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Technical Memorandum

To:	Kathy Arnold	**From:**	Michael E. Zeller, P.E., P.H.
Company:	Rosemont Copper Company	**Date:**	July 11, 2011
Re:	Predicted Regulatory (100-Yr) Hydrology and Average-Annual Runoff Downstream of the Rosemont Copper Project	**Doc #:**	
CC:	David Krizek, P.E. (Rosemont Copper Co.)		

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Expires 12/31/13

1.0 INTRODUCTION

This Technical Memorandum provides a summary of Tetra Tech's findings related to predicted regulatory (100-year) hydrology and average-annual runoff at key locations downstream of the proposed Rosemont Copper Project, to be located in Sections 25 and 36 of T18S, R15E; Sections 19, 20, 21, 28, 29, 30, 31, and 32 of T18S, R16E; Section 1 of T19S, R15E; and Sections 5 and 6 of T19S, R16E, G&SRM, Pima County, Arizona.

The Rosemont Project facilities will be located in drainage areas that all drain to a concentration point located in Lower Barrel Canyon Wash at the United States Geological Survey (USGS) Gaging Station at SR 83, as shown on Figure 1 in Attachment No 1. The location of this USGS Gaging Station is the most upstream stormwater control point for the evaluating regulatory (100-year) hydrology and average-annual runoff downstream of the Rosemont Copper Project. The key watershed points of concentration that were analyzed are:

- At the USGS Gaging Station
- Where flows from the USGS Gaging Station enter Davidson Canyon Wash
- Where flows from Davidson Canyon Wash enter Cienega Creek
- Where Cienega Creek becomes Pantano Wash
- Where the Pantano Wash enters the Rillito River
- Where the Rillito River enters the Santa Cruz River

2.0 REGULATORY HYDROLOGY AND PREDICTED AVERAGE-ANNUAL RUNOFF

2.1 Data Application

Regulatory hydrology for areas downstream of the USGS Gaging Station were determined from conducting research of existing, readily available hydrologic data prepared by federal and local governmental agencies—the principal agencies being FEMA, the USGS, and the Pima County Regional Flood Control District (District). Predicted estimates of average-annual runoff were determined from existing, readily available data prepared by the USGS, as well as via a USGS regression equation and a Tetra Tech regression equation developed from data provided by the USGS. The entirety of the points of concentration comprises the Pantano - Rillito Watershed.

The table below lists the results obtained in the preparation of this Technical Memorandum. The hydrologic data for the USGS Gaging Station at SR 83 are available from a prior Tetra Tech Technical Memorandum dated March 5, 2010, and titled *"Mine Plan of Operations Stormwater Assessment"* (Tetra Tech, 2010). The pre-mine hydrologic data for Davidson Canyon Wash, Pantano Wash, and the Rillito River come from USGS surface water records, which can be found online at http://waterdata.usgs.gov/az/nwis/sw.

TABLE 1

Point of Concentration	**Watershed Size** (square miles)	**Regulatory (100-yr) Peak Discharge** (cfs)	**Mean-Annual Discharge** (cfs)	**Average-Annual Runoff** (acre-feet)
at Pre-Mine USGS Gaging Station (SR 83)	14.0	8,072	1.94*	1407*
at Post-Mine USGS Gaging Station (SR 83)	6.8	3,785	1.20*	869*
Pre-Mine USGS Gaging Station to Davidson Canyon Wash	15.0	8358*	2.06*	1489*
Post-Mine USGS Gaging Station to Davidson Canyon Wash	7.8	4067*	1.34*	971*
Pre-Mine Davidson Canyon Wash at Old USGS Gaging Station	50.5	19,000	0.70	507
Post-Mine Davidson Canyon Wash at Old USGS Gaging Station	43.3	17,729*	0.63*	456*
Pre-Mine Davidson Canyon Wash at Cienega Creek	51.3	19,133*	0.71*	514*
Post-Mine Davidson Canyon Wash at Cienega Creek	44.1	17,877*	0.64*	464*
Pre-Mine Where Cienega Creek becomes Pantano Wash	457	30,000	6.09	4412
Post-Mine Where Cienega Creek becomes Pantano Wash	449.8	29,843	6.03*	4369*
Pre-Mine Pantano Wash at the Rillito River	604	32,000	3.58	2594
Post-Mine Pantano Wash at the Rillito River	596.8	31,878	3.55*	2572*
Pre-Mine Rillito River at the Santa Cruz River	928	32,000	13.51	9787
Post-Mine Rillito River at the Santa Cruz River	920.8	31,926	13.44*	9737*

*From regression equations or extrapolation

3.3 Interpretation of Results

For both pre-mine and post-mine conditions, the data presented in the preceding table demonstrate a general pattern of decline in both regulatory peak discharges per unit area and average-annual runoff per unit area as watershed size increases in the Pantano - Rillito Watershed system. This decline is characteristic of semi-arid and arid lands hydrology.

