The Mining Industry Is a Chemical Industry

A Case Study of Nickel-Copper Extraction's Historical Cumulative Effects in the Sudbury and Sault Ste. Marie Regions

Infrastructure Beyond Extractivism
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ABOUT THE REPORT

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About Infrastructure Beyond Extractivism

The **Infrastructure Beyond Extractivism (IBE)** project is a SSHRC-funded Partnership Grant housed at York University. It is led by Dayna Nadine Scott (Osgoode/EUC, York University) and Heidi Kiiwetinepinesiik Stark (CIRCLE, University of Victoria), in partnership with the Yellowhead Institute, the Department of Geography and Planning at University of Toronto, and the University of British Columbia. The IBE project aims to develop an agenda for fundamentally remaking socio-technical systems for an anti-colonial and radically just transition. It is about conceptualizing and building infrastructure that restores and revitalizes Indigenous territorial governing authority or "jurisdiction."

To learn more, visit jurisdiction-infrastructure.com.

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TABLE OF CONTENTS

INCO’s Superstack looms over the town of Sudbury. Photo by Sean Marshall on Flickr.

OVERVIEW

What is today called Canada is a relatively recent settler-colonial state with an economic foundation deeply rooted in the extraction of resources from Indigenous territories. These territories, which have been part of Indigenous sovereignty for thousands of years, possess histories and relationships that extend back to time immemorial. This report uses critical archival methods and anti-colonial analytical approaches to explore: 1) the historical relationship between nickel-copper mining and petrochemical industries in the Sudbury and Sault Ste. Marie regions, and 2) how road, railway, and other abandoned mining infrastructure could be reconfigured by Indigenous nations to support jurisdiction back[1] and the green energy transition.

The Sudbury and Sault Ste. Marie regions provide a unique case study. Understanding how the territories' nickel-copper deposits have been systematically removed for profit allows for a comprehensive view of regional impacts within a rough 120-km radius. The settler state did not implement many regulations addressing pollution and waste from industrial developments, including mining extractivism, until well into the 1970s, and these regulations remain woefully inadequate. Given this widespread lack of settler accountability, it remains paramount to problematize the justificatory logics deployed in the mistreatment of Indigenous nations' lands, air, and waters. Examining the cumulative regional effects of mining extractivism might inform future articulations of Indigenous jurisdiction in relation to territory, including resource and environmental policy, climate policy, and reparations, including climate reparations. The period before 1980 is significant, as it parallels important changes in Ontario governance in the first half of the 20th century, particularly regarding the signing of Treaty No. 9 and subsequent adhesions, including those by the Atikameksheng Anishnawbek and Wahnapitae First Nations in 1929 in what is now known as the Sudbury region.

This report's introduction is an overview of historical road and railway infrastructure in the Sudbury and Sault Ste. Marie regions. Used for settler-colonial nickel-copper mining, these infrastructures facilitated, and were a product of, chemical and mining extractivism. These infrastructures also seep — that is, they do not stay in place, but rather mix with soils, water flows, and water tables, spilling out of place, bioaccumulating in plants and animal populations, and sometimes shifting their chemical composition. Several examples begin to illustrate the consequences of infrastructural material seepage that frame the rest of the report, including the sourcing of railway slag and ballast from mining activities, and the use of mining waste rock in the construction of roads and railways.

Part 1, **"The Mining Industry *Is* a Chemical Industry,"** outlines historical nickel-copper extraction in the Sudbury and Sault Ste. Marie regions, revealing how petrochemicals are integral to the metal mining supply chain. Examining chemical compounds used in milling, it problematizes the existing scientific orthodoxy surrounding ore-processing petrochemicals, particularly those that are a part of flotation. Tracing the evolution of chemical use and types over time, it highlights their toxicity and potential environmental impacts.

Part 1 explores a key question: How does understanding the mining industry as a chemical industry enable us to reimagine and critically approach knowledge production about nickel-copper mining extractivism, by *centring the chemical infrastructures required for it to function?*

This section:

- emphasizes the deep material connections and dependencies of nickel-copper mining on petrochemical infrastructures and, by extension, fossil fuel extractivism;
- traces the historical development of petrochemicals used in nickel-copper mining, thus challenging the notion of techno-optimism, or the idea that technological advancements or increased efficiency in industrial processes necessarily lead to reduced environmental destruction;
- points to mining industry greenwashing, critiquing the lack of public access to understanding mining chemicals that are patented and therefore often hidden by trade secrets and commercial confidentiality; and
- highlights the absence of scientific data and long-term information on toxicology and cumulative effects of most chemicals that continue to be used in high volumes each year, problematizing the industry's claims of environmental responsibility.

Part 2, **"The Politics of Evidence in Nickel-Copper Mining,"** outlines the core environmental issues and impacts surrounding nickel-copper mining in the Sudbury and Sault Ste. Marie regions. It exposes the material seepage of mining infrastructure, including mining tailings, paste

1. Dayna Nadine Scott, "Extractivism: Socio-Legal Approaches to Relations with Lands and Resources," in *Handbook of Law and Society*, ed. Mariana Valverde, Kamari Clarke, Eve Darian-Smith and Prabha Kotiswaran (Routledge, 2021), 124–127. And Shiri Pasternak et al., "Infrastructure, Jurisdiction, Extractivism: Keywords for Decolonizing Geographies," *Political Geography 101* (2023).

backfill, and acid mine drainage. Analyzing archival mining industry documents, it considers how settler-colonial ideas of "environment" imagine territory as able to absorb and erase the material seepage of pollution into the air, land, water, and biosphere. This report rejects this settler-colonial imaginary, underscoring the scale and stakes of regional extractivism's long-term, cumulative effects.

Part 2 explores the following question: What does a critical archival approach to nickel-copper mining reveal about the politics of evidence relied upon by Canadian settler-colonial mining extractivism in the Sudbury and Sault Ste. Marie regions? How does colonial politics conceal material seepage from mining infrastructure?

This section:

- shows waste infrastructures operating exactly as they were designed to — through a "permission to pollute" logic;
- shows that more data that monitor the environmental impacts of mining extractivism, without changes to the overarching extractive infrastructure, are not automatically better (critical scholars of toxicity caution against a romance of data rooted in Eurocentric quantitative traditions[2]). However, we can also problematize how an absence of data has become equated with a lack or absence of environmental harm or long-term intergenerational impacts;
- names and articulates how forms of data colonialism[3] have operated in the region, and reflects on how data colonialism is inscribed in the Canadian state's settler-colonial archive: in particular, by problematizing the logics of containment and dilution of mining pollution; and
- suggests that future data gathered and created about the effects of mining on Indigenous territories be guided by the principles of Indigenous data sovereignty, environmental data justice, and Indigenous science.

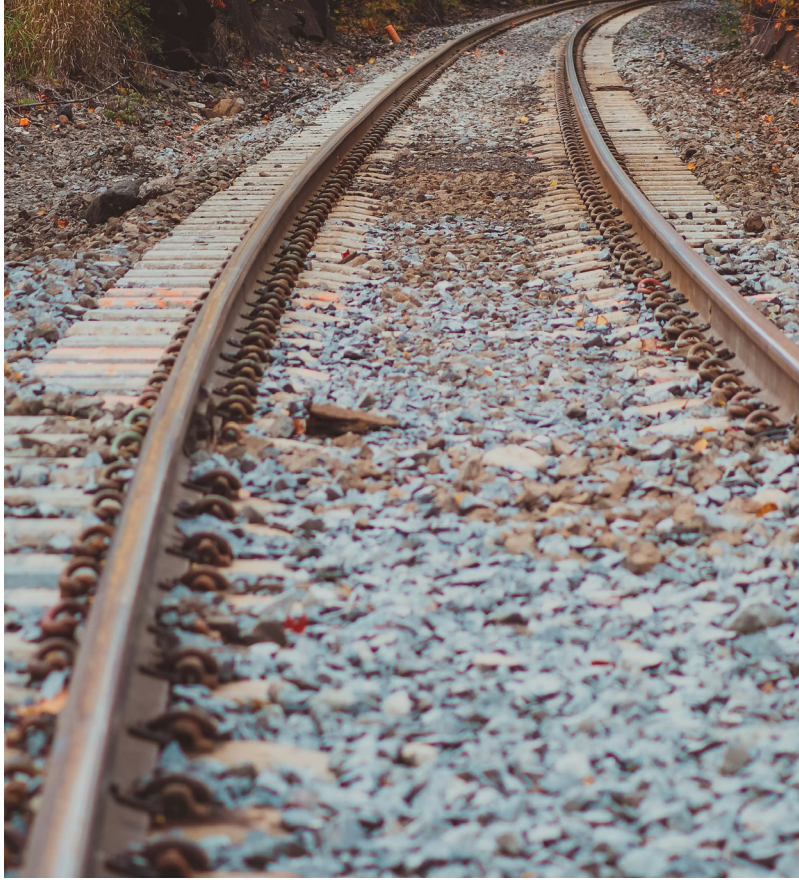
This report is linked to a companion publication, which provides a brief literature review of Anishinaabe articulations of jurisdiction in relation to territory in northern Ontario, including the importance of treaties, Indigenous law, and protocol. The companion publication poses the question of how roads, railway, and abandoned mining infrastructure might be reclaimed and repurposed by Indigenous Nations to both benefit sustainable energy generation and support the decolonization of roads and railways in ways that are grounded in Indigenous authority and relationships to place.

Overall, this archival research offers new insights into the cumulative regional impacts of the Canadian state's environmental policies concerning nickel-copper mining. In doing so, it begins to respond to a question posed by Rob Clifford (Tsawout), citing Deborah Cowen, "How might we resist…the erasure or ignoring of Indigenous jurisdiction and instead continue to express and regenerate ontologies of care and work toward 'infrastructure otherwise'?"[4] Focusing on the material seepage of extractive infrastructures allows for a preliminary elaboration of, and indicates further directions for, what Cowen calls the ongoing "maintenance" of infrastructure; a tending to its future materiality that exceeds colonial infrastructures and extends across webs of relations, including with rivers and watersheds.[5]

What follows also unpacks how the erasure of material seepage by extractive infrastructure is built into settler-colonial science, data, and records, which are both anthropocentric and Eurocentric. By highlighting how capitalist extractive logics centre profit rather than relationship, we can better understand how to practice and cultivate "responsibility towards a region or territory [which] necessitates a very different approach to risk assessment, and precludes the area being sacrificed for national interests of people and governments outside of the region."[6] Indigenous legal scholars and knowledge holders have long pointed out how existing and historical forms of capitalist resource extraction in Canada often contradict Indigenous laws that assert Nations' jurisdiction specific to each place, which includes centring the responsibilities to relationships with place.[7]

2. See Max Liboiron, Manuel Tironi, and Nerea Calvillo, "Toxic Politics: Acting in a Permanently Polluted World," *Social Studies of Science* 48, no. 3 (June 2018).
3. Vanessa Gray et al., *Data Colonialism in Canada's Chemical Valley: Aamjiwnaang First Nation and the Failure of the Pollution Notification System* (Yellowhead Institute, 2023), https://yellowheadinstitute.org/wp-content/uploads/2023/09/Data-Colonialism-YI-Special-Report-Sept-2023-3-compressed-1.pdf .
4. Pasternak et al., "Infrastructure, Jurisdiction, Extractivism," 2.
5. Pasternak et al., "Infrastructure, Jurisdiction, Extractivism."
6. Deborah Curran, Eugene Kung, and Marilyn Slett, "Ǧviḷás and Snəwayəɬ: Indigenous Laws, Economies, and Relationships with Place Speaking to State Extractions," *South Atlantic Quarterly* 119, no. 2 (2020).
7. Curran et al., "Ǧviḷás and Snəwayəɬ."

THE SAULT STE. MARIE AND SUDBURY REGIONS AS A CASE STUDY OF MINING EXTRACTIVISM: INTRODUCING THE SEEPAGE OF SETTLER-COLONIAL ROAD AND RAILWAY INFRASTRUCTURE



In the midst of a global rush for critical minerals, itself coming in the wake of a post-reconciliation turn where governments continue to only pay lip service to jurisdiction, Indigenous jurisdiction is not a thing that floats free; instead, the political economy dictates how jurisdiction can be enacted. In order to situate how extractive economies connect to local and global systems that make place-based jurisdiction difficult to actualize, this report begins by outlining several ways in which road and railway infrastructure in the Sudbury and Sault Ste. Marie regions are essential supports to mining extractivism.

Extraction requires infrastructure, yet the material integrity of infrastructure isn't fixed — rather, it chemically seeps into the surrounding air, water, soil, and lifeforms. Seepage can have a significant scale of impact. Mining infrastructure can seep for thousands of years.

Approximately 1.8 billion years ago, a large meteor struck the Sudbury region. Forming an elliptical basin, similar to that which would be made by a collapsing volcano, the impact created one of Earth's largest astroblems, an extraterrestrial crater-like impression measuring 200 to 250 kilometres in diameter.

In 1883, the construction of the Canadian Pacific Railway (CPR) unwittingly traversed the edge of the astrobleme. The CPR played a significant role in consolidating settler-colonial occupation of Indigenous lands by linking Eastern Canada to the West and establishing routes pivotal for transporting mining materials to and from major urban centres. During the North-West Resistance, the CPR assisted the government's suppression of the uprising led by Louis Riel (Métis) and other Indigenous leaders, including Plains Cree Chief Mistahimaskwa, by deploying military reinforcements and providing logistical support for troop movements and supplies. Exploiting Chinese migrant labourers for railway construction, the CPR's internal "Department of Colonization" recruited white settlers and land speculators, who populated towns and surveyed territory for extractive industries and real estate profit.[8,9] Under settler property law, some railways were leased for extraordinarily long periods, such as in 1884 when the Ontario & Quebec Railway was leased to the CPR for 999 years.

Though settler copper mining began near Sault Ste. Marie as early as 1846, it was reportedly railway workers who "rediscovered" nickeliferous copper pyrites in the Sudbury Basin in the 1880s. Prospectors rushed to the region, as the colonial free-entry system incentivized settlers to

8. Deborah Cowen, "Following the Infrastructures of Empire: Notes on Cities, Settler Colonialism, and Method," *Urban Geography* 41, no. 4 (2020): 474.

9. It also promoted anti-Black border patrolling with racist acts like the 1911 Order-in-Council PC 1911–1324, a proposed (but never instituted) one-year prohibition of Blacks entering Canada, while at the same time hiring Black porters as a workforce on the trains (Cowen, "Following the Infrastructures," 474).

pursue natural resource extraction for personal gain.[10,11] Under the free-entry system, prospectors could retain rights to Crown minerals without owning the land, and once a claim was recorded, the holder of the claim was then entitled to engage in potentially intrusive exploration activities.[12] Real estate investors began buying mineral lands from the Crown at low prices for resale to capitalize on rising property value, in addition to the mineral resource value.[13] Speculation remains integral to Ontario's free-entry mining claim system, which treats Crown land as always available for exploration.[14] The Sudbury region's mineral wealth was deemed "inexhaustible."[15] This was echoed in a news article applauding railway expansion as an incentive to settlement: "open up the inexhaustible mineral and cultivable regions and the population will come in."[16]

As with the railways, late 19th–century roads to the region were explicitly termed "colonization roads," and managed by a Colonization Roads Branch of the provincial Department of Public Works.[17] By 1953, a new provincial road plan was undertaken, with one of its explicit goals being to open up northern Ontario to mineral exploration. A journalist captured this sentiment, writing that "a main objective would be to make these roads pass through known greenstone areas and open up huge mineral areas with resultant employment. In many cases it had been found that prospectors followed right along behind the construction crews as these new roads were put through."[18]

By the late 1950s, the number of nickel-copper mines and milling plants had greatly expanded.

Mine access roads are commonly constructed using aggregate rock sourced from mining waste rock and gravel from nearby mine sites. Aggregate rock typically consists of a mixture of materials like crushed stone, sand, and gravel, and is widely utilized in construction due to its durability and versatility. Early mine road maps indicate gravel (likely mine aggregate) as the predominant road material.[19] In the 1950s, concrete and asphalt paving became prevalent, coinciding with an increase in mining chemical transport via freight companies. Early nickel-copper mines also utilized slag (waste after ore is put in a furnace) as a road-building material, with the International Nickel Company of Canada (INCO) utilizing slag piles as a primary source of road material and railroad ballast.[20]

Burrowing into rock and excavating it to build routes for vehicles and trains disturbs biochemical and geological balances. On the page opposite, multiple forms of material seepage from transportation infrastructure are imagined in concert, as a way to begin pointing towards a much larger picture of material seepage as an unavoidable externality or inevitable byproduct of wider systems of mining extractivism.

Taken together, historical accumulations of acid-generating road aggregate, chemical runoff from heavy metal–containing explosives and ANFO, de-icing salts and dust sprays, and chemical spills are all ways that the road and railway infrastructure serving mining extraction materially seeps. Accounting for the cumulative effects from material seepage of road and railway infrastructure is vital to include in any account of the mining industry's region-

10. Dianne Newell, *Technology on the Frontier: Mining in Old Ontario* (University of British Columbia Press, 1986), 87.
11. Other historians such as Munton and Temby suggest that settlers had knowledge of the region much earlier. (Don Munton and Owen Temby, "Smelter Fumes, Local Interests, and Political Contestation in Sudbury, Ontario, During the 1910s," *Urban History Review* 44, no. 1-2 (2016). https://www.researchgate.net/publication/347660865_Smelter_Fumes_Local_Interests_and_Political_Contestation_in_Sudbury_Ontario_during_the_1910s.)
12. Karen Drake, "The Trials and Tribulations of Ontario's Mining Act: The Duty to Consult and Anishinaabek Law," *McGill International Journal of Sustainable Development Law and Policy* 2, no. 2 (2015): 190.
13. "Sudbury: Sketch of Our Mineral Resources," *The Globe (1844-1936)*, October 29, 1892, 1.
14. How these processes engage in seeking Indigenous consent remains complex, as Indigenous articulations of jurisdiction in relation to the mining claim "free-entry" system are still evolving (see Part 2 for a more detailed discussion).
15. "Minerals Galore: Inexhaustible Resources of Northwestern Ontario Awaiting Development," *The Globe (1844-1936)*, October 3, 1895, 6.
16. J.A. McNeil, "Canada Opening up Vast New Regions: Dominion Has Great Railway," *New York Times*, October 21, 1928.
17. "Colonization Roads Make New Record: Over 1,300 Miles Improved or Constructed Last Year," *The Globe (1844-1936)*, February 16, 1914, 9.
18. "Ore, Timber: Plan Roads To Open The North," *The Globe and Mail*, December 7, 1953.
19. Department of Northern Development, Mining Transportation Programme, "Road Map of the North Eastern Portion of the Province of Ontario 1937–1938," Government of Ontario, 1938
20. Letter from the Minister of Mines to the Office of the Prime Minister, April 28, 1966, Library and Archives Canada. See also: *Proceedings of the First Ontario Industrial Waste Conference*, June 15–18, 1954, 9: "Waste rock is being put to good use…During the early years of a mine, rock is needed for the levelling and conditioning of mine yards. It is also used as railway ballast, in concrete aggregate, converter flux, and in the construction of roads….Waste rock is used to fill in mined-out areas underground." See also: *Toronto Daily Star (1900–1971)*, May 17, 1902, 25, and *Toronto Daily Star (1900–1971)*, April 2, 1927, 2. In another example, a newspaper article describes INCO selling CP rail 150,000 tonnes of slag for a 52-km stretch of railway repairs in 1985.

