SRK Consulting
Engineers and Scientists

SRK Consulting (U.S.), Inc.
3275 West Ina Road, Suite 240
Tucson, Arizona
USA 85741

vugorets@srk.com
www.srk.com

Tel: 520.544.3688
Fax: 520.544.9853

Memorandum

To:	Dale Ortman, P.E.	**Date:**	January 13, 2011
From:	Vladimir Ugorets, Ph.D.	**cc:**	Tom Furgason, SWCA Cori Hoag, SRK File
Reviewed by:	Larry Cope, M.S.		
Subject:	Technical Review of Tetra Tech (2010i) Report: *Regional Ground-water Flow Model Rosemont Copper Project*	**Project #:**	183101/2300

This memorandum provides a technical review of the full version of the report *Regional Groundwater Flow Model Rosemont Copper Project* (Tetra Tech, 2010i) dated November 2010. This review was undertaken and the Technical Memorandum prepared at the request of SWCA and the Coronado National Forest, in accordance with a *Technical Review Scope of Work, Request for Cost Estimate and Schedule* from Mr. Dale Ortman dated December 2, 2010. This memorandum was prepared by Vladimir Ugorets and reviewed by Larry Cope of SRK Consulting (U.S.), Inc. (SRK).

1 Tetra Tech Responses to SRK Comments

Tetra Tech issued the initial sections of this report in the format of technical memoranda (Tetra Tech, 2010a through Tetra Tech 2010h). SRK's original review comments on the Tetra Tech memoranda are presented in SRK (2010a) through SRK (2010f) and are not replicated here. The correlation between the initial Tetra Tech documents and SRK's review memoranda is shown in Table 1.

Table 1: Correlation between Original Tetra Tech Report Sections and SRK Review Documents

Tetra Tech Report Sections	Tetra Tech Documents	SRK Review Documents
Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts	Tetra Tech, 2010a&b	SRK, 2010a&b
Hydrogeologic Framework Model	Tetra Tech, 2010c	SRK, 2010c
Hydraulic-Property Estimates	Tetra Tech, 2010d	SRK, 2010d
Predictive Groundwater Flow Model Construction and Calibration	Tetra Tech, 2010e	SRK, 2010e
Steady-State Sensitivity Analyses	Tetra Tech, 2010f	
Rosemont Groundwater Flow Model Sensitivity Analyses	Tetra Tech, 2010g	SRK, 2010f
Predictive Groundwater Flow Modeling Results	Tetra Tech, 2010h	

Tetra Tech's comprehensive responses to SRK's review comments are contained in Tetra Tech (2010j).

The purpose for this review is to confirm that the comments made in SRK's original reviews have been addressed in the final version of the report. SRK reviewed the Tetra Tech (2010j) response to SRK's comments and the final version of the report (Tetra Tech, 2010i) and confirms here that the pertinent issues in the SRK comments were addressed.

2 SRK Additional Comments and Recommendations

Several observations are presented below that may be outside the scope of this final review, but are made to provide insight that has been gained by the reviewers since the submittal of the individual sections of the report.

2.1 Simulation of Quartz-Porphyry Dike

The quartz-porphyry dike between the open pit and Davidson Canyon is a very important feature that restricts groundwater flow in the conceptual hydrogeological and numerical groundwater models.

Tetra Tech (2010i) states that "The quartz-porphyry dike strikes sub-perpendicular to groundwater flow in the Davidson Canyon area, is over four (4) miles long, and based on a field investigation, has a low fracture density and a thickness generally greater than 100 feet. The steep hydraulic gradient from the Open Pit area to Davidson Spring in Davidson Canyon is likely due, at least in part, to this quartz-porphyry dike. However, there has been no hydraulic testing of this dike to characterize its hydraulic properties and to confirm its influence on the groundwater system. The cross-cutting nature, width, and length of the dike, however, suggest that it restricts groundwater flow."

This dike was simulated (and finally calibrated to measured water levels) by using a Horizontal Flow Barrier (HFB) package with:

a) Hydraulic conductivity K=3.28x10^{-6} ft/day,
b) Width of 100 feet, and
c) Penetration within all model layers.

It should be noted that the calibrated K of the quartz-porphyry dike (simulated as a HFB) is more than three orders of magnitude lower than the horizontal hydraulic conductivity of the Upper Cretaceous and Early Tertiary intrusive rocks (KTi).

Tetra Tech concluded in their report that, *"Simulating a more permeable HFB resulted in the model under predicting water levels up-gradient of the HFB and over predicting water levels down-gradient of the HFB. The calibrated HFB hydraulic characteristic improved the match to water levels on the up- and down-gradient sides of the dike and improved the match to the observed hydraulic gradient in Davidson Canyon."* However, SRK did not find any technical discussion or data to support that conclusion in the text of the report. The maps of simulated pre-mining water levels shown on Figures 6-1, 6-2, and 6-29 do not show the location of the dike. Figures 6-4 through 6-23 depicting the hydraulic conductivity distribution of the simulated Hydrogeologic Units (HGU) also do not the show location of the simulated, almost impermeable dike. This makes it difficult to compare the hydraulic conductivity of the HFB with that of the surrounding HGU and to evaluate changes in the groundwater gradient to confirm the existence of such a hydrologic barrier.

