Internet Case Study #11 (*www.mdag.com*)

ONSET OF ACIDIC DRAINAGE FROM A MINE-ROCK PILE

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Abstract

In studies of acidic drainage, a “lag time” between near-neutral conditions and the onset of net-acidic drainage is well recognized, generally ranging from a few days to more than 15 years. However, the manner in which the onset occurs, such as smoothly or erratically, in full-scale minesite components in not well documented.

This Internet Case Study shows how one mine-rock pile evolved from near-neutral-pH to acidic conditions, and then highlights the geochemical indicators warning of that impending onset of acidic drainage. The North Dump (approximately $84x10^6$ metric tonnes of rock and till) at the Island Copper Mine in British Columbia showed that the onset of acidic conditions involved a time period of significant fluctuations in pH and concentrations, from a few years (Monitoring Station EDD) to perhaps a decade or more (Station NDD). These fluctuations were apparently due to variable contributions and conditions in upstream pathways according to the conceptual model. At Island Copper, all upstream pathways in the North Dump were expected to eventually become acidic, so drainage was expected to become consistently acidic. At other minesites, some pathways may remain near neutral indefinitely so that ongoing fluctuations in water chemistry may become a long-term feature rather than an eventual onset of constant net acidity.

Monitoring of aqueous sulfate at minesites with sulfide-bearing rock may provide warnings of any impending onset of acidic drainage, with sufficient response time to install remedial or control measures. This case study of the North Dump showed that sulphate concentrations increased significantly, by a factor of two, about two years before the first appearance of acidic water (pH < 6.0). However, sulfate will not act as a reliable indicator if its concentrations are limited by solubility of minerals like gypsum, because the concentrations would not reflect actual reaction rates inside the mine-rock pile.

Case Study

Introduction

Predictions of acidic drainage from mine rock often recognize the concept of a “lag time” between the creation of the mine-rock pile and the appearance of acidic drainage. Estimates of lag time, which often range from a few days to more than 15 years, typically assume implicitly that the eventual onset of net acidity occurs with a short transition time.

While this can occur in small-scale tests like humidity cells (Morin and Hutt, 1997), this may not happen in full-scale mine-rock piles. However, there is little information on onsets to net acidity at actual minesites. This Internet Case Study presents a full-scale example, showing the temporal fluctuations in water chemistry and the early-warning indicators that signalled the impending onset.

The Island Copper Mine (Figure 1) is located near Port Hardy on the northern end of Vancouver Island, British Columbia (Horne, 1993), and is situated on the shore of Rupert Inlet which is connected to the Pacific Ocean on the western side of Vancouver Island. The mine consists of several components including a relatively large pit from which ore and waste rock were removed, a Beach Dump where waste rock was placed into Rupert Inlet, and several on-land waste-rock dumps. Due to exhaustion of ore, Island Copper closed in 1995 after approximately 25 years of operation.