Historical mine access roads seep acids and heavy metals. Because it is often a type of sulphide ore, aggregate from the Sudbury and Sault Ste. Marie regions may have a high presence of heavy metals and minerals. Because this wasn't understood until the 1990s, aggregate rock in historical road construction and railway ballast before this time can thus pose significant environmental risks that may last thousands of years. These risks are amplified by climate change. Exposed to air and rain, sulphide rock can oxidize, leading to acid generation that alters water pH, and mobilizes heavy metals, facilitating their release into surrounding environments. Metal leaching at lesser but still potentially dangerous levels also occurs at a neutral pH. The issue of acid mine drainage (AMD) finally gained attention with the federal Mine Environment Neutral Drainage (MEND) program. The 1994 MEND study was the first nation-wide survey to investigate AMD, and it is unclear whether mining companies historically tested the acid-generating potential of aggregate rock before use, or if they kept their own internal records.[1] After the creation of roads and railways, there may be a delay before the signs of acid drainage show up. Unfortunately, this often happens after mines have closed.

Blasting and explosives are another example of how mining infrastructure is dependent on chemicals that seep. Detonation plays a crucial role in land clearing and road construction for mining operations, and in the actual construction of mines. Explosives have evolved chemically over time.[2] Early explosives included mercury fulminate (which enters the environment when it is detonated) and dynamite.[3] There is also something at stake for the concept of seepage in the ways in which blasting changes water systems, by literally changing the ways in which seepage moves.

As a key explosive, ammonium nitrate fuel oil (ANFO) became widely used in Ontario from the 1950s onwards, and is still the most commonly used mining explosive.[4] Under the wrong conditions, specifically those involving the risk of fire in confined spaces, ANFO can spontaneously explode. Blasting ANFO spreads petroleum-based fuel and diesel fumes into the landscape, and incomplete or undetonated ammonium nitrate is highly water-soluble, which can result in releases of nitrate, nitrite, and ammonia into surface water and groundwater. Yet, despite its toxic byproducts, ANFO use was only recently regulated under Canadian law in 2015, and is now covered under the federal explosives act.[5]

Road de-icing salts and dust suppression sprays, such as calcium chloride and oil, also contribute to chemical runoff, which can affect surrounding soil and waterways.[6]

Chemical spills are often not public knowledge. Lastly, despite the extensive use of potentially toxic chemicals in mining, information about the locations, extent, and clean-up of chemical transportation and spills is lacking. This includes on-site spills at mines, and surface runoff which may be amplified by climate change and extreme weather.[7] Instead, the public is given only limited data about the number of spills. To this effect, a (2021) hazardous spills auditor report, 1 states, "Ontario experiences about 8,000 spills per year, some of which injure workers, kill wildlife and pollute the air, land and water. Added to the short-term effects of these spills are unknown long-term and cumulative effects…Thousands of such spills are recorded in Ontario annually — 73,000 between 2011 and 2020."[8]

1. See: L.J. Wilson, *Canada-Wide Survey of Acid Mine Drainage Characteristics: MEND Report 3.22.1.* (Mine Environment Neutral Drainage Program, 1994), 35. https://mend-nedem.org/wp-content/uploads/2013/01/3.22.1.pdf.
2. According to archival chemical directories, Canadian Industries Limited (C-I-L) was one of the largest manufacturers of explosives including dynamite and blasting powder in Canada, especially between 1918 and 1954. See: Dominion Bureau of Statistics, Chemical Directory 1954, Industry and Merchandising Division, 1954 for more information on specific manufacturers.
3. Selin (2023) notes: "Not all chemically sequestered mercury is transformed into more stable forms by chemical reaction. For example, [Guererro and Schneider 2023] consider mercury in mercury fulminate as chemically sequestered, yet it immediately enters the environment when it explodes." Susan Selin, "Mercury Sequestration in Explosives," in *Handbook of Chemical Hazards*, ed. Guererro and Schneider (NRC Press, 2023).
4. According to national chemical directories, mercury fulminate was sold by Aetna explosives in Prescott, Ontario, and Dominion Arsenal in Lindsay, Ontario, in both 1918 and 1921.
5. (*Explosives Regulations*, 2013, SOR/2013-211, s 6(1)(b.1).) By the early 1960s, ammonium nitrate began to replace nitroglycerine-based explosives used in underground mining, and a C-I-L plant for the former was constructed in Sudbury (C-I-L, *Annual Report*, 1962, 7). ANFO is currently largely imported into Ontario via rail, however Canada remains the fifth-largest producer in the world, mostly for the Western Canadian mining sector. In 1998, a truck carrying ANFO went foff the road near Walden, Ontario, and "the resulting explosion created a 30-meter-long crater in the ground, caused tremors that were felt within a 10 km radius, and cast fragments of the truck up to 2.7 km away" (Transport Canada, *Transportation in Canada 2022: Annual Report*, Government of Canada, 2022, 11. https://tc.canada.ca/en/corporate-services/transparency/corporate-management-reporting/transportation-canada-annual-reports/transportation-canada-2022). Because of the potential adverse environmental effects of ANFO, its use in Canada is regulated by Section 36(3) of the *Fisheries Act*, which prohibits the deposit of deleterious substances into waters frequented by fish, unless otherwise permitted by regulation (*Fisheries Act*, RSC 1985, c F-14, s. 36(3).). The Institute of Makers of Explosives stipulates that "No use of ammonium nitrate-fuel oil mixtures occurs in or near water due to the production of toxic byproducts (ammonia)" (D.G. Wright and G.E. Hopky, *Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters*. Department of Fisheries and Oceans, 1998.) Source: https://publications.gc.ca/collections/Collection/Fs97-6-2107E.pdf.
6. A recent example of chronic chloride impacts is Lake Simcoe.
7. MEND 2011, 2 states: "More frequent heavy precipitation events are projected for Canada…there is a risk that hydraulic structures at mine sites (dams, ditches, spillways, holding points) will have insufficient capacity for such events resulting in more contaminated runoff from the mine site or in other temporary measures being taken, such as flooding pits, which could result in shutdowns. Based on our analysis of the net present value of a hypothetical copper mine in Canada, such shutdowns alone would not make the mine uneconomical but could have a significant impact on the bottom line."
8. Chemical transport by rail gained sustained regulatory attention after the 1979 Mississauga Railway disaster, where evacuation took place primarily due to the threat of potentially lethal chlorine gas, which is heavy, lies low to the ground, and carries no scent. The case led to the passage of the 1980 provincial *Transportation of Dangerous Goods Act*.

al-level impacts to the surrounding territories. In the case of the regions discussed in this report, historical access roads may cross many watersheds covering hundreds of square kilometres, including the Upper and Lower Wanapitei River (Waanabidebiing), Vermilion River (Atikamgzib or Dikmegzubi), and Spanish River (Skiminitigan/Eskimanetigon) watersheds near Sudbury (N'Swakomok, on Atikameksheng Anishnawbek territory), and the St. Mary's River (Baawitigong), Thessalon River (Neyashewun), and Lower Mississagi River watersheds near Sault Ste. Marie (Bawating, Batchewana First Nation territory).

Part 1: The Mining Industry *Is* a Chemical Industry

Part 1 of this report shows how the history of the nickel-copper mining industry is also the history of a chemical industry. Although we often treat the mining industry as distinct from oil and gas, material seepages of mining infrastructure intertwine industrially transformed petro-fossil molecules (as petrochemicals) with metal-containing ore. Pinpointing the material whereabouts of mining chemicals after they are used in flotation underscores how a romanticized image of dry rock being scooped from below then smelted into a glossy metal bar is false, misleading, and ultimately a form of greenwashing. This imaginary erases thousands of tonnes of chemical soup baths that happen in between. The production of metals from minerals is awash in chemicals, and the whole process prioritizes profit over the prevention of devastating ecological effects.

The regional and long-term implications of mining chemicals around Sudbury and Sault Ste. Marie remain largely unexplored through a cumulative effects lens, despite the significant role of chemical manufacturing in facilitating resource extraction on Indigenous territories. Archival research for this report spanned from around 1900 to 1980, an era where chemical manufacturing thrived within Canada's colonial borders. Subsequent globalization of petrochemical manufacturing post-1980 ushered in profound changes within Canada's industrial landscape, reshaping not only the chemical and mining industries but also how supply chains cross territories.

Although the *Mining Act* is one of Canada's oldest statutes, it was not until 1989 that its first amendments occurred aiming to revise Ontario's free-entry system to comply with the Constitutional duty to consult with Indigenous peoples.[21] Basic environmental provisions included at the time largely favoured industry — early exploration activities, in particular, did not require prior consultation, were not required to respect Indigenous treaty rights to hunt and harvest, and violated Anishinaabe law about land use.[22] Further amendments in 1996 outlined frameworks for mine closure and rehabilitation, but these relied on industry self-regulation, and the issue of cumulative regional petrochemical effects continues to be sidelined. No provincial environmental assessments (EA) are required before mines begin operations, nor are any required to cover the entire extent of a mining project, although mines could voluntarily opt for a provincial assessment concurrent with a federal EA.[23] As of 2020, in the Sudbury region, only one mine, the Totten Mine, had completed a full EA.[24] After closure, impacts from the

21. (*Mining Act*, RSO 1990, c M.14, s. 2 as it appeared on October 28, 2009.) Into the present, there is valid concern about the "constitutional compliance" from this round of amendments. While some argue that they adequately support Indigenous consultation (see: Martin-Joe Ezeudu, "The Duty to Consult in Ontario's Mining Act: A Critical Review," *CanLII Commentary* 2020), others point out that legal compliance with the duty to consult frequently does not translate into adequate or meaningful consultation in practice (Shiri Pasternak, *Grounded Authority: The Algonquins of Barriere Lake Against the State* (University of Minnesota Press, 2017.).

22. See: Drake, "The Trials and Tribulations." See also: B. Pardy and A. Stoehr, "The Failed Reform of Ontario's Mining Laws," *Journal of Environmental Law and Practice* 23, no. 1.

23. (*Environmental Assessment Act*, R.S.O. 1990, c. E.18, s. 3.01(1).) A report by the Auditor General summarizes this as follows: "Ontario is the only Canadian jurisdiction in which environmental assessments are generally not required for private-sector projects. These projects — such as mining operations or chemical manufacturing facilities — proceed without an up-front evaluation of the environmental impacts of the project" (Office of the Auditor General of Ontario, *Annual Report 2016, Volume 1: Section 3.06 Environmental Assessments*, Queen's Printer, 2016, c 3, s 3.06: 338, https://www.auditor.on.ca/en/content/annualreports/arreports/en16/v1_306en16.pdf.). A Mining Watch Canada publication from November 5, 2020 (*Ontario Must Assess the Impacts of Mines and Smelters Before They are Built!*), notes: "Ontario has never required new or expanding mines, mills, smelters, and refineries to undergo an assessment of their impacts on the environment, the economy, or society. Out of 31 mines and mills currently operating in Ontario, only four have gone through an EA, and only one of those was by the province; the other three were reviewed by the federal government. With one exception, mines and smelters in Sudbury, Timmins, and Kirkland Lake have never completed an EA."

24. Mining Watch Canada, *Ontario Must Assess*, 2. The report also points out that even at the federal level under the new (2020) Impact Assessment Act (replacing the Canadian *Environmental Assessment Act* of 2012), many smaller-scale mines remain exempt from EAs (Mining Watch Canada, *Ontario Must Assess*, 4).

seepage of mining infrastructure are left for public taxpayers and future generations.[25]

What follows underscores just how elusive much of the information about the intertwined histories of mining and chemical production remains, despite the extent to which these industries have shaped the economic and environmental landscapes of Ontario's mining regions. Examining the material connections between chemicals, metal commodities, and territory critically responds to what Anishinaabe scholar Patty Krawec articulates as "land theft [which] is not only the taking of land; [but] is the profound alteration of it through extraction rather than relationship."[26] Anti-colonial perspectives towards archives also question the future stakes of nickel-copper mining extractivism in Canada, and globally — especially as, in 2024, over half of all global nickel mines are now unprofitable.

25. Ontario Auditor General, *Annual Report 2016,* 341. See also: Mining Watch Canada, *Ontario Must Assess*.

26. Patty Krawec, *Becoming Kin: An Indigenous Call to Unforgetting the Past and Reimagining Our Future* (Broadleaf Books, 2022), 180.

Roast yard at the Copper Cliff mine, Sudbury district. Source: Library and Archives Canada. Box number: T-5050, Item #: 3373755, 1862-1910, ecopy #: a050952-v8.

Chemical Use in Nickel-Copper Ore Flotation: Historical to Present

Most people associate mining with the output of "tailings," but few focus on the thousands of tonnes of chemical inputs that mining requires. Nickel-copper milling methods, especially flotation, rely heavily on petrochemicals. (So do critical minerals — each has its own extensive set of chemical accompaniments in milling). Flotation started in Canada as early as 1917, but burgeoned with the growth of the petrochemical industry in the 1950s.[27] This section will focus on the flotation part of nickel-copper processing as a case study in how chemicals are an integral part of mining extractivism.

There is a profound irony in mining industry branding: obscuring the deep interconnections between mining and the petrochemical industry furthers industry efforts to sell mining as "clean" and necessary for the green economy, but mining cannot actually offer a just transition from fossil extractivism if mining has always required, and continues to require, oil and gas extraction to thrive.

After nickel-copper sulphide ore is mined, it is processed via crushing, grinding, and flotation in a mill (to obtain approximately 10% nickel). It then undergoes pre-roasting, smelting, and refining. The flotation process involves highly complex steps with several categories of chemicals: collectors, frothers, regulators, depressants, and flocculants.[28] Many chemicals are used across the mining process, including some of the most environmentally persistent, like Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS). While the chemicals used in any given "slurry" vary, the outline below gives a sense of key chemicals that may be used in nickel-copper mill processing to create, skim, gather, and control a carefully sculpted froth of bubbles and minerals:

1. Combining the ore with a frother, commonly methyl-isopropyl carbinol (MIBC), pine oil, DOWFROTH™, or a glycol-type frother.
2. Mixing the ore with a surfactant and agitating it with various machinery to generate bubbles and form a slurry.
3. Conducting bulk flotation to skim off floating minerals from the surface.
   For acid-type flotation, using modifiers like sulphuric acid or sulfurous acid, or for alkaline flotation, using soda ash or lime.
4. Possibly conducting a second separation round, which may require additional chemicals such as depressants for selective flotation.
   Using lime and quicklime as depressants for nickel, and sodium cyanide or potassium cyanide for copper.
   Using a combination of starch, guar, dextrins, carboxymethylcellulose, quaternary ammonium antistatic reagents, or aluminum chloride as depressants if the ore contains hydrophobic gangue organics (unwanted ore that doesn't behave as intended in water).
5. If the ore contains pyrrhotite, employing depressants like ethylene diamine (EDA), diethylene triamine (DETA), triethylenetetramine (TETA), 2-(2-amino ethyl amino) ethanol (AEAE), diethylenetriamine (DETA), and sulphur dioxide during a second round of "scavenger flotation."
6. If the ore contains marcasite, monoclinic, or hexagonal pyrrhotite, using the P200 series ($Na_2SO_2O_5$, $NaHSO_3$, and $Na_2S_2O_3$) with penta-amine or EDTA during flotation of copper-zinc ores.

After the ore is depressed (if it needs to be, in either a second round of selective flotation, third round post-scavenger flotation, or third round of nickel flotation), reagents are the main chemicals that are used to separate different types of metals and minerals from one another in a chemical bath.

Flotation separation reagents may be any of the following chemicals — example patents for industrial processes post-1991 include: mercaptans, thionocarbamate, phosphinic acid, mercaptobenzothiazole, dixanthogen formate, and sodium diisobutyl dithiophosphate, dithiophosphates, butyl xanthate, amyl xanthate, sodium ethyl xanthate, sodium amyl xanthate, sodium isopropyl xanthate, sodium isobutyl xanthate, potassium amyl xanthate, or ammoniacal copper sulphate ($CuSO_4$).

Copper-nickel separation reagents (combinations depend on the amount of pyrrhotite in the ore):

- Sodium hydrosulfide (NaHS) (pre-treatment), aeration with SO_2 and lime followed by copper flotation, hypochlorite, cyanide and oxidation, lime SO_2, starch, lime and cyanide.
- If the ore needs further alkalizing, calcium pentasulphide or sodium pentasulphide may be added after lime and soda ash.

