TECHNICAL MEMORANDUM

Date: August 5, 2010 **Project No.:** 093-81962

To: Dale Ortman

From: George Annandale, Jennifer Patterson, Craig Baxter

RE: ROSEMONT COPPER PROJECT, TECHNICAL REVIEW OF SITE WATER MANAGEMENT UPDATE

1.0 INTRODUCTION

Golder Associates (Golder) conducted a review of the *Site Water Management Update for the Rosemont Copper Project* (April 2010, Tetra Tech). The Site Water Management Update is presented in five volumes. The review consisted of reading the pertinent sections of the report and supporting documents and rendering a professional opinion regarding whether or not the data, assumptions, and methods used in the report conform to currently accepted industry practice. Review was limited to the goals specified by SWCA as listed in each section below as they relate only to water and erosion management. No review of geotechnical stability or other disciplines were addressed.

This memorandum summarizes the findings Golder's review of the Site Water Management Update. The goal of the review is to identify any red flags and potential fatal flaws associated with the concepts used or the design of site stormwater management structures.

2.0 RUNOFF CALCULATIONS

Goal: Compare Tetra Tech's selected method(s) of runoff calculation and the method(s) proposed by Pima County; comment on the applicability of all methods to the Rosemont Project.

Tetra Tech analyzed both the NRCS method and the Pima County method (PC-HYDRO) to determine the most suitable storm criteria for the Rosemont site. Table 1 ranks the design storms obtained by applying these methods in terms of severity.

TetraTech selected the NRCS method to determine peak flows and runoff volumes for the design of structures at the Rosemont site. Golder agrees this method is more appropriate because the Pima County method is more suitable for small urban watersheds and is not as conservative as the selected method.

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TABLE 1

SUMMARY OF DESIGN STORM COMPARISON BY TETRATECH

		Peak Flow Rate Ranking	Runoff Volume Ranking
NRCS Method	1000-yr, 24-hr NRCS Type II Dist.	2	3
NRCS Method	500-yr, 24-hr NRCS Type II Dist.	3	4
NRCS Method	100-yr, 24-hr NRCS Type II Dist.	5	5
NRCS Method	100-yr, 1-hr thunderstorm	6	7
NRCS Method	100-yr, 1-hr compressed 6-hr event	7	7
NRCS Method	100-yr, 1-hr NRCS Type II Dist.	8	7
NRCS Method	6-hr Local PMP	1	2
NRCS Method	72-hr General PMP	9	1
Pima County Method	Pima County Method (PC-HYDRO) 100-yr, 6-hr	4	6

Published reports give the average-annual precipitation as ±24 inches; however, Tetra Tech concludes that the average-annual precipitation is 18 inches. This was obtained by using both site-measured precipitation as well as back-calculating precipitation depth using average-annual runoff from the Arizona Water Atlas (106.7 ac-ft/sq-mi). This raises a few questions:

- How was the selected average rainfall of 18 inches used, and what was the sensitivity of that application compared to using the 24 inches average rainfall?
- Is the use of the Arizona Water Atlas appropriate? Golder understands that the water atlas back calculation was likely only used as a check of the site-calculated average rainfall. However, if one knows what the answer to a problem is, it is easy to select parameters for the back calculation to get to that answer. The question is whether those selected parameters are reasonable.
- How many years of site collected data were used to determine that the average-annual precipitation of 18 inches? Was the record long enough to justify not using the 24 inches average rainfall?

Also lacking in the runoff analyses is an assessment of the effects of the maximum saturation event. Arizona's worst-case runoff volume conditions typically occur during consecutive precipitation days, as for example illustrated in Figure 1.

Experience in Arizona is that long duration, relatively low intensity rains often results in larger flow volumes than the 24-hr or shorter duration design storms. It is recommended that the maximum saturation event runoff be identified for the site and used to evaluate the capacity of the structures impounding water.

