



**THE SCIENCE:** Sulfide-Ore Copper Mining Threatens Aquatic and Terrestrial Ecosystems of the South Kawishiwi River area, Mining Protection Area, Boundary Waters Canoe Area Wilderness, Voyageurs National Park, Quetico Provincial Park, and proposed Withdrawal Area

**April 2017**

**Tom Myers, Ph.D.**, in his December 3, 2013, report entitled “Technical Memorandum: Twin Metals Mining and the Boundary Waters Canoe Area Wilderness, Risk Assessment for Underground Metals Mining,” focused on essential facts demonstrating why sulfide-ore copper mining threatens irreparable harm to priceless northern forest ecosystems (Parentheticals explain why facts identified by Dr. Myers are significant):

- Waters that would receive acid mine drainage (AMD) are currently of extremely high quality (therefore, pollution caused by mining would degrade an increasingly rare resource).
- The waters that would receive AMD contain few base compounds (therefore, natural buffering of AMD will be extremely low).
- The many streams, wetlands, lakes and aquifers downstream of the mine sites are massively interconnected (therefore, damage from AMD will be widespread and uncontrollable).
- Mine sites lie in close proximity to these water resources (therefore, preventing AMD from entering the waters would be impossible).
- The high probability of AMD coming from the mine sites, waste rock piles, and tailings pond failures (no practical possibility exists of preventing air, rainwater and snowmelt from reaching sulfide-bearing rock).
- The difficulty of predicting when and where AMD may occur because of the nature of cracks and faults in the bedrock (therefore, no practical possibility exists of effectively blocking AMD movement through the ground).
- The potential that AMD could impact waters far downstream from the mine sites (therefore, major waterways of the Boundary Waters Canoe Area Wilderness, Quetico Provincial Park and Voyageurs National Park would be threatened).
- The high cost and low probability of remediating AMD when it occurs.
- River discharge and aquifer recharge are highly seasonal, with the bulk of it occurring between mid-April and mid-June (therefore, drawdowns of surface water and groundwater by mining activity outside that period of higher flows will deplete water available in the affected ecosystems at times when the flows are already at annual or decadal low points).

**Dr. Myers later developed** a model for the Rainy Headwaters that shows the flow of ground and surface water and the transport of contaminants. The Rainy Headwaters includes the South Kawishiwi, Birch Lake, and Stony River watersheds. The purpose of the model is to estimate pathways and rates for contaminants to reach the Boundary Waters Canoe Area Wilderness if sulfide-ore copper mining occurs within these watersheds. The model can be used to estimate the risk of mine spills and leaks affecting the Boundary Waters Canoe Area Wilderness and the lakes and rivers between the proposed mines and the Wilderness. Dr. Myers modeled three scenarios for underground mines and a proposed concentration facility in the South Kawishiwi and Birch Lake watersheds based on the Twin Metals Minnesota Pre-Feasibility Study.

- First scenario: a release of a conservative pollutant (sulfate) from five locations in underground mines using a realistic concentration of sulfate for closed and flooded underground mines in the Duluth Complex and a low discharge rate.
- Second scenario: a one-year release to groundwater from mine waste stored on the surface in the watershed, representing a range of releases that can occur.
- Third scenario: a mid-level spill at the Maturi mine site and at the proposed concentration facility site.
- Scenarios one and two (releases) show that substantial contaminant loads from leaks typical of sulfide-ore mining could impact waters that drain into the Boundary Waters Canoe Area Wilderness.
  - Once started, leaks would continue for decades (even a short-term spill would take years or decades to travel through groundwater) and would thus likely coincide with low flow periods and could create devastating impacts.
  - Contaminants entering the rivers and lakes during low flow conditions have a high potential to impact water in the Boundary Waters Canoe Area Wilderness.
  - Historically, it has been almost impossible to stop leaks at similar mines.
  - Leaks would have a significant impact on streams, rivers, wetlands, rivers and other waters adjacent to the sulfide-ore copper mine sites and in the Superior National Forest.
  - Pollution from sulfide-ore copper mines in these areas would extend into the Boundary Waters Canoe Area Wilderness.
- Scenario three (a spill at the proposed concentration plant) could devastate adjoining lakes, rivers and streams in the Superior National Forest.
- A spill could have a devastating impact on the Boundary Waters Canoe Area Wilderness, depending on level of toxicity, load and location.
- “If the sulfide mines are developed in the Rainy Headwaters, it is not a question of whether, but when, a leak will occur that will have major impacts on the water quality of the Boundary Waters Canoe Area Wilderness.”

