FIGURES

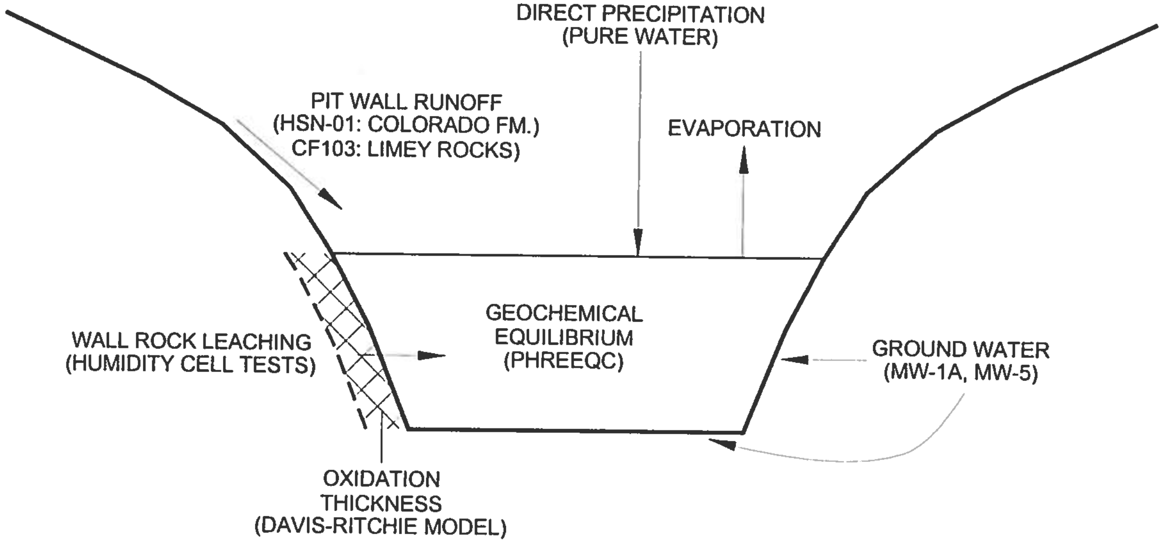

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FIGURE G-1
CONTINENTAL PIT LAKE
CONCEPTUAL MODEL

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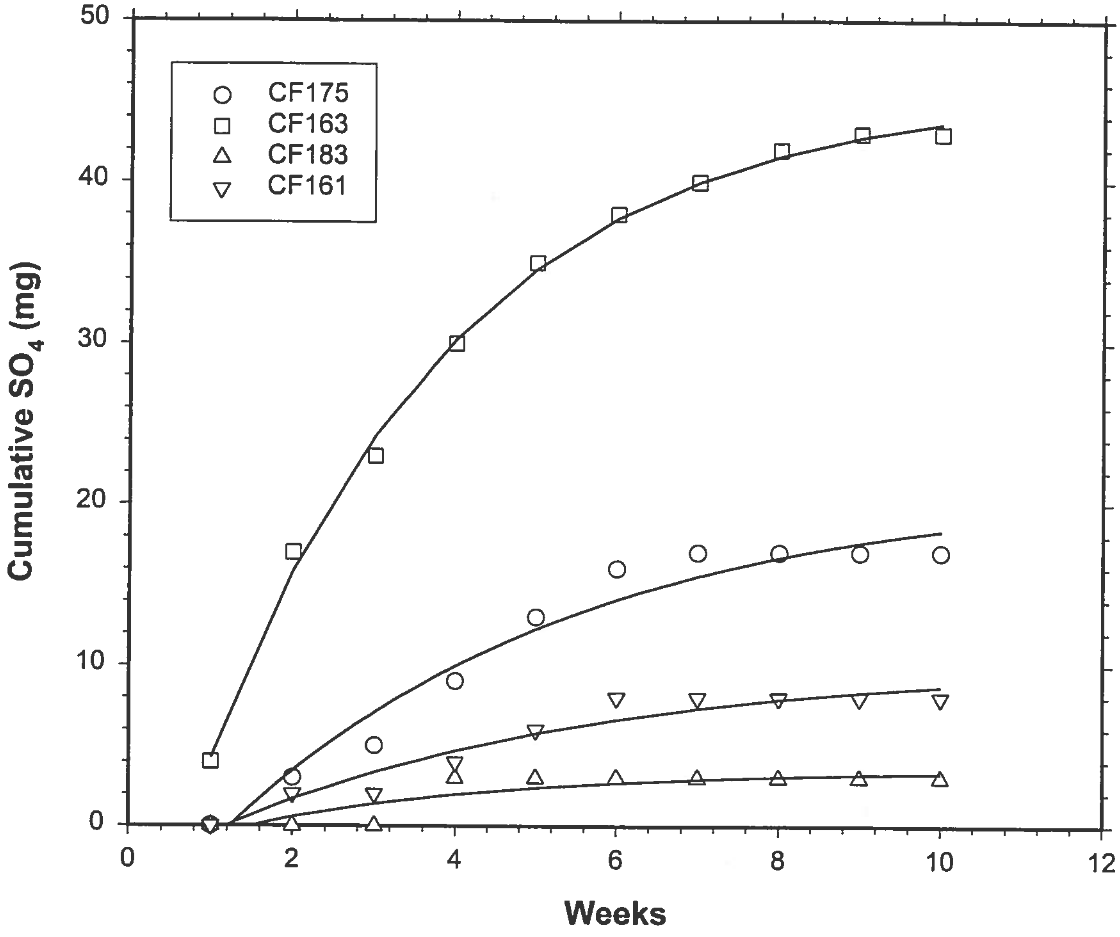

