Predictive Geochemical Modeling of Pit Lake Water Quality at the Copper Flat Project, New Mexico

Report Prepared for

THEMAC Resources Group Ltd.

Report Prepared by

SRK Consulting (U.S.), Inc.
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Executive Summary

SRK Consulting, Inc. (SRK) has undertaken a predictive geochemical modeling exercise to assess potential future pit lake chemistry associated with the Copper Flat project, New Mexico. This work has been undertaken on behalf of New Mexico Copper Corporation (NMCC – a subsidiary of THEMAC Resources Group Ltd. [THEMAC]) to evaluate the future environmental impacts of the project from a National Environmental Policy Act (NEPA) perspective as well as a State regulatory compliance perspective. The work forms part of the geochemical characterization study to assess the Acid Rock Drainage and Metal Leaching (ARDML) potential of the project. This report describes the approach taken for the pit lake predictive modeling, details the assumptions made and presents the results of the pit lake geochemical predictions.

The Copper Flat project is a porphyry copper-molybdenum deposit located on the western margin of the Rio Grande Rift. The deposit also contains minor, but potentially recoverable, gold and silver mineralization. The deposit is hosted by a small quartz monzonite stock that intrudes a sequence of andesitic volcanic rocks. Geochemical testwork identified the potential for sulfide bearing rocks in the area to potentially release trace metals and sulfate and have limited generation of acidic drainage. A numerical geochemical predictive model was developed in PHREEQC and calibrated to the existing pit lake to ensure all active geochemical mechanisms could be accounted for.

The pit lake in the proposed Copper Flat open pit is expected to be seasonally stratified, well mixed, oxygenated, and not acidic. Waters are predicted to be moderately alkaline (pH ~8), primarily due to the buffering capacity of the inflowing groundwater. During the initial stages of pit infilling (i.e., during the first six months post-closure), removal/flushing of soluble salts from the pit walls is likely to result in a flush in sulfate, cadmium, molybdenum, selenium, sodium, chloride and sulfate concentrations in the early pit lake. The effects of this initial flush will be dissipated by inflowing groundwater and precipitation and pit lake chemistry will then evolve over time, with several parameters increasing in concentration as a result of evapoconcentration effects. This is similar to the trends observed in the existing pit lake, where elemental concentrations have increased since the start of pit infilling.

The model simulations demonstrate that all of the modeled chemical parameters are expected to be below New Mexico livestock standards (NMAC 20.6.4.900) in the 100 years post closure pit lake, with the exception of selenium. The geochemical model over-predicts selenium by an order of magnitude, but selenium concentrations are still predicted to exceed the wildlife standard when adjusted for this over-prediction. The current pit water also contains selenium concentrations above the wildlife standard, therefore selenium is likely to represent a constituent of concern for wildlife in any future pit lake that forms. The likely future geochemical behavior of selenium in the pit lake and the potential controls by precipitation and adsorption will be investigated as part of the proposed pit reclamation and source controls.

Vanadium concentrations are reported above the livestock standard; however, due to limitations on mineralogical controls, the current geochemical code over predicts the concentration of vanadium by approximately four times, as demonstrated by the calibration model. The geochemical behavior of vanadium in the future pit lake will likely be controlled by precipitation and adsorption reactions, but these reactions are not adequately characterized for vanadium in the PHREEQC thermodynamic code. Therefore the predicted exceedance of the wildlife standard in the Copper Flat pit lake at 75 and 100 years post-closure relates to the lack of appropriate mineralogical controls for vanadium in the PHREEQC database, rather than a true exceedance. Vanadium concentrations are also below analytical detection limit in the existing pit water. For these reasons vanadium is not a considered to be a constituent of concern and is not expected to exceed the livestock standard in the future pit lake.

Mercury concentrations are anticipated to increase over time, but remain below the livestock standard (0.01 mg/L) through year 100, post closure. Mercury concentrations are predicted to be marginally above the stringent wildlife standard of 0.00077 mg/L by year 25. However, this exceedance is minimal, and may not represent a true ecological risk to wildlife within the Copper Flat project area. The model-simulated input for mercury is based on reported trace detections in the HCT effluent; however there is no source mineral for mercury identified in the ore body and concentrations in the HCT testing are near the detection limit, as is the NMWQCC surface water standard for wildlife of 0.00077 mg/L. For these reasons, mercury will not likely be a constituent of of concern.

The water quality predictions represent a conservative estimate of future pit lake chemistry in order that constituents of concerns can be identified and mitigated though reclamation efforts. However, there are several components that will be evaluated in more detail as part of the post-mining source controls and in-pit reclamation plan. These include, but are not limited to:

- An evaluation of significant variations of open-pit water balance on the projected pit water chemistry, including potential minimizing, maximizing or re-routing of the pit wall and watershed components of runoff, and possible rapid filling of the pit with a clean alkaline groundwater source.
- An evaluation of pit bench reclamation, remediation of individual fractures, or re-routing of in-pit stormwater runoff and the effects on predicted pit lake chemistry. These factors would alter the interaction with pit wall fractures and may affect the predicted pit lake chemistry. Potential mitigation may include limiting the contact of storm water inflow with the pit shell.

1 Introduction

1.1 Purpose and Scope

SRK Consulting, Inc. (SRK) has undertaken a predictive geochemical modeling exercise to assess potential future pit lake chemistry associated with the Copper Flat project, New Mexico. The purpose of the exercise is to evaluate the future environmental impacts of the project from a National Environmental Policy Act (NEPA) perspective as well as a State regulatory compliance perspective. The work forms part of the geochemical characterization study to assess the Acid Rock Drainage and Metal Leaching (ARDML) potential of the project. This report describes the approach taken for the pit lake predictive modeling, details the assumptions made, and presents the results of the pit lake geochemical predictions.

1.2 Background

The Copper Flat project is a porphyry copper/molybdenum deposit located in the Las Animas Mining District in South Central New Mexico, in Sierra County located approximately 150 miles south of Albuquerque, New Mexico and approximately 20 miles southwest of Truth or Consequences, New Mexico straight-line distances). Access from Truth or Consequences is by 24 miles of paved highway and 3 miles of all-weather gravel road. The Copper Flat project location is shown in Figure 1-1.

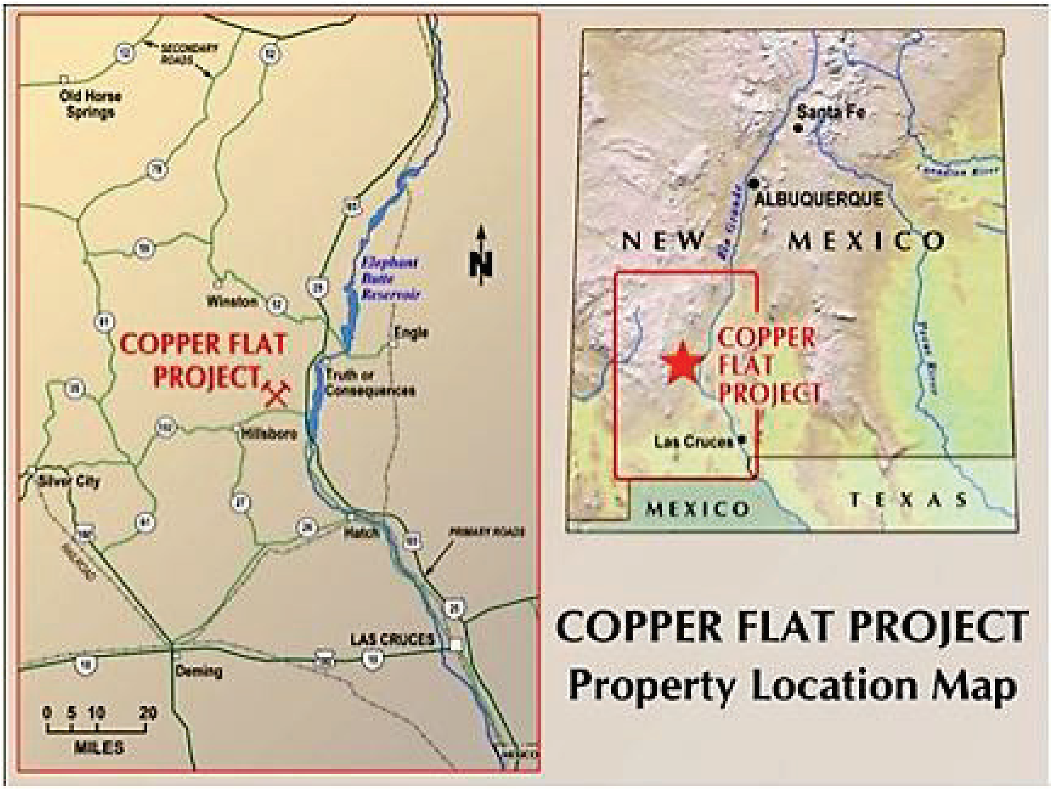


Figure 1-1: Project Location

1.2.1 Climate

The regional climate is high desert, and is generally hot with a July average of 76°F (maximum 107°F), and January average of 39°F (record minimum 1°F). The area is generally dry with about 13 inches of average annual precipitation, which occurs mostly as rainfall during July to September.

Winters are cold and dry. Snowfall is possible from October through April, but more typically occurring between December and February. The average annual total is 8 inches of snowfall. Prevailing wind direction is predominantly from the west, and secondarily from the north, and averages 10 to 15 miles per hour. Wind speeds in excess of 50 mph may occur as major storms pass through the area.

1.2.2 Prior Mining Operations

Mining activities in the Hillsboro Mining District began in the 1800s. Gold was mined from shafts and adits at the Copper Flat project and from placer workings developed along drainages to the east and southwest of Black and Animas Peaks. Gold mining was further developed during the early 1900s and continued until World War II. Today, small scale placer mining continues. Copper exploration began in the 1950s and continued to the early 1980s, when Quintana Minerals Corporation defined 60 Mt of reserves sufficient to operate for a 10 year mine life at an extraction rate of 15,000 tons per day (tpd). Operations included the development of the open pit, waste rock piles, TSF and other mine disturbances observed today, but mining stopped after 3 months due to low metal prices. No commercial mining activities have occurred at Copper Flat since 1982. The mine was under maintenance status until 1986, when mine facilities were dismantled and some areas were partially reclaimed. During the 1990s several companies submitted plans to reopen the mine but none of the plans were realized. Existing surface disturbances and facilities in the project area include the following:

- A pit lake;
- Waste rock disposal facilities (WRDFs);
- Mine and mill foundations (buildings have been removed);
- Site grading and roads;
- A 115-kilovolt power line;
- A 20-inch welded steel water line from the production well field to the base of the tailings storage facility (TSF);
- A diversion channel re-routing Grayback Arroyo around the mine site; and
- A TSF containing approximately 1.2 Mt of tailings from historic mining operations.

1.2.3 Mine Plan

The proposed project consists of an open pit mine, flotation mill, TSF, WRDF, two low grade ore stockpiles (LGOs) and ancillary facilities. During the mine life, the proposed project is expected to produce approximately 125 million tons of copper ore, which includes 12 million tons of low grade ore and 33 million tons of waste rock. Depending on economic conditions, the low grade ore may not be processed become waste rock. This possibility was accounted for in the geochemical characterization work. Ore extraction will take place by conventional truck and loader methods using 25-foot high benches. Because the deposit cannot be mined sequentially, backfilling of the pit will not take place.

Beneficiation will be achieved through the use of a conventional concentrator using standard crushing, grinding and flotation technologies. Milling will also include a molybdenum processing circuit. The nominal ore throughput rate is 30,000 tpd and an operational life of approximately 11 years is projected. The proposed layout of the mine facilities is shown in Figure 1-2.

The current pit configuration is based on the pit design from the Definitive Feasibility Study (DFS) published in November 2013. However, the predictive geochemical pit model was initiated prior to the DFS and is based on the Pre-feasibility Study (PFS) pit design. However, the DFS pit fits within the footprint of the PSF pit. SRK performed a data gap analysis between the PFS and DFS pit and found the PFS pit characterization to be more conservative than the DFS configuration. Details of this analysis is documented in an SRK external technical memorandum dated February 13, 2014 (SRK, Feb 13, 2014).

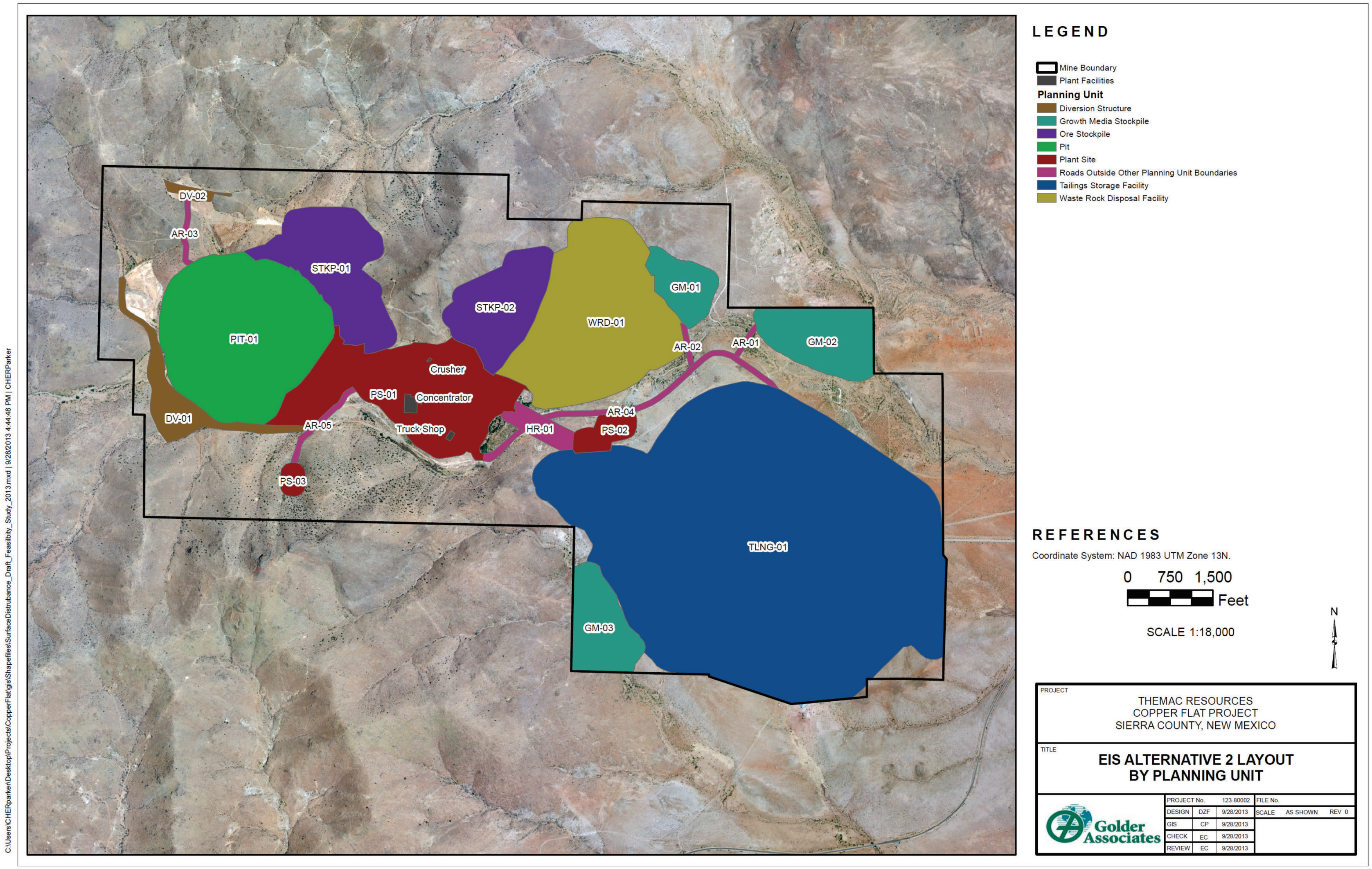


Figure 1-2: Copper Flat Facility Layout

From: THEMAC Resources Group Ltd (2012). Mine Operation and Reclamation Plan, Copper Flat Mine Project, Sierra County, New Mexico.

1.2.4 Geology and Mineralization

The Copper Flat project is a porphyry copper-molybdenum deposit located on the western margin of the Rio Grande Rift. The deposit also contains minor, but potentially recoverable, gold and silver mineralization. The deposit is hosted by a small quartz monzonite stock having a porphyritic texture that intrudes a sequence of andesitic volcanic rocks of similar age covering an area approximately 4 miles in diameter.

Regional Geology

The Copper Flat project lies within the Mexican Highlands portion of the Basin and Range Physiographic Province. The project is located in the Hillsboro Mining District in the Las Animas Hills, which are part of the Animas Uplift, a horst on the western edge of the Rio Grande valley. The Animas Uplift is separated from the Rio Grande by nearly 20 miles of Santa Fe Group alluvial sediments, referred to as the Palomas Basin of the Rio Grande valley. To the west of the Animas Uplift is the Warm Springs valley, a graben that parallels the Rio Grande valley. Further west, the Black Mountains form the backbone of the Continental Divide, rising to about 9,000 feet above sea level. The regional geology is discussed in more detail in the *Baseline Data Report for the Copper Flat Mine* (BDR) (INTERA, 2012). The focus of this report is on the local and Copper Flat ore body geology.

Basement rocks in the area consist of Precambrian granite and Paleozoic and Mesozoic sandstones, shales, limestones, and evaporites. Sedimentary units that crop out within the Animas Uplift include the Ordovician Montoya Limestone, the Silurian Fusselman Dolomite, and the Devonian Percha Shale. The Cretaceous-age Laramide orogeny, which was characterized by the intrusion of magma associated with the subduction of the Farallon plate beneath the North American plate, affected this region between 75 and 50 million years ago (Ma). Volcanic activity during the late Cretaceous and Tertiary periods resulted in localized flows, dikes, and intrusive bodies, some of which were associated with the development of the nearby Tertiary Emory and Good Sight-Cedar Hills calderas. Later basaltic flows resulted from the tectonic activity associated with the formation of the Rio Grande rift. Tertiary and Quaternary alluvial sediments of the Santa Fe Group and more recent valley fill overlie the older Paleozoic and Mesozoic units in the area.

Local Geology

The district geology described below is modified from McLemore et al. (2000) and Raugust (2003). The predominant geologic feature of the Hillsboro Mining District is the Cretaceous Copper Flat stratovolcano, a circular body of Cretaceous andesite that is 4 miles in diameter (Figure 1-3). The Hillsboro Mining District comprises the Las Animas Hills, a low range formed by the Animas Hills horst at the western edge of the Rio Grande Rift. Faults that bound the Animas Hills horst are related to the tectonic activity of the Miocene-age Rio Grande Rift (Dunn, 1982). Due to the difference in ages and in spite of its close proximity, there is no known connection between the Rio Grande rift and the Copper Flat volcanic/intrusive complex. The Copper Flat volcanic/intrusive complex has been interpreted as an eroded stratovolcano based on the presence of agglomerate and flow band textures in some of the andesite (Richards, 2003).

The Copper Flat Quartz Monzonite (CFQM) intrudes the core of the volcanic complex. The CFQM stock has a surface expression of approximately 0.4 mi^2 and has been dated by the argon-argon (40Ar/39Ar) techniques to be 74.93 ±0.66 million years old (McLemore et al., 2000). The surrounding andesite has also been dated using argon-argon techniques to be 75.4 ±3.5 million years old (McLemore et al., 2000).

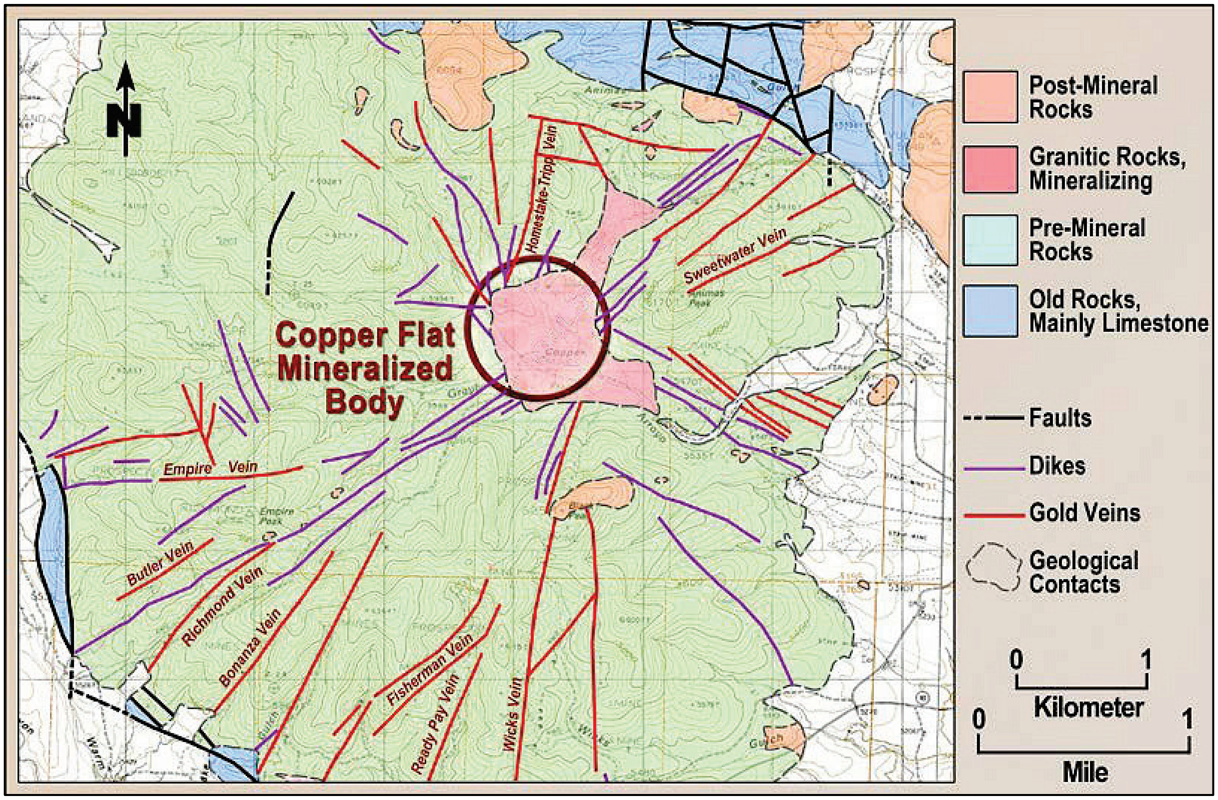


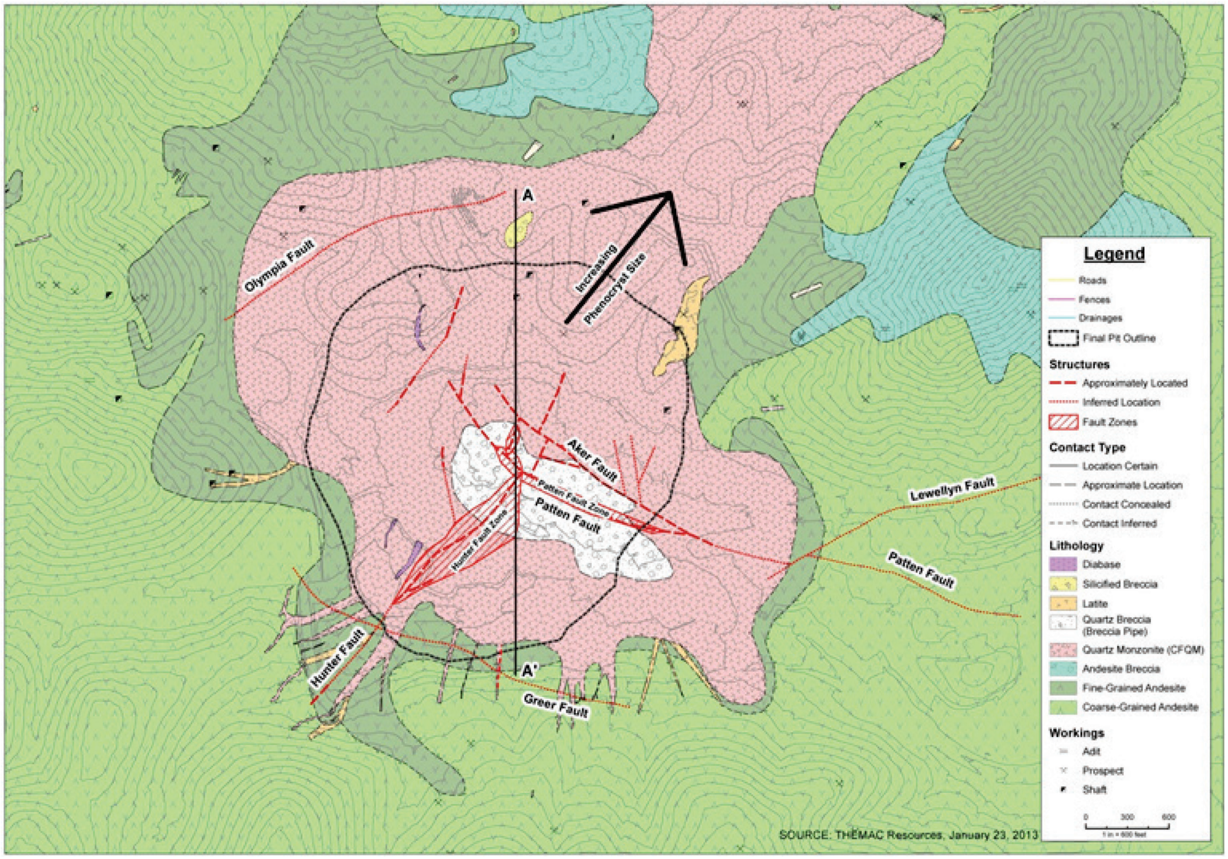
Figure 1-3: Geology of the Copper Flat Mine (Dunn, 1982)

Geology of the Copper Flat Orebody

The Copper Flat andesite is generally fine-grained with phenocrysts of plagioclase (andesine) and amphibole in a groundmass of plagioclase and potassium feldspar and rare quartz. Some agglomerates or flow breccias are locally present, but the andesite is generally massive. Magnetite is commonly associated with the mafic phenocrysts, and accessory apatite is commonly found.

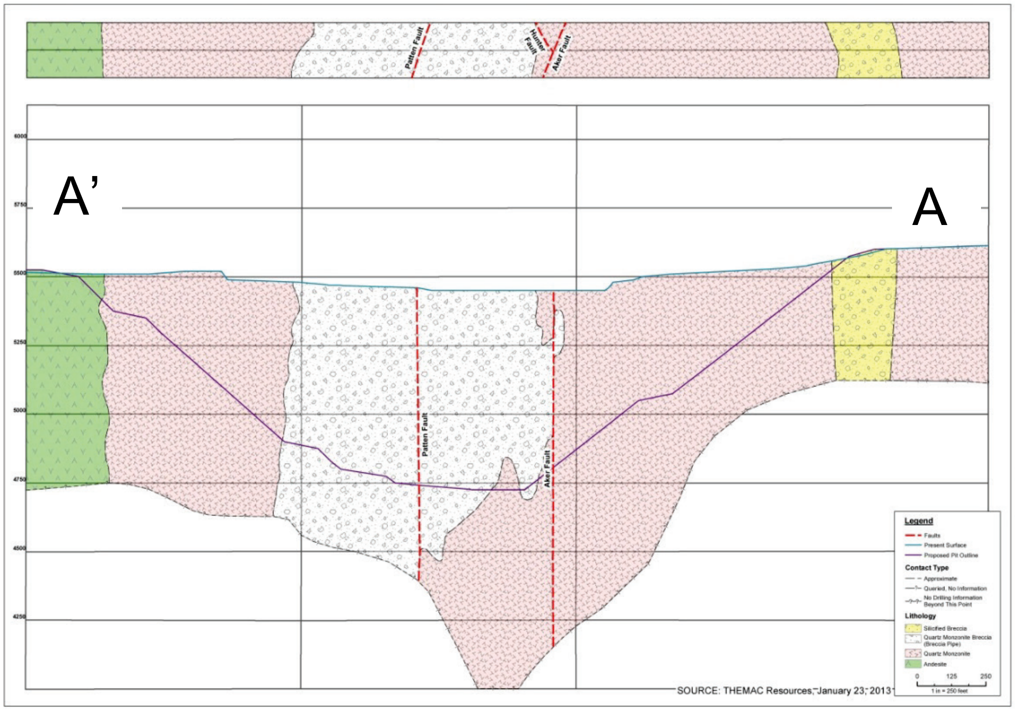
Although the depth of erosion is uncertain, the center of the stratovolcano was eroded to form a topographic low. To the east of the site, this andesite body is in fault contact with Santa Fe Group sediments, which are at least 2,000 feet thick in the immediate Copper Flat area and thickening to the east. Near-vertical faults characterize the contacts on the remaining perimeter of the andesite body; these faults juxtapose the andesite with Paleozoic sedimentary rocks. Historical drill holes indicate the andesite is locally more than 3,000 feet thick. This feature, combined with the concentric fault pattern, indicate that the local geology represents a deeply eroded Cretaceous-age volcanic complex. A detailed geologic map of the Copper Flat orebody is provided in Figure 1-4 and a south-north geologic cross section through the Copper Flat orebody is provided in Figure 1-5.

Copper Flat Quartz Monzonite (CFQM) intrudes the core of the volcanic complex. Sulfide mineralization is present as veinlets and disseminations in the CFQM, but is most strongly developed in and adjacent to the west end of a steeply dipping breccia pipe that is centrally located within the CFQM stock and elongated in the northwest-southeast direction (Figure 1-5).