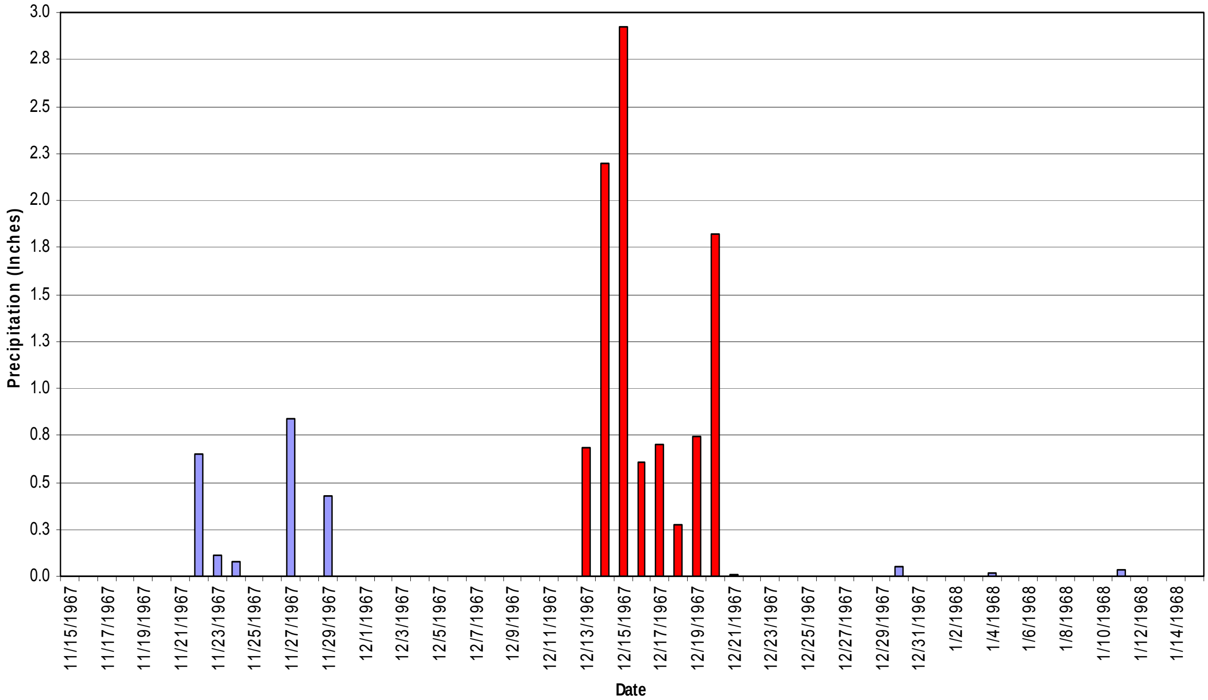

FIGURE 1

EXAMPLE OF A LONG-DURATION STORM NEAR SUPERIOR, ARIZONA

3.0 DESIGN CRITERIA FOR WATER CONTROL STRUCTURES

Goal: Concisely tabulate the design criteria selected by Tetra Tech for each water control structure and determine if the design calculations used the selected design criteria values. This information is summarized in Table 2.

As shown in Table 2, it is unknown if the Pit Stormwater Pond and Crusher Stormwater Pond meet the specified design criteria, because no detailed sizing calculations were included in the Site Water Management Update.

The client requested Golder to indicate concurrence with the application of the design criteria. Concurrence or not by Golder is indicated in the last column of Table 2.

TABLE 2

STORMWATER STRUCTURE DESIGN CRITERIA

Area	Water Control Structure	Design Criteria Established in Volume 1	Criteria Followed?	Golder Concurrence?
Open Pit and Southern Plant Site Area	Pit Diversion Channel	Local PMP Event conveyance	YES	YES
	Pit Stormwater Pond	General PMP Volume	Unknown	NO* + requires further clarification
	Crusher Stormwater Pond	General PMP Volume	Unknown	NO* + requires further clarification
Main Plant Site Area	Permanent Diversion Channel No. 1	Local PMP Event conveyance, 200-yr, 24-hour erosion protection	YES	Why use different criteria? Clarify.
	PWTS Pond and Settling Basin	100-yr, 24-hr event	YES	NO*
	Detention Basin No. 1	Manage General and Local PMP Volume, contain 200-yr, 24-hr	YES	NO*
	Permanent Diversion Channel No. 2	Local PMP Event conveyance, 200-yr, 24-hour erosion protection	YES	Why use different criteria? Clarify.
	Detention Basin No. 2A	Manage General and Local PMP Volume, contain 200-yr, 24-hr	YES	NO*
	Detention Basin No. 2B	Manage General and Local PMP Volume, contain 200-yr, 24-hr	YES	NO*
	Detention Basin No. 3	Manage General and Local PMP Volume, contain 200-yr, 24-hr	YES	NO*
Rosemont Ridge Landform	Waste Rock Storage Area	Detention Pools on benches contain 500-yr, 24-hr event. PCAs capacity for General PMP event	YES	NO*
	North Dry Stack Tailings Facility	Drainage channels and drop structures 500-yr, 24-hr.	YES	YES
		Depression areas on top of dry stack contain 1000-yr, 24-hr event, berms also on top control larger than general PMP event	YES	NO*
	South Dry Stack Tailings Facility	Drainage channels and drop structures 500-yr, 24-hr.	YES	YES
		Depression areas on top of reclaimed surface. Storms up to 1,000-yr, 24-hr event controlled behind rock weir on top of dry stack.	YES	NO* Is rock weir watertight?
		Larger flows discharged over weir to rock slope leading to flow-through drain	Unknown	Unclear what it meant by larger flows. How is stability ensured?

