

## Relocation and Submergence of Net-Acid-Generating Waste Rock for Control of Acidic Drainage: A Case Study

Kevin A. Morin and Nora M. Hutt<sup>1</sup>

### ABSTRACT

One technique for controlling ongoing acidic drainage is to relocate and submerge net-acid-generating waste rock in a lake or water-retaining impoundment. This can lead to the overall improvement of water quality and the reduction in short-term environmental liabilities. A case study of this technique is the Eskay Creek Mine in northern British Columbia.

Some findings of the study are: (1) the addition of lime to each truckload of rock, based on its rinse pH, neutralized the accumulated acidity and suppressed the accumulated-metal release, (2) only 10-20% of the dump's neutralization potential had been consumed when acidic drainage appeared, (3) water chemistry in the watershed recovered roughly three years after relocation, and (4) environmental liability was reduced due to the cessation of on-land acidic drainage with no degradation of lake chemistry.

### INTRODUCTION

Empirical observations, trial-and-error, and research have led to numerous techniques for the control of acidic drainage and accelerated metal leaching. These techniques can be combined into two general groups (Morin and Hutt, 1997a). The first is "proactive" where actions are taken beforehand to minimize acid generation, and the second is "reactive" where actions are taken in response to acid generation. There are times when the selected proactive approach fails, and a minesite must revert to a reactive technique. There are also times when a selected reactive approach is found later not to be the best solution, and so another technique is implemented. The objective of this paper is to present a case study of such situations, involving the eventual relocation and submergence of net-acid-generating waste rock. This paper is based on a study completed for the former Canadian Mine Environment Neutral Drainage (MEND) Program (Morin et al., 1997).

### GEOLOGY, MINERALOGY, AND GEOCHEMISTRY OF THE ESKAY CREEK MINE

The Eskay Creek Mine is an underground polymetallic mine, with high-grade ore containing gold- and silver-bearing base-metal sulphides including sphalerite, tetrahedrite, pyrite, and galena (Prime Resources, 1994). The five primary rock units are: hanging-wall andesite, hanging-wall argillite (or mudstone), the contact zone, footwall rhyolite, and dacite (T.W. Higgs Associates, 1993; Higgs et al., 1997). Physically, the grey rhyolite and black argillite range from hard and indurated to clayey and non-indurated. The fine-grained rock plays an important role in the hydrogeology and geochemistry of the waste-rock dump as explained below.

Based on more than 400 EPA-600 acid-base accounts (Sobek et al., 1978), most of the measured total sulphur in all rock units was acid-generating sulphide (Morin et al., 1997), and total sulphur was typically less than 5%S with a maximum of approximately 22%S. Additionally, neutralization potential (NP) ranged from negative values (net acidity) to more than 600 t CaCO<sub>3</sub> equivalent/ 1000 t. Most of the NP in fine-grained rock consisted of fast-reacting carbonate minerals, and most of the NP in coarser-grained rock consisted of slower-reacting aluminosilicate minerals. Approximately 15 t/1000 t of measurable NP was not available for neutralization based on a scatterplot of paste pH with NP (Figure 1), where paste pH is the pH measured in a "paste" of deionized water and pulverized sample.

Most samples (Figure 2) had negative values of Total Net Neutralization Potential (TNNP = NP - TAP, where TAP = 31.25 \* %S total). Therefore, a significant portion of all rock units had the capacity to generate net acidity at some point, and some were doing so at the time of analyses based on paste pH measurements.

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<sup>1</sup> Minesite Drainage Assessment Group (www.mdag.com), # 2401, 289 Drake St., Vancouver, B.C., Canada V6B 5Z5