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FIGURE G-2

Cumulative Sulfate Release Rates from Colorado Formation Leach Cap Rocks Used to Represent Wallrock Leaching

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TABLES

Table G-1 Water Compositions Used to Represent Inflows to the Continental Pit Lake. Concentrations in mg/L.

	Calcareous Formation Ground Water	Colorado Formation Ground Water	Pit Wall Runoff (Seep) for Colorado Fm. Rocks	Pit Wall Runoff (MWMP) for Calcareous Rocks	Direct Precipitation
Sampling Site	**MW-5[a]**	**MW-1A[b]**	**HSN-01[c]**	**CF103[d]**	**Gila Cliff Dwellings**
Aluminum	0.025	0.024	0.025	0.010	-
Antimony	0.025	0.025	0.025	0.001	-
Arsenic	0.025	0.0046	0.06	0.02	-
Bicarbonate (as HCO_3)	410	204	7	80	-
Cadmium	0.0025	0.0017	0.0025	0.0012	-
Calcium	200	51	61	48.3	0.16
Chloride	19	17	5	7.21	0.13
Chromium	0.0025	0.0033	0.0025	0.0025	-
Cobalt	0.0025	0.0035	0.16	0.0025	-
Copper	0.0025	0.0032	0.024	0.006	-
Fluoride	0.25	0.83	0.25	0.18	-
Iron, Total	0.01	0.27	55	0.012	-
Lead	0.025	0.016	0.025	0.002	-
Magnesium	13	27	46	7.14	0.021
Manganese	0.0025	0.24	3.1	0.066	-
Mercury	0.00005	0.00005	0.00005	0.0001	-
Molybdenum	0.0025	0.0025	0.0025	0.105	-
Nickel	0.01	0.0084	0.13	0.0085	-
Nitrate plus Nitrite	5.6	0.025	0.06	0.08	0.75
pH (field) (s.u.)	6.65	7.52	4.83	8.08	4.8
Potassium	2.5	3	3.9	19.4	0.022
Selenium	0.025	0.018	0.025	0.008	-
Silicon (as Si)	8.6	7.1	11	-	-
Sodium	10	47	13	25.6	0.098
Sulfate	180	153	440	99	0.88
Temperature (°C)	11.6	14.2	7.9	-	-
Zinc	0.05	0.007	1.4	0.001	-
Charge-Balance (%)[e]	0.7	-1.2	-0.3	13.2	-15.0

Notes:

a - Sample collected 2/26/96.
b – Average of 5 samples collected between 2/28/96 and 10/17/97.
c - Sample collected 2/28/96.
d - Meteoric Water Mobility Test result for composite sample CF103 (Appendix D).
e – 100*(Cations – |Anions|)/(Cations + |Anions|)