**Dr. Myers extended his analysis** to consider the risks posed to Voyageurs National Park from the development of metallic mineral leases in the watersheds draining to and through it, including the Rainy Headwaters, Vermillion Lake, and Rainy River-Rainy Lake Watersheds. In his 2015, Technical Memorandum to the Voyageurs National Park Association and National Parks Conservation Association, Dr. Myers reported:

- Streams draining toward Voyageurs National Park have high water quality and would be affected by small amounts of contamination for a long time.
- The low buffering capacity of the rivers in the Rainy Headwaters watershed could allow contamination from mining waste to be transported a long distance downstream, including to Voyageurs National Park.
- Contaminant seepage into groundwater could last for decades, and there would be little chance of preventing the pollution from reaching Voyageurs National Park.
- Mercury contamination is already present in Voyageurs National Park, and AMD seepage over a long time period would likely exacerbate the existing mercury problem.
- A spill in the Vermillion watershed could pose critical threats to Voyageurs National Park, especially if the waste flowed through Vermillion Lake instead of mixing.
- Discharge or leaking of high salinity water resulting from mine dewatering could ruin nearby streams and increase total dissolved solids from the Kawishiwi River to Voyageurs National Park.
- Development of tailings impoundments presents a large risk to Voyageurs National Park, especially considering their proximity to the river system, the need for a tailings impoundment to not fail forever, the connectivity of the surface waters in the watershed and increases in extreme weather events due to climate change.

**Dr. Myers condensed and submitted for publication** his numerical hydrological model in the peer-reviewed Journal of Hydrology. In the paper, published in February, 2016, and titled, Acid mine drainage risks – A modeling approach to siting mine facilities in Northern Minnesota USA, (*J. Hydrology* 533: 277-290.), Dr. Myers demonstrated that:

- Groundwater with substantial contaminant concentrations would discharge to streams whether sourced from deep underground or on the ground surface.
- Even relatively short-term leaks on the surface could cause substantial loads of pollutants to reach the rivers and valuable downstream resources. Underground leaks have lower discharge concentrations but continue for long time periods, such that contamination may not be obvious until after a mine closes and impacts can continue for hundreds of years.
- Longer-term leaks could cause peak concentrations reaching the rivers to be much higher than simulated.
- Leases trending southwest to northeast in the Birch Lake area would discharge fairly quickly to surface water.
- Leases in the headwaters of the Stony River would discharge to nearby surface water.
- Under the course of normal operations, proposed mines near the Boundary Waters Wilderness could cause significant damage to rivers and the Boundary Waters due to leaks to surface waters or substantial groundwater contamination.

**Dr. Myers developed and applied** a numerical groundwater model to assess the relationship between the proposed Twin Metals Minnesota tailings storage facility and the management and closure of the Peter Mitchell Pit, which is a series of taconite mine pits that have substantial effect on the local groundwater system. The Laurentian Divide, the boundary separating the Boundary Waters Wilderness and Lake Superior watersheds, naturally and originally ran across what is now the location of the Peter Mitchell Pit. Dr. Myers summarized the findings of the model in his 2016 technical memo titled, Twin Metals Mine and the Peter Mitchell Pit, Simulation of the Development of the Peter Mitchell Pit and Its Effects on the Proposed Twin Metals Tailings Impoundment:

- Removal of bedrock pillars separating the Lake Superior and Boundary Waters watersheds during mining prior to closure of the Peter Mitchell Pit, will essentially move the watershed boundary for a period of time.
- Heavily contaminated seepage from the proposed Twin Metals tailings storage facility would flow from the tailings facility through the bedrock and into the Peter Mitchell Pit for a period of 25-50 years, and thus into the Boundary Waters Wilderness watershed.