The results of the predictive simulations during post-mining conditions as shown on Figures 9-8, 9-9, 9-16, and 9-27 through 9-73 in the report, suggest that the quartz-porphyry dike as modeled serves as a hydraulic barrier to groundwater flow that limits the propagation of drawdown into Davidson Canyon.

The completed sensitivity analysis of the hydraulic conductivity of the quartz-porphyry dike (increasing and decreasing the value of K by a factor of 10) showed that this parameter is:

a) Least sensitive to simulated pre-mining water levels (normalized composite scaled sensitivity is only 0.08 (see Table 9-2 of Tetra Tech (2010i), and

b) Very sensitive to the predict propagation into the Davidson Canyon area during post mining conditions.

This means that:

a) Because of the low sensitivity for the steady state condition (to which the groundwater model was calibrated), the calibrated value of the dike hydraulic conductivity is not very defensible and as a result, the predictive simulations are not likely to be conservative; and

b) A larger range of dike hydraulic conductivity is required for the predictive sensitivity analysis to more clearly evaluate possible ranges of impact to the groundwater system within Davidson Canyon.

It should be noted that Montgomery and Associates' groundwater flow model (M&A, 2010) does not simulate the quartz-porphyry dike. Instead, they modeled a zone of higher hydraulic conductivity in the area of the Davidson Canyon fault. They were able to obtain a steady state calibration as well. Given that a steady state calibration can be achieved from such differing approaches suggests that Tetra Tech consider further evaluation of the dike. SRK is of the opinion that the defensibility of the simulation of the dike is impacted by what is viewed as conclusions that are less than fully supported by the analyses and simulations. To improve defensibility, SRK suggests the following:

a) Run an additional sensitivity analysis scenario for the post-mining conditions without the quartz-porphyry dike as a HFB to cover all possible ranges of propagation of drawdown.

b) Prepare a better description of the data used to incorporate the quartz-porphyry dike into the hydrogeologic model as a groundwater barrier and use this dike as a very low conductive HGU for the Base Case predictive scenario.

c) Show the quartz-porphyry dike simulated as a HFB in all model layers that indicate the hydraulic conductivity distribution (Figures 6-4 through 6-23) for comparison of its hydraulic characteristics with the K values of the surrounding HGU.

d) Add the quartz-porphyry dike to the pre-mining water level on Figures 6-1, 6-2, and 6-29 and specify in which monitoring wells the measured water levels indicate that this dike is a hydraulic barrier.

2.2 Simulation of Pit Lake Stage-Volume Relationship by the Groundwater Flow Model

The range of simulated pit lake stage, shown on Figure 8-9, varies in elevation from 3,050 to about 4,350 feet above mean sea level (amsl). This range covers the majority of completed simulations, but not all of them. For example, the pit lake elevation was predicted to be 4,429 feet amsl at 1,000 years from a sensitivity run considering a decrease of lake evaporation by 20 percent. It is not clear to SRK whether Figure 8-9 needs to be revised or the stage-area relationship in the Lake Package (LAK2) should be revised and the sensitivity predictions re-run.

2.3 Precipitation to the Pit Lake

It is noted that Tetra Tech applied annual precipitation of 17.37 inches to the pit lake during post-mining recovery using data from the NOAA Nogales weather station. Montgomery and Associates (M&A) in a similar study (M&A2010) used the Santa Rita weather station, which reported an annual precipitation of 22.19 inches. The Santa Rita station is located at a higher elevation compared to the NOAA Nogales (4,300 feet amsl vs. 3,560 feet amsl) and is closer to the elevation of the Rosemont site (elevation about 5,300 feet amsl). SRK did not find an explanation in the model report of Tetra Tech's preference for the Nogales station vs. the Santa Rita station; however, use of the Nogales data, with lower annual precipitation, provides a more conservative assumption to evaluate the pit lake infilling and the impact to the groundwater system during post-mining conditions.

The justification for the use of the NOAA Nogales weather station data was explained in Rosemont Infiltration, Seepage, Fate and Transport Response to Comments (Tetra Tech, 2010k). The explanation for using the NOAA Nogales weather station data also should be in the *Regional Groundwater Flow Model Rosemont Copper Project* (Tetra Tech, 2010i).

3 SRK Conclusions

The groundwater model was not calibrated to the transient conditions induced by the 30-day pumping test, and there remain some uncertainties with a simulation of such a complex natural system. Specifically, SRK suggests that a better assessment of the hydrogeological role of the quartz-porphyry dike between the open pit and Davidson Canyon be performed via additional sensitivity simulations. At a minimum, SRK suggests that an additional sensitivity run should be performed without the dike to increase the defensibility of the model predictions and to cover the possible range of potential impacts to the groundwater system and to surface-water bodies in Davidson Canyon.

