Technical Memorandum

<table>
<thead>
<tr>
<th>To:</th>
<th>Kathy Arnold</th>
<th>From:</th>
<th>Grady O’Brien, P.G.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company:</td>
<td>Rosemont Copper Company</td>
<td>Date:</td>
<td>August 17, 2011</td>
</tr>
<tr>
<td>EA No.:</td>
<td>110195, Task 103</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Re:</td>
<td>Pit Backfill Simulation</td>
<td>CC:</td>
<td>David Krizek, Rosemont Copper Company</td>
</tr>
</tbody>
</table>

1.0 EXECUTIVE SUMMARY

At the request of Rosemont Copper Company, Engineering Analytics (EA) has completed a post-closure analysis to determine the impact of pit backfill on predicted groundwater level drawdown. The post-closure groundwater flow model developed by Tetra Tech (2010) was used for the analysis.

The predicted long-term (1,000 year) pit-lake level was 4,279 feet and backfill was simulated at an elevation of 4,279 feet. This backfill elevation maintains the same hydraulic sink condition as without backfill present. The pit-lake water balance illustrates that the pit lake reaches the top of the backfill after approximately 52 years and then equilibrates to a long-term lake stage of 4,286 feet (Figure 1). Drawdown predicted by the base model, without backfill, was compared to the backfill simulation to determine the impact of a backfilled pit. There was minimal change in predicted drawdown at 20 and 1,000 years and a small decrease in the extent of drawdown propagation at 50 and 150 years (Figures 2-5). There was no simulated decrease in the extent of the 5-foot drawdown contour in Davidson Canyon.

2.0 INTRODUCTION

The post-closure groundwater flow model developed by Tetra Tech (2010) was used to simulate the effects of backfilling the pit with waste rock. Simple model modifications were made to simulate the hydrologic impacts of backfill. The purpose of the simulation was to determine if backfill reduces the extent of drawdown propagation.

Following the cessation of pit dewatering groundwater, precipitation, and runoff will flow into the pit and a lake will form. Groundwater inflow however, is the largest component of inflow to the pit. Backfill added to the pit during the post-closure period would perform two functions. First, when the water surface is within the backfill there will be no evaporation. Evaporation is a significant groundwater loss from a pit lake and this loss increases as the lake’s surface area increases. Eliminating evaporation in the backfill scenario results in the lake stage rising more rapidly than if evaporation were occurring. The second effect is that the backfill volume reduces the volume of groundwater required to fill the pit. This effectively reduces the volume of groundwater that is removed from storage in the groundwater system, which in theory should reduce drawdown propagation away from the pit.
When the pit lake stage rises to the top of the backfill evaporation losses will occur. Over time the evaporation losses equal the inflows and a steady-state lake level is reached. A simulated backfill level of 4,279 feet, which is equal to the predicted long-term (1,000 year) pit-lake stage (Tetra Tech, 2010), was selected for this analysis. The long-term pit-lake stage with this backfill scenario was 4,286 feet, which is 7 feet higher than without backfill.

3.0 FLOW MODEL MODIFICATIONS

The post-closure Tetra Tech (2010) flow model was modified to simulate the effects of backfill on pit lake formation. These flow model modifications were simplifications of the actual pit conditions that would exist, but they adequately represent the controlling hydrologic conditions. The same assumptions and backfill modeling approaches were used for the Tetra Tech (2010) and Montgomery and Associates (2011) models to ensure that consistent and comparable results were obtained. The following conditions and assumptions were simulated:

- Backfill can be placed into the pit at a faster rate than the pit will fill with water. As a result the groundwater inflow rates are the controlling factor on how fast the pit-lake stage rises. Since the rising water level will remain within the backfill and there will be no evaporation in the first 52 years of the post-closure period.

- The backfill volume to fill the pit to an elevation of 4,279 feet was 4.28 billion cubic feet.

- Compacted waste rock porosity was assumed to be 30 percent based on the compacted swell factor and waste rock densities (bank and compacted) provided by Rosemont Copper. The void space in the backfilled pit, which would be filled with water, was 1.28 billion cubic feet.

- Based on the groundwater inflows in the base flow model (without backfill) groundwater inflows were estimated to fill the backfill’s void space volume in 52 years.

- Groundwater inflow, pit-wall runoff, and precipitation recharge on the backfill surface will fill the pit with water. It was assumed that pit-wall runoff and recharge through the backfill would be 30-percent of average annual precipitation. This was consistent with the 30 percent runoff coefficient used in the base Tetra Tech model (Tetra Tech, 2010).

The MODFLOW lake package (Council, 1999) was adapted to simulate the 52 year pit filling period and the pit lake period. The following changes were made to the lake package:

- Water was added to the pit at a rate equivalent to the backfill volume over the 52 year pit filling period. This volume of water was a surrogate for the solid portion of the backfill material and it reduces the volume of groundwater inflow required to fill the pit.