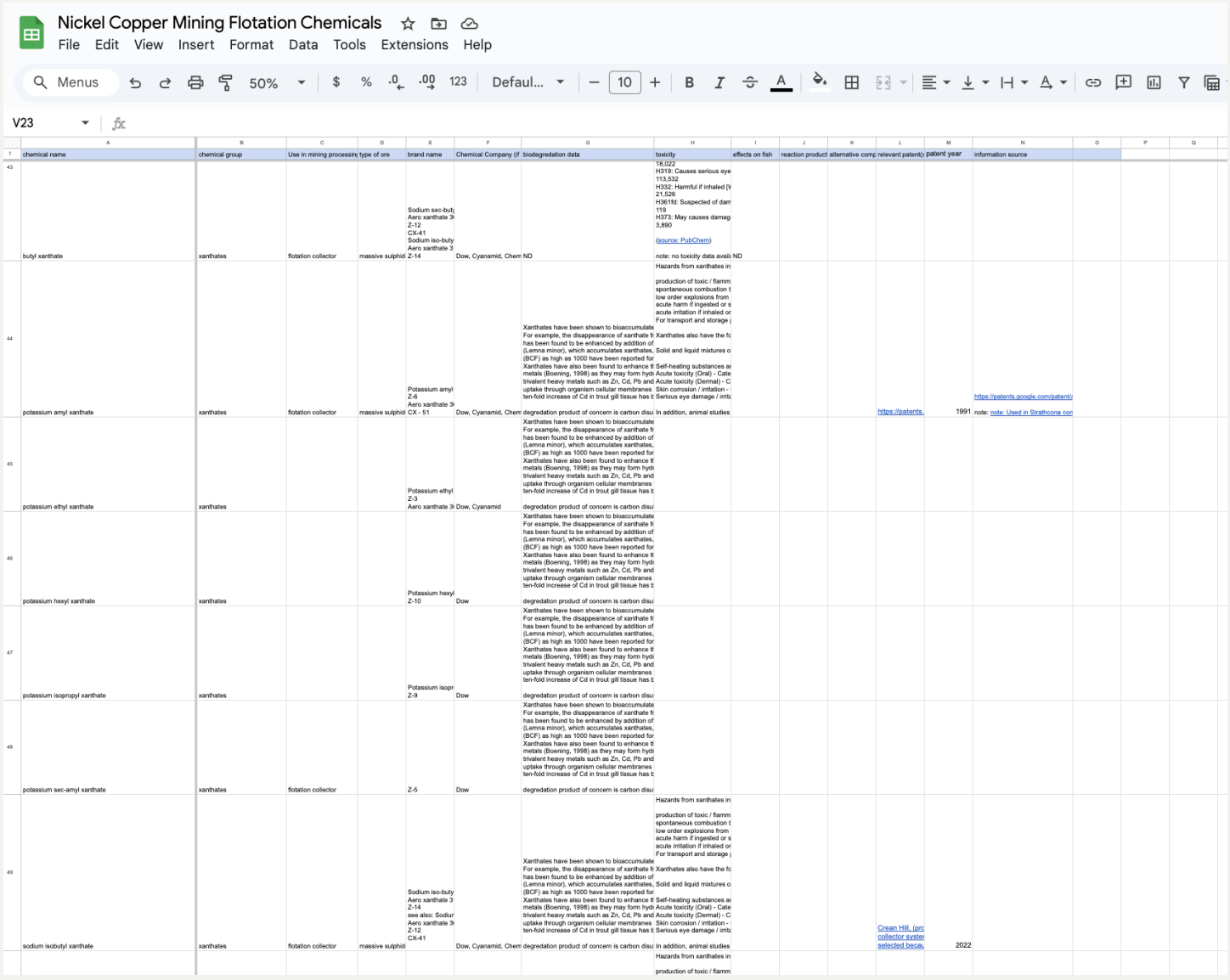
(Secondary collector for platinum group metals and cobalt: thiocarbamates (3894, X-31)**.)**

27. A.J. Lynch, J.S. Watt, J.A. Finch, and G.E. Harbort, "History of Flotation Technology," in *Froth Flotation: A Century of Innovation for Mining*, ed. Maurice C. Fuerstenau, Graeme J. Jameson, and Roe-Hoan Yoon (Society for Mining, Metallurgy, and Exploration, 2007), 74, 76.

28. For a detailed description of several nickel-copper mills in Ontario, see: D.E. Pickett, Watson S. Hall, and Gordon W. Smith, "Milling of Nickel-Copper Ores," in *Milling Practice in Canada*, ed. D.E. Pickett. CIM Special Volume 16. (Harpells Press, 1978), 133–151.

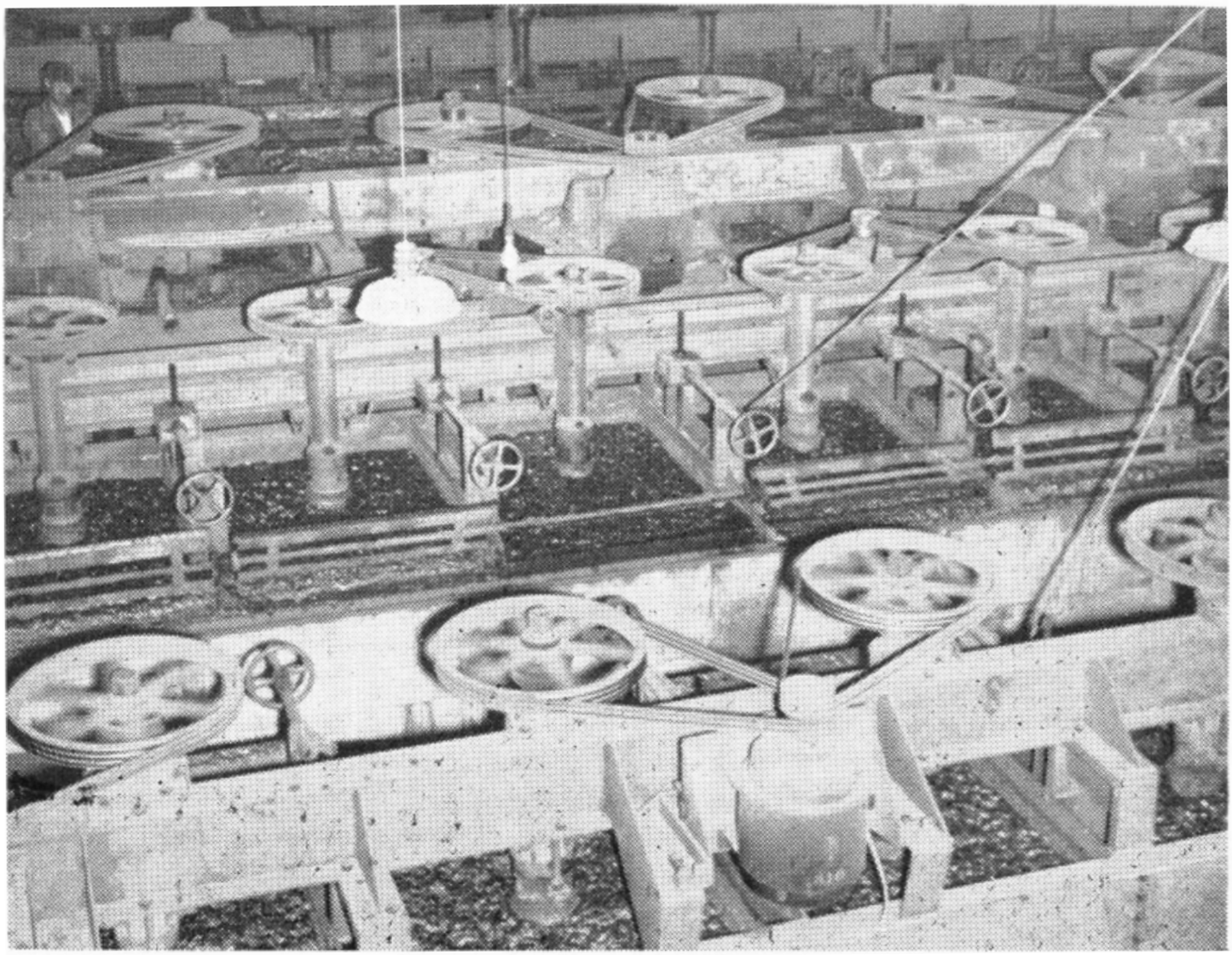
Note on Methods

Determining which chemicals are actually used in mine milling is not an easy task. Research for this report attempted to find information about mining chemicals using two main methods: 1) analyzing publicly available patents, and 2) consulting other archival sources, including provincial archives, reports, and historical trade bulletins published by the mining industry. While only providing a partial picture, bringing difficult-to-access information together in one place, this publicly accessible Excel spreadsheet (Figure 1, below) gives a clearer sense of how reliant mining mill processes are on chemical inputs, and helps translate technical data into publicly accessible knowledge. It could be expanded to include chemicals used to process other types of metal ore, as well as critical minerals.



	chemical name	chemical group	Use in mining processin	type of ore	brand name	Chemical Company (if	biodegradation data	toxicity	effects on fish	reaction product	alternative comp	relevant patent(s	patent year	information source
43	butyl xanthate	xanthates	flotation collector	massive sulphid	Sodium sec-buty Aero xanthate 3 Z-12 CX-41 Sodium iso-buty Aero xanthate 3 Z-14	Dow, Cyanamid, Chem	ND	18,022 H319: Causes serious eye 113,532 H332: Harmful if inhaled (21,526 H361fd: Suspected of dam 119 H373: May causes damag 3,890 (source: PubChem) note: no toxicity data avail	ND						
44	potassium amyl xanthate	xanthates	flotation collector	massive sulphid	Potassium amyl Z-6 Aero xanthate 3 CX - 51	Dow, Cyanamid, Chem	Xanthates have been shown to bioaccumulate For example, the disappearance of xanthate fr has been found to be enhanced by addition of (Lemna minor), which accumulates xanthates, (BCF) as high as 1000 have been reported for Xanthates have also been found to enhance th metals (Boening, 1998) as they may form hydr trivalent heavy metals such as Zn, Cd, Pb and uptake through organism cellular membranes ten-fold increase of Cd in trout gill tissue has b degredation product of concern is carbon disu	Hazards from xanthates in production of toxic / flamm spontaneous combustion t low order explosions from acute harm if ingested or s acute irritation if inhaled or For transport and storage Xanthates also have the fo Solid and liquid mixtures o Self-heating substances a Acute toxicity (Oral) - Cate Acute toxicity (Dermal) - C Skin corrosion / irritation - Serious eye damage / irrita In addition, animal studies				https://patents.	1991	https://patents.google.com/patent/ note: note: Used in Strathcona con
45	potassium ethyl xanthate	xanthates			Potassium ethyl Z-3 Aero xanthate 3	Dow, Cyanamid	Xanthates have been shown to bioaccumulate For example, the disappearance of xanthate fr has been found to be enhanced by addition of (Lemna minor), which accumulates xanthates, (BCF) as high as 1000 have been reported for Xanthates have also been found to enhance th metals (Boening, 1998) as they may form hydr trivalent heavy metals such as Zn, Cd, Pb and uptake through organism cellular membranes ten-fold increase of Cd in trout gill tissue has b degredation product of concern is carbon disu							
46	potassium hexyl xanthate	xanthates			Potassium hexyl Z-10	Dow	Xanthates have been shown to bioaccumulate For example, the disappearance of xanthate fr has been found to be enhanced by addition of (Lemna minor), which accumulates xanthates, (BCF) as high as 1000 have been reported for Xanthates have also been found to enhance th metals (Boening, 1998) as they may form hydr trivalent heavy metals such as Zn, Cd, Pb and uptake through organism cellular membranes ten-fold increase of Cd in trout gill tissue has b degredation product of concern is carbon disu							
47	potassium isopropyl xanthate	xanthates			Potassium isopr Z-9	Dow	Xanthates have been shown to bioaccumulate For example, the disappearance of xanthate fr has been found to be enhanced by addition of (Lemna minor), which accumulates xanthates, (BCF) as high as 1000 have been reported for Xanthates have also been found to enhance th metals (Boening, 1998) as they may form hydr trivalent heavy metals such as Zn, Cd, Pb and uptake through organism cellular membranes ten-fold increase of Cd in trout gill tissue has b degredation product of concern is carbon disu							
48	potassium sec-amyl xanthate	xanthates	flotation collector		Z-5	Dow	Xanthates have been shown to bioaccumulate For example, the disappearance of xanthate fr has been found to be enhanced by addition of (Lemna minor), which accumulates xanthates, (BCF) as high as 1000 have been reported for Xanthates have also been found to enhance th metals (Boening, 1998) as they may form hydr trivalent heavy metals such as Zn, Cd, Pb and uptake through organism cellular membranes ten-fold increase of Cd in trout gill tissue has b degredation product of concern is carbon disu							
49	sodium isobutyl xanthate	xanthates	flotation collector	massive sulphid	Sodium iso-buty Aero xanthate 3 Z-14 see also: Sodiur Aero xanthate 3 Z-12 CX-41	Dow, Cyanamid, Chem	Xanthates have been shown to bioaccumulate For example, the disappearance of xanthate fr has been found to be enhanced by addition of (Lemna minor), which accumulates xanthates, (BCF) as high as 1000 have been reported for Xanthates have also been found to enhance th metals (Boening, 1998) as they may form hydr trivalent heavy metals such as Zn, Cd, Pb and uptake through organism cellular membranes ten-fold increase of Cd in trout gill tissue has b degredation product of concern is carbon disu	Hazards from xanthates in production of toxic / flamm spontaneous combustion t low order explosions from acute harm if ingested or s acute irritation if inhaled or For transport and storage Xanthates also have the fo Solid and liquid mixtures o Self-heating substances a Acute toxicity (Oral) - Cate Acute toxicity (Dermal) - C Skin corrosion / irritation - Serious eye damage / irrita In addition, animal studies				Crean Hill, (pro collector syster selected becau	2022	
								Hazards from xanthates in production of toxic / flamm						

Figure 1. Nickel-Copper Mining Flotation Chemicals

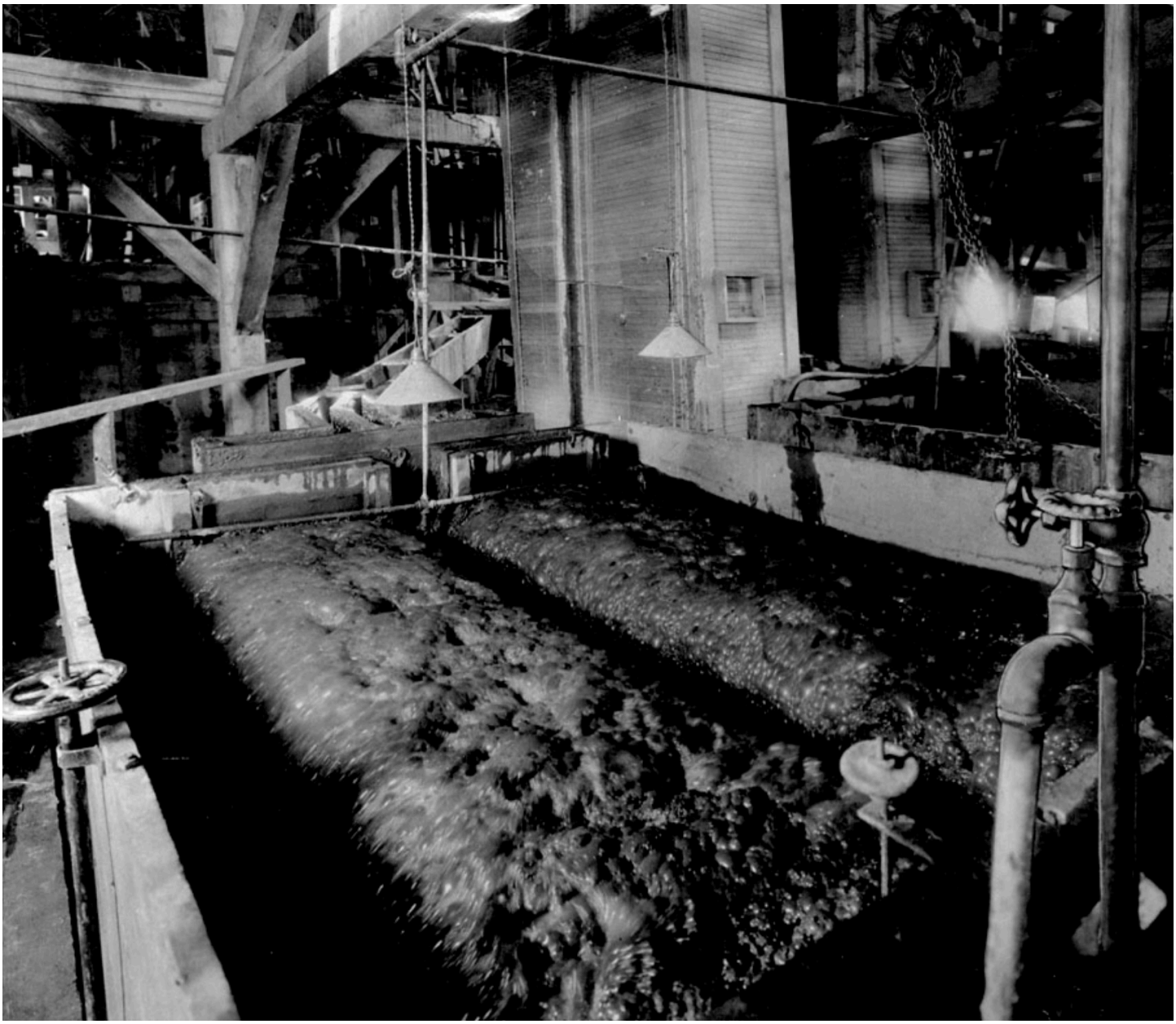


Typical instalation of flotation machines. Source: Guide to Flotation Cells in Mineral Processing
(a reproduction of an excerpt of public domain documents held in 911Metallurgy Corp's private library).

Flotation: flotation separation of nickel containing sulphide mineral from gangue, patent describes use of xanthates as collectors alone or in combination with activators and depressants to enhance or vary the selectivity of flotation separation: aliphatic amido propyl quaternary ammonium salt, stearamidopropyl dimethyl-B-hydroxy-ethyl ammonium nitrate, *or* amido-alkanol quaternary amine (antistatic agent), stearamidopropyl dimethyl-2-hydroxyethyl ammonium nitrate (Cyastat® SN Antistatic Agent made by American Cyanamid).