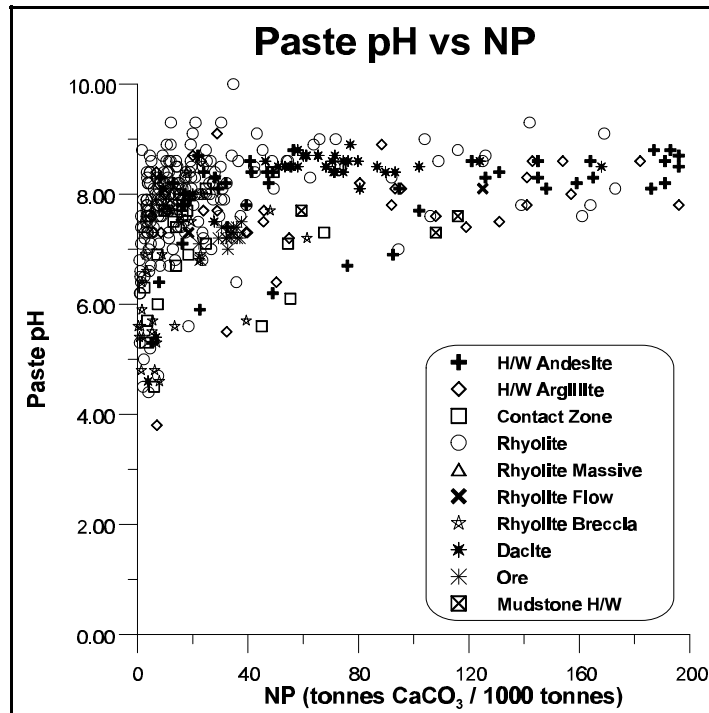


Figure 1 Scatterplot of paste pH vs neutralization potential for NP < 200 t/1000 t.

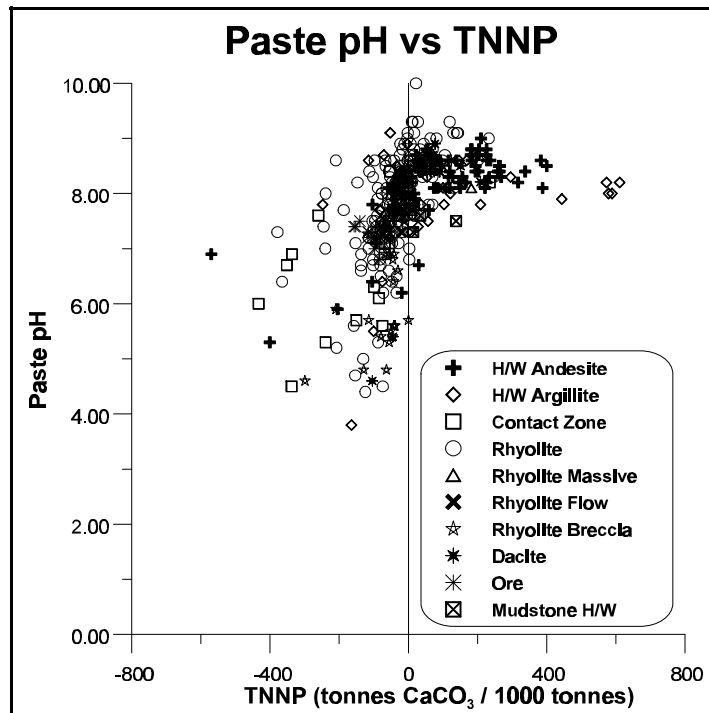


Figure 2 Scatterplot of paste pH vs total net neutralization potential [TNNP = NP - (%S total \* 31.25)].

Furthermore, there were 15 humidity cells conducted on various rock samples to obtain bulk primary-mineral reaction rates (T.W. Higgs Associates, 1993; Higgs et al., 1997). These cells were based on the Sobek technique (Sobek et al., 1978; Morin and Hutt, 2000a, these proceedings), and thus were designed to provide reaction rates, without the added complication of secondary-mineral precipitation that leads to the underestimation of primary rates. These cells, when compared to the International Kinetic Database (Morin and Hutt, 1997a; MDAG Publishing, 1999), showed that the bulk rate of oxidation was high to very high.

#### **CONSTRUCTION OF THE WASTE-ROCK DUMP**

The waste-rock dump at Eskay Creek was a Type 2 dump as defined by Morin et al. (1991) and Morin and Hutt (1997a). Such a dump resides entirely within a valley (Figure 3). Valley-wall runoff and groundwater both discharge into the waste rock in a relatively wet climate, like at Eskay Creek, and valley-bottom creeks flow into and through the base of the rock.