SOURCE: THEMAC Resources, January 23, 2013

Figure 1-4: Detailed Geologic Map of the Copper Flat Orebody (THEMAC, 2013)



SOURCE: THEMAC Resources, January 23, 2013

Figure 1-5: Geologic Cross Section through the Copper Flat Orebody (THEMAC, 2013)

Lithology

The CFQM intruded into the center of the andesite sequence at the intersection of two principal structures that trend respectively N50°W and N20°E. The CFQM is an irregular-shaped stock underlying a surface area of approximately 0.40 square miles and has been dated to approximately 75 Ma. In the few exposures in which the CFQM is in contact with the andesite, the andesite shows no obvious signs of contact metamorphism. The CFQM is a medium- to coarse-grained, holocrystalline porphyry composed primarily of potassium feldspar, plagioclase, hornblende, and biotite; trace amounts of magnetite, apatite, zircon, and rutile are also present, along with localized mineralized zones containing pyrite, chalcopyrite, and molybdenite. About 15 percent of the monzonite is quartz, which occurs both as small phenocrysts and as part of the groundmass; however, quartz is absent in some parts of the stock.

Numerous dikes, some of which are more than a mile in length and mostly of latite composition, radiate from and cut the CFQM stock. Most of the dikes trend to the northeast or northwest and represent late stage differentiation of the CFQM stock. Diabase has been mapped in contact with the CFQM at Copper Flat. Immediately south of the quartz monzonite, the andesite is coarse-grained, perhaps indicating a shallow intrusive phase. An irregular mass of andesite breccia along the northwestern contact of the quartz monzonite contains potassium feldspar phenocrysts and andesitic rock fragments in a matrix of sericite with minor quartz. This may represent a pyroclastic unit. Magnetite, chlorite, epidote, and accessory apatite are also present in the andesite breccia.

Structure

Three principal structural zones are present at Copper Flat, the most prominent of which is a northeast-striking fault that trends N 20°-40°E that includes the Hunter and parallel faults or the Hunter fault zone. In addition, west-northwest striking zones of structural weakness (N50°-70°W) are marked by the Patten and Greer faults, and east-northeast striking zones are marked by the Olympia and Lewellyn faults. All faults have a near-vertical dip; the Hunter fault system dips 80°W, the Patten dips approximately 70°S-80°S, and both the Olympia and Lewellyn fault systems dip between 80°S and 90°S. These three major fault zones appear to have been established prior to the emplacement of the CFQM and controlled subsequent igneous events and in the case of the Patten and Hunter controlled mineralization.

As previously stated, the CFQM emplacement is largely controlled by the three structural zones. The southern contact parallels and is cut by the Greer fault, although the contact is cut by the fault, and the southeastern and northwestern contacts are roughly parallel to the Olympia and Lewellyn faults, respectively. The CFQM stock is principally elongated along the Patten fault, as well as along the Hunter fault zone.

Although latite dikes strike in all the three principal fracture directions, most of the dikes strike northeast. The northeast trending fault zones contain a high proportion of wet gouge, often with no recognizable rock fragments. Reportedly in underground exposures the material comprising the Hunter fault zone has the same consistency as wet concrete and has been observed to flow in underground headings. Based on recent drilling the Patten fault consists of a mixture of breccia and gouge. However, the material in the east-northeast fault zones contains only highly broken rock and minor gouge. The width of individual structures in all three systems varies along strike from less than a foot to nearly 25 feet in the Patten fault east of the Project. Despite intense brecciation, the total displacement along the faults does not appear to exceed a few tens of feet. At the western edge of the CFQM intrusion, a younger porphyritic dike was emplaced in a fault that offsets an early latite dike, indicating that fault movement occurred during the time that dikes were being emplaced.

Post-dike movement is evident in all the three principal fault zones, and both the Hunter and Patten fault systems show signs of definite post-mineral movement. Fault movement has smeared sulfide deposits and offset the breccia pipe as well as the zones within the breccia pipe. Post-mineral movement along faults has resulted in wide, strongly brecciated fault zones. Some of the post-mineral dikes have been emplaced within these fault zones.

NMCC has mapped the pit area and diversion cuts in detail at 1 inch equals 40 feet (1:480) and has examined the pre- and post-mineral stress orientations in the andesite and CFQM. Findings indicate no significant difference in the stress fields before and after mineralization. During NMCC's mapping efforts, the Greer and Olympia previously mapped fault locations could not be verified; therefore, these faults were labeled as inferred.

Mineralization

The CFQM hosts mineralization dominated by pyrite and chalcopyrite with subsidiary molybdenite, minor bornite and minor but recoverable amounts of gold and silver. The mineralization is focused along intersecting northeast- and northwest-trending faults, and these intersections may have originally controlled emplacement of the CFQM.

Although copper occurs almost exclusively as chalcopyrite locally accompanied by trace amounts of bornite, minor amounts of chalcocite and copper oxide minerals are locally present near the surface and along fractures. The supergene enrichment typical of many porphyry copper deposits in the Southwest is virtually non-existent at Copper Flat. During the early mining days, a 20 to 50-foot leached oxide zone existed over the ore body, but this material was stripped during the mining activities that occurred in the early 1980s. Most of the remaining ore is unoxidized and consists primarily of chalcopyrite and pyrite with some molybdenite and locally traces of bornite, galena and sphalerite. Recently completed mineralogical studies indicate that fine grained disseminated chalcopyrite is often intergrown with pyrite and occurs interstitial to silicate minerals. Deposition of chalcopyrite and molybdenite (76.2 Ma) occurred within the same mineralizing event as the pyrite.

Sulfide mineralization is present as veinlets and disseminations in the CFQM, but is most strongly developed in and adjacent to the west end of a steeply dipping breccia pipe, that is centrally located within the CFQM stock and elongated in the northwest-southeast direction roughly along, but south of the Patten fault. The sulfide mineralization first formed in narrow veinlets and as disseminations in the quartz monzonite with weakly developed sericitic alteration. This stage of mineralization was followed by the formation of the breccia pipe with the introduction of coarse, "clotty" pyrite and chalcopyrite along with veinlet controlled molybdenite and milky quartz, and the development of strong potassic alteration.

The breccia pipe, which can best be described as a crackle breccia, consists largely of subangular fragments of mineralized CFQM, with locally abundant mineralized latite where dikes exposed in the CFQM projected into the brecciated zone that range in size from an inch to several inches in diameter. Andesite occurs only as mixed fragments partially in contact with intrusive CFQM and appears to represent the brecciation of relatively unaltered andesite xenoliths in the CFQM. The matrix contains varying proportions of quartz, biotite (phlogopite), potassium feldspar, pyrite, and chalcopyrite, with magnetite, molybdenite, fluorite, anhydrite, and calcite locally common. Apatite is a common accessory mineral. Breccia fragments are rimmed with either biotite or potassium feldspar, and the quartz and sulfide minerals have generally formed in the center of the matrix.

Two types of breccia within the quartz monzonite breccia pipe have been identified as distinguishable units based on the dominant mineral filling the matrix between clasts. Recent drilling has shown that the two breccia types, biotite breccia and feldspar breccia, grade into one another as well as with the CFQM. Interestingly, from a recovery perspective, metallurgical testing has shown that the mineralization behaves virtually the same irrespective of the lithology.

The total sulfide content ranges from 1 percent (by volume) in the eastern part of the breccia pipe and the surrounding CFQM to 5 percent in the CFQM to the south, north, and west. Sulfide content is highly variable within the breccia, with portions in the western part of the breccia containing as much as 20 percent sulfide minerals. The strongest copper mineralization is concentrated in the western half of the breccia pipe and in the adjoining stockwork veined CFQM in the vicinity of the intersection of the Patten fault and the Hunter fault zone. Sulfide mineralization is concentrated in the CFQM and breccia pipe, and drops significantly at the andesite contact. Minor pyrite mineralization extends into the andesite along the pre-mineral dikes and in quartz-pyrite-bearing structures, some of which were historically prospected for gold.

Molybdenite occurs in some steeply dipping quartz veins or as thin coatings on fractures. Minor sphalerite and galena are present in both carbonate and quartz veinlets in the CFQM stock. Preliminary 2011 evaluations of the mineralization at Copper Flat indicate that copper mineralization concentrates and trends along the N50°W structural influences, whereas the molybdenum, gold and silver appear to favor a N10°-20°E trend.

1.2.5 Hydrology

Hydrological information pertaining to the Copper Flat project has been summarized from the Baseline Data Report (INTERA, 2012) and is provided herein to provide a context for the pit lake modeling. The mine permit area is located in the Lower Rio Grande watershed, which includes approximately 5,000 square miles in Catron, Socorro, Sierra, and Doña Ana Counties and is dominated by the Rio Grande and its tributaries as well as the two large reservoirs of Elephant Butte and Caballo. Numerous tributaries drain into the Rio Grande from the west, but none contribute perennial flow to the Rio Grande. The mine permit area is drained by ephemeral streams (arroyos) within the Greenhorn Arroyo Drainage Basin. The Greenhorn Arroyo Drainage Basin is composed of Greenhorn Arroyo, Grayback Arroyo, and Hunkidori Gulch. The Grayback Arroyo passes through the permitted mine area and is diverted around the existing mine pit. Drainages within this watershed are ephemeral, flowing in response to heavy or sustained precipitation events. Water quality data for the Greyback Arroyo are summarized in Table 1-1.

Table 1-1: Summary of Hydrochemical Information in the Grayback Arroyo (INTERA, 2012)

Details	pH (s.u.)	Chloride (mg/L)	Sulfate (mg/L)	TDS (mg/L)
Min	7.42	0.71	11	78
Max	7.92	130	2,900	4,500

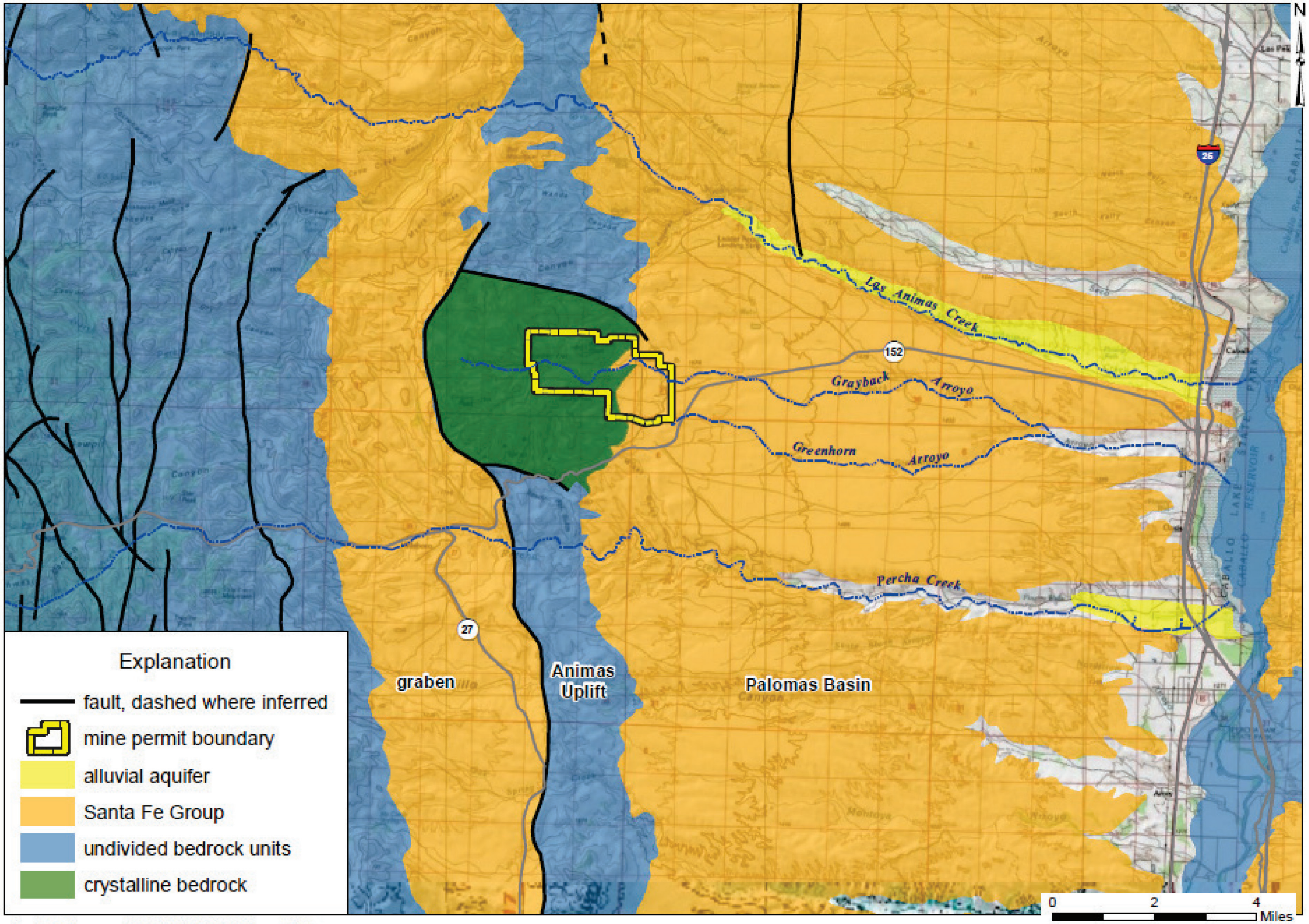
Surface waters in the Grayback Arroyo are typically characterized by higher major ion and trace element concentrations, with sulfate concentrations up to 2,900 mg/L and TDS up to 4,500 mg/L.

1.2.6 Hydrogeology

Hydrogeological information pertaining to the Copper Flat project has been summarized from the Baseline Data Report (INTERA, 2012) and is provided herein. This report identifies three aquifers within the Copper Flat project area (Figure 1-6) including:

1. Crystalline bedrock aquifer;
2. Santa Fe Group aquifer; and
3. Quaternary alluvial aquifer.

Details of these aquifers are provided below.



Geologic Source: USGS OFR 97-0052 modified

Figure 1-6: Map Showing Location of Crystalline Bedrock, Santa Fe Group Sediments and Alluvial Aquifer Zones (INTERA, 2012)

1. ***Crystalline Bedrock Aquifer:*** Groundwater is present within the crystalline volcanic rocks (quartz monzonite and andesite) that constitute much of the western portion of the mine permit area. Though the rocks themselves have practically no inter-granular permeability, faulting and jointing of the monzonite have created locally permeable zones through which water can move. Groundwater flow is generally from west to east, with the exception of the area surrounding the pit lake, which behaves as an evaporative sink. The permeability of the andesite is extremely low (<0.003 feet/day), whereas the permeability of the monzonite rocks averages 0.1 feet/day due to localized secondary porosity from fracturing. Groundwater in the Crystalline Bedrock Aquifer is characterized by moderately alkaline pH (~8 s.u.) and can generally be classed as sodium / calcium plus bicarbonate (Na / Ca + HCO_3) type waters based on their major ion signature (Figure 1-7).
2. ***Santa Fe Group Aquifer:*** Overlying and adjacent to the crystalline bedrock aquifer is the Santa Fe Group Aquifer system, which receives recharge from precipitation. The aquifer is located approximately 1 mile downgradient of the existing pit lake, and the low hydraulic conductivity of the andesite limits cross formational flow. The sediments of the Santa Fe Group are stratified, contain a wide variety of grain sizes, and, in general, dip to the east. The direction of groundwater flow is from west to east and the groundwater elevation contours indicate groundwater flows from the andesite to the alluvium and Santa Fe Group sediments. Groundwater in the Santa Fe Group Aquifer is characterized by circum-neutral to moderately alkaline pH (7 – 8 s.u.) and can generally be grouped into the calcium plus bicarbonate (Ca + HCO_3) or calcium plus sulfate (Ca + SO_4) hydrochemical facies based on major ion chemistry (Figure 1-7). The sulfate signature of some of the groundwater samples is associated with wells within the Santa Fe Group Aquifer near the existing TSF, which are known to be influenced by a sulfate plume from the historic tailings.
3. ***Quaternary Alluvial Aquifer:*** This aquifer is comprised of channel and floodplain gravels, sands and silts and represents the uppermost aquifer in the vicinity of the Copper Flat project. The alluvial aquifer is typically recharged by infiltration of rainfall.

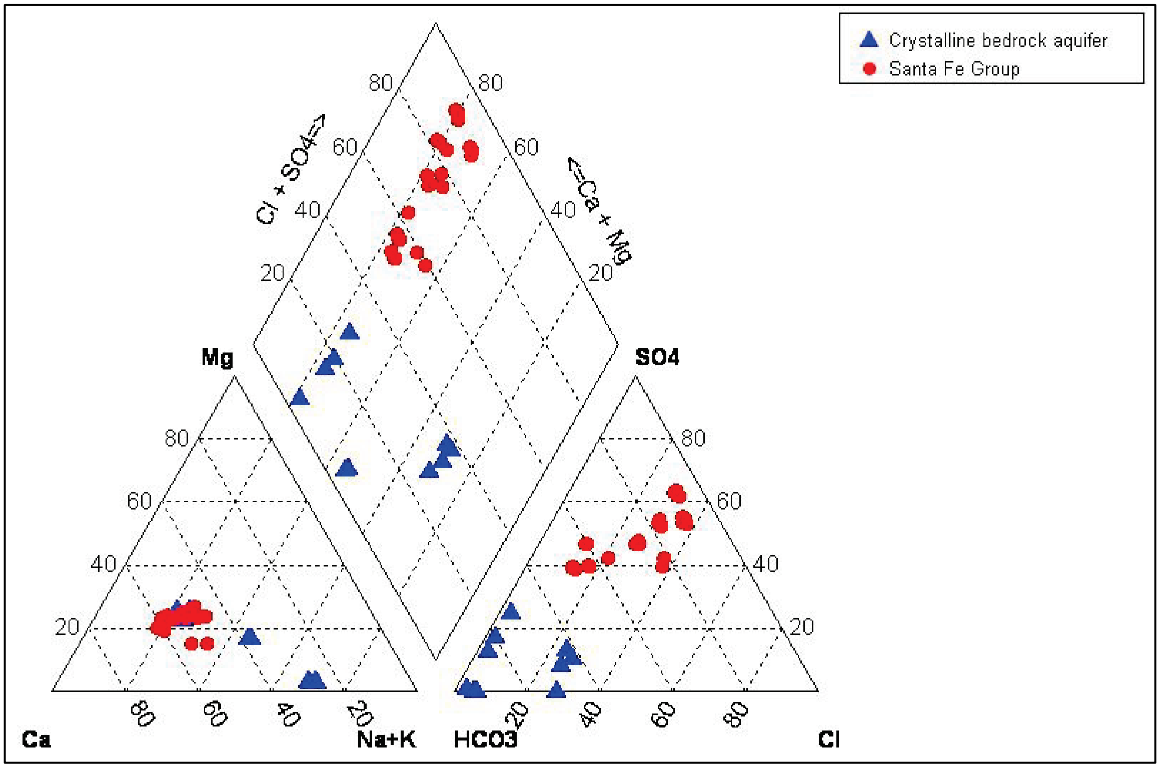


Figure 1-7: Piper Plot of Major Ion Chemistry of Groundwater in the Mine Permit Area (analyses from 2010 and 2011 only)

1.2.7 Existing Pit Lake

During the late 1980s and 1990s, a pit lake formed in the existing pit. During this period, the pit lake was approximately 13.8 acres, but has subsequently reduced in size as a result of evaporation and limited precipitation (i.e., drought conditions). A recent evaluation by JSAI (2011) indicates that the pit lake currently covers an area of approximately 5.2 acres and contains approximately 60 acre-feet of water. Bathymetric measurements carried out as part of the INTERA (2012) baseline data collection program indicate that the depth of the existing pit lake varies between 28 and 36 feet. Water levels are typically highest in the winter month of January and lowest in the summer month of July. The analytical results do not indicate the presence of a chemocline or any chemical stratification in the lake. However, the temperature profiles for the winter and summer sampling showed a greater than 1^{o}C per meter change, indicating the presence of a thermocline. The pit currently represents a hydraulic sink, with evaporation from the lake surface exceeding groundwater inflow, precipitation and surface runon.

Existing pit lake water quality was assessed as part of the INTERA (2012) baseline data collection program, which included collection of samples from the deepest part of the pit lake in September 2010, January 2011, April 2011 and July 2011. JSAI collected four quarters of additional data in 2013 as part of the Stage 1 abatement investigation (JSAI, May 2014). The results of this monitoring program are summarized in Table 1-2 and demonstrate that pit lake waters are currently characterized by circum-neutral to moderately alkaline pH (6 – 7.9 s.u.), with sulfate concentrations between 5,200 mg/L and 8,690 mg/L. Furthermore, concentrations of sulfate, chloride, TDS, manganese, magnesium, cobalt, fluoride, sodium and potassium have all increased between 1989 and 2013 (Appendix D). In particular, evapoconcentration effects have increased the concentrations of sulfate and chloride (Figure 1-8), resulting in supersaturation of pit lake waters and subsequent precipitation of salts (primarily gypsum) around the rim of the existing pit lake. These precipitated solids now form a thick crust on the pit walls (Figure 1-11). The pH of existing pit lake waters has generally increased over time most likely through a combination of groundwater alkalinity and localized buffering by wall rock silicate and carbonate mineralogy.

Comparison of existing pit lake chemistry in with NMAC 20.6.4900 surface water standards for livestock watering and wildlife demonstrates that cadmium, copper and selenium are above the respective standards for these parameters (Table 1-2). Copper concentrations in the open pit are influenced by Acid Wall Seep (AWS) events. Figure 1-9 shows that there appears to have been an AWS event around 2008 and then again during September 2013. The elevated copper concentrations observed in 2010 are naturally mitigated to below analytical detection limits by 2011. This demonstrates that pit lake chemistry is temporally variable, with copper concentrations varying from below analytical detection limits up to a maximum of 26.5 mg/L.

Temperature and dissolved oxygen profiles for the existing pit lake (INTERA, 2012) show the pit water is not significantly stratified. The water stays well oxygenated for the entire depth for each season (6 to 8 mg/L dissolved oxygen). Thermal stratification requires a 1°C change in temperature per meter (Wetzel, 2001), which can occur in the summer months as the upper water column heats up and the lower water column remains cool, and well oxygenated. Figure 1-12 also shows that there is no depth-dependent variation in key chemical constituents (pH, TDS, copper, iron, zinc, manganese). This supports the assumption that the current pit lake is not stratified and that no chemocline exists.

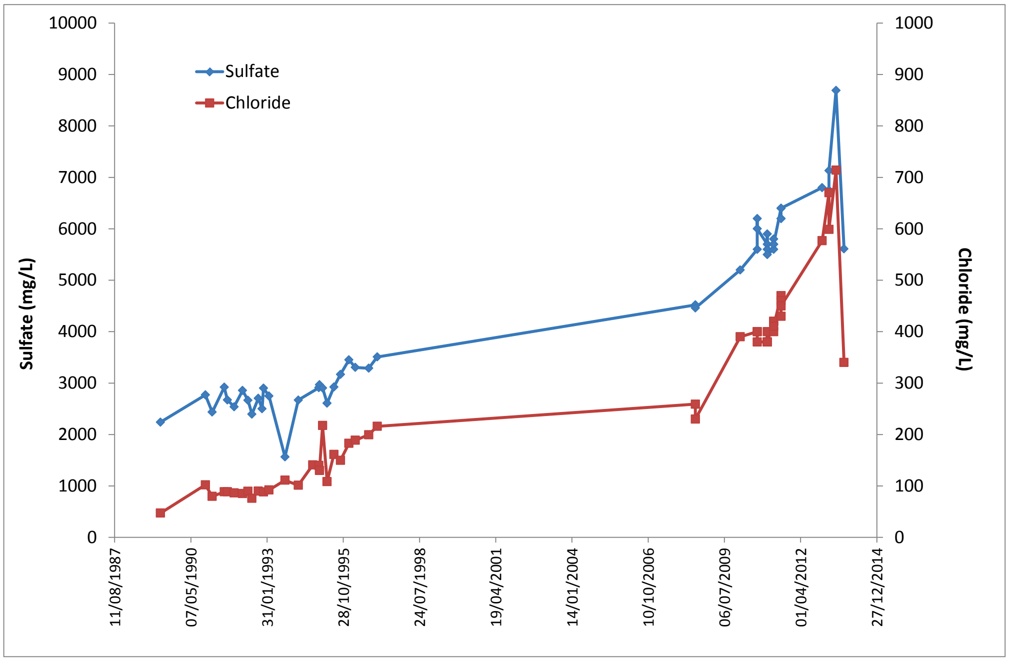


Figure 1-8: Plot of Sulfate and Chloride Concentrations in Existing Pit Lake

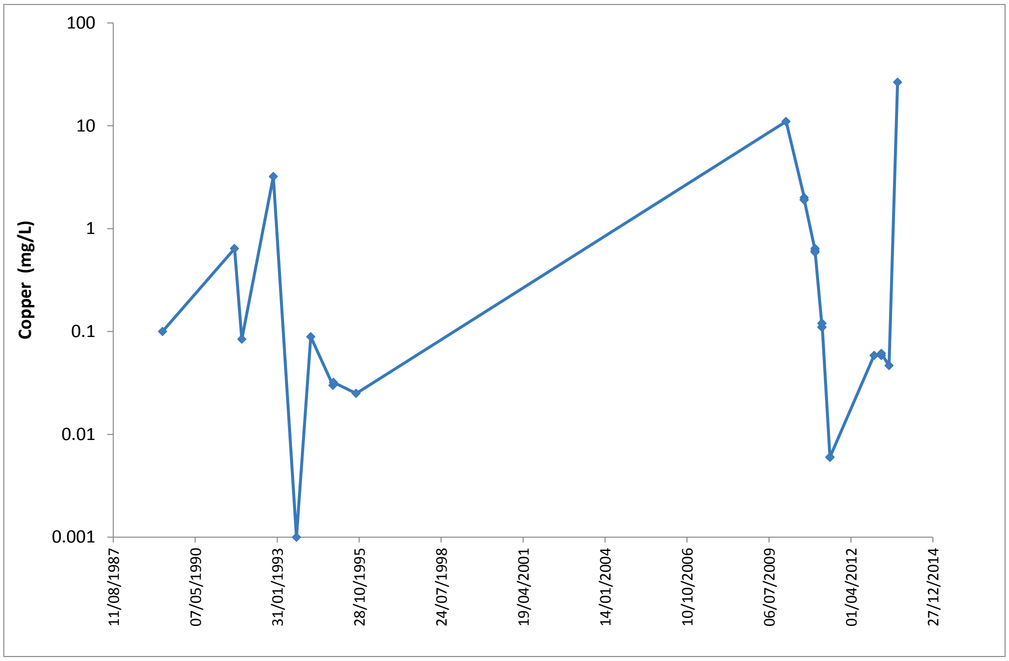


Figure 1-9: Plot of Copper Concentrations in Existing Pit Lake

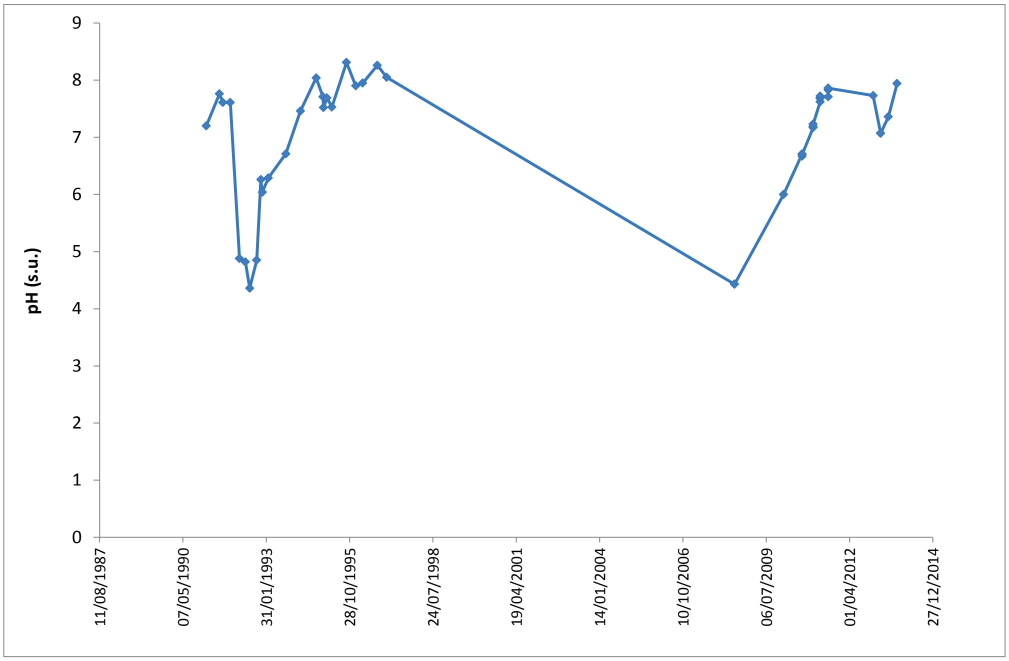


Figure 1-10: Plot of pH in Existing Pit Lake

Figure 1-11: Precipitated Salts around Rim of Existing Pit Lake

Table 1-2: Existing Pit Lake Chemistry (2010 – 2013)