The last step in flotation:

- May involve leaching, if concentrates are not dried, or smelted in flash and bath processes. For activation, copper sulphate and ammonia were lon≠g used by INCO (may use other combinations of ammonia and chemicals for ammoniacal leaching depending on ore impurities).
- Copper ore that is oxide-based involves heap leaching, where ores are piled up, placed onto a leach pad, and covered in a sulphuric acid solution.
- If dried, dewatering and conditioning agents to create filter cake may include: polyoxyethylene ether (hexitol anhydride partial long chain fatty acid ester), polyoxyethylene sorbitan monooleate, polyoxyethylene sorbitan tristearate, polyoxyethylene sorbitan trioleate (INCO), or tri hydroxyethyl amine and hydrocarbon oil (INCO).



Froth process in a flotation cell in the Canadian Graphite Mill. Source: Library and Archives Canada. Accession number: 1965-040 NPC, Box number: 149, #1922. Item #: 3375231. No Date. E-copy #: a017735-v8.

The leftover materials, or tailings, may or may not go through various cleaning steps before they are discarded. These materials are often also referred to as "slimes."

The nickel matte may undergo further ammonia pressure leaching, or it may be roasted to produce nickel oxide and then pressure leached.

After the nickel and copper are smelted in furnaces, each will produce slag waste.

Nickel matte will then undergo another round of flotation, where the main matte separation reagent (mainly used by INCO into the present) is diphenylguanidine (DPG). Nickel sulphide concentrate will then undergo roasting and refining.

Any remaining copper sulphide separated from nickel matte during this stage is returned to the smelter to go through the process again.

Overall, the main classes of chemicals for sulphide ores are xanthates, dithiophosphates, dithiocarbamates, and non-sulphide ores, amines-based surfactants such as ether amines, and fatty and salt amines.

Inadequate Regulation and Chemical Experimentation

Gaining some understanding of the chemicals present in flotation tailings, and thus those potentially present in mine wastewater, is important, as effluent from tailings is very often released without treating mill chemicals.[29]

Take, for example, DETA, a chemical which is commonly used to suppress pyrrhotite in nickel-copper sulphide ore. DETA was only given a draft screening assessment under the Canadian Chemical Management Plan in 2021. However, as of now, there are no specific regulations that set concentration limits for DETA in mining wastewater. Likewise, mercaptobenzothiazole is now frequently employed as a flotation reagent, but it underwent federal screening assessment only in 2021, and is now under consideration as a toxic substance under the Canadian Environmental Protection Act. Mercaptobenzothiazole is permitted to be directly released to water under the logic that "when MBT is discharged to the environment, it is diluted by the receiving water body."[30] Industrial wastewater reporting, mandated in Canada only since 2004, provides limited parameters. Only vague categories like "flow" and "particulate residue" are required under its scope, and monitoring any of the aforementioned or similar chemicals is left out.[31] The task of understanding the potential consequences of chemical release in effluent — a waste infrastructure that materially seeps into air, soil, and water — is complex and requires access to many resources and kinds of technical expertise. The absence of comprehensive effluent regulations and monitoring — in particular, those which adequately account for the cumulative environmental fate of chemicals used in mining flotation processes — is deeply concerning.[32] This is exacerbated by an absence of scientific studies that focus on the consequences of long-term, low-level exposure to flotation chemicals, and their impacts on humans and wildlife.[33]

Some companies tout chemical advancements as environmental controls, claiming improved mineral recovery and thus less volume of chemicals used. Yet, the assumption that increased recovery equates to reduced environmental harm raises questions. It remains dubious how these advancements translate into pollution prevention, mitigation, or improved understanding of chemical toxicology after mine closure.[34] Likewise, reducing the concentration of metals in tailings may be assumed to be an environmental benefit of improved extraction efficiency. However, if the reduction of metals occurs by more kinds of chemicals being used with little research on their potentially harmful effects, this begs the question of whether pollutants are really being reduced.

The design of nickel-copper milling infrastructure, endorsed by settler law, effectively grants a licence to pollute. This systemic failure enables unchecked environmental degradation through the continued use of toxic chemicals, without meaningful accountability:

1. **Scientific literature does clearly show significant evidence of the potential impact of these chemicals on fish and aquatic environments.**

Accounting for the toxicity of chemicals, particularly towards aquatic life, remains paramount. Compounds that

29. It is also important to understand that as the re-mining of tailings gains prevalence, ore-grades decrease, meaning that less nickel or copper is available per unit of ore mined. This is because over time, high-grade ore deposits (where the metal content is relatively high) have become depleted, leading mining companies to turn to lower-grade deposits, which requires extracting more rock (and possibly using more chemicals) to get the same quantity of metal. See Guillermo Calvo et al., "The Economics of Natural Resource Extraction," *Journal of Development Economics* 120 (2016).

30. "Assuming that not all MBT could effectively be used during mining operations, nor destroyed by existing treatment processes at a given mining site, the remnant wastewater containing MBT may be discharged to a tailings pond located at a mine site and then discharged to the environment after additional treatment (settling of MBT)." See: Environment and Climate Change Canada and Health Canada, *Draft Screening Assessment for Benzothiazoles and Benzotriazoles Group* (Government of Canada, 2021).

31. These reporting requirements are outlined according to the Provincial *Effluent Monitoring and Effluent Limits (EMEL/MISA) Regulations* (repealed in 2021, replaced by site-by-site Environmental Compliance Approvals), and Federal *Metal and Diamond Mining Effluent Regulations* (SOR/2002-222) under the Department of Fisheries and Oceans. Under the EMEL/MISA limits, no identification, analysis, or monitoring of any other specific chemical parameters (beyond cyanide, and un-ionized ammonia as of 2021) was legally required.

32. Government of Ontario, O. Reg. 462/21: *Effluent Monitoring and Effluent Limits - Metal Mining Sector*, s. 1.

33. See: Environmental Canada, *Assessment of the Aquatic Effects of Mining in Canada: AQUAMIN Final Report*, Government of Canada, 1996 for an analysis of the impacts of mining effluent on aquatic life.

34. INCO's 1980 annual report notes that "since 1973 basic research and pilot plant testing of a novel flotation technique to remove additional pyrrolite from nickel concentrates prior to smelting had been underway as well as a new nickel concentrate smelting process." The above was framed as a form of "environmental control" because the "improved" chemical conditioning of sulfide minerals resulted in improved recovery of nickel and platinum group metals. Yet, the logic that more minerals being recovered using more chemical treatments, requiring less mining or extraction proportionally needed to get the same profits, is not sufficient pollution prevention. INCO Ltd., *Annual Report 1980* (International Nickel Company of Canada, 1980).

have known data about their acute toxicity to aquatic environments and fish include MIBC, quaternary ammonium compounds, carboxymethylcellulose, and aluminum chloride.[35] Ethylene diamine (EDA), diethylenetriamine (DETA), and triethylenetetramine (TETA) are also all newer depressants with data that suggest they are harmful to aquatic life.[36] Another newer depressant that indicates potential toxicity to fish is 2-amino ethylamino ethanol.

2. **Something mines don't want to advertise is that milling involves ongoing chemical experimentation. In fact, the specific chemicals used in a particular mine milling process depend in large part on trial and error enacted on site.**

Fuerstenau, Jameson and Yoon describe this process as follows: "Consequently, at present, the process of reagent selection and optimization can be characterized as rather informal, reductionistic, and frequently based on extension of personal experience from one mineral system or plant to another, gut feeling, anecdotes, and myths...There is no recognized standard practice, and the informal process is fraught with pitfalls."[37]

3. **During some stages of nickel-copper processing, a greater variety and volume of chemicals are actually being used now than in the past.**

One example is the use of solvent extraction for metal recovery using hydrometallurgical processing. Previously, this process, especially for copper, would take place using ammoniacal pressure leaching of ore heaps. However, by 1975, companies like INCO were using extractants like Di(2-ethylhexyl)phosphoric acid (D2EHPA) for nickel and copper, Falconbridge was using TBP for copper in its refinery in Kristiansand, Norway, and others were being recommended to use extractants like Kelex 100, LIX 64N, or MIBK. The rationale for increased solvent use is that it was necessary "as ore grades become lower, and more complex ores are encountered," especially sulphides, the predominant type of ore in the Sudbury and Sault Ste. Marie regions.[38]

4. **The commercial confidentiality — including, but not limited to, patenting — of mining processes complicates environmental assessment, as the chemical formulas and specifics of mining flotation processes are often proprietary.**

Lab data about the behaviour of chemical compounds are part of chemical development, but are not public-facing as they are used for chemical marketing and internal research. For decades, companies like INCO and Falconbridge (giants in the Canadian nickel-copper mining industry before being acquired by Vale and XStrada in the 1990s) invested heavily in research and development. Behind closed doors, laboratories across Ontario conducted scientific and technical studies on chemical processes, from flotation to smelting.[39] That much of this research wasn't shared with the public is a problem when it comes to the right to know about pollution (another challenge is how chemical use is largely site-dependent). Difficulty in accessing and understanding chemical information impedes communities' capacities to be informed. In turn, this hinders engagement and public pressure for particular forms of governmental and industry accountability.

5. **Many petrochemical producers have historically manufactured the equipment used in milling or other processing, and been heavily involved in the business of pollution abatement technology.**

To maintain or bolster profit margins, members of the Canadian domestic chemical industry "diversified" their assets. As an example, Canadian Industries Limited (C-I-L) historically has been one of the largest mining chemical manufacturers in the country, especially in relation to nickel-copper mining, and has also been a major explosives producer. They constructed an on-site liquid xanthates production plant at Copper Cliff in 1970. In a 1970 annual report, the company discusses diversification — they acquired a major share in a North Bay mining equipment company, purchased a geophysics mining explora-

35. Several other relevant examples: a) MIBC is a known neurotoxin. It is associated with acute solvent toxicity and encephalopathy, and is acutely toxic to fish. b) A trend in the use of depressants is the more recent combination of guar gum with quaternary ammonium compounds, as the latter are also highly toxic to fish. c) Traditional mining compounds have long been known to be toxic to fish: sulfuric acid changes pH, and soda ash and sodium carbonate can increase pH levels.

36. For example, EDA has acute toxicity for a range of fish, aquatic organisms, and aquatic plants. These include Daphnia magna, the most sensitive aquatic invertebrate, which is often used as a measure to deduce impacts to other aquatic organisms.

37. Maurice C. Fuerstenau, Graeme J. Jameson, and Roe-Hoan Yoon, eds., *Froth Flotation: A Century of Innovation* (Society for Mining, Metallurgy, and Exploration, 2007), 415.

38. G.M. Ritcey, "Some Economic Considerations in the Recovery of Metals by Solvent Extraction Processing," *CIM Bulletin* 68, no. 758 (June 1975): 93.

39. INCO had research laboratories at Copper Cliff and Port Colborne in Ontario; Thompson, Manitoba; and the J. Roy Gordon Research Laboratory at Sheridan Park, Ontario (Chemical Institute of Canada, *Annual Directory of Research Laboratories in Canada 1966/67*, 13). Falconbridge Nickel Mines Limited had a research organization at its operations near Sudbury and the Richvale Laboratory at Thornhill, Ontario, which are engaged in process research and related problems. In the 1940s, laboratories at Algoma Steel Co. offered their services free of charge to prospectors who wanted samples of mineral ore analyzed.

tion company that operated transnationally, purchased a large West African chemicals and explosives company, and purchased a company that manufactured chemical process equipment and pollution abatement technology transnationally. Given these intertwined vested interests, it quickly becomes clear why chemical pollution prevention (by way of state regulation) gets sidelined — chemical companies are heavily invested in the entire infrastructure of pollution. C-I-L has also invested in a chemical company that produces industrial water treatment chemicals, showing how pollution itself has become commodified, and thus companies are incentivized to continue releasing effluent in a business-as-usual manner while touting their environmental sustainability measures.

Taking these challenges together, the normalized industrial release of hundreds of little-researched synthetic chemical compounds into ecosystems reflects extractivist logics. The so-called "green transition" is not a break from this logic, but, at present, a continuation of it — an extractivist bonanza driven by demand for critical minerals and the rapid electrification of energy systems. As Kyle Whyte argues,[40] such "wrongful actions are defensible because they are responding to some crisis," namely, the climate crisis. Critical minerals' strategies and clean energy plans are thus pushing for more mining in order to secure supply chains of minerals seen as essential to battery production and green infrastructure.[41]

While climate change is undeniably urgent and a just transition led by Indigenous nations is vital, it's important to recognize that "crisis" itself is not new. On one level, capitalist logic treats crisis as an opportunity — an excuse to accelerate extraction under the banner of urgency. On another, more structural level, capitalism is a crisis-producing system: it generates economic, ecological, and social instability as part of its functioning. Either way, crisis cannot be an excuse to abandon ethical relation; if anything, it should compel us more deeply toward it.

To illustrate, take the scale of chemical consumption by a single nickel-copper mine. A sample estimate of tonnage from a contemporary proposed mine includes:

- 77 tonnes of flotation collector
- 28 tonnes of flotation frother
- 1,101 tonnes of flotation gangue depressant
- 8 tonnes of concentrate flocculant
- 25 tonnes of tailings flocculant
- 12 tonnes of effluent treatment flocculant

Total: 1,251 tonnes of petrochemicals per year[42]

Thinking of this hypothetical example, if these are *inputs* to the mining process, it is unsurprising that huge volumes of tailings waste would be generated. Otherwise, where would all these tonnes of chemicals go?

Given that the typical lifespan of a nickel mine is around 20 years, that's over 25,000 tonnes of petrochemicals unaccounted for.

And yet, the long-term, cumulative, regional effects of flotation chemical waste remain largely unknown. The seriousness of this picture for cumulative effects becomes clear when we remember that any regional load of nickel-copper mining waste and pollution on watersheds and surrounding ecosystems also overlaps with many other kinds of uranium, gold, cobalt, silver, and other rare earth mining, mineral waste, and chemical pollution. The additive effects of hundreds of trace amounts of different chemicals only multiply exponentially.[43] While each chemical might be present in concentrations that are below toxicologically defined harmful thresholds, their combined presence can synergistically lead to toxic effects far greater than what would be expected from each chemical individually. They also can bioaccumulate in organisms, and produce cumulative effects that lead to chronic impacts to organism health in the long term when persistently overwhelmed with many low-level toxicants. For example, one chemical might weaken the immune system of aquatic organisms, making them more vulnerable to the toxic effects of another. While petrochemicals remain integral to nickel-copper mining, and all mining, this does not need to mean "infrastructural lock-in" to petrochemicals in the current status quo.[44]

Thus far, this report has shown that a full understanding of the scale of nickel-copper extraction and its regional cumulative effects includes environmental impacts beyond mines and mill processing sites alone; rather, it requires attending to environmental impacts of infrastructural seepage at many stages of the mining supply chain.

40. Kyle Whyte, "Against Crisis Epistemology, in *Routledge Handbook of Critical Indigenous Studies*, eds. A. Moreton-Robinson, L. Tuhiwai-Smith, C. Andersen, and S. Larkin (Routledge, 2020), 52.

41. Saima Desai and Isaac Thornley, *Greenwashing the Ring of Fire: Indigenous Jurisdiction and Gaps in the EV Battery Supply Chain* (Infrastructure Beyond Extractivism, February 2024), 6. jurisdiction-infrastructure.com/research/greenwashing-the-ring-of-fire-report/.

42. Noront Resources Ltd., *Eagles Nest Mine. Air Quality Technical Supporting Document* (November 2013), A4 of 5.

43. Of note is a significant overlap with flotation chemicals and some of the key chemicals used in fracking, such as polyacrylamides (used as flocculants), and quaternary ammonium compounds, which are persistent in the environment.

44. Alice Mah, *Petrochemical Planet: Multiscalar Battles of Industrial Transformation* (Duke University Press, 2023), 147.

Part 2: The Politics of Evidence in Historical Nickel-Copper Mining

This section explores several different kinds of historical mining waste infrastructures in the Sudbury and Sault Ste. Marie regions in concert: mining tailings, effluent release, and paste backfill. Piecing these infrastructures — and the consequences of their material seepage — together reveals that scientific study and toxicological data for much of these waste infrastructures' long-term impacts do not exist or, when they do, they contain many gaps. It also reveals the need for other kinds of knowledge — that which attends to the significant large-scale, cumulative, regional ecological impacts of nickel-copper mining waste infrastructures — infrastructures that seep chemicals.

By examining various Canadian settler-colonial environmental archives, specifically reports housed in the Archives of Ontario, including those published by the provincial Ministry of Environment, Department of Mines, and the Ontario Water Resources Commission, what follows begins to critically highlight the genealogies of mining waste infrastructure pollution data.

What tensions emerge in the politics of evidence surrounding nickel-copper mining waste?

In many instances, mining pollution monitoring or emission reporting has not been, and is still not, required by settler law. Even though pollution reporting is not comprehensive, or inclusive of all emissions, many chemicals still have potentially harmful effects. By not testing or monitoring for petrochemicals, it leaves the impression that they aren't there. An example of this is when monitoring is encouraged for "discharge or seepage exiting on-site sources," "discharge or seepage exiting the property boundary," and "on-site water bodies and water bodies downstream from the site," implying that long-term discharge and seepage is likely and inevitable.[45]

Industry monitoring produces data that do not address the structural causes of industry-created environmental harm and long-term ecological damage. Monitoring that is industry self-regulated can be performative, rather than preventative. The effectiveness of monitoring programs is contingent upon accurate data collection, transparent reporting, and robust enforcement mechanisms, all of which may be lacking in practice. It has been shown time and time again throughout Canadian extractive zones that affected communities come to realize that "[they] are the monitors now." In other words, people's bodies made ill from toxic exposures themselves become the "technologies" through which we measure the emissions of chemicals.[46] Affecting multiple generations, these "chemical intimacies" and "intoxications," when they don't present as acute harm, often present as chronic illness and disability. As such, "how we then define where chemicality begins and ends becomes not a question of quantification, threshold, scientific trace, or material history alone,"[47] but rather of structural forms of environmental oppression that have long unevenly impacted Indigenous, racialized, are marginalized communities — with gendered divisions of labour and social burden.

Therefore, while monitoring can serve as a tool for identifying environmental risks, it does not necessarily lead to increased environmental protection.

