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# Technical Memorandum

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| **To:** | Kathy Arnold | **From:** | Amy Hudson, REM |
| **Company:** | Rosemont Copper Company | **Date:** | January 14, 2010 |
| **Re:** | Minimum Thickness Analysis for Waste Rock Placed Over Spent Heap Leach Ore Material | **Doc #:** | 041/10-320832-5.3 |
| **CC:** | David Krizek (Tetra Tech) | | |

## 1.0 Introduction

This technical memorandum presents Tetra Tech's infiltration and seepage modeling associated with a waste rock cover over the proposed Heap Leach Facility for the Rosemont Copper Project (Project) in Pima County, Arizona. The purpose of this modeling was to assess the minimum thickness of waste rock needed on top of the heap in order to minimize meteoric water from infiltrating into the spent ore. The modeling was completed using both the VADOSE/W and CTRAN/W programs from the GeoStudio 2007 software package (GEO-SLOPE, 2007). Modeling was performed on the final Heap Leach Pad configuration (approximately 129 acres).

## 2.0 Model Construction

After leaching is complete, the heap will be allowed to drain for approximately two (2) to three (3) years before the ponds located at the base of the heap are covered with waste rock. Based on modeling, the flow rate from the heap will be less than ten (10) gallons per minute (gpm) at the end of the two (2) to three (3) year period. This represents a near steady-state condition prior to the addition of waste rock over the spent ore. Waste rock may be placed over the spent ore prior to the ponds being covered.

The conceptual model provided as Illustration 1 shows the system water balance components after this three (3) year drain-down period. The system water balance components consist of:

- Precipitation;
- Evaporation;
- Runoff;
- Infiltration; and

▪ Seepage.

Seepage includes continued drain-down of the residual leach solutions, as well as any infiltration that reaches the bottom of the heap. A waste rock cover is also shown on Illustration 1.

During operation and the initial two (2) to three (3) year drain-down period following the cessation of leaching, it is assumed that both runoff and seepage will be collected in the double-lined PLS Pond located at the base of the Heap Leach Pad. Therefore, the Heap Leach Facility will be a zero (0) discharge facility with the seepage being collected in the PLS Pond. At closure, and following the placement of waste rock over the spent ore material and over the former PLS and Stormwater Ponds, only drain-down seepage will report to the base of the heap. Separate technical memoranda were prepared to describe closure of the PLS and Stormwater Ponds.