The Eskay Creek Dump (Figure 4) began with a basal pad of dacite in the summer of 1990, which was expected to neutralize acidity from rock placed above it. For the next few years, rock was then taken from the upper portal and then placed and dozed on the dacite pad. However, the final volume of waste rock, approximately 100,000 metric tonnes (t), was greater than expected and some of the waste rock extended off the edges of the pad. On the western edge of the dump, this caused some waste rock to be placed adjacent to an intermittent meltwater stream, which flows up to 8000 L/minute during snowmelt.

The final dump was approximately 350 m long in the southwest-northeast direction and roughly 80 m wide on average (Figure 4). The northeastern half was only a few meters thick at most, and at the elevation of the upper portal. The southwestern half was several meters higher in elevation, with a maximum thickness of approximately seven meters.

Some of the rock was non-indurated and clayey, and this formed a low-permeability cap over most of the dump. As a result, drainage was due to stream water passing through the lower layers, particularly during wet seasons.

#### **DRAINAGE CHEMISTRY FROM THE WASTE-ROCK DUMP**

Shortly after the dump construction began in 1990, drainage was reportedly near neutral pH. However, by the fall of 1992, drainage pH began fluctuating between 7 and 3, as flow in the stream increased and began moving through the waste rock. By winter, pH had reportedly stabilized around 3, with elevated concentrations of some metals like copper and nickel (Table 1). In response, Eskay Creek initiated water treatment using NaOH and lime, with settlement in a downstream pond.

#### **RELOCATION AND SUBMERGENCE OF THE WASTE ROCK**

Unfortunately, the dacite basal layer failed to prevent acidic drainage. Also, Eskay Creek was not satisfied with the requirement for ongoing water treatment and disposal of treatment wastes, or with the potential costs and environmental liabilities for long-term collection and treatment. As a result, the mine decided in 1994 to dig up the waste rock, relocate it to a nearby biological-barren alpine lake in an adjacent watershed, and submerge it under the lake water.

**Table 1 Approximate average annual drainage chemistry from the waste-rock dump at pH 3 (from Morin et al., 1997)**

Parameter	Concentration (mg/L)	Parameter	Concentration (mg/L)
Specific Conductivity	1450 $\mu$ S/cm	Alkalinity	0
Acidity	1080	Arsenic	0.780
Calcium	204	Cadmium	0.154
Cobalt	0.193	Copper	5.52
Iron	147	Nickel	1.45
Lead	0.217	Antimony	0.0093
Zinc	51.9		

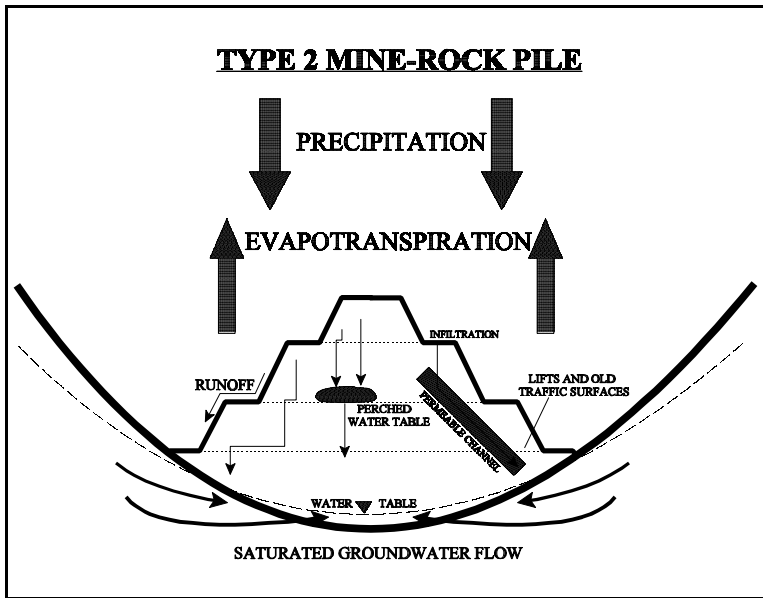


Figure 3 Schematic diagram of a Generalized Type 2 waste-rock dump (adapted from Morin and Hutt, 1997a).