Mining pollution data is non-innocent. Grasping regional-level histories sheds light on environmental degradation, and underscores the non-innocent nature of the

45. An example of this attitude continues with the very recently revised (April 2024) *Mine Rehabilitation Code of Ontario*, where "[i]f a shaft, raise or stope is to be backfilled rather than capped, [it] shall be designed in a manner to allow for long term stability once backfilled" and "a report certified by a qualified professional…submitted to the Minister, stating the long term stability of the backfilled opening" (O. Reg. 35/24, incorporating by reference the *Mine Rehabilitation Code of Ontario*, at s. 17, 8.). In this instance, despite the requirement to certify stability, there is no other requirement for long-term monitoring or guarantee of stability. Moreover, it is unclear how stability is defined. If buried chemicals leach into groundwater how is that still stable? Similarly, surface water chemical monitoring might include a list of chemicals, but what about the chemicals used as flotation reagents, frothers, etc. — which may also end up in surface water but are left out of this list? Likewise, open pits are suggested to be backfilled, but can also be flooded, stoped, or fenced off, depending on what is "fully justified in the closure plan" (*Mine Rehabilitation Code*, s. 21, 9.). This leaves a lot of room to mining companies, and only minimal long-term environmental considerations. If open pits are flooded, "additional rehabilitation is required only with respect to workings above the final water elevation," which leaves unclear what the requirements are for long-term groundwater monitoring (*Mine Rehabilitation Code*, s. 23(a), 10.). Omissions such as these seem strange given how other sections of the Code are very specific, such as the requirement that signs "shall have at least the words 'Danger — Open Hole', in both English and French, in letters that are at least 3.5 cm in size" (*Mine Rehabilitation Code*, s. 27(c), 10.).

46. Dayna Nadine Scott, "'We Are the Monitors Now': Experiential Knowledge, Transcorporeality and Environmental Justice," *Social & Legal Studies* 25, no. 3 (2016): 261–287.

47. Mel Y. Chen, *Intoxicated: Race, Disability, and Chemical Intimacy Across Empire* (Duke University Press, 2023), 5.

data that do exist. This perspective follows Indigenous scholars who call for an attention to "data colonialism," and how pollution data are made available in bad faith.[48] It follows that despite this, it is both possible and necessary to "use this information to expose colonial environmental violence."[49]

Better data or improved technoscientific understanding of pollution effects, while important, will also not address structural issues (like the tensions between mining extraction and Indigenous jurisdiction). Assuming that data will solve a problem without reflecting on how the ways those data are created and used, or the politics of data, can reinforce the very forms of power it intends to speak back to.

Mining waste infrastructure design, and the absence of data about its material seepage, is shaped by flawed logics of dilution. The logic of dilution, or the idea that chemicals will self-attenuate, or be attenuated by the environment, is a settler-colonial epistemology with a recent history.[50] That logic is also baked into settler environmental law and the regulation of toxics, where the "myth of thresholds" has been widely influential.[51] Problematizing how heavy metals and chemicals are assumed to "be tolerated by" the surrounding environment requires attending to how pollution and waste dilution is part of mining chemical infrastructure, part of the supply chain design, and part of extractivism working how it is intended. For every tonne of copper produced, 99 tonnes of waste are produced,[52] and 200–500 tonnes of waste for every tonne of nickel.[53]

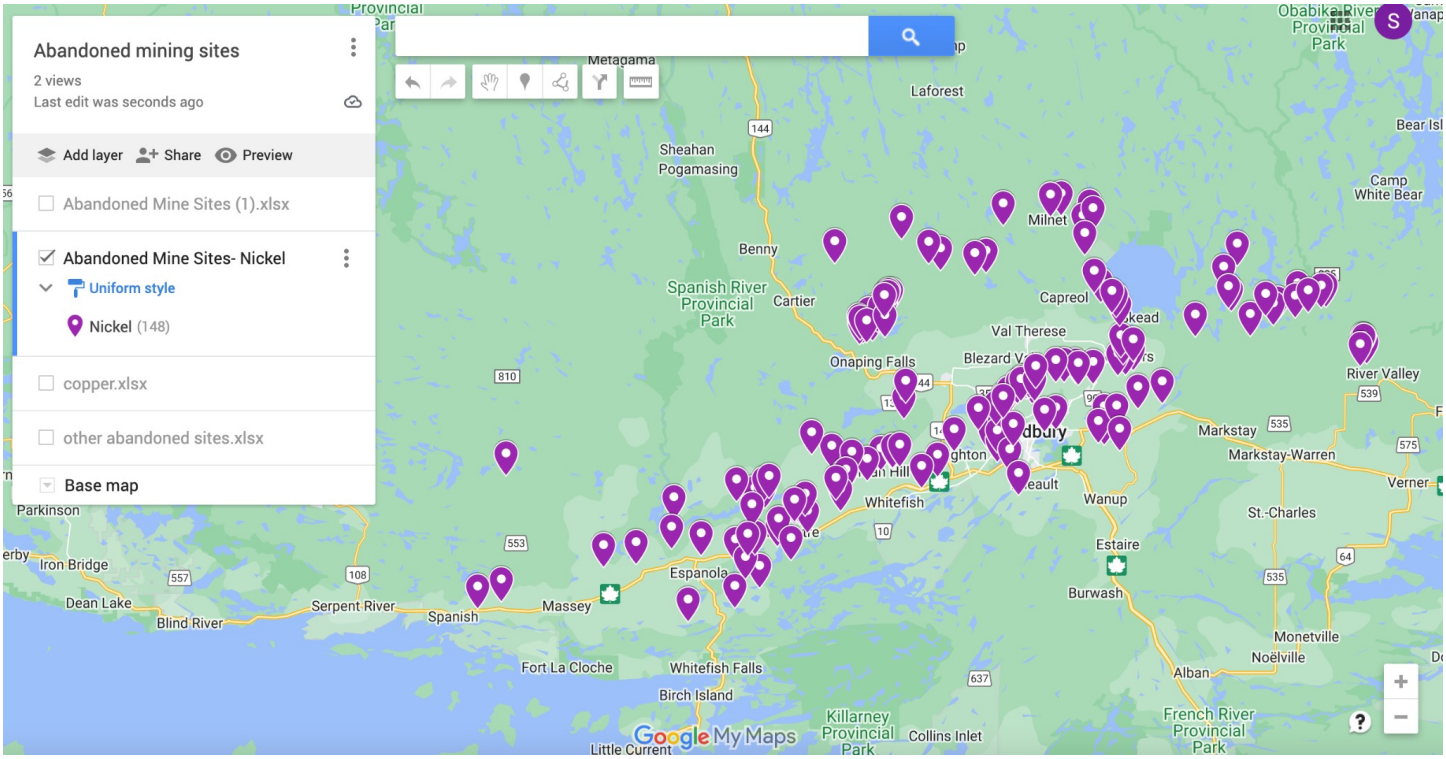
While impacts of mining chemicals extend far beyond the confines of mine sites, permeating entire watersheds and ecosystems over a hundred years of heavy industrial exploitation, it is important to not replicate a "damage-centred theory of change."[54] This involves bringing how settler technoscientific knowledge of nickel-copper mining and chemicals can nonetheless be subverted together with support of Indigenous jurisdiction in relation to territory informed by Indigenous data sovereignty, Indigenous science, and Indigenous law and protocol.

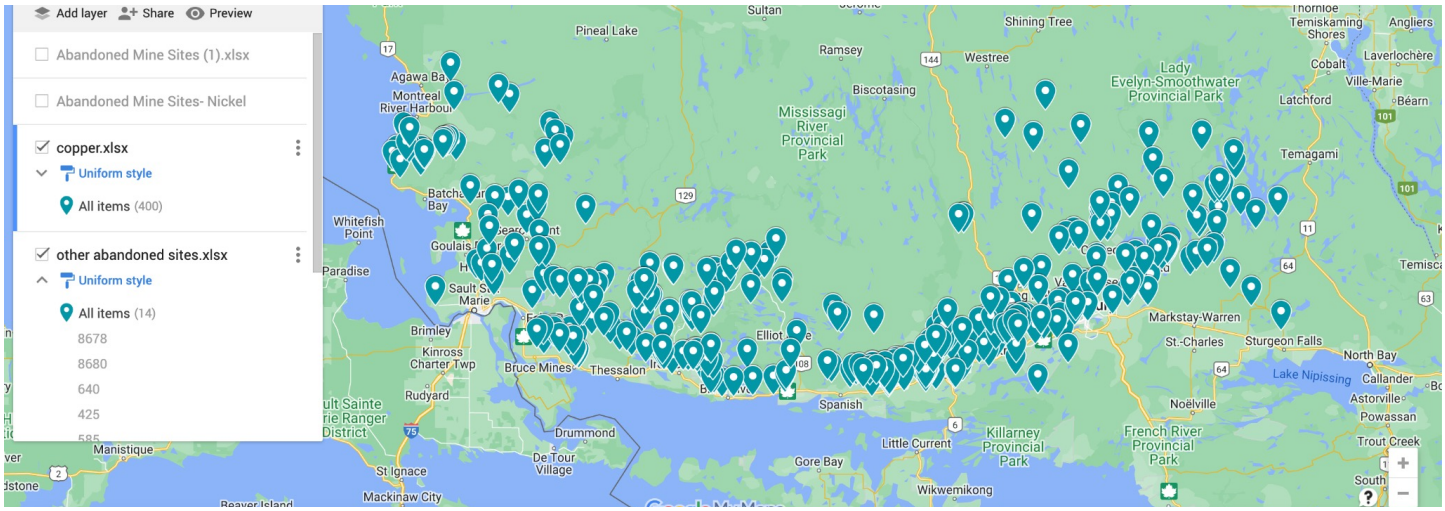
Research and analysis cannot stand in for building relationships with the land, and centring community knowledge about pollution and ethical relations to place. A focus on data rather than relationships and local knowledge might also inadvertently promote substitution politics. In the latter, certain toxic chemicals are just replaced with others, rather than challenging the underlying logics and centring interventions that support a reciprocity of relations. By translating information that is difficult to access, and thinking about it comprehensively, this report aims to be a background resource for building community-based knowledge and relationships to territory that can strengthen Indigenous jurisdiction. In turn, problematizing nickel-copper mining's politics of evidence can support calls for future regional cumulative effects studies guided by the aforementioned principles.

Waste Overview

According to the Abandoned Mines Information System (AMIS), there are approaching 6,000 abandoned mines in Ontario.[55] While there is a triage process whereby more dangerous sites are prioritized for cleanup, this betrays an assumption that most of these sites will never be cleaned up by either mining corporations or government. "Orphaned" is a phrase that refers to abandoned mines that are no longer in operation and for which the owner either cannot be found or is financially unable or unwilling to carry out site rehabilitation and remediation. The paternalistic language of "orphan" reflects settler-colonial views about the land that are more infantilizing than respectful when interpreted within the context of colonial/bourgeois notions of the family as defined by its isolated nuclear structure. An "orphan" in colonial/bourgeois society is functionally left without care; whereas in Anishinaabek society (and many other Indigenous cultures), an orphan becomes the responsibility of the whole community.[56] Since 1999, a provincial Abandoned Mines Rehabil-

48. Gray et al., *Data Colonialism*.
49. Gray et al., *Data Colonialism*, 8.
50. See Max Liboiron, *Pollution is Colonialism* (Duke University Press, 2021).
51. Dayna Nadine Scott, "Conclusion: Thinking About Thresholds, Literal and Figurative," in *Our Chemical Selves: Gender, Toxics, and Environmental Health*, ed. Dayna Nadine Scott (UBC Press, 2015), 387–393.
52. BC Wild and Environmental Mining Council of BC, *Acid Mine Drainage: Mining and Water Pollution Issues in BC*, 2000. https://miningwatch.ca/sites/default/files/amd.pdf.
53. Eau Secours, *The Impacts of Mining Activities on Water: A Technical and Legislative Guide to Support Collective Action*, 2023. https://eausecours.org/sites/eausecours.org/wp-content/uploads/2023/11/Citizens-guide-mining-industry_EN.pdf.
54. Eve Tuck and K. Wayne Yang, "Decolonization is Not a Metaphor," *Decolonization: Indigeneity, Education & Society* 1, no. 1 (2012): 1–40.
55. AMIS is managed by the Ontario Geological Survey (OGS), a branch of the Ontario Ministry of Energy, Northern Development and Mines. https://data.ontario.ca/dataset/abandoned-mines-information.
56. See, for instance, Heidi Kiiwetinepinesiik Stark and Gina Starblanket, "Toward a Relational Paradigm: Four Points for Consideration (Power, Gender, Mobility, Technology),"





Figures 2 and 3: The categories of waste sites focused on in this analysis include:

- chemical storage facilities (1 rehabilitated) and chemical wastes (1 active hazard),
- landfill (11, including 9 active hazards and 2 rehabilitated),
- ore stockpile (10, including 9 active hazards and 1 rehabilitated) and overburden stockpile (1 active hazard),
- roasting yards (4, including 3 active hazards and 1 not available),
- tailings confined (35, including 4 rehabilitated, 1 not available, and 31 active hazards), tailings unconfined (25, including 1 rehabilitated, 2 not available, 1 not a hazard, and 21 active hazards), and tailings dams (1 not available and 183 active hazards),
- underground storage tanks (2 active hazards), and
- waste rock dumps (100, including 11 not a hazard, 19 not available, 3 rehabilitated, and 67 active hazards).

(Screenshots from Google Maps by the author. Data obtained from AMIS.)

itation Fund has supported the rehabilitation of 75 mines. At this rate, even after 1,600 years, there would still be several hundred mines left to rehabilitate, and this assumes no new sites will be added. This effectively puts the burden of the cleanup on the public, even as the profits from the extraction are held privately. In effect, it's a subsidy to corporate polluters.

Focusing on the Sault Ste. Marie and Sudbury regions up to 1980, within approximately a 120-km radius, AMIS indicates the presence of around 563 abandoned mining sites primarily associated with nickel or copper production (Figures 2 and 3 above). This count includes 14 sites where the primary commodity is not formally identified in AMIS, but the author considers them likely to be linked to nickel or copper production. Among these sites, 476 lack a closure plan, while the status for 26 is unknown, and 60 have an existing closure plan in place.[57]

An analysis of abandoned mine features shows 375, of which only 12 are currently rehabilitated, while 327 remain active hazards. The hazards were produced at 64 different mines or mining sites, for an average of almost six waste features per mine site.[58]

The regional scale of waste sites in this case study raises profound questions about future approaches to cumulative infrastructural material seepage. How should we address the care of land and waters impacted by hundreds of mines that were opened without environmental assessments, closed without closure plans, used acid-generating aggregate for roads, failed to report spills, left tailings and waste rock piles unmonitored, neglected to track chemical leaching from tailings buried deep underground, and potentially affected aquifers or created migrating groundwater plumes?

Mine Tailings and Paste Backfill

The OWRC and Effluent

Formed in 1957, the Ontario Water Resources Commission (OWRC) became heavily involved in managing and monitoring mining pollution by the mid 1960s, when it adopted and published the first Ontario Tailings Guidelines (1965), based on those of the United States Atomic Energy Commission and US Public Health Service.[59] Stating that "In the mining industry in general the existing methods of building tailings dams have evolved on the basis of experience *gained by trial and error* [author's emphasis] and until recently there have not been many attempts to use a scientific basis for their design," the OWRC guidelines hinted at a flawed logic of dilution, with diagrams promoting the incorporation of ideas that would today seem almost unbelievable — such as suggesting that "*infinite* [author's emphasis] subsurface drainage" be a guideline for tailings dam designs alongside other options such as an impermeable foundation or a blanket drain."[60] These pollution laws have been shaped by aesthetics, where the logic is that "as long as everything looks fine, it must be fine."

Mining "effluent" refers to both wastewater created after nickel-copper ore is processed in a mill, and wastewater from the mine itself. Mill wastewater contains slurried solids, dissolved metals, "residuals of process reagents added in the mill" (chemicals added to process the ore), chemical complexes formed during processing, a high level of dissolved solids and usually a high pH."[61] After milling, part of the waste ore may be "deslimed" then used in underground backfill or stockpiles, while "slimes" are sent to tailings ponds and overflow areas.[62] There, tailings water would have slime solids settle, or sink, to the bottom of a pond or dam over time.

Many mill chemicals, such as flotation reagents, can oxidize, or react with both oxygen and sunlight, which led to the assumption that they would be "stabilized" through the oxidation process by sitting in tailings ponds over time.[63] Of course, the breakdown products are not necessarily innocuous, and some are even more harmful than the original compounds. When sunlight hits the tailings ponds, it can cause some, but not all, chemicals used in nickel-copper milling to oxidize, or break down. Sunlight may also facilitate photochemical reactions, where the energy from photons is absorbed by chemicals, potentially forming reactive intermediates or radicals. Tailings ponds were explicitly discussed as having advantages

in *Reconciliation and Resurgence: Indigenous-Settler Relations and Earth Teachings*, eds. Michael Asch, John Borrows, and James Tully (University of Toronto Press, 2018).

57. As a comparison, in the US, there are an estimated 390,000 abandoned hardrock mine features, 22,500 of which may be environmental hazards.

58. Author's analysis.

59. See: D.P. Caplice, "The Ontario Water Resources Commission Regulatory Control Programme for the Mining Industry — Introduction" (Paper presented at the 1968 Annual Meeting of the Society for Mining, Metallurgy & Exploration [Ontario Water Resources Commission]), 3. Source: OneMine.

60. Caplice, "Ontario Water Resources Commission," 17.

61. Alain V. Bell, "The Tailings Pond as a Waste Treatment System," *CIM Bulletin* 67 (April 1974): 73.

62. See, for example, Horne and Siscoe, "Falconbridge Mill Flowsheet," in *Milling Practice in Canada*, ed. D.E. Pickett, CIM Special Volume 16 (Harpells Press, 1978): 137.

