



# Relocation of net-acid-generating waste to improve post-mining water chemistry

Kevin A. Morin\*, Nora M. Hutt

*Minesite Drainage Assessment Group, Suite 2401, 289 Drake Street, Vancouver, British Columbia, Canada V6B 5Z5*

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## Abstract

Acidic drainage and metal leaching are long-term environmental liabilities that can persist for many decades to millennia. One technique to improve the water chemistry and ecology of post-mining landscapes is to relocate and submerge net-acid-generating mine materials in a lake or water-retaining impoundment. One example of a carefully executed relocation of waste rock took place at the Eskay Creek Mine in Canada. Pre-relocation studies included an empirical relationship that related (1) the amount of acidity retained by the waste rock during past oxidation to (2) the amount of lime needed in each truckload for neutralization of the acidity and for suppression of metal release. During relocation, thousands of rinse pH measurements indicated net acidity varied significantly over short distances within the waste rock and that acidic rock could not be reliably segregated from near-neutral rock. After relocation, water from the watershed continued to be acidic for a few years, then returned to near-neutral pH and near-background concentrations of metals. The chemistry of the lake where the waste rock was submerged remains near background conditions. Therefore, with careful planning and implementation, the relocation and submergence of net-acid-generating materials can greatly improve post-mining water chemistry. © 2001 Elsevier Science Ltd. All rights reserved.

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## 1. Introduction

A major threat to post-mining ecology is long-term degraded water chemistry from waste rock, tailings, mine walls, or other minesite components. Degraded water chemistry can arise from two major geochemical processes, acidic drainage and enhanced metal leaching, which can persist for many decades to millennia. As a result, post-mining ecology can be degraded for many generations.

One technique to improve the water chemistry and ecology of post-mining landscapes is to relocate and submerge, into a lake or water-retaining impoundment, mine materials that are already releasing acidic, metal-laden drainage. Although simple in concept, such relocation is expensive and requires careful ecological and geochemical design to ensure there is a net benefit to the environment.

An example of such a relocation project is found at the Eskay Creek Mine, located 83 km north of Stewart, British Columbia, Canada. The mine is owned and

operated by Homestake Canada Inc. Economic metals at Eskay Creek are high-grade gold- and silver-bearing base-metal sulphides, primarily sphalerite, tetrahedrite, pyrite and galena. Eskay Creek's ore is mined through underground workings at a rate of approximately 300 metric tonnes (t) a day, with a mine life of approximately 10 years.

In order to document this relocation effort, Homestake Canada Inc. and the former Canadian MEND (Mine Environment Neutral Drainage) Program initiated a detailed study. The objectives of this study (Morin et al. [1]) were:

1. to summarize geochemical characteristics of Eskay Creek waste rock,
2. to describe the construction of the waste-rock dump,
3. to record the methods of relocation for the waste-rock dump,
4. to log visual examinations and collect samples of selected cut faces of exposed waste rock,
5. to visibly stain and examine small-scale flowpaths within the dump,
6. to document the evolution of water chemistry in the dump area, prior to dump construction until after relocation, and

\* Corresponding author. Present address: Suite 3301, 1199 Marine Crescent, Vancouver, British Columbia, V6Z 2Y2, Canada.

E-mail address: contact@mdag.com (K.A. Morin).

7. to examine the mass balance of acidity within the dump using two independent approaches.

Due to the large amount of data, not all these objectives can be discussed in detail here.

During mine development and the initial phase of mining in the early 1990s, approximately 100,000 t ( $1 \times 10^5$  t) of waste rock was placed in a narrow, shallow valley near the upper portal (Fig. 1). Within a few years, metal-laden acidic drainage began flowing from the dump, and active treatment with NaOH and lime was initiated. By 1994, long-term environmental liabilities and economics indicated that relocation and submergence were likely to be less expensive than long-term treatment. As a result, the mine carried out the relocation in 1994 and 1995, using 10-t trucks and placing the rock underwater in a nearby alpine lake. This lake is located at the top of a watershed with no fish and little biological activity. As a result, no major

local ecological impacts were expected within the lake, and no downstream impacts in the watershed were expected as long as the pre-oxidized waste rock did not release significant amounts of metals and acidity upon submergence.

