A TALE OF TWO PIT LAKES – THE KEMESS MINE EXPANSION

Rob Marsland, P.Eng. [1]
Rob Booker, MIE Aust. [2]
Harold Bent, P.Geo. [3]

1. Marsland Environmental Associates, 203 West Beasley St., Nelson, BC V1L 3K4
2. Klohn Crippen Consultants, Suite 500-2955 Virtual Way, Vancouver, BC V5M 4X6
3. Northgate Minerals, PO Box 3519, Smithers, BC V0J 2N0

ABSTRACT

Northgate Minerals is currently considering expanding their Kemess Mine operation to include the nearby Kemess North open pit. As part of the environmental impact assessment, post-closure pit pond hydrologic and water quality models were developed for both the existing Kemess South open pit and the proposed Kemess North open pit. This paper describes the methods used to develop the models and compares the approach taken for the two pits.

INTRODUCTION

The Kemess mining and milling operation is located in the mountains of north-central British Columbia, 250 kilometres north of Smithers. The operation currently consists of the Kemess South open pit mine and a 52,000 tonnes per day mill. 300,000 ounces of gold and 75 million pounds of copper are produced annually with ore reserves to last until Q1 2009.

The proposed Kemess North operation involves open pit mining the Kemess North deposit, located approximately 5.5 kilometres north of the Kemess South open pit, and increasing the milling capacity to approximately 100,000 tonnes per day. Copper and gold concentrate would continue to be produced with ore reserves to last approximately 14 years. The location of the Kemess Property is shown in Figure 1 and the relative location of Kemess South pit and Kemess North area is presented as Figure 2.

The final walls of both pits contain potentially acid generating rock units and in the case of the Kemess North open pit, a Gossan Zone is already acid generating. Following completion of mining, the Kemess South open pit would be filled with potentially acid generating waste rock from Kemess South and tailings from milling of Kemess North ore. In contrast the Kemess North open pit would slowly fill from direct precipitation, runoff and groundwater inflow.