		NMAC 20.6.4.900 Surface Water Standards		**Concentration in period 2010 - 2013**		
		Livestock	*Wildlife*	**Average**	**Minimum**	**Maximum**
pH	s.u.	*6.6 - 9*		7.3	6.0	7.9
Bicarbonate	mg/L	-	-	49.7	<20	123
Aluminum	mg/L	-	-	4.58	<0.02	82.6
Arsenic	mg/L	*0.2*	-	0.003	<0.001	0.0077
Boron	mg/L	*5*	-	0.17	0.13	0.19
Calcium	mg/L	-	-	567	453	670
Cadmium	mg/L	*0.05*	-	0.055	0.038	0.064
Cobalt	mg/L	*1*	-	0.29	0.049	0.49
Chromium	mg/L	*1*	-	<0.006†		
Copper	mg/L	*0.5*	-	2.21	<0.006	26.5
Fluoride	mg/L	-	-	18.4	15	29.8
Iron	mg/L	-	-	0.12	<0.02	1.3
Mercury	mg/L	*0.01*	*0.00077*	<0.0002	<0.0002	<0.0002
Potassium	mg/L	-	-	33	24	49
Magnesium	mg/L	-	-	720	570	1120
Manganese	mg/L	-	-	41	28	48
Molybdenum	mg/L	-	-	0.02	<0.015	0.025
Sodium	mg/L	-	-	871	604	1400
Nickel	mg/L	-	-	0.058	0.039	0.069
Lead	mg/L	*0.1*	-	0.011	<0.005	0.026
Antimony	mg/L	-	-	<0.001†		
Selenium	mg/L	*0.05*	*0.005*	0.027	0.013	0.059
Uranium	mg/L	-	-	0.12	0.11	0.12
Vanadium	mg/L	*0.1*	-	<0.05†		
Zinc	mg/L	*25*	-	4.29	0.78	7.36
Sulfate	mg/L	-	-	6,128	5200	8690
Chloride	mg/L	-	-	451	380	714

†	*Indicates parameter was uniformly below detection limits Inpit lake water over monitoring period, but detection limit was variable. Concentration shown in table represents lower limit of analytical detection.*
🟥	*Indicates value is greater than NMAC 20.6.4900 surface water standard*
'-'	*Indicates no standard for parameter*

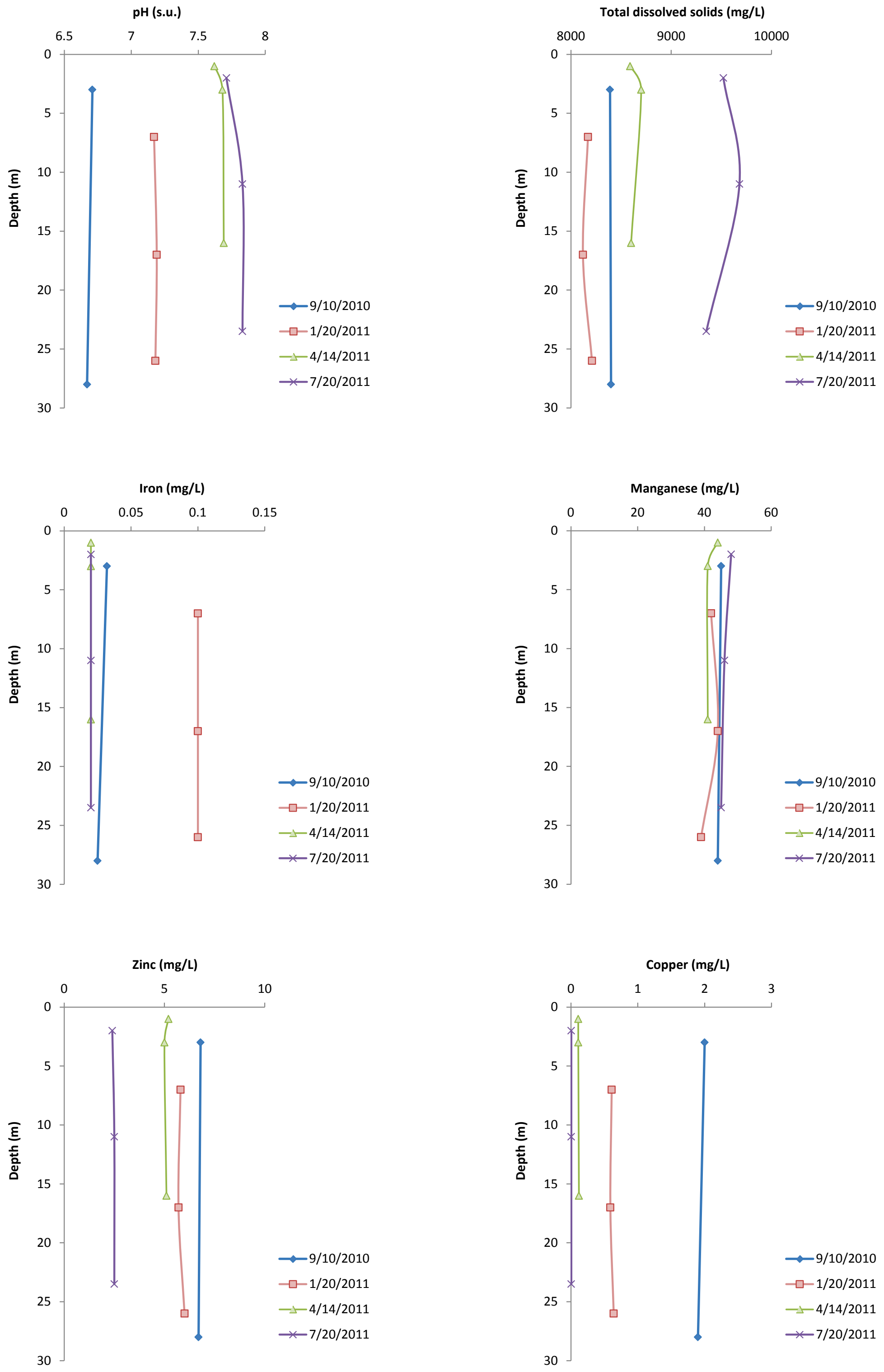


Figure 1-12: Depth Profiles of Key Constituents in Existing Pit Lake

2 Geochemical Characterization Testwork Summary

SRK has conducted a geochemical characterization program for the Copper Flat project, which has included the testing of 91 waste rock samples, 41 samples representative of low grade ore and 11 samples of tailings material to investigate the potential for ARDML generation. The results of this program are presented in the *Geochemical Characterization Report for the Copper Flat Project, New Mexico* (SRK 2012) and the main findings are summarized below.

Waste rock and ore sample intervals were selected from both exploration core holes drilled within the proposed pit boundaries in 2009, 2010 and 2011 and from the surface of existing WRDs and pit walls on site. Samples were selected to represent the range of waste rock and ore material types that will be encountered during future mining. Tailings samples were collected from the metallurgical program and from the existing (historic) TSF on site. The static test methods used for the geochemical characterization program include multi-element analysis using four-acid digest and ICP-MS analysis, modified Sobek Acid Base Accounting (ABA), Net Acid Generation (NAG) test and the Nevada Meteoric Water Mobility Procedure (MWMP). These static tests were selected to address total acid generation or neutralization potential of the samples and concentration of constituents in leachates derived from the material. However, these static tests do not consider the temporal variations that may occur in leachate chemistry as a result of long-term changes in oxidation, dissolution and desorption reaction rates. To address these factors, kinetic testing was also carried out as part of the geochemical characterization program and includes 32 humidity cell tests (HCTs) conducted on samples of waste rock, ore and tailings according to the ASTM D-5744-96 methodology.

The results of the characterization program demonstrate that the acid generating potential of the Copper Flat waste rock is largely dependent on the sulfide mineral content, with sulfide concentrations varying from less than analytical detection limits to a maximum of 2.52 wt%. The static testwork results indicate that the transitional waste material (i.e. mixed sulfide/oxide) is likely to be potentially acid forming based on a generally higher sulfide mineral content and the presence of secondary oxide minerals that formed as a result of supergene weathering. In contrast, the diabase, andesite and tailings are likely to be non-acid forming materials. The main material type for the project consists of sulfide (i.e., non-oxidized) Quartz Monzonite and Breccia, which typically exhibited either non-acid forming characteristics or a low potential for acid generation. This is related to the encapsulation of sulfide minerals in a quartz matrix or occasionally in potassium feldspar. In addition, the sulfide minerals in the Copper Flat deposit are crystalline and often coarse grained and as such have slow weathering reaction kinetics. It is likely that the Copper Flat materials will offer limited silicate buffering (neutralizing) capacity; although this is unlikely to be high magnitude, it may modify/buffer pH in the near neutral range.

The Copper Flat waste rock and ore materials were found to be enriched in copper, sulfur and selenium in whole rock chemistry, which relates to the primary mineralization (predominantly chalcopyrite - $CuFeS_2$). Silver, arsenic, cadmium, molybdenum, lead, thallium, uranium, tungsten, and zinc were also found to be enriched in one or more material types, with the greatest levels of enrichment occurring in the sulfide and transitional ore material types. Many of these elements are typically associated with copper porphyry deposits, which explain their enrichment in the Copper Flat materials (and more specifically in the ore grade samples). The diabase and andesite material types typically showed much lower levels of elemental enrichment, which is likely related to the lack of primary mineralization in these lithological units.

MWMP tests were conducted on a total of 49 waste rock and tailings samples to provide an indication of elemental mobility and metal(loid) release from the Copper Flat materials during meteoric rinsing. Metal mobility and release was also assessed from the results of the HCT program, the results of which are summarized in Appendix C. In general, metal leaching from the Copper Flat materials was found to be low and the majority of leachates generated during the MWMP and HCT test programs could be classed as near-neutral, low-metal waters. However, several of the grab samples of transitional material collected from historic waste rock dumps produced acidic leachates and showed the potential for higher metal release than observed for the unoxidized sulfide materials. The higher release of acidity and metals from these samples likely represents the flushing of soluble acidic sulfate salts from the material surface that were produced by the prolonged weathering (over geological time) of the material.

3 Pit Lake Geochemical Model Approach

During mining operations, dewatering will keep the pit operational and limited water will pond within the pit itself. At the end of open pit mining operations, dewatering will cease and a pit lake will ultimately form. Pit lake water quality predictions were made at selected time intervals (beginning when the pit lake starts to fill after mining and dewatering operations cease). Water quality predictions were made for the time periods of 0.5, 1, 2, 5, 10, 25, 50, 75, and, 100 years after the start of pit lake formation. These predictions were based on mass load mixing of waters from different sources and allowing the resulting mix to establish thermodynamic equilibrium under imposed conditions by dissolving or precipitating specified solids, with attenuation of trace elements through sorption reactions.

3.1 Conceptual Model

A conceptual geochemical model was developed for the Copper Flat pit lake from a review of background and site-specific data in addition to experience with similar projects. The conceptual model assumes that a lake will form within the pit after dewatering operations cease as a result of inflow of groundwater into the pit, direct precipitation onto the pit lake and run-off from the pit walls. Data that were used as inputs to the model were derived from the following sources:

- Geological and mine planning information from the Baseline Data Report (INTERA, 2012) and the geologic block model;
- Hydrologic and hydrogeologic information from the JSAI pit lake water balance. The current version of the JSAI groundwater model is presented in JSAI August 2014; however, portions of the model have been updated since the geochemical modeling began in 2012 based on inputs from various external reviews. Therefore the groundwater model has been updated several times; however, the pit water balance has remained consistent throughout the geochemical modeling effort;
- Geochemical data from laboratory humidity cell tests performed on representative waste rock lithologies and then scaled to field conditions. These data were utilized to provide source term data for chemical leaching of exposed rock in the pit walls;
- Precipitation chemistry data from long-term monitoring at the Gila Cliff Dwellings National Monument meteorological station, New Mexico; and
- Groundwater chemistry data from the ongoing groundwater monitoring program.

Full details of these input data are provided in the following sections. The conceptual geochemical model for the Copper Flat pit is provided in Figure 3-1 and is consistent with the industry-standard approach for modeling pit lake chemistry. Comparable approaches are reported in Tempel et al. (2000), Eary (1998) and Castendyk and Webster-Brown (2007).

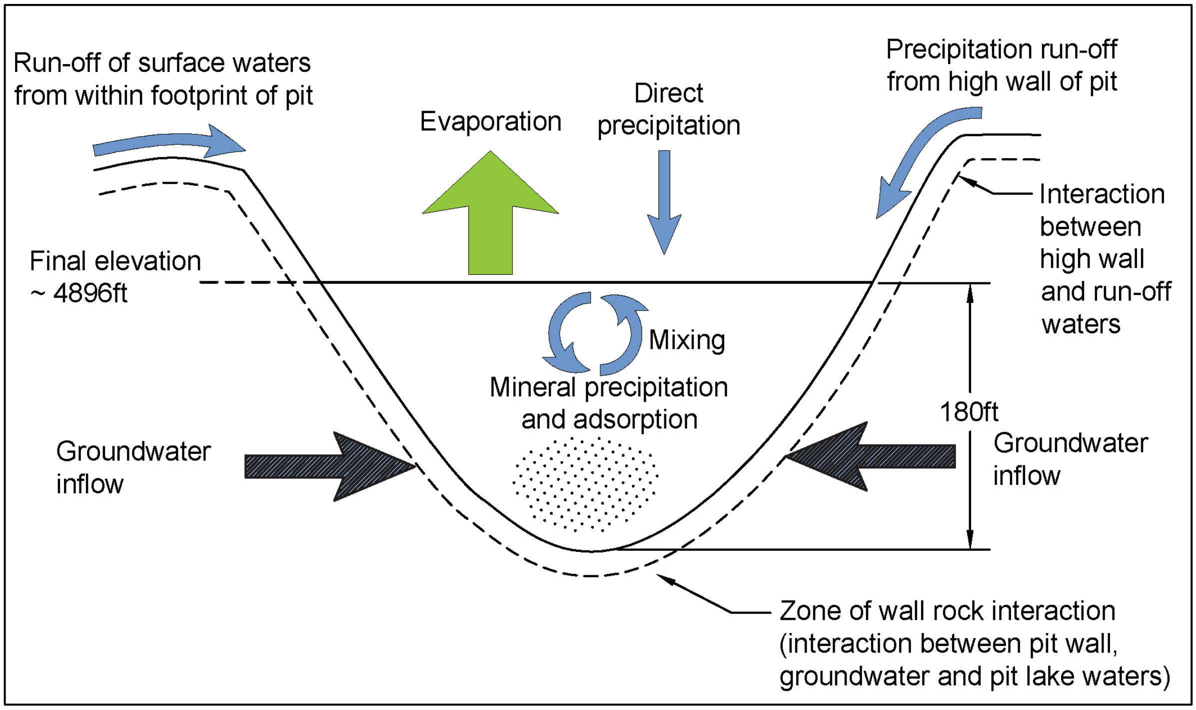


Figure 3-1: Conceptual Model

3.2 Geologic Model

3.2.1 Pit Wall Surface Areas

The proportional surface areas of the main lithologies that will be exposed in the final pit walls have been calculated from the geologic block model. The three dimensional surface areas of each lithology in the pit walls at the end of mine life are provided in Table 3-1 and are illustrated in Figure 3-2. This demonstrates that unoxidized quartz monzonite represents the dominant lithological unit that will be exposed in the final pit walls.

The geological block model was used to calculate the three dimensional surface area of each material type that will be exposed in the pit wall both above and below the water level as pit filling progresses. Three dimensional surface areas were calculated for each of the modeled time steps (i.e. for 0.5, 1, 2, 5, 10, 25, 50, 75, and 100 years after the start of pit lake formation).

Table 3-1: 3D Surface Areas of Pit Wall Rock Material Types

Material type	Oxidation	3D surface area (ft^2)	3D surface area (m^2)	Proportion
Andesite	Oxide / transitional	9,173	852	0.12%
Biotite breccia		-	-	-
Quartz feldspar breccia		6,703	623	0.09%
Quartz monzonite		79,578	7,393	1.01%
Coarse crystalline porphyry		27,277	2,534	0.35%
Undefined		47,881	4,448	0.61%
Andesite	Sulfide (non-ox)	86,611	8,046	1.10%
Biotite breccia		316,873	29,438	4.02%
Quartz feldspar breccia		491,257	45,639	6.23%
Quartz monzonite		5,794,482	538,325	73.5%
Coarse crystalline porphyry		1,022,725	95,014	13.0%
Undefined		-	-	-

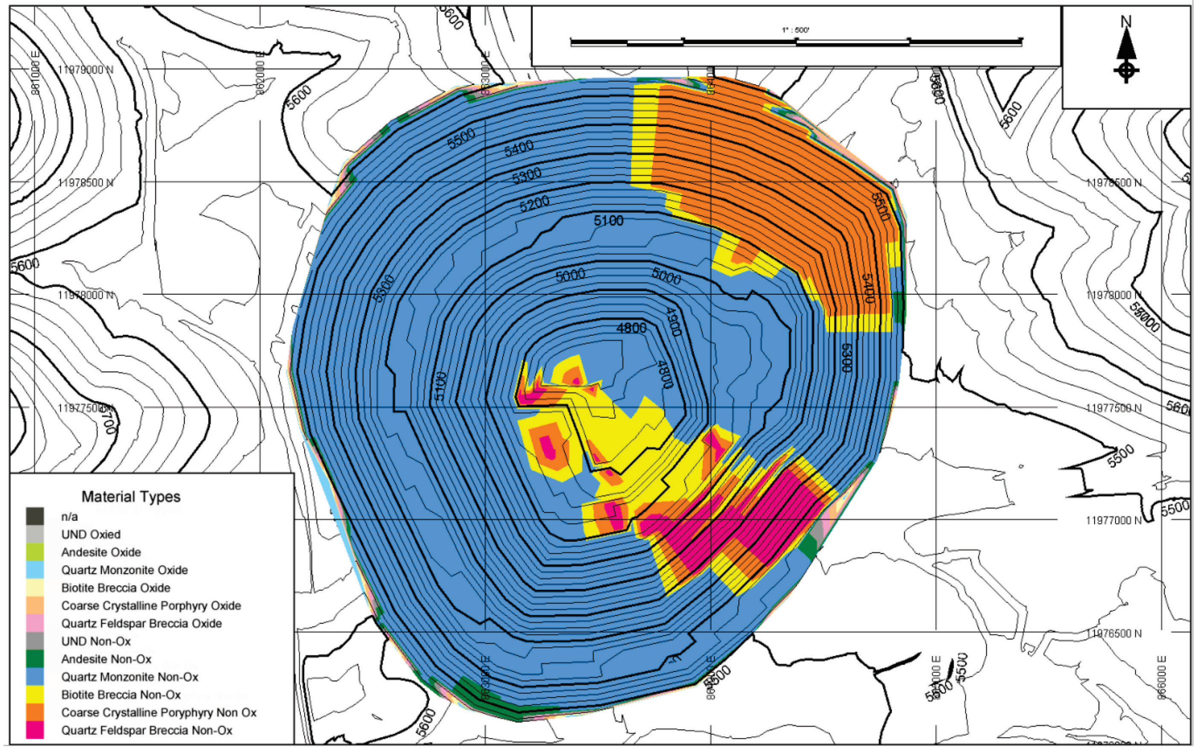


Figure 3-2: Exposed Material Types in Final Pit Walls

3.2.2 Calculation of Pit Wall Rock Available for Leaching

During the period of dewatering the pit walls will be exposed to oxygenated conditions and will weather to form secondary minerals, including soluble salts. As the pit wall resaturates during rebound of the groundwater table, soluble salts and other weathering products will dissolve into the ambient groundwater that drains into the pit. In addition, dissolution of these soluble salts by run-off waters in the unsaturated high wall of the pit may occur. In order that laboratory leach data can be used to determine the mass release of solutes under field leaching conditions, it was necessary to determine the total reactive mass (R_m) of material available for leaching in the pit walls based on the exposed surface areas of each lithology in both the unsaturated high wall and in the submerged pit walls. The reactive mass will be dependent on the density of the pit wall rocks, the density of any fractures produced by blasting, and the depth to which this fracturing penetrates in the pit walls.

A number of studies have evaluated the density and thickness of pit wall fracturing caused by blasting (e.g. Carroll and Scott, 1966; Siskind and Fumanti, 1974; Kelsall et al., 1984; Molebatsi et al., 2009). A detailed summary of this research is presented in Appendix A. This demonstrates that the depth of pit wall fracturing is found to be variable between 1 and 16 feet. Furthermore, the research demonstrates that there is no standard approach for the incorporation of pit wall fracturing information into pit lake geochemical predictions.

An estimate of the reactive mass in the future pit high wall at Copper Flat was made based on the review of the published information on pit wall fracturing (Appendix A) and from site-specific information provided by NMCC. Future blasting practices at Copper Flat will include pre-split drilling and smooth wall blasting, which is considered best practice for geotechnical stability and will effectively reduce fracturing within the final pit walls. Kelsall et al. (1984) studied blasting effects in granite and basalt wall rock and found that blasting enhances permeability by approximately 10 times near the blast face. However, the extent of blast effects are generally limited to <1m (<3.3ft), and as little as 0.3m (1ft) when using low-charge blast methods. Given that the future blasting techniques at Copper Flat will include smooth wall blasting and that the pit wall composition (i.e. quartz monzonite) will be similar to the granitic material studied in Kelsall et al. (1984), a 1 foot thickness of reactive rock in the pit walls has been assumed for the purpose of the model. It is assumed that fracturing in this crushed zone will average 10% (Siskind and Fumanti, 1974; Kelsall et al., 1984). This assumption (i.e., 10% fractures) is considered conservative because the rock comprising the proposed pit shell has low fracture permeability and the limited natural fractures are mineralized (quartz and calcite are common minerals in fractures). In the current pit, water flows through a few individual fractures. Because chemical loading from the pit walls is likely to be one of the major controls on future pit water chemistry, control of water-yielding fractures and pit-wall runoff will be investigated as part of the proposed pit reclamation and source controls study.

In addition to the crushed zone described above, mineralogy work carried out by SRK on humidity cell tests for previous projects indicates particles generally show water infiltration and products of reactivity up to 0.04 feet into the individual rock fragments. Therefore an oxidized rind of 0.04 feet (0.012 m) thickness has also been assumed on the surface of the pit walls (Figure 3-3).

Using these assumptions for the crushed zone and oxidized rind, the reactive mass (R_m) of material in the pit wall was calculated as:

$$R_m = (S \times F_D \times T_{CZ} \times D) + (S \times T_{OR} \times D)$$

Where:

S is the three-dimensional pit wall surface area in square meters (defined by the geological block model; see Table 3-1);

F_D is the fracture density in the crushed zone (10%);

T_{CZ} is the thickness of the crushed zone in meters (0.3m);

T_{OR} is the thickness of the reactive rind in meters (0.012m);

D is the rock density in kg/m^3 (2700 kg/m^3, Young and Olhoeft, 1976).

Water flow is assumed to be mobile within the crushed zone and oxidized rind and it is assumed that only this outermost layer is leached by precipitation that falls on the pit high wall. Therefore, the mass of rock calculated within the crushed zone and oxidized rind is equivalent to the mass of rock available for leaching by surface run-off from the exposed high wall during life-of-mine (LOM) scenarios and also for the submerged high wall within the oxic pit lake zone during pit infilling. This is expanded on in Section 3.4.2. Although oxidation of sulfide minerals will occur within the fluctuation zone, it is unlikely that these oxidation products will be leached until pit infilling occurs and the inflow of groundwater becomes significant in the highwall post closure.

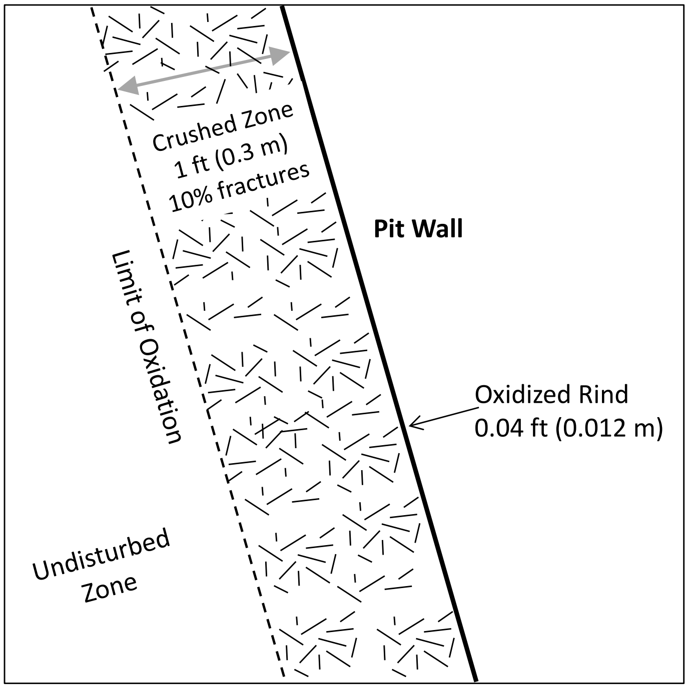


Figure 3-3: Future Pit Wall Conceptual Model

3.3 Hydrogeologic Model

Hydrogeologic modeling for the Copper Flat pit lake was undertaken by JSAI. Details on the groundwater flow model and the projected pit water level and water balance are presented in JSAI (August, 2014). The post-mining pit water levels and water balance were simulated assuming the pit geometry and watershed shown in Figure 3-4. The PFS pit footprint area is 143 acres and the watershed area affecting the pit is approximately 230 acres. Upon cessation of mining, pumping will cease in and around the pit, allowing the pit to refill over a number of years. The primary solution inputs to the pit are assumed to be groundwater inflow, direct precipitation onto high walls of the pit and run-off from the pit walls. Evaporation represents the dominant solution loss.

The final post-closure PFS pit water elevation is estimated to be at an elevation of approximately 4,900 feet. The resulting lake would cover an area of about 18.6 acres with a depth of approximately 180 feet. The final pit water balance will be 100 acre-feet per year, comprising 63 acre-feet per year of precipitation/run-off, 37 acre-feet per year of groundwater inflow and 100 acre-feet of annual evaporation. The post closure DFS pit water balance is estimated to be essentially the same as the PFS pit at 101 acre-feet per year and the water elevation estimated to be a little lower at 4,860 feet. For geochemical modeling purposes, there is no significant difference between the PFS and DFS pit water balances (SRK, February 13, 2014).

The water level of the lake would fluctuate a few feet seasonally depending on precipitation and evaporation rates, rising during periods of lower evaporation (winter months) and decreasing during summer months.

The pit is expected to form a hydrologic sink, capturing groundwater flowing from all directions (INTERA, 2012; JSAI, 2011). Surface water from within the footprint of the pit will also be captured. Even with surface water inflows, the pit lake area is expected to be a hydraulic sink with evaporation rates greatly exceeding precipitation and groundwater inflows over most of the year (THEMAC Resources Group Ltd., 2012). Full details of the pit lake water balance can be found in the JSAI (August, 2014) report.

The primary factor controlling the pit water elevation and water balance in the future pit lake at Copper Flat is the availability of water. The three main components of inflow to the pit (i.e., watershed runoff, pit wall runoff and groundwater inflow) are dependent on the details of the mine closure plans, including in-pit reclamation, watershed management and source controls. The water balance water chemistry implications of different closure options are being evaluated as part of the pit reclamation and source control study. Included in this is the evaluation of pit water conditions during wet and dry periods.

Mine pit lakes can develop vertical density stratification that may be seasonal or permanent. The density of water is a function of both its temperature and its salinity or total dissolved solids (TDS) content. Freshwater is densest at a temperature of about 4°C. At a given temperature, water density increases with increasing TDS. As TDS increases, the temperature of the maximum density of water also decreases (Atkins et al., 1997; Parshley and Bowell, 2003).

Long-term (multi-year) or permanent density stratification can occur if a lake has a significant vertical variation in TDS due to large differences in the TDS of various source waters to the lake and/or to processes in the lake that increase the TDS. This in turn affects the density of the deeper water. For example, if a lake contains enough organic matter to deplete oxygen in the hypolimnion, then during the summer, ferric hydroxide that precipitates at the surface will sink, become reduced, and dissolve in the basal anoxic water, raising the TDS content and the density of the bottom water.

Water below the hypolimnion will generally become anoxic and will continuously dissolve any ferric hydroxide precipitates falling into it from above. This process further increases the TDS of the hypolimnion and strengthens the density gradient between it and the overlying layer, perpetuating the stratification. Sulfidization in the hypolimnion will lead to natural attenuation of metals and metalloids as well as sulfur. Few studies reporting site-specific limnological data have been published to date (Atkins et al., 1997; Parshley and Bowell, 2003). For Copper Flat, the presence of solute material that will modify pit lake chemistry (i.e., sulfide minerals and gypsum) will likely prevent permanent chemical stratification or layering of the lake. This was validated in the 1990s from depth sampling of the pit lake at Copper Flat (SRK, 1996), and in 2010 and 2011 from baseline data collection (INTERA, 2012). The results from this study demonstrated that the current pit lake is homogeneous and no stratification exists. Temperature and dissolved oxygen profiles for the existing pit lake (INTERA, 2012) show the pit water is not significantly stratified. The water stays well oxygenated for the entire depth for each season (6 to 8 mg/L). Thermal stratification requires a 1°C change in temperature per meter (Wetzel, 2001), which can occur in the summer months as the upper water column heats up and the lower water column remains cool, and well oxygenated. A more detailed discussion on the potential for thermal and/or chemical stratification in the future Copper Flat pit lake is provided in Section 4.3.

