MEMORANDUM

DATE: January 6, 2011

TO: Kathy Arnold
    ROSEMONT COPPER COMPANY

FROM: Hale Barter and Marla Odom
      MONTGOMERY & ASSOCIATES

SUBJECT: ADDITIONAL DISCUSSION OF ROSEMONT MINE WATER SUPPLY MODELING AND ANALYSIS OF CALIBRATION

In our professional evaluation of modeling requirements for the proposed 20-year Rosemont water supply, we determined the ADWR Tucson Active Management Area (TAMA) model is the best option for simulating regional groundwater level changes caused by proposed groundwater withdrawals. The model was developed by the U.S. Geological Survey and ADWR for the purpose of simulating groundwater level changes in the TAMA. Hydrogeologic conditions in the TAMA, including aquifer parameters and hydrogeologic units, have been substantially investigated and incorporated into the model over the almost 40-year development period of the model, resulting in the current calibrated regional model we selected to project effects of proposed Rosemont pumping.

ADWR requires that applicants for a 100-year Assured Water Supply (AWS) in the TAMA use this model to demonstrate physical availability of groundwater to meet needs of a proposed development. Typically ADWR requires the AWS applicant to conduct hydrogeologic investigations in the area of the proposed groundwater withdrawals, and to incorporate this additional data into the TAMA model for the 100-year AWS projections. Additionally, the applicant is required to update current and future groundwater pumping in the vicinity of the proposed withdrawals, including future water demands associated with approved AWSs. In the case of the Rosemont project, these updates to current and future groundwater pumping in the TAMA model were extraordinarily extensive and detailed; comprehensive documentation of all the updates was provided to ADWR to assist in their review of the work as a cooperating agency and to potentially facilitate their future update of the model. Finally, ADWR requires the applicant to assess the ability of the model to simulate observed groundwater level conditions, and to adjust results of projections for any differences between simulated and observed groundwater levels. Refinements done to the TAMA model in order to simulate effects of pumping for the Rosemont mine water supply were consistent with this methodology.

This approach recognizes that not only will long-term Rosemont pumping affect water levels in the regional aquifer system, but regional pumping and recharge will also cause groundwater level changes in the Rosemont wellfield area. Responses to Rosemont pumping and other pumping in the region are controlled by regional aquifer conditions which are well represented in the TAMA model. Aquifer hydraulic parameters determined from aquifer testing at wells E-1 and RC-2 were used to improve the model’s predictive capabilities in the immediate vicinity of the Rosemont wellfield; however, outside of the immediate vicinity of wells E-1 and RC-2, aquifer parameters specified in the model are considered representative of the regional system and are unchanged.
Evaluation of the TAMA model calibration in the Rosemont wellfield area is best accomplished by comparison of simulated and observed historic groundwater level trends. Calibration to actual observed groundwater level elevations is difficult because of substantial seasonal variation in response to spring and summer agricultural pumping in the area, and because the TAMA model uses annual stress periods which simulate annual average groundwater stresses which do not result in seasonally variable simulated groundwater levels. In addition, observed groundwater levels are measured predominantly in the winter months when there is no agricultural pumping; lack of spring/summer groundwater level measurements makes it difficult to determine the range of seasonal groundwater level variations and an associated annual average groundwater level. Consideration was given to switching to a seasonally representative model, but the effort would have essentially required a new smaller model be built and the seasonal stress data for much of the area would have been estimated, introducing additional error to the model. In fact the model’s calibration to the observed groundwater level trends is good and demonstrates the model’s ability to accurately predict future groundwater level changes in response to Rosemont pumping. Graphs of the calibrated groundwater level trends are presented in the original April 30, 2009 modeling study by Montgomery & Associates (M&A) titled: “Groundwater Flow Modeling Conducted for Simulation of Rosemont Copper’s Proposed Mine Supply Pumping, Sahuarita, Arizona.”

As summarized in the M&A November 12, 2010 Report Addendum (“Addendum to Groundwater Flow Modeling Conducted for Simulation of Rosemont Copper’s Proposed Mine Supply Pumping, Sahuarita, Arizona”), updates and refinements to simulated groundwater pumping and recharge in the model substantially improved calibration of the model. Changes to local aquifer parameters in the vicinity of test wells E-1 and RC-2 resulted in relatively small changes to the model calibration. In addition, results of predictive simulations of future conditions indicate that projected drawdown for the 20-year Rosemont pumping period was relatively insensitive to changes in local aquifer parameters, outside of the immediate vicinity of well RC-2. We believe the Rosemont model is the best available tool for predicting groundwater level drawdown from Rosemont pumping and that no additional available data exists which can be incorporated into the model to improve the model’s predictive capabilities.

Analysis of Model Calibration

In response to a request for an explicit quantification of the Rosemont model’s calibration to observed groundwater level data, an analysis of the model calibration for the transient period from 1981 through 2005 was conducted. This period was selected due to availability of observed groundwater level data for wells in the Rosemont study area. The length of this period is longer than the 20-year predictive Rosemont mine pumping and there are substantial changes in groundwater stresses and groundwater levels during this period which are sufficient to allow a good evaluation of the transient calibration. Our objective is to quantify how well the model simulates groundwater level change in response to those stresses, compared with observed groundwater level change.