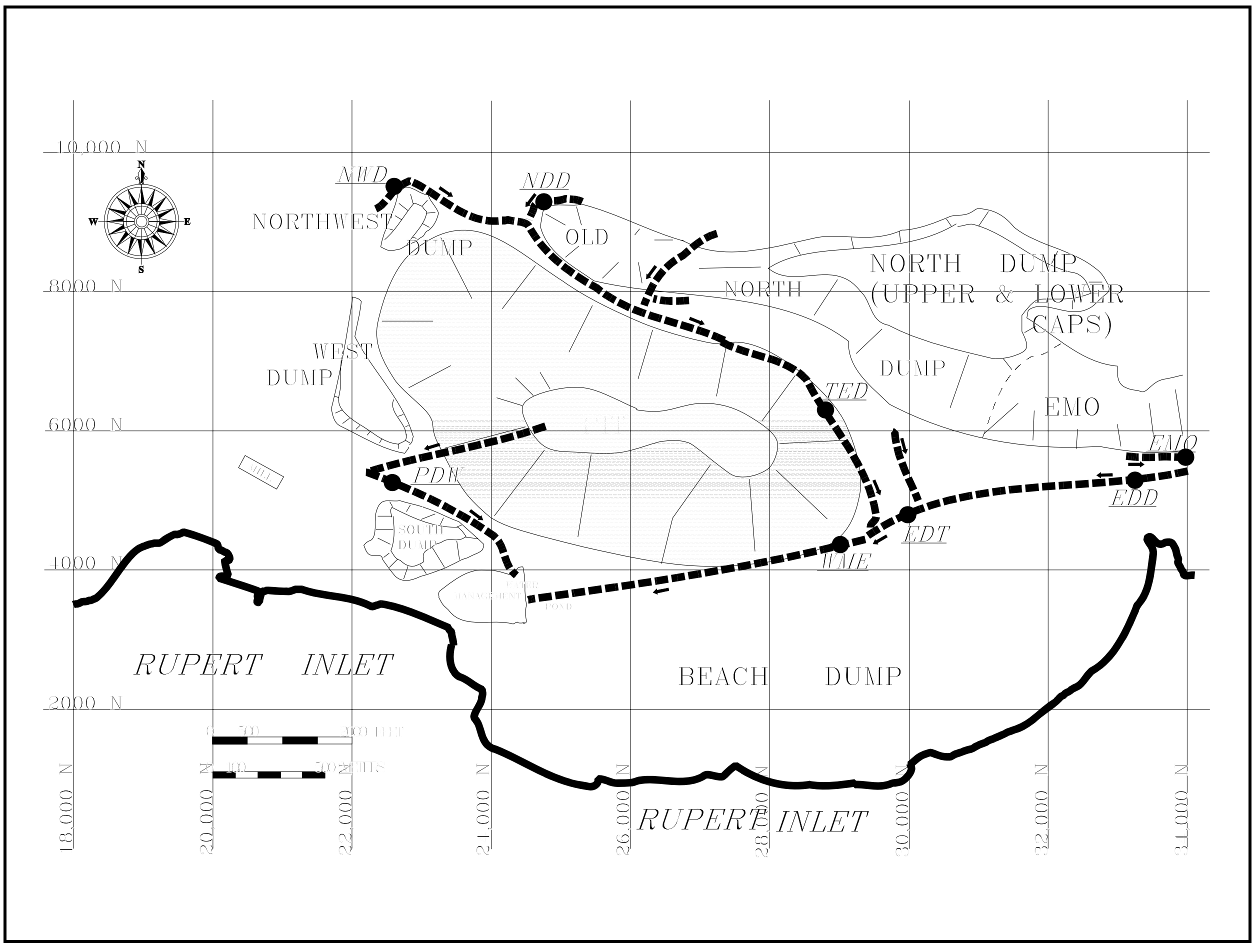

FIGURE 1. Schematic Map of the Island Copper Minesite, Including the Ditch-Collection System and Water-Chemistry Monitoring Stations.

As part of mine-closure planning, site-wide monitoring data extending back to 1970 were compiled and interpreted (Morin et al., 1995). This information revealed the geochemical evolution of the North Dump (Figure 1) as portions of it became acidic, and also pointed out early-warning indicators of impending acidic drainage.

The North Dump at Island Copper is the largest and oldest on-land mine-rock pile at the site, containing approximately $84x10^6$ metric tonnes of rock and till. The North Dump at Island Copper consists of several sections (Figure 1). The Old (Lower) North Dump extends roughly east-to-west on the northwest side of the pit. The Upper and Lower Caps contain additional waste rock placed on part of the Old North Dump. The Eastern Most Outslopes (EMO) comprise the lower-lying eastern extension of the North Dump.

The North Dump crosses two former watershed divides. Because the underlying natural soils and rock are relatively impermeable, basal drainage through and from the North Dump follows the former creek channels in the watersheds. A creek on the north side of the dump flows into the waste rock, mixes with water percolating through acid-generating waste rock, and reappears in the ditch near Monitoring Station NDD (Figure 1). Water percolating through acid-generating waste rock in the Eastern Most Outslopes is captured in a ditch monitored by Station EMO. This seepage water then mixes with seepage flowing from the north side of the Outslopes (not shown on Figure 1) and is monitored at Station EDD. Most monitoring stations at Island Copper were established after acidic drainage appeared widely at the site in 1985, approximately 15 years after the initiation of mining. As a result, the period of monitoring at most stations is not sufficient to document the onset of acidic drainage. However, Stations NDD and EDD have monitoring data extending back to 1981 and 1980, respectively, and these two stations can be used to discuss the onset.

Conceptual Model

Island Copper's North Dump is a Type 3 Mine-Rock Pile (Morin and Hutt, 1997). This means that it rests on sloping ground so that some natural groundwater and surface water can move into and through the basal rock, and then all water and infiltration flows downgradient to the toes of the pile. A simplified conceptual model of water movement (Figure 2) will be used to explain the observed drainage chemistry during onset of net acidity. This model shows that the drainage chemistry is dependent on the location of the monitoring point within or below the pile ("levels" in Figure 2).