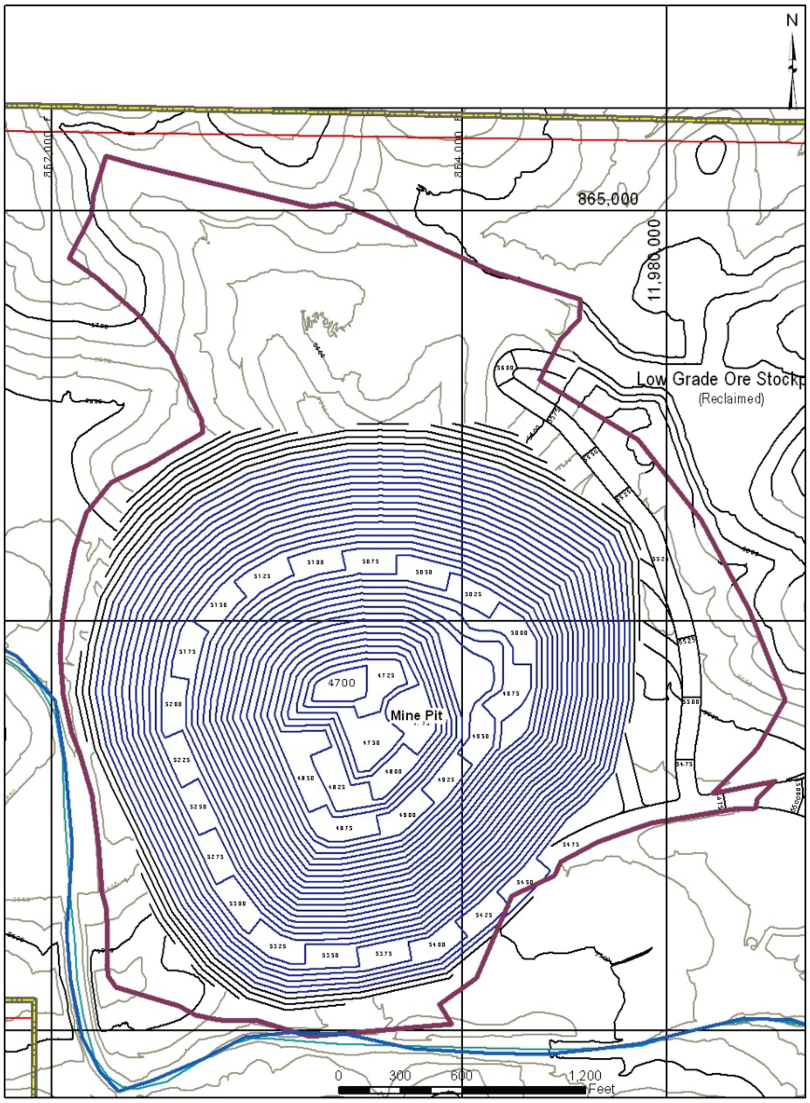


Figure 3-4: Ultimate Open Pit and Watershed

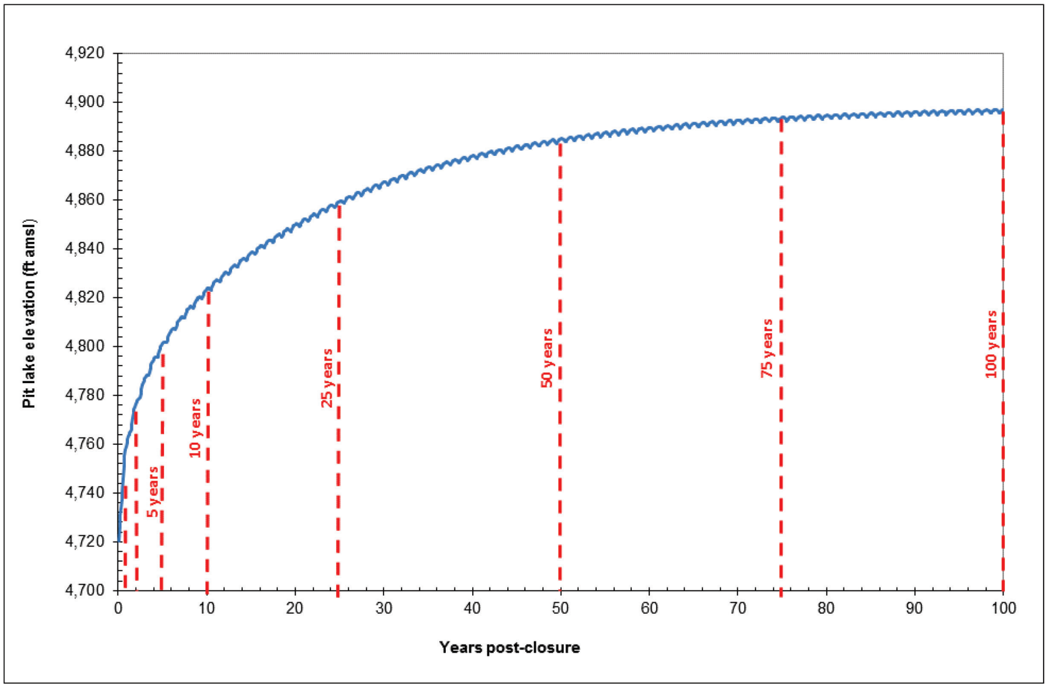


Figure 3-5: Pit Lake Elevation Curve showing Geochemical Model Iterations

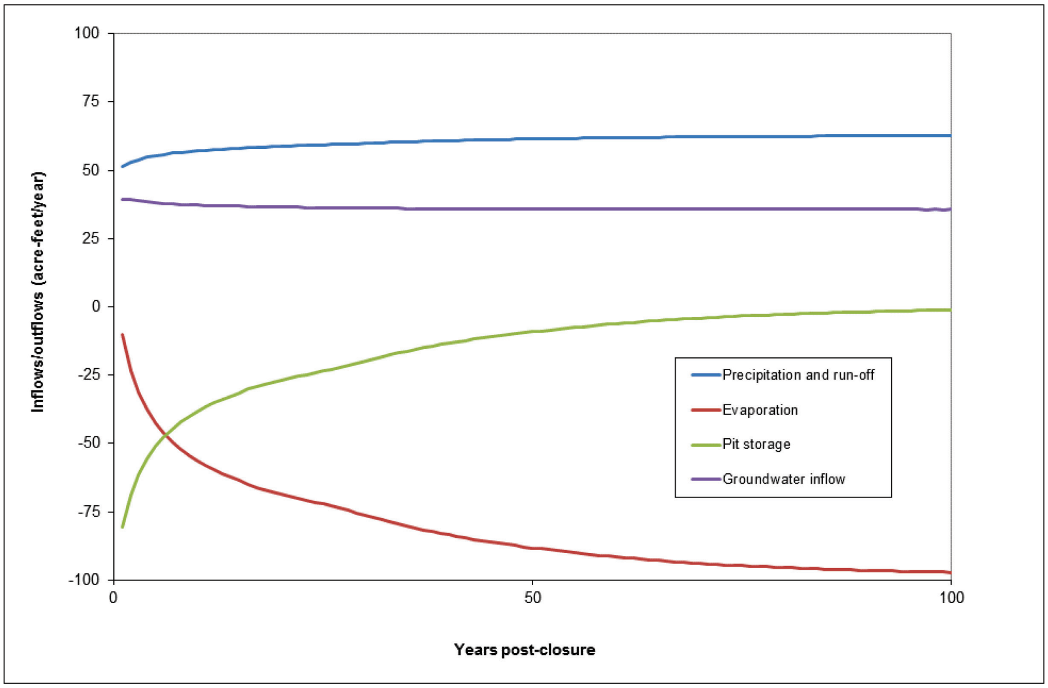


Figure 3-6: Pit Lake Flux

3.4 Solution Inputs

3.4.1 Groundwater Chemistry

Groundwater discharging into the pit lake will be a combination of inflowing regional groundwater plus additional solutes acquired through oxidation, desorption or dissolution reactions within the weathered pit walls. Therefore the chemistry of the groundwater source term for the Copper Flat pit lake model was represented by both hydrochemical data from the groundwater monitoring wells in addition to geochemical data from the ongoing HCT program.

There are four sets of piezometers surrounding the existing pit that have been sampled as part of Stage 1 Abatement monitoring, with two piezometer sets in the andesite rocks (GWQ96-22, GWQ96-23), and two in the quartz monzonite (GWQ11-24 and GWQ11-25). The results from these wells were used as inputs to the pit lake geochemical model, with the relative contribution from the quartz monzonite and andesite bedrock being proportioned according to the hydraulic conductivities of these units (Table 3-2). Wells GWQ11-24A and GWQ11-25A were not used in the model input as they may have been affected by oxidation of sulfides in fractures during well development and are not representative of groundwater reporting to the open pit. Furthermore, GWQ11-25A represents a localized and isolated fracture system recharged by oxygenated meteoric water that is not connected to the open pit (*personal comm.* JSAI, November 2014).

For the base case model, it was assumed that approximately 98% of the groundwater flowing into the pit will come from the quartz monzonite bedrock and the remaining 2% will come from the andesite based on geology of the crystalline bedrock. A sensitivity analysis was also run that assumes the groundwater contribution from the quartz monzonite and andesite units would be equal. The groundwater chemistry used as the input to the pit lake PHREEQC model for the base case and sensitivity analysis is presented in Table 3-3 along with a comparison to NMWQCC groundwater standards and NMAC 20.6.4.900 surface water wildlife habitat and livestock watering standards. From this comparison, all constituents are below the NMWQCC groundwater standards with the exception of fluoride, iron, manganese and sulfate. In comparison to the surface water wildlife habitat and livestock watering standards, all constituents are below the respective standards.

Groundwater chemistry was reacted in PHREEQC with source terms for leaching of wallrock represented by the HCT leachate chemistries in the proportions defined by the geological block model (i.e., according to the surface areas of the various lithologies exposed in the final pit walls).

The groundwater chemistry input reflects current equilibrium conditions and the existing groundwater chemistry is likely to be in equilibrium with the bedrock surrounding the existing pit. For the future pit lake geochemical predictions, the primary solute loading is likely to come from rinsing of oxidation products from the pit wall surfaces and any fractures in the immediate (<1-foot) wall rock rather than from the entire cone of depression surrounding the pit.

Table 3-2: Summary of hydraulic conductivity estimates from wells in the vicinity of the pit (modified from JSAI, 2014)

Borehole and zone	Depth interval (ft)	Lithology	Hydraulic conductivity			Relative contribution to flow
			cm/sec	ft/day	Average ft/day	
GWQ96-22	170-386	Andesite	6×10^{-9}	0.00003	0.0014	2.01%
GWQ96-23	420-471	Andesite	9.5×10^{-7}	0.0027		
GWQ11-24, Zone 1	100-147	Quartz monzonite	7×10^{-6}	0.02	0.067	97.99%
GWQ11-24, Zone 2	150-197	Quartz monzonite	3×10^{-5}	0.085		
GWQ11-24, Zone 3	204-251	Quartz monzonite	4.9×10^{-5}	0.14		
GWQ11-25, Zone 1	100-148	Quartz monzonite	~0	~0		
GWQ11-25, Zone 2	150-198	Quartz monzonite	2.9×10^{-5}	0.081		
GWQ11-25, Zone 3	207-251	Quartz monzonite	2.6×10^{-5}	0.074		

Table 3-3: Groundwater Chemistry used in the PHREEQC Model

Parameter	Units	NMWQCC groundwater standards	NMAC 20.6.4.900 standards for livestock watering	NMAC 20.6.4.900 standards for wildlife	Base case[1]	Sensitivity analysis[2]
pH	s.u.	6 – 9	-	-	7.15	6.47
HCO_3	mg/L	-	-	-	334	273
Aluminum	mg/L	5	-	-	0.29	0.17
Antimony	mg/L	-	-	-	<0.002†	
Arsenic	mg/L	0.1	0.2	-	0.003	0.0001
Boron	mg/L	0.75	5	-	0.14	0.003
Barium	mg/L	1	-	-	0.09	0.002
Calcium	mg/L	-	-	-	275	454
Cadmium	mg/L	0.01	0.05	-	<0.002†	
Chloride	mg/L	250	-	-	38.5	27.7
Cobalt	mg/L	0.05	1	-	<0.006†	
Chromium	mg/L	0.05	1	-	<0.006†	
Copper	mg/L	1	0.5	-	0.009	0.005
Fluoride	mg/L	1.6	-	-	2.04	5.87
Iron	mg/L	1	-	-	1.49	0.031
Mercury	mg/L	0.002	0.01	0.00077	<0.000002†	
Potassium	mg/L	-	-	-	4.04	5.07
Magnesium	mg/L	-	-	-	48.5	75.9
Manganese	mg/L	0.2	-	-	2.01	3.31
Molybdenum	mg/L	1	-	-	0.02	0.0005
Sodium	mg/L	-	-	-	116	113
Nickel	mg/L	0.2	-	-	<0.01†	
Lead	mg/L	0.05	0.1	-	<0.005†	
Sulfate	mg/L	600	-	-	742	1362
Silver	mg/L	0.05	-	-	0.019	0.0004
Selenium	mg/L	0.05	-	0.005	0.003	0.004
Uranium	mg/L	0.03	0.05	-	0.002	<0.001
Vanadium	mg/L	-	0.1	-	<0.0009†	
Zinc	mg/L	10	-	-	0.066	0.102
Ion balance	*%*	*-*	*-*	*-*	*1.96%*	*0.53%*

Indicates exceedance of NMWQCC

[1] *Represents weighted average groundwater chemistry for wells GWQ96-22(A,B), GWQ96-23(A,B), GWQ11-24(B) and GWQ11-25(B). Chemistry is weighted according to the hydraulic conductivity of the quartz monzonite and andesite bedrock units*

[2] *Represents numeric average groundwater chemistry for wells GWQ96-22(A,B), GWQ96-23(A,B), GWQ11-24(B) and GWQ11-25(B). Assumes equal groundwater contribution from quartz monzonite and andesite bedrock units*

† *Indicates parameter is uniformly below detection limits in groundwater over monitoring period and was excluded from the PHREEQC input. Concentration shown in table represents lower limit of analytical detection.*

'-' *Indicates no standard for parameter*

3.4.2 Wall Rock Chemistry

Source term solutions for the pit wall rocks were developed from the results of site-specific HCT testing conducted as part of the SRK (2012) geochemical characterization program that were scaled to field conditions. The application of a scaling factor is necessary because laboratory tests are operated at a higher water-to-rock ratio than would be expected in the field, meaning that mineral-water reaction rates are enhanced in the laboratory. The scaling factor is based on site-specific information relating to the pit water balance, geological model, pit wall fracturing and wall rock density.

The reactive mass (R_m) of pit wall rock available for chemical weathering reactions in both the unsaturated high wall and the submerged pit wall was calculated using the methodology outlined in Section 3.2.2. This reactive mass was coupled with the pit water balance to determine the changes in run-off and groundwater chemistry as any water that interacts with the pit walls migrates through the reactive fracture zones. This is demonstrated by the equation below:

$$C_i = \frac{r_i . R_m}{Q}$$

Where:

C_i represents the predicted concentration (in mg/L) of element *i*,

r_i represents the average release rate of element *i* in mg/kg/week in the humidity cell tests,

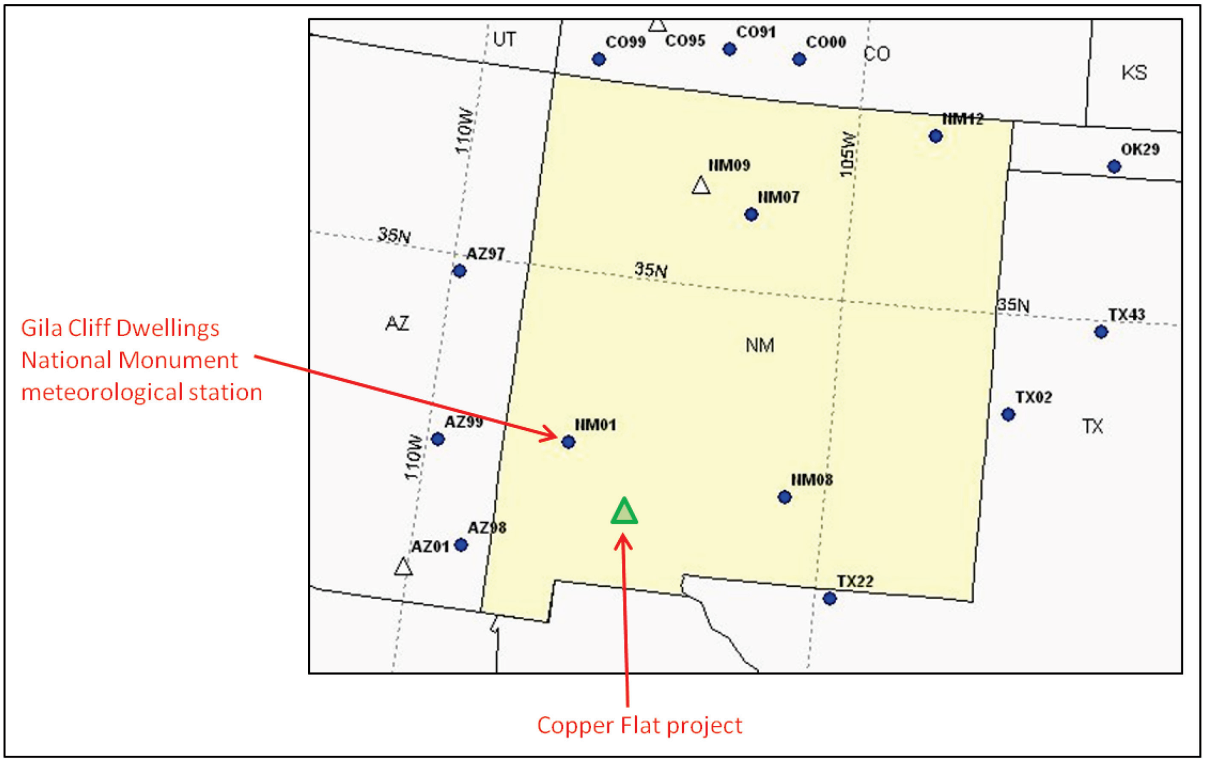
R_m indicates the pit wall reactive mass in kg and

Q represents either the rate of groundwater inflow into the pit or the rate of pit wall run-off in L/week.

The modified chemistry of the precipitation from these pit rim reactions was then used as the source term contribution to the pit. Scaled and averaged data from kinetic humidity cell tests completed for representative samples as part of the SRK (2012) geochemical characterization program were used as the source term solutions for the pit wall run-off. The humidity cells showed minimal variation in effluent chemistry between samples, thus justifying the use of average HCT chemistry data for each material type as the model inputs. The solutions used as inputs to the geochemical model are provided in Table 3-4.

3.4.3 Precipitation Chemistry

For the purposes of the geochemical model, the primary wall rock lixiviant for the high walls was assumed to be rainwater. Representative rainwater chemistry data were obtained from monthly monitoring carried out between 1985 and 2011 at the Gila Cliff Dwellings National Monument meteorological station, Catron County, New Mexico (NADP, 2012) (Figure 3-7). In the absence of any site-specific rainwater chemistry, this is considered the most representative precipitation chemistry available for use in the modeling exercise. For the purpose of the model, average rainwater chemistry data for the period 1985 to 2011 were used (see Table 3-5).



Gila Cliff Dwellings National Monument meteorological station

Copper Flat project

Figure 3-7: Location of Gila Cliff Dwellings National Monument Meteorological Station

Table 3-4: Source Term Chemistry for Each Material Type in the Pit Walls

	Units	Andesite	Biotite breccia - oxide/ transitional	Biotite breccia - sulfide	Quartz feldspar breccia - oxide/ transitional	Quartz feldspar breccia - sulfide	Quartz Monzonite - oxide/ transitional	Quartz Monzonite - sulfide	Coarse crystalline porphyry - oxide/ transitional	Coarse crystalline porphyry - sulfide
		Cells SRK 0864 and SRK 0866	*Cells SRK 0854 and SRK 0872*	*Cells 604811, 604854, 604862, 604867 and 605033*	*Cells 604767 and 604787*	*Cells 604767 and 604787*	*Cells 604569 and SRK 0867*	*Cells 604562, 604606, 604653, 604656, 604669, 604673 and 605153*	*Cell CF-11-02 (0-27)*	*Cell CF-11-02 (367-408)*
Percentage of waste (%)		*1.06%*	*0.05%*	*1.10%*	*0.09%*	*4.48%*	*2.78%*	*75.4%*	*0.93%*	*14.0%*
pH	s.u.	7.38	5.52	7.91	7.80	7.80	7.12	6.82	7.94	7.80
Alkalinity	mg/L as HCO_3	11.1	3.44	54.4	28.1	28.1	15.6	30.1	33.2	21.6
Aluminium	mg/L	0.008	0.27	0.01	-	-	0.05	0.01	0.01	0.05
Arsenic	mg/L	-	0.0006	0.0005	-	-	-	-	-	-
Boron	mg/L	-	-	0.01	0.01	0.01	0.02	0.01	0.01	0.01
Calcium	mg/L	9.23	23.8	28.9	17.4	17.4	19.0	15.4	10.7	7.69
Cadmium	mg/L	-	0.002	-	-	-	0.0004	-	-	-
Chloride	mg/L	0.39	0.30	1.09	0.83	0.83	0.57	1.41	0.78	1.26
Chromium	mg/L	0.0002	-	-	-	-	-	-	-	-
Copper	mg/L	0.002	17.4	0.011	-	-	0.51	0.035	-	0.006
Fluoride	mg/L	0.46	0.31	1.23	0.92	0.92	0.66	0.71	0.94	0.60
Iron	mg/L	0.002	0.47	-	-	-	0.059	0.002	0.006	0.004
Mercury	mg/L	0.000005	-	-	-	-	-	0.00001	0.00005	0.00002
Potassium	mg/L	1.00	0.99	5.05	2.53	2.53	1.73	3.46	2.66	1.95
Magnesium	mg/L	1.41	1.41	4.17	3.92	3.92	2.46	2.76	1.95	0.53
Manganese	mg/L	0.01	0.28	0.04	0.12	0.12	0.28	0.09	0.02	0.008
Molybdenum	mg/L	0.008	0.033	0.013	0.011	0.011	0.006	0.011	0.005	0.002
Sodium	mg/L	1.91	0.40	2.93	1.94	1.94	-	3.16	2.87	2.49
Nickel	mg/L	0.0005	0.0045	0.0005	0.0006	0.0006	0.0061	-	-	-
Lead	mg/L	0.0001	0.0016	-	-	-	-	0.0003	-	0.0002
Sulfate	mg/L	23.4	97.6	52.6	39.5	39.5	51.8	32.6	13.8	8.57
Antimony	mg/L	0.0001	0.0002	0.0002	0.0002	0.0002	0.0015	0.0002	-	0.0001
Selenium	mg/L	0.0003	0.002	0.003	0.002	0.002	0.001	0.001	-	-
Uranium	mg/L	0.0005	0.003	0.008	0.022	0.022	0.004	0.008	0.004	0.003
Vanadium	mg/L	0.002	0.001	0.006	0.003	0.003	0.002	0.003	-	-
Zinc	mg/L	0.0009	0.16	0.001	0.005	0.005	0.013	0.004	0.0005	-
Ion balance (%)		*0.44%*	*-21.8%*	*0.61%*	*1.29%*	*1.29%*	*-2.57%*	*0.50%*	*1.99%*	*1.66%*

\- Indicates parameter was uniformly below analytical detection limits in the HCT effluent leachates and was excluded from the PHREEQC model input for the specified material type

Table 3-5: Precipitation Chemistry used in the Model

Parameter	Units	Concentration
pH	s.u.	4.93
Ca	mg/L	0.21
Mg	mg/L	0.02
Na	mg/L	0.08
K	mg/L	0.03
Cl	mg/L	0.12
SO_4	mg/L	0.86
NH_4	mg/L	0.17
NO_3	mg/L	0.83

3.5 Mineral and Gas Phase Equilibration

For the purpose of the predictive geochemical model, it was assumed that the leachates produced from each lithology in the pit walls would mix evenly and completely. Under these circumstances the solutes in these waters will react with each other and may form chemical precipitates if the concentrations and geochemical conditions (Eh, pH, pCO_2, pO_2, and ionic strength) allow super saturation to occur. The geochemical model required the specification of a number of equilibrium phases that were allowed to precipitate if they become oversaturated. The suite of minerals chosen was based on the geology and mineralization of the deposit, an understanding of the types of minerals commonly observed in waste rock leachates and an assessment of mineral phases that were close to saturation based on the initial model iterations.

The relative saturation of all minerals was calculated by comparing the calculated concentration of dissolved ionic pairs with their theoretical thermodynamic limit. Where these values were equal, the saturation index was zero and the solution was said to be at equilibrium with that mineral. At equilibrium, any amount of the mineral that dissolves will precipitate to maintain the relative solute: mineral balance. The target saturation index was set to zero and the minerals that were allowed to form in the geochemical model are given in Table 3-6. These precipitates will sink to the bottom of the pit lake and be removed from future chemical interactions as a sediment layer accumulates on the pit bottom. The precipitated mineral phases are unlikely to re-dissolve unless the pH or redox conditions of the pit lake change substantially. As such, the model assumes that precipitated mineral phases are removed from the system and that subsequent re-dissolution of these phases does not occur.

Sulfide mineral reactions are already accounted for in the model because HCT data were used as inputs. The HCT test provides an estimate of long-term accelerated rates of elemental release as a result of oxidation reactions, including sulfide mineral oxidation. Kinetic data for sulfide mineral phases are also limited, with data generally being limited to silicate mineral phases. Further, in evaluating long term changes to water chemistry it is reasonable to assume thermodynamic equilibrium will be attained by the system and as such the approach taken in this study is valid.

Table 3-6: Equilibrium Phases Included in the Pit Lake Geochemical Model

Equilibrium phase*	Ideal formula	Rationale for inclusion in PHREEQC model
Alunite	$KAl_3(SO_4)_2(OH)_6$	Mineral observed at Copper Flat (SRK, 1996; 1997)
Anhydrite	$CaSO_4$	Close to saturation in initial model runs.
Ag_2Se	Ag_2Se	Close to saturation in initial model runs.
Barite	$BaSO_4$	Primary control on barium at neutral to alkaline pH (Eary, 1999). Mineral observed in Copper Flat mineralogical study (SRK, 2014)
$Ba_3(AsO_4)_2$	$Ba_3(AsO_4)_2$	Close to saturation in initial model runs.
Boehmite	AlOOH	Close to saturation in initial model runs.
Brochantite	$Cu_4^{2+}(SO_4)(OH)_6$	Primary control on copper at neutral to alkaline pH (Eary, 1999). Mineral observed at Copper Flat (SRK, 1996; 1997).
Brucite	$Mg(OH)_2$	Close to saturation in initial model runs.
Calcite	$CaCO_3$	Primary control on alkalinity at neutral to alkaline pH (Eary, 1999). Mineral observed at Copper Flat (SRK, 1996; 1997)
Carnotite	$K_2(UO_2)_2(VO_4)_2.H_2O$	Close to saturation in initial model runs.
Chrysotile	$Mg_3Si_2O_5(OH_4)$	Close to saturation in initial model runs.
Diaspore	α-AlOOH	Close to saturation in initial model runs.
Epsomite	$MgSO_4.7H_2O$	Close to saturation in initial model runs.
Ferrihydrite	$5Fe_2O_3.9H_2O$	Major control on iron. Thermodynamic properties well defined (Dzombak and Morel, 1990).
Fluorite	CaF_2	Primary control on fluoride (Eary, 1999). Mineral observed in Copper Flat mineralogical study (SRK, 2014)
Gibbsite	$Al(OH)_3$	Primary control on aluminum at neutral to alkaline pH (Eary, 1999)
Gummite	UO_3	Close to saturation in initial model runs.
Gypsum	$CaSO_4.2H_2O$	Primary control on sulfate (Eary, 1999). Observed in significant quantities around existing pit lake (SRK, 1996; 1997; 2014).
HgSe	HgSe	Close to saturation in initial model runs.
Magnesite	$MgCO_3$	Close to saturation in initial model runs.
Malachite	$Cu_2^{2+}(CO_3)(OH)_2$	Primary control on copper at neutral to alkaline pH (Eary, 1999). Mineral observed at Copper Flat (SRK, 1996; 1997).
Mirabilite	$NaSO_4.10H_2O$	Mineral observed at Copper Flat (SRK, 1996; 1997)
$NiCO_3$	$NiCO_3$	Primary control on nickel at neutral to alkaline pH
Otavite	$CdCO_3$	Primary control on cadmium at neutral to alkaline pH (Eary, 1999)
Pyromorphite	$Pb_5(PO_4)_3Cl$	Close to saturation in initial model runs.
Rhodochrosite	$Mn^{2+}CO_3$	Primary control on manganese at neutral to alkaline pH (Eary, 1999)
Rutherfordine	UO_2CO_3	Close to saturation in initial model runs.
Schoepite	$UO_2(OH)_2.H_2O$	Close to saturation in initial model runs.
Sepiolite	$Mg_4Si_6O_{15}(OH)_2.6H_2O$	Close to saturation in initial model runs.
SiO_2 (am-ppt)	SiO_2	Close to saturation in initial model runs.
Tenorite	$Cu^{2+}O$	Close to saturation in initial model runs. Likely solubility control for copper at neutral to alkaline pH (Eary, 1999)
U_3O_8	U_3O_8	Close to saturation in initial model runs.
UO_3	UO_3	Close to saturation in initial model runs.
$UO_2(OH)_2$ (beta)	$UO_2(OH)_2$ (beta)	Close to saturation in initial model runs.