## 2. Dump construction

The Eskay Creek waste-rock dump is a Type 2 dump as defined by Morin and Hutt [2]. These dumps reside in valleys and thus valley-wall runoff and basal creek flow are directed into and through the waste rock. The Eskay Creek waste-rock dump was built in the early 1990s, and is elongated in the northeast-southwest direction (Fig. 1). The areal extent of the dump is approximately 350 m by an average of 80 m. The approximate elevation of the northeastern half was roughly 923 m (same as the upper portal), whereas the southwestern half was several meters higher.

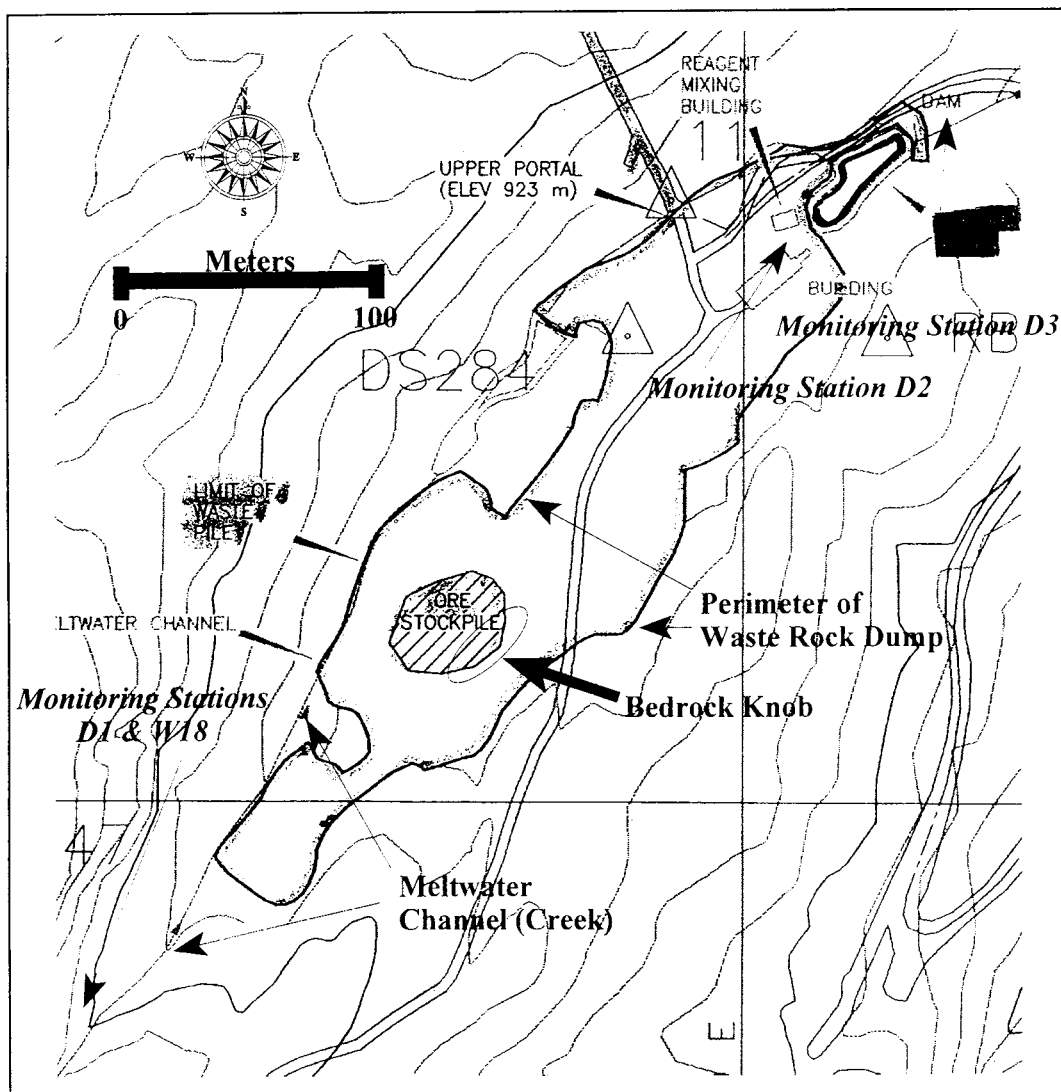


Fig. 1. Map of the Eskay Creek waste-rock dump (from prime resources files); contour interval 10 m.

so water drained toward the northeast. The greatest volume of waste rock was in the southwestern half.