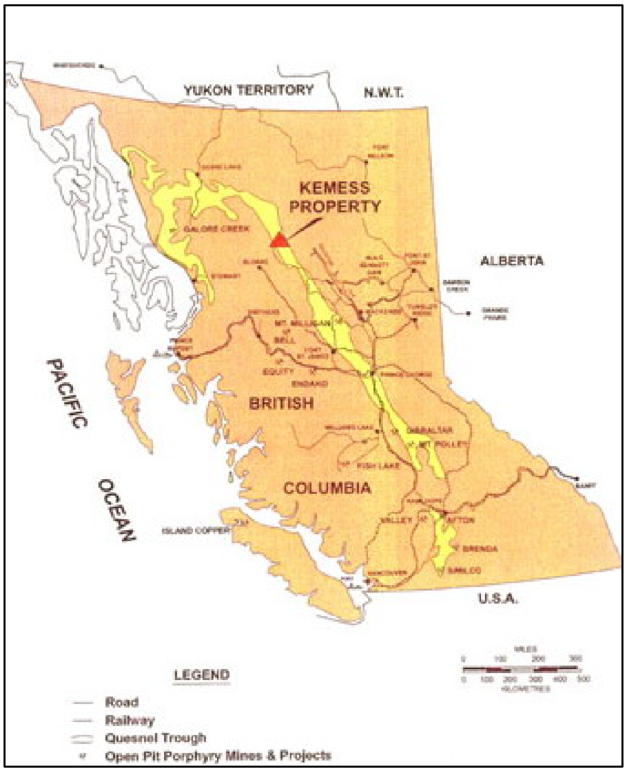

Figure 1 Kemess Property Location

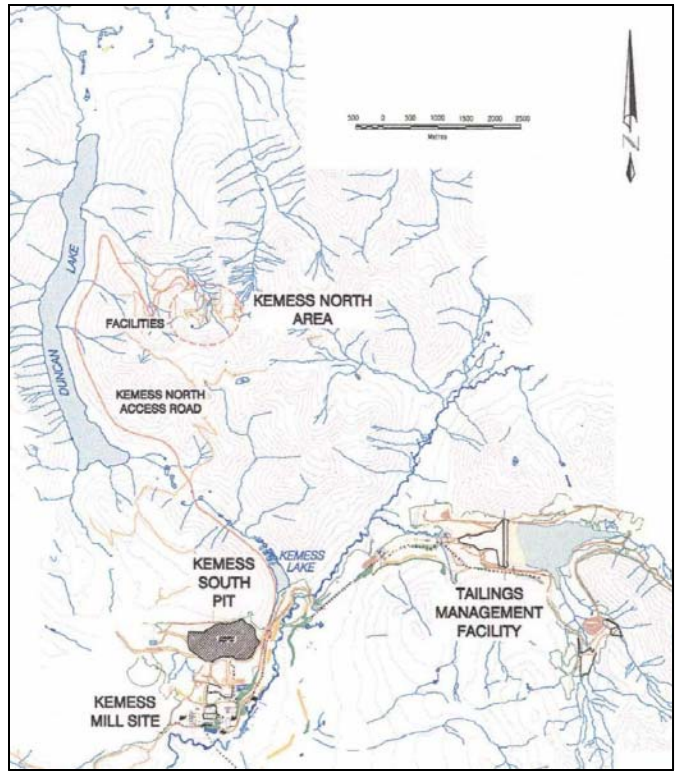

Figure 2 Relative Location of Kemess South and Kemess North

SITE DESCRIPTION AND GEOLOGY

Both the Kemess North site and the existing Kemess South open pit have small catchment areas due to their location high on ridges in mountainous terrain. Total precipitation exceeds total evaporation at the Kemess site, however, monthly evaporation exceeds monthly precipitation from May to August. Runoff is seasonal with 60% of the annual runoff occurring during May and June.

The Kemess North deposit is a low-grade porphyry dome deposit. The four main rock mass units are an upper gossanous zone, the Toodoggone Volcanic unit, the Takla Volcanic (containing also a Bladed Feldspar Porphyry (BFP)) unit and the Intrusive Monzonite unit. In addition to these main four rock mass units a Broken Zone (weathered zone caused by the oxidation of pyrite producing secondary iron oxide minerals) is present within the Gossan Zone and a Sovereign Pluton rock unit is present to the south of the proposed open pit.

Each rock unit was designated a specific geochemical class based on their respective geochemical properties as outlined in Table 1.

Table 1 Geochemical Classification

PASTE pH	ROCK UNIT	GEOCHEMICAL CLASS
pH ≤ 6, NPR<0.1	Gossanous Takla and Gossanous BFP	Acid Generating
6 < pH ≤ 7.5, NPR <0.6	Takla and BFP	
pH > 7.5, NPR<1	TDG and Intrusive	Potentially Acid Generating
pH>7.5, NPR >1	TDG, Takla, BFP	Uncertain
pH>7.5, NPR>3	TDG	Non-acid generating

Rock units with a paste pH of less than pH 7.5 were considered to be already surface acid generating. Therefore, the gossanous material and the Takla and BFP rock units were considered to be acid generating rock units. Rock units with a paste pH greater than pH 7.5 were considered to be potentially acid generating; however, concentrations of solutes leaching from rock units with a paste pH greater than pH 7.5 are insignificant. Therefore, the Toodoggone Formation and Intrusive rock units were considered to be potentially acid generating rock units with insignificant leaching potential.

The Kemess South deposit is a low grade copper-gold porphyry deposit that unlike the Kemess North deposit does not have an already acid generating Gossan Zone. The four potentially acid generating rock units that occur above the final pit lake level are Hypogene Ore, Hypogene, Asitka (Takla) Group and Asitka (Takla) Group Graphitic Sediments.

KEMESS NORTH PIT WATER QUALITY MODEL

The objective of the Kemess North pit water quality model was to estimate the chemistry and hydrology of the pit water as the pit lake forms and once it overflows. Key parameters of concern for the pit water quality were determined from the results of ICP scans of rock samples representative of the pit wall rock (to determine elements greater than 5x crustal values), surface water quality results from the existing site drainage (indicating which parameters currently exceed BC Water Quality Objectives), and the results of shake flask tests on rock samples representative of the pit wall rock (indicating which elements are most mobile).