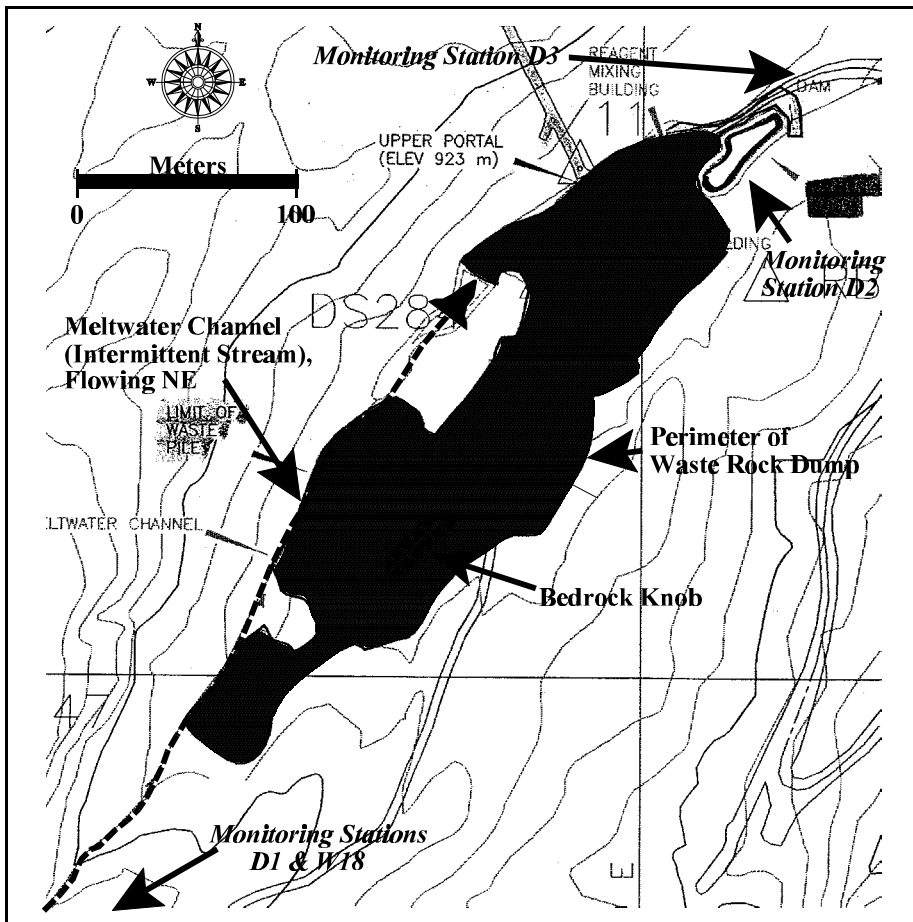


Figure 4 Map of the Eskay Creek Waste-Rock Dump based on mine files and maps.

In essence, the failure of proactive control by the dacite resulted in a reactive treatment scenario, and the mine decided to implement another control technique using underwater disposal to minimize acid generation and metal leaching. The Canadian MEND Program decided this should be documented for the benefit of other minesites (Morin et al., 1997).

Such relocation of actively acid-generating waste rock to an underwater disposal site has been carried out in the past. For example, on the west coast of Greenland, the Black Angel minesite included 320,000 t of waste rock draped down a slope into an adjacent fjord (Asmund, 1992a and 1992b; see also Case Study 6.3-1 in Morin and Hutt, 1997a). Pre-relocation leaching tests indicated the total volume of rock would immediately release 4.7 t of zinc upon initial submergence in the fjord, due to secondary-mineral accumulation over the years of weathering. This would be followed by slower releases of 48 kg Zn/yr decreasing after 50 years to 3.4 kg/yr. Monitoring confirmed the anticipated rapid release of zinc, as well as cadmium, lead, and other metals.

In order to avoid the rapid release of accumulated metals to the alpine lake, which could adversely affect downstream water quality, Eskay Creek carried out a series of batch tests with lime to raise pH and suppress metal solubility. This led to an empirical relationship between rinse pH of the rock (measured in a simple mixture of several liters of water and several kg of rock in a large pail) and the required amount of lime added to each truckload of rock.

Approximately 3000-4000 t of waste rock was moved in 1994 until bad weather halted the relocation. The relocation began again in 1995, with approximately 100,000 t of waste rock moved to the lake. This rock was first dumped onto a waste-rock pad extending into the lake, and a dozer later pushed the rock farther into the lake. After all rock was moved, the exposed rock of the pad was pushed into the lake until little rock was exposed above the water line.