Table G-2 Summary of Best-Fit Results to Humidity Cell Data for Leach Cap Rocks From the Colorado Formation Used to Represent Wallrock Leaching of Low-Sulfide Rocks for the Continental Pit (CDM, 1997)

		Results of Best Fits to $Cum_{SO4} = y_0 + a(1 - exp^{-bt})$			Cumulative SO_4 Released at End of Humidity Cell Test	Cumulative SO_4 Released at t →∞
Sample	**Weeks**	**y0**	**a**	**b**	**(mg/0.25 kg)[a]**	**(mg/0.25 kg)[a]**
CF175	10	-6.85	28.06	0.229	18.37	21.22
CF163	10	-11.89	57.68	0.33	43.63	45.79
CF183	10	-2.09	5.61	0.32	3.30	3.53
CF161	10	-2.98	13.12	0.22	8.69	10.14
					Average	20.17

Note:a - The humidity cell procedure used 0.25 kg of rock.

Table G-3 Summary of Inflows to the Continental Pit Lake Predicted by Hydrologic Modeling (SMI, 1998)

Bench Elevation	Time to fill	Depth	Volume	Precipi -tation	Ground-water	Wallrock Runoff	Evapor-ation	Inflow – Evaporation
(ft)	(yrs)	(ft)	(gal)	(gpm)	(gpm)	(gpm)	(gpm)	(gpm)
6000	0	0	0.00E+00	1.4	51.5	17.8	4.3	66.4
6020	0.1	20	5.21E+06	1.6	61.4	17.8	4.9	75.9
6040	0.4	40	9.88E+06	2.0	70.0	17.7	6.0	83.7
6060	0.7	60	1.70E+07	2.6	77.7	17.6	7.9	90.0
6080	1.3	80	2.54E+07	3.4	84.4	17.5	10.4	95.0
6100	1.9	100	3.20E+07	4.4	90.3	17.4	13.5	98.6
6120	2.7	120	4.23E+07	5.7	95.3	17.2	17.2	100.9
6140	3.7	140	5.34E+07	7.1	99.7	17.0	21.6	102.1
6160	4.8	160	5.98E+07	8.7	103.4	16.7	26.6	102.3
6180	6.1	180	7.08E+07	10.5	106.5	16.5	32.1	101.4
6200	7.7	200	8.16E+07	12.5	109.1	16.2	38.2	99.5
6220	9.4	220	8.79E+07	14.7	111.1	15.8	44.9	96.7
6240	11.4	240	1.01E+08	17.1	112.7	15.5	52.1	93.1
6260	13.8	260	1.15E+08	19.6	113.8	15.1	59.8	88.6
6280	16.6	280	1.25E+08	22.3	114.4	14.7	68.0	83.4
6300	20.1	300	1.47E+08	25.1	114.6	14.3	76.7	77.4
6320	24.5	320	1.71E+08	28.1	114.4	13.8	85.7	70.6
6340	30.3	340	2.03E+08	31.2	113.7	13.4	95.2	63.1
6360	38.2	360	2.45E+08	34.4	112.6	12.9	105.0	54.8
6380	48.3	380	2.67E+08	37.8	110.9	12.4	115.2	45.8
6400	61.2	400	2.78E+08	41.2	108.7	11.9	125.7	36.1
6420	79.9	420	3.05E+08	44.7	106.0	11.3	136.4	25.6
6440	111.5	440	3.32E+08	48.3	102.7	10.8	147.4	14.4
6460	190.1	460	3.44E+08	52.0	98.6	10.2	158.6	2.3
6463	501.8	463	2.24E+08	52.5	98.0	10.2	160.2	0.4

Table G-4 Predicted Bulk Chemical Compositions for the Continental Pit Lake. Concentrations in mg/L.