Note: NO* indicates that the storage volumes should be checked to also contain the maximum saturation event

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4.0 FLOW-THROUGH DRAINS

Goal: Review the design of the Flow-Through Drains and comment on their short- and long-term functional viability.

The purpose of Flow-Through Drains is to convey up-gradient water into the natural drainage downstream of the tailings and waste rock facilities. The Flow-Through Drains are constructed in addition to the typical under drains. The long-term viability of these structures is uncertain due to the potential effects of clogging by sediment. We recommend every effort be made to route water around the structures instead of using the flow-through drains. If this is not possible, then the Flow-Through Drains need to be constructed in a manner by which sediment can be trapped at the inlet and maintenance can be performed. Without an agreement to this maintenance, this structure poses, in our opinion, a fatal flaw.

Golder was requested to specifically comment on the entrance arrangement to the flow-through drains, shown in Figure 2. It is our opinion that sediment from upstream will likely clog the berm over the medium to long term. This is due to the fact that no upstream provision is made to prevent sediment from entering the berm.

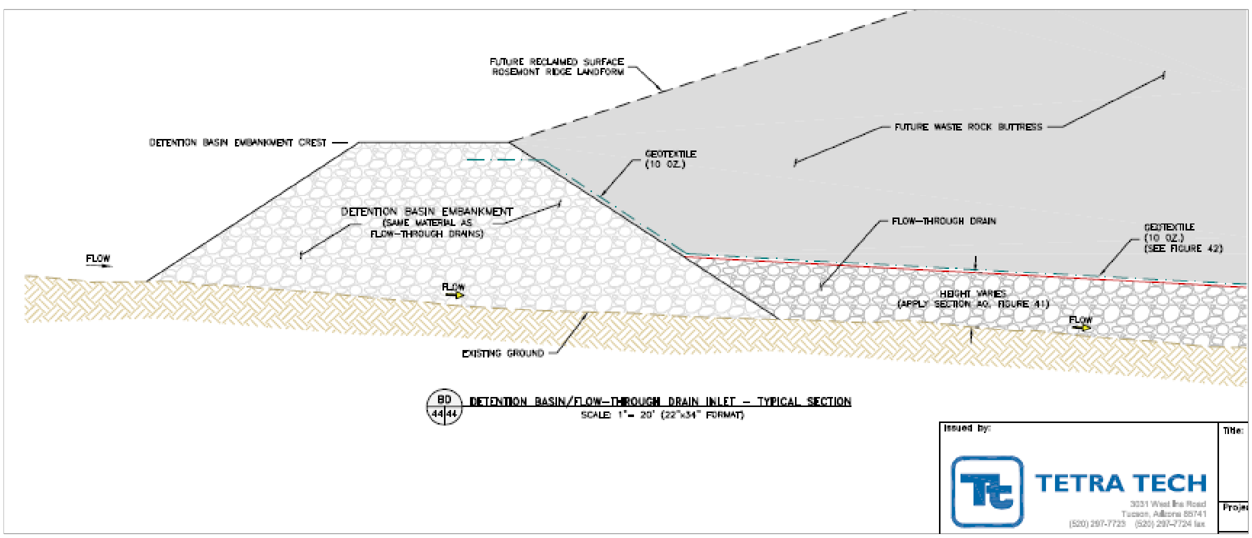

FIGURE 2

DETAIL OF THE FLOW-THROUGH INLET

Both the long-term and short-term functionality of the Flow-Through drains are dependent upon the capacity of the upstream ponds. The capacity is based on the incoming runoff, which should be calculated using both PMP and maximum saturation event conditions to crosscheck results. The capacity is also based on the outflow rate, which is calculated using the following equation:

$$Q = \left(\frac{1}{D}\right)^{\frac{1}{b+2}} \frac{\alpha w}{(3+b)^{\frac{1}{b+2}}} \left(H_{up}^{b+3} - H_{down}^{b+3}\right)^{\frac{1}{b+2}}$$

Where:

- $\alpha = \left(\frac{2gu^b}{a(d_{50}-\sigma)^{b-1}}\right)^{\frac{1}{b+2}}$
- $D = L - 0.7S_1$
- $S_1 = H_{up} cot\beta$
  - d_{50} is the particle diameter size where 50% of the total particles' weight is smaller
  - *a* and *b* are empirical coefficients of the equation related to the flow and particles
  - u is the kinematic viscosity
  - *σ* is the standard deviation of rock size distribution
  - *Q* is the outflow rate through the rockfill dam structure
  - H is the water depth inside the structure
  - *w* is the width of the flow cross section
  - β is the angle of the upstream and downstream dam face with horizontal
  - L is the length of the dam

The reference for this equation is: Samani, J. M. V. and Heydari, M. *Reservoir Routing through Successive Rockfill Detention Dams.* Journal of Agricultural Science and Technology. Vol. 9. (2007). Pgs. 317-326.

