



Technical Memorandum

To: Kathy Arnold (Rosemont)
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From: David Levy
Doc #: 077/09-320842-5.3
Subject: **Evaluation of Rosemont Geochemical Testing Results and Local Water Quality**
Date: May 5, 2009

1.0 Introduction

The Rosemont Copper Project (Project) is a proposed copper-molybdenum mining project located in Pima County, Arizona. Project facilities proposed include an oxide ore Heap Leach Facility, a Waste Rock Storage Area, and Dry Stack Tailings Facilities to accommodate the planned ore recovery and processing operations. The Heap Leach Facility will be constructed atop a synthetic liner and all surface water runoff from the facility will be collected. This minimizes the potential for seepage infiltrating into the groundwater. Because the Waste Rock Storage Area and Dry Stack Tailings Facilities will be constructed directly on the ground surface, the potential for seepage and the subsequent groundwater quality issues must be evaluated. The objectives of this memorandum are to address questions related to acid rock drainage and livestock grazing. This memorandum presents: 1) a summary of the acid-base accounting (ABA) properties of all waste rock and tailings samples tested to date, and 2) an evaluation of geochemical leaching results from waste rock and tailings relative to both local ground/surface water conditions and to Arizona standards for human drinking water and agricultural livestock watering (Arizona Administrative Code [A.A.C.], Title 18, Chapter 11).

2.0 Existing Characterization Data

Site geochemical and water quality characterization data used in the analysis included: 1) ABA data from waste rock and tailings samples, 2) short-term leach test data from waste rock and tailings samples (Synthetic Precipitation Leach Procedure and Meteoric Water Mobility Procedure), 3) site stormwater runoff quality data, and 4) groundwater quality data from site monitor wells. Table 2.01 summarizes the number of ABA and short-term leaching tests that have been performed on the various waste rock types and tailings samples.

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Table 2.01. Summary of ABA and Leach Tests for Rosemont Waste Rock and Tailings

Rock Type	No. ABA Tests	No. SPLP Tests	No. MWMP Tests
Willow Canyon Formation, Arkose	55	8	8
Tertiary Gravel	3	0	0
Abrigo Formation	6	5	0
Horquilla Limestone	26	8	2
Glance Conglomerate	4	0	0
Willow Canyon Formation, Andesite	38	4	6
Concha Limestone	6	1	1
Martin Formation	7	4	0
Earp Formation	14	6	0
Epitaph Formation	16	6	0
Escabrosa Limestone	10	4	0
Bolsa Quartzite	15	6	0
Colina Limestone	11	4	0
Quartz Monzonite Porphyry	9	2	1
Scherrer Formation	0	0	0
Pre-Cambrian Granodiorite	0	0	0
Overburden	6	2	2
Tailings	4	4	2

2.1 Acid-Base Accounting Data

Numerous waste rock and tailings samples were analyzed for ABA properties in order to characterize their bulk chemical characteristics and the potential to generate acidity upon weathering. ABA characterization consists of two measurements: Acid generation potential (AGP) and acid neutralization potential (ANP). The AGP is calculated by determining the content of potentially acid generating sulfide-sulfur (sulfide-S) in a sample, while the ANP is measured by determining the amount of acid that can be consumed by the sample. The difference between ANP and AGP is called the Net Neutralization Potential (NNP = ANP-AGP). Therefore, a sample with a negative NNP value has the potential to generate acidity upon weathering, while a positive NNP value indicates the sample is non-acid generating (net acid-consuming). The neutralization potential ratio (NPR = ANP/AGP) is also used to assess the risk of acid generation, where an NPR greater than 3 is considered a low risk for acid generation, and an NPR value less than 1 indicates a high risk of acid generation (Price, 1997). In addition, the State of Arizona has a draft policy indicating that samples with an NPR greater than 3 or with an NNP greater than 0, and less than 0.3% total sulfur (total-S), are considered inert (ADEQ, 1999).

A summary of the average ABA results for waste rock is provided in Table 2.02. Based on the Arizona Department of Environmental Quality (ADEQ) total-S criteria, rock types which are not considered inert are the Epitaph Formation, Bolsa Quartzite, and Colina Limestone.



However, the Bolsa Quartzite (1.9% of waste rock) is the only rock type considered potentially-acid generating based on the negative NNP value (Table 2.02). While some individual samples of Andesite and Arkose, both part of the Willow Canyon Formation, have been identified as potentially-acid generating, these materials have demonstrated no capacity to generate acidity when subjected to long-term weathering tests using humidity cells (Tetra Tech, 2007). Taken as a whole, the weighted-average ABA characteristics indicate that the waste rock is non-acid generating and is net acid-consuming (Table 2.02).