	Time (years)						
Constituent	2.7	11.4	20.1	38.2	79.9	111.5	190.1
Alkalinity as HCO_3	322	344	357	369	381	385	389
Aluminum	0.024	0.026	0.027	0.028	0.028	0.029	0.029
Antimony	0.017	0.018	0.018	0.019	0.020	0.020	0.020
Arsenic	0.020	0.020	0.020	0.021	0.021	0.021	0.022
Calcium	119	127	132	136	141	142	144
Cadmium	0.002	0.002	0.002	0.002	0.002	0.003	0.003
Chloride	16	1.80	19	19	20	20	20
Chromium	0.003	0.003	0.003	0.003	0.003	0.003	0.004
Cobalt	0.015	0.014	0.013	0.013	0.013	0.013	0.013
Copper	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Fluoride	0.5	0.5	0.6	0.6	0.6	0.6	0.6
Iron	10.5	9.0	8.5	7.9	7.8	7.7	7.5
Lead	0.020	0.021	0.022	0.023	0.023	0.023	0.024
Magnesium	22	23	23	24	25	25	25
Manganese	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Mercury	5.9E-05	6.1E-05	6.3E-05	6.4E-05	6.6E-05	6.6E-05	6.7E-05
Molybdenum	0.016	0.014	0.014	0.014	0.014	0.014	0.014
Nickel	0.019	0.018	0.018	0.018	0.018	0.019	0.019
Nitrate as N	2.1	2.3	2.4	2.5	2.6	2.6	2.7
pH	6.56	6.61	6.62	6.64	6.66	6.65	6.66
Potassium	5	5	5	5	5	5	5
Selenium	0.021	0.023	0.024	0.024	0.025	0.025	0.025
Silicon as SiO_2	4.7	5.1	5.2	5.4	5.6	5.6	5.7
Sodium	28	30	32	32	34	34	34
Sulfate	240	245	250	254	261	262	264
Zinc	0.11	0.097	0.094	0.093	0.091	0.092	0.090

Table G-5 Predicted Equilibrated Chemical Compositions for the Continental Pit Lake. Concentrations in mg/L.

	Time (years)						
Constituent	2.7	11.4	20.1	38.2	79.9	111.5	190.1
Alkalinity as HCO_3	160	160	159	159	158	158	158
Aluminum	0.0006	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007
Antimony	0.017	0.018	0.018	0.019	0.020	0.020	0.020
Arsenic	2.2E-06	2.1E-06	2.0E-06	2.0E-06	1.9E-06	1.9E-06	1.9E-06
Cadmium	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Calcium	101	101	101	102	103	103	103
Chloride	17	18	19	19	20	20	20
Chromium	0.000304	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Cobalt	1.0E-09	1.1E-09	1.2E-09	1.2E-09	1.3E-09	1.3E-09	1.3E-09
Copper	2.4E-05	2.2E-05	2.1E-05	2.0E-05	2.0E-05	1.9E-05	1.9E-05
Fluoride	0.5	0.5	0.6	0.6	0.6	0.6	0.6
Iron	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Lead	5.1E-06	5.0E-06	4.9E-06	4.8E-06	4.7E-06	4.7E-06	4.6E-06
Magnesium	21	22	23	23	24	24	24
Manganese	1.8E-11	2.1E-11	2.2E-11	2.4E-11	2.5E-11	2.6E-11	2.6E-11
Mercury	5.9E-06	5.8E-06	5.7E-06	5.6E-06	5.5E-06	5.5E-06	5.5E-06
Molybdenum	0.012	0.011	0.011	0.010	0.010	0.010	0.010
Nickel	0.011	0.010	0.010	0.010	0.010	0.010	0.010
Nitrate as N	2.1	2.3	2.4	2.5	2.6	2.6	2.7
pH	7.56	7.56	7.56	7.56	7.56	7.56	7.56
Potassium	5	5	5	5	5	5	5
Selenium	0.021	0.023	0.023	0.024	0.025	0.025	0.025
Silicon as SiO_2	4.7	5.1	5.2	5.4	5.6	5.6	5.7
Sodium	29	30	32	32	34	34	34
Sulfate	238	243	248	253	259	260	261
Zinc	7.2E-05	7.2E-05	7.3E-05	7.3E-05	7.4E-05	7.4E-05	7.4E-05

APPENDIX G

PRELIMINARY PREDICTION OF WATER QUALITY, FOR THE CONTINENTAL PIT LAKE, GRANT COUNTY, NEW MEXICO,

Prepared for:
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December 1999

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INCORPORATED

APPENDIX G

PREDICTION OF WATER QUALITY FOR THE CONTINENTAL PIT LAKE, GRANT COUNTY, NEW MEXICO, COBRE MINING COMPANY, INC.

