TECHNICAL MEMORANDUM

DATE: April 11, 2011
PROJECT: 1232.32

TO: Katherine Arnold
    ROSEMONT COPPER COMPANY

FROM: Hale Barter and Jonathan Whittier
      MONTGOMERY & ASSOCIATES

SUBJECT: Addition of Runoff to Post-Mining Predictive Simulation
         Rosemont Mine Model

INTRODUCTION

During post-submittal review of the Rosemont Mine model submitted in 2010, Montgomery & Associates (M&A) determined that precipitation runoff into the pit lake from the area above the spill level was not simulated in the LAK2 package. This area encompasses approximately 187 acres. Runoff from this area is estimated to be approximately 64 gallons per minute (gpm). Addition of this runoff will decrease projected groundwater drawdown impacts and increase projected lake stage. The model was revised to evaluate sensitivity of model projections to inclusion of the additional 64 gpm runoff inflow to the pit lake.

BACKGROUND

Following cessation of mining and pit dewatering, groundwater levels will begin to recover, and groundwater inflow will form a lake at the bottom of the pit. To simulate hydrogeologic conditions during this period, the MODFLOW Lake Package, LAK2 (Council, 1999) is used. The LAK2 package accounts for storage in the lake, evaporation from the lake surface, precipitation that falls on the lake, and precipitation runoff from the surrounding lake catchment area. In the 2010 Rosemont Mine model (M&A, 2010), the lake catchment area specified in the LAK2 package is limited to the area below the spill elevation of 5,050 feet above mean sea level (msl), the maximum potential vertical height of the pit lake. Additional precipitation runoff into the pit lake from the area above the spill elevation was unintentionally not simulated in the lake water balance.
**METHODS**

To account for the area above the spill level elevation and within the extent of the proposed pit, a fixed inflow term is added to the LAK2 package input. Since this area will not change in extent over time, a fixed term is appropriate. Thirty percent of the precipitation that falls in the lake catchment area surrounding the lake (i.e. above the lake stage) is simulated as runoff into the lake. The precipitation rate used in the model to simulate direct precipitation falling in the lake catchment area is $5.06 \times 10^{-3}$ feet per day (ft/d). Therefore, the portion of the precipitation rate converted to runoff is approximately $1.52 \times 10^{-3}$ ft/d. The area above the spill level elevation and within the extent of the proposed pit is approximately 187 acres (8,150,000 square feet). Therefore, the volumetric flow is estimated to be approximately 64 gpm (12,400 cubic feet per day).

**RESULTS**

Results are presented for the revised runoff simulation in comparison to the 2010 model results which did not incorporate the additional runoff (M&A, 2010).

**Pit Lake Formation**

Projected pit lake water balance for the 1,000 year post-closure period is shown on Figure 1. A comparison of the revised projected lake water balance to the 2010 model lake water balance is tabulated below.

<table>
<thead>
<tr>
<th></th>
<th>Pit Lake Formation Simulation (with Additional Runoff)</th>
<th>Pit Lake Formation Simulation (without Additional Runoff)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater Inflow</td>
<td>95 gpm</td>
<td>104 gpm</td>
</tr>
<tr>
<td>Evaporation</td>
<td>489 gpm</td>
<td>411 gpm</td>
</tr>
<tr>
<td>Precipitation</td>
<td>217 gpm</td>
<td>182 gpm</td>
</tr>
<tr>
<td>Runoff</td>
<td>176 gpm</td>
<td>122 gpm</td>
</tr>
<tr>
<td>Lake Stage</td>
<td>4,208 feet msl</td>
<td>4,097 feet msl</td>
</tr>
</tbody>
</table>

Results indicate the pit is a hydraulic sink 1,000 years after mine closure with no water discharging from the pit lake to the groundwater system. Projected groundwater level elevations around the perimeter of the pit 1,000 years after mine closure range from 4,300 to 4,850 feet above mean sea level (msl), as shown on Figure 2. The minimum difference between lake stage and projected groundwater level along the delineated capture zone is approximately 250 feet (Figure 2), compared to approximately 350 feet for the 2010 model results.
Projected Impacts 20 Years After Mine Closure (2052)

