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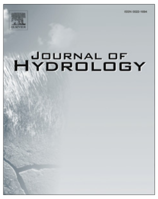

Acid mine drainage risks – A modeling approach to siting mine facilities in Northern Minnesota USA

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SUMMARY

Most watershed-scale planning for mine-caused contamination concerns remediation of past problems while future planning relies heavily on engineering controls. As an alternative, a watershed scale groundwater fate and transport model for the Rainy Headwaters, a northeastern Minnesota watershed, has been developed to examine the risks of leaks or spills to a pristine downstream watershed. The model shows that the risk depends on the location and whether the source of the leak is on the surface or from deeper underground facilities. Underground sources cause loads that last longer but arrive at rivers after a longer travel time and have lower concentrations due to dilution and attenuation. Surface contaminant sources could cause much more short-term damage to the resource. Because groundwater dominates baseflow, mine contaminant seepage would cause the most damage during low flow periods. Groundwater flow and transport modeling is a useful tool for decreasing the risk to downgradient sources by aiding in the placement of mine facilities. Although mines are located based on the minerals, advance planning and analysis could avoid siting mine facilities where failure or leaks would cause too much natural resource damage. Watershed scale transport modeling could help locate the facilities or decide in advance that the mine should not be constructed due to the risk to downstream resources.

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1. Introduction

Acid mine drainage (AMD) is a problem associated with mines throughout the world (Jacobs and Testa, 2014). In the United States, promoting mining on public lands has been a priority since the 1800s (Leshy, 1987), with little consideration for the waste other than getting it away from the mine site being the practice prior to about 1970 (Church, 1996; Ferderer, 1996). Mines were developed with little concern regarding AMD (Crews, 1973; Williams, 1975).

That is no longer the situation. Mining-caused contamination is a global problem and few sites are isolated or sufficiently underused that potential contamination can be ignored. One example of global cooperation among the mining industry, conservation groups, and stakeholders to set a higher standard for mining, including the prevention of AMD and promotion of it remediation is the Initiative for Responsible Mining Assurance (IRMA) (http://www.responsiblemining.net/). The goal of IRMA is to promote responsibility by certifying the most responsible mines.

Watershed-scale planning is necessary to avoid the most serious problems. However, much watershed-scale research focuses on remediation (Church et al., 2007; Crews, 1973; Kimball et al., 2006; Nimick and von Guerard, 1998; Skousen et al., 1999), often with the perspective of optimizing treatment (Crews, 1973; Kimball et al., 1999). Conceptual and numerical modeling at various scales can aid in prioritizing sites for remediation (Myers, 2013; Runkel et al., 2013). Herr et al. (2003) developed a watershed-scale model of AMD entering a river to show the contaminant sources and potentially demonstrate the effectiveness of remediation of specific sites. Runkel and Kimball (2002) simulated flow and equilibrium chemistry along a stream heavily impacted by AMD to demonstrate the effects of remediation. Related modeling showed that simulation results are most affected by model parameters affecting a nearby stream reach or watershed (Gooseff et al., 2005). Myers (2013) suggested priorities for remediating phosphate mines based on a groundwater model of a large western watershed contaminated with selenium. Statistical models also can show the mining features or geology that best explain the variability in salinity discharging from a mined watershed (Evans et al., 2014). These studies however do not suggest a means of avoiding AMD or other contamination issues as part of the planning process.

Preventing future mines from becoming AMD problems is often considered an engineering issue at the mine site (Jacobs et al., 2014; Buxton et al., 1997; EPA, 1994), although failures occur often

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(Caldwell and Charlebois, 2010; Kuipers et al., 2006; Rico et al., 2008). The level of damage caused by these failures can depend on their location in the watershed. Missing from the literature and generally from mine planning is research showing methods designed to site mines and mine facilities to avoid large-scale AMD problems when leaks occur.

The objective of this study was to use watershed-scale groundwater flow and transport modeling to predict which mine sites in a sulfide rich watershed would be more likely to cause downstream AMD problems if engineering controls fail. It demonstrates how watershed-scale modeling prior to the actual development of mines can improve mine planning to facilitate future remediation when engineering failures occur, a topic currently not substantially addressed in the literature. The setting is the Birch Lake watershed, located within the larger Rainy Headwaters watershed in northern Minnesota, USA (Fig. 1). The area has no current mining and one historic mine. Mining companies hold leases on at least six different copper/nickel deposits (MNDNR, 2014) within the watershed. The Boundary Waters Canoe Area Wilderness (BWCAW), a high value and one of the most-visited wilderness areas in the United States (Heinselman, 1996), lies directly downstream of the potential mining (Fig. 1).

The model could help to optimize mining and waste disposal locations or to decide whether the risks of mining are too high as well as providing information on where more information is needed for decision making. The model could be an example for countries and companies around the world contemplating entering relatively pristine watersheds currently valued for resources that could be damaged by mine pollution.