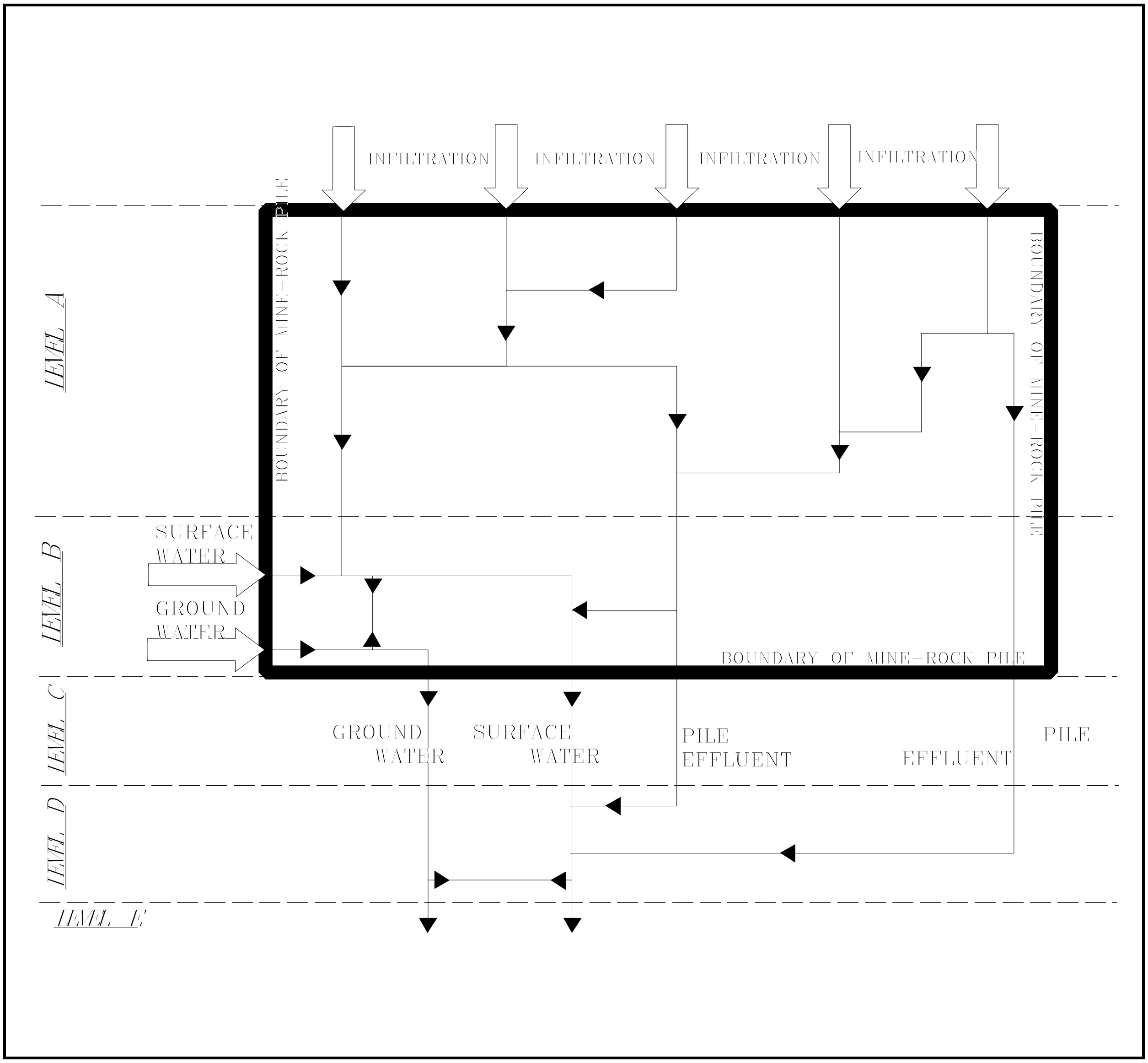

FIGURE 2. Schematic Conceptual Model for Water Movement and Pathways Through a Type 3 Mine-Rock Pile.

Station NDD

Monitoring Station NDD is located near a discrete discharge point of subsurface water. At least part of the discharge is from a creek that enters the dump farther to the east. The pH values at this station apparently showed a slow drift towards lower values through the early 1980's (Figure 3). However, average annual values of pH do not confirm this drift. As a result, the minor pH changes, especially in the range around 6.0 to 8.0, may have suggested the impending onset of acidic drainage (pH < 6.0), but are not considered reliable indicators. On the other hand, sulfate was a more reliable indicator of the impending onset (Figure 4).