- Lake evaporation was set to zero during the 52-year filling period.

- Pit-wall runoff and recharge on the backfill was simulated as 30-percent of average annual precipitation.
• Post-closure years 53 to 1,000 were unchanged from the base simulation.

4.0 RESULTS

The predicted pit lake water balance and drawdown from the backfill simulation are compared with the base model simulation to determine the impact of backfill.

4.1 Pit-Lake Water Balance

The predicted pit-lake water balance for the backfill simulation is provided in Figure 1. The water balance illustrates that the pit lake reaches the 4,279 foot stage in approximately 52 years rather than after nearly 500 years in the no backfill simulation. At 1,000 years the lake water balance is effectively the same with and without backfill as shown in Table 4-1. The backfilled pit will remain a hydraulic sink due to the evaporative losses on the lake surface.

| Table 4-1 Simulated Pit-Lake Water Balance 1,000 Years after End of Operations |
|---|---|---|
| **Inflows** | **Backfill/Pit Lake Simulation** | **Pit Lake Base Simulation** |
| Pit-Wall Runoff and Precipitation-Backfill Recharge | 323 | 322 |
| Groundwater Inflow | 229 | 230 |
| Upgradient Runoff | 0 | 0 |
| **Total Inflow** | 552 | 552 |
| **Outflows** | **Average Annual Rate (gpm)** | **Average Annual Rate (gpm)** |
| Evaporation | 552 | 552 |
| Groundwater Outflow | 0 | 0 |
| **Total Outflow** | 552 | 552 |
| **Inflow – Outflow** | 0 | 0 |

1 gpm = gallons per minute

4.2 Predicted Groundwater Level Drawdown

Drawdown predictions for 20, 50, 150, and 1,000 years post closure are presented in Figures 2-5. Minimal differences in drawdown were simulated at 20 and 1,000 years. However, there was less drawdown simulated at 50 and 150 years in the backfill simulation compared to the base, no-backfill simulation (Figures 3 and 4).

Over the 1,000 year post-closure simulation period groundwater inflow was 14,655 acre-feet less in the backfill simulation than the base simulation. This indicates that less groundwater was removed from storage, which results in less groundwater drawdown. The lower groundwater inflows resulted in less drawdown simulated at 50 and 150 years. In contrast, after 20 years the change in groundwater inflows and the decrease in water removed from storage were not significant enough to change the predicted drawdown. At 1,000 years post-closure the
drawdown was the same since the groundwater system had effectively equilibrated to the same steady-state condition in the backfill and base simulations. Specific changes in drawdown were as follow:

- **20-years post-closure:** The predicted 10-foot contour recedes slightly in the Barrel Canyon area relative to the base simulation (Figure 2). Minimal change in drawdown was simulated at 20 years since it takes 52 years for the water level to reach the top of the backfill and the full backfill effect has not occurred.

- **50-years post-closure:** The extent of the 5-foot drawdown contour in Davidson Canyon was unchanged in the backfill simulation (Figure 3). The predicted 10-foot contour however, recedes a maximum of approximately 0.6 miles in the Barrel Canyon area.

- **150-years post-closure:** Differences in the 5 and 10-foot drawdown contours were simulated after 150-years (Figure 4). The maximum decrease in the extent of the 10-foot contour in the backfill simulation was approximately 2 miles in the Barrel and upper Davidson Canyon areas. There was a decrease in the extent of the 5-foot contour to the north and east of the pit. However, the extent of the 5-foot drawdown contour in Davidson Canyon was unchanged in the backfill simulation.

- **1,000-years post-closure:** Minimal changes in drawdown were simulated at 1,000 years (Figure 5). The long-term drawdown was predicted to be equivalent with or without backfill since the groundwater system reaches essentially the same equilibrium condition.

### 5.0 SUMMARY

Pit backfill simulations predict that there will be less drawdown in the Barrel and upper Davidson Canyon areas at 50 and 150 years post closure. Minor changes in drawdown were predicted at 20 and 1,000 years post closure. The decrease in drawdown propagation can be attributed to the decrease in groundwater inflow to the pit lake. Backfill effectively occupies volume in the pit that would otherwise be filled by groundwater. Less groundwater was therefore required to fill the pit lake to its steady-state stage in the backfill simulation.
6.0 REFERENCES


Figure 1. Pit-lake water balance for the backfilled pit simulation.

Additional water added to the pit to account for the backfill volume, which reduces the volume of groundwater needed to fill the pit.

**Years 0 - 52**
Backfilled pit filling with water from groundwater inflow, pit wall runoff, and recharge (30% of precipitation falling on backfill). No evaporation since the water level is within the backfill.