#### **OBSERVATIONS FROM THE RELOCATION**

The following paragraphs summarize some of the important observations from the study (Morin et al., 1997).

1. The amount of lime added to each truckload of rock, approximately 10 t, was typically 10-35 kg (0.10-0.35%). While this was not enough to offset all potential acidity in the rock, its purpose was only to neutralize accumulated acidity and suppress metal release. The restricted oxygen under water and the background alkalinity in the lake would control future acid generation.
2. Initially, too much lime was added to the waste rock based on increasing lake pH, and the amount was reduced. In any case, the lime properly suppressed the release of accumulated metals, because no significant changes in metal concentrations were detected at the outlet of the lake.
3. Before being placed in a truck, the lime was added to the shovel containing waste rock just excavated from the dump. The truck then dumped the rock on the pad at the lake, and the rock was then pushed by dozer. Based on monitoring at the outlet of the lake, this provided sufficient mixing of the rock and lime to suppress the release of accumulated metals.
4. The trend of rinse pH with time, as rock was excavated from the dump (Figure 5), shows that there were occasionally large and continuous zones of purely acidic and purely neutral rock. In other locations, pH varied widely over short distances.
5. Two independent estimates of acid generation (humidity cells, and bags of lime plus cumulative drainage acidity) indicated the dump was generating 220-530 t of acidity as CaCO<sub>3</sub> per year. Because acidic drainage appeared within two years, only 10-20% of the dump's neutralization potential (NP) had been consumed at that point. Possible explanations for this apparent non-reactivity of the NP include (a) the shallowest rock with NP was not exposed to acidic drainage from the lower levels and (b) water was preferentially channelled into acid-generating rock and away from acid-neutralizing rock, which is the cause for unexpected acidic drainage at another waste-rock dump in British Columbia (Morin and Hutt, 1997b; Case Study 6.4-5 in Morin and Hutt, 1997a; Morin and Hutt, 2000b, these proceedings).
6. The dump contained fine-grained layers of rock, including an unintentional capping layer over most of the surface. These layers limited the amount of infiltration from precipitation. As a result, lateral flow of the intermittent stream through the lower rock was a key factor in flushing acidity and metals from the rock during wet seasons.
7. Detailed studies of flow through the fine-grained waste-rock layers employed dilute white latex paint to mark flowpaths, following the rationale of ElBoushi (1975). One such "paint flush" (PF) site showed that paint initially flowed downward almost vertically and then flowed laterally over a relatively fine-grained layer (Figure 6). However, a coarse pebble in the fine layer allowed some paint to pass through, demonstrating that a pebble could affect the local pattern of water movement through the waste rock and initiate channelling of vertical flow.
8. Total cost for the relocation and submergence was reportedly around CDN\$500,000, or about CDN\$5/t.