The transient calibration evaluation is made difficult due to the inherent difference between seasonally variable observed groundwater levels and simulated groundwater levels resulting from simulated annual groundwater stresses. This difference is not an error in the model and needs to be eliminated in order to directly compare simulated and observed data. At each observed data well location we determined the difference between winter (no-agriculture pumping) measurements and simulated groundwater levels, for 1981/1982. For each well location this difference is used as the correction factor to normalize the simulated data to observed, and to evaluate the transient calibration for the period 1981 through 2005. There are 20 wells in the Rosemont study area which have groundwater level data over
this period, shown on Figure 1. Observed winter groundwater levels for 1981/1982, corresponding simulated groundwater levels, calculated differences (correction factor), and the corrected 1981/1982 simulated groundwater levels, for the 20 well locations, are presented in Table 1. The corrected 1981/1982 simulated groundwater levels are equivalent to observed winter groundwater levels, as intended.

The 2005 simulated groundwater level was adjusted by the correction factor for the 20 well locations. Comparison of the 2004/2005 observed winter groundwater levels to the corresponding corrected simulated groundwater levels allows evaluation of how well the model simulates transient change in the system over the 1981 to 2005 period. Figure 2 shows comparison of the observed and simulated groundwater levels. Observed minus simulated residuals ranged from -7.10 to 47.33 feet. The residual mean is 20.77 feet, which is 9 percent of the range in observed data (238.2 feet) and indicates a small bias toward projecting lower groundwater levels over the calibration period. The absolute residual mean is 21.66 feet, or 9 percent of the total range in observed groundwater levels. The residual mean square error (RMSE) is 25.26 feet, or 10.6 percent of the range in observed levels, in other words, 89.4 percent of the residuals are within about 25.26 feet of the observed values. It is the goal to have the RMSE/observed data range be within 10 percent, for an acceptably calibrated model.

In this evaluation results indicate the model is showing a small bias to overpredict regional groundwater level decline during the calibration period. This bias does not render the model results invalid, but does indicate a potential that projected drawdown from Rosemont pumping could potentially be slightly smaller than simulated; i.e. the projected drawdown may be conservatively large. This calibration analysis provides useful insight to the ability of the model to project groundwater drawdown response from Rosemont pumping and the results of the analysis are consistent with our expectations for a regional model which demonstrates good calibration to observed groundwater levels trends in the Rosemont study area.

FIGURE CORRECTION TO REPORT ADDENDUM

In the M&A Addendum Report submitted November 12, 2010, data presented in Figures A-2 and A-5 were inadvertently switched. These figures have been corrected and are attached.

SENT VIA EMAIL AND U.S MAIL
### TABLE 1. SIMULATED AND OBSERVED GROUNDWATER LEVELS, CORRECTION FACTORS, AND CORRECTED GROUNDWATER LEVELS FOR 20 WELLS IN ROSEMONT STUDY AREA

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* The following wells were excluded from the evaluation due to lack of data during the specified time period:
  (D-16-14) 19ccd (no 2004-2005 data)
  (D-17-13) 13adb (no 2004-2005 data)
  (D-17-14) 08bdd2 (no 2004-2005 data)
  (D-17-14) 17dcc (no data after 1980)
  (D-17-14) 28dda (no data after 1980)
  (D-17-14) 01bac (no data in 1980's)
  (D-17-14) 06bac (no data in 1980's)
  (D-17-14) 07cda2 (no data in 1980's)
  (D-18-13) 02baa (no data in 1980's)

b For dates shaded in grey, winter 1981-1982 water level measurements do not exist. Data from nearest 1980's winter measurement was used for evaluation.

c For date shaded in grey, winter 2004-2005 water level measurement does not exist. Winter 2003-2004 measurement was used for evaluation.
FIGURE 2. GRAPH OF OBSERVED AND SIMULATED (CORRECTED) GROUNDWATER LEVEL ELEVATIONS FOR WINTER 2004-2005

Residual Mean Square Error (RMSE) = 25.26
Min Residual = -7.10
Max Residual = 47.33
Min Measured = 2,449.6
Max Measured = 2,687.8
Range in Measured Values = 238.2
RMSE/Range = 10.60%
Total number of measurements = 20
FIGURE A-2. COMPARISON OF OBSERVED AND SIMULATED WATER LEVELS FOR ROSEMONT MODEL WITH AND WITHOUT ADWR TAMA MODEL AQUIFER PROPERTIES IN ROSEMONT WELLFIELD AREA, FOR JANUARY / FEBRUARY 2005
FIGURE A-5. COMPARISON OF OBSERVED AND SIMULATED WATER LEVELS FOR ROSEMONT MODEL AND ORIGINAL ADWR TAMA MODEL, FOR JANUARY / FEBRUARY 2005

EXPLANATION
- Observed Groundwater Level, January / February 2005
- Residual Error for Rosemont Model
- Residual Error for Rosemont Model With ADWR TAMA Hydraulic Conductivity Values
- Observed Groundwater Level Contour from January / February 2005
- 2005 Simulated Groundwater Level Contour from Rosemont Model
- 2005 Simulated Groundwater Level Contour from Rosemont Model with ADWR TAMA Hydraulic Conductivity Values
- Layer 3 No-Flow Boundary