discussion with the author, July 2013; Benedict, *Lake Superior Milling Practice*, 122.

environment, and to know the science behind the chemical. How and when these chemicals were made and what they were made for makes an impact on how historical research is done. The historical research then can predict how the chemical could have been used on a landscape and decrease the number of sampling locations. The two disciplines can work in tandem to solve problems. The use of archival and other historic material, combined with hard sciences such as chemistry and biology, help connect the past with the present. Interdisciplinary teams look to the past to map and understand processes, while modern techniques seek to find solutions for problems such as pollution.

Mining history is not just about the production and profits. It is not only about what the company did while it was alive. The key to mining history is to understand the rise and fall of operations as well as the legacy it left behind. Calumet and Hecla's legacy, like so many other industrial companies whether it be copper mining or not, is about the environmental consequences left after the closing of the company and how they will continue to affect the landscape and environment for years to come.

Recommendations

My recommendations going forward are to have additional focused sampling for PCB contamination done near the Ahmeek Mill, specifically where the power plant was located, and at the Tamarack Reclamation Plant near its transformer room. These two areas have only had preliminary sampling during the summer of 2015.

Between the closing of Calumet & Hecla and the present, there have been many studies into the different pollutants that have affected Torch Lake. Stamp sands from the milling process, creosotes and xanthates from the flotation and leaching processes, and heavy metals from the rock itself have all had negative effects on the landscape. PCBs may be the worst because of their toxicity to aquatic life as well as human life. As long as PCBs remain in and around Torch Lake there will be environmental problems. With this new research and mapping, perhaps PCB contamination in Torch Lake can be found and removed from the environment before it causes more harm.

Appendix A - Copyrights

Figure 1: Map of Michigan showing location of Torch Lake in the Upper Peninsula.
Fair Use. Image from Google and Google Earth.

Figure 2: Photograph of the original Calumet Stamp Mill.
Public domain. Photograph taken in 1867.

Figure 3: Map of Calumet and Hecla owned facilities between 1870 and 1970.
Fair Use. Image from Google and Google Earth.

Figure 4: Photograph of Calumet & Hecla Railroad Locomotive.
Fair Use. Keweenaw Digital Archives.

Figure 5: C&H Reclamation Plant – Leaching Plant.
Fair Use. Keweenaw Digital Archives.

Figure 6: Table showing the percentage of Michigan Copper coming from C&H between 1871 and 1946.
Table created by author.

Figure 7: 1935 Sanborn of Lake Linden #14 showing the Tamarack Reclamation Plant.
Copyright permission obtained from the Michigan Technological University Archives and Copper Country Historical Collections (Michigan Tech Archives).

Figure 8: Table showing the C&H copper production in pounds for both underground mining and reclamation.
Table created by author.

Figure 9: Photograph of the Osceola Stamp Mill, 1911.
Fair Use. Keweenaw Digital Archives.

Figure 10: Photograph of the Lake Chemical Company storing Copper Hydrate.
Fair Use. Keweenaw Digital Archives.

Figure 11: Photograph of ruins of the C&H Smelter.
Photograph by author.

Figure 12: Photograph of the C&H Stamp Mills.
Fair Use. Keweenaw Digital Archives.

Figure 13: 1928 Sanborn of Lake Linden #13 showing the Ahmeek Stamp Mill facilities.
Copyright permission obtained from the Michigan Tech Archives.

Figure 14: The Ball Steam Stamp.
Public domain. Original copyright 1955. No evidence copyright was renewed in 1983.

Figure 15: The Allis Steam Stamp, circa 1884.
Public domain. Original copyright 1955. No evidence copyright was renewed in 1983.

Figure 16: The Nordberg Compound Steam Stamp.
Public domain. Original copyright 1955. No evidence copyright was renewed in 1983.

Figure 17: Calumet Mill Flow-Sheet, circa 1907.
Public domain. Original copyright 1955. No evidence copyright was renewed in 1983.