Table 2.02. Summary of Rosemont Waste Rock Tonnage and Average ABA Characteristics

Rock Type	Tons of Material	Percent of Material	No. of ABA Tests	NNP T CaCO ₃ /kT	NPR	Total-S %
Arkose	546,421,000	44.4%	55	45.3	112	0.23
Tertiary Gravel	141,249,000	11.5%	3	62.4	148	0.09
Abrigo	113,822,000	9.2%	6	580	1930	0.01
Horquilla	87,050,000	7.1%	26	364	1060	0.23
Glance	81,262,000	6.6%	4	625	2080	0.01
Andesite	49,113,000	4.0%	38	35.6	44.8	0.99
Concha	34,110,000	2.8%	6	650	2170	0.01
Martin	31,655,000	2.6%	7	692	1860	0.08
Earp	29,586,000	2.4%	14	110	64.5	0.24
Epitaph	27,176,000	2.2%	16	492	1540	0.47
Escabrosa	22,871,000	1.9%	10	607	1930	0.01
Bolsa	23,694,000	1.9%	15	-2.42	8.09	0.32
Colina	16,161,000	1.3%	11	393	714	1.31
Quartz Monzonite Porphyry	12,953,000	1.1%	9	11.3	37.6	0.02
Scherrer	8,524,000	0.69%	0	-----	-----	-----
Pre-Cambrian Granodiorite	4,204,000	0.34%	0	-----	-----	-----
Undefined	1,223,000	0.10%	0	-----	-----	-----
Overburden	391,000	0.03%	6	20.2	56.4	0.18
Total Amounts and Weighted Averages for NNP, NPR, and Total-S	1,231,465,000	100%	226	216	650	0.21

The ABA characteristics of four (4) tailings samples are shown in Table 2.03. The tailings contain low total-S concentrations (<0.05 %) and highly-positive NNP and NPR values. The tailings are therefore considered both inert and non-acid generating and are net acid-consuming.



Table 2.03. Summary of Rosemont Tailings ABA Characteristics

Sample Date	NNP T CaCO ₃ /kT	NPR	Total-S %
July 2008	304	1013	0.01
June 2007	248	827	0.04
February 2007	332	1107	0.01
May 2006	425	426	0.05
Average	327	843	0.03

2.2 Short-Term Leach Test Data

Selected samples of waste rock and tailings were subjected to short-term leach tests using the Synthetic Precipitation Leaching Procedure (SPLP) and the Meteoric Water Mobility Procedure (MWMP) (Table 2.01). The SPLP was designed to determine the potential for constituent mobility from geologic materials when exposed to precipitation (USEPA, 1986). The SPLP is a batch testing procedure which uses a solution:solid ratio of 20:1. The SPLP extraction solution is adjusted to a pH of 5.0 using a nitric/sulfuric acid mixture, and the sample is extracted for approximately 18 hours prior to filtering of extracts for analysis. The average waste rock SPLP results for the regulated constituents and total dissolved solids (TDS) are provided in Table 2.04. The only numeric A.A.C. Aquifer Water Quality Standard (AWQS) exceeded for drinking water protected use (human drinking water standard) was for arsenic in the Willow Canyon Formation Andesite/Arkose and Overburden SPLP extracts; however, none of the constituents in the SPLP extracts exceeded livestock watering standards. Antimony, arsenic, and thallium concentrations could not be fully evaluated for human drinking water standards because their detection limit was greater than the respective standard (Table 2.04). TDS values ranged from 22.5 to 817 mg/L.

The MWMP is another leaching test used to evaluate the potential for dissolution and mobility of certain constituents from mine rock when exposed to meteoric water (ASTM, 2003). The MWMP incorporates a single-pass column deionized water leach (unspecified pH) over a 24-hr period, after which the leachate is filtered and analyzed. The average waste rock MWMP results for the regulated constituents and TDS are provided in Table 2.05. The only human drinking water standard exceeded was for arsenic in the Overburden MWMP extracts; however, none of the MWMP extracts exceeded livestock watering standards. Antimony and thallium concentrations could not be fully evaluated for human drinking water standards because their detection limit was greater than the respective standard (Table 2.05). TDS values ranged from 20 to 220 mg/L.

The short-term leach test results for the tailings sample (SPLP and MWMP) are provided in Table 2.06. Antimony, arsenic, and thallium concentrations could not be evaluated with respect to human drinking water standards because some sample detection limits were greater than the respective standard. However, none of the remaining constituents exceeded either human drinking water or livestock watering standards, except for pH in the July 2008 SPLP extract (Table 2.06) (note: the analytical laboratory confirmed that this high



pH was an artifact of filtering). TDS values ranged from 13 mg/L (SPLP) to 505 mg/L (MWMP).

