White Paper:
An Overview of Mine Facilities and Issues

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Introduction

This paper is intended to provide contextual information about the Duluth Complex and a brief overview of the inherent processes and facilities, components, chemical inputs, and equipment (hereinafter, referred to as facilities) necessary at any sulfide-ore copper mining project in the Duluth Complex. Also provided are brief descriptions of the types of impacts that these mining related processes and facilities can have on the landscape and ecosystem.

Predicted mining components, structures, equipment, and facilities of a sulfide-ore copper mine in the Duluth Complex would include but not be limited to an open pit, underground mines and related workings, or both; power lines, ventilation, and heating/cooling infrastructure; waste rock piles (permanent and/or temporary); crushing and process/milling facilities;[1] floatation tanks and beneficiation chemical/process water storage and mixing facilities; tailings storage/impoundments; run-of-mine ore stockpiles; tailings storage stockpiles; garage and equipment repair buildings; chemical and milling materials storage; waste rock, ore, tailings, concentrate transport facilities (such as conveyors, roads, pipelines; roads for vehicles; possibly railroad facilities); and offices and employee facilities, etc.

Duluth Complex Geology

The geologic composition of the Duluth Complex dictates to a significant degree the processes and facilities most likely required for mining.

Dr. Chambers[2] describes the mineralized geology:

> The Duluth Complex consists of 12 mafic sub-intrusions emplaced into the older rocks during continental rifting over a 10 to 12 million year period about 1.1 billion years ago. It covers an area of 6,500 km2.
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> ...Large resources of low-grade, disseminated copper-nickel sulphides that locally contain anomalous Platinum Group Element (PGE) mineralization occur in the basal zones of the South Kawishiwi and the Partridge River intrusions. Nine deposits have been delineated in these intrusions.
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> ...The mineralization consists predominantly of disseminated sulfides that collectively constitute over 4.4 billion tons of material averaging 0.66 percent copper and 0.2 percent nickel (Listerud and Meineke 1977).[3]

[1] Notably, if ore concentrate were further processed to recover commodity metals on-site then hydrometallurgical treatment would require additional processing facilities and additional storage facilities for wastes.
[2] Dr. David Chambers. The Potential for Acid Mine Drainage and other Water Quality Problems at Modern Copper Mines Using State-of-the-Art Prevention, Treatment, and Mitigation Methods A Report by the Center for Science in Public Participation November 20, 2014.

Because the Duluth Complex's mineralogy comprises low-grade ore a large volume of rock would have to be mined. This large quantity of low grade ore would have to be processed on-site because it would not be economical to ship such a large volume of ore any distance. If concentrates are sufficiently concentrated after an initial phase of processing it may be possible to ship them offsite for further processing/smelting/refining.

Any Duluth Complex mine would likely include the following processes and facilities.

Mining Overview and Facilities

Whether large or small, a mine would have waste rock that would have to be stored - either permanently or temporarily until it can be placed in retired underground workings or in the abandoned pit. Ore from the mine (whether open pit or underground) would need to be processed. A low grade deposit would require mining a very large volume of ore to be economical, making up in volume what the ore lacks in grade quality. Low grade deposit ore would likely require additional onsite concentrating or other beneficiation. This high volume of milled/concentrated material would yield large quantities of tailings/waste - which would have to be treated and stored on-site, some portion of which may be placed back into retired underground workings or in an abandoned pit or a tailings basin in a greenfield. Other infrastructure, described below, is needed to maintain the mine and keep it running until and after mine closure. Most facilities, especially mining/milling for a large, low grade deposit, could operate for decades.

<u>Land Clearing and Facilities Construction</u>. Among the first major activities at any mine is removing trees from the forested landscape and topsoil for storage in piles until needed for reclamation. This is followed by blasting, grading and/or filling to create level spaces for construction of surface buildings. These include mine structures and facilities such as mine office buildings, vehicle and equipment shop facilities; chemical and explosives storage facilities, milling and chemical processing and paste plant buildings, ventilators for underground mines, electrical substation(s) (and/or diesel generators for power or backup), and waste disposal/storage facilities.

<u>Connections and Transportation</u>. Infrastructure necessary for electrical power would have to be constructed. Similarly, new and/or expanded roads and railroad spurs would be necessary to transport equipment, materials, and people to and from the site. Conveyor belts may be needed to move materials within the mine site or from the mine site to processing and storage sites. Miles of pipeline can be expected for everything from natural gas to transferring contact water, leachate, tailings, etc., from and to their various sources and endpoints.