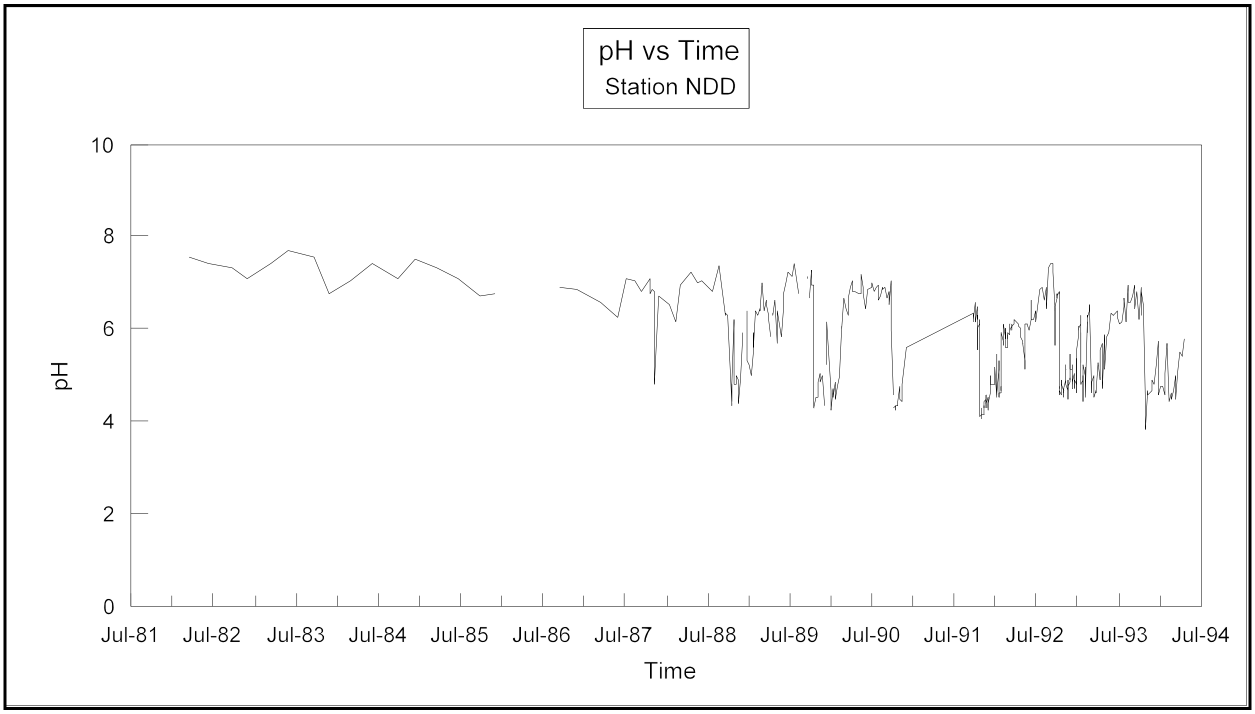

FIGURE 3. Temporal Trend of Aqueous pH at Station NDD.