December 1999

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4.0 CONCLUSIONS

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1.0 INTRODUCTION

The purpose of this Appendix is to provide a prediction of water quality for the pit lake that is expected to form in the Continental Pits after mine closure. The predictions are based on data available for characterizing the reactivities of the rocks that comprise the pit walls and consideration of geochemical processes that are generally known to affect water quality. The details of the methods used to make the predictions and the results are provided below[1].

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[1] In February 1998, preliminary predictions of water quality were made for the Continental and Hanover Pits (SMI, 1998, Appendix G). At that time, only a limited set of humidity cell data was available to characterize rocks from the Hanover Pit. Additional experimental and characterization work at the mine was conducted in 1999. This additional work was used to a construct a more detailed model for predicting water quality in the Hanover Pit Lake. This detailed model is presented in Appendix H.

The predictions for the Continental Pit were not updated in 1999 because the future operations at the pit were not finalized at the time the 1999 baseline report was issued. Newly acquired information from the Continental Pit area does not indicate that updating the calculations would differ significantly from the preliminary results.

This appendix contains the portion of the previous report (February 1998) that described the methods used to predict water quality only for the Continental Pit Lake and the results of those predictions. The preliminary predictions made for the Hanover Pit Lake made in the February 1998 report are superseded by those presented in Appendix H of this report.

2.0 CONTINENTAL PIT

Mining began in the Continental Pit in 1970s. The Cobre Mining Company, Inc. (Cobre) starting mining the Continental Pit in 1993. Currently, the pit is about 2500 feet long in the north-south direction with a width of about 1800 ft. The bottom of the pit is at an approximate elevation of 6500 ft above mean sea level, which is about 500 ft below the summit of Hermosa Mountain on the northwest portion of the pit. The proposed expansion of the Continental Pit will occur primarily in the northwest direction.

At the Continental Pit, the majority of the copper ore is found in calcic skarns formed in the Syrena, Oswaldo, and Lake Valley Formations near the contact with the Hanover-Fierro stock. The skarn mineralogy typically includes andradite, hedenbergite, epidote, ilvaite, magnetite, sphalerite, chalcopyrite, and pyrite and lesser amounts of bornite and chalcocite (Hillesland and others, 1995).

The predominant wallrocks currently exposed in the Continental Pit currently include the Abo, Syrena, Oswaldo, and Lake Valley Formations, which are all described as carbonate-bearing limestones or limey shales. Geochemical testing of the carbonate rocks shows that most have high positive NNP values, hence are expected to produce neutral to alkaline leachates (Appendix D).

A portion of the eastern side of the pit also consists of the Hanover-Fierro stock, which is a granodiorite porphyry. A small portion of the pit wall currently consists of the Colorado Formation, a silicified shale to silty sandstone unit. Rocks from the Colorado Formation in the Continental Pit generally have negative NNP values, similar to analyses of rock samples of the unoxidized Colorado Formation from the future Hanover Pit. The expansion plan for the Continental Pit will result in the exposure of a greater percentage of the Colorado Formation in the ultimate pit wall surface than in the existing pit, although the majority of the pit wall will still consist of calcareous rocks of the Abo, Syrena, Oswaldo, and Lake Valley Formations.

2.1 Continental Pit Conceptual Model

The main factors that are expected to affect the water quality of the Hanover Pit Lake include (Figure G-1):

- Ground water inflow
- Pit wall runoff
- Direct precipitation to the lake surface
- Wallrock leaching
- Geochemical processes
- Evaporation.

The methods used to represent each of these factors in the predictive model of water quality for the Continental Pit Lake are described below.

2.2 Ground Water Inflow

Ground water inflow to the Continental Pit lake will be derived primarily from the Colorado Formation and calcareous units of the Abo, Syrena, Oswaldo, and Lake Valley Formations. The hydrologic model of pit infilling shows that a majority of the water will come from the lower Paleozoic-age formations, which are predominantly calcareous rocks (Appendix D). To be chemically conservative, it was assumed that 50 percent of the pit lake water would be derived from the Colorado Formation and 50 percent from the underlying calcareous units.