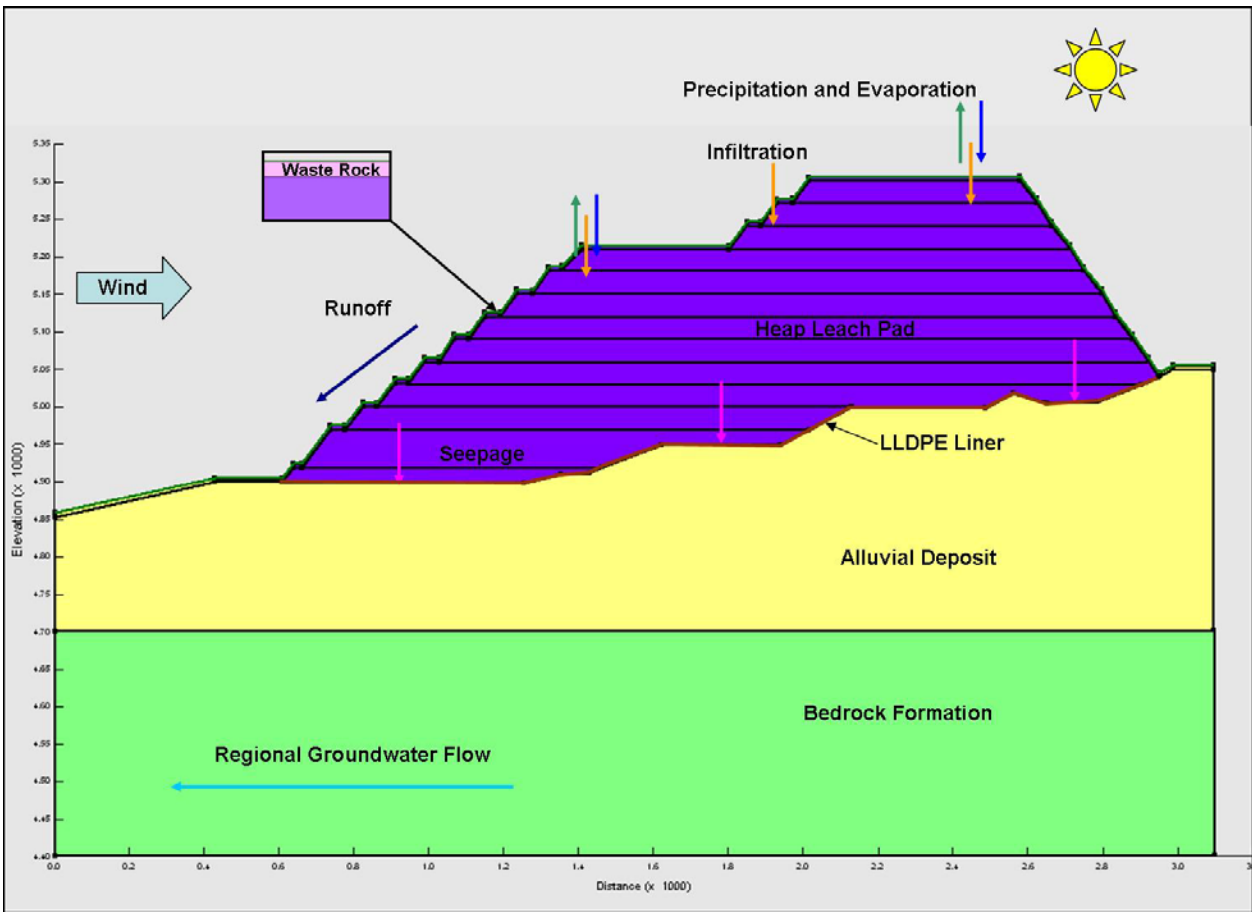


**Illustration 1 Heap Leach Pad Conceptual Model**

Modeling was performed with waste rock placed over the spent ore ranging in thickness from five (5) to 25 feet. Additionally, modeling was completed with and without a one (1) foot layer of soil added to the surface of the waste rock cover. In summary, the various scenarios modeled included:

- Five (5) feet of waste rock with and without a one (1) foot of soil layer on the surface;
- Ten (10) feet of waste rock with and without a one (1) foot of soil layer on the surface;
- Fifteen feet of waste rock with and without a one (1) foot of soil layer on the surface;
- Twenty feet of waste rock with and without a one (1) foot of soil layer on the surface; and
- Twenty five feet of waste rock with and without a one (1) foot of soil layer on the surface.

## 2.1 Model Input Parameters

Site specific climate data was used in the model to evaluate the infiltration and seepage of meteoric water. The parameters in the climate data file included:

- Minimum and maximum daily temperature;
- Daily precipitation;
- Minimum and maximum daily humidity;
- Daily evaporation or net radiation; and
- Average daily wind speed.

The average climate conditions data set is an average of over 50 years of daily measurements taken at the Nogales 6N Meteorological Station located approximately 30 miles from the Project site. This analysis only considers the average climate conditions and does not include any specific storm events.

Unsaturated flow parameters of the materials used in the model where taken from both laboratory and library data sets. Both the ore placed on the Heap Leach Pad and the waste rock placed on the spent ore will be run-of-mine (ROM) sized material. The ROM material was modeled with a permeability of 170 feet per hour (ft/hr) ($10^0$ cm/sec). This is equivalent to a coarse material with a broad distribution of sizes (poorly sorted) from gravel (0.1 inches) to large boulders (greater than 12 inches).

The primary difference between the spent ore and the waste rock is the moisture content of the material. The waste rock is expected to have a moisture content of less than ten (10) percent by volume when it is placed on the surface of the heap. The spent ore moisture content is expected to be higher than the waste rock due to leaching during the heap operation. A moisture content of about 15% is anticipated for the spent ore. Additionally, the soil cover material used in the modeling had a grain size ranging from gravel to fines and a permeability of 10-5 cm/sec based on field testing results as documented in the Geotechnical Addendum (Tt, 2009).