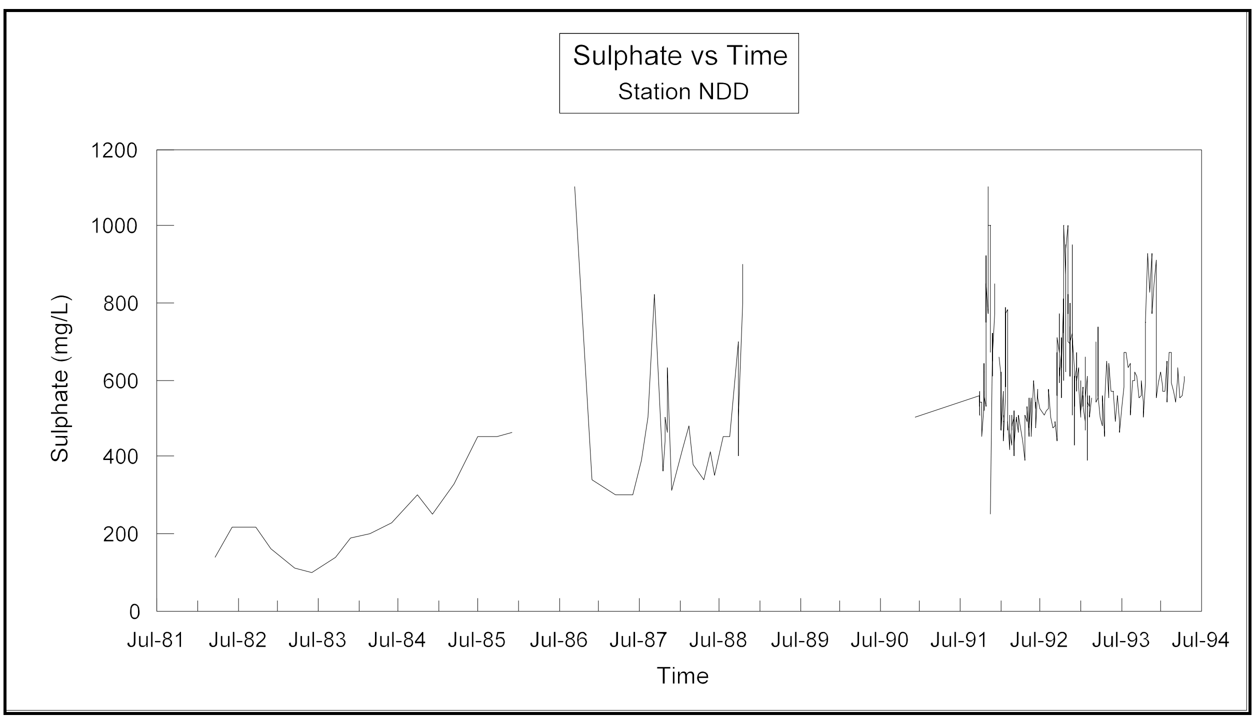

FIGURE 4. Temporal Trend of Aqueous Sulfate at Station NDD.

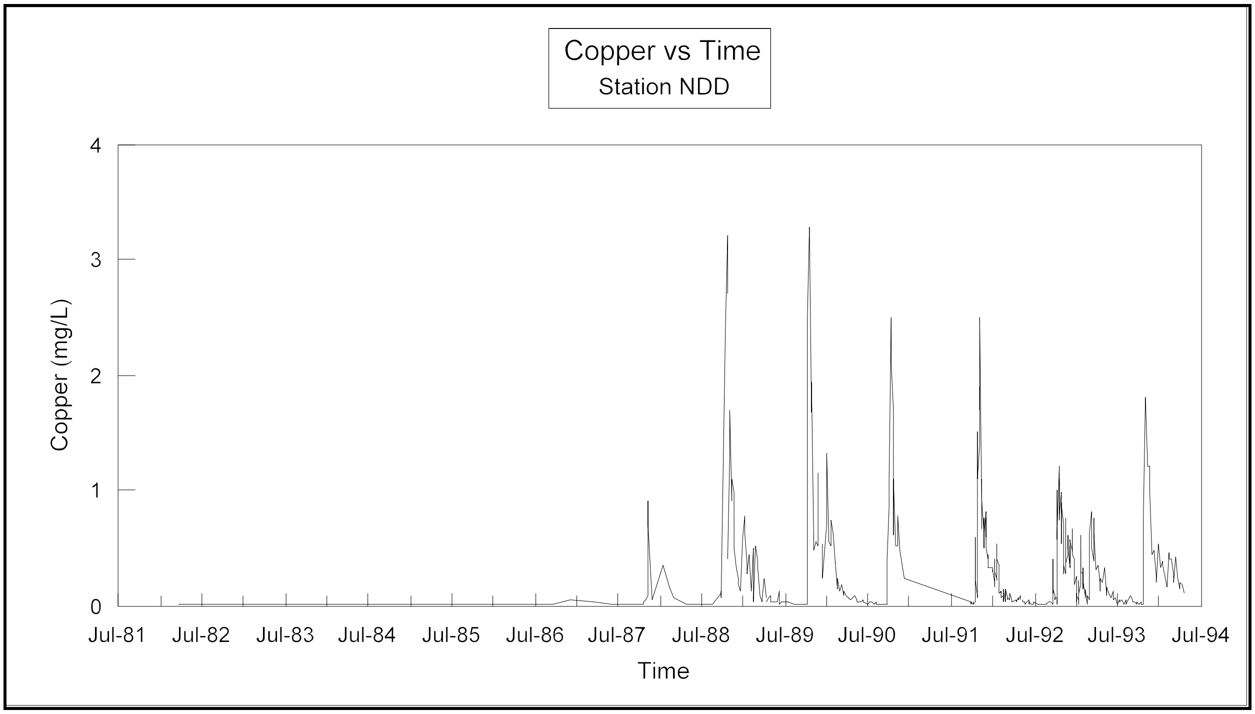

FIGURE 5. Temporal Trend of Aqueous Dissolved Copper at Station NDD.