The Kemess North pit water quality model was set up using Microsoft Excel and consists of a number of worksheets performing different functions with the end goal of determining the pit lake water quality. A schematic of the Kemess North pit water quality model when the pit is full and overflowing is presented as Figure 3.

During preparation of the pit lake water quality model all available information was gathered to construct as accurate a model as possible with the current level of understanding of the pit area. When available data was not sufficient to model how certain processes are likely to operate in the pit lake, such as biological and photochemical reactions and climate change, they were not incorporated into the model.

The time step used for the model was determined from the water balance model. In turn the time step in the water balance model was the time taken for the pit lake to rise from one 15 metre elevation interval to the next 15 metre elevation interval. Hence, the time step was initially quite small and then increased to a maximum value immediately prior to initial overflow.

In order to estimate post-mining drawdown of the water table and to estimate seepage rates into the Kemess North open pit, both steady state and transient finite element seepage analyses were undertaken using the Computer Program SEEP/W, written by Geo-Slope International. Seepage inflow rates, precipitation, evaporation, runoff and open pit characteristics were input into a water balance model to determine the time taken to fill the pit and to estimate the rate of pit overflow.

As stated previously, the Kemess North deposit is capped by a Gossan Zone, which is already generating acidic drainage. Measuring the concentration of metals in the drainage from the Gossan Zone enabled the leaching rates from the Gossan Zone to be determined in milligrams of metal per tonne of rock per month. From grain size distribution analyses it was estimated that only 10% of the rock mass contributed loads at the calculated leaching rate. The larger competent rocks provide negligible surface area and hence negligible load compared to the reactive fine fraction.