3.6 Adsorption

In solution, trace element concentrations are mostly controlled by adsorption onto common mineral phases or are removed from solution through a process of co-precipitation. The models assumed that trace metals may be removed from solution via sorption onto freshly generated mineral precipitates such as iron oxides. Sorption is likely to represent an important metal removal mechanism at circum-neutral to moderately alkaline pH, with many metal ions sorbing more effectively under these pH conditions. Ferrihydrite ($5Fe_2O_3.9H_2O$) was selected as a sorption surface because it is a common sorption substrate in oxygenated natural waters and because the trace element sorption thermodynamic properties of these reactions are well defined by numerous empirical studies. Adsorption of soluble phases to hydrous ferric oxides (HFO) is highly pH dependent as is the solubility of HFO itself. Below a pH of around 4.5, only minimal sorption of most dissolved metal species is observed (Stumm and Morgan, 1996). The mass of ferrihydrite used in the models was assumed to be identical to the mass of the mineral phase ferrihydrite precipitated in the previous model reaction step and is controlled by the chemistry of the system. The model assumes that the ferrihydrite is characterized by both strong (HFO_s) and weak (HFO_w) surface adsorption sites. In order to be consistent with the properties of ferrihydrite published by Dzombak and Morel (1990) the geochemical models assumed a surface site density of 0.2 moles of weak sites and 0.005 moles of strong sites per mole of ferrihydrite. Because the future pit lake predictions start from time zero (i.e., cessation of mining), there will be no prior pit lake in the void at that point. Any HFO/ferrihydrite will therefore originate from the precipitation of oversaturated mineral phases that develop upon solution mixing.

As with mineral phase precipitation, the adsorbed mass of trace elements removed through this mechanism is assumed in the conceptual model to be permanently removed from the system following incorporation and co-precipitation with the HFO phase. In the case of a major shift in pH or redox conditions, it is possible that material adsorbed to the HFO surface may be released. However, based on the HCT results available to date, a major shift in pH conditions is not likely.

3.7 Evapoconcentration

The pit lake will lose water through direct evaporation from the pit lake surface, thus solutes within the pit lake will evapoconcentrate. The only mechanism for removing solutes within the pit lake is the formation and settling of chemical precipitates and the adsorption of trace elements onto these particulates. The only mechanism for removal of water from the lake is evaporation.

3.8 Model Logic and Coding

The conceptual model developed for the Copper Flat pit lake (Section 3.1) has been translated into a numerical model using a geochemical thermodynamic equilibrium code and several limiting and simplifying assumptions. Water chemistry predictions were made using the USGS code PHREEQC (Parkhurst and Appelo, 2010), which has been rigorously tested and is the industry standard for pit lake, waste rock dump and tailings facility geochemical predictions. The PHREEQC models used a modified version of the minteq.v4 thermodynamic database supplied with the v3.0.0.7430 version of PHREEQC (released February 1st 2013). This database is widely used for geochemical modeling and was selected for this study because it includes the full range of elements for consideration in this water quality prediction as well as key sorption reactions for iron oxyhydroxides. The database was modified to include sorption data for manganese species.

The PHREEQC model consists of several components including the input data file, the thermodynamic database, the executable code and the output file. The input file consists of a series of logic statements and commands that define each of the components of the system and explains how these components interact. The input file is read by the executable code and commands are executed in a stepwise manner. Influent component waters were speciated and mixed to generate a series of intermediate waters, solid phases, and adsorbed phases. Selected outputs are specified and parceled out to various output files for analysis of results.

A logic flow diagram for the structure of the input code is provided in Figure 3-8 and discussed below. An example of the PHREEQC input code is provided in Appendix B.

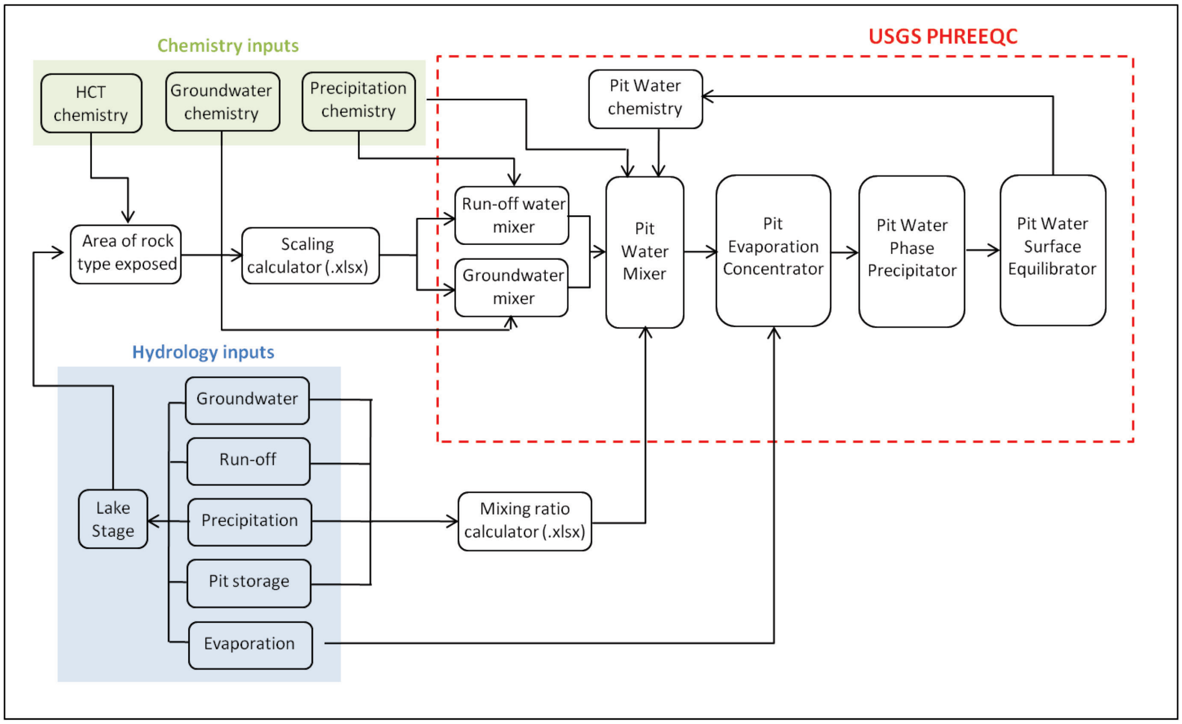


Figure 3-8: Copper Flat Pit Lake Model Execution Mechanics

The steps in the modeling process include the following items:

1. Define run-off water input specific to each exposed rock type. The run-off solution chemistries are comprised of scaled kinetic test cell leachate concentrations for each material type. These leachates are scaled to the water:rock ratio from the cell to the field based on the estimated presence of fractures in the wallrock and the thickness of the reaction rind.
2. Define the run-off solution mixing ratios. Mixing ratios are based on the amount of each material type that is sub-aerially exposed in the pit high wall at each time step.
3. Define the groundwater input. Groundwater chemistry is based on a mass addition function that combines the existing mass found within the groundwater with the mass of solute (per unit surface area and rock mass) released in the kinetic tests for specific material types exposed in the final pit walls. This is scaled to the water:rock ratio from the cell to the field, based on the estimated thickness of the reaction rind within the fractured wallrock.
4. Define groundwater solution mixing ratios based on the exposed surface area for each material type within the pit wall below the pit lake surface (i.e. within the submerged pit wallrock). As with the run-off mixing ratio, this ratio is dependent on the pit lake elevation and changes at each simulated time step.
5. Define precipitation water chemistry based on representative chemical analyses of rainwater.

6. Perform a master mixing calculation where run-off waters, groundwater, atmospheric precipitation and existing pit lake waters are mixed in ratios defined by the site-wide water balance for each time step.
7. Evapoconcentration. The resulting pit water is concentrated by a factor equivalent to the calculated evapoconcentration determined by the site-wide water balance for each determined time step. A fixed percentage of water is removed as a reverse titration of water. At the end of each titration, the volume of water is readjusted to one liter.
8. Equilibrate and precipitate. Once mixed, the model is equilibrated with atmospheric gases and select mineral phases are allowed to precipitate at the calculated pH, with pE fixed at a subatmospheric value equal to 12 – pH. This represents a transitional equilibrium between mixed pit lake water and the atmosphere and is the most likely scenario based on the conceptual model.
9. Calculate sorption. After mineral precipitation, trace elements were allowed to adsorb onto iron oxyhydroxides (i.e. ferrihydrite). The total mass of ferrihydrite is equivalent to the mass predicted to be generated during the previous reaction step. This assumption is conservative in that it does not account for sorption to other minerals such as aluminum oxide or clay, or to iron oxides present in the pit wallrock.
10. Save chemistry for the next time step. At the end of each time step, the predicted pit water chemistry is exported to a spreadsheet for analysis.
11. The model was terminated after sufficient iterations to simulate water quality over a 100-year filling period.

3.8.1 Treatment of Analytical Detection Limits

When analysis of HCT effluent leachates or source inflow groundwater identified certain elements to be uniformly at or below the analytical method detection limit (ADL) for a particular material type, that element was exempted from the PHREEQC evaluation. This prevents false exceedances of water quality standards that may arise as an artifact of the modeling exercise from the scaling of humidity cell data to field conditions or from equilibration of groundwater source data that are below analytical detection limits.

Nitrate was excluded from the geochemical predictions due to the lack of mineralogical controls in PHREEQC code. The exemption of nitrate is supported by the data as this parameter is consistently below analytical detection limits in both the humidity cell effluent leachates and the groundwater surrounding the pit. Nitrate is also below detection limits in the existing pit lake, supporting the assumption that this parameter is unlikely to be a problem during future operations.

3.9 Geochemical Modeling Assumptions

Despite site-specific data collection activities, several assumptions and model boundaries must be defined to construct a numerical model that predicts future water quality. Specific assumptions of the pit lake numeric models include:

1. Steady-state, average conditions are assumed for each time period modeled.
2. The geochemical model framework is defined by the water inputs and losses to/from the system.
3. The models are defined by the elements, mineral phases, gas phases, and chemical species specified in the model input files.
4. The models are limited to inorganic reactions and do not take into account the complexities associated with biologically mediated reactions.

5. The models are limited to thermodynamic equilibrium reactions and do not simulate the effects of reaction kinetics and rates.
6. The models rely on an external database of thermodynamic constants for mineral phase precipitates and sorbed surface complexes. These thermodynamic constants are valid at 25°C and 1 atmosphere of pressure.
7. The models assume atmospheric equilibrium with oxygen and carbon dioxide gas, with pH + pE equal to 12 (based on calculations by Baas-Becking et al., 1960 to define stability limits of natural waters).
8. The models do not consider the effects associated with the formation and precipitation of mineral species other than those specified. Due to kinetic constraints, a portion of the potentially oversaturated mineral phases will not actually precipitate. A select suite of minerals is therefore specified that are allowed to precipitate based on relevance for the environment in question, site-specific knowledge, experience in evaluating kinetic constraints and relevance of key phases for given styles of mineralization (Eary, 1998).
9. The models assume that solution input chemistry can be simulated using laboratory leachate chemistries from HCT tests.

3.10 Analysis of Model Input Variability

The various parameters that have been used as data inputs for the pit lake geochemical model have been assessed to determine their relative significance in influencing the model results. For the purpose of this exercise, each parameter has been assigned a qualitative value based on the degree to which it influences the final predicted solution chemistry:

- “Minor” represents less than 1% control on the final model output;
- “Moderate” represents between 1% and 10% control on the final model output; and
- “Significant” represents between 10% and 50% control on the final model output.

The results of this exercise are displayed in Table 3-7.

Table 3-7: Analysis of Pit Lake Model Input Variability

Category	Parameter	Assumptions / data used in model	Source	Control on final model results*
Hydrogeologic information	Pit lake water balance	100-year water balance provided by JSAI, including water elevation and surface area, groundwater inflows, direct precipitation, run-off and evaporation data.	JSAI, 2012	Significant. The water balance defines the mixing ratios for the PHREEQC input solutions.
Chemical inputs	Groundwater chemistry	Baseline groundwater chemistry data from the ongoing monitoring program: • Average of data for wells GWQ96-22A, GWQ96-22B, GWQ96-23A, GWQ96-22B, GWQ11-24B and GWQ11-25B.	INTERA, 2012	Significant during the early years post-closure when groundwater is likely to represent the dominant solution input to the pit lake.
	Precipitation chemistry	Averaged precipitation chemistry from Gila Cliff Dwelling National Monument Meteorological Station (1985-2011)	NADP, 2012	Minor. The precipitation chemistry represents a near-pure solution chemistry. In the absence of site-specific data, published precipitation chemistry from this meteorological station in New Mexico is the best representation of precipitation chemistry in the area.
	HCT chemistry	Averaged HCT chemistry from the ongoing HCT programs.	SRK	Significant. The solutions generated by the HCT programs represent the main chemical inputs to the PHREEQC models.
Geological information	Pit wall surface area and lithologic composition	Pit wall surface areas were calculated for each simulated time step using the geologic block model and pre-feasibility study pit shell.	SRK/ THEMAC	Significant. The lithological composition of the pit wall defines the mixing ratios for the PHREEQC input solutions.
Geochemical model assumptions	Mass of pit wall rock available for reaction	Mass of future pit wall available for reaction was calculated assuming an oxidized rind of 0.04 feet thickness and a fractured zone of 1 feet thickness (with 10% fractures).	SRK/ THEMAC	Moderate. The values were assigned based on communication with NMCC regarding future blasting practices for the project and are considered a conservative estimate.
	Equilibrium/mineral phases	Alunite, Ag_2Se, albite, anhydrite, azurite, barite, boehmite, brochantite, brucite, calcite, chrysotile, Cr_2O_3, diaspore, epsomite, ferrihydrite, fluoride, gypsum, gibbsite, gummite, kaolinite, magnesite, malachite, mirabilite, otavite, pyromorphite, rhodochrosite, rutherfordine, schoepite, sepiolite, SiO_2; tenorite, U_3O_8, UO_3, $UO_2(OH)_2$	SRK	Moderate. Mineral precipitation will influence final solution chemistry. Equilibrium phases were selected based on knowledge of site-specific geologic and mineralogic conditions and were then verified and refined by calibrating with the existing pit lake chemistry.

* Minor: <1%
Moderate: 1 - 10%
Significant: 10 - 50%

3.11 Comparative Guidelines

Simulated pit lake water quality has been compared to NMAC 20.6.4.900 wildlife habitat and livestock watering standards. There is no existing or planned future use for aquatic life in the open pit water body. A Use Attainability Analysis (UAA) is being pursued to remove the designated use of aquatic life; therefore, only wildlife habitat and livestock watering standards are considered in this report. The standards used in the assessment are provided in Table 3-7.

Table 3-8: NMAC 20.6.4.900 Wildlife Habitat and Livestock Watering Standards

Parameter	NMAC 20.6.4.900 standards for livestock watering	NMAC 20.6.4.900 standards for wildlife†
As	0.2	-
B	5	-
Cd	0.05	-
Cr	1	-
Co	1	-
Cu	0.5	-
Hg	0.01*	0.00077*
Pb	0.1	-
Se	0.05	0.005*
V	0.1	-
Zn	25	-

Values in mg/L for dissolved constituent unless otherwise noted

* *Indicates standard applies to total (i.e. unfiltered) fraction*

† *'-' indicates no standard for parameter*

4 Pit Lake Geochemical Model Results

4.1 Existing Pit Lake Calculations

In addition to the predictions of future potential pit lake chemistry, numerical predictions have been undertaken to model the current (i.e. existing) pit lake chemistry to calibrate and verify the future pit lake geochemical predictions. A water balance for the period 1980 to 2014 was provided to SRK by JSAI and this was coupled with the results of the HCT testwork and data relating to the existing pit wall geology to carry out numerical simulations of existing pit lake water quality.

The water balance data used in the existing pit lake predictions are summarized in Figure 4-2 and Figure 4-3. In addition the pit wall surface areas (per lithology) are provided in Table 4-1.The method used to calculate existing pit lake water quality is the same as that described in Sections 3.2.2 to 3.8, above, with the exception of the reactive mass and fracture thickness/density in the pit wall.

During Quintana's operations, the existing pit at Copper Flat was not prepared using pre-split drilling and smooth wall blasting. Therefore, the existing pit wall has significantly deeper fracturing than predicted for the future final pit wall from the proposed operation. The literature demonstrates that open pit wall blast damage for granite, granodiorite and quartz monzonite rocks extends 2 to 4 ft in depth when assessing effects from production type blasting (e.g. Carrroll and Scott, 1966; Siskind and Fumanti, 1974; Kelsall et al., 1984) (Appendix A).

For this scenario, an estimate of the reactive rind thickness is provided by results from a U.S. Bureau of Mines experimental study on fracturing produced in the vicinity of large-diameter blast holes in Lithonia granite (Siskind and Fumanti, 1974). From this study, a severely fractured zone (i.e., crushed zone) was identified that extends approximately 2.1 feet into the pit wall and a second zone (i.e., transition zone) characterized by a lesser degree of fracturing extends from 2 to 4 feet (Figure 4-1). It is assumed that oxygen infiltration extends no further than the predicted depth of fracturing of 2 feet, and that the percent of the rim rock mass fractured during mining will range from 5% within the crushed zone to 10% within the transition zone. This estimate of fracturing is supported by Atchison (1968). As described in Section 3.2.2 above, an oxidized rind of 0.04 feet thickness has also been assumed in the pit walls. This scenario is considered a conservative input of pit wall fracturing based on the information provided in Appendix A.

Table 4-1: Pit Wall Surface Areas Used in the Existing Pit Lake Calculations

Material type	Oxidation	3D surface area (ft^2)	3D surface area (m^2)	Proportion
Biotite breccia	Oxide	137,327	12,758	13.2%
Quartz feldspar breccia		11,728	1,090	1.13%
Quartz monzonite		291,598	27,090	28.1%
Undefined		42,613	3,959	4.10%
Biotite breccia	Sulfide (non-ox.)	90,494	8,407	8.71%
Quartz feldspar breccia		46,096	4,282	4.44%
Quartz monzonite		414,065	38,468	38.9%
Undefined		5,154	478	0.50%

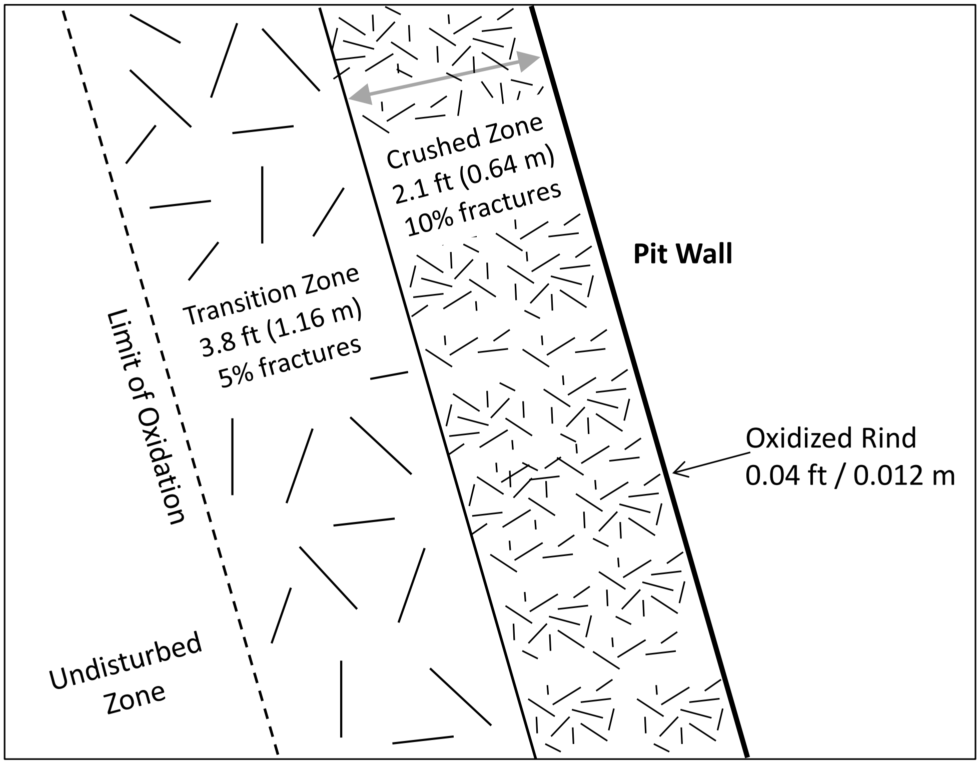


Figure 4-1: Existing Pit Wall Conceptual Model

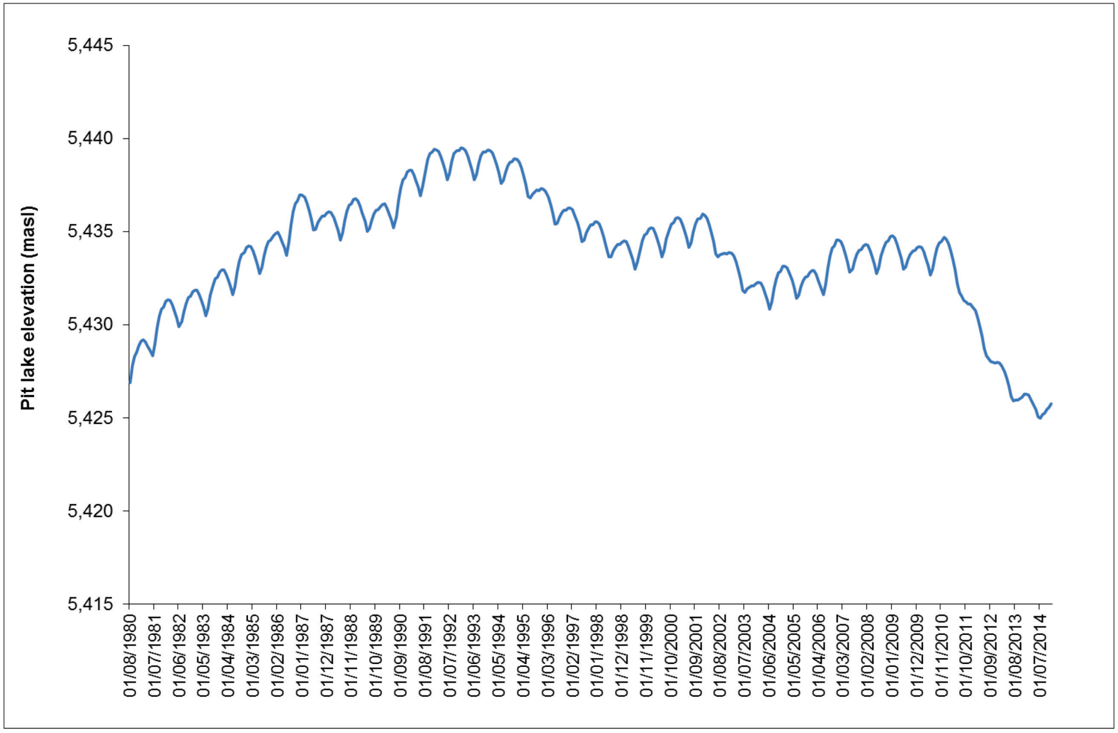


Figure 4-2: Existing Pit Lake Water Level

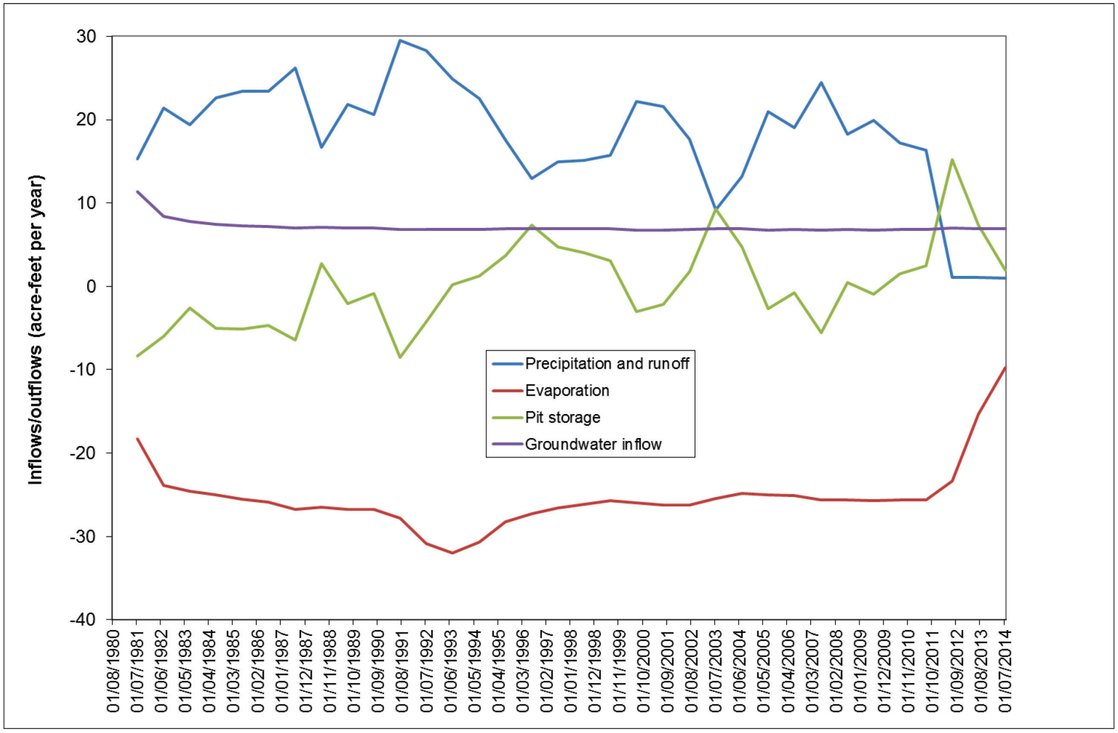


Figure 4-3: Existing Pit Lake Inflows/outflows

The results of the existing pit lake calculations are shown in Table 4-2. The model shows good calibration for pH, alkalinity, calcium, cadmium, cobalt, copper, magnesium, manganese, sodium, zinc, sulfate and TDS. This demonstrates that these constituents can be predicted with reasonable accuracy for the future pit lake. However, a number of constituents are either positively- or negatively-biased in the pit lake calibration model. The model overestimates the concentrations of boron, potassium, selenium and vanadium. This likely relates to a combination of factors of one or more of; evapoconcentration effects within the PHREEQC model; challenge of incorporating analyses below detection; and the lack of appropriate mineralogical controls in the thermodynamic code. This means the mechanisms that are responsible for removal of these constituents from solution in the existing pit lake (e.g., adsorption onto clays or precipitation of mineralogical phases that are not included in the .minteq database) are not accounted for in the geochemical model, resulting in concentrations of these constituents being artificially increased over time.

The model underestimates the concentrations of a number of parameters, including arsenic, chromium, copper, chloride, fluoride and iron. For iron, this underestimate likely relates to the fact that PHREEQC reports only truly dissolved phases. It is possible that iron in the existing pit lake may exist in the form of fine-grained colloids that pass through a 0.45 μm filter, which explains the higher measured concentrations of these parameters. For fluoride, the lower concentrations predicted by the model may relate to an over-estimate of fluorite precipitation. Although fluorite has been observed around the existing pit lake at Copper Flat and is likely to form based on the predicted chemistry, the model may overestimate the mass of fluorite that will precipitate, resulting in a lower predicted concentration. In the case of chromium and arsenic, a challenge is incorporation of results below the detection limit that can lead to an under or over estimate depending on value selected. In addition the calculations predict that both chromium and arsenic will adsorb onto Fe-oxyhydroxides; however the calculations assume thermodynamic equilibrium and it may be that speciation of these oxyanions in the lake is more complex than predicted and that they do not occur in the thermodynamically stable species predicted but due to kinetic effects in another species that is less strongly adsorbed. For example, arsenic may occur as arsenite (AsIII) and not arsenate (AsV).

Two scenarios were considered for the existing pit lake geochemical model. The base case model (i.e., most likely scenario) assumes that the relative contribution of groundwater flowing into the pit void is proportional to the hydraulic conductivities of the quartz monzonite and andesite bedrock. For the sensitivity analysis, it was assumed that the quartz monzonite and andesite units will contribute equally to pit lake filling. The results for both the base case model and sensitivity analysis are presented in Table 4-2 and show there is minimal difference between the two scenarios. As such, only the base case groundwater input was used for the future pit lake predictions.