One parameter that is not explicitly apparent, though, is the impact of variability in annual runoff that occurs on a yearly basis. Variability of watershed runoff in a semi-arid or arid environment is extremely large. The following table demonstrates this extreme variability at USGS Gaging stations located within Pantano - Rillito Watershed, which encompasses the subwatersheds influenced by the planned Rosemont Mine.

TABLE 2

USGS Gaging Station (Gage Number)	**Watershed Size** (square miles)	**Minimum Mean-Annual Discharge** (cfs)	**Mean-Annual Discharge** (cfs)	**Maximum Mean-Annual Discharge** (cfs)	**Min. - Max. Percent Annual Variability**
Arcadia Wash at Tucson (09485550)	2.72	0.05	0.36	0.74	720
Atterbury Wash Trib. at Tucson (9485390)	4.97	0.11	0.23	0.45	209
Bear Creek near Tucson (9484200	16.30	0.14	4.69	11.70	3,350
Cienega Creek near Sonoita (9484550)	289	0.87	2.03	3.86	233
Cienega Creek near Pantano (9484560)	289	0.84	2.35	6.21	280
Davidson Canyon near Vail (9484590)	50.5	0.00	0.70	1.44	∞
Pantano Wash near Vail (9484600)	457	0.74	6.09	15.70	823
Pantano Wash near Broadway (9485450)	599	0.06	3.58	10.40	5,967
Rillito Creek at Dodge Blvd. (9485700)	871	0.12	26.10	163.70	21,750
Rillito Creek at La Cholla Blvd. (9486055)	922	0.00	13.51	54.10	∞
Rillito Creek near Tucson (9485850)	928	0.43	13.74	72.00	3,195
Rincon Creek near Tucson (9485000)	44.80	0.07	6.13	33.40	8,757
Sabino Creek near Mt. Lemmon (9483300)	3.19	0.14	1.63	3.57	1,164
Sabino Creek near Tucson (9484000)	35.50	0.86	20.48	64.60	2,381
Tanque Verde Creek near Tucson (9483100)	43.00	1.06	8.90	31.80	840
Tanque Verde Creek at Tucson (9484500)	219	0.01	21.11	147.00	211,100

General Impacts to the Pantano - Rillito Watershed

Table 1 demonstrates that as the watershed size increases beyond a few tens of square miles, reductions in the regulatory peak discharge within the Pantano - Rillito Watershed are no longer discernable for post-mining conditions.

Likewise, as the watershed size increases beyond a few tens of square miles changes to average-annual runoff values become very small for post-mining conditions and, as demonstrated in Table 2, fall well within the annual variability of hydrologic processes which occur in the Pantano - Rillito Watershed. In fact, excluding the undefined value for Davidson Canyon Wash near Vail and the undefined value for Rillito Creek at La Cholla Boulevard), as well as the extremely large value for the Tanque Verde Creek at Tucson (assuming all three as outliers), as listed in Table 2, the average of the maximum versus minimum percent of annual variability is calculated to be 3,821 percent, or nearly a 40:1 average maximum versus minimum variability ratio. Even the smallest variability is still more than 200 percent. What this means is that neither direct nor indirect changes in the annual variability of annual runoff within the overall Pantano - Rillito Watershed can be reasonably ascribed to a small change in the hydrologic system that will be created by post-mining conditions.