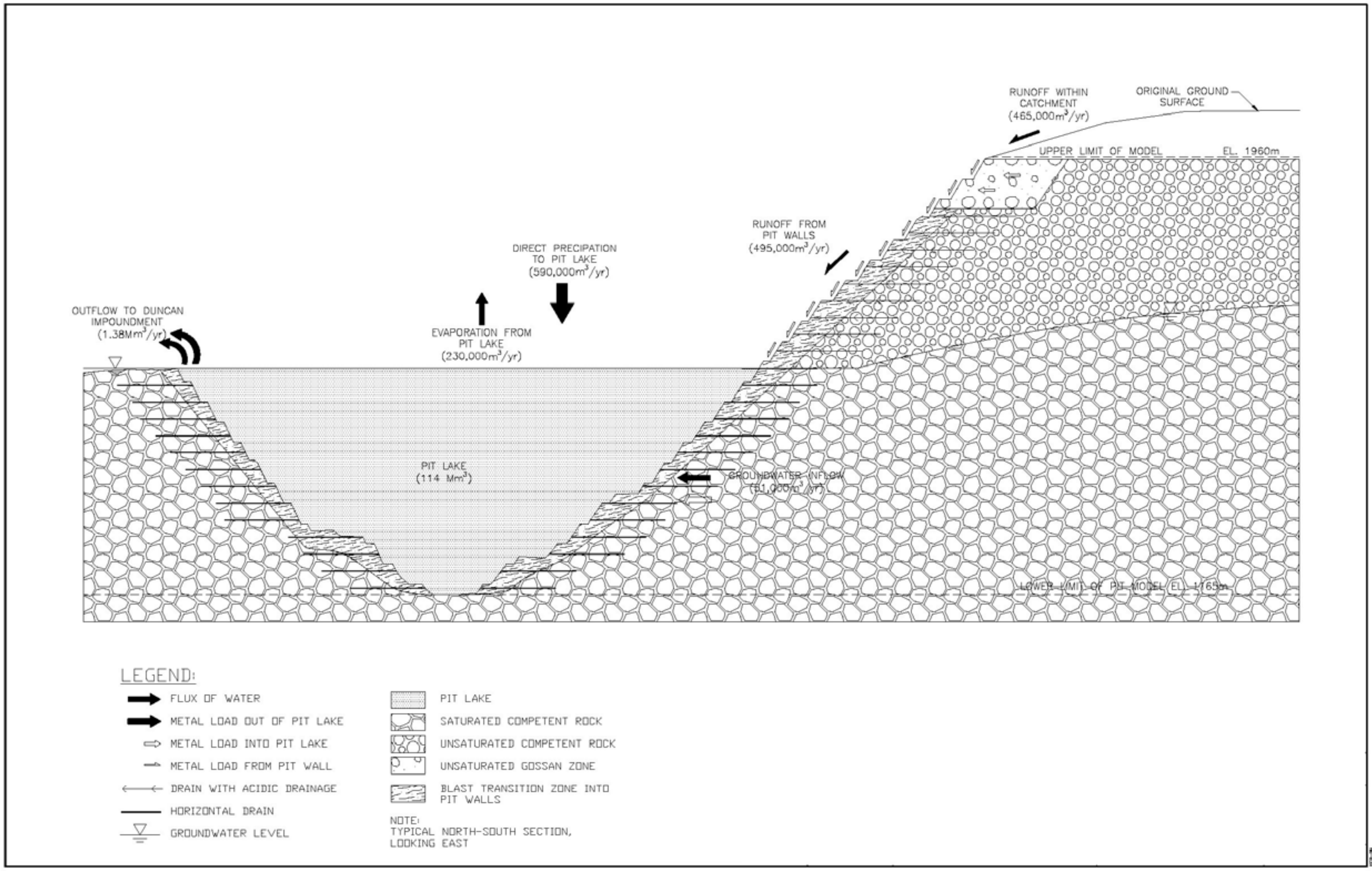

Figure 3 Schematic of Kemess North Pit Water Quality Model Following Initial Overflow

With the water balance model complete and leaching rates established, the next challenge was how to apply leaching rates calculated in milligrams of metal per tonne of rock per month to pit wall surface areas. This challenge was overcome by calculating the volume, and hence tonnage, of rock within the blast transition zone into the pit walls. The fractured and influenced zones comprising the blast transition zone into the pit walls were estimated based on the proposed blasting practices for the Kemess North open pit. Once again, based on the anticipated grain size distributions within the fractured and influenced pit wall rock, the percentage of rock mass contributing was estimated at 10% and 5%, respectively.

The concentration of metals in groundwater inflow from saturated rock surrounding the pit was set as the background concentration established through baseline groundwater quality monitoring. Water draining from unsaturated horizontal drains drilled into the pit walls (required to maintain stability of the pit walls) was also considered as a source of metal load into the pit lake.

A 15 year lag time to the onset of acid generation from the time of exposure was calculated based on the acid production and neutralization consumption rates observed during kinetic testing of Kemess North waste rock. The model was set up so that acid generation ceased as soon as acid generating rocks become saturated. Hence the acid generating rock units in the bottom of the pit never generate acid as they are not exposed for more than 15 years before being saturated by the rising pit lake. This approach necessitated the pit to be divided into 15 meter intervals so that once a certain interval became saturated it could be shut down. In contrast, the Gossan Zone has no lag time to acid generation and, due to the uneven topography is never saturated by the rising pit lake as it is present on the highwall of the pit rim.

The water balance and geochemical models were combined, in the form of a dilution model, to predict the pit lake water quality.

KEMESS SOUTH PIT WATER QUALITY MODEL

Similar to the Kemess North pit water quality model, the Kemess South pit water quality model was set up in Microsoft Excel with the purpose of estimating the chemistry and hydrology of the pit water as the pit lake forms and once it overflows.

The proposed filling plan for the Kemess South open pit involves returning approximately 13 Mt of potentially acid generating Kemess South waste rock back into the pit during the first year following closure of the mine. Another 75 Mt of tailings from the milling of Kemess North ore would then be deposited into the pit. The Kemess North tailings would be deposited on the Kemess South waste rock over a period of approximately two years and would result in the solids volume within the pit approaching an elevation 45 m below the lowest point of the pit rim. Should tailings deposition cease at this point, overflow of the pit lake is estimated to occur 25 years following cessation of tailings deposition. This delay would allow monitoring of the pit water to occur prior to overflow into receiving waters. A schematic of the Kemess South pit water quality model once the pit is full and overflowing is presented as Figure 4.

The time step used for the model was varied from a monthly time step during the rapid filling of the pit with waste rock and tailings to a yearly time step following completion of the tailings deposition phase.

Sources of metal load to the pit lake considered in the Kemess South pit water quality model were load from potentially acid generating Kemess South waste rock, tailings water from milling of Kemess North Ore, and potentially acid generating pit walls above the final pit lake level. Loads from the potentially acid generating pit walls and from groundwater inflow were the only continuing sources considered in the model.