## 2.2 Modeling Technique

The waste rock thickness analysis was completed in two (2) separate steps. The first step involved seepage and infiltration modeling using VADOSE/W (GEO-SLOPE, 2007a) to determine the flux into the spent ore and the moisture content of the soil layer, waste rock cover material, and the spent ore. The next step was particle tracking using CTRAN/W (GEO-SLOPE, 2007b) to determine the path of the water flow, including the direction of flow (into the facility [infiltration] or out of the facility [evaporation]). The following sections provide more detail on these two (2) model steps.

## 3.0 Model Results

Modeling results are presented below as graphs comparing the various cover scenarios presented in Section 2.0. Illustrations 2 and 3 present the results of the five (5) waste rock only scenarios. Illustration 2 presents the flow (flux) of water into and out of the spent ore over a period of one (1) year while Illustration 3 presents the change in moisture content at the upper surface of the spent ore. Illustrations 4 and 5 present the results of the five (5) combined waste rock/soil layer scenarios. Illustration 2 presents the water flux, and Illustration 5 presents the moisture content at the upper surface of the spent ore.

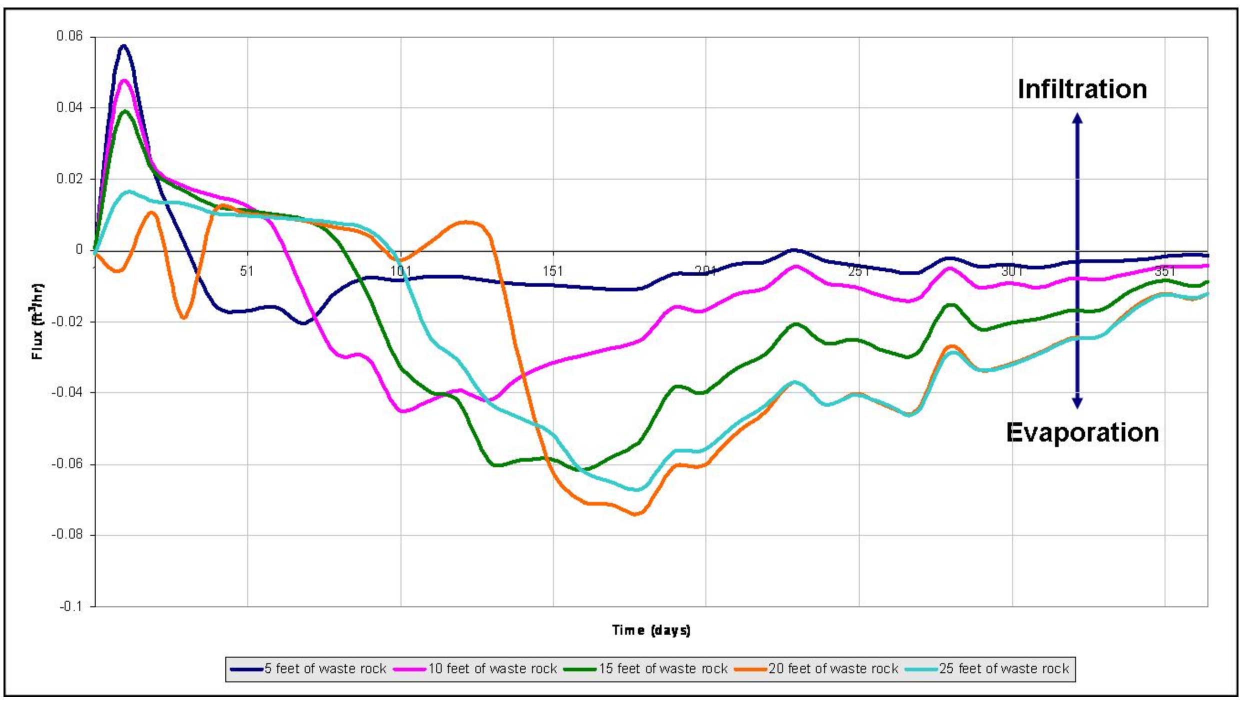


**Illustration 2 Water Flux – Waste Rock Only Over Spent Ore**

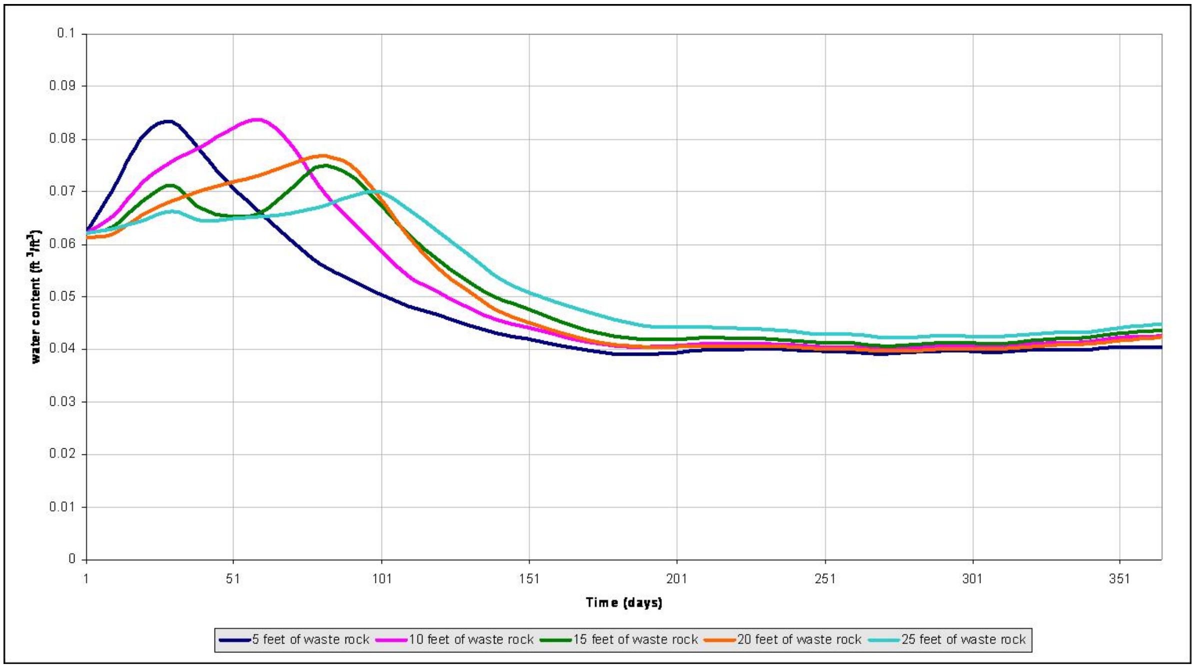


**Illustration 3 Moisture Content – Waste Rock Only Over Spent Ore**

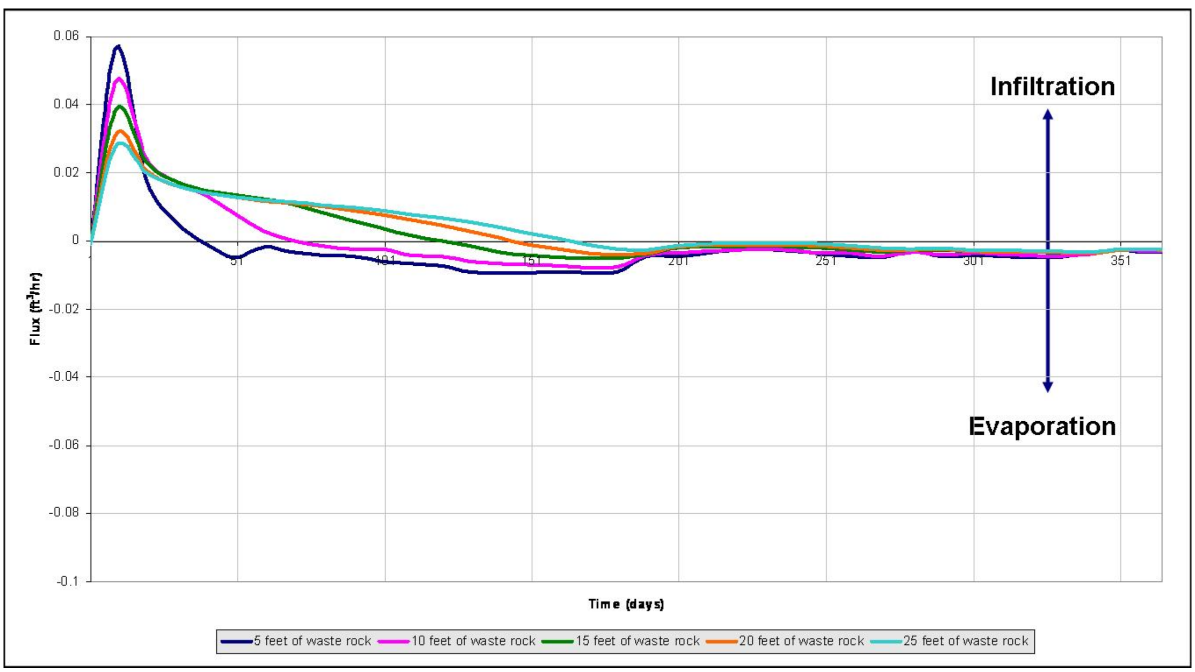