Table 4-2: Predicted vs. Measured Pit Lake Chemistry for the Existing Pit Lake

			Average measured chemistry in existing pit lake (2010-2013)	Range of measured chemistry in existing pit lake (2010 – 2013)	PHREEQC predicted chemistry for existing pit lake – BASE CASE[1]	PHREEQC predicted chemistry for existing pit lake – GROUNDWATER SENSITIVITY ANALYSIS[2]
pH	**pH**	s.u.	7.3	6.0 – 7.9	7.85	7.85
pe	**pe**	s.u.	-	-	4.92	4.92
HCO_3	**Bicarbonate**	mg/L	49.7	<20 – 123	31.2	31.0
As	**Arsenic**	mg/L	0.003	<0.001 – 0.0077	0.0002	0.0002
B	**Boron**	mg/L	0.17	0.13 – 0.19	2.45	2.27
Ca	**Calcium**	mg/L	567	453 – 670	467	463
Cd	**Cadmium**	mg/L	0.055	0.038 – 0.064	0.04	0.05
Co	**Cobalt**	mg/L	0.29	0.049 – 0.49	0.36	0.38
Cr	**Chromium**	mg/L	<0.006	<0.006	0.0001	0.0001
Cu	**Copper**	mg/L	2.21	<0.006 – 26.5	0.03	0.03
F	**Fluoride**	mg/L	18.4	15 – 29.8	4.71	4.86
Fe	**Iron**	mg/L	0.12	<0.02 – 1.3	0.0001	0.0001
Hg	**Mercury**	mg/L	<0.0002	<0.0002	0.001	0.001
K	**Potassium**	mg/L	33	24 – 49	493	494
Mg	**Magnesium**	mg/L	720	570 – 1120	537	573
Mn	**Manganese**	mg/L	41	28 - 48	31.7	33.4
Na	**Sodium**	mg/L	871	604 – 1400	736	752
Pb	**Lead**	mg/L	0.011	<0.005 – 0.026	0.00005	0.00005
Se	**Selenium**	mg/L	0.027	0.013 – 0.059	0.25	0.26
V	**Vanadium**	mg/L	<0.05	<0.05	0.31	0.32
Zn	**Zinc**	mg/L	4.29	0.78 – 7.36	4.29	4.34
SO_4	**Sulfate**	mg/L	6,128	5,200 – 8,690	5,142	5,337
Cl	**Chloride**	mg/L	451	340 – 714	221	207
TDS	**Total Dissolved Solids**	mg/L	9,188	7,770 – 14,800	7,672	7,904

[1] Assumes weighted average groundwater chemistry for the quartz monzonite and andesite

[2] Assumes numeric average groundwater chemistry for the quartz monzonite and andesite

4.2 Future Pit Lake Results

The predicted pit lake chemistry for each of the post-closure time steps are summarized in Table 4-3 and are provided in Figure 4-4 to Figure 4-14 for selected parameters. These show predicted/modeled pit lake chemistry compared to New Mexico surface water standards for livestock and wildlife. The full PHREEQC output file is provided in Appendix E, which shows precipitating and dissolving mineral species at each time step as part of the mass transfer calculations.

Pit lake waters are predicted to be moderately alkaline (pH ~8), with a magnesium plus sulfate (Mg + SO_4) major ion signature. During the early stages of pit infilling (i.e. first six months post-closure), the prediction is that an early flush will occur in cadmium, selenium, sodium, chloride, and sulfate concentrations in the pit lake. This initial flush occurs due to dissolution of soluble sulfate salts that will have developed on the pit walls during life of mine. Inflowing groundwater and direct precipitation on the pit lake surface will then provide some dilution and the effects of this initial flush will be dissipated. The pit lake chemistry is expected to evolve over time, with several parameters increasing in concentration as a result of evapoconcentration effects. This is similar to the trends observed in the existing pit lake, where elemental concentrations (particularly boron, cadmium, fluoride, magnesium, manganese, sodium, and sulfate) have increased over time (Figure 4-13). The macrochemistry (Mg-Na-SO_4) changes are reflected in the Piper plot in Figure 4-14, which shows a progressive change in pit lake major ion chemistry post-closure, with waters becoming increasingly dominated by sulfate and magnesium over time.

Pit lake chemistry is likely to be dominated by surface run off, evapoconcentration effects, and by equilibrium chemistry in the lake. Over time, the groundwater contribution will decrease slightly as the pit lake is established. Both adsorption and the secondary mineral precipitation are likely to be the major controls on trace element chemistry. However, arsenic chemistry is likely to be controlled by sorption onto iron oxyhydroxides due to its strong affinity for these surfaces at the predicted pH of the pit lake.Modeled pit lake chemistry has been compared against New Mexico surface water standards for livestock watering and wildlife and shows most parameters are expected to be below New Mexico livestock standards following the initial flush post-closure. The exceptions to this are selenium, mercury and vanadium. Selenium is predicted to exceed the livestock watering standard of 0.05 mg/L after 5 years. Mercury is expected to increase in concentration over time, and is predicted to marginally exceed the stringent wildlife standard after approximately 15 years. Vanadium is also predicted to increase over time in the future pit lake, with concentrations increasing to above the livestock standard approximately 75 years post-closure. Additional discussion on the likely geochemical behavior of these parameters (and other key parameters) in the future pit lake at Copper Flat is provided below.

Mercury

The pit lake model predicts that mercury in the pit lake will increase over time, with estimated concentrations between 0.001 mg/L (at year 25) and 0.003 mg/L (at year 100) compared to the stringent wildlife standard for total mercury of 0.00077 mg/L. However, concentrations are not predicted to be elevated above the livestock watering standard of 0.01 mg/L for total mercury.

JSAI has undertaken a detailed evaluation of mercury as a COC at Copper Flat (Appendix F). This concludes that mercury does not present a COC for the future pit lake for a number of reasons:

(i) The calibration model for the existing pit lake shows mercury concentrations are over-predicted by approximately an order of magnitude. The predicted mercury concentrations in the future pit lake are based on reported trace level detection in the HCT effluent, which are close to both the analytical detection limit and the NMAC 20.6.4900 guideline. The over-prediction is likely an artifact of scaling trace concentrations that are close to analytical detection limits, coupled with the effects of evapoconcentration.

(ii) Mercury has not been detected in the existing pit lake, with concentrations being consistently below analytical detection limits (0.001 mg/L or 0.0002 mg/L) throughout the period 1991 to 2011.

(iii) Mercury has not been detected in the groundwater wells adjacent to the pit (GWQ96-22A, GWQ96-22B, GWQ96-23A or GWQ96-23B) during the period 1996 to 2011. Additional analyses conducted with lower analytical detection limits in July 2013 showed very low mercury concentrations (0.0000009 mg/L to 0.000004 mg/L). Therefore any groundwater flowing into the future pit is likely to have non-detectable mercury concentrations.

(iv) Mercury has not been detected in surface run-off waters either above or below the pit during the period 1982 to 2011.

(v) Although mercury may occur as a trace element in pyrite, sphalerite and copper sulfosalts (all of which have been identified at Copper Flat), there has been no source mineral for mercury identified in the ore body.

(vi) Mercury has not been detected in the salt rim surrounding the existing pit lake, indicating there has been minimal adsorption of mercury onto iron oxyhydroxides in the salt rim and/or that evapoconcentration of the pit lake waters has not resulted in formation of any HgCl minerals.

Selenium

Selenium is predicted to be elevated above the wildlife standard in the future pit lake with concentrations ranging from 0.07 mg/L (at year 1) to 0.29 mg/L (at year 100) in comparison to the wildlife standard of 0.005 mg/L. This likely relates to the observed release of selenium from the sulfide humidity cells, particularly during the first 25 weeks of testwork. Selenium is present at detectable concentrations (0.013 – 0.059 mg/L) in the existing pit lake and there is likely to be evapoconcentration effects over time due to the mobility of selenium at moderately alkaline pH, which will limit the formation of selenium-bearing mineral phases. Under the aerobic conditions of the Copper Flat pit lake, Se(VI) should be the dominant oxidation state of selenium. However, pure mineral forms that incorporate Se(VI) are too soluble to be expected to limit selenium concentrations (Eary, 1999) and thus selenium may remain in solution. One of the primary controls on selenium attenuation in mine pit lakes has been shown to be adsorption onto ferrihydrite (Eary, 1999). However, this process is negligible when sulfate concentrations are greater than 100 mg/L (as with Copper Flat) because sulfate effectively prevents Se(VI) adsorption. In addition, Se(VI) forms anionic solutes that are less strongly adsorbed under neutral to alkaline pH conditions, thus explaining the presence of selenium in the existing pit lake at Copper Flat (~pH 7.4) and the predicted selenium concentrations in the future pit lake (~pH 8.0).

The calibration model for the existing pit lake overestimates selenium by eight-fold (approximately one order of magnitude; Section 4.1). Most likely similar over-estimation issues will occur in the predictions for the future pit lake as well. Nonetheless, it is likely that selenium will be present at detectable concentrations in any future pit lake that forms.

Vanadium

The model results predict that vanadium concentrations may become marginally elevated above the livestock watering standard approximately 75 years post-closure, with predicted concentrations of 0.17 mg/L (at year 100) compared to a standard of 0.1 mg/L. The geochemical behavior of vanadium in the future pit lake will likely be controlled by precipitation and adsorption reactions. Because of vanadium's tendency to form anions, a fairly high solubility is possible in oxidizing alkaline environments such as the Copper Flat pit lake (Hem, 1992). It is recognized, however, that precipitation reactions involving vanadium-bearing mineral species are not adequately characterized in the PHREEQC thermodynamic code and hence the model shows a tendency to over-predict vanadium concentrations. Although the sulfide humidity cells showed detectable release of vanadium during the first 20 weeks of testing (Appendix C), the calibration model for the existing pit lake overestimates vanadium by approximately six-fold (Section 4). These results suggest the predicted exceedances for vanadium in the future pit lake relate to the lack of appropriate mineralogical controls for this element within the PHREEQC database rather than evapoconcentration. Based on the calibration model, the vanadium concentrations in the future pit lake are estimated to be approximately 15-20% less than the predicted concentration, which reduces vanadium concentrations to below the livestock watering standard. Furthermore, vanadium concentrations are also below analytical detection limits in the existing pit water. For these reasons vanadium is not considered a constituent of concern for the project.

Boron

Although boron concentrations in the future pit lake at Copper Flat are not predicted to exceed the livestock standard of 5 mg/L, the model results show a significant predicted increase in boron concentrations over time. This is likely a function of the combined effects of evapoconcentration and the lack of appropriate mineralogical control in PHREEQC. Boron in the existing pit lake has been shown to increase slightly in concentration from <0.1 mg/L in 1989 to 0.18 mg/L in 2011 (Appendix D), indicating that marginal climate or evapoconcentration influence on boron is possibly taking place within the existing pit lake. However, the calibration model for the existing pit (Section 4) shows that PHREEQC overestimates boron concentrations by an order of magnitude, demonstrating that the mineralogical controls in PHREEQC are not adequate for determining boron chemistry. Although boron will be present at detectable concentrations in any future pit lake that forms, concentrations are not anticipated to exceed the livestock watering standard of 5 mg/L.

Cadmium

Cadmium is not expected to be a constituent of concern in the future pit lake at Copper Flat; it is below analytical detection limits in the existing groundwater and was almost uniformly below analytical detection limits in the HCTs. Detectable cadmium concentrations were only recorded for two samples of transitional material for the initial 50 weeks of the humidity cell program. The PHREEQC model also showed good calibration for cadmium in the existing pit lake.

Under the circum-neutral to moderately alkaline pH conditions predicted by the pit lake model, cadmium will be present at very low concentrations (<0.001 mg/L) and its chemistry will likely be controlled by adsorption onto ferrihydrite. At these low concentrations, the solubility limit of mineral phases such as otavite is unlikely to be reached (Hem, 1992) and precipitation of cadmium-bearing mineral phases is an unlikely mechanism for the removal of cadmium from solution. The model results support this theory, showing otavite to be significantly undersaturated in the model output.

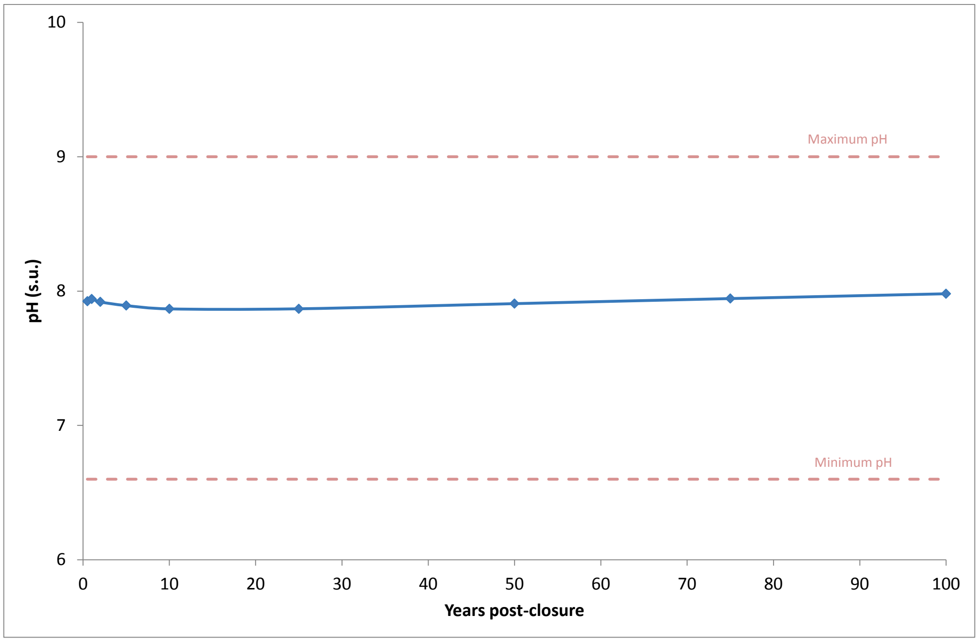


Figure 4-4: Time-series Plot of Pit Lake Predicted pH

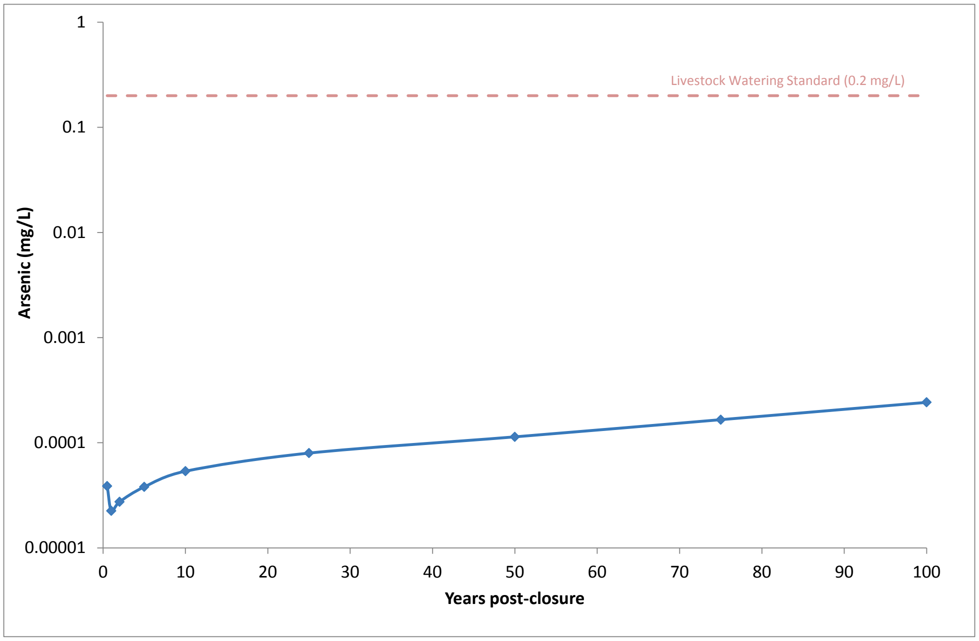


Figure 4-5: Time-series Plot of Pit Lake Predicted Arsenic

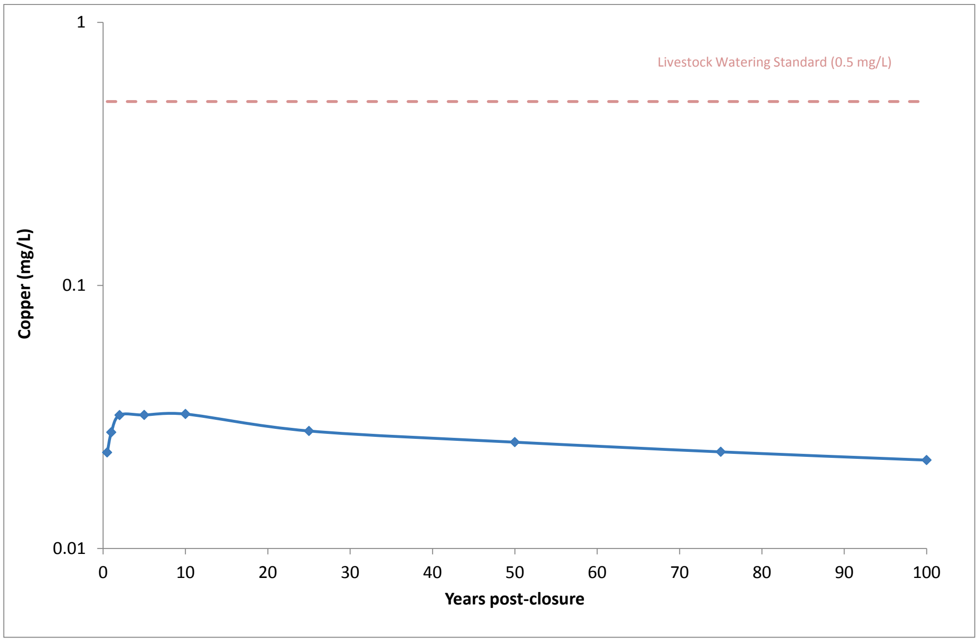


Figure 4-6: Time-series Plot of Pit Lake Predicted Copper

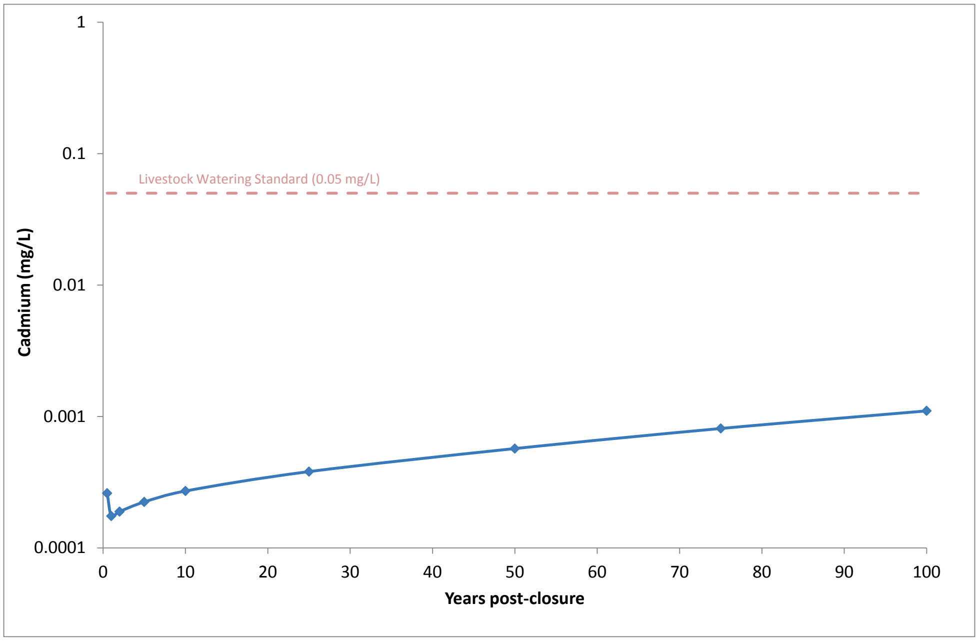


Figure 4-7: Time-series Plot of Pit Lake Predicted Cadmium

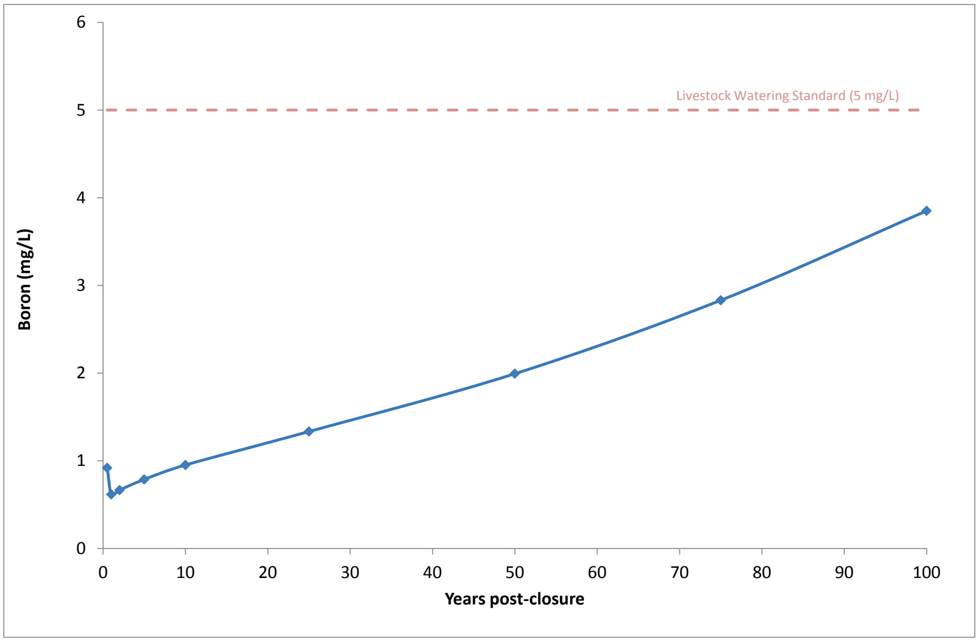


Figure 4-8: Time-series Plot of Pit Lake Predicted Boron

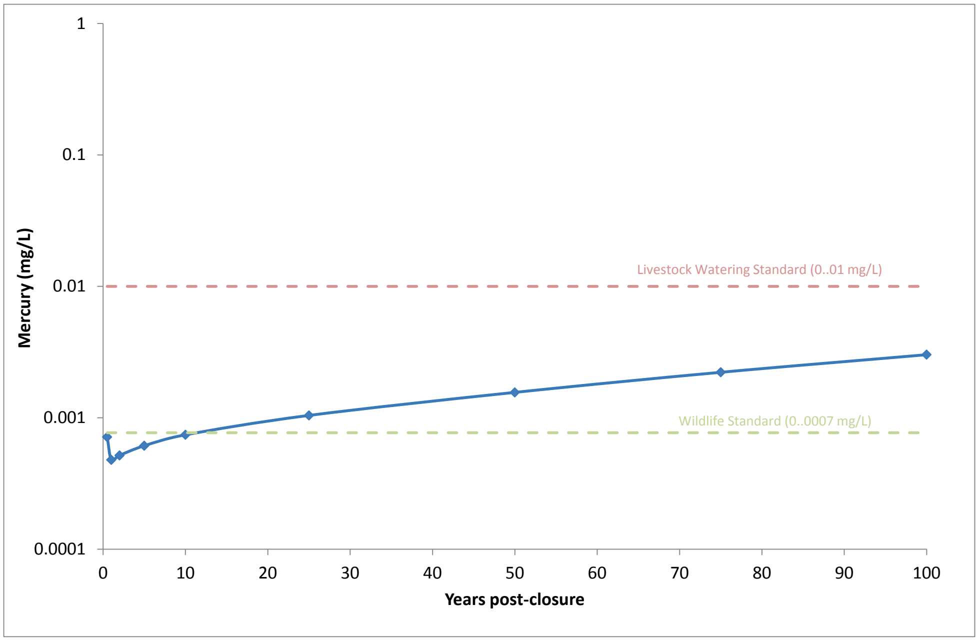


Figure 4-9: Time-series Plot of Pit Lake Predicted Mercury

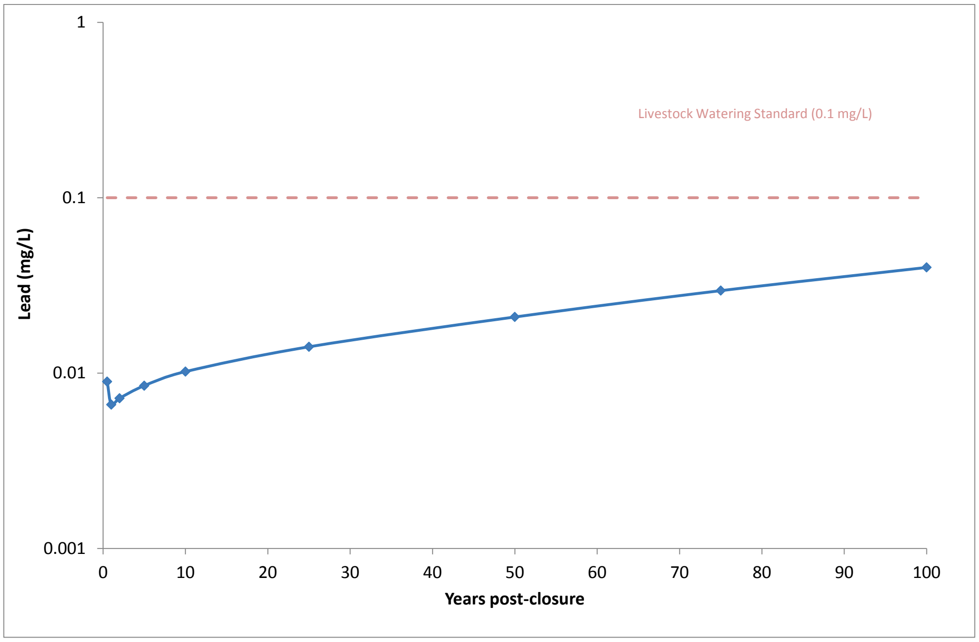


Figure 4-10: Time-Series Plot of Pit Lake Predicted Lead

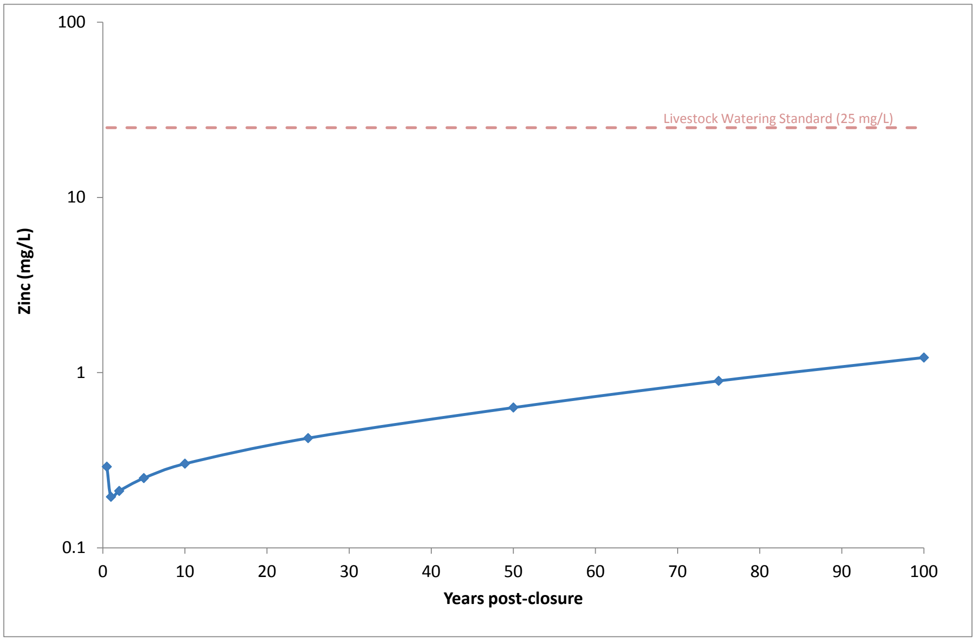


Figure 4-11: Time-Series Plot of Pit Lake Predicted Zinc

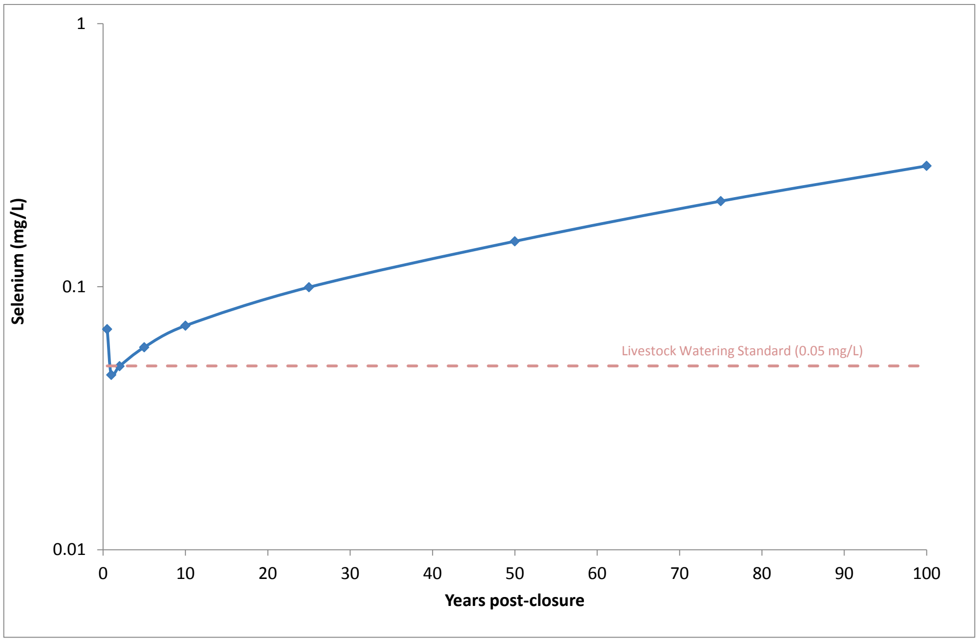


Figure 4-12: Time-Series Plot of Pit Lake Predicted Selenium

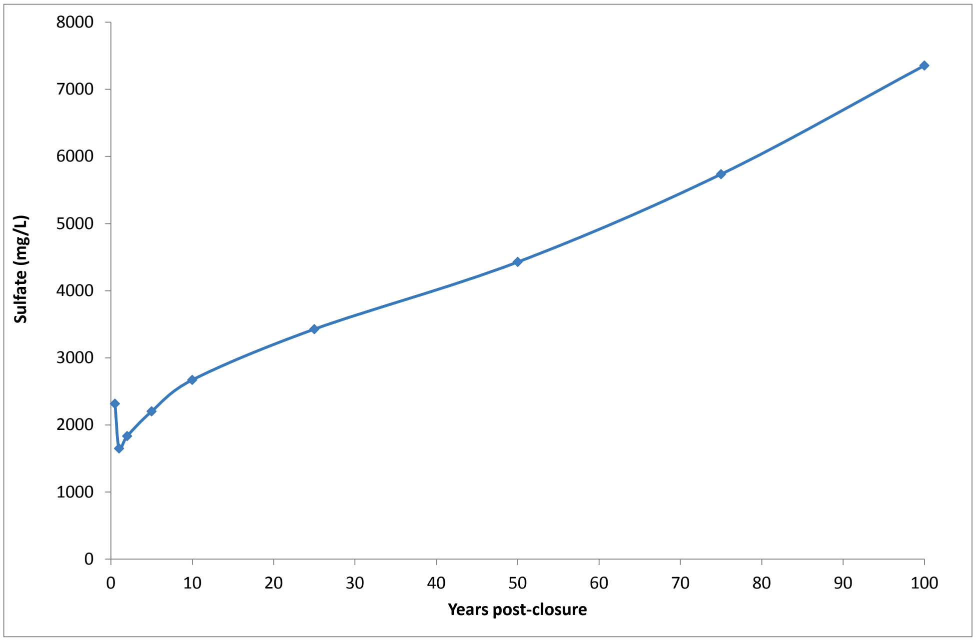


Figure 4-13: Time-Series Plot of Pit Lake Predicted Sulfate

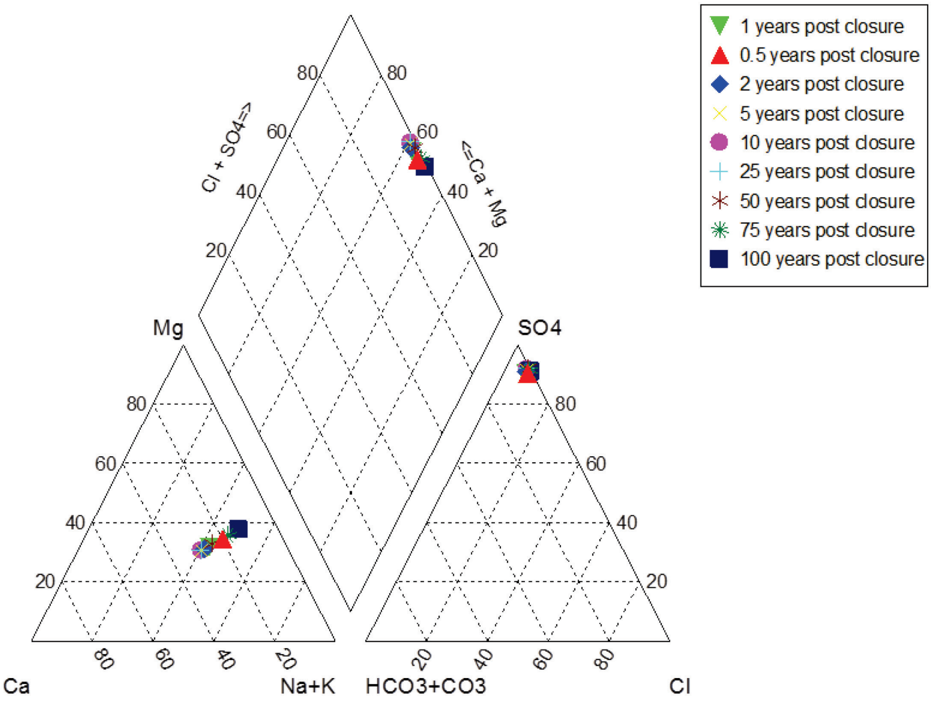


Figure 4-14: Piper Plot Showing Predicted Pit Lake Major Ion Chemistry

Table 4-3: Future Predicted Pit Lake Chemistry (Base Case Scenario)