Results of shake flask tests undertaken on Kemess South waste rock provided an estimate of the initial flush of soluble metals when the rock is initially deposited into the pit. The model assumes any metals that went into solution in the shake flask test will also go into solution from the waste rock when it is placed in the pit and flooded. The waste rock would be at the bottom of the pit and completely covered with tailings within one year, therefore, no on-going loading rate from the waste rock was considered in the model.

In the model, the solid portion of the Kemess North tailings are assumed to have no solute load, rather the tailings water contains the soluble metals. The total concentration of metals was measured in the supernatant water of Kemess North tailings produced in laboratory scale locked-cycle metallurgical tests. These concentrations enabled calculation of a metal load for each metal entering the Kemess South pit in the tailings water.

The loading rates for the potentially acid generating wall rock units were sourced from column (lysimeter) leaching test results. The column weathering tests were conducted on fine grained material over a 43 month period. To account for the much coarser rock of the blast fractured pit walls a fraction of rock mass contributing function, similar to that used for the Kemess North pit water quality model, was applied to adjust the column leaching rates to field conditions. The mass of fractured and influenced pit wall rock was calculated using the same procedure as used for the Kemess North open pit.

The concentration of metals in the groundwater inflow from saturated rock surrounding the pit was set as the background concentration established through compilation of baseline groundwater quality monitoring undertaken prior to construction of the Kemess South open pit.

The water balance model combined with the volumes of material entering the pit from the open pit filling plan was used to calculate the time it will take to fill the pit and rate of pit overflow. To predict the pit water quality, loads from Kemess South waste rock, Kemess North tailings water, potentially acid generating pit walls and groundwater inflow were calculated and incorporated with the water balance model and volumes of material entering the pit.