Twenty years after mine closure, maximum projected drawdown corresponds to the projected lake stage of 3,645 feet msl, which is approximately 1,461 feet below initial simulated groundwater level at the center of the pit, shown on Figure 3. This represents an increase in projected lake stage of approximately 27 feet due to simulation of the additional runoff. Projected maximum extent of the 5-foot groundwater level drawdown contour is unchanged at approximately 4.2 miles east-northeast from the proposed pit along Barrel Canyon. Projected drawdowns at the simulated perennial stream reaches nearest the pit in upper Cienega Creek and Davidson Canyon are unchanged at approximately 0 and 0.01 feet, respectively; shown on Figures 4 and 5, respectively. Outside of Davidson Canyon, impacts do not propagate into lower Cienega Creek basin.

Projected decreases from pre-mining conditions for evapotranspiration, streamflow, and west boundary outflow are unchanged and summarized as follows:

- Projections for upper Cienega Creek and the Cienega Creek narrows
  - decreased evapotranspiration rate – 0 acre-feet per year (AF/yr)
  - decreased length of perennial reach – 0 miles
  - decreased base flow rate – 0 cubic feet per second (cfs)
- Projections for Davidson Canyon
  - decreased evapotranspiration rate – 0 AF/yr
  - decreased length of perennial reach – 0 miles
  - decreased base flow rate – 0.01 cfs
- Projected decrease in groundwater outflow from the west boundary – 0 AF/yr
- Three identified perennial springs and seeps are within the projected 5-foot drawdown contour: MC-1, Deering, and Rosemont

Results of predictive impact projections are summarized in Table 1.

Projected Impacts 150 Years After Mine Closure (2202)

One hundred and fifty years after mine closure, maximum projected drawdown corresponds to the projected lake stage of 4,049 feet msl, which is approximately 1,057 feet below initial simulated groundwater level at the center of the pit, shown on Figure 6. This represents an increase in projected lake stage of approximately 72 feet due to simulation of the additional runoff. Projected maximum extent of the 5-foot groundwater level drawdown contour is unchanged at approximately 9.6 miles east-northeast from the proposed pit along Davidson Canyon. Projected drawdown at the simulated perennial stream reach nearest the pit in upper Cienega Creek is unchanged at approximately 0 feet (Figure 4). Projected drawdown at the simulated perennial reach nearest the pit in Davidson Canyon is reduced by approximately 0.01 feet to 0.30 feet (Figure 5). Outside of Davidson Canyon, impacts do not propagate into lower Cienega Creek basin.
Projected decreases from pre-mining conditions for evapotranspiration, streamflow, and west boundary outflow are unchanged and summarized as follows:

- Projections for upper Cienega Creek and the Cienega Creek narrows
  - decreased evapotranspiration rate – 0 AF/yr
  - decreased length of perennial reach – 0 miles
  - decreased base flow rate – 0 cfs
- Projections for Davidson Canyon
  - decreased evapotranspiration rate – 8 AF/yr
  - decreased length of perennial reach – 0 miles
  - decreased base flow rate – 0.02 cfs
- Projected decrease in groundwater outflow from the west boundary – 12 AF/yr
- Five identified perennial springs and seeps are within the projected 5-foot drawdown contour: MC-1, Deering, Rosemont, Questa, and Helvetia

Results of predictive impact projections are summarized in Table 1.