<u>Waste Rock</u>. Waste rock is the rock removed that does not contain economically recoverable minerals. Waste rock would need to be stored and must be disposed of in some way. Most waste rock is permanently disposed of simply by putting it in piles on the surface. These should employ top and bottom impermeable liners as well as leak detection and leachate collection systems. Some of the waste rock stored on the surface for a period of years or decades may then be

[3] It should be noted that not all of these deposits are located in the watershed of the BWCAW.

transported to the mine pit or to underground workings for disposal. This stored waste rock also requires appropriate contaminant containment and monitoring.

Ore Processing. Ore is the rock that is economically extractable and processable. Because the Duluth Complex contains low grade ore the ore probably must be processed on-site. Processing uses physical and chemical methods that include mixing physically processed ore with fresh water and toxic and hazardous materials known as beneficiation chemicals. In a low-grade ore such as the Duluth Complex, a large amount of ore must be processed in order to justify the expense of designing and building a mine. As a consequence of that circumstance, and the additional fact that more than 99% of all ore mined and processed would wind up as tailings, the amount of waste (material left after recovery of recoverable minerals) from milling and concentrating processes would also be very large. If the high volume of ore produced by the mine exceeds the mill's processing capacity then that excess ore must be stored, usually in stockpiles on the surface. Processing generally includes crushing/grinding (comminution; physically reducing the size of the pieces of ore, often to a fineness of face powder) and concentration (increasing the concentration of the valuable metals; each metal may require its own processes). Copper concentration usually requires a floatation process, whereby the ore is agitated in reagent solution as air is bubbled through it, so that most copper attaches itself to bubbles that float to the top for collection). The large quantities of low grade ore would usually require large quantities of reagents and other chemical additives (common chemicals may include but are not limited to sulfuric acid, sodium cyanide, and solvents). Many of these reagents are hazardous or toxic to fish, wildlife, and humans.

Tailings.

Tailings materials/wastes would have to be treated[4] and/or stored in perpetuity. Transporting fifty or more thousands of tons/day of tailings and unrecovered water and beneficiation chemicals from the processing facilities to the tailings storage facility would generally require miles of pipeline. Additional water may be required to form a tailings slurry for pipeline transport. Long-term tailings storage may come in numerous forms.

Some methods, such as paste or dry technologies, reduce the tailings' water content to form a paste or semi-solid material that can be transported and stored without water,[5] but water can still be an issue. Wet tailings disposal usually disposes of the tailings and the water/solutions that are used to transport the tailings through the pipeline to the storage facility. Tailings impoundments employ geosynthetic and/or clay liners - or simply employ compacted ground to hold the tailings and create the "pond."

Water Treatment.

Few mines, particularly in a wet region, operate as a zero-discharge facility. Therefore, if there is any possibility of water treatment being required, it is important to plan for treatment to last as

[4] *See* Environmental Protection Agency (EPA), 1994. Technical Document: Acid Mine Drainage Prediction. Office of Solid Waste, Special Waste Branch, Washington, DC.
[5] Water removed from the dewatering process will usually require treatment or permanent storage and the paste materials must be protected from water; if they become wet/leak they could still become a source or contaminants.

long as contaminants could be produced. Contaminated water in the form of surface water pollution and/or groundwater seepage comes from all mining-related facilities but commonly come from waste rock, pit or underground workings, mill and concentrating facilities, and tailings facilities. Pipelines and other water transport equipment can have major failures or leaks and/or can create "linear" contamination zones such as by seepage or slow leaks along joints, etc. Collecting the seepage is difficult and often creates impacts or disturbances of its own. Additionally, catastrophic failures generating and releasing very large volumes of contaminated solids, slimes, and wastewater can occur at hydrometallurgical residue storage facilities, tailings piles and tailings basin dams, and mine pits and underground workings.

There are many water treatment technologies[6] - each with its own advantages and disadvantages (such as reliability, cost, effectiveness, maintenance required, etc.). Most must be tailored specifically to the water being treated. Most of these technologies are decades-old. These may include, but are not limited to, chemical treatment (such as raising pH by the addition of basic material in order to precipitate-out toxic metals), membrane treatment systems (passing the water through membranes that separate the cleaned water from contaminants - usually metal salts), reverse osmosis (employing fine membranes it is the finest/most microscopic form of filtration), and ion exchange (undesirable ions are exchanged for more desirable ions).