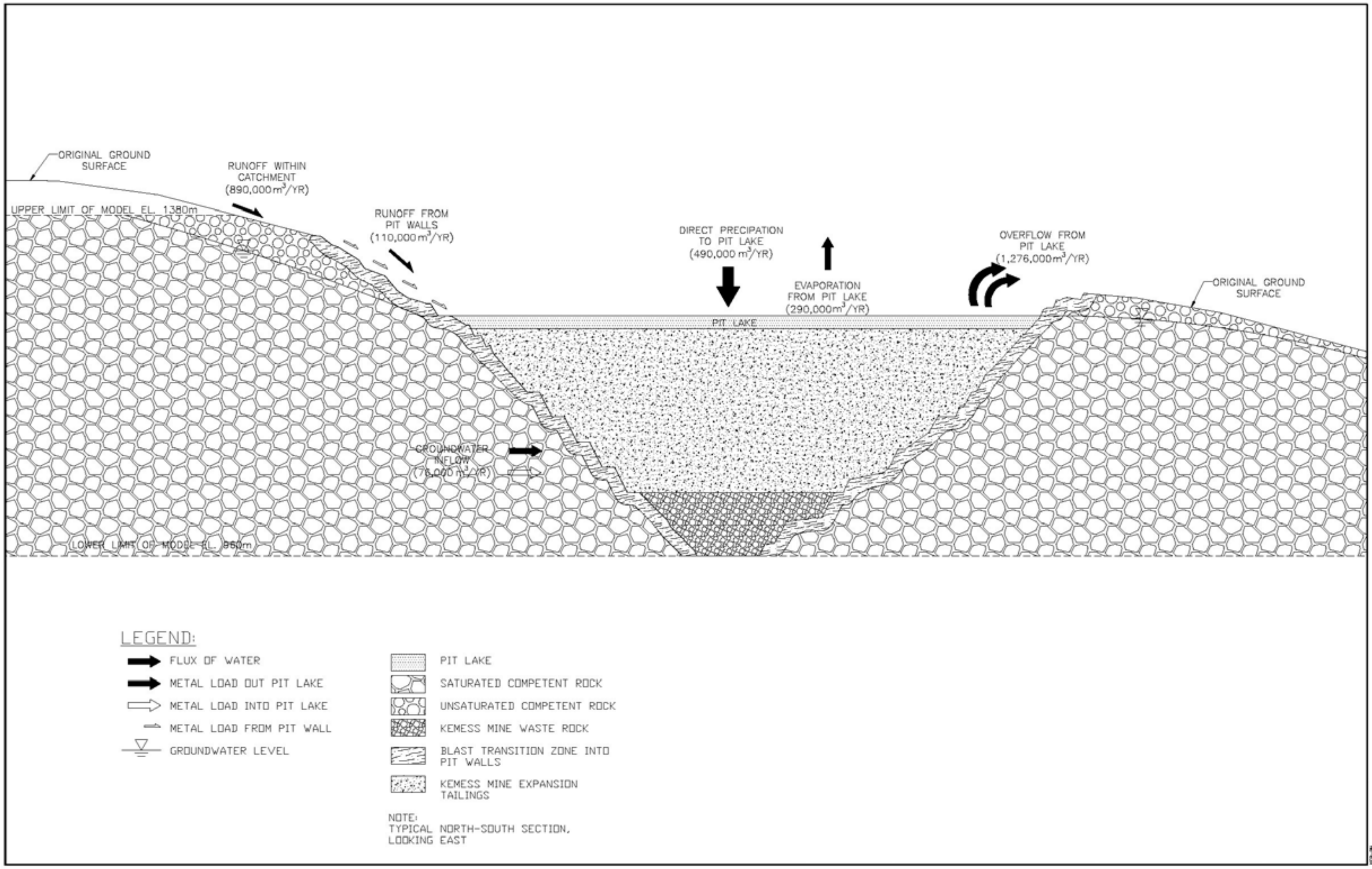

Figure 4 Schematic of Kemess South Pit Water Quality Model Following Initial Overflow

RESULTS AND COMPARISON

Direct precipitation, runoff and groundwater inflow is predicted to fill the Kemess North pit in approximately 80 years, after which time it would overflow at a rate of 1.4 Mm^3/year. The Kemess South pit, which is of similar volume, would take approximately 70 years to fill from precipitation, runoff and groundwater inflow. However, due to waste rock and tailing deposition the Kemess South pit is expected to begin to overflow 25 years following cessation of mining, at a rate of 1.3 Mm^3/year.

The predicted water quality of the two pit lakes is substantially different as is the variation in pit water quality over time and relative contribution of load from different sources. During all stages (from initial filling to during overflow) the Kemess North pit lake water quality remains fairly constant with the Gossan Zone being the main source of metal load to the pit lake. The final pit lake has an acidic pH with elevated concentrations of some metals.

In contrast to the Kemess North pit lake, the Kemess South pit lake has distinct filling phases each with different water chemistry. The pit water quality is initially controlled by the metal loads flushed from Kemess South waste rock, by rainfall, as it enters the pit. However, once tailings begin to be disposed in the pit, the water quality is controlled by the concentration of metals within the tailings slurry water. Ultimately, the long-term water quality of the pit is determined by the loadings from the acid generating wall rock and loadings from groundwater flowing into the pit. The affect these distinct filling phases has on the pit lake water quality are that metal concentrations are initially high during waste rock deposition phase. During tailings deposition the concentrations of metals in the pit are constant and lower than that during the initial phase. Following cessation of tailing deposition the water quality improves until it asymptotes at an ultimate concentration determined by the load from groundwater inflow and leaching from the pit walls only. The ultimate pit water quality is expected to be at near-neutral pH with generally low metal concentrations.

The ultimate pit water quality of both the Kemess North pit lake and Kemess South pit lake is controlled by metal loads from the pit walls and from groundwater inflow. The Kemess North pit lake also has the additional load from the Gossan Zone, which forms the top of the Kemess North pit rim. Despite this difference, in each model the ultimate pit water quality is independent of how the pit is filled. Back-filling of the pit does, however, influence the initial overflow pit water quality. Differences in the ultimate pit water quality of pit lakes are due to differences in the continuing sources of metal load to the pit lakes. This observation ignores the water quality effects that may result over time from having a shallower pit lake and the potential for aquatic plants to grow in the tailings contained within the Kemess South pit.

The significance of the predicted water quality and the potential downstream environmental effects will be addressed in detail in the joint CEAA/BC EAO Panel Review Project Report.