			NMAC 20.6.4900 Surface water standards		Years post-closure								
			Livestock	*Wildlife*	**0.5**	**1**	**2**	**5**	**10**	**25**	**50**	**75**	**100**
pH	**pH**	s.u.	*6.6 - 9*		7.92	7.94	7.92	7.89	7.87	7.87	7.91	7.94	7.98
pe	**pe**	s.u.	-	-	4.85	4.83	4.85	4.88	4.90	4.90	4.87	4.83	4.79
HCO_3	**Bicarbonate**	mg/L	-	-	33.8	34.0	32.7	31.3	30.2	31.0	34.7	38.8	43.4
As	**Arsenic**	mg/L	*0.2*	-	0.00004	0.00002	0.00003	0.00004	0.00005	0.00008	0.0001	0.0002	0.0002
B	**Boron**	mg/L	*5*	-	0.92	0.62	0.67	0.79	0.95	1.33	1.99	2.83	3.85
Ca	**Calcium**	mg/L	-	-	336	270	312	380	460	512	483	457	434
Cd	**Cadmium**	mg/L	*0.05*	-	0.0003	0.0002	0.0002	0.0002	0.0003	0.0004	0.001	0.001	0.001
Co	**Cobalt**	mg/L	*1*	-	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02
Cu	**Copper**	mg/L	*0.5*	-	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02
F	**Fluoride**	mg/L	-	-	3.74	3.62	3.49	3.39	3.32	3.56	4.25	5.08	6.03
Fe	**Iron**	mg/L	-	-	5.87E-05	5.68E-05	5.85E-05	6.08E-05	6.33E-05	6.39E-05	6.16E-05	5.96E-05	5.79E-05
Hg	**Mercury**	mg/L	*0.01*	*0.00077*	0.0007	0.0005	0.0005	0.0006	0.0007	0.001	0.002	0.002	0.003
K	**Potassium**	mg/L	-	-	216	145	157	186	225	316	472	671	914
Mg	**Magnesium**	mg/L	-	-	208	139	151	178	215	299	440	621	843
Mn	**Manganese**	mg/L	-	-	7.0	4.68	5.06	5.97	7.2	10.1	15.0	21.3	29.0
Na	**Sodium**	mg/L	-	-	276	185	200	236	285	397	592	840	1,142
Pb	**Lead**	mg/L	*0.1*		0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.04
Se	**Selenium**	mg/L	*0.05*	*0.005*	0.07	0.05	0.05	0.06	0.07	0.10	0.15	0.21	0.29
V	**Vanadium[1]**	mg/L	*0.1*	-	0.05	0.04	0.04	0.04	0.05	0.06	0.09	0.13	0.17
Zn	**Zinc**	mg/L	*25*	-	0.29	0.20	0.21	0.25	0.30	0.42	0.63	0.90	1.22
SO_4	**Sulfate**	mg/L	-	-	2,316	1,650	1,833	2,201	2,671	3,427	4,427	5,736	7,354
Cl	**Chloride**	mg/L	-	-	116	78.2	84.5	100	120	168	251	355	483
TDS	**Total Dissolved Solids**	mg/L	-	-	3,514	2,511	2,780	3,323	4,018	5,166	6,723	8,752	11,256

🟧	Indicates exceedance of NMAC 20.6.4.900 standard for wildlife
🟥	Indicates exceedance of NMAC 20.6.4.900 standard for livestock watering

[1] Due to limitations on mineralogical controls, the geochemical code over-predicts the concentration of vanadium as demonstrated by the calibration model

-' Indicates no standard for parameter

4.3 Calibration to Hydrogeologic Model

The pit lake geochemical model was developed using the JSAIopen pit and groundwater flow model. The JSAI water model was calibrated to water levels, water budgets and hydraulic properties of the site. The water model has also been used herein to address calibration to the Copper Flat open pit evaporation (see also Appendix A). Figure 4-15 to Figure 4-17 illustrate the model-simulated effects of evaporation on TDS, sulfate and chloride concentrations in the open pit when considering mixing without mineral precipitation. In addition Table 4-4 compares water-model and geochemical-model simulated TDS, chloride and sulfate concentrations to measured concentrations in the Copper Flat pit. This comparison shows that both the water and geochemical models are well calibrated to the effects of evaporation (See JSAI 2014, Appendix A).

Table 4-4: Comparison of water-model and geochemical-model simulated TDS, chloride and sulfate concentrations to measured concentrations in the Copper Flat pit

Parameter	Measured concentration in existing pit lake (2010 - 2011) (mg/L)	Geochemical model result (mg/L)	Water model result (mg/L)
TDS	7,770 - 9,410	7,672	11,621
Sulfate	5,200 - 6,400	5,142	7,263
Chloride	380 - 470	221	436

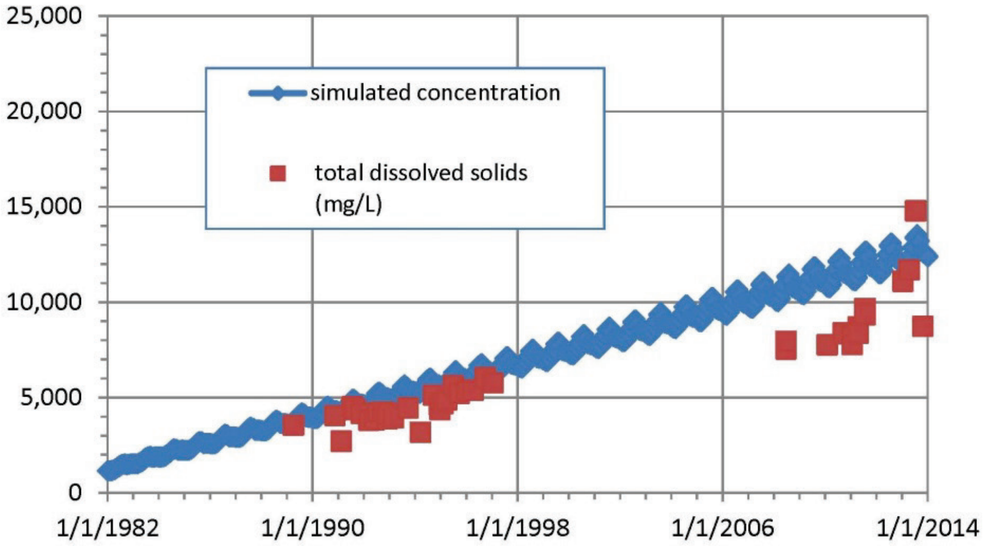


Figure 4-15: Comparison of water-model simulated and measured TDS concentrations in the existing Copper Flat pit

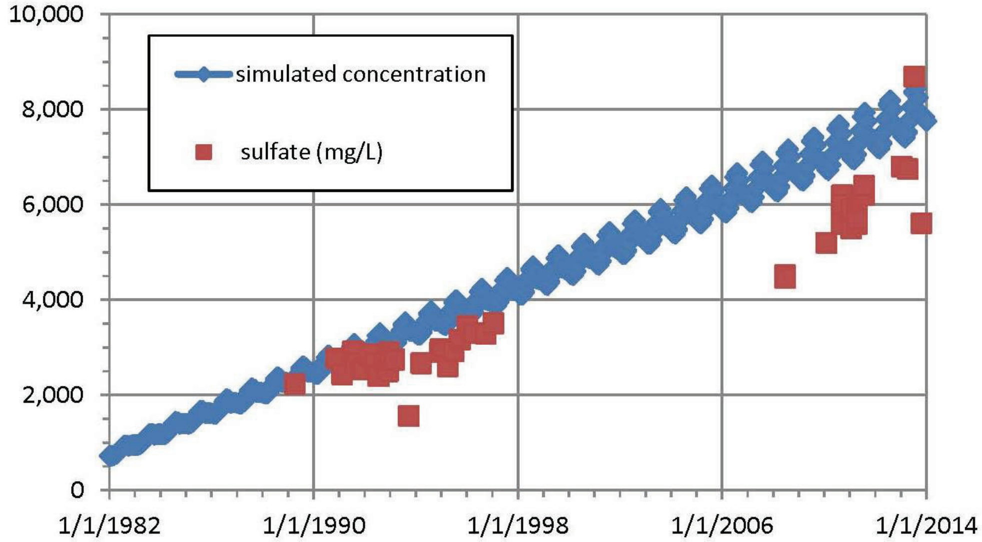


Figure 4-16: Comparison of water-model simulated and measured sulfate concentrations in the existing Copper Flat pit

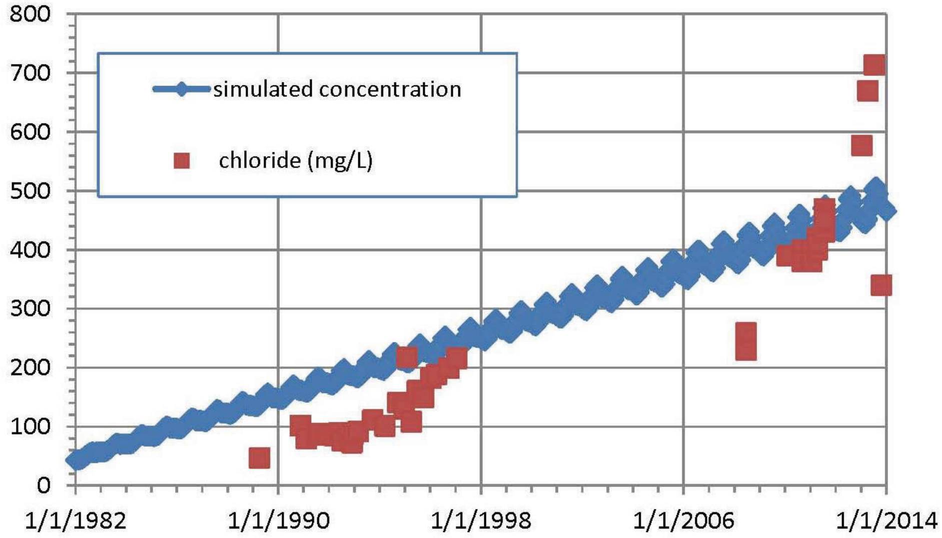


Figure 4-17: Comparison of water-model simulated and measured chloride concentrations in the existing Copper Flat pit

4.4 Potential for Future Pit Lake Stratification

Based on elevation and latitude, the Copper Flat open pit water body is classified as a warm monomitic type lake (Wetzel, 2001). A warm monomitic lake mixes freely once a year in the winter assuming the temperature is above 4 °C. However, wind effects and water body geometry can have an effect on the magnitude and frequency of mixing (Castendyk, 2009). Baseline data from the existing pit water body provides evidence that a thermocline develops in the summer and mixing occurs in the winter (INTERA, 2012). A chemocline does not appear to develop, and the water body remains oxygenated (DO = 6 to 9 mg/L) throughout the full water column year-round with similar chemistry throughout the lake (see JSAI 2014, Appendix A).

The current Copper Flat open pit water body has an area of about 5 acres, maximum depth of 30 ft, and length of about 460 ft. The relative depth (RD) of the future Copper Flat open pit water body at the maximum pit water stage is approximately 18%. RD relates the maximum depth of a lake (Z) to the width (d). Assuming an approximately circular lake, the width is a function of surface area (A) and can be determined from:

$$d = 2(A/\pi)^{\wedge}0.5$$

The percent RD is defined as:

$$RD = (Z/d)*100\%$$

The estimated RD for the current Copper Flat pit lake is 18% which is considerably greater than the average value of 2% for natural lakes and suggests the lake is likely to stratify. Such stratification may result in oxidizing conditions in the upper portions of the lake and more chemically reducing (oxygen-deprived) conditions at depth. However, this stratification is likely to be temporary and influenced by seasonal changes. A prerequisite for permanent stratification is that precipitation plus runoff is greater than evaporation during the summer months when the water body is potentially undergoing temporary thermal stratification (Jewell, 2009). This is not the case at Copper Flat, where annual evaporation from the pit lake (100 acre-feet per year) will greatly exceed precipitation plus run-off (63 acre-feet per year). As such, permanent stratification is unlikely for the current and future Copper Flat pit lake. Consequently, in keeping with many pit lakes in arid regions there is a lower potential for stratification than the topography relationships would predict (Jewell, 2009).

While stratification of an open pit water body has implications for water chemistry at depth, particularly in terms of redox changes, the near surface waters will tend to remain oxidizing. These near surface waters are considered the most critical from a perspective of potential ecological risks associated with the lake. The water quality at depth is less important since the proposed Copper Flat pit will remain a terminal sink post closure.

Jewell (2009) evaluated six permanently stratified and eight seasonally stratified open pit lakes, and concludes that permanently stratified lakes have vertical density contrast greater than 0.0005 g/cm^3 and a Wedderburn number greater than 1. The Wedderburn number considers thermocline depth, maximum lake length, water density, and wind speed. Jewell (2009) failed to note that most permanently-stratified open pit lakes receive AWS inputs and have resulting acidic water at the surface. A summary table of existing open pit water bodies and their characteristics is presented in Table 4-5.

The proposed Copper Flat open pit is expected to be well mixed, oxygenated, and not acidic, although seasonal stratification may occur. Relative depth does not appear to govern the conditions for creating a permanently stratified open pit water body; however acidic water and higher latitude are key conditions for creating permanent stratification. In addition, another related control is the total dissolved solids or salinity which will also exert control over the density or buoyancy of the mine pit lake. At Copper Flat direct surface water inputs to the existing lake over time are unlikely to be significant and therefore the potential for turnover is less.

Stratification within the pit lake has implications for redox conditions, mineral solubility and sorption reactions. The pit lake model results presented herein assume the pit lake will be fully mixed. A number of studies on deep mine pit lakes, including Summer Camp Pit in Nevada (Parshley and Bowell, 2003) and unpublished reports on Lone Tree Mines, Yerrington mine and the Robinson Mining District, also in Nevada, have demonstrated the tendency for incomplete seasonal overturn.

Based on observations of the current Copper Flat pit lake, the development of a metal-rich brine in the hypolimnion of the future pit lake is unlikely. The conditions for this are summarized in Castendyk (2009). Rather, the future pit lake is expected to be mixed and well oxygenated because: 1) the existing and future pit lake can be classified as monomicitic with frequent or continuous periods of circulation with no ice cover in the winter; 2) the existing and future pit lake can also be characterized as oligotrophic - having little to no nutrient input and organic production, with dissolved oxygen content regulated largely by physical processes; and 3) during pit reclamation, efforts will be made to prevent chemical stratification by eliminating significant inputs of highly concentrated dissolved solids.

Table 4-5: Summary of open pit water bodies and stratification characteristics

Open pit	Location	Effective length (ft)	Maximum depth (ft)	Relative depth (%)	Thermocline depth (ft)	Acidic
Permanently stratified						
Brenda	British Colombia	2,296	492	21	39	No
Spenceville	California	253	50	20	13	Yes
Berkeley	Montana	5,900	426	7	23	Yes
Seasonally stratified and well mixed						
Humbolt	Nevada	944	137	15	8	No
Blackhawk	Utah	492	na	na	33	No
Blowout	Utah	656	230	35	39	No
Colosseum	California	482	157	33	na	No
Cunningham	New Mexico	407	90	22	20	No
Copper Flat (existing)	New Mexico	537	30	6	20	No*
Copper Flat (proposed)	New Mexico	1105	200	18	TBD	No
Yerington	Nevada	5,412	400	13	49	No

* Predominantly circum-neutral with the development of occasional temporary acidity

TBD – to be determined

4.5 Model Limitations

The pit water quality predictions presented herein are considered the best representation of likely future water quality associated with the Copper Flat pit lake. However, it is recognized that there are a number of limitations associated with the predictive calculations including:

- Modeling was limited to predicting water quality within the pit lake for a 100-year time period. This length of time was chosen as a period of regulatory interest, and is not intended to imply that the pit lake geochemistry or hydrogeology will achieve steady-state, hydrogeochemical equilibrium at 100-years. The lake is expected to continue to evolve hydrologically and geochemically after this period of time, but uncertainties related to extending predictions beyond the 100-year period diminish the utility of longer-term predictions.
- The model does not consider the effects associated with the formation and precipitation of mineral species other than those specified. Due to kinetic constraints, a portion of the potentially oversaturated mineral phases will not actually precipitate. A select suite of minerals is therefore specified that are allowed to precipitate, based on relevance for the environment in question, site-specific knowledge, experience in evaluating kinetic constraints and relevance of key phases for given styles of mineralization, and literature review (Eary, 1999).
- The models rely on an external database of thermodynamic constants, which have been developed under controlled laboratory conditions and are valid at 25^{o}C and 1 atmosphere of pressure. The nature of the thermodynamic databases means that the constants for all major elements and a large number of trace elements are well understood and have been rigorously tested and verified. However, constants for certain parameters (for example vanadium) are not as well understood. As such, the mineralogical controls on these elements in PHREEQC are poorly defined, which may affect their precipitation (i.e., removal) from solution in the predictive calculations. This limitation with the thermodynamic database is evidenced by the over-prediction of vanadium in the calibration model for the existing pit lake, demonstrating that the future pit lake prediction for vanadium is not a valid prediction.
- The results of the predictive calculations do not take into account site specific ecological risk. Model results indicate that mercury concentrations in the future Copper Flat pit lake are predicted to become marginally elevated above the wildlife standard approximately 15 years post-closure, with predicted concentrations between 0.001 mg/L and 0.003 mg/L compared to a standard of 0.00077 mg/L. Although above the stringent wildlife standard, the predicted mercury concentrations are uniformly (and significantly) below the livestock watering standard of 0.01 mg/L. Furthermore, the model over-predicts mercury concentrations by approximately an order of magnitude. Mercury concentrations are below analytical detection limits in both the existing pit lake and in the groundwater wells adjacent to the pit. There has also been no source mineral for mercury identified in the ore body. As such mercury is not expected to present an ecological risk in the future pit lake.
- The model assumes that groundwater and surface water input chemistry can be simulated using laboratory kinetic (humidity cell) leachate chemistries, which are appropriately scaled to field conditions. The reactive surface area, ratio of water-to-rock and flushing rates in laboratory tests are different from actual field conditions. Grain size is smaller in the kinetic and static test cells and the resulting surface area for reactivity is greater. The laboratory test cells are operated at a higher water-to-rock ratio than would be expected in the field and are flushed more frequently, so that mineral-water reaction rates are enhanced. Because the future Copper Flat pit does not yet exist, field scale parameters cannot be measured, so scaling relies on published estimates of future groundwater flux and fracture density.
- The models have been developed using site-specific geochemical, hydrochemical, geological, hydrogeological and mine plan information. Therefore, changes in operational decisions may result in a change in the future pit lake water quality at Copper Flat.

- Consideration of the effects of climate change is beyond the scope of the current study. Effects of possible variations of the main components of the pit water balance are being evaluated as the details of the mine closure plans, including in-pit reclamation, watershed management and source controls, are considered. Included in this is the evaluation of pit water conditions during wet and dry periods. The water-balance and water-chemistry implications of different possibilities and options are being evaluated as part of pit reclamation and source control study.

5 Conclusions and Recommendations

SRK has undertaken a predictive geochemical modeling exercise to assess potential future pit lake chemistry associated with the Copper Flat project, New Mexico. The Copper Flat deposit is a copper-gold mineralized breccia pipe associated with, and genetically linked to, an alkalic porphyry system.

The proposed Copper Flat open pit is expected to be seasonally stratified, well mixed, oxygenated, and not acidic. Waters are predicted to be moderately alkaline (pH ~8), primarily due to the buffering capacity of the inflowing groundwater. During the early stages of pit infilling (i.e., during the first six months post-closure), removal/flushing of soluble salts from the pit walls is likely to result in a flush in cadmium, selenium, sodium, chloride, and sulfate concentrations in the early pit lake. The effects of this initial flush will be dissipated by inflowing groundwater and precipitation and pit lake chemistry will then evolve over time, with several parameters increasing in concentration as a result of evapoconcentration effects. This is similar to the trends observed in the existing pit lake, where elemental concentrations have increased since the start of pit infilling.

The model simulations demonstrate that all of the modeled chemical parameters are expected to be below New Mexico livestock standards (NMAC 20.6.4.900) in the 100 years post closure pit lake with the exception of selenium. Vanadium concentrations are reported above the livestock standard; however, due to limitations on mineralogical controls the current geochemical code over predicts the concentration of vanadium, as demonstrated by the calibration model. Once this is taken into account, vanadium is not expected to exceed the livestock standard.

Mercury concentrations are anticipated to increase over time, but remain below the livestock standard (0.01 mg/L) through year 100, post closure. Mercury concentrations are predicted to be marginally above the wildlife standard of 0.00077 mg/L by year 25. However, this exceedance is minimal, and may not represent a true ecological risk to area wildlife within the Copper Flat project area. The model-simulated input for mercury is based on reported trace level detections in the HCT effluent; however a source mineral for mercury has not been identified in the ore body and concentrations in the HCT testing are near the detection limit, as is the NMWQCC surface water standard for wildlife of 0.00077 mg/L. For these reasons, mercury will not likely be a constituent of concern. The water quality predictions represent a conservative estimate of future pit lake chemistry in order that constituents of concerns can be identified and mitigated though reclamation efforts. However, there are several components that will be evaluated in more detail as part of the post-mining source controls and in-pit reclamation plan. These include:

- An evaluation of significant variations of open-pit water balance on the projected pit water chemistry, including potential minimizing, maximizing or re-routing of the pit wall and watershed components of runoff, and possible rapid filling of the pit with a clean alkaline groundwater source.
- An evaluation of pit bench reclamation, remediation of individual fractures, or re-routing of in-pit stormwater runoff and the effects on predicted pit lake chemistry. These factors would alter the interaction with pit wall fractures and may affect the predicted pit lake chemistry. Potential mitigation may include limiting the contact of storm water inflow with the pit shell.

The results of the mitigation options study will be provided under separate cover.

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Appendix A – Review of Methods and Assumptions for Predicting Open Pit Water Quality

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TECHNICAL MEMORANDUM

To: Steve Raugust, New Mexico Copper Corporation
Katie Emmer, New Mexico Copper Corporation

From: Steven T. Finch, Jr., Principal Hydrogeologist-Geochemist, JSAI

Date: December 17, 2014

Subject: Review of methods and assumptions for predicting open pit water quality, Copper Flat Project, New Mexico

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New Mexico Copper Corporation (NMCC) is in the process of obtaining a mining permit for the Copper Flat property near Hillsboro, New Mexico. To determine if the proposed Copper Flat open-pit water would meet New Mexico Water Quality Control Commission (NMWQCC) standards for stock and wildlife use, SRK (2013) prepared a report titled *Predictive Geochemical Modeling of Pit Lake Water Quality at the Copper Flat Project, New Mexico*. The SRK (2013) geochemical model incorporated the water model developed by JSAI (2013). Reviewers of the SRK (2013) report have raised questions about the following issues:

1. More detail is needed to validate the assumption of 10-percent average fracture density in the pit walls and the amount of wall rock available for leaching.
2. More detail is needed to demonstrate that the proposed open pit water body will be well mixed, remain oxygenated, and not chemically stratify.
3. The geochemical model needs to be calibrated to chloride concentrations in the existing open pit to make sure the effects of evaporation are accounted for.

This Technical Memorandum consists of three sections for addressing the issues listed above. Sections 1.0 and 2.0 compare the SRK (2013) approach and assumptions to other open pit geochemical investigations, Section 3.0 presents calibration and sensitivity analysis results of the water model (JSAI, 2013) to historical water-quality data from the existing open pit, and Section 4.0 is a summary of findings.

1.0 REVIEW OF OPEN PIT WALL-ROCK STUDIES

1.1 SRK (2013) Copper Flat Model

SRK (2013) used different conceptual models of wall rock available for leaching: one for the existing and one for the future Copper Flat open pit. The difference is due to the blasting technique; the existing pit was mined in 1982 using production blasting similar to the blasting effects analyzed by Siskind and Fumanti (1974), and the proposed pit would be mined using presplit drilling and smooth wall blasting practices. The two conceptual models are summarized below.

1.1.1 Existing Open Pit

For the existing Copper Flat open pit, SRK (2013) estimated 10-percent fracturing in the first 2 ft of open pit wall rock (crushed zone) and 5-percent fracturing for a 3.8-ft-thick transition zone. The limit of oxidation and depth to undisturbed rock was assumed to be about 6 ft behind the pit wall (see fig. 3-9; SRK, 2013). A reactive rim of 0.04 ft around the fractures was assumed for the rock in the pit walls (based on HCT results).

Quintana Minerals only used production blasting to create the existing pit. Production blasting uses large widely-spaced explosive charges that are designed to fragment a large amount of *burden* (the rock that lies between the existing slope face and the blast hole). Production blasting is the most efficient way to remove large rock burdens, but it typically creates radial fractures around the blast hole and back break (fractures that extend into the final slope face), which reduce the strength of the remaining rock mass and increase its susceptibility to slope raveling and rock fall.

1.1.2 Proposed Open Pit

For the future Copper Flat open pit, SRK (2013) estimated fracturing is 10 percent of rock volume for the first 1 ft of open pit wall rock (crushed zone), with no transition zone between the crushed zone and undisturbed zone (see fig. 3-3; SRK, 2013). The open pit wall rock approximate 1 ft from the surface was assumed to be the limit of oxidation and the depth to undisturbed rock (see fig. 3-9, SRK, 2013). A reactive rim of 0.04 ft around the fractures was assumed for the rock in the pit walls. The 1-ft crushed zone and no transition zone represent presplit drilling and smooth wall blasting practices. Presplit holes are blasted before production blasts. Procedure uses small diameter holes at close spacing and lightly loaded with distributed charges. Presplit holes protect the final pit wall cut by producing a fracture plane along the final slope face that fractures from production blasts cannot pass.

1.1.3 Rock Mass Available for Leaching

For both scenarios, water flow is assumed to be mobile in the crushed zone and oxidized rind. The calculation of reactive mass was based on an average rock density of 169 lb/ft^3 (2,700 kg/m^3).