**Lawrence A. Baker, Ph.D.**, in his November 24, 2013 report entitled “Potential Ecological Impacts of the Twin Metals Mine,” stated the following conclusions, among others:

- “The potential impacts of the mine are high because this is a very large mine located in an ecologically sensitive area.”
- Fish in these waters are sensitive to acidification; even small changes in pH caused by AMD would result in losses of species. If pH were to decline below 5.0 most species would be lost.
- Leaching of heavy metals associated with AMD impairs fish and other aquatic life.
- Because wild rice is harmed or destroyed by sulfate levels greater than 10 mg/L, and because background sulfate levels in these waters are around 6 mg/L, elevated sulfate levels associated with sulfide-ore copper mining would likely impair wild rice production. It may also harm other rooted aquatic plants.
- Sulfates are a factor in the creation of methyl mercury, which is the form of mercury taken up in the food chain. The increased methylation would increase the concentrations of mercury in fish and thus expose human and other consumers of fish to the risks associated with elevated levels of mercury in their bodies.
- AMD input and elevated sulfate levels would affect the natural cycling of phosphorus between sediments and waters. The release of phosphorus to waters would cause increased algal growth, loss of water clarity and eutrophication.
- AMD and associated contamination may affect a large number of shallow, easily contaminated domestic drinking wells in the area.

- Tailings dam failures, because of an extreme weather event, human error or other reason, pose a serious risk to downstream ecosystems; the downstream distribution of acidic water and sediments contaminated with heavy metals would pollute many kilometers of waters. Damage from metal-laden sediments would persist for years.

**Dr. Baker extended his analysis** to model the chemical impacts of a possible spill at the Twin Metals mine site, the impacts of water usage by the mine, and the confounding influence of climate change on mine impacts. He reported:

- A mixing model based on observations and studies of realistic AMD generation potential would result in elevated sulfate levels “well above” Minnesota’s 10 mg/liter wild rice standard and likely accelerate mercury methylation in sediments.
- Water withdrawal for copper production is projected by company documents to be 0.8 million gallons per day; water usage in Ely is estimated to be about 0.94 million gallons per day for comparison. Water usage for sulfide-ore copper mining could reduce the decadal low flow of the South Kawishiwi River by 7-13%.
- Water usage, energy usage and tailings productions per unit copper produced increase over the life of a mine.
- Climate change will make it even more difficult to predict impacts, especially those triggered by more extreme precipitation events that threaten mine infrastructure like tailings dams, process ponds and tailings pipelines.

**Lee Frelich, Ph.D.**, has determined that significant negative impacts of sulfide-ore mining would likely occur on terrestrial ecosystems of the Boundary Waters Canoe Area Wilderness and adjacent areas of the Superior National Forest. Those impacts include, among others:

- Forest fragmentation within the mining area, the effects of which would extend into the Boundary Waters Canoe Area Wilderness.
  - Forest fragmentation results in changes to both plant and wildlife communities.
  - Of particular concern are species such as fisher, pine marten and interior forest songbirds that need large tracts of unfragmented forest.
- Disruption of the intricate web of water that flows through the soil, forest roots and other organisms lying on top of bedrock throughout the Quetico-Superior ecosystem. Construction of roads, waste storage and water drawdown would repeatedly disrupt water flow and cause significant additive and cumulative impacts:
  - Interference with the interaction between forests, streams and groundwater.
  - Interference with the flow and chemistry of the water in the ecosystem, resulting in changes in decomposition and nutrient cycling, changes in balance of vegetation types and tree mortality.
  - Because of the interconnectedness of the systems, activities outside the Boundary Waters Canoe Area Wilderness would have impacts within the Wilderness.
- Dispersal of invasive plant species, which would extend beyond the actual surface disturbance from mines and transportation infrastructure.
- Dispersal of nonnative earthworms, which are present but not yet well-established in the area.
  - The movement of soils associated with mining would very likely spread nonnative earthworms to areas not currently infested.
  - Fragmentation would speed nonnative earthworms’ movement across the landscape.
  - Earthworms can trigger a variety of impacts with a wide range of ecological repercussions.
- Loss of native biodiversity.
  - Soil dwelling species that have not yet been discovered, including insects, worms, bacteria and fungi, probably exist in the mining area and could be lost both within the mining footprint and beyond.
- Effects of a vast increase in traffic, including heavy truck traffic, close to the Boundary Waters Canoe Area Wilderness that mining would entail. For example, road salt is likely to cause root damage and tree death for species such as white pine, basswood, red oak, bur oak and red maple. Other impacts of roads on ecosystems and wildlife are well known.
- Changes in wildlife migration and habitat use patterns.