In the summer of 1990, an acid-neutralizing basal pad of dacite was placed at the bottom of the small valley. Waste rock was then dumped and dozed as necessary. The first 30 m length of waste rock mined from the underground workings was already oxidized and this rock was likely placed directly over the dacite pad. The sericitic (clay-rich) rock of argillite and rhyolite was observed to form tight sealing layers in the dump.

Eventually waste rock was dumped outside the dacite-pad perimeter due to unanticipated volumes. In particular, some waste rock was placed adjacent to the intermittent stream or “meltwater channel” (Fig. 1) along the northwest side of the valley. This stream, with flows up to 8000 l/min, then occasionally flowed into and through the waste rock, aiding the flushing and transport of acidity and metals.

The basal dacite pad located under a portion of the dump was intended to neutralize acidic drainage through its neutralization potential and, from 1990 to the summer of 1992, the dump drainage was reportedly neutral. However, by the fall of 1992 as precipitation and diverted flows from the adjacent stream began increasing, pH began fluctuating between 7 and 3, although no correlation was noted between pH and flow. This transient behaviour during a wet season and the lack of correlation with flow have also been noted at other minesites [2]. By winter of 1992–1993, dump drainage pH had stabilized and remained around 3, with aqueous concentrations around those listed in Table 1. Collection and treatment of the acidic drainage were implemented.

Mass-balance calculations indicated that only roughly 10–20% of total neutralization potential within the waste rock was consumed before acidic drainage began. In other words, acidic drainage appeared while 80–90%

of the neutralizing capacity was still present. This may be the result of physical factors like channelling or stratification within the dump, which was noted in a detailed study of another acid-generating waste-rock dump in British Columbia (Case Study 6.4–5 in Morin and Hutt [2]). Mass balances for net acidity are discussed later.

### 3. Dump relocation

Relocation of the Eskay Creek dump began in 1994 and waste rock was transported by dump truck to a nearby lake. By the time poor weather halted the disassembly in 1994, only an estimated 3000–4000 t had been moved. In 1995, relocation resumed in early May and continued until August. A combined total of approximately 100,000 t of waste rock was excavated in 1994 and 1995.

Because the waste rock had been oxidizing for years and had retained some acidity and metals, the rock was capable of releasing significant loadings to the alpine lake upon submergence which could degrade downstream water chemistry. Such problems have occurred at other sites in the past. For example, movement of approximately 320,000 t of oxidized waste rock into a marine fjord at the Black Angel Mine in Greenland resulted in the rapid release of roughly 10 t of zinc into the fjord ([3,4]; Case Study 6.3-1 in Morin and Hutt [2]).

To suppress the rapid release of metals and acidity from submerged Eskay Creek rock, lime in 50-lb bags was added to every truck load as needed (Fig. 2), based on a laboratory-determined empirical relationship between rinse pH and required lime. To implement this, “rinse pHs” of excavated rock were measured dozens of times a day during relocation, by rinsing and soaking several kilograms of rock with distilled water in a large pail.

In 1994, rinse pH was measured at the top, middle, and bottom of each newly exposed face of waste rock. In 1995, rinse pH was measured at the top, middle, and bottom of each excavated pile of rock, but only the average value of these three was recorded and used to determine appropriate lime addition. The locations at which these pH values were measured were not recorded, because they were not important to the relocation. Nevertheless, the temporal trends in the values reveal the frequency with which acidic and neutral rock were encountered during relocation (Figs. 3 and 4).

The 1994 data showed that similar, but not identical, trends in rinse pH were found at all three vertical locations on the waste-rock faces (Fig. 3: values above 10 probably reflect cross-contamination with lime). As a result, the severity of the retained acidity was generally constant throughout a vertical profile. However, significant fluctuations in pH were encountered almost on a daily basis in the horizontal plane, but occasional

Table 1  
Approximate average annual drainage chemistry at pH 3 from the waste-rock dump at Eskay Creek Mine

Parameter	Average annual concentration (mg/l)
Specific conductivity	1450
Acidity	1080
Calcium	204
Cobalt	0.193
Iron	147
Lead	0.217
Zinc	51.9
Alkalinity	0
Arsenic	0.78
Cadmium	0.154
Copper	5.52
Nickel	1.45
Antimony	0.0093