Sulfate is a byproduct of sulfide oxidation and acid generation, and is an indicator of increasing rates of acid generation as long as it is not limited by solubility of minerals like gypsum. In laboratory-scale tests, sulfate has already been identified as an early-warning indicator of acidic conditions (Morin and Hutt, 1997). At NDD, sulfate roughly doubled in concentration, to over 400 mg/L, about two years before the first measured acidic pH below 6.0 (Figure 4).

Concentrations of metals, such as copper (Figure 5), changed markedly at NDD only after the start of pH fluctuations. This is due to the close correlation of pH and copper which allowed detailed predictions of future water chemistry and short-term (one-hour) fluctuations (Morin and Hutt, 1993; Morin et al., 1994).

The first pH measurement below 6.0 at NDD was obtained in late 1987. This and other peaks of acidity were likely due to sharply increasing seasonal precipitation which flushed accumulated acidity from the rock (Morin et al., 1994).

Through 1994, the annual time interval of acidic pH (less than 6.0) increased at NDD and sulfate concentrations showed a generally increasing trend. These effects can be explained by upstream pathways (Figure 2) that include near-pH-neutral stream water flowing into the dump (Level B in Figure 2), infiltrating water passing through carbonate-bearing till placed in this part of the North Dump (Level A), and infiltrating water passing through acidic rock (Level A). Acidic conditions persisted mostly during winter months when precipitation, infiltration, and flushing of accumulated acidity in Level A pathways were highest. Therefore, the onset of acidic drainage at NDD is attributed to only a few upstream pathways in Level A becoming acidic and being periodically flushed by infiltration. However, the prognosis for Station NDD is that additional pathways will become acidic (Li, 1991; Lister, 1994), resulting in more persistent acidic drainage passing through this monitoring point.

Station EDD

Station EDD monitors flow from Station EMO about 300 m upstream (Figure 1) and from local catchments on the north and east sides of the Outslopes. The trend of pH through time shows a sharp decrease in late 1987, from around 8 to almost 6 (Figure 6), when the EMO ditch was connected to the EDD ditch. In early 1988, the first acidic pH (less than 6.0) was detected. By mid 1988, pH recovered, but began a trend of fluctuation until stabilizing near pH 4.0 in late 1990.

Upstream Station EMO, and thus all pathways above it, remained steadily acidic since initiation of monitoring at EMO in late 1987. Therefore, the pH fluctuations in the late 1980's at EDD are attributable to the northern side of the Outslopes which only became steadily acidic in 1990. This was confirmed by cursory monitoring data on the northern side.

Although pH first showed an acidic value in late 1988, sulfate concentrations produced a sharp increase in mid 1986 by a factor of two and again in mid 1987 by another factor of two (Figure 7). As a result, sulfate provided a warning period of about two years before acidic pH was first measured. This observation is consistent with the observations at Station NDD. Metals such as copper (Figure 8) responded to pH fluctuations due to the correlation between these two parameters.

Station EDD is now consistently around 4.0. There are apparently no further major upstream pathways that can become acidic. As a result, water chemistry is expected to remain relatively constant for at least several decades, until sulfide minerals and leachable metals are depleted (Lister, 1994).