63. Bell, "The Tailings Pond," 74.

precisely because their "large surface area[s] aids oxidation and evaporation" of chemicals.[64]

The idea was that heavy metals and larger particulates would remain in the tailings to eventually be dried and used as backfill, or "stabilized" and revegetated. In many tailings dams, this "supernatant" water, or clear water that separates from heavier particulates that settle below, is dealt with by settling followed by decantation, which then releases it into the environment.[65] It may or may not go through an additional "clarification" pond that "improves water quality by settling or aging" before it is discharged.[66]

This approach ties back to aesthetics, because it operates on the assumption that if the water appears clear, it must be safe to discharge into the environment, as it would be sufficiently diluted to discharge directly into water systems.[67] The visible clarity of the water, the "supernatant" that separates from heavier particulates in tailings dams, is prioritized over deeper chemical analysis. This logic mirrors the flawed idea in pollution laws that if something *looks* fine, it *is* fine. There is a secondary assumption that heavy metals, which tend to settle out in sediment, are the only toxins worth worrying about. As long as the water looks clean, it can be released — regardless of whether it still contains dissolved metals or other harmful substances. The reliance on aesthetic judgment, rather than thorough environmental testing, risks overlooking the hidden toxicity that clear water may still carry.

Eventually, as awareness of pollution's effects on the outputs of effluent parameters like pH grew, some effluent began to be treated to regulate pH.[68] While the "practice of chemical water treatment [was] erratic" and when done, typically only used lime, which alkalizes and precipitates heavy metals, it may not fully address all low levels of chemicals present in effluent.[69] More recently, treatment processes have been developed in the research literature to target specific chemicals, but it is not required that they be applied in practice, or removed under settler law. One example described the use of activated charcoal to remove a quaternary ammonium compound from wastewater, and also oxidation of "residual thiocyanate" with chlorine "to an undetectable level."[70]

While chemical breakdown processes and products are complex, assuming mill wastes are sufficiently "diluted," "diffused," or oxidized, by "passive water treatment aging" or breakdown of chemicals by sun, water, or bacteria, is not enough to fully prevent long-term, cumulative ecosystem effects that exceed the visual appearance of water, and changes to its pH.[71] These effects remain unknown. There is an historical absence of monitoring and sampling of downstream effects, of chemicals related to "recalcitrant molecules" or abandoned mining waste areas.[72]

The long-term challenges of abandoned tailings and waste dump areas are gestured at in descriptions such as: "undesirable effluents that will continue to emanate from them through precipitation and slimes consolidation."[73] An example of this are large plumes of heavy metals that can form below tailings and migrate in groundwater towards aquifers. A recent scientific article was the first to assess the success of a buffer put in place at Nickel Rim in 1995 to stop a large plume from migrating further into an aquifer. The author(s) observed the effectiveness of the buffer, however failed to test for the presence of trace amounts of any mining chemicals, focusing only on heavy metals. It seems that milling chemicals and their reaction byproducts are assumed to either self-attenuate, diffuse, or react "away." This is evidenced in the language used to describe aquifers that defines their function in terms of their ability to absorb or mitigate contamination, where, for example, the redux-buffering capacity (oxidation capacity and total reduction capacity) of an aquifer

64. Bell, "The Tailings Pond," 74.

65. R.L. Coleman and B.P. Wallace, "Tailing Disposal in Canada," in *Milling Practice in Canada*, ed. D.E. Pickett, CIM Special Volume 16 (Harpells Press, 1978): 15-19.

66. Coleman and Wallace, "Tailing Disposal," 17.

67. This process is described as typical in J.M. Oko and L.W. Taylor, "Treatment of Acid Mine Wastewater at Falconbridge's Hardy Crown Pillar Project," *CIM Bulletin* 67, no. 744 (1974): 43–49.

68. Ontario Ministry of the Environment, *Effluent Guidelines and Receiving Water Quality Objectives for the Mining Industry in Ontario*, 1973.

69. Coleman and Wallace, "Tailing Disposal," 17.

70. "Tailings Disposal Technology," *CIM Bulletin*, October 1976, 91.

71. Coleman and Wallace, "Tailing Disposal," 18.

72. "Xanthates are commonly used as collectors of sulphide ores through flotation. Xanthates were reported in effluents and their receiving waters in concentrations up to 4.0 mg/L. These concentrations are sufficient to cause potential toxicity, given that xanthates exhibited toxicity (as measured by IC25) ranging from 0.5 mg/L to 3 mg/L" (B. Vigneault, M. Desforges, and J. McGeer, "Mining Reagents and By-Products (e.g. Thiosalts) As Potential Toxicants in Mine Effluents," in Environment Canada, *Environmental Effects Monitoring Investigation of Cause Workshop for Metal Mining: Proceedings*, Gatineau, QC, 2012.). "Thiosalts (thiosulphate, trithionate, tetrathionate, and other polythionates) are generated as a result of the flotation of sulphidic ore…Thiosulphate has been reported in mine effluent concentrations of 700 mg/L, thus in sufficient quantity to cause toxicity" (Vigneault et al. 2012). "Other process reagents and wastewater treatments likely to be discharged in concentrations sufficient to cause toxicity include Magnafloc, Nalmet, and lime" (Vigneault et al., "Mining Reagents and By-Products.").

73. Coleman and Wallace, "Tailing Disposal," 19.

is referred to, almost anthropomorphically, as its level of "poise."[74] Whether intentional or not, this language normalizes the presence of toxic groundwater plumes below tailings, romanticizing aquifers as always already "poised" to absorb extractivist waste.

Important for understanding tailings as waste infrastructure is that they promote material seepage by nature of their construction. Tailings dams can, and often do, fail, due to overtopping, foundation deformation, erosion, leaching, and seepage.[75] They can also suddenly fail due to the static liquefaction of loose materials like sand and silt. However, while a tailings dam or storage area may not have completely or catastrophically "failed" or "broken," it might still seep chemicals into the surrounding environment for the duration of its existence, potentially for hundreds of years or more. This seepage might not be noticeable unless it is explicitly looked for.
Material seepage combines with existing geochemistry that has fine tuned itself over millions of years, where seepage of new, little-understood and researched petrochemical compounds spur novel reactions that over time spur others in a prolonged cascade effect where the millions-of-years-in-the-making biochemical composition of watersheds is upset, and heavy metals and toxic compounds and degradation products abound.

When mine water began to be reused, around 1970, mines had to face the consequences of reintroducing chemicals that lingered in tailings, and their unexpected combinations with milling and flotation chemicals. A paper discussing one of the first mines in Canada to reuse waste water, the Brenda Mine in BC, described the challenges with this process: "Where chemical reagents are used, such as in froth flotation processes or leaching operations, these reagents and water soluble products in the case of leaching can further add to the characteristics of any particular mill wastewater stream."[76] The author went on to say, "Fortunately, oxidation reactions in the tailings pond change most of the reagents used by Brenda into *relatively* [author's emphasis] inactive decomposition products, some of which are retained by the settled solids...Some of the reagents, notably the frothers, are returned by the reclaim water in their original form... but [alcohol-based types] are subject to a *partial* [author's emphasis] evaporation in the tailings pond and are therefore preferred."[77] They then stated, "Return of reagents in reclaim water is said to reduce the requirements for ore currently being treated and therefore reduces operating costs. This is true to some extent, but on occasion even greater quantities of new reagents are needed to overcome the effects of a reagent that has been introduced at the wrong point in the process."[78]
As will be discussed later in this section, some mines are now opting to store tailings entirely underground in the form of paste backfill. Given their chemical content and the unknown effects of long-term chemical leaching and breakdown, impacts remain unclear, especially after mine closure.

Now, industry monitors tailings facilities using technologies like drones, radar, and statistical and remote sensing methods. They test the slow deformation of tailings dams, using technical categories and difficult-to-understand terms like brittleness.

Effluent Dumping

Archives suggest that largely unregulated industrial effluent dumping persisted in Ontario until almost 1970, evidenced by a 1963 OWRC publication that surveyed water systems in the Sudbury region where mines discharged their wastes.[79] It was also explicitly articulated in a 1967 brief that stated: "No efforts have been made, to our knowledge, to prevent any industrial wastes from polluting the rivers, lakes and streams."[80]

74. Coleman and Wallace, "Tailing Disposal."

75. See Shianna McAllister, "DAMMING COLONIAL EVASION: An Accounting of the Unaccountable in the Mount Polley Mine Disaster," *BC Studies* no. 221 (Spring 2024).

76. D.P. Caplice, "The Regulatory Control Programme of the Ontario Water Resources Commission for the Mining Industry" (Paper presented at the Ontario Mining Association meeting, Toronto, 1966), in *Ontario Mining at the Threshold of a New Century: Report of the Department of Mines for the Year 1966* (Ontario Department of Mines, 1967), 124.

77. Caplice, "Regulatory Control Programme," 128.

78. Ontario Ministry of the Environment, *Proceedings of the 20th Ontario Industrial Waste Conference* (Ministry of the Environment, 1973): 199–200.

79. Ontario Water Resources Commission, *Water Resources Survey, District of Sudbury: Part II, A Survey of Industrial Water Use and Waste Disposal* (Queen's Printer for Ontario, 1963). https://archive.org/details/WATERRESOURCES-SU00SNSN09063.ome.

80. Two 1970 letters also highlighted concerns over loopholes in tailings pollution monitoring. One, written by J.W. Este, the Secretary-Treasurer of the Porcupine Planning Board, addressed the Minister of Mines, Mr. G.C. Wardrope (Source: RG 13-13-0-78 Pollution Control Advisory Committee. Ontario Archives.). Este expressed concerns regarding the unclear responsibility for rehabilitation after mine closure. He emphasized the potential consequences of waste dump and tailing disposal areas being abandoned by mining companies, raising fears of dust pollution and chemical contamination that could hinder growth if not properly contained. Este stressed that these dangers were not unique to specific mining areas but were common across the board. Similarly, a 1970 letter from the Deputy Minister of Lands and Forests to the Chairman of the Advisory Committee of Air Pollution Control echoed concerns about vague definitions

By the 1970s, under the Ontario *Mining Act*, mines were obligated to revegetate tailings areas and maximize water reuse where possible.[81] Yet a Ministry of Environment report still described tailings practices up to this point, despite the earlier OWRC guidelines, as largely insufficiently self-regulated: "Waste mill tailings have been disposed of in lakes, low-lying swampy areas, natural depressions near the mines, enclosed valleys and in engineered impoundment basins. Properly designed for each particular situation, the latter point of disposal provides the best long term disposal of waste mill tailings."[82] Until at least 1977, failure to prevent watercourse pollution from mining effluent and waste disposal was due to several regulatory gaps: 1) a lack of federal *Fisheries Act* enforcement, meant to be administered at the provincial level, that prevented pollution of waterways from waste disposal areas, which were under provincial jurisdiction, and 2) gaps in water pollution control between the Ontario Ministries of Environment and Natural Resources (which administers the *Mining Act*).[83]

In 1977, Metal Mining Liquid Effluent Regulations (MMLER) were introduced under the *Fisheries Act*, alongside a federal *Environmental Code of Practice for Mines*, which focused on metal mines. Recommendations from the more recent 2009 version of the *Environmental Code of Practice for Metal Mines* that pertain to effluent include:

- locate discharge points away from environmentally sensitive areas;
- design and implement site-specific programs for the prediction of wastewater quality that include other potentially harmful components in mine wastewater, such as processing reagents, ammonia, algae-promoting substances, thiosalts, chlorides, and elevated pH;
- identify potential environmental concerns associated with proposed chemical processes and related environmental effects; and
- assess the use of alternative processes and chemicals, when they are available, with a view to mitigating or eliminating environmental effects.[84]

The above are limited; they are only guidelines and not legally binding.[85] Furthermore, these recommendations hinge on vague definitions of what constitutes environmentally sensitive areas, potentially harmful components, and potential environmental concerns.

This archival synopsis shows that historically, and into the present, the regulation of tailings facilities has been subject to a temporal logic that reflects short-sighted settler-colonial notions of time, wherein short-sightedness is especially a function of colonial capitalist business/profit cycles.

Beginning in 1999, the ironically named Toxicological Investigations of Mining Effluents (TIME) network addressed the toxicological issues surrounding the Metal Mining Effluent Regulations (MMER), but there is still much work to do.[86] This network of Environment Canada scientists and regulators, with collaboration from industry representatives, assessed the existing parameters of mining effluent, and was responsible for achieving more stringent criteria and additional metals, but was, however, unable to address the issue of chemical reagents.[87] Rather than

of rehabilitation. The letter questioned whether phrases like "plant or maintain or otherwise stabilize" in relation to tailings areas equated to the concept of rehabilitation. Additionally, it raised questions about the responsibility for rehabilitation in mines that had ceased operations and whether rehabilitation extended beyond tailings areas. (Deputy Minister of Lands and Forests to G.H. Bayly, September 24, 1970. Source: RG 13-13-0-78 Pollution Control Advisory Committee. Ontario Archives.)

81. *Mining Act*, RSO 1970, c. 274, s. 176(1). https://digitalcommons.osgoode.yorku.ca/rso/vol1970/iss3/35

82. D.P. Caplice, "Aspects of Waste Control in the Mining Industry," in *Waste Control Problems in the Mining Industry: Technical Papers and Articles Published by the Ontario Water Resources Commission, Division of Industrial Wastes, 1970–1971* (Ministry of the Environment, Industrial Wastes Branch, Special Projects Section – Mining, 1971), 4.

83. Federal Department of Fisheries and Environment, *Control Of Water Pollution From Land Use Activities in the Canadian Great Lakes Basin: An Evaluation of Legislative, Regulatory, and Administrative Programs* (Canadian Environmental Law Research Foundation, 1977), 43, 179, 287. https://publications.gc.ca/collections/collection_2020/eccc/en40/En40-961-1977-eng.pdf

84. Environment Canada, *Environmental Code of Practice for Metal Mines* (Environment Canada, 2009). https://www.canada.ca/content/dam/eccc/migration/main/lcpe-cepa/documents/codes/mm/mm-eng.pdf

85. Environment Canada, *Environmental Code*, 7.

86. MMER require that all Canadian metal mines produce effluent that is non-acutely lethal to rainbow trout when tested in accordance with Environment Canada test methods (SOR/2002-222, s. 4(1)(c).). Mine operations will also be required to monitor the acute lethality of effluent to Daphnia magna. If a rainbow trout test produces mortality of more than 50% of the test organisms in 100% effluent, the sample is considered to "fail" the acute lethality test (SOR/2002-222, s. 1(1).). See the *Guidance Document for Acute Lethality Testing of Metal Mining Effluents*.

87. A MEND report notes, regarding future recommendations about reagents in effluent: "For all (sub)sectors, testwork is recommended to confirm proprietary reagent demand, efficacy, and precipitate settleability, as well as to verify that treated effluent complies with toxicity requirements. It is also advised that treated effluent be discharged rather than recirculated for any purpose such that cycling up of residual chemical concentration is limited. Due to the relatively recent adoption of these reagents and the proprietary nature of their formulations, *little is known about*

reimagining how to address intergenerational futures that will continue to be impacted by the material legacies of tailings waste as infrastructural seepage, short-term industry profit remains prioritized, via extractive economies that in turn rely on the commodification of Crown and.

Present-day standards continue to allow for pollutants and toxic chemicals to be released in effluent as long as they are below a certain threshold of detection, which doesn't account for the regional cumulative impact of many mines all releasing into the same watershed. The idea that given sufficient "time" sitting in a tailings pond or dam, the solids in mill effluent will separate from the liquids, and the chemical reagents from processes like flotation or leaching will break down, or self-attenuate (such as via oxidation) is still reflected in the existing Mining Environmental Code of Practice for Ontario: "In designing tailings management facilities, the retention time for wastewater in the facilities should be maximized to allow for settling of suspended solids and the *natural degradation of contaminants* [author's emphasis] such as ammonia and cyanide."[88] Yet, taken all together, even so-called "diluted" or "broken-down" effluents, or seepages from tailings storage into groundwater, when at an order of magnitude like in the Sudbury and Sault Ste. Marie regions — once they include a long list of base metal, mineral, and precious metal mining infrastructural seepages — are not below thresholds of harm, if such thresholds even exist.[89] Low levels of hundreds of sources of chemicals, and their reaction byproducts, add up. At the regional level, regulations willfully ignore the complex material reality of synergistic and cumulative mining chemical fates in the environment, and their collective effects on the land, air, and water.

The recently updated (2024) *Mine Rehabilitation Code of Ontario* requires that surface water and ground monitoring programs include ongoing testing of "prescribed deleterious substances": a series of heavy metals, as well as the chemicals cyanide, ammonia, and sulphate. However, still (!), no other chemical testing beyond the aforementioned substances is required in long-term monitoring.[90] Updated *Metal and Diamond Mining Effluent Regulations* for ongoing mine operations (in effect since 2000, part of the *Fisheries Act*, renamed Metal and Diamond Mining Effluent Regulations) stipulate that effluent containing the latter compounds can be released into water bodies, under "authority to deposit in water or place" if it is below an acutely lethal level, defined as if less than 50% of rainbow trout, threespine stickleback, Daphnia magna, or acartia tonsa perish in monthly laboratory tests (a completely inadequate short list of both chemicals and living beings).[91] The 50% rule is known as "LC50." Sublethal toxicity testing is required for a larger list of fish and aquatic species, however it is only required on an effluent sample "collected from the mine's final discharge point that has potentially the most adverse environmental impact on the environment" and not all discharge points.[92]

When profitability is the overriding concern, it becomes obvious why meaningful monitoring and intervention aren't happening — they would cut into industry margins. As a result, trace amounts of mining chemicals continue to be released with little regard for their potential health impacts on ecosystems and lifeforms. This is especially troubling given that recent scoping reviews acknowledge that "the organic composition of mining wastewater is not completely understood and is not explored by the literature, making it difficult to predict the concentrations and all the contaminants."[93]

We are left in the situation where parameters such as pH, turbidity, total dissolved solids, and suspended solids are the only (indirect) indices of mill petrochemicals in effluent.