Figure 18: Ahmeek Mill Flow-Sheet.
Public domain. Original copyright 1955. No evidence copyright was renewed in 1983.

Figure 19: Mass copper at the Ahmeek Mine, circa 1915-1916.
Fair Use. Keweenaw Digital Archives.

Figure 20: Amygdaloid copper rock.
Creative Commons. Image from flickr user James St. John.

Figure 21: Conglomerate copper rock.
Creative Commons. Image from flickr user James St. John.

Figure 22: Photograph of the C&H Smelter.
Fair Use. Keweenaw Digital Archives.

Figure 23: Photograph of Smelter Slag at the Trap Rock Road dumpsite.
Photograph by author.

Figure 24: 1917 Sanborn of Lake Linden #12 showing the Tamarack Stamp Mill and future reclamation area.
Copyright permission obtained from the Michigan Tech Archives.

Figure 25: Flow Sheet of the Ahmeek Flotation Plant.
Public domain. Original copyright 1955. No evidence copyright was renewed in 1983.

Figure 26: 1935 Sanborn of Lake Linden #8 of the Lake Linden Reclamation Facilities.
Copyright permission obtained from the Michigan Tech Archives.

Figure 41: Breakdown of Total Electricity Produced in 1931.
Chart created by author.

Figure 42: 1928 Sanborn of Lake Linden #9 showing the smelter and coal pulverizing plant.
Copyright permission obtained from the Michigan Tech Archives.

Figure 43: General molecular structure of Polychlorinated Biphenyls.
Creative commons. Image from Wikimedia user D.328.

Figure 44: National Fire Protection Association panel for PCBs.
Fair use. Criticism, comment, news reporting, teaching, scholarship, and research use of the image is listed as fair use by Sott.net.

Figure 45: Photograph of transformer oil over the course of its usefulness.
Copyright permission obtained from Hydrodec Development Corporation, who owns the rights to the photo used by CSIRO.

Figure 46: Chart of fish on the 2015 Fish Consumption Advisory.
Copyright permission obtained from the Michigan Department of Health and Human Services.

Figure 47: Semipermeable Membrane Device.
Public domain. Unless otherwise noted, information presented on this website is considered public information and may be distributed freely.

Figure 48: Map of Torch Lake: Correlation between Buildings and Testing.
Copyright permission obtained from Ankita Mandelia.

Figure 49: Photograph of the C&H Lake Linden Power Plant.
Fair Use. Keweenaw Digital Archives.

Appendix B - Relevant Copyright Documents

Figures 7, 13, 24, 26, 27, 29, 31, 37, 40, 42: Michigan Technological University Archives and Copper Country Historical Collections.

MICHIGAN TECHNOLOGICAL UNIVERSITY ARCHIVES
AND
COPPER COUNTRY HISTORICAL COLLECTIONS

DIGITAL PHOTOGRAPHIC AGREEMENT

FOR NON-COMMERCIAL USE ONLY

NAME OF RESEARCHER Emma Zawisza

ADDRESS 7000 Sandpiper Dr. Unit 17
Houghton, MI 49931

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Signature of staff membe[redacted]

Signature of researcher [redacted]

DESCRIPTION OF MATERIAL

MS-005: Image 12307, MS-002: Army Corps of Engineers Waterway Maps, Lake Linden Sanborn Maps, MS-002 Box 87 Folder 3 Tamarack Rec. Flow Sheet, MS-002 Box 60 Folder 4 Lake Chemical Flow Sheet, MS-002 Box 151 Folder 25 Ahmeek Stamp Mill Flow Sheet, & MS-005 Image 12307.

DATE 4-1-2016

Figure 45: Hydrodec Development Corporation.