The water composition from monitoring well MW-1A was used to represent typical Colorado Formation water (Table G-1). Monitoring well MW-1A is screened at 40 to 70 ft below ground surface in a sandstone unit of the Colorado Formation. The water composition from monitoring well MW-5 was used to represent typical water from a calcareous unit (Table G-1). Monitoring well MW-5 is screened at about 230 to 250 ft below ground surface in the Lake Valley limestone.

2.3 Pit Wall Runoff

For the Continental Pit lake, runoff from areas of the pit comprised of Colorado Formation rocks was represented by the composition of water determined for the acidic seep at sampling site HSN-01 (Table G-1). Water from areas of the pit comprised of calcareous rocks was represented by the composition of water determined in a meteoric water mobility procedure (MWMP) test on a composite sample of rock from the Continental Pit (Appendix D) (Table G-1).

2.4 Direct Precipitation

As the pit fills with water, an increasing portion of its inflow will be derived from precipitation that directly falls on the lake surface. The composition of precipitation was obtained from the National Atmospheric Deposition Program (NADP) for the nearest site at the Gila Cliff Dwellings. This composition shows and slightly acidic pH and low concentrations of major cations and anions (Table G-1).

2.5 Evaporation

As the pit lake surface increases, evaporation becomes an increasingly more important component of the water balance. In the pit lake model, evaporation was represented by the removal of pure water.

2.6 Wallrock Leaching

The rates of release of constituents to the pit lake from wall rock leaching were represented by the results obtained from humidity cell tests, proportioned to the relative areas of different rock types in the pit wall. The portion of the Continental Pit wall predicted to be inundated by water is comprised of about 95 percent calcareous rocks of the Abo, Syrena, Oswaldo, and Lake Valley Formations and 5 percent silicate rocks of the Hanover Fierro stock. Rocks of the Colorado Formation are not predicted to be inundated by the pit lake.

Humidity cell tests had not been conducted on the calcareous rocks from the Continental Pit at the time of this modeling effort. Consequently, the release of acid and sulfate from the calcareous rocks was represented by the average rate of sulfate release determined in four humidity cell tests conducted on samples from the Colorado Leach Cap Formation from the Hanover Pit[2] because the Leach Cap rocks have near-zero NNP values and produced only small amounts of sulfate and near-neutral pH leachates in the humidity cell tests (Appendix D).

The calcareous rocks of the Continental typically have strongly positive NNP values (Appendix D) and are expected to produce neutral to alkaline leachates with low metal concentrations. In contrast, the Leach Cap rocks have very low carbonate contents. Hence, their use in the pit lake modeling is expected to provide a very conservative underestimate of the amount of alkalinity and an overestimate of the sulfate levels, that, in reality, would be produced by leaching of the calcareous rocks of the Continental Pit.

The rates of sulfate release from the leach cap rocks were determined by fitting the humidity cell test data of cumulative sulfate (C_{SO4}) with time (t) to a curve defined by:

$$C_{SO4} = y_0 + a(1- \exp^{-bt}) \qquad (1)$$

where y_0, a, and b are constants determined by least-squares fitting of the data. Equation (1) provides a reasonable representation of the asymptotic increase in cumulative sulfate over time observed in the humidity cells (Figure G-2).

As time increases to a large value, the rate of increase in sulfate decreases, and Equation (1) can be approximated by:

$$C_{SO4}(\max) = y_0 + a \qquad (2)$$

For the four humidity cell tests conducted with leach cap rocks from the Colorado Formation, an average $C_{SO4}(\max)$ = 20.2 mg SO_4/0.25 kg rock was calculated, with a

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[2] These tests refer to those available prior to the issuance of the preliminary results of the Continental Pit Lake modeling in February 1998.

range of 3.5 to 45.8 mg SO_4/0.25 kg rock (Table G-2). Normalizing this value to 1.0 kg rock of rock, yields an average C_{SO4}(max) = 81 mg SO_4/kg rock, with a range of 14 to 183 mg SO_4/kg rock. This sulfate release rate was used to represent wallrock leaching of the calcareous rocks (i.e., the Abo, Syrena, Oswaldo, and Lake Valley Formations) that will comprise about 95 percent of the inundated pit wall of the ultimate Continental Pit.