If effluent is not acutely lethal for 12 months, the mine can then test only once per year — but this seems to contravene potential increase in AMD over time, or showing up decades later. Does testing once a year catch unanticipated leaks and seepage, especially those amplified by climate change, increasing things like surface runoff,

the long term stability of residuals [author's emphasis] and the potential for acid generation and metals remobilization. If residuals are not kept stable through prudent disposal techniques, significant costs associated with residuals stabilization technology or retreatment of residual leachate could be incurred. Hatch cautions that this technique should only be considered BATEA for operations that are capable of and dedicated to careful control of operating regimes to prevent effluent toxicity, as well as, careful control of residuals storage conditions to prevent long term instability and the potential generation of acid through sulfide oxidation and metals remobilization" (Mine Environment Neutral Drainage Program, *Study to Identify BATEA for the Management and Control of Effluent Quality from Mines,* September 2014, iv). The report continues: "as the [proprietary reagent] chemicals may be acutely lethal to rainbow trout and Daphnia magna at certain residual chemical concentrations in effluent, testing is advised to verify that treated effluent complies with toxicity requirements" (MEND, *Study to Identify BATEA*, 10).

88. MEND, *Study to Identify BATEA*, 9.

89. Another reason for this is that chemicals in groundwater, for example, can form plumes with high levels of toxicity that migrate into the surrounding area.

90. *Mine Rehabilitation Code of Ontario*. O. Reg. 35/24, 2024, 17, 20.

91. SOR/2002-222, s. 14.1, 14.2, 14.3, 14.4.

92. SOR/2002-222, s. 5(3).

93. Isabela Brandolis Alves Falconi et al. "An Overview of Treatment Techniques to Remove Ore Flotation Reagents from Mining Wastewater," *Journal of Environmental Chemical Engineering* 11, no. 6 (December 2023). https://www.sciencedirect.com/science/article/pii/S2213343723020092#bib19.

or damage to mine infrastructure from floods, fires, and extreme weather?

A Mining Watch analysis of the third national (2019) audit of metal mines' environmental effects monitoring shows that while 95% of mines were supposedly abiding by effluent limits, there remain rampant gaps. These gaps are in data collection, follow-through on long-term effects when exceedances are reported, and the existence of actual legal requirements that result in enforcement or remediation of effluent effects on ecosystems.[94] Clearly, existing legislation allows for ecosystem impacts. Ongoing reevaluation of existing regulations, and community push-back and calls for regional cumulative assessments, are important as part of centring Indigenous-led jurisdiction in relation to territory.

Given that in the case study area of Sudbury and Sault Ste. Marie regions alone there are still 563 abandoned nickel-copper mining sites (primary producers), and 375 abandoned nickel-copper hazardous mining features, understanding the cumulative and regional-level impacts of the chemical breakdown and reaction products of mill processing chemicals everywhere remains paramount.[95]

Paste Backfill

Backfill can generate acid mine drainage that contaminates groundwater and aquifers.

In the late 1950s and early 1960s, INCO, Falconbridge, and the Canada Cement Company undertook extensive research on stabilizing backfill by adding small quantities of Portland cement.[96] Initially loose fill was used to backfill mines. While it was often described as sand and gravel, in many cases it also referred to mine tailings. One problem with loose fill was that it wasn't always structurally cohesive, which could lead to washouts. The intention behind creating paste backfill was described as follows: "At some Canadian mines the mill tailings contain substances which are a potential health hazard (e.g., radium) and the volume of tailings may be such that surface disposal sites are inadequate. In these cases returning part of the tailings to underground worked-out stopes is being considered. The primary purpose of backfill is waste disposal and the support characteristics are secondary."[97]

By the mid-1970s both Falconbridge and INCO used this technique. They considered slag as a substitute, but Portland cement remained the most common material used.[98] In 1983, at INCO mines in Ontario alone, an estimated two million tonnes of cemented backfill were placed underground in a normal operating year.

Preliminary screening criteria were proposed for backfill tailings to assess risks such as auto-ignition and potential for adverse effects on engineering structures. Development of these criteria was instigated due to an incident at Brunswick Mine in New Brunswick where the use of high-sulphide slimes as uncemented backfill in the upper sections of the mine resulted in a fire that burned sulphide dioxide gas *for over two decades*, despite efforts to extinguish it.[99]

Paste backfill may itself contain significant amounts of chemical additives. Some mines add even more chemicals — flocculants — to tailings used as backfill in order to regulate and control their consistency, and how they settle or congeal underground. For example, in one case, "Separan 2610" made by Dow Chemical was added to tailings for this purpose.[100] Separan 2610 is a polyacrylamide, a group of chemicals used to treat many kinds of wastewater. However, it has potentially toxic breakdown products that may include ketone, aldehyde, and carboxylic groups of chemicals.[101]

The use of polymer treatment of tailings is rapidly expanding under the logic that it reduces mine footprints and land required for waste, and stabilizes the other chemical reagents and heavy metals that may be in tailings. But does using *more* chemicals to hold other chemicals in place underground address the issue of long-term environmental impacts? Or does it create even more environmental impacts by adding additional chemicals that might generate toxic leachate?

94. Ugo Lapointe, *Mine Water Pollution in Canada: Are Waters & Fish Habitat Protected? Response to the Canada's Commissioner on Environment & Sustainable Development's (CESD) Audit Released on April 2, 2019* (Mining Watch Canada, April 2019).https://miningwatch.ca/sites/default/files/2019-04-05-miningwatchcanada-cesdreport_7_0.pdf.

95. Today, Copper Cliff contains over 700 million tonnes of tailings, and Xstrata Nickel over 45 million tonnes. *Sudbury Area Risk Assessment, Vol. 1, Ch. 2: History of the Sudbury Smelters* (January 2008), 2–15 (citing Gunn 1995). http://www.sudburysoilsstudy.com/EN/media/Volume_I/SSS_Vol_I_Chapter_2_HistoryoftheSudburySmelters_FINAL_Jan2008.pdf.

96. Ajit Singh and Michael Hedley, *The Chemical Industry and the Third World* (St. Martin's Press, 1980), 43.

97. Singh and Hedley, *Chemical Industry*, 50.

98. Singh and Hedley, *Chemical Industry*, 45.

99. Mine Environment Neutral Drainage Program (MEND), *Paste Backfill Geochemistry: Environmental Effects of Leaching and Weathering* (April 2006), 7 (citing Wheeland and Payand 1991). https://mend-nedem.org/wp-content/uploads/2013/01/10.2.pdf.

100. R.C., Mott, "The Handling and Placement of Hydraulic Backfill Underground," *CIM Bulletin* 53, no. 581 (September 1960): 699.

101. Boya Xiong et al., "Polyacrylamide Degradation and its Implications in Environmental Systems," *npj Clean Water* 1, no. 1, Article 17 (2018).

Chemical grouts may also be used to stabilize mine structures underground. While information is limited, historically, compounds promoted in the Canadian Mining Bulletin included chrome lignin, formed by combining lignin liquor, a byproduct from pulp and paper making, with sodium dichromate to form a gel. Other proprietary chemical grouts included "AM-9" made by American Cyanamid, a mixture of acrylamide and methylenebisacrylamide that would be combined with catalysts like ammonium persulphate and dimethylamino-propionitrite to form a gel that could be spread over mine cracks prone to water seepage and leaking.[102] All of the latter catalysts are acutely toxic to fish. Research is inconclusive as to how paste backfill behaves in the long term, rendering its ongoing use somewhat experimental. There continues to be a lack of published in-situ studies on long-term cement paste backfill behaviour. This means that it is still not entirely known, decades later, exactly how paste backfill might react and break down into the future. The attitude thus far has been to leave paste backfill underground, putting it out of sight and out of mind, as with many other kinds of landfill, hazardous waste deep well dumps, and buried fracking chemicals injected to extract natural gas. But "underground" is land intimately interconnected with soil, water, air, and human, animal, and plant lifeforms.

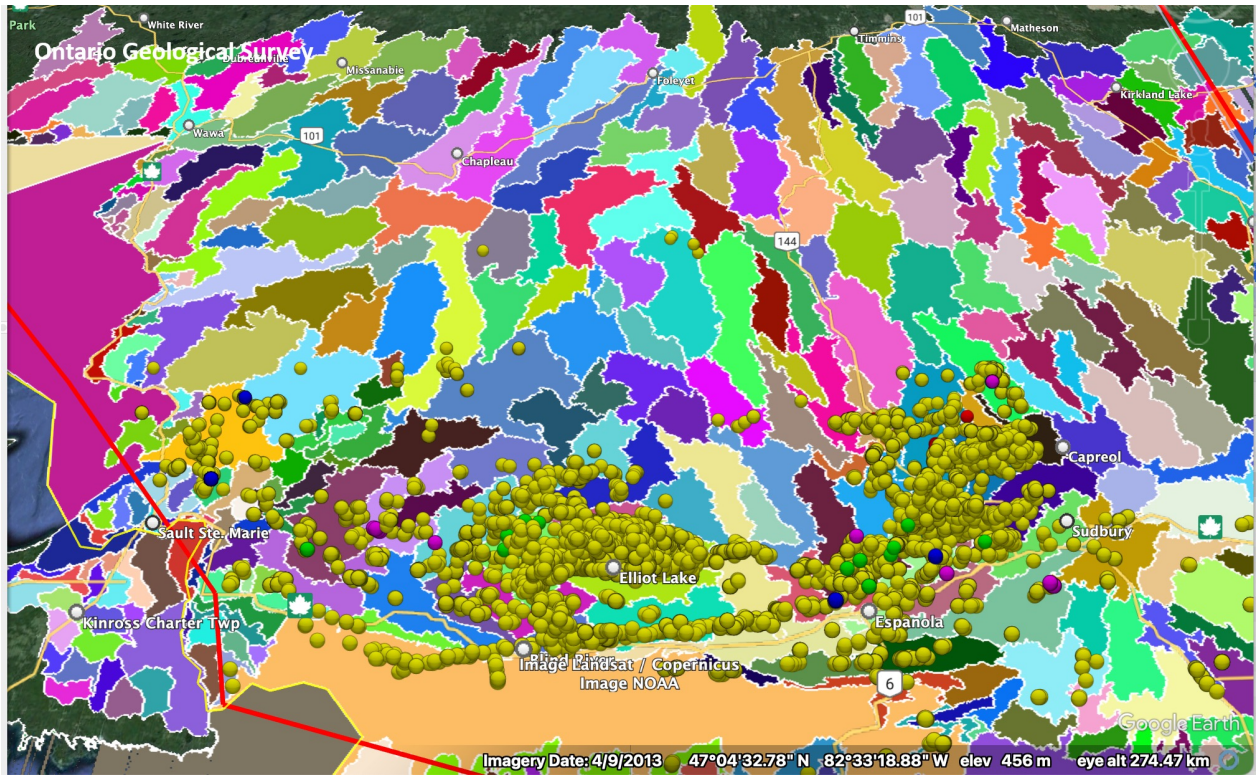
That there is still not adequate research or understanding of the in-situ long-term effects of paste backfill on groundwater and watershed systems is supported by a more recent study by the MEND program: "Underground conditions may reduce the reactivity of tailings minerals… However, minerals present, or produced through chemical interactions with binders, may also reduce the long-term strength of the paste, with the potential for: changes to ground water flow patterns through the paste, as porosity typically increases in association with reduced strength."[103] The same report goes on to capture the ongoing attitude towards paste backfill in general, stating, "water quality in underground mines is often not considered in detail."[104]

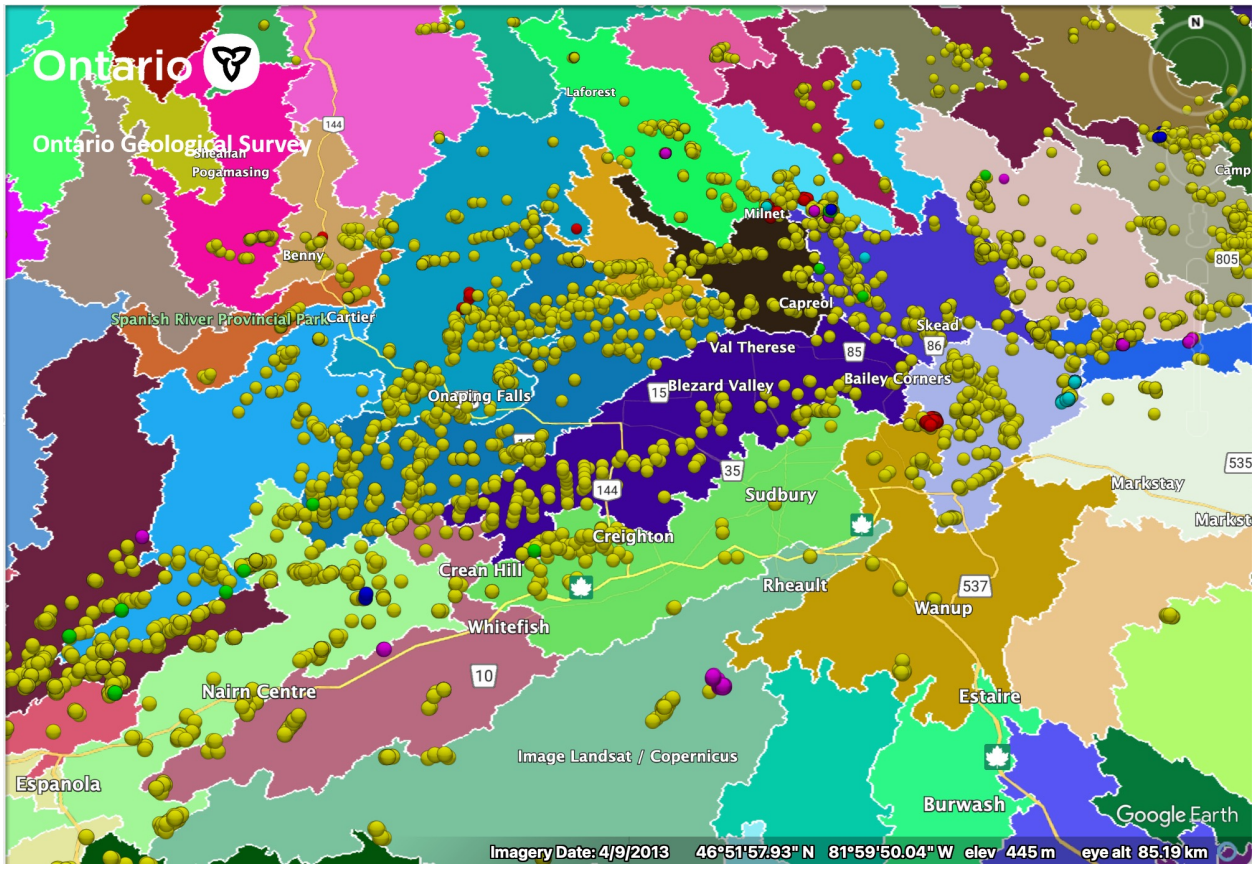
Likewise, recent studies suggest that while cemented paste backfill "reduces the presence of free water" and "offers extra capacity for neutralization…decreasing the effective porosity" of sulphide-bearing tailings material, it only decreases, but does not prevent, leachate production, or contamination of paste backfill heavy metals and chemicals into the surrounding groundwater.[105] It also only decreases, but does not prevent, significant "chemical reactivity of tailings and movement of pollutants."[106] Recent studies also show that depending on the composition of tailings and type of binder used, there can be "severe deterioration in the durability of CPB [cement paste backfill]."[107] Further chemical-based mitigation measures like "grout curtains" might then be put into place to stop seepage flow migration.[108] Other measures might include back-pumping tailings-contaminated water to divert it from entering streams and watercourses. However, this in itself can dramatically harm fish and aquatic habitats.[109]

Acid Mine Drainage (AMD)

While the introduction to this report discussed acid mine drainage resulting from mining roads, it can also result from exploration drill holes. There are over 126,000 drill holes in Ontario and thousands in the Sudbury and Sault Ste. Marie regions alone (Figures 4 and 5).[110] In full-scale mines, sulphide-bearing mine wastes such as waste rock and tailings may continue to generate contaminated acid mine drainage for years or even centuries after the closure of the operation.[111] For example, acid mine drainage generated from the remains of ancient silver and copper

102. "The Use of Chemicals in Mine Grouting," *CIM Bulletin* (July 1962): 481. This article notes that "in the uncatalyzed state, AM-9 is neurotoxic and normal precautions must be observed in mixing and handling the chemicals. Usual procedure is for personnel to wear rubber gloves and to wash the skin when contact is made with the chemicals. After nearly ten years of use, there is not a single recorded case of an individual being harmfully affected…There is no known solvent for AM-9 gel. It is inert and permanent."
103. MEND, *Paste Backfill Geochemistry,* 7.
104. MEND, *Paste Backfill Geochemistry,* 15.
105. See Mohammad Shafaet Jamil, Michael Marsh, and Stephen Butt, *Experimental Evaluation of Acid Mine Drainage Potential for Cemented Paste Backfill*, Proceedings of Tailings and Mine Waste (November 2023), 864. https://open.library.ubc.ca/media/stream/pdf/59368/1.0438143/3.
106. Jamil et al., *Experimental Evaluation,* 854.
107. Ayhan Kesimal, Erol Yilmaz, Bayram Ercikdi, Ibrahim Alp, and Hacı Deveci, "Effect of Properties of Tailings and Binder on the Short- and Long-Term Strength and Stability of Cemented Paste Backfill," *Materials Letters* 59 (July 2005): 3708. https://www.academia.edu/download/46480304/j.matlet.2005.06.042201606l4-22364-3hjcns.pdf.
108. Ryan Blanchard and Judson Kennedy. *Using Technology to Identify Seepage Flow Paths Through, Under and Around Tailings Impoundments.* C. Tailings and Mine Waste Conference (November 30, 2019).
109. Jonathan Keizer, "Beyond Foundation Seepage: Hydrogeology, Seepage and GISTM," in *Proceedings of Tailings and Mine Waste 2023* (November 5–8, 2023, Vancouver, Canada), 764.
110. Northern Development, Mines, Natural Resources and Forestry, Ontario Drill Hole Database. https://web.archive.org/web/20210720224409/https://data.ontario.ca/dataset/ontario-drill-hole-database
111. Khosrow Aref, "A Study of the Geotechnical Characteristics and Liquefaction Potential of Paste Backfill" (Doctoral dissertation, McGill University, 1989), 5-1, ProQuest Dissertations Publishing.