Table 2.04. Average SPLP Results (dissolved, mg/L) for Rosemont Waste Rock Samples

Parameter	Abrigo	Andesite	Arkose	Bolsa	Colina	Earp	Epitaph	Human Standard ¹	Livestock Standard ²
Antimony	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.006	-----
Arsenic	0.01	0.020	0.015	0.009	<0.02	<0.02	0.008	0.01	0.2
Barium	0.002	0.003	0.007	0.003	0.019	0.006	0.015	2	-----
Beryllium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.004	-----
Cadmium	<0.002	<0.002	<0.002	0.002	<0.002	<0.002	<0.002	0.005	0.05
Chromium	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.10	1.0
Copper	<0.01	<0.01	0.008	0.06	<0.01	<0.01	<0.01	-----	0.50
Fluoride	0.26	0.29	0.26	0.25	1.28	0.42	0.93	4.0	-----
Lead	<0.01	<0.01	<0.01	<0.01	<0.0075	<0.01	<0.01	0.05	0.10
Mercury	0.0002	<0.0002	0.0003	0.0001	<0.0002	<0.0002	<0.0002	0.002	0.010
Nickel	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.10	-----
pH	NM ³	NM	NM	NM	NM	NM	NM	5 - 9	6.5 - 9
Selenium	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	<0.040	0.05	0.05
Thallium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.002	-----
Zinc	<0.01	<0.01	<0.01	0.024	<0.01	<0.01	<0.01	-----	25
TDS	34.7	71.1	37.2	22.5	817	46.6	677	-----	-----

Parameter	Escabrosa	Horquilla	Martin	Overburden	Qmp	Concha	Human Standard ¹	Livestock Standard ²
Antimony	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.006	-----
Arsenic	<0.02	<0.02	<0.02	0.03	0.008	<0.003	0.01	0.2
Barium	0.002	0.017	0.003	0.063	0.019	0.0182	2	-----
Beryllium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.004	-----
Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.005	0.05
Chromium	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.10	1.0
Copper	<0.01	<0.01	<0.01	<0.01	0.031	<0.01	-----	0.50
Fluoride	0.42	0.51	0.30	0.32	0.30	<0.1	4.0	-----
Lead	<0.01	<0.01	<0.0075	0.02	<0.01	<0.01	0.05	0.10
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.002	0.010
Nickel	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.10	-----
pH	NM	NM	NM	NM	NM	NM	5 - 9	6.5 - 9
Selenium	<0.040	<0.040	<0.040	<0.040	<0.040	<0.04	0.05	0.05
Thallium	<0.02	<0.02	<0.02	<0.015	<0.02	<0.02	0.002	-----
Zinc	<0.01	<0.01	<0.01	0.010	<0.01	<0.01	-----	25
TDS	32.3	310	36.6	38.7	34.5	28.1	-----	-----

¹ Based on Arizona Administrative Code Aquifer Water Quality Standard for drinking water protected use.

² Total Recoverable

³ NM = Not Measured



Table 2.05. Average MWMP Results (dissolved, mg/L) for Rosemont Waste Rock Samples

Parameter	Andesite	Arkose	Horquilla	Concha	Qmp	Overburden	Human Standard ¹	Livestock Standard ²
Antimony	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.006	-----
Arsenic	0.020	0.015	0.02	0.003	<0.003	0.067	0.01	0.2
Barium	0.018	0.005	0.008	0.003	0.0034	0.020	2	-----
Beryllium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.004	-----
Cadmium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.005	0.05
Chromium	<0.01	<0.01	<0.01	<0.01	<0.006	<0.006	0.10	1.0
Copper	<0.01	0.02	<0.01	<0.01	<0.01	0.014	-----	0.50
Fluoride	1.03	0.79	1.09	0.17	0.26	1.3	4.0	-----
Lead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.10
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.002	0.010
Nickel	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.10	-----
pH	7.75	7.70	8.61	7.42	7.41	7.84	5 - 9	6.5 - 9
Selenium	0.11	<0.04	0.09	<0.04	<0.04	<0.04	0.05	0.05
Thallium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.002	-----
Zinc	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-----	25
TDS	78	113	88	35	20	220	-----	-----

¹ Based on Arizona Administrative Code Aquifer Water Quality Standard for drinking water protected use.