It appears this equation was developed to calculate flow though relatively short lengths of rockfill dams. It does not include allowances for losses due to long reaches or bends within the Flow-Through Drain. It is anticipated that the ponded water on the up-gradient portion of the tailings impoundment may not drain as quickly as calculated in the Management Plan.

5.0 REVIEW SITE STORMWATER CONTROLS

Goal: Review the design of the stormwater controls for the Rosemont Ridge Landform, including the Waste Rock Storage Area and Dry Stack Tailings Facility and comment on their short- and long-term functional viability.

5.1 Dry Stack Tailings Facility

The Dry Stack Tailings Facility is broken into North and South facilities with very similar stormwater management designs for each facility. Depressions on top of the North tailings facility contain the 1,000-year, 24-hour storm event before allowing runoff to enter decanting structures and discharge off the tailings facility. Containment berms located on top of the North Dry Stack Tailings Facility have capacity to contain a volume from larger than the General PMP event. Similarly, the South Dry Stack Tailings

Facility has depressed areas to contain runoff from the 10-year, 24-hour event. Larger flows but smaller than the 1,000-year, 24-hour event will be retained behind a rock weir on the west side of the landform. Larger flows than the 1,000-year, 24-hour event will be discharged over the rock weir and will eventually be conveyed to a flow-through drain.

One concern with this type of design is the need for accuracy during construction. If one berm containing the water has a low-lying spot, the entire area of ponded water may escape causing massive erosion should water flow through that low-level spot. Another concern with this design is the estimated magnitude of the required capacity. Golder recommends that the volumes be checked using the maximum saturation event.

The riprap protection on downchutes on the slopes of the tailings facility is designed to convey flow from bench channels to natural ground using the Robinson method. This method was originally developed using, to the best of Golder's knowledge, a maximum d_{50} of 9 inches. The downchutes for the Rosemont project use rocks with median diameters (d_{50}) between 20-24 inches, which is outside the range of the Robinson method. Additionally, the ratio of normal flow depth to riprap thickness is much lower than 1. This leads to a situation where part of the water will likely flow through the rocks and not on top of them, as per the design intent. This can lead to unexpected failure.

Finally, the design specifies an 8 oz. min. geotextile fabric under the riprap. In Golder's experience, geotextile fabric does not perform well as bedding for riprap on steep slopes. Although, in some cases, riprap-lined chutes are still used on steep slopes, we recommend that its application for closure be reconsidered as such steep channels can be relatively unstable. This is not compatible with the closure demands of long-term stability.

Drainage exiting the Dry Stack Tailings enter existing natural drainages at several points including the permanent diversion channel to the north side of the tailings facility, riprap lined downchutes, and channels flowing along benches. No erosion protection has been identified at these locations. These areas should be analyzed to ensure flow transitions from the engineered channels to the natural drainages without causing erosion to the natural channels.

5.2 Waste Rock Storage Area

Similar to the Dry Stack Tailings Facilities, the Waste Rock Storage Area has designed depression areas to contain a certain storm event. The Waste Rock Storage Area's depression areas contain up to the 500-year, 24-hour storm event. Flows up to the General PMP event will be conveyed to the toe of the storage area and will be retained by perimeter containment areas (PCAs). Conveyance to the PCAs will be by rocked slopes on the 3:1 slopes of the Waste Rock Storage Area. No specifications for the gradation of the rock to be used on the 3:1 slopes were provided.

Concerns with this storage are similar to the Dry Stack Tailings Facility. The design will require tight controls on construction methods to ensure consistent elevations if the berms around all the benches. Additionally, the storage volumes should be checked using the maximum saturation event.

Golder was unable to locate designs for the downchutes on the waste rock storage area. The document indicated a need for riprap, but no structures were designed.

5.3 Perimeter Containment Areas

There is no identified fatal flaw with the perimeter containment areas; however, there is a long-term concern with the lack of outlet from these locations. These may also potentially fill with sediment.