**Years 52 - 1,000**
Lake state above the backfill and evaporation is occurring. Lake stage being maintained by groundwater inflow, pit wall runoff, direct precipitation, and evaporation.
Figure 2
Predicted Groundwater Level Drawdown 20 Years After End of Operations (Layer 17)
Legend

- Base Model - Groundwater Level Drawdown Contour (Feet)
- 100 - Backfill to 4,279 feet Lake Level Model - Groundwater Level Drawdown Contour (Feet)
- Proposed Roemont Open Pit
- Quartz-Porphyry Dike
- Extent of Model Domain
- Perennial Stream
- Ephemeral Drainage
- Cienega Creek Watershed
- No Flow Cells
- Regional Springs
- Towns

Figure 3
Predicted Groundwater Level Drawdown 50 Years After End of Operations (Layer 17)
Figure 4
Predicted Groundwater Level Drawdown 150 Years After End of Operations (Layer 17)
Figure 5
Predicted Groundwater Level
Drawdown 1000 Years After End of Operations (Layer 17)
Memorandum

To: Bev Everson
Cc: Chris Garrett
From: Kathy Arno
Doc #: 090/11-15.5.2
Subject: Transmittal of Technical Data in Hard Copy and CD Format
Date: 6 September 2011

Rosemont Copper Company is having delivered by courier, the following materials in hard copy and CD format as were previously submitted electronically:

- Equipment Emissions, Summary, Empire CAT, June 27, 2011
- Rosemont Pit Backfill Simulation, Montgomery & Associates, August 18, 2011
- Pit Backfill Simulation, Engineering Analytics, Inc., Technical Memorandum, August 17, 2011
- Predicted Groundwater Level Drawdown 20 Years after End of Operations (Layer 17), Engineering Analytics, Inc., Maps, August 2011
- Comments Regarding Memorandum Safety Bench Alternatives for Rosemont Pit Walls on Face of Santa Rita Mountains, Call & Nicholas, Inc., Memorandum, July 8, 2011
- Response to Golder Comments on Drop Chutes – Site Water Management Update Report, Rosemont Copper Company, Memorandum, June 8, 2011
- Response to SRK Pit Lake Comments, Rosemont Copper Company, Memorandum, May 13, 2011
- Predicted Regulatory (100-Yr) Hydrology and Average-Annual Runoff Downstream of the Rosemont Copper Project, Tetra Tech, Technical Memorandum, July 21, 2011
- Rosemont Facility Infiltration and Seepage Response to Comments, Tetra Tech, Technical Memorandum, April 22, 2011
- Response to Comments – Infiltration, Seepage, Fate and Transport Modeling, Tetra Tech, Technical Memorandum, June 9, 2011
- Additional Rosemont Response to FS/BLM Comments ES-1 on Tetra Tech Groundwater Model, Tetra Tech Technical Memorandum, May 18, 2011
- Response to PCRFCD Comments Regarding Hydrology, Tetra Tech, Technical Memorandum, August 18, 2011
• *Rosemont Facility Fate and Transport Modeling Response to Comments*, Tetra Tech, Technical Memorandum, May 16, 2011
• *AERMOD Modeling Analyses for the Alternatives to the Proposed Action for the Rosemont Copper Project*, Applied Environmental Consultants, August 15, 2011
• *Response to Golder Comments*, Rosemont Copper Company, Technical Memorandum, May 6, 2011
• *Misc. Docs. Submitted via Email*, Rosemont, September 2011 CD

Please do not hesitate to contact me should you require anything further.
August 18, 2011

Mr. Jim Upchurch
Forest Supervisor
Coronado National Forest
300 West Congress
Tucson, Arizona 85701

Re: Analysis of Backfill on Impact on Groundwater

Dear Mr. Upchurch:

During a regularly scheduled status meeting, you requested that Rosemont Copper Company (Rosemont) have the groundwater models run to determine the impact that partial backfill would have on groundwater elevations. Rosemont requested that both models be run to give you a full view of the potential.

Both of these reports are included in this email:

• Pit Backfill Simulation, Engineering Analytics, August 17, 2011 (this is the Tetra Tech model)
• Rosemont Pit Backfill Simulation, Montgomery & Associates, August 18, 2011

You will note that in both cases the impact on the groundwater elevations is minimal to nonexistent.

Also included with this transmittal is a replacement figure for the 50-year post closure drawdown. There was an error discovered in the figure when the backfill memo was being completed.

Regards,

Katherine Ann Arnold
Vice President, Environmental and Regulatory Affairs

Cc: Jamie Sturgess, Augusta Resource Corporation
    Chris Garrett, SWCA
    File

Doc. No. 80/11-15.3.1