Chemistry of open pit run-off, for each pit wall material type, is estimated from scaled kinetic test cell (HCT) leachate concentrations. Average HCT solute concentrations are scaled up based on the pit wall water-rock ratio, and computed based on the estimated degree of fracturing and thickness of the reactive rind (SRK, 2013; p. 30).

1.2 Review of Pit Wall Fracturing References

1.2.1 Blasting Effects

Siskind and Fumanti (1974), a key reference used by SRK (2013), studied the fracturing produced in the vicinity of large-diameter blast holes (production blasting) in Lithonia Granite. The purpose of the Siskind and Fumanti (1974) study was to evaluate the use of production blasting to increase permeability for in-situ mining, where the amount of fracturing between holes is intended to be maximized for economic efficiency. A severely fractured zone was found to extend approximately 25 inches (64 cm) from the center of the 6-1/2-inch (16.5 cm) blast holes. A second zone, characterized by a lesser degree of fracturing, extended from 25 to 45 inches (64 to 114 cm). Beyond 45 inches (114 cm), the rock was undamaged. Carroll and Scott (1966) evaluated blasting effects on quartz monzonite and granodiorite (Climax Stock near Mercury, Nevada) and found that production blasting created an altered zone 0 to 8 ft in depth, and blast damage 2 to 4 ft in depth.

Kelsall and others (1984) found that in granite and basalt blasting enhanced permeability by about 10 times near the blast face, but the extent of blast effects were generally limited to <3.3 ft (<1 m), and possibly as little as 1 ft (0.3 m) when using low-charge blast methods.

It is important to note that granite, granodiorite, and quartz monzonite are similar intrusive rocks with similar rock properties. The primary difference is the quartz and feldspar content. The quartz monzonite at Copper Flat is therefore analogous to the granite and granodiorite in the blasting studies cited above. The Siskind and Fumanti (1974) study cites physical properties of the Lithonia Granite. Recent physical properties or the principal rock types of the Copper Flat Ore are presented in a 2013 report prepared by Mine Design Engineering of Kingston, Ontario, Canada for THEMAC Resources (Mine Design, 2013). The Mine Design report (2013) was prepared for the purposes of engineering the future pit walls for geotechnical stability. Table 1 presents a comparison of selected physical properties Lithonia Granite to the Copper Flat Quartz Monzonite and Quartz Monzonite Breccia.

Figure 1 presents the Copper Flat pit outline (Pre-Feasibility Study; PFS) from the 2013 Mine Design report, which shows the major rock types, their distribution, and the locations of the geotechnical drill holes where the samples from Table 1 were collected. From information presented in Mine Design (2013), and other available information, the Definitive Feasibility Study (DFS) pit geometry was developed. For geochemical characterization purposes, the PFS pit is very similar to the DFS Pit (SRK, 2014).

Table 1. Summary of the physical properties of the Lithonia Granite with Copper Flat Quartz Monzonite (QM) and Quartz Monzonite Breccia (QMBX)

Laboratory Analysis	Lithonia Granite (Tested by prevous investigators)	Lithonia Granite (Tested by authors at H-100 control hole)	QM (Average Values)	QM (Maximum Values)	QM (Minimum Values)	QMBX (Average Values)	QMBX (Maximum Values)	QMBX (Minimum Values)
Specific Gravity	2.63	-	2.68	-	-	2.57	-	-
Density (lb/ft^3)	164	-	167	-	-	160	-	-
Tensile Strength (lb/in^2)	450	-	2,132	3,075	493	1,247	1,697	653
Compressive Strength (lb/in^2)	30,000	28,000	18,490	29,400	11,810	6,614	6,614	6,614
Young's Modulus (lb/in^2)	3,000,000	6,400,000	5,018,000	6,135,000	3,626,000	2,973,000	2,973,000	2,973,000
Poisson's Ratio	0.26	-	0.10	0.09	0.11	0.12	0.12	0.12

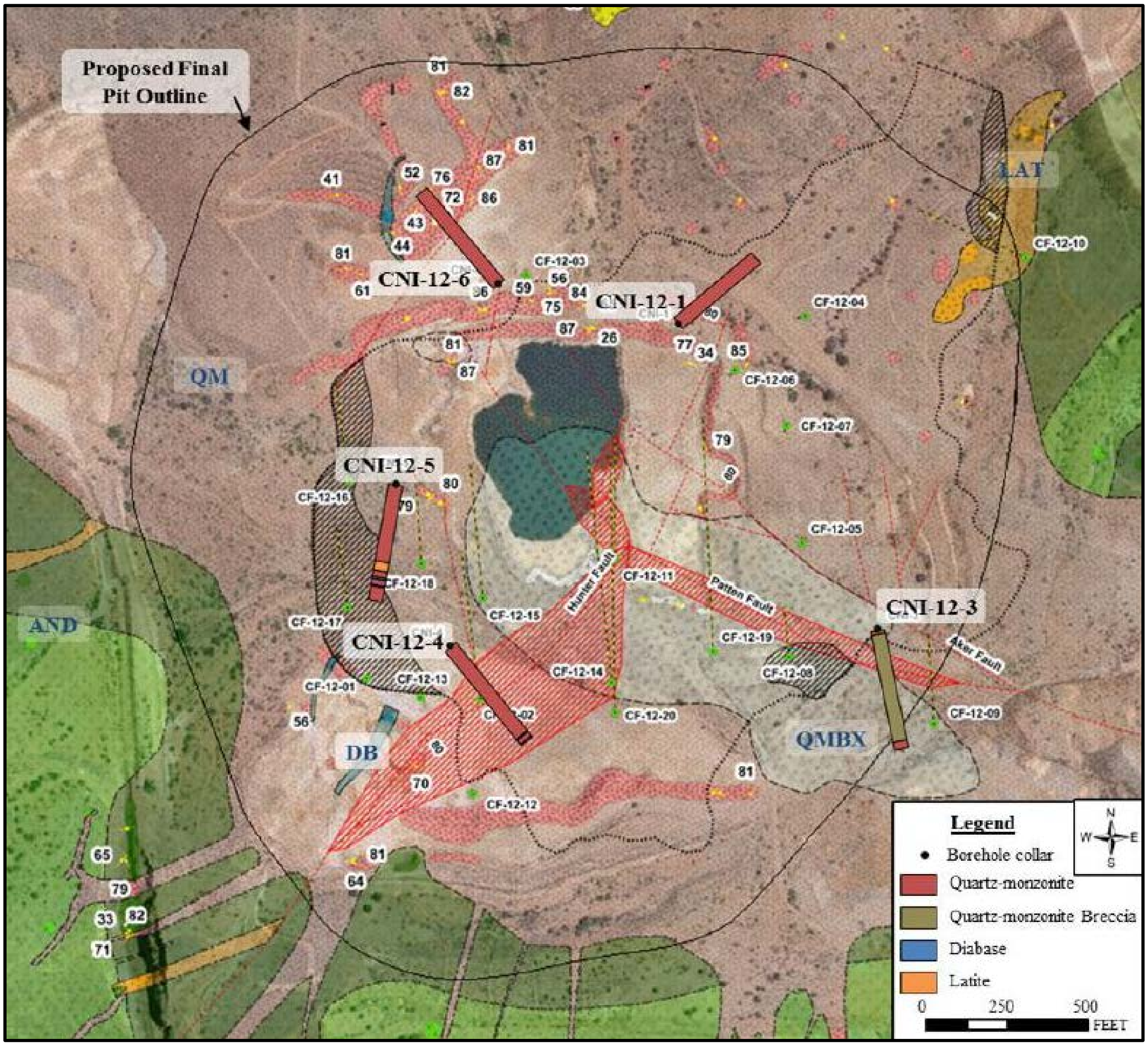


Figure 1. Geotechnical drill hole locations and the Pre-Feasibility Study pit outline (Mine Design, 2013).

1.2.2 Fracture Permeability

Molebatsi and others (2009) noted that many open-pit mines are located in fractured rock systems where water flow paths are complex and difficult to predict. These flow paths are typically controlled by a small subset of fractures that are permeable and interconnected. Most models of flow in fractured rock systems are based on a network of interconnected fractures that are all assumed to be permeable. However, this assumption is rarely observed in natural rocks where a significant number of the fractures within a connected cluster may be impermeable.

Field observations have shown that only a small proportion of fractures contribute to the overall flow, resulting in a complex and heterogeneous flow system. Up to 20 percent of the total number of fractures may contribute to overall flow (Bear et al., 1993). Although fracture connectivity has been used to explain heterogeneous phenomena (de Marsily, 1985), it is likely that additional aspects such as the effect of partial or total closure of individual fractures could further increase flow heterogeneity and tortuosity. Effectively impermeable fractures that (although mappable) will not conduct flow will thus need to be excluded from the conductive fracture cluster.

Not discussed in detail by Molebatsi and others (2009) is the rock type and mineralization of fractures, degree of fracturing, hydraulic conductivity in comparison to fracture density, and specific yield of rock. Obviously, fractured rock with low hydraulic conductivity would have more impermeable fractures than high hydraulic conductivity fractured rock that effectively behaves as a porous medium.

1.3 Other Open-Pit Geochemical Models

1.3.1 URS (2009) Little Rock Mine Post-Closure Pit Lake Model

The Little Rock open pit mine is located near Silver City, New Mexico, and is currently operating. URS (2009) assumed that a mixture of the in-situ field leaching tests and the HCT leachates represents the pit wall runoff. For the most likely case, an equal-weight mixture of the mean in-field leachate results, week-0 HCT results, and HCT results from the first 4-week idle period was used to represent run-on from the exposed pit walls above the pit lake. URS (2009) assumed: 1) rock samples collected within 100 ft of the final pit wall are representative of the exposed wall rock, and 2) a combination of the in-situ field leachates and the HCT leachates mimics weathering of pit wall rock. There is no discussion of blasting effects or increased fracture density on leaching of wall rock.

1.3.2 Tetra Tech (2010) Rosemont Copper Project

The Rosemont Copper project is located in southeastern Arizona. For simulating the initial flushing of blast-fractured pit walls, Tetra Tech (2010) used the first rinse from the HCTs to represent the chemical source terms. The HCT concentrations were generally higher than from the Synthetic Precipitation Leaching Procedure (SPLP) results, which generally correspond to rock that has had more time to weather before contacting water.

The near-surface wall rock of the anticipated ultimate pit shell is expected to be affected by blasting. An initial chemical flushing of the blast-affected pit wall rock was incorporated into the pit lake model. The near-pit wall rock is anticipated to have altered hydraulic properties and increased fracture density as a result of blasting and the extraction of surrounding rock. An increase in the porosity and specific yield (3 to 15 percent) of the near-surface wall rock is expected. The blast-affected wall rock was considered to extend for a distance of six (6) ft behind the ultimate pit wall; there was no basis provided for this assumption.

Where available, the chemical source terms used for flushing of the blast-affected wall rock for each formation were developed using the averaged first-rinse HCT data. Scaling of HCT data was not considered. For formations without HCT data, the concentrations of major cations and anions derived from SPLP tests were multiplied by a factor of three (3) and the trace metals were multiplied by a factor of two (2). Three (3) pore volumes of the blast-affected wall rock were considered in the model for the initial flush, after which standard groundwater inflow chemistry was assumed.

1.3.3 Schafer (2007) Betze Pit Lake Water Quality Predictions

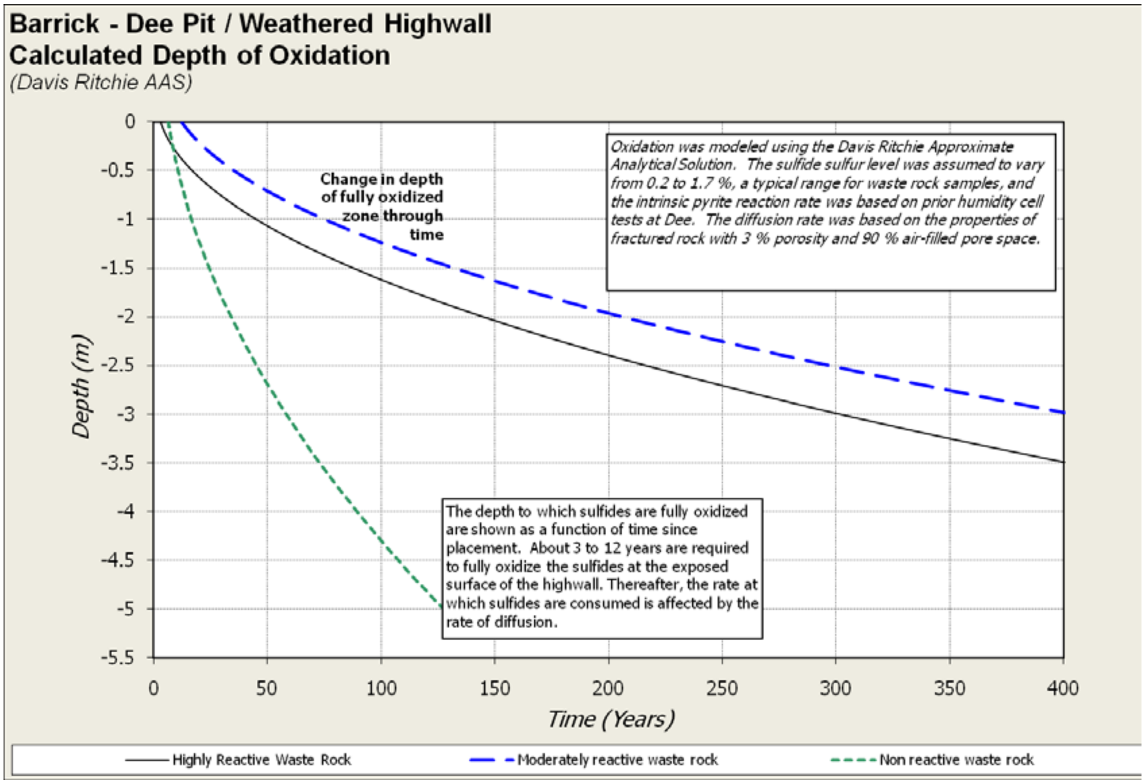
Schafer (2007) estimated the thickness of the weathered zone behind the pit wall by applying the approximate analytical solution (shrinking core model) derived by Davis and others (1986). The shrinking core model considers that particle size and the reactive core shrink simultaneously; therefore, sulfide oxidation rates decrease over time. A porosity of 2 percent was used to represent the highwall, while the rate of interparticle diffusion was determined from historical humidity cell tests. The rate of interparticle diffusion was calculated using the Millington Quirk equation (Jury et al., 1991). For portions of the highwall with relatively low sulfide levels, oxygen can penetrate nearly 16.4 ft (5 m) after 400 years, while the depth of oxygen penetration is closer to 9.8 ft (3 m) after 400 years for higher sulfide zones. The overall average thickness of the oxidized wall rock was estimated to be 9.8 ft (3 m).

1.3.4 Schafer (2010) Dee Pit Lake, Arturo Mine

Schafer (2010) assumes the thickness of a weathered highwall increases with increasing exposure to oxidation. The thickness of the weathered zone was estimated for the Dee pit lakes by applying the approximate analytical solution derived by Davis and others (1986). A porosity of 3 percent was used to represent the highwall. Other data needed to calibrate the Davis and others (1986) equations were determined from pyrite weathering rates observed in humidity cell tests. The rate of interparticle diffusion was calculated using the Millington Quirk equation (Jury et al., 1991). For portions of the highwall with relatively low sulfide levels, oxygen can penetrate over 15 ft (5 m) after 400 years, while the depth of oxygen penetration is closer to 10 ft (3 m) after 400 years for higher sulfide zones (see Fig. 2 below).

1.3.5 Adrian Brown (1997) Cunningham Hill Mine Open Pit

A water model and geochemical model were coupled to predict open pit water quality. The model was calibrated to existing water levels and water-quality data (alkalinity, calcium, and sulfate). Inputs from existing acid wall seepage (AWS) were used to simulate open pit water-rock interactions. The water-quality model was simply a mixing model if open pit water quality remained under-saturated with respect to gypsum.



Oxidation was modeled using the Davis Ritchie Approximate Analytical Solution. The sulfide sulfur level was assumed to vary from 0.2 to 1.7 %, a typical range for waste rock samples, and the intrinsic pyrite reaction rate was based on prior humidity cell tests at Dee. The diffusion rate was based on the properties of fractured rock with 3 % porosity and 90 % air-filled pore space.

The depth to which sulfides are fully oxidized are shown as a function of time since placement. About 3 to 12 years are required to fully oxidize the sulfides at the exposed surface of the highwall. Thereafter, the rate at which sulfides are consumed is affected by the rate of diffusion.

Figure 2. Graph showing depth of oxygen penetration based on the Davis and others (1986) approximate analytical solution (Schafer (2010) Fig. 13).

A groundwater flow and solute transport model of the open pit and surrounding groundwater system was developed by JSAI (1999), and later updated and recalibrated by JSAI (2011). It was demonstrated that the open pit general chemistry is more influenced by water budget components (mixing) than by mineral precipitation reactions.

1.3.6 Kempton and Atkins (2009)

Kempton and Atkins (2009) provide a review of methods for predicting water quality in open pits where sulfide oxidation is a major source term. Shrinking core models have been demonstrated to effectively simulate conditions in uniform materials, such as tailings. However, it is difficult to evaluate accuracy in the more heterogeneous pit benches and walls.

Kempton and Atkins (2009) evaluated a method for direct measurement of sulfide oxidation rates in mine pit benches by sealing a drape-chamber apparatus to the surface. They found that application of this method to benches and waste rock have not found the measured oxidation rates to be meaningfully correlated to sulfide sulfur, presence of surface rubble, moisture conditions, or carbonate content of the underlying rock. This suggests that physical processes such as blast-induced wall rock porosity and depth of pit-wall oxidation were more important than chemical processes. It was noted that fracturing is lower in competent rock, such as granite, and that careful blasting can reduce fracturing. Kempton and Atkins (2009) concluded that reliable comparisons of model-simulated versus observed pit lake water quality are needed to accurately assess model capabilities; this is exactly what SRK (2013) has done.

1.4 Discussion

Geochemical models for predicting open pit water quality are commonly most sensitive to the water budget components and the calculated solute contributions from sulfide oxidation. Open pit water-quality models with the least accurate predictions have under-estimated the potential for sulfide oxidation in wall rock and poorly represented water budget components (Kuipers and others, 2006). One reason for inaccurate water quality predictions is the lack of historical data for model calibration; most projects do not have an existing open pit water body with good time-series data. In contrast, the proposed Copper Flat open pit geochemical and groundwater flow model is calibrated to an existing open pit water body with 30 years of data.

Open pit wall blast damage for granite, granodiorite, and quartz monzonite rocks extends 2 to 4 ft in depth when assessing effects from production type blasting (Carroll and Scott, 1966; Siskind and Fumanti, 1974; and Kelsall and others, 1984).

Kelsall and others (1984) found that production blasting enhances permeability by about 10 times near the blast face. Molebatsi and others (2009) indicate that a small percentage (<20 percent) of the total fractures will contribute to permeability of the system. Typically, fractured rock groundwater systems are assumed to have a specific yield of less than 5 percent, and commonly less than 1 percent. The calibrated Copper Flat groundwater flow model simulates a specific yield of 0.001 (0.1 percent) in the quartz monzonite. If blast fracturing increased the effective porosity (specific yield) by an order of magnitude, the specific yield of the blast zone would be 1 percent. The 5 to 10 percent fracture density used by SRK (2013) can be considered conservative given the properties of the open pit wall rock estimated from the calibrated groundwater flow model.

A summary of the case studies reviewed is presented in Table 2. SRK (2013) is the only open pit water-quality model that includes blasting effects in the pit walls, scaled HCT data, and calibration to existing pit water chemistry.

Table 2. Summary of open pit water-quality prediction studies

reference	open pit	pit wall fracture assumptions	sulfide oxidation model	calibration to existing pit
SRK (2013)	Copper Flat	5 - 10 % fracture density (porosity) with depth based on blasting method; ranging from 1 to 6 ft	based on scaled HCT data	yes
Adrian Brown (1997)	Cunningham Hill	used measured acid wall seepage (AWS) data	used measured AWS data	yes
URS (2009)	Little Rock	none	based on HCT data	no
Tetra Tech (2010)	Rosemont	3 to 6% porosity, 6 ft depth	based on HCT data	no
Schafer (2007)	Betze	2 % porosity with oxidation depth increasing with time; 10 to 16 ft after 400 years	shrinking core model	no
Schafer (2010)	Dee	3 % porosity with oxidation depth increasing with time; 10 to 15 ft after 400 years	shrinking core model	no

2.0 STRATIFICATION OF OPEN PIT WATER BODIES

SRK (2013) concluded the proposed Copper Flat pit will not stratify, and will remain oxygenated. The proposed Copper Flat open pit water body will have a maximum depth of approximately 200 ft with a maximum surface area of about 22 acres.

2.1 Overview

Based on elevation and latitude, the Copper Flat open pit water body is classified as a warm monomitic type lake (Wetzel, 2001; fig 6-7). A warm monomitic lake mixes freely once a year in the winter at or above 4 °C. However, wind effects and water body geometry can have an effect on the degree and frequency of mixing. Baseline data (INTERA, 2012) from the existing pit water body provides evidence that a thermocline develops in the summer and mixing occurs in the winter. A chemocline does not develop, and the water body remains oxygenated (dissolved oxygen = 6 to 9 mg/L) throughout the full water column year-round. The existing open pit water body has an area of about 5 acres, maximum depth of 30 ft, and length of about 460 ft.

The relative depth (RD) of the predicted Copper Flat open pit water body at the maximum pit water stage is approximately 18 percent. RD relates the maximum depth of a lake (Z) to the width (d). Assuming an approximately circular lake, the width is a function of surface area (A) and can be determined from:

$$d = 2(A/\pi)^\wedge 0.5$$

The percent RD is defined as:

$$RD = (Z/d)*100 \text{ percent}$$

The estimated RD of 18 percent is considerably greater than 5 percent, which typically suggests that the lake is likely to stratify. Such stratification may result in oxidizing conditions in the upper portions of the lake and more chemically reducing (oxygen-deprived) conditions at depth. However, pit lakes that form in arid regions are unlikely to stratify, relative to lakes that form in cooler, wetter climates (Jewell, 2009). A prerequisite for permanent stratification is that precipitation plus runoff is greater than evaporation during the summer months when the water body is potentially undergoing temporary thermal stratification (Jewell, 2009).

While stratification of an open pit water body has implications for water quality at depth, the near-surface waters will remain oxidized. These near-surface waters are considered the most important from an open pit water-quality perspective given the potential ecological risks associated with them. The water quality at depth is less important given the expected terminal nature of the open pit water body.

2.2 Case Studies

Jewell (2009) evaluated six permanently-stratified and eight open pit lakes with seasonal thermocline, and concludes that permanently stratified lakes have vertical density contrast greater than 0.0005 g/cm^3 and a Wedderburn number greater than 1. The Wedderburn number considers thermocline depth, maximum lake length, water density, and wind speed. Jewell (2009) failed to note that most permanently-stratified open pit lakes receive AWS inputs and have acidic water. A summary table of existing open pit water bodies and their characteristics is presented in Table 3.

Table 3. Summary of open pit water bodies and stratification characteristics

open pit	location	effective length (ft)	maximum depth (ft)	relative depth (percent)	thermocline depth (ft)	acidic
permanently stratified						
Brenda	B.C.	2,296	492	21	39	no
Spenceville	California	253	50	20	13	yes
Berkeley	Montana	5,900	426	7	23	yes
Seasonal thermocline and well mixed						
Humbolt	Nevada	944	137	15	8	no
Blackhawk	Utah	492	na	na	33	no
Blowout	Utah	656	230	35	39	no
Colosseum	California	482	157	33	na	no
Cunningham Hill	NM	407	90	22	20	no
Copper Flat (existing)	NM	537	30	6	20	no[1]
Copper Flat (proposed)	NM	1,105	200	18	TBD	no
Yerington	Nevada	5,412	400	13	49	no

[1] there have been temporary acidic conditions where the pit water naturally neutralizes over time

TBD - to be determined

2.3 Discussion

The proposed Copper Flat open pit is expected to have a seasonal thermocline, be well mixed, oxygenated, and not acidic. Relative depth does not appear to govern the conditions for creating a permanently stratified open pit water body; however, acidic water and higher latitude are key conditions for creating permanent stratification.

3.0 COPPER FLAT OPEN PIT WATER MODEL

The Copper Flat open pit and groundwater flow model (water model) developed by JSAI (2013) was calibrated to water levels, water budgets, and hydraulic properties. The water model was used by SRK (2013) in the geochemical model. The JSAI (2013) water model was an interim version that was finalized in 2014, but the pit water balance did not change.

The water model is used here to address calibration to the Copper Flat open pit evaporation. Evaporation accounts for all of the outflow from the open pit water body; however, the water model only simulates average climate conditions. Figures 3 through 5 illustrate the model-simulated effects of evaporation on total dissolved solids, (TDS), sulfate, and chloride concentrations in the open pit when considering mixing without mineral precipitation.

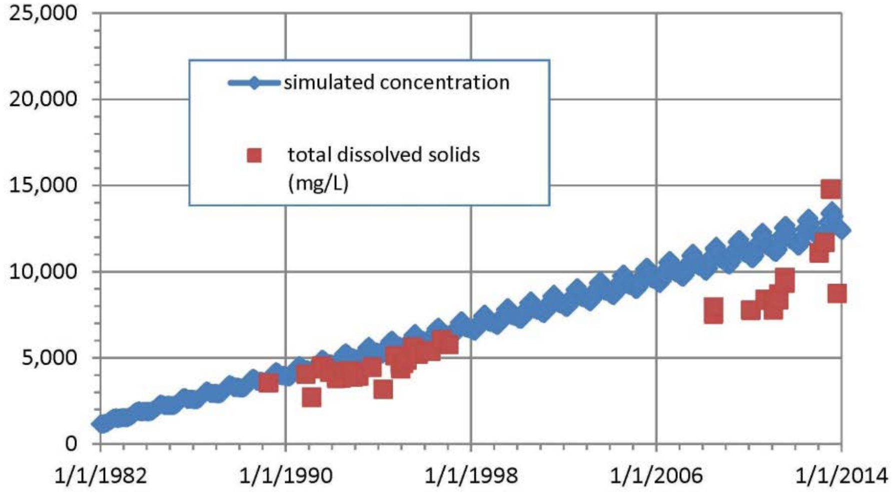


Figure 3. Graph showing water-model simulated and measured TDS concentrations for the Copper Flat open pit water body.

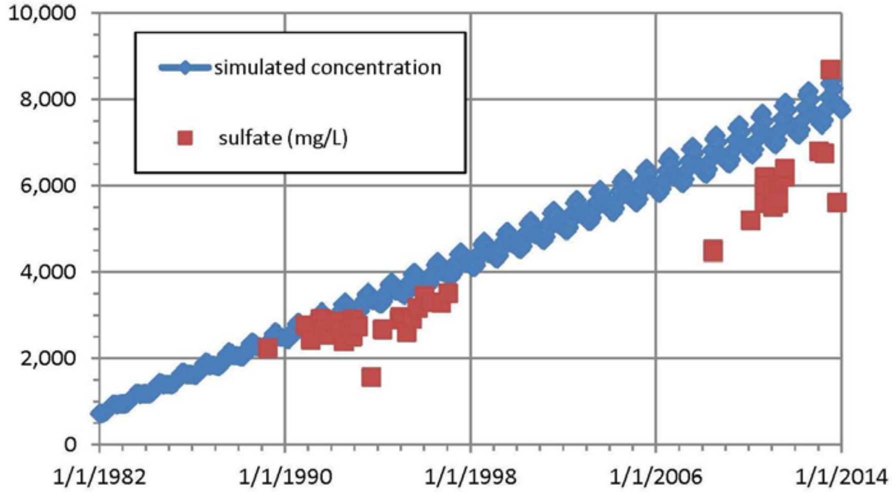


Figure 4. Graph showing water-model simulated and measured sulfate concentrations for the Copper Flat open pit water body.

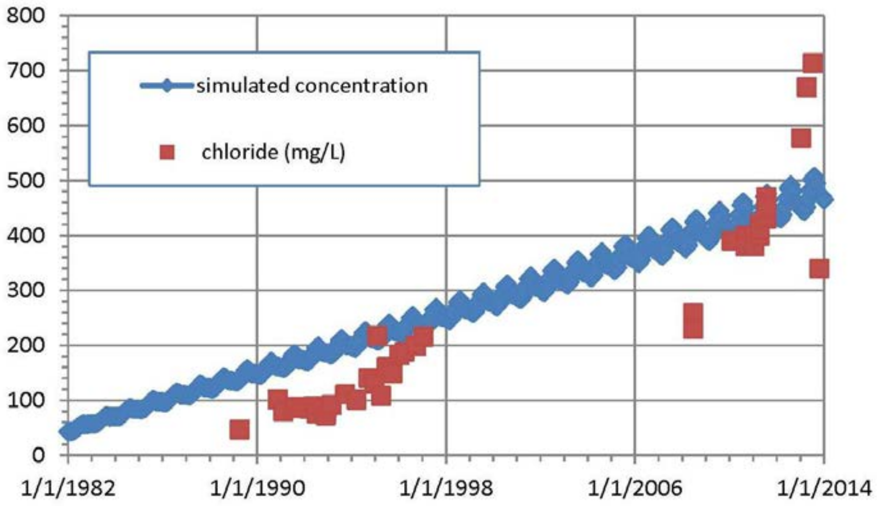


Figure 5. Graph showing water-model simulated and measured chloride concentrations for the Copper Flat open pit water