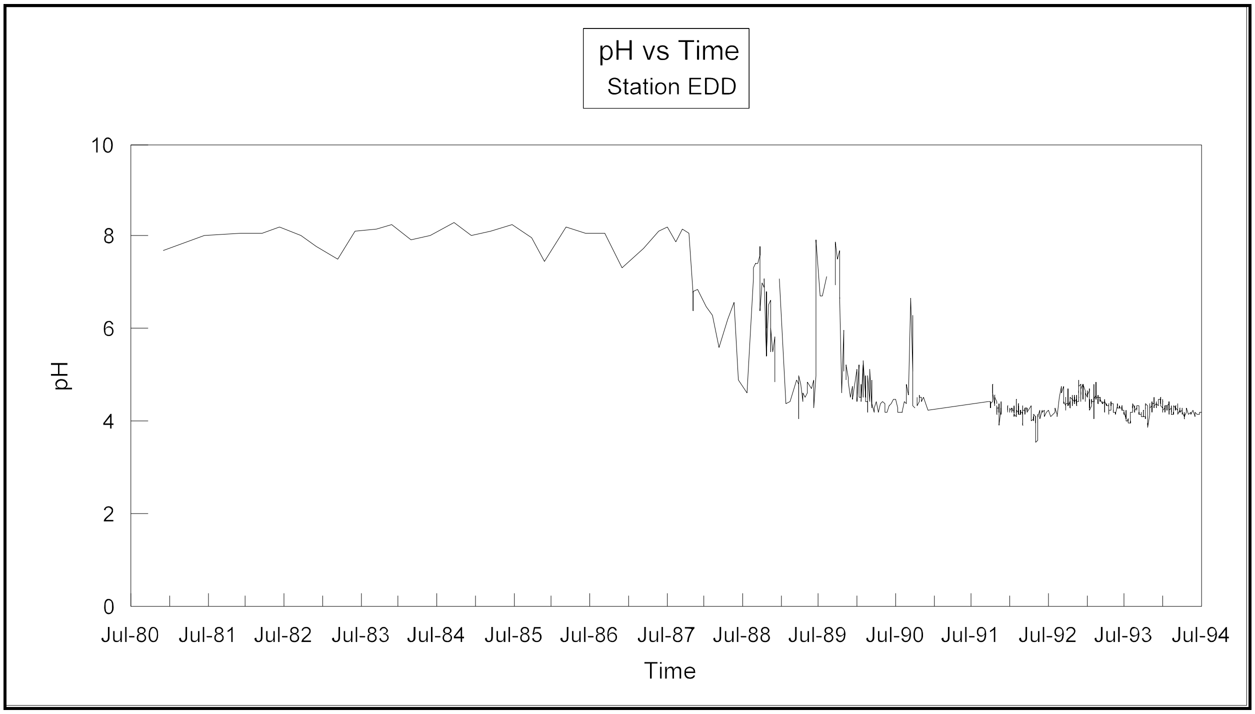

FIGURE 6. Temporal Trend of Aqueous pH at Station EDD.

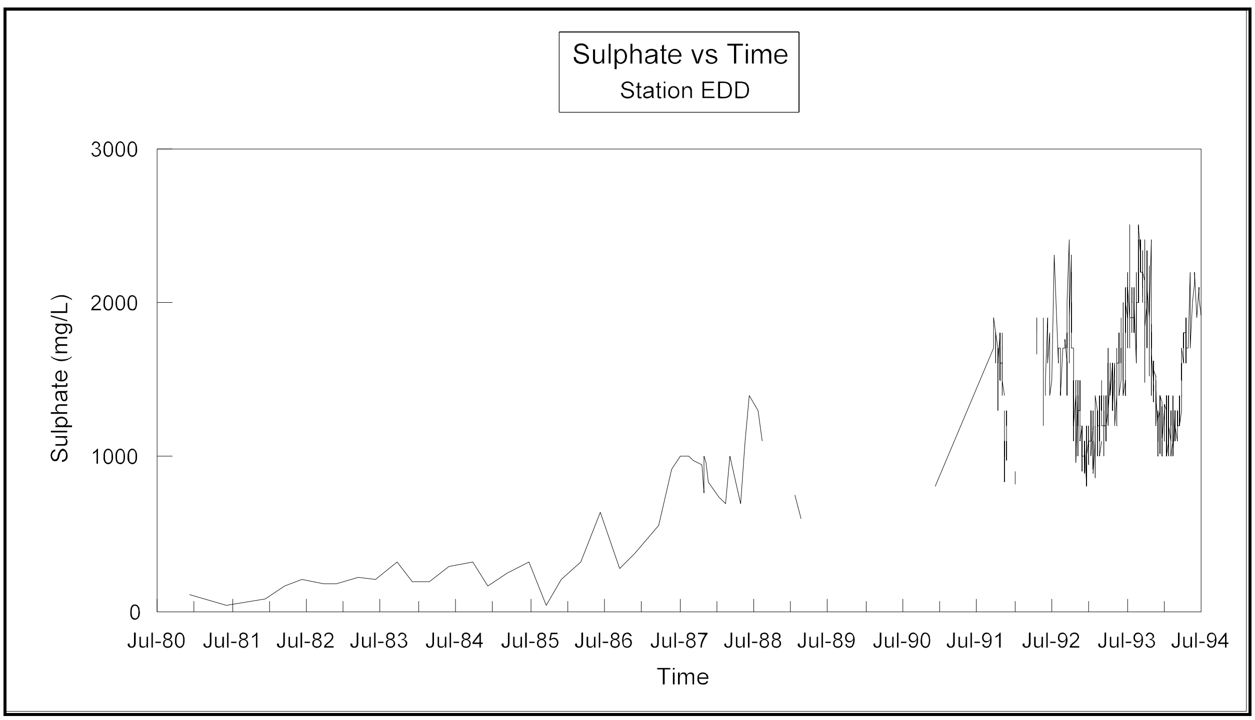

FIGURE 7. Temporal Trend of Aqueous Sulfate at Station EDD.