In a similar manner as above, the release rate determined for sulfidic potential ore rocks from the Hanover Pit of 1,179 mg SO_4/kg rock was used to represent sulfate release from the silicate rocks (i.e., the Hanover Fierro stock) that will comprise about 5 percent of the pit wall of the ultimate inundated Continental Pit.

Given these cumulative releases for sulfate per unit mass of rock, the total amount of sulfate release to the pit lake as a function of lake level elevation was calculated from an estimated mass of oxidized rock in the pit wall. The Davis-Ritchie model of sulfide oxidation was used to estimate the mass of oxidized rock in the pit wall (Braun and others, 1974; Davis and Ritchie, 1986; Davis and others, 1986; Davis and Ritchie, 1987) as described below.

The input values used for the Davis-Ritchie modeling were: (1) average sulfide content of 1.4%, (2) a bulk porosity of 5%, and (3) a rock density of 2.65 g/cm^3 (Table G-3). The average time of exposure of the pit wallrocks is assumed to be approximated as one-half of the time (95 years) needed for the pit lake to reach approximate hydrologic steady-state (190.1 years). Using these values, the average thickness of the oxidized rock is predicted to be about 1.45 m by the Davis Ritchie model. Multiplication of this thickness by the pit wall surface covered by water at each 20-ft bench level yields the mass of oxidized rock.

The total mass of sulfate released to the pit lake was obtained by multiplication of the oxidized rock mass by the average sulfate release rate of 81 mg SO_4/kg rock for the 95 percent of the pit wall surface present as calcareous rocks plus 1,179 mg SO_4/kg rock for the 5 percent of the pit wall present as silicate rocks. The division of this sulfate mass by the volume of the lake at each 20-ft bench level yields a sulfate concentration that represents the sulfate influx to the pit lake from wallrock leaching.

2.7 Rates of Hydrologic Inflow

The rates of water inflow from different sources (i.e., ground water, pit wall runoff, precipitation, evaporation) were taken from the results of the hydrologic modeling for the Continental Pit (SMI, 1998). These hydrologic flow rates are summarized in Table G-3 as a function of time and bench elevation. For input to the geochemical model, the relative amounts of water contribution from the various sources were converted to cumulative percentages, which were then used to specify mixing proportions for the geochemical equilibrium calculations.

2.8 Geochemical Modeling Procedures

The modeling procedures followed for predicting the chemical composition of the Continental Pit lake were as follows. First, the source solutions were mixed according to the proportions indicated by hydrologic modeling of inflow rates. The PHREEQC geochemical model (Parkhurst, 1995) was used to perform mixing calculations and all equilibrium calculations. Next, sulfate was added according to the rate of wallrock leaching, and the solutions were evaporated according to the results of hydrologic modeling.

Then, the resulting solutions were equilibrated with the partial pressures of atmospheric oxygen at 0.2 atm and an estimated level of CO_2(g) at $10^{-2.5}$ atm or 10 times the ambient atmospheric level of $10^{-3.5}$ atm. This CO_2(g) level is consistent with observations of CO_2(g) partial pressures in existing pit lakes with near-neutral pH (Eary, 1999).

Finally, the solutions were equilibrated with the solubilities of solids that were oversaturated that could be expected to form under low-temperature conditions. The solutions were also equilibrated with adsorption reactions involving metal ions and the surface of ferric iron oxyhydroxide, assuming that a low level of 0.1 mg of ferrihydrite would be present in the water column. Standard properties for the surface of ferrihydrite were obtained from Dzomback and Morel (1990) to represent ionic adsorption reactions.