Figures 4 and 5. The Ontario Drill Hole Database (in yellow) overlaid on a map of Ontario watersheds. (Screenshots from Google Earth by the author).

mines of central Sweden, some over 1,000 years old, are still a matter of planning and investigation. As of 1995, Copper Cliff alone contained over 700 million tonnes of tailings and Xstrata Nickel (previously INCO) over 45 million tonnes, some of which is acid generating.[112] Between 1984 and 1987, the extent of acid-generating waste at base-metal mining operations across Canada was assessed, showing a total area of over 12,000 hectares of tailings and 350 million tonnes of waste mine rock.[113]

112. J.M. Gunn, ed., *Restoration and Recovery of an Industrial Region: Progress in Restoring the Smelter-Damaged Landscape Near Sudbury, Canada* (Springer-Verlag, 1995).

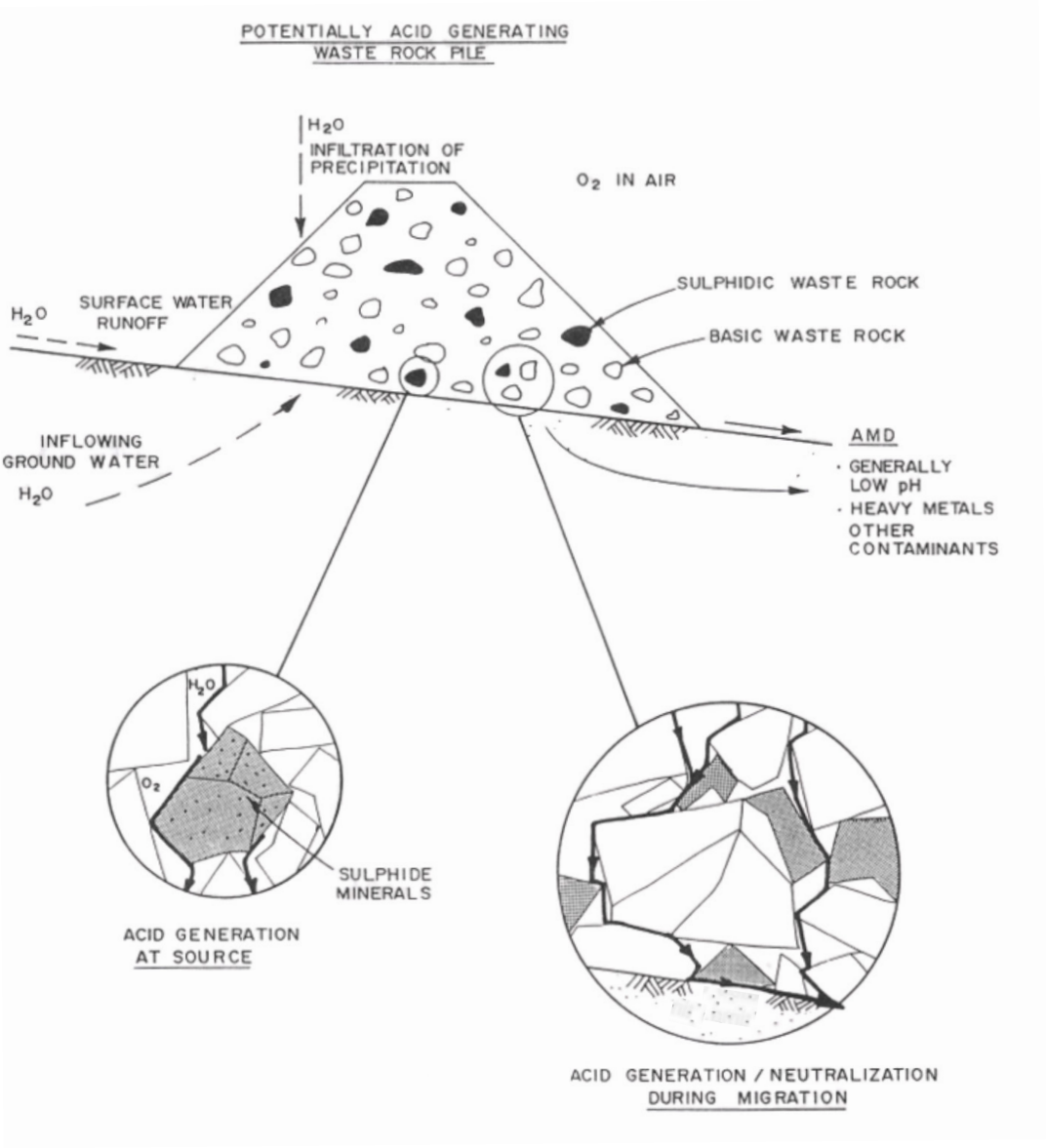
113. Khosrow, "Study of Geotechnical Characteristics," 5-2.

Figures 4 and 5 above show the Ontario drill hole database overlaid on a map of Ontario watersheds. What is clear from the image is how acid mine drainage might impact a much larger region than just the immediate vicinity of a drillhole.

AMD can occur during the operating cycle of a mine, and could start within two to five years.

Alternatively, AMD may take several decades to begin, such as around waste rock piles, in tailings areas, or in migrating contaminated groundwater plumes.

AMD might show up as part of mine closure, when mines are flooded. Mines are either intentionally flooded when they are closed, or flooding happens inevitably as soon as



Schematic showing concept of acid generation and ARD Migration.
Source: BC AMD Task Force, *Draft Technical Guide, Vol. 1.* August 1989.

dewatering processes are discontinued. The problem with this is that groundwater flows transport AMD and contaminants, whether from surface or groundwater inflow.

Overall, a lack of monitoring, including testing AMD predictions, leads to inadequate closure bonds and closure requirements, which in turn leads to companies being let off the hook when mines are decommissioned or abandoned, regardless of long-term environmental liabilities including AMD. An extended time lag between extraction and acid rock draining (ARD) exacerbates the potential for failure, and a gap between nickel-copper ore extraction and its subsequent impacts on territory makes it very difficult to hold individuals and mining companies accountable for AMD, especially when long-term monitoring is not always required, or monitoring requirements that are part of mine closure plans have been considered "fulfilled." In this way, mining companies continue to avoid ethical accountability for infrastructural material seepage, while maximizing profit margins, with very few regulatory requirements to remediate or build prevention into a mine's design.

The temporal scale of nickel-copper extraction extends thousands of years into the future. Changes to ecosystems and environmental harm from historical sulphur dioxide, fugitive emissions, tailings, paste backfill, and acid mine drainage from mines and road aggregate will continue for many generations.

Thus, rather than regarding mines in settler-colonial terms as "historical" or "abandoned," it is important to consider these sites as still active and as still in relation with many life forms — human, non-human, and spiritual. Now is the time to build relationships with, be accountable to, and care for, the land, water, and air — and to support Indigenous land and water protectors and caretakers.[114] Mining sites continue to seep: through acid generation, or the release of heavy metals and chemicals into groundwater, soil, and surface water. These movements remain active, ongoing relationships between pollutants and land. While mines may operate for only 20 years, their material consequences stretch hundreds or thousands of years, demanding much more capacious temporal frameworks for Indigenous jurisdiction.

In this context, infrastructure — and the work of its so-called "maintenance" — is a key site of jurisdictional struggle.[115] Indigenous jurisdiction in relation to infrastructure must be grounded in Indigenous authority and shaped through community centred, reciprocal relationships with land.[116] As Heidi Stark reminds us, such jurisdiction must attend to the materiality of infrastructure and extend beyond the human — operating in a terrain of "multi-national political authorities," where animals, plants, and spirits also hold jurisdiction.[117] These forms of governance are tied together with territorial sovereignty, follow Indigenous law and protocol, and prioritize connections to land, including those impacted by colonial resource extraction.

Indigenous jurisdiction insists on a long view ahead, one rooted in reciprocity, and intergenerational responsibility. In stark contrast to settler extractivist time, which would seem to take all that is profitable until the last possible moment, Indigenous jurisdiction can account for the spatio-temporal afterlives of extraction — including the chemical seepage of milling infrastructure and its enduring impacts on land, water, and non-human kin.

CONCLUSION

Exposing how the mining industry is a chemical industry, this report has provided a preliminary account of the interconnecting forms of cumulative, regional, and intergenerational material seepage that span the infrastructures of nickel-copper mining extractivism in the Sudbury and Sault Ste. Marie regions. Such an analytical approach may be useful to inform further understandings about the scale, impact, and future interventions into the many ongoing forms of settler-colonial mining extractivism in Ontario, especially as it supports Indigenous exercising of jurisdiction in relation to territory.

Outside this particular case study, understanding the mining industry as a chemical industry is also important so that the public and community members can understand the ongoing transformation of mineral tenure and mining in the province at large, as well as have the knowledge and tools to organize, move forward, hold industry and governments accountable, and imagine new ways forward for Indigenous-led climate justice.

In the near future, chemical-material infrastructural seepage will be influenced by how the chemical industry is reliant on the market for chemical commodities. A snapshot of the logics informing chemical use in mining mills reveals how it is shaped by the ongoing pressures of profit margins, which in turn compromises any truly reciprocal attempt at environmental ethics:

114. Jeff Ganohalidoh Corntassel, "An Interview With Tiffany Joseph: Land and Water Stewardship in a Time of Crisis," *Borders in Globalization Review* 5, no. 1 (2024). https://doi.org/10.18357/bigr51202421803.

115. Pasternak et al., "Infrastructure, Jurisdiction, Extractivism."

116. Sarah de Leeuw and Sarah Hunt, "Unsettling Decolonizing Geographies," *Geography Compass* 12, no. 7 (2018).

117. Pasternak et al., "Infrastructure, Jurisdiction, Extractivism," 4.

Despite significant price erosion and commoditization of many of the flotation reagents, the market for specialty reagents and the associated application technology is still healthy owing to the following factors. Plants are coming under intense pressure from global economic and environmental factors to maximize productivity and minimize effluents that have the potential to be hazardous. This will, then, force the plants to look for advanced technology to go beyond what traditional products can offer. In many mines, the high-grade, easy-to-treat ores have been mostly exhausted. The new deposits are significantly more challenging to treat and require the use of alternative chemistries. Also, flotation plants that have used the same products over a long period of time, irrespective of significant changes in ore types (mineralogy) and plant conditions, would not be optimized and would have large swings in plant performance. The survival of such plants will be predicated upon how readily (and quickly) they can implement new technology and use robust performance products that are designed to handle changes in mineralogy and routine plant conditions. The need for ever-increasing productivity improvements and the eventual emergence of the less-developed countries into the global market economy will require the higher performance benefits produced by specialty reagents. Also, with the large increase in raw material costs in recent years, the profit margins have diminished dramatically for xanthates, and are now at a point where the selling prices are barely above the level of the raw material costs; consequently, xanthate producers will no longer be able to defend the price against the benefits of the specialties. Because the industry will not be able to reduce costs on the basis of price of reagents, they will have to look at other means. A holistic, solution-based approach is needed to take the performance to the next level. In many cases, this may require plants to adopt conditions and reagents different from those used traditionally.[118]

The ongoing preeminence of the chemical commodity market, much like the value of metals, is far from fixed. Circular economy solutions like "reduce, reuse, and recycle," and other alternative energy sources for a just transition, including the possibilities of solutionary rail, or solutionary mining via bioleaching, are more relevant, and potentially more competitive, than ever. Solutionary rail refers to the electrification of existing, or historical, rail infrastructure, leading to modernizations that support a just transition. Solutionary mining, including approaches like bioleaching, uses biological processes (such as microbes) to extract metals from ore or waste materials, often reprocessing existing tailings rather than developing new sites. As we enter an era where many are calling for economic degrowth as central to addressing the climate crisis, envisioning petrochemical degrowth, metal mining degrowth — and by extension, mining petrochemical degrowth — remains crucial.[119] This must foremost be accompanied by Indigenous jurisdiction in relation to territory. Writing within the context of ongoing colonial occupation, this report does not speak for or on behalf of Indigenous legal orders. Rather, it calls for a centring of Indigenous jurisdiction in relation to how the mining industry is a chemical industry. Far from a static or traditionalist counterpoint, the former has already established practices that, over thousands of years, have enacted dynamic, place-based legal and ethical frameworks. These are compatible with future fossil capitalist degrowth but also operate as their own legal orders not predicated on capitalist systems. Crucially, they remain responsive to the shifting spatio-temporal material realities of extraction and climate breakdown brought about through colonization.

In the future, policies that might meaningfully address the ongoing historical legacies of infrastructural seepage will nonetheless continue to be in tension with the increased privatization of resource extraction, financialization, and commodification of critical minerals as a source of geopolitical power. Under these conditions, as governments greenlight exponentially intensified mining extraction, a new colonial frontier rush occurs: "Expected future scarcity of raw materials as a result of heightened demand by productive capital — often artificially fabricated or dramatized by financial actors — contributes to the speculative frenzies that have driven price increases across most raw materials during the last two decades."[120] These effects are relevant in Canada, and provide a picture of similar regional cumulative effects of mining extractivism across the globe.

Acknowledging the regional cumulative effects of mining extractivism, and that these effects have, in many ways, been historically ignored and obscured — even as they are foundational to both mining practices and Canada's extractive economies — requires also, "dismantling the disavowals so foundational to modernity" wherein infrastructural seepage and pollution are normative conditions for the production of metals as essential materials or, in the case of nickel, for other essential materials such as steel.[121] Petrochemical pollution's migration across large swaths of territory also necessitates dismantling the disavowal that responsibility or accountability for infrastructural seepage stops at a mine's property line. Using regional cumulative assessments to challenge the un-

118. Fuerstenau et al., *Froth Flotation*, 412–413.

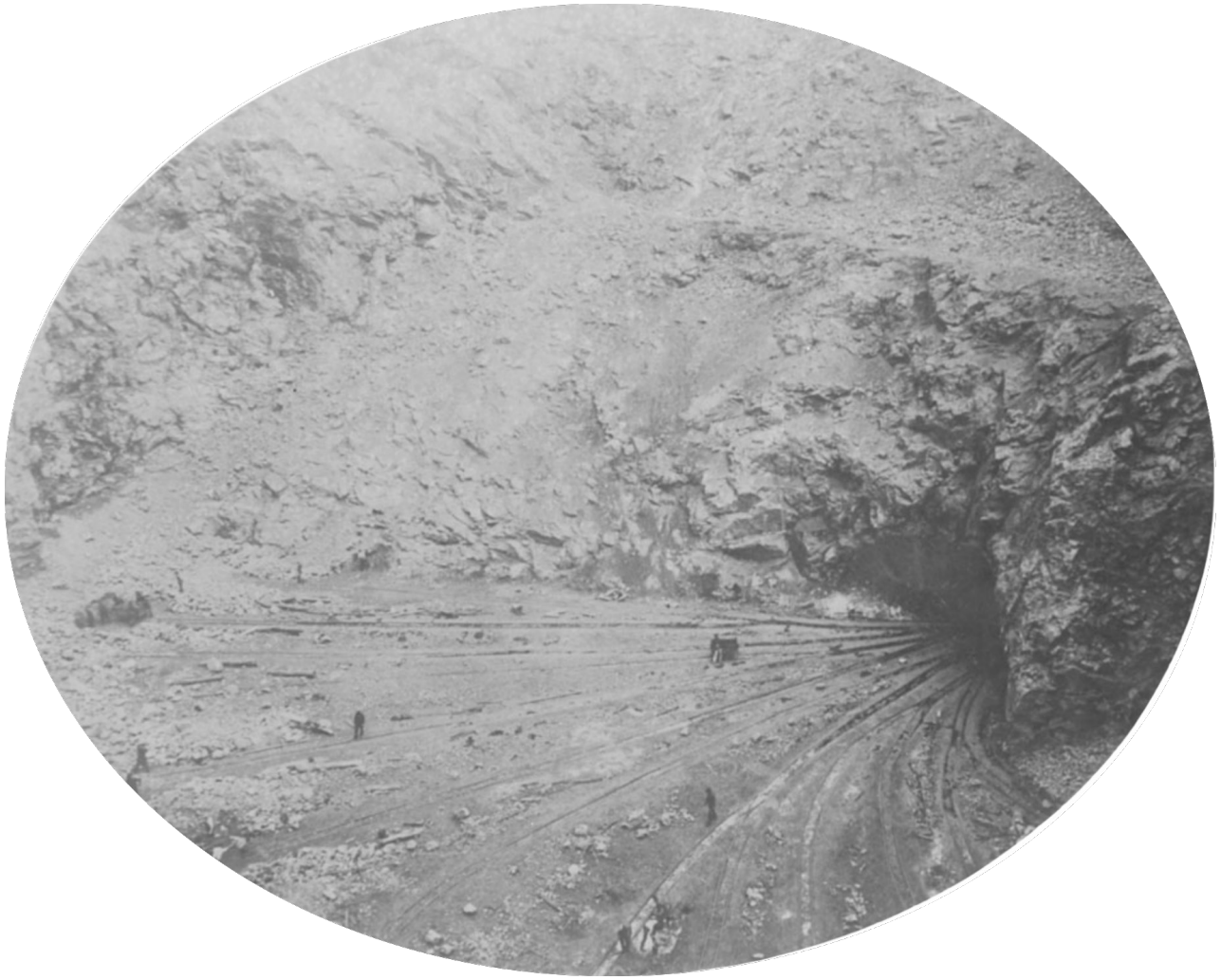
119. Mah, *Petrochemical Planet,* 128.

120. Martin Arboleda, *Planetary Mine: Territories of Extraction Under Late Capitalism* (Verso Books, 2020).

121. Deborah A. Thomas and Joseph Masco, eds., *Sovereignty Unhinged: An Illustrated Primer for the Study of Present Intensities, Disavowals, and Temporal Derangements* (Duke University Press, 2023), 86.

derlying assumptions that position mine properties within the settler-colonial grid of "Crown land" is thus integral to remedying how the mining industry is a chemical industry, and supporting Indigenous jurisdiction.[122]

122. Brenna Bhandar, *Colonial Lives of Property: Law, Land, and Racial Regimes of Ownership* (Duke University Press, 2018).



Cut entrance to Canadian Copper Company's Creighton nickel-copper mine, Sudbury district. Source: Library and Archives Canada. Accession number: 1965-040 NPC, Box number: 113,item #: 3375543, No date. ecopy#: a013654-v8.

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Infrastructure Beyond Extractivism
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