Specific Impacts to Outstanding Waters of Davidson Canyon Wash

Review of the data in Table 1 and Table 2 reveal that specific impacts to the Pantano-Rillito Watershed for post-mining conditions are essentially confined to those areas located upstream of the confluence of Davidson Canyon Wash with Cienega Creek. Table 1 indicates that post-mining regulatory peak discharges are predicted to be reduced by about 56.5 percent as flows reach the USGS Gaging Station at SR 83, by about 51.3 percent as flows reach Davidson Canyon Wash, and by about 6.6 percent as flows reach Cienega Creek, where 70 percent of the Davidson Canyon Wash watershed is not impacted by post-mining conditions. It is noted that often reductions in regulatory peak discharges have a positive benefit on the hydrologic systems of alluvial watercourses such as Davidson Canyon Wash, benefits such as decreases in the extent of floodplains and smaller erosion-hazard areas.

Table 2 indicates that post-mining average-annual runoff values are predicted to be reduced by about 38 percent as flows reach the USGS Gaging Station at SR 83, by about 35 percent as flows reach Davidson Canyon Wash, and by about 10 percent as flows reach Cienega Creek. Because 70 percent of the Davidson Canyon Wash watershed is not impacted by post-mining conditions; and because, as demonstrated in Table 2, these predicted changes are based upon average-annual values, the large variability in annual runoff that occurs within the semi-arid regions of southern Arizona means that during a particular water year post-mining annual runoff reductions within Davidson Canyon Wash cannot be directly attributed to any runoff emanating from watersheds directly affected by Rosemont Mine.

4.0 REFERENCES

Blakemore, T. E., Hjalmarson, H.W., and Waltemeyer, S.D., United States Geological Survey (1997). *Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States*. Water-Supply Paper 2433.

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Pima County Regional Flood Control District (2007). *Table of Regulatory Peak Discharges*. Version Dated January 2007.

Tetra Tech (2010). *Technical Memorandum, Mine Plan of Operations Stormwater Assessment*. Prepared for Rosemont Copper Company. Memorandum Dated March 5, 2010.

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ATTACHMENT

DEVELOPMENT OF REGRESSION EQUATIONS

For Regulatory Peaks

Other than stormwater runoff emanating from the Rosemont Mine watersheds that flows to the USGS Gaging Station at SR 83, and which was previously calculated (Tetra Tech, 2010), the USGS Regional Regression Equation for Region 13, which encompasses the Pantano - Rillito Watershed, was used in ratio format to predict reductions in regulatory peaks flows created by post-mining watershed area reduction within the 928-square-mile Pantano - Rillito Watershed.

The equation is: $Q_{100} = 10^{(5.52-2.42A^{-0.12})}$

Thus the ratio of Reduced Area (A_r) to Natural Area (A_n) is:

$$\frac{LOG(Q_{100Ar})}{LOG(Q_{100An})} = \frac{5.52-2.42A_r^{-0.12}}{5.52-2.42A_n^{-0.12}}\text{; so, } LOG(Q_{100Ar}) = \frac{5.52-2.42A_r^{-0.12}}{5.52-2.42A_n^{-0.12}} LOG(Q_{100An})$$

Where Q_{100Ar} and Q_{100An} are the reduced and natural regulatory flood peaks, respectively.

For Average-Annual Runoff

A multi-variable relationship was developed by Tetra Tech for the analysis of the Rosemont Mine watersheds, terminating at the USGS Gaging Station at SR 83. The relationship was regressed on:

- USGS-supplied contributing watershed area;
- Average-annual precipitation; and
- Mean watershed elevation.

The relationship is: $Q_{AA} = (8.44885x10^{-06})A^{0.9821}P^{2.1198}E^{1.2101}$

Where,

Q_{AA} = Average-annual runoff, in acre-feet;

A = Watershed area, in square miles;

P = Average-annual precipitation, in inches (18 inches); and

E = Mean watershed elevation, in feet.

However, in order to determine post-mining impacts created by watershed area reduction within the 928-square-mile Pantano - Rillito Watershed, it was necessary to develop a more inclusive regression equation for areas downstream of the USGS Gaging Station at SR 83, as follows:

$Q_{AA} = A^{0.6636}P^{2.1068}$.

This equation was then used in ratio format to determine the changes in average-annual runoff due to reduction in post-mining watershed size, as follows, assuming that on a watershed-wide basis the average-annual precipitation, P, would not change meaningfully as a consequence of a small reduction in watershed size:

$$Q_{AAr} = \left(\frac{A_r}{A_n}\right)^{0.6636} Q_{AAn}$$

Where Q_{AAr} and Q_{AAn} are the reduced and natural average-annual runoff, respectively.