- Effects of windblown dust and other forms of air pollution.
- Additive and synergistic effects of mining with the effects of climate change.
  - Mining would add a significant stressor to a system that will already be stressed, perhaps beyond the point of resiliency.
- Loss to science: the Boundary Waters Canoe Area Wilderness provides a baseline for a landscape otherwise affected by logging, mining, roads, housing and other human activities.
  - “This role of wilderness and other natural areas as a scientific baseline has become critical in the last few decades, to assess the overall impacts of human activity at local, regional and global scales. Without these baselines, we are essentially ‘flying blind’ in our ability to manage ecosystems to provide the many types of services needed by humanity.”

**Dave Chambers, Ph.D.**, reviewed sulfide-ore copper mining in the Duluth Complex and currently available copper mining technologies in his November 2014 report, “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.” Dr. Chambers found:

- Most of the waste rock and pit wall rock so far studied in the Duluth Complex would contain some sulfur, mainly as the mineral pyrrhotite, a primary cause of AMD. There are essentially no acid-neutralizing carbonate minerals in the waste rock.
- Copper is particularly toxic to aquatic organisms, but current National Ambient Water Quality Criteria for Protection of Aquatic Life for copper are not totally protective of all aquatic species.
- Uncertainties based in the inherent complexity of natural materials and their environments prevent predictive ability, which prevents the conclusion that a mine will have only insignificant impacts.
- Difficulties of adjusting water treatment and seepage collection technologies to meet real-world chemical composition, geomorphology and water cycle variation are much greater than suggested by assumptions within the environmental assessment process.
- No significantly new water treatment technologies have been developed in recent decades. The most complete systems, including reverse osmosis, are highly expensive and require their own follow-up treatment systems.
- No tailings storage facility seepage collection system is perfect (“all liners leak”), and disposing of tailings or waste rock in an old facility would likely use an unlined system.
- The U.S. Environmental Protection Administration has observed that mines continue to operate even if they know their treatment does not meet established water quality standards.
- Records of analogous mines indicate a high likelihood that any mine would release water exceeding its environmental permit within its lifetime.
- “It is not feasible, given today’s or tomorrow’s technology, to reduce the risk of impacting waters downstream from a copper/nickel mine in a sulfide ore body to zero.”

**Earthworks summarized the state of current US copper mining environmental impacts** in its peer-reviewed report “U.S. Copper Porphyry Mines: The Track Record of Water Quality Impacts Resulting from Pipeline Spills, Tailings Failures, and Water Collection and Treatment Failures” (July 2012, revised November 2012). Earthworks found:

- Of fourteen sulfide-ore copper mines representing 89% of U.S. copper production found that 100% of the mines studied had experienced pipeline spills or other accidental releases, and 92% (13 of 14) had experienced water collection and treatment failures resulting in significant effects on water quality.
- Leaks occur at all mines.
- Although the likelihood of a particular type of leak cannot be predetermined (and this is true even with a detailed, comprehensive mine plan), the probability of some type of leak is high.