**Projected Impacts 1,000 Years After Mine Closure (3032)**

One thousand years after mine closure, maximum projected drawdown corresponds to the projected lake stage of 4,208 feet msl, which is approximately 898 feet below initial simulated groundwater level at the center of the pit, shown on Figure 7. This represents an increase in projected lake stage of approximately 111 feet due to simulation of the additional runoff. Projected maximum extent of the 5-foot groundwater level drawdown contour is unchanged at approximately 11.5 miles east-northeast from the proposed pit along Davidson Canyon. Projected drawdown at the simulated perennial stream reach nearest the pit in upper Cienega Creek is unchanged at approximately 0.01 feet (Figure 4). Projected drawdown at the simulated perennial reach nearest the pit in Davidson Canyon is reduced by approximately 0.06 feet to 0.92 feet (Figure 5). Outside of Davidson Canyon, impacts do not propagate into lower Cienega Creek basin.

Projected decreases from pre-mining conditions for evapotranspiration, streamflow, and west boundary outflow are summarized as follows, with a few slight changes resulting from simulation of the additional runoff, as noted below:

- Projections for upper Cienega Creek and the Cienega Creek narrows
  - decreased evapotranspiration rate – 47 AF/yr
    - 1.5 percent of the 3,100 AF/yr estimated ET
    - reduced by approximately 4 AF/yr with the additional runoff
  - decreased length of perennial reach – 0.16 miles
    - 2.1 percent of the 7.6 mile observed length
  - decreased base flow rate – 0.02 cfs
    - 1 percent of the estimated 2 cfs rate
• Projections for Davidson Canyon
  o decreased evapotranspiration rate – 21 AF/yr
    ▪ 18 percent of the 115 AF/yr estimated ET
    ▪ reduced by approximately 1 AF/yr with the additional runoff
  o decreased length of perennial reach – 0.29 miles
    ▪ 41 percent of the 0.7 mile observed length
  o decreased base flow rate – 0.04 cfs
• Projected decrease in groundwater outflow from the west boundary – 41 AF/yr
  o reduced by approximately 1 AF/yr with the additional runoff
• Five identified perennial springs and seeps are within the projected 5-foot drawdown contour: MC-1, Deering, Rosemont, Questa, and Helvetia

Results of predictive impact projections are summarized in Table 1.

**SUMMARY**

The addition of runoff from the area within the proposed pit above the spill level elevation changes the pit lake water balance after 1,000 years as follows:

- groundwater inflow decreases
- evaporation from the pit lake surface increases
- precipitation to the pit lake surface increases
- runoff to the lake increases
- pit lake stage increases

The pit lake remains a hydraulic sink and the reduced groundwater inflow results in slightly smaller drawdown impacts to the groundwater system.

Simulation of the additional runoff results in reduced impacts to the groundwater system at 1,000 years post-mining, summarized as follows:

- For upper Cienega Creek and the Cienega Creek narrows after 1,000 years, the projected rate of evapotranspiration is reduced by approximately 4 AF/yr.
- For Davidson Canyon, the projected rate of evapotranspiration is reduced by approximately 1 AF/yr and the projected drawdown at the perennial reach nearest the pit is reduced by approximately 0.06 feet.
- The projected decrease in groundwater outflow from the west boundary is reduced by approximately 1 AF/yr.
REFERENCES