Where mine processes require water, such as for milling or slurry transport, the mine may treat and reuse the treated water (often treatment is only "as clean as necessary") in those processes. Invariably, however, some water is lost in the mining and processing of ore and disposal of tailings, in which case fresh "make-up" water is constantly added to the treated water in order to supply the total volume required by the mine. These treatment processes may require additional treatment infrastructure and would require disposal of the resulting wastes. Likewise, pipeline and water storage infrastructure would be necessary to siphon, store and meter-out the required amount of make-up water during mining and processing operations.

Lastly, treatment facilities create their own toxic sludges that include heavy metals precipitates, and byproducts that would have to be stored onsite (such as in the tailings impoundment) or shipped for offsite disposal.

Other Infrastructure

In addition to primary features described above, a disseminated copper mine in the Duluth Complex would require additional infrastructure, some of which would be supporting infrastructure for the primary facilities.[7] Other infrastructure facilities generally include, but may not be limited to, gasoline/diesel storage/distribution facilities (for equipment and vehicles, backup generators, etc.), materials storage (chemical and physical), blasting agent storage,

[6] Dr. David Chambers. The Potential for Acid Mine Drainage and other Water Quality Problems at Modern Copper Mines Using State-of-the-Art Prevention, Treatment, and Mitigation Methods A Report by the Center for Science in Public Participation November 20, 2014.

[7] For example, in addition to the tailings storage facility itself, tailings disposal would likely include a filter plant to process tailings and other waste materials, and facilities to pipe, load/unload (such as from rail cars), or otherwise convey the tailings wastes. Return water would have to be transported and stored. Many of these and other facilities would require electric and/or other utilities.

maintenance shops and buildings, offices, worker buildings (ranging from lunchroom to possible housing), parking, etc.

Selected examples include, but are not limited to:

- Surface diversions and holding ponds. If these fail then the amount of water requiring treatment and storage can increase significantly.
- Pumpback facilities for keeping mine contaminated groundwater, such as from pits or underground workings, from clean/uncontaminated groundwater (aquifers, springs, etc.) and nearby surface waters. These may operate with existing wells or boreholes or may require new drilling - and may occur onsite or offsite.
- Mines require repair and maintenance shop facilities capable of most every form of repair and routine maintenance. This includes everything from washing vehicles to disposing of used motor oil and other lubricants and fluids (e.g. brake fluid, hydraulic fluid, etc.). These are usually required on the surface and also underground for underground mines.
- Mines require a variety of corridors for conveying materials, people, and power. These include, but are not limited to roads, rail lines, conveyor belt systems, pipelines, powerlines and underground tunnels.
- Mines also require housing and other domestic infrastructure and the services necessary for the mining workforce and their families. This may expand existing infrastructure or create new housing in previously unpopulated areas.

Mine Risks

Almost all mines degrade onsite and offsite resources – impacting lands, natural resources, ecosystems, and ecosystem-based functions. In addition to the risks described above, sulfide-ore copper mining next to the Boundary Waters and in the headwaters of the Boundary Waters would almost certainly impact water, air, quiet, the night sky, people, and wildlife resources.

<u>Water Quality</u>

Sulfide-ore copper mining could be expected to contaminate water in a variety of ways, including, but not limited to:

1. Leaching and/or seeping acid mine drainage and/or other pollutants from waste rock piles.
2. Contaminating ground and surface waters through water seeping/leaching from open pits and underground workings.
3. Seepage and leachate from storage ponds (tailings and hydrometallurgy wastes, process water, contact water, filtrate storage, etc.), delivering acid mine drainage and chemical beneficiation reagents to groundwater and surface waters.[8]

[8] A longer-term threat than ore processing itself is the transport and storage of the resulting tailings, which would have to be treated and/or stored in perpetuity. The threat to water resources from tailings materials may last forever because no form of tailings storage guarantees permanent isolation of contaminants. There are no known storage methods that are perfect at preventing leakage, or collecting and treating seepage. In spite of decades of efforts to perfect the technologies and their implementation, at some point in their operational lives many if not most tailings storage facilities have seeped, leaked, or otherwise failed. It is usually only the catastrophic failures that make news

4. Rail lines, roadways, and pipelines become linear contamination sites and are subject to acute contamination (such as from a crash, breach, or major spill causing sudden potentially high-volume contamination) and chronic contamination (such as slow leaks, seepage, minor spills, wind blowing contaminants from improperly covered or uncovered truck or rail loads, etc.).[9]
5. Contaminant releases from impoundment and containment breaches.
6. Water treatment system failure. According to one USEPA study, 93% of recent U.S. sulfide-ore copper mines had reportable water collection and treatment failures.[10]
7. Impairing natural wetlands and other natural ecologic functions.
8. Eutrophication and other pollution results from nutrient contamination where mine contaminants, especially sulfate, may cause increases in the release of nitrogen and phosphorous from lake and riverine sediments into the water column.
9. Environmental degradation from releasing uncontrolled and/or contaminated stormwater. Stormwater or other diversions failure can lead to an influx of stormwater or other waters that can inundate contaminant treatment or storage facilities or underground workings and cause them to flood or fail.