## Eskay Creek Waste Rock Dump

### Lime Added vs 1995 Waste Rock Rinse pH

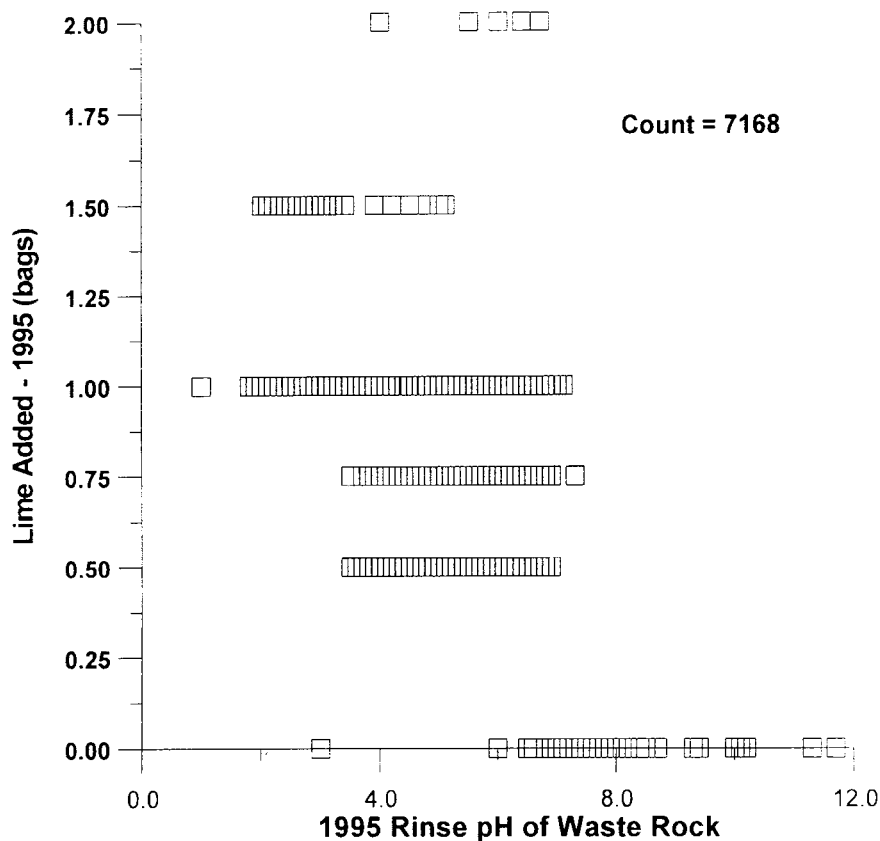


Fig. 2. Bags of lime added per truckload of waste rock based on rinse pH in 1995.

weeks of predominantly acidic or neutral conditions occurred. The neutral rock highlighted the abundant neutralization potential still remaining in the dump.

Again, pH could not be correlated with lateral location, because location was not important to the relocation and thus not recorded. Nevertheless, this showed that acidic and near-neutral rock could not be reliably separated, and thus all rock was relocated to the lake for submergence.

In 1995, the averaged vertical-profile values showed similar trends and behaviour as the 1994 data (Fig. 4). Consequently, there were again no extensive areas of acidic or neutral rock.

Detailed visual logging of four vertical profiles were conducted during relocation. Additional profiles were not warranted due to the relatively consistent physical layering within the dump, although chemical characteristics (rinse pH) were not. Strata ranged in grain size from silt to gravel, demonstrating that this dump was relatively fine grained compared to other, "hard-rock" dumps in British Columbia. In most locations where waste-rock thickness exceeded roughly 1.5 m, a well compacted shallow layer of silt (grey rhyolite or black argillite) was observed.

One objective of the study was to examine small-scale flowpaths through the Eskay Creek dump. To accomplish this, a durable, visible tracer was required, and white latex paint was used following the approach of ElBoushi [5]. Even a small amount of white paint would be visible on the rock which varied in colour between orange, grey and black. Also, the latex paint could be peeled off upon drying for inspection of underlying rock surfaces. A total of 12 paint-flush (PF) sites were established. However, at most PF sites, virtually none of the paint infiltrated over a 24-h period, indicating infiltration was too low to be measured. During this time, water from snowmelt also ponded in places on the dump. This reflected the relative impermeability of the surficial argillite and rhyolite that resembled a well compacted cap.