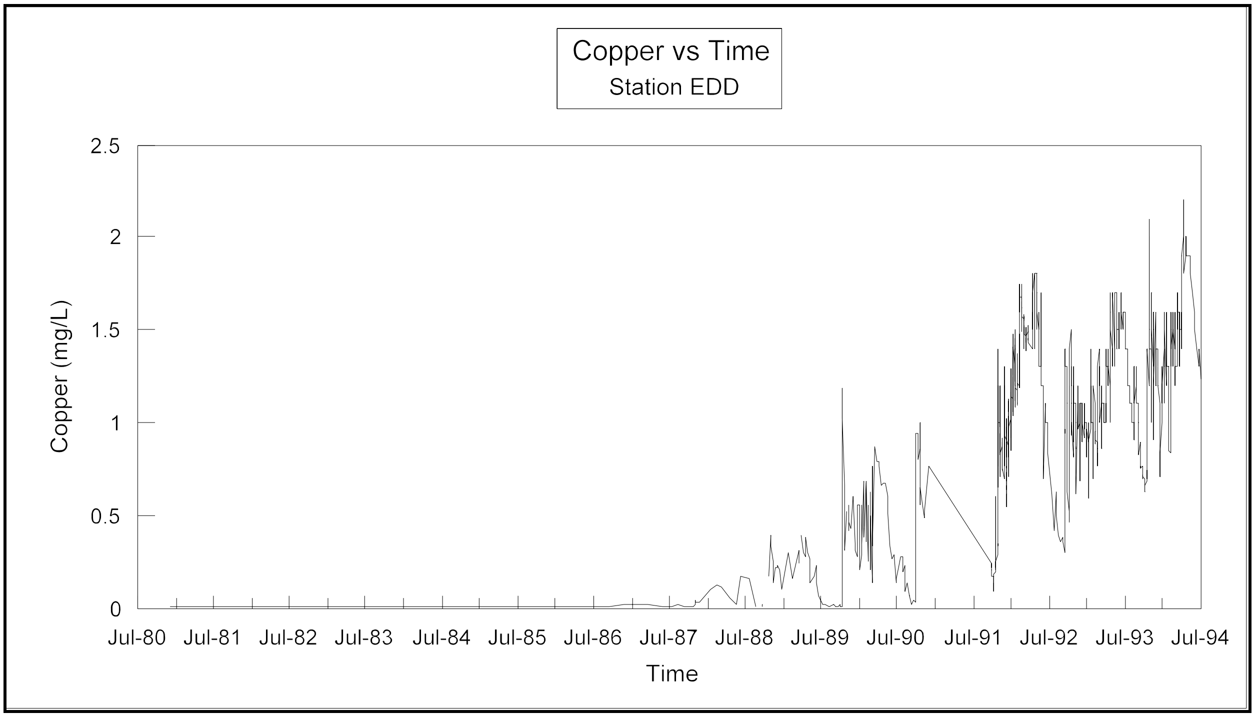

FIGURE 8. Temporal Trend of Aqueous Dissolved Copper at Station EDD.

Conclusion

A case study and conceptual model have been presented in this MDAG Internet case study to illustrate the onset of acidic drainage from a full-scale mine-rock pile. At the Island Copper Mine in British Columbia, the onset of acidic conditions involved a transition period of chemical fluctuations, from a few years (Station EDD) to perhaps a decade or more (Station NDD). The conceptual model shows that this onset is difficult to model and is highly location-specific. According to this model, the chemical fluctuations are due to the relative contributions and conditions in all upstream pathways. At Island Copper, all upstream pathways are expected to become acidic, so drainage from the on-land dumps is expected to become consistently acidic. At other minesites, some pathways may remain near neutral indefinitely so that ongoing fluctuations in water chemistry may become a long-term feature, with no persistent long-term net acidity.

Based on the two monitoring points (EDD and NDD), concentrations of sulfate show marked increases in concentrations, by a factor of two, about two years before the first appearance of acidic water (pH < 6.0). As a result, monitoring of aqueous sulfate at minesites with sulfide-bearing rock may provide warnings of any impending onset of acidic drainage, with sufficient response time to install remedial or control measures. However, sulfate will not act as a reliable indicator if its concentrations are already limited by solubility of minerals like gypsum, because the concentrations would not reflect actual reaction rates inside the mine-rock pile (e.g., Morin and Hutt, 1993).

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