Water Quantity

Mining usually consumes large quantities of fresh water. The specific impacts of this consumption would likely be location-specific and impacted by the type and size of sulfide-ore copper mine. Impacts can be to both surface and ground water. Reduction of ground water resources may take decades or longer to return to pre-mine levels, if a return to these levels is possible. Further, not only are groundwater levels affected, but the actual direction of groundwater flow may be altered. Some of these impacts may persist only while the mine is operating (such as while the mine is creating a "cone of depression" while the mine is operating) and then slowly return to normal. Surface water withdrawals can draw down or dewater pre-mine flow volumes and patterns. Similarly, groundwater withdrawals can impact surface waters temporarily or permanently.

Air

Mines generally emit significant quantities of air pollutants. The bulk of the volume of these emissions is often particulates - such as dust from mine roads, blasting, crushing, conveyors, blowing dust/particulates from dried tailings,[11] and the forced-air ventilation of underground

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beyond the localized mine area. This is to say nothing of the decades, centuries, and millennia after mine closure that they must prevent leakage. It is not ironic that the warranties associated with most liners are for decades and finite timeframes - they simply cannot be warrantied for as long as the piles above them are expected to endure.

[9] Tailings pipelines are particularly prone to breakage because of the high density and abrasiveness of the materials being transported. *See also* The Track Record of Water Quality Impacts Resulting from Pipeline Spills, Tailings Failures and Water Collection and Treatment Failures, Gestring, B, Earthworks, July 2012.

[10] An Assessment of Potential Mining Impacts on Salmon Ecosystems of Bristol Bay, Alaska. U.S. EPA, 2014. Report 910-R-14-001A, January 2014. Available thru: https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=253500.

[11] Interestingly, if tailings become dry then the tailings impoundment can cause contamination by blowing materials but if the tailings impoundment has too much water then seepage may result (such as from increased head or a failure tied to the high water level).

workings, etc. A portion of mine air emissions can be toxic, sometimes in the form of acid-forming NOx, sulfides, and heavy metals and blasting gasses/byproducts.[12] These could harm human health and the environment.

Noise

A mine is an industrial facility and would create significant noise during all phases of operations and mine life. Examples may include, but not be limited to, blasting (in both surface and underground mines); waste rock hauling and other truck traffic on the site; the loading, transport, and dumping of materials on and off the site; the pumping of tailings slurry and other materials; the transport of people to and from the site; and ore processing (such as ore stockpiling, screening and crushing and transport to storage facilities), etc. Further, noise may take multiple forms - such that lower-decibel noise may be more noticeable and disturbing to humans and wildlife than higher-decibel noise, even at lower volumes.[13]

Other Impacts

Powerlines and other "corridors" generally create linear impacts to timber and may result in erosion. All of these rights of way would necessitate deforestation and other impacts to develop and maintain them.[14] Other impacts could include, but not be limited to introduction of non-native species, light pollution (impacting humans and wildlife), increased human traffic and use, development facilitated/promoted by mine infrastructure and people, etc.

Conclusions

The majority of mine features are predictable and many of their impacts to human health and the environment are similarly predictable. The BWCAW is a unique water-based wilderness area characterized by very high water quality and an extensive interconnected system of surface and ground waters. Predictable impacts, most notably to water, from mining in the Duluth Complex could significantly alter the BWCAW's natural resource and wilderness values. The Forest Service should have sufficient information about sulfide-ore copper mining to reasonably predict and describe the general environmental impacts that such mining in the watershed would have on the BWCAW.

[12] Common examples of mine emissions may include, but are not limited to NOx, CO, CO2, SO2, and particulate matter.

[13] These include tonal, low frequency, fluctuating, and impulsive. They are particularly important because their impacts are greater and more complex (and interacting) than simple decibel (loudness) prediction or measurement. They behave differently from many noises (sometimes traveling further than other types of noise) and cause different impacts (being more disruptive and disturbing than other types of noise) such that they may pose particular threats to the BWCAW's quite use and enjoyment (by both humans and wildlife).

[14] Not all infrastructures would be newly required by a mine. For example, "TMM plans to use existing power corridors for power and pipeline infrastructure where practical, and develop new corridors where necessary" PFS p. 4-30.