Emma Schwaiger <emschwai@mtu.edu>

Copyright Permission for Academic Thesis

2 messages

Emma Zawisza <emschwai@mtu.edu> Tue, Jul 26, 2016 at 12:18 PM
To: usedoilcollection.northamerica@hydrodec.com, usedoilcollection.australia@hydrodec.com

Hello,

I am a Master's student at Michigan Technological University in the US. I am writing to request permission to use a photograph from the CSIRO website (http://www.industrialdisposal.net/uploaded_images/transformer-and-oil-removal_06b.jpg) as an image in my thesis about the harmful effects of PCBs in a lake in Michigan. I contacted CSIRO and they informed me that the copyright lies with your company. I will give proper credit to your company and cite the source.

Thank you for your time and I will wait for written permission.

--
-Emma Zawisza
Industrial Archaeology Master's Candidate
Michigan Technological University

Mark McNamara <mark.mcnamara@hydrodec.com> Sun, Jul 31, 2016 at 7:51 PM
To: "emschwai@mtu.edu" <emschwai@mtu.edu>

Dear Emma,

Regarding your request below. Your request is approved. Our company wpould also be pleased to be involved in PCB remediation works should that opportunity arise.

Regards

Mark McNamara

Director

Hydrodec Development Corp

www.hydrodec.com

M: +61 (0)412 130 942

Figure 46: Michigan Department of Community Health.

7/20/2016 Michigan Technological University Mail - Copyright Permission

MichiganTech **Emma Schwaiger <emschwai@mtu.edu>**

Copyright Permission

2 messages

Emma Zawisza <emschwai@mtu.edu> Mon, Jul 18, 2016 at 3:23 PM
To: eisnerj@michigan.gov

Hello,

I am a Master's student at Michigan Tech writing my thesis on the PCB issue in Torch Lake (Houghton County). I am requesting to use the 2015 Fish Consumption Advisory chart, specifically for Torch Lake, from the MDCH's Eat Safe Fish Guide. It will be used as a visual to help people see the environmental issues that are still plaguing this area of the UP.

Thank you for your time and I will await your written response.

--
-Emma Zawisza
Industrial Archaeology Master's Candidate
Michigan Technological University

Eisner, Jennifer (DHHS) <EisnerJ@michigan.gov> Mon, Jul 18, 2016 at 5:03 PM
To: Emma Zawisza <emschwai@mtu.edu>

Ms. Zawisza:

Yes, you may use the guide with a citation. If possible, we always appreciate when the citation is to our website so people can get the full context of the information.

Thank you, and best,

Jennifer Eisner

Public Information Officer

Michigan Department of Health and Human Services

Office: 517-241-2112 or EisnerJ@michigan.gov

Cell: 517-230-9804

Figure 48: Ankita Mandelia.

MichiganTech **Emma Schwaiger <emschwai@mtu.edu>**

Copyright Permission for Map

2 messages

Emma Zawisza <emschwai@mtu.edu> Wed, Aug 3, 2016 at 3:06 PM
To: Ankita Mandelia <ajmandel@mtu.edu>

Ankita,

I am just writing to ask permission to use the map you sent me showing the correlation between the sampling locations/areas of higher concentration and the Torch Lake facilities in my thesis.

Thank you and I will wait for a written response.

--
-Emma Zawisza
Industrial Archaeology Master's Candidate
Michigan Technological University

Ankita Mandelia <ajmandel@mtu.edu> Wed, Aug 3, 2016 at 3:30 PM
To: Emma Schwaiger <emschwai@mtu.edu>

Emma,

Thank you for asking for my permission to use the map displaying the locations of PCB samples / elevated concentrations relative to the locations of historical industrial facilities along the Torch Lake western shoreline. This map was a collaborative effort by you and me. You have my permission to use the map in your thesis.

Please let me know if you need anything else.

Ankita

On Aug 3, 2016 3:06 PM, "Emma Zawisza" <emschwai@mtu.edu> wrote:

> Ankita,
>
> I am just writing to ask permission to use the map you sent me showing the correlation between the sampling locations/areas of higher concentration and the Torch Lake facilities in my thesis.
>
> Thank you and I will wait for a written response.
>
> --
> **-Emma Zawisza**
> *Industrial Archaeology Master's Candidate*
> *Michigan Technological University*

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