The conclusion from most of the PF sites was that (1) the rate of water movement vertically into most of the waste rock dump was minimal due to the silt cap and could not be measured with the technique and (2) the dump retained a large amount of acidity due to the minimized infiltration, which was demonstrated by the rinse pHs during relocation (Figs. 3 and 4). This also confirmed the major role of the adjacent intermittent stream,

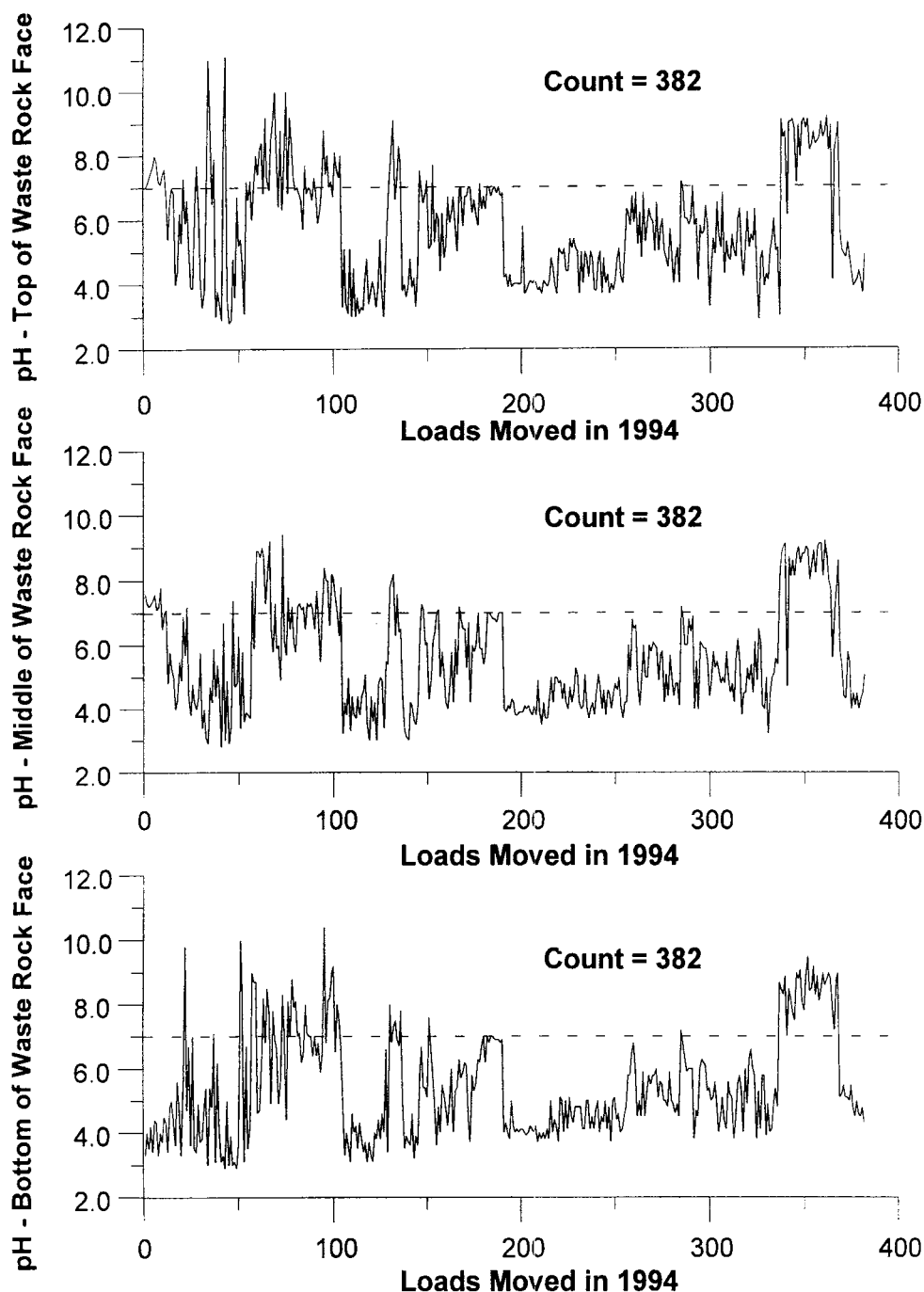


Fig. 3. Rinse pH from top, middle and bottom of waste-rock face in 1994.

which diverted water into and through the dump, in the mobilization of acidity and metals from the dump.