² Total Recoverable

Table 2.06. Short-Term Leach Test Results (dissolved, mg/L) for Rosemont Tailings

Parameter	May 2006	February 2007	June 2007		July 2008		Human Standard ¹	Livestock Standard ²
	SPLP	SPLP	SPLP	MWMP	SPLP	MWMP		
Antimony	NM ³	NM	<0.02	<0.02	<0.02	<0.02	0.006	-----
Arsenic	<1	<0.003	<0.003	<0.003	<0.02	<0.003	0.01	0.2
Barium	<10	<0.002	0.0032	0.0172	0.02	0.0229	2	-----
Beryllium	NM	NM	<0.002	<0.002	<0.002	<0.002	0.004	-----
Cadmium	<0.5	<0.002	<0.002	<0.002	<0.002	<0.002	0.005	0.05
Chromium	<1	<0.006	<0.006	<0.006	<0.006	<0.006	0.10	1.0
Copper	NM	<0.010	<0.010	<0.01	<0.01	<0.01	-----	0.50
Fluoride	NM	1.25	1.29	1.02	0.85	1.11	4.0	-----
Lead	<1	NM	<0.0075	<0.0075	<0.0075	<0.008	0.05	0.10
Mercury	<0.01	<0.0002	<0.0002	0.00033	0.0007	<0.0002	0.002	0.010
Nickel	NM	<1	<0.01	<0.01	<0.01	<0.01	0.10	-----
pH	NM	NM	NM	7.43	9.5	8.5	5 - 9	6.5 - 9
Selenium	<0.5	<0.5	<0.04	<0.04	<0.04	<0.04	0.05	0.05
Thallium	NM	NM	<0.015	<0.015	<0.02	<0.015	0.002	-----
Zinc	NM	NM	<0.01	<0.01	<0.01	<0.01	-----	25
TDS	NM	13	66	505	NM	NM	-----	-----

¹ Based on Arizona Administrative Code Aquifer Water Quality Standard for drinking water protected use.

² Total Recoverable

³ NM = Not Measured



2.3 Background Stormwater Runoff Quality

Stormwater runoff samples were collected from the Barrel Canyon Wash by Tetra Tech on July 8 and 10, 2008 (Table 2.07). Both dissolved (filtered) and total (unfiltered) samples were collected. A single total copper value and two (2) total lead values exceeded the A.A.C. standards (based on total concentration) for livestock watering (Table 2.07). Antimony, arsenic, beryllium, cadmium, selenium, and thallium concentrations could not be evaluated with respect to human drinking water standards (and also livestock standards for selenium) because the reporting limits are greater than the respective standard. Mercury concentrations were not determined. Total concentrations were generally higher compared to dissolved concentrations due to the additional contribution of metals from total suspended solids (TSS) (Table 2.07). Dissolved concentrations for regulated constituents in the stormwater could not be compared to those from the SPLP or MWMP tests because they were below detection limit values. TDS values for the stormwater samples (122 to 266 mg/L) were within the range of TDS values measured on short-term leachates from waste rock (20 to 817 mg/L) and tailings (13 to 505 mg/L).

Table 2.07. Rosemont Stormwater Results (mg/L) from Barrel Canyon Wash

Parameter	Dissolved (filtered)		Total (unfiltered)		Human Standard ¹	Livestock Standard ²
	7/10/2008	7/10/2008	7/10/2008	7/10/2008		
Antimony	< 0.20	< 0.20	< 0.20	< 0.20	0.006	-----
Arsenic	< 0.10	< 0.10	< 0.10	< 0.10	0.01	0.2
Barium	<1.0	<1.0	1.7	< 1.0	2	-----
Beryllium	<0.10	<0.10	< 0.050	< 0.050	0.004	-----
Cadmium	<0.05	<0.05	< 0.050	< 0.050	0.005	0.05
Chromium	<0.10	<0.10	< 0.10	< 0.10	0.10	1.0
Copper	<0.10	<0.10	0.17	4.3	-----	0.50
Fluoride	-----	-----	<0.1	<0.17	4.0	-----
Lead	<0.15	<0.15	0.25	1.2	0.05	0.10
Mercury	NA ³	NA	NA	NA	0.002	0.010
Nickel	<0.08	<0.08	< 0.08	0.08	0.10	-----
pH	-----	-----	8.2	7.8	5 - 9	6.5 - 9
Selenium	<0.10	<0.10	< 0.1	< 0.10	0.05	0.05
Thallium	<0.10	<0.10	< 0.1	< 0.10	0.002	-----
Zinc	<0.5	<0.5	0.6	2.9	-----	25
TDS ⁴	266	122	-----	-----	-----	-----
TSS	-----	-----	20,000	2,600	-----	-----

¹ Based on Arizona Administrative Code Aquifer Water Quality Standard for drinking water protected use.