2. Method of analysis

2.1. Study area

The study area is in the Birch Lake watershed south of the South Kawishiwi River in northeastern Minnesota, USA (Fig. 1). The middle two thirds of the study area overlies the Duluth Complex while the north end abuts Granite Range granite (Fig. 2, Table 1). The Duluth Complex hosts nickel–copper–platinum sulfide deposits in the basal portion of the South Kawishiwi intrusion as much as 1200 m below ground surface (Miller et al., 2002; Parker and Eggleston, 2014). The deposits are potentially significant acid-producers (EPA, 1994; Lapakko, 1988; Lapakko and Olson, 2015; Polymet Mining, 2013b; Polymet Mining, 2012; Severson et al., 2002). The sulfide content of the Spruce Road deposit is 2–5% by volume and 3–4% by weight (Parker and Eggleston, 2014), which may on the high end of the range for the Duluth Complex (Seal et al., 2015). The host mineralized zone has previously produced AMD (EPA, 1994; Lapakko, 1988; Lapakko and Olson, 2015).

Most mining leases lie south of the South Kawishiwi River in the Birch Lake and Stone Creek watersheds (Fig. 2). Proposed mines are expected to initially be underground (Cox et al., 2009; Parker and Eggleston, 2014), including some underground waste rock and tailings disposal (Twin Metals, 2014). Waste rock is rock and overburden removed to reach the ore and tailings are the processed ore from which the valuable mineral has been removed. Waste rock and tailings are considered contaminant sources for this paper because mine planning as to the placement of either material is not sufficiently advanced to distinguish among the properties of either type.

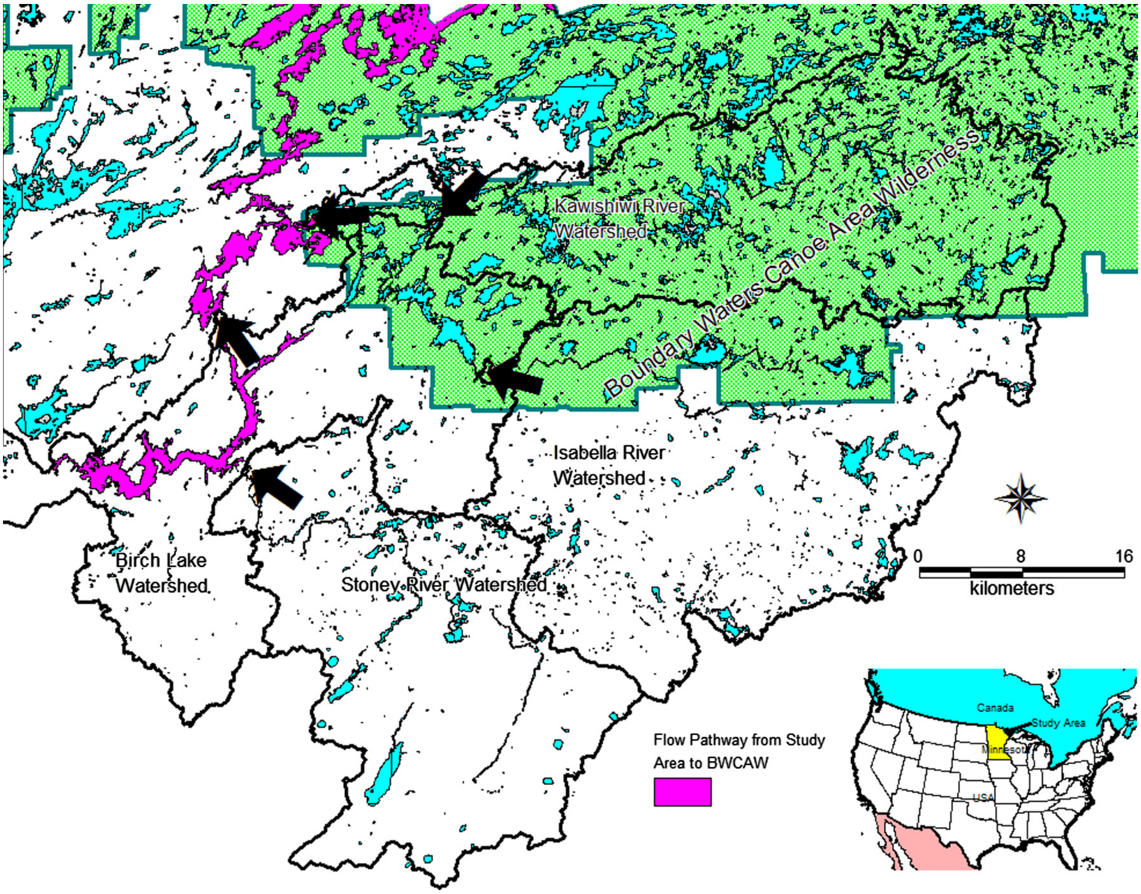

Fig. 1. Rainy Headwaters watershed and study area, showing subwatersheds, rivers, and lakes. Arrows are flow direction from watersheds. Watershed boundaries from Dnr100kwatersheds, www.mngeo.state.mn.us/chouse/metalong.html.

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