**Illustration 4 Water Flux – Waste Rock/Soil Layer Over Spent Ore**

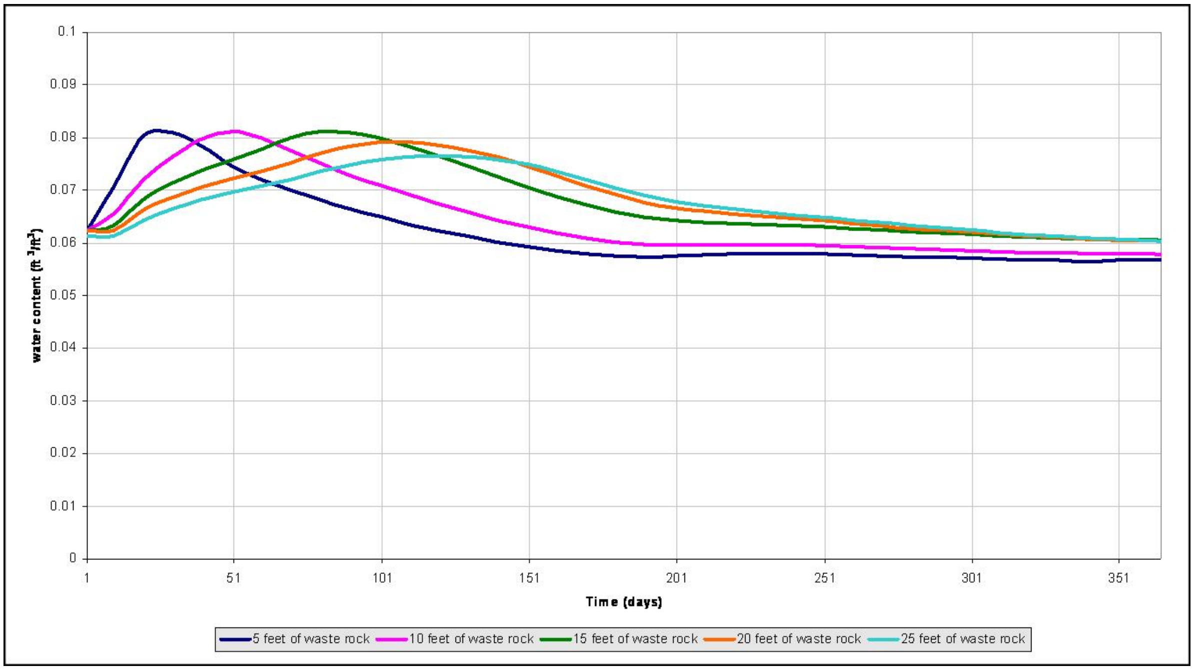


**Illustration 5 Moisture Content – Waste Rock/Soil Layer Over Spent Ore**

The contact between the waste rock and the spent ore was used as the location in the model to analyze each of the scenarios, and to provide the data for Illustrations 2 through 5. In Illustrations 2 and 4, positive flux values represent the water that is infiltrating into the waste rock or combined waste rock/soil layer and reaching the surface of the spent ore while negative values represent water being removed from the spent ore and waste rock through evaporation.

Based on the results presented in Illustrations 2 and 4, some precipitation infiltrates into the spent ore during the first month of the model (positive flux values). This is due to the very low moisture content of the waste rock or combined waste rock/soil material being placed on the spent ore. The thinnest waste rock scenario (five [5] feet) had the highest infiltration rate while the thickest waste rock scenario (25 feet) had the lowest infiltration rate (both with and without a soil layer).

Once the initial wetting of the waste rock material was completed, each of the scenarios showed a decrease in the flux, and eventually realized an evaporation controlled period (negative flux values). Both Illustrations 2 and 4 show this initial increase and then decrease. However, the waste rock only scenarios have a much more erratic pattern over the one (1) year modeling period than the combined waste rock/soil layer scenarios. This