² Total Recoverable

³ NA = Not Analyzed

⁴ TDS calculated from major ion composition, minus chloride which was not determined.



2.4 Background Ground and Spring Water Quality

Water quality data from Rosemont monitoring wells and springs were reported by Montgomery & Associates (2009). Groundwater data from Pit Characterization (PC) wells, Hydrologic Characterization (HC) wells, Groundwater Monitoring (RP) wells, and five (5) springs were averaged and are summarized in Table 2.08. In the vicinity of the proposed Open Pit, the groundwater is dominated by calcium and bicarbonate. To the east of the proposed Open Pit, the groundwater is a mixture of calcium bicarbonate, sodium bicarbonate, and calcium sulfate water types (Montgomery & Associates, 2009). Arsenic in three (3) natural springs is the only regulated constituent which exceeds human drinking water standards, but all average constituent concentrations in springs and groundwater are below livestock watering standards (Table 2.08). Average TDS values in springs and groundwater ranged from 160 to 597 mg/L, within the range of TDS values measured on short-term leachates from waste rock (20 to 817 mg/L) and tailings (13 to 505 mg/L).

3.0 Conclusions

Evaluation of all ABA data for the Rosemont geologic materials tested to date indicate that the bulk waste rock and tailings properties are classified as inert and are non-acid generating. Overall, the Rosemont waste rock and tailings are net acid-consuming and present very little to no risk for the generation of acidic drainage. Short-term leaching tests of these materials produced leachates with similar bulk composition to stormwater and groundwater samples based on the range of TDS values. Naturally occurring background concentrations of copper and lead exceeded human drinking water and livestock watering standards in the stormwater, while arsenic was naturally-elevated only above the human drinking water standard in three (3) of the five (5) natural springs at Rosemont.

Evaluation of short-term leach test data from waste rock and tailings showed that bulk leachate composition, as measured by TDS, was within the range of natural TDS values observed in stormwater and groundwater. Arsenic concentrations exceeded the human drinking water standard in three (3) SPLP leachates (Andesite, Arkose, Overburden) and one (1) MWMP leachate (Overburden) from waste rock. These exceedances approximate naturally occurring levels and are indicative of the rock type rather than a change in chemistry due to operational processes. None of the constituents exceeded human drinking water or livestock watering standards in short-term leachates from tailings. While leachate concentrations above the AWQS standards indicate a potential for impacts to groundwater, under actual field conditions the leachate will be subjected to dilution, dispersion, and attenuation processes. Therefore, it is unlikely that seepage from the Rosemont waste rock or tailings facilities will significantly change the chemical composition or designated use of groundwater at the site.



Table 2.08. Trace Element Summary (mg/L) for Rosemont Groundwater and Springs

Parameter (mg/L)	HC Wells	PC Wells	RP Wells	MC-1 Spring	MC-2 Spring	Questa Spring	Rosemont Spring	Sycamore Spring	Human Standard ¹	Livestock Standard ²
Antimony	<0.0004	<0.0004	<0.0004	0.0032	0.0009	<0.0004	<0.0004	0.0006	0.006	-----
Arsenic	0.006	0.0034	0.005	0.0048	0.01845	0.0154	0.01345	0.0043	0.01	0.2
Barium	0.022	0.026	0.084	0.007	0.0525	0.022	0.0975	0.05	2	-----
Beryllium	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.004	-----
Cadmium	0.0003	<0.0001	<0.0001	<0.0001	0.0001	0.0002	<0.0001	0.0003	0.005	0.05
Chromium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.10	1.0
Copper	<0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	-----	0.50
Fluoride	1.48	0.85	0.85	0.30	1.4	0.50	0.30	0.20	4.0	-----
Lead	0.0006	0.0003	0.0006	0.0001	<0.01	0.0006	<0.0001	0.0006	0.05	0.10
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.002	0.010
Nickel	<0.01	0.010	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.10	-----
pH	7.36	7.54	7.64	6.91	7.29	8.0	7.81	7.47	5 - 9	6.5 - 9
Selenium	0.0007	0.0021	0.0004	0.0002	0.0003	0.0002	<0.0001	0.0014	0.05	0.05
Thallium	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.002	-----
Zinc	0.014	0.24	0.02	<0.01	0.02	0.02	0.02	<0.01	-----	25
TDS	439	597	374	160	505	270	260	440	-----	-----

¹ Based on Arizona Administrative Code Aquifer Water Quality Standard for drinking water protected use.

² Total Recoverable



4.0 References

- Arizona Administrative Code (AAC), Title 18, Chapter 11.
http://www.azsos.gov/public_services/Title_18/18-11.htm
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