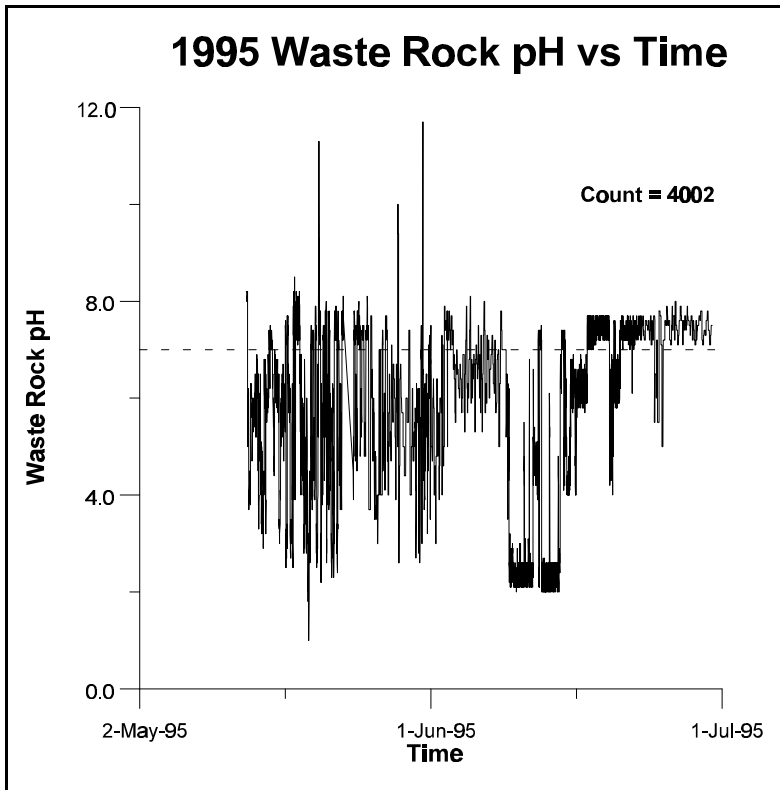


Figure 5 Time-series plot of rinse pH in excavated waste rock during relocation.

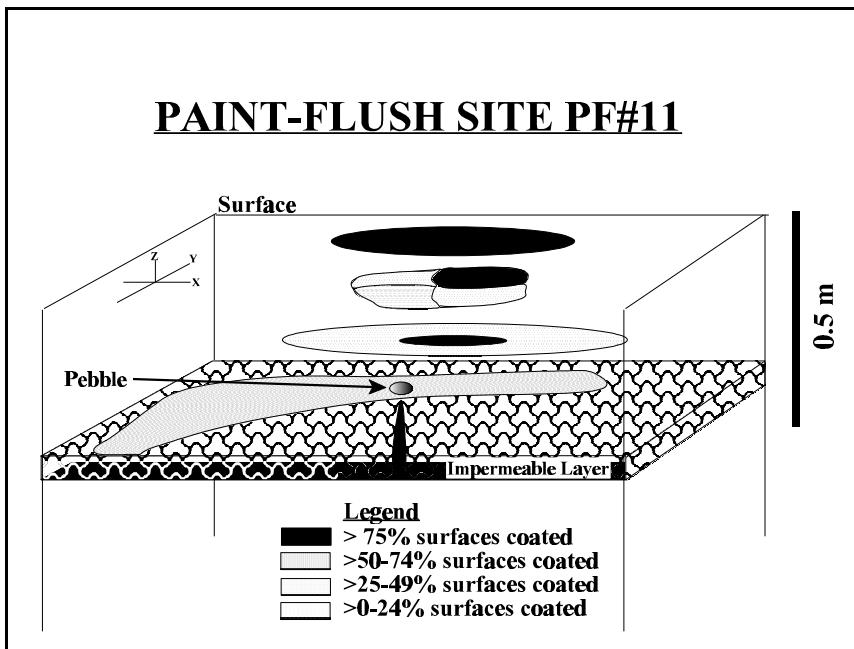


Figure 6 Vertical migration and lateral spreading of dilute latex paint applied at the surface of the waste rock.

### RECOVERY OF WATER CHEMISTRY IN THE WATERSHED AFTER RELOCATION

Because a major objective of the relocation was to improve the water chemistry in the valley's watershed and thus halt water treatment, an important issue was the time to recovery of background levels, which are relatively high in this mineralized area. During the summer of 1996, one year after relocation, pH in the watershed's water was relatively constant around 4.7, with zinc and lead up to approximately 5 and 0.2 mg/L, respectively. However, after three years, pH was roughly 7.0 with zinc and lead generally less than 0.2 and 0.009 mg/L, respectively. Therefore, approximately three years were needed to re-establish near-background concentrations. Meanwhile, concentrations within the lake in the adjacent watershed remained around background levels. Therefore, the relocation of the acid-generating waste rock to an underwater location provided a net benefit to the environment.

### CONCLUSION

Eskay Creek's initial plan for proactive control of acidic drainage by the basal dacite layer was not successful, and thus reactive collection and treatment was initiated. The mine's subsequent decision to relocate and submerge net-acid-generating waste rock into an alpine lake was made with attention to potential problems, like the release of accumulated acidity and metals. This lowered environmental liabilities and long-term treatment costs by (1) placing the rock underwater where its drainage no longer required treatment, as demonstrated by the background concentrations before and after submergence, and (2) restoring the water quality of the watershed where the dump was once located to near-background levels within three years.

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