Another objective of this study was to assess acidity-generation balances for the dump using two independent techniques. The first technique used cumulative acidity in drainage prior to relocation plus retained acidity in the waste rock, leading to an estimated production rate of 530 t  $\text{CaCO}_3$  equivalent/year. The second technique applied acid-generation rates from small-scale laboratory kinetic tests to the entire mass of waste rock, indicating the production rate was 220 t  $\text{CaCO}_3$

equivalent/year. In light of these simplistic techniques applied to a complex waste-rock dump, the two results are considered to be in general agreement.

#### 4. Post-relocation recovery of water chemistry

Almost a year after dump relocation, acidic water around pH 4.7 with zinc up to 5 mg/l and lead up to nearly 0.2 mg/l was draining from the watershed where the waste rock had been, which was a considerable

## Eskay Creek Waste Rock Dump

### 1995 Waste Rock Rinse pH vs Time

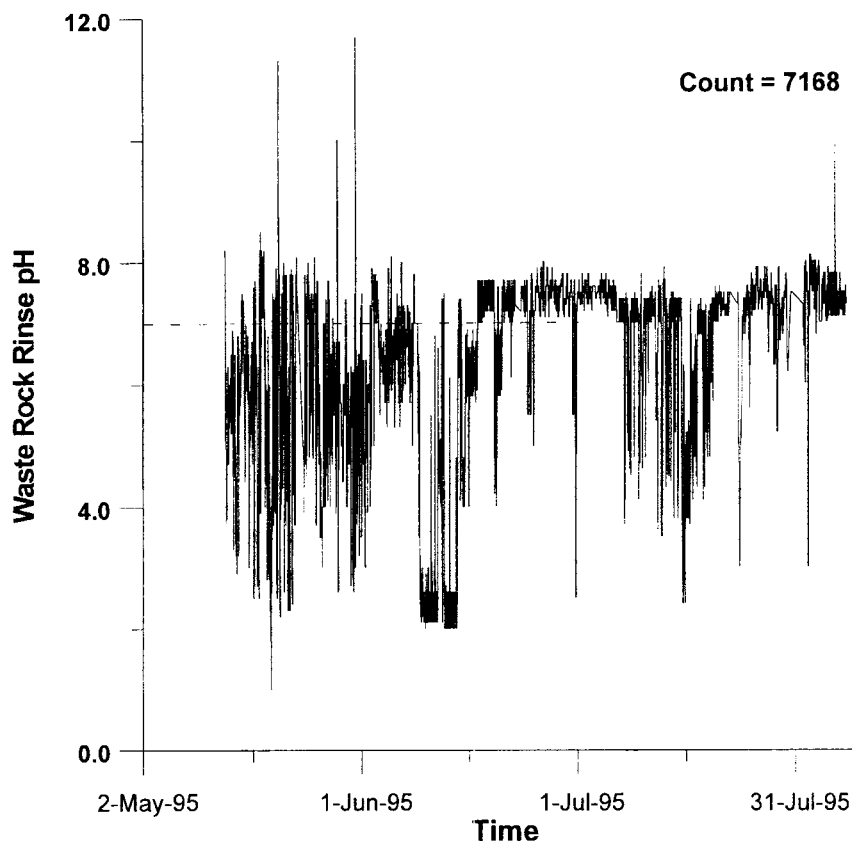


Fig. 4. Average rinse pH from excavated waste rock in 1995.

improvement from past levels (Table 1). Nevertheless, this water was still being treated at the time. However, after approximately 3 years, pH had recovered to near 7.0 with zinc concentrations generally less than 0.2 mg/l and lead concentrations less than 0.009 mg/l. Therefore, recovery to near-background concentrations required less than 3 years. Also, the chemistry of the lake receiving the waste rock remained near background levels during and after the relocation. As a result, this approach can be used to greatly improve acidic post-mining water chemistry if designed and implemented carefully.

#### Acknowledgements

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