### TABLE 1. SUMMARY OF MODEL PROJECTIONS FOR 1,000-YEAR POST-MINING SIMULATIONS

#### ROSEMONT PROJECT, PIMA COUNTY, ARIZONA

| YEARS AFTER END OF MINING | PROJECTED MAXIMUM EXTENT OF 5-FOOT DRAWDOWN CONTOUR (miles) | PROJECTED PIT LAKE STAGE (feet, amsl) | NUMBER OF SEEPS/SPRINGS WITHIN 5-FOOT DRAWDOWN CONTOUR | PROJECTED DECREASE IN GROUNDWATER OUTFLOW FROM MODEL BOUNDARY WEST FROM PIT (AF/yr) | PROJECTED DRAWDOWN AT PERENNIAL STREAM REACH (feet) | PROJECTED DECREASE IN PERENNIAL STREAM REACH LENGTH (miles) | PROJECTED DECREASE IN STREAM BASE FLOW (cfs) | PROJECTED DECREASE IN ET (AF/yr) | PROJECTED MAXIMUM EXTENT OF 5-FOOT DRAWDOWN CONTOUR (miles) | PROJECTED PIT LAKE STAGE (feet, amsl) | NUMBER OF SEEPS/SPRINGS WITHIN 5-FOOT DRAWDOWN CONTOUR | PROJECTED DECREASE IN GROUNDWATER OUTFLOW FROM MODEL BOUNDARY WEST FROM PIT (AF/yr) | PROJECTED DRAWDOWN AT PERENNIAL STREAM REACH (feet) | PROJECTED DECREASE IN PERENNIAL STREAM REACH LENGTH (miles) | PROJECTED DECREASE IN STREAM BASE FLOW (cfs) | PROJECTED DECREASE IN ET (AF/yr) | PROJECTED MAXIMUM EXTENT OF 5-FOOT DRAWDOWN CONTOUR (miles) | PROJECTED PIT LAKE STAGE (feet, amsl) | NUMBER OF SEEPS/SPRINGS WITHIN 5-FOOT DRAWDOWN CONTOUR | PROJECTED DECREASE IN GROUNDWATER OUTFLOW FROM MODEL BOUNDARY WEST FROM PIT (AF/yr) | PROJECTED DRAWDOWN AT PERENNIAL STREAM REACH (feet) | PROJECTED DECREASE IN PERENNIAL STREAM REACH LENGTH (miles) | PROJECTED DECREASE IN STREAM BASE FLOW (cfs) | PROJECTED DECREASE IN ET (AF/yr) | PROJECTED MAXIMUM EXTENT OF 5-FOOT DRAWDOWN CONTOUR (miles) | PROJECTED PIT LAKE STAGE (feet, amsl) | NUMBER OF SEEPS/SPRINGS WITHIN 5-FOOT DRAWDOWN CONTOUR | PROJECTED DECREASE IN GROUNDWATER OUTFLOW FROM MODEL BOUNDARY WEST FROM PIT (AF/yr) | PROJECTED DRAWDOWN AT PERENNIAL STREAM REACH (feet) | PROJECTED DECREASE IN PERENNIAL STREAM REACH LENGTH (miles) | PROJECTED DECREASE IN STREAM BASE FLOW (cfs) | PROJECTED DECREASE IN ET (AF/yr) |
| 0 | 3.2 | 3,050 | 3 | 0 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 |
| 20 | 4.2 | 3,618 | 3 | 0 | 0.00 | 0.00 | 0.00 | 0 | 0.01 | 0.00 | 0.01 | 0 | 0 | 0 | 0 | 0 |
| 20 | 4.2 | 3,645 | 3 | 0 | 0.00 | 0.00 | 0.00 | 0 | 0.01 | 0.00 | 0.01 | 0 | 0 | 0 | 0 | 0 |
| 150 | 9.6 | 3,977 | 5 | 12 | 0.00 | 0.00 | 0.00 | 0 | 0.31 | 0.00 | 0.02 | 8 | 0 | 0 | 0 | 0 |
| 150 | 9.6 | 4,049 | 5 | 12 | 0.00 | 0.00 | 0.00 | 0 | 0.31 | 0.00 | 0.02 | 8 | 0 | 0 | 0 | 0 |
| 1,000 | 11.5 | 4,097 | 5 | 42 | 0.01 | 0.16 | 0.02 | 51 | 0.98 | 0.29 | 0.04 | 22 | 0 | 0 | 0 | 0 |
| 1,000 | 11.5 | 4,208 | 5 | 41 | 0.01 | 0.16 | 0.02 | 47 | 0.92 | 0.29 | 0.04 | 21 | 0 | 0 | 0 | 0 |