suggests that the larger pore spaces and higher permeability of the ROM waste rock is more responsive to changes in climate conditions. The addition of a one (1) foot thick soil layer to the surface of the waste rock smoothes the erratic pattern observed in Illustration 2 and shows a more consistent rate of evaporation.

Based on just the flux data, the combination waste rock/soil layer options are more protective than the waste rock only scenarios. A five (5) foot waste rock thickness with a one (1) foot soil layer performs as effectively as the thicker waste rock only or thicker waste rock/soil layer scenarios. If only waste rock will be placed on the spent ore, the thickness would need to be at least 20 feet in order to minimize meteoric water infiltrating into the spent ore.

Illustrations 3 and 5 present the change in moisture content over time at the waste rock/spent ore contact. These illustrations also show the material being wetted in the early stage of the model. The thinnest waste rock scenarios have the largest increase in moisture content while the thicker layers have less increase. The thinner layers also have a faster increase in moisture content than the thicker layers. This is due to the position of the model point being used for the data analysis. As discussed above, the modeling point being described in the illustrations is located at the contact of the waste rock and the spent ore material. Therefore, the model point is located further from the top surface of the model with the thicker covers, (i.e., the point is deeper in the cover system).

The scenarios modeled without a soil layer also have a faster increase in the moisture content, and a faster decrease. This is related to the smaller pore spaces in the soil layer and associated lower permeability. Regardless of the scenario, the moisture contents are sufficiently low to suggest that no meteoric water will reach the spent ore material at closure. Modeling assumed that all surfaces had a positive drainage of at least one (1) percent, (i.e., no ponding on the cover surface).

## 4.0 Conclusions

The most protective covers modeled in this analysis were represented by a combination of waste rock and a soil layer. A five (5) foot waste rock cover with one (1) foot of soil had much less variation in the flux of water in and out of the system (less responsive to changing climate conditions) than a waste rock only cover scenario having a thickness of 20 feet. However, a waste rock only cover of at least 20 feet in thickness will be sufficient to prevent meteoric water infiltration into the spent ore. This assumes positive drainage is maintained on the outer slopes.

## 5.0 References


GEO-SLOPE International, Ltd. (GEO-SLOPE). (2007a). *Vadose Zone Modeling with VADOSE/W 2007: An Engineering Methodology*. GEO-SLOPE International Ltd.: Calgary, Alberta, Canada.

GEO-SLOPE, (2007b). *Contaminant Modeling with CTRAN/W 2007: An Engineering Methodology.* GEO-SLOPE International Ltd.: Calgary, Alberta, Canada.

Tetra Tech (Tt) (2009). Geotechnical Addendum. Prepared for Rosemont Copper Company. Dated February 2009.