5.4 Water Storage on Waste Rock and Tailings Facilities and Benches

This issue, in our view, is such an unusual application that we wish to emphasize it here. It appears as if the consultant went to a lot of effort to size these facilities to minimize risk. Golder wishes to point out that it is unusual to store large amounts of water on top of waste rock and tailings facilities, and on benches, particularly after closure. It is recommended that appropriate stability calculations be executed to ensure that geotechnical slope failures would not occur and that internal erosion might not lead to failure. Additionally, it is recommended that maintenance measures that will ensure that such containment volumes can be retained in the long term be outlined. Our concern is that a low spot that might develop on a perimeter berm could initiate a release, which can result in significant erosion. Such a low spot can be fairly small, but can lead to a massive release of all the water in the containment area once erosion commences. This may lead to massive failure along the slopes of the waste rock and tailings facilities.

As for storage on the benches, we recommend careful review of potential failure mechanisms. For example: Would it be possible for water to seep into the slope, eventually resulting in internal erosion and eventual failure of the slope? Such an erosion event can act in the same way as outlined in the previous paragraph, leading to a massive release of the water stored on the bench.

6.0 SEDIMENT CONTROLS AND YIELD

Goal: Review the sediment control design and sediment yield calculations and comment on the short- and long-term functional viability of the sediment control system and the applicability of the sediment yield calculations.

6.1 Sediment Yield Calculation Methodology

The method used for the calculation of sediment yield for the site is the Pacific Southwest Inter-Agency Committee (PSIAC) method. This method was developed in 1968 in Southern California and is recommended for basins that are larger than 10 mi^2 in size. The baseline and post-mining scenarios analyzed have basin areas of 8.20 mi^2 and 1.93 mi^2 respectively. Therefore, Golder recommends that the sediment yield calculations be evaluated using a method that is more appropriate for this site.

Additionally, Golder has concerns with the results of the sediment yield calculations. Both baseline and post-mining conditions give the average-annual specific sediment yield as 1.15 acre-feet/mi^2/year. It is reasonable to expect that the baseline scenario will differ from the post-mining scenario because the addition of the landform will change the surface conditions. Currently no difference is indicated by the analysis results provided by TetraTech.

Golder produced a report *Rosemont Mine Landforming – Evaluation of Mine Waste Slope Geometry* dated February 17, 2010 wherein it was estimated that the expected erosion from the Rosemont landform surface prior to stabilization will be 14.4 inches. It is anticipated that large amounts of this sediment will report to all areas where water will be ponded. This will therefore reduce the storage capacity of the bench storage areas and perimeter containment areas. Allowance for such storage loss should be made.

6.2 Sediment Control during Operations

The report states that BMPs will be used during operations to manage sediment on the site; however, no specific definitions are described as to the locations and phasing of these sediment controls during operations. The report also calls for concurrent reclamation, which is very difficult in an arid climate. It is recommended that BMPs be defined and that reliance on concurrent reclamation be minimized.

7.0 LANDFORMING

Golder was not requested to comment on the landforming arrangement, but feels compelled to do so as we have developed and estimated the hydraulic and erosion performance of the elements that were used to develop the landforming shape. We recommend that TetraTech develop a table showing adherence to the recommendations previously made by Golder in this regard.

8.0 CONCLUSION

Golder has classified concerns into two categories: red flags and potential fatal flaws associated with the Site Water Management Update. Those findings are summarized in 3.

TABLE 3

RED FLAGS AND POTENTIAL FATAL FLAWS

Red Flags	Using smaller precipitation depth (18in) to calculate average annual runoff instead of NRCS recommended depth (24in)
	No volume check calculations using maximum saturation event conditions
	No calculations presented for pit diversion channel and pit stormwater pond
	Methodology used for sediment yield calculations should be reviewed as it is believed to be inappropriate
	Lack of drainage from perimeter containment areas
	Demonstrate adherence to geometric recommendations on landform element suggestions previously proposed by Golder
	Lack of detail for sediment control designs during operations
	Specific sediment yield is the same for pre- and post-mining conditions, which appears to be incorrect
Potential Fatal Flaw	Storage on top of benches is unusual for long-term closure and could lead to massive failure
	Down chutes on both tailings facility and waste rock can lead to failure as riprap lining may be inappropriate protection type
	Flow-through drains: potential long-term difficulties with maintenance and retaining discharge capacity
	Water storage on top of tailings facility and waste rock dump is unusual for long-term closure and could lead to massive failure
	No allowance has been made for anticipated erosion from landforms into storage locations on benches and perimeter containment areas. 14 to 15 inches of erosion is anticipated from the landform areas.