Despite those uncertainties, SRK concludes that the groundwater model presented in the final version of the report was conceptualized, constructed, and presented to standard industry practices. The model addresses the comments and recommendations made by SRK in its review of the individual sections of the report. Further, SRK finds that the model generally represents hydrogeological conditions that are appropriate to the available data, is robust, and well calibrated to the pre-mining steady-state conditions. Model predictions for both mining and post-mining conditions are reasonable, are based on the results of comprehensive sensitivity analyses, and provide a range of potential impacts to the groundwater system and to surface-water bodies.

4 References

Montgomery & Associates, 2010, *Groundwater Flow Modeling Conducted for Simulation of Proposed Rosemont Pit Dewatering and Post-Closure*: unpublished report prepared for Rosemont Copper, August 30, 2 vol., 123 p.

SRK, 2010a, Technical Review of *Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts Report* (Tetra Tech, 2010) and *Comparison of Natural Fluctuation in Groundwater Level to Provisional Drawdown Projections* (Montgomery & Associates, 2010): Technical Memorandum prepared for SWCA, May 11, 2010, 4 p.

____ 2010b, Technical Review of *Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts—Final Version* (Tetra Tech, 2010a): Technical Memorandum prepared for SWCA, August 3, 2010, 3 p.

____ 2010c, Technical Review of Hydrogeologic Framework Model (Tetra Tech, 2010): Technical Memorandum prepared for SWCA, July 30, 2010, 2 p.

____ 2010d, *Review of (Tetra Tech, 2010) Hydraulic Property Estimates*: Technical Memorandum prepared for SWCA, August 2, 3 p.

____ 2010e, *Technical Review of Predictive Groundwater Flow Model Construction and Calibration* and *Steady-State Sensitivity Analyses*: Technical Memorandum prepared for SWCA, August 17, 2010, 5 p.

____ 2010f, *Review of Tetra Tech Documents Predictive Groundwater Modeling Results (Tetra Tech, 2010a) and Rosemont Groundwater Flow Model Sensitivity Analyses (Tetra Tech, 2010b)*: Memorandum prepared for SWCA, September 27, 2010, 5 p.

Tetra Tech, 2010a, *Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts*: unpublished report prepared for Rosemont Copper, Tetra Tech Project No. 114-320869, April 2010, 72 p., 1 appendix.

_____ 2010b, *Davidson Canyon Hydrogeologic Conceptual Model and Assessment of Spring Impacts*: unpublished final version of report prepared for Rosemont Copper, Tetra Tech Project No. 114-320869, July 2010, 40 p., 1 appendix.

_____ 2010c, *Hydrogeologic Framework Model*: Technical memorandum submitted to Rosemont Copper Company on July 3, 2010, 13 p.

_____ 2010d, *Hydraulic-Property Estimates:* Technical memorandum submitted to Rosemont Copper Company on July 9, 2010, 21 p., 1 attachment.

____ 2010e, *Groundwater Flow Model Construction and Calibration*: Technical memorandum submitted to Rosemont Copper Company on July 26, 2010, 76 p., 2 attachments.

____ 2010f, *Steady-State Sensitivity Analysis*: Technical memorandum submitted to Rosemont Copper Company on July 30, 2010, 12 p.

____ 2010g, *Rosemont Groundwater Flow Model Sensitivity Analyses*: Technical memorandum submitted to Rosemont Copper Company on August 17, 2010, 93 p.

____ 2010h, *Predictive Groundwater Flow Modeling Results*: Technical memorandum submitted to Rosemont Copper Company on July 30, 2010, 28 p.

____ 2010i, *Regional Groundwater Flow Model, Rosemont Copper Project*: unpublished report prepared for Rosemont Copper, Tetra Tech Project No. 114-320874, November 2010, 291 p, 3 appendices.

____ 2010j, *Responses to SRK's Technical Review Comments on Tetra Tech's Groundwater Flow Model Technical Memoranda*: Technical memorandum submitted to Rosemont Copper Company on November 17, 2010, 15 p., 5 attachments.

_____ 2010k, *Rosemont Infiltration, Seepage, Fate and Transport Response to Comments*: Technical Memorandum submitted to Rosemont Copper Company, Tetra Tech Project No. 268/10-320884-5.3, November 23, 2010, 24 p.

5 Reviewer Qualifications

Vladimir Ugorets, Ph.D., is a Principal Hydrogeologist with SRK Consulting in Denver, Colorado. Dr. Ugorets has more than 31 years of professional experience in hydrogeology, developing and implementing groundwater flow and solute-transport models related to mine dewatering, groundwater contamination, and water resource development. Dr. Ugorets' areas of expertise are in design and optimization of extraction-injection well fields, development of conceptual and numerical groundwater flow and solute-transport models, and dewatering optimization for open-pit, underground and in-situ recovery mines. Dr. Ugorets was directly responsible for reviewing the groundwater flow model. His resume has been provided to SWCA in prior submissions.