3.0 PREDICTED WATER QUALITY FOR THE CONTINENTAL PIT LAKE

The lake is predicted to reach hydrologic steady-state at 190.1 years. Results of the predictive modeling for the Continental Pit Lake are provided for 2.7, 11.4, 20.1, 38.2, 79.9, 111.5, and 190.1 years after closure for bulk chemical (Table G-4) and equilibrated compositions (Table G-5). Compared to the predicted bulk compositions, the equilibrated compositions have higher pH, and lower bicarbonate, calcium, iron, manganese, arsenic, copper, lead, and zinc. The increase in pH and decreases in bicarbonate and calcium are all related and are caused by equilibration of the pit water with CO_2(g) and calcite solubility. The decreases in iron and manganese are caused by equilibration with the calculated solubilities of ferrihydrite and manganite. The decreases in arsenic, copper, lead, and zinc are a result of calculated equilibrium of adsorption reactions of these metals with the ferrihydrite surfaces.

4.0 CONCLUSIONS

The Continental pit lake is predicted to have a near-neutral pH and a chemical composition dominated by calcium and bicarbonate. Metal concentrations are predicted to be low as a result of the near-neutral pH.

The predictions of future water quality were based on a number of conservative assumptions, including:

- During infilling of the pit lake, 50 percent of the groundwater inflow was specified as being derived from the Colorado Formation and 50 percent from the underlying calcareous units. In reality, most of the groundwater inflow will probably be derived from the calcareous units, which have high alkalinities, hence high acid-buffering capacities.

- The release of acid and sulfate from the calcareous rocks was represented by the average rate of sulfate release determined in four humidity cell tests conducted on samples from the Colorado Leach Cap Formation from the Hanover Pit. In contrast to the calcareous units of the Continental Pit, the Leach Cap rocks from Hanover have near-zero NNP values, hence their leachates provide a very conservative estimate of the alkalinity that would be derived from leaching of the calcareous rocks present in the Continental Pit.

These assumptions make it likely that the predictions for the Continental pit lake represent a reasonably conservative estimate of future water quality. The most important factors that control the predicted water quality are the high carbonate contents of the Continental Pit walls and high alkalinities of the ground water inflows. The influx of alkalinity from these sources are sufficient to mitigate any acid generation by sulfide oxidation and maintain the predicted pH at near-neutral values.

5.0 REFERENCES

Braun, R.L., A.E Lewis, and M.E. Watson. (1974). In-place Leaching Of Primary Sulfide Ore: Laboratory Leaching Data And Kinetic Model. *Metall. Trans.* 5, 1717-1726.

Camp, Dresser & McKee (CDM). (1997). *Results Of Static And Kinetic Acid/Base Testing*. Report to Cobre Mining Company, Inc., February 13.

Davis, G.B. and A.I.M. Ritchie. (1986). A Model Of Oxidation In Pyritic Mine Wastes: Part 1, Equations and Approximate Solutions. *Appl. Math. Modelling*, 10, 314-322.

Davis, G.B. and A.I.M. Ritchie. (1987). A Model Of Oxidation In Pyritic Mine Wastes: Part 3, Import of Particle Size Distribution. *Appl. Math. Modelling*, 11, 417-422.

Davis, G.B., G. Doherty, and A.I.M. Ritchie. (1986). A Model Of Oxidation In Pyritic Mine Wastes: Part 2, Comparison of Numerical And Approximate Solutions. *Appl. Math. Modelling*, 10, 323-329.

Dzomback, D. A. and F. M. M. Morel (1990) *Surface Complexation Modeling, Hydrous Ferric Oxide*. John Wiley & Sons, New York.

Eary, L. E. (1999) Geochemical and Equilibrium Trends in Mine Pit Lakes. *Appl. Geochem.* 14, 963-987.

Hillesland, L. L., W. T. Worthington, and R. B. Hawkin. (1994). General geology of the Continental Mine, Grant County, NM. Cobre Mining Company, Inc.

Parkhurst, D. L. (1995). User's Guide to PHREEQC - A *Computer Program For Speciation, Reaction-Path, Advective-Transport, And Inverse Geochemical Calculations*. Water-Resources Investigations Report 95-4227, U.S. Geological Survey, Lakewood, Colorado.

Shepherd Miller, Inc. (SMI). (1998). *Preliminary Predictions of Water Quality for the Hanover and Continental Pit Lakes, Grant County, New Mexico, Cobre Mining Company, Inc.* Shepherd Miller, Inc., Fort Collins, Colorado.