- **a** feet, amsl = feet above mean sea level
- **b** AF/yr = acre-feet per year
- **c** = at hydrograph locations shown on Figures 110 through 113
- **d** = at simulated streamflow locations shown on Figure 97
- **e** cfs = cubic feet per second
- **f** ET = evapotranspiration
- **g** ET zones 4 and 5 (Figures 27 and 96)
- **h** ET zones 6, 7, and 8 (Figures 27 and 96)
- **i** Dry Pit Bottom
- **j** includes springs: MC-1, Deering, and Rosemont (Figures 110 and 111)
- **k** includes springs: MC-1, Deering, Rosemont, Questa, and Helvetia (Figures 112 and 113)

*Results from Revised Projections*
FIGURE 1. GRAPH OF SIMULATED PIT INFLOW AND OUTFLOW RATES, AND LAKE STAGE AFTER CESSION OF MINING OPERATIONS
ROSEMONTE PROJECT, PIMA COUNTY, ARIZONA

EXPLANATION
- Red: Groundwater Inflow
- Green: Evaporation
- Blue: Precipitation
- Black: Runoff
- Brown: Lake Stage
LOCAL PIT-AREA PROJECTED GROUNDWATER LEVEL ALTITUDES 1,000 YEARS AFTER END OF MINING

EXPLANATION

- Contour of Projected Groundwater Level Altitude, in feet above mean sea level
- Revised Contour of Projected Groundwater Level Altitude, in feet above mean sea level

Projected Pit Lake Stage, in feet above mean sea level
Revised Projected Pit Lake Stage, in feet above mean sea level

Footnotes:
1. Projected Pit Lake Stage, in feet above mean sea level
2. Revised Projected Pit Lake Stage, in feet above mean sea level

Hydraulic Sink Capture Zone Outline

ROSEMONT COPPER

MONTGOMERY & ASSOCIATES

FIGURE 2

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EXPLANATION

- Hydrograph Location
- Contour of Projected Drawdown, in feet
- Revised Contour of Projected Drawdown, in feet
- Ephemeral Drainage Channel
- Perennial Stream Reach
- Perennial Spring or Seep
- Cienega Creek Watershed
- Proposed Rosemont Open Pit
- Extent of Model Domain
- Tailings Impoundment
- Waste Rock Impoundment

Footnotes:
Approximate Depth to Simulated Pit Lake Surface from Simulated Pre-Mining Groundwater Level of 5,106 feet above mean sea level.
Approximate Depth to Revised Simulated Pit Lake Surface from Simulated Pre-Mining Groundwater Level of 5,106 feet above mean sea level.
FIGURE 4. HYDROGRAPH OF SIMULATED DRAWDOWN AT UPPER CIENEGA CREEK PERENNIAL REACH NEAREST TO ROSEMONT PIT, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
FIGURE 5. HYDROGRAPH OF SIMULATED DRAWDOWN AT DAVIDSON CANYON PERENNIAL REACH NEAREST TO ROSEMONT PIT, ROSEMONT PROJECT, PIMA COUNTY, ARIZONA
EXPLANATION

- Hydrograph Location
- Contour of Projected Drawdown, in feet
- Revised Contour of Projected Drawdown, in feet
- Ephemeral Drainage Channel
- Perennial Stream Reach
- Perennial Spring or Seep

Footnotes
Approximate Depth to Simulated Pit Lake Surface from Simulated Pre-Mining Groundwater Level of 5,106 feet above mean sea level.

PROJECTED GROUNDWATER LEVEL DRAWDOWN 150 YEARS AFTER THE END OF MINING OPERATIONS

FIGURE 6
EXPLANATION

Hydrograph Location

Contour of Projected Drawdown, in feet

Revised Contour of Projected Drawdown, in feet

Ephemeral Drainage Channel

Perennial Stream Reach

Perennial Spring or Seep

Footnotes

Approximate Depth to Simulated Pit Lake Surface from Simulated Pre-Mining Groundwater Level of 5,106 feet above mean sea level.

Approximate Depth to Revised Simulated Pit Lake Surface from Simulated Pre-Mining Groundwater Level of 5,106 feet above mean sea level.