**Onello, E., M.D., et al.** 2016. Sulfide Mining and Human Health in Minnesota. *Minnesota Medicine* 2016 (6) 51-55. This review in *Minnesota Medicine*, the magazine of the Minnesota Medical Association, addresses from a public health

perspective the ways in which sulfide-ore copper-nickel mining in the Duluth Complex is distinct from and potentially more hazardous than Minnesota's traditional iron (taconite) mining. Key points addressed include:

- Sulfide mining may affect public health through the release into the environment of amphibole fibers, fugitive dust, and heavy metals;
- Some of the heavy metals expected to be released from Duluth Complex rock include arsenic, asbestos, cadmium, lead, and mercury, which are identified by the World Health Organization as being of major public health concern;
- Mercury is already a public health threat, as the results of a Minnesota Department of Health study found (one in ten infants in Minnesota's Lake Superior region were born with unsafe amounts of mercury in their blood);
- Sulfide-ore copper mining would exacerbate mercury contamination and bioaccumulation due to the release of additional sulfate – which plays a key role in mercury methylation – into groundwater and groundwater inflows to water bodies; and
- A Health Risk Assessment and Health Impact Assessment should be part of any environmental review on the question of future sulfide-ore copper-nickel mining.

**Venturelli, Paul, Ph.D., and Bruce Vondracek, Ph.D.,** described in their report “The Fish and Fisheries of the Boundary Waters Canoe Area Wilderness and Voyageurs National Park, and Their Vulnerability to Copper Sulfide Mining” (April 2017) the fish and fisheries of the Boundary Waters Canoe Area Wilderness (BWCAW) and Voyageurs National Park (VNP), and their vulnerability to copper sulfide mining. Important points include:

- The BWCAW and VNP support important, healthy recreational and subsistence fisheries with high species and genetic strain richness, which are a direct result of past efforts to maintain the pristine nature and ecological integrity of the region;
- A comparison of fish catches inside and outside of the BWCAW and VNP suggests that anglers target the BWCAW and VNP when fishing for lake trout (and other prized cold-water species) and smallmouth bass. State survey data suggest that some game fish species are larger in the BWCAW and VNP, probably due to relatively large lakes and pristine habitat, and low fishing pressure;
- The scientific literature indicates that acid mine drainage (AMD) causes long-term declines in fish abundance, species number, and genetic diversity, and may facilitate the establishment of invasive species;
- Acid mine drainage lowers pH and exposes fish and other aquatic organisms to toxic metals (e.g., copper, cadmium, lead, mercury, nickel, and zinc), which accumulate in all major organs, impair system function, cause deformities, behavioral changes, reproductive failure, and mortality, and may render fish unfit for human consumption; and
- Evidence from previous hard rock mines demonstrates overwhelmingly that a copper-sulfide mine in the Rainy River watershed will impact fish, and that such damage is likely to extend far from the mine site and persist for centuries causing damage to a relatively pristine region of the state, and the diversity of popular and rare fishes that it supports

**Roger A Powell, Ph.D.,** in his report, “Mammals and Mining for Minerals in Sulfur-Bearing Rock Formations in Northeastern Minnesota” (April 2017) describes the life histories and vulnerabilities of the mammals of the Boundary Waters region to effects of sulfide-ore copper mining. Effects of sulfide-ore copper mining on mammals of the Boundary Waters region would result via numerous pathways, such as:

- pollution of water (all mammals drink);
- pollution, diminishment, or eradication of aquatic vegetation on which many mammals rely as habitat, for forage, or for nutrients like sodium;
- contamination and bioaccumulation of toxic metals such as methyl-mercury in fish and in mammals that consume fish;

- the direct, indirect, and cumulative effects caused by fragmentation of terrestrial habitat required for foraging, mating, rearing, denning, and dispersal; and
- destruction of important habitats, such as mature forested habitats and mature forest-wetland complexes.

**Assumptions for the assessments by Dr. Myers, Dr. Baker, Dr. Frelich, Dr. Chambers, Drs. Venturelli and Vondracek, and Dr. Powell:**

- Twin Metals Minnesota deposits would be developed in accordance with the 2014 Technical Report 43-101, Duluth Metals, Inc., with state-of-the-art methods, facilities, and management practices.
- Studies addressed impacts and risks that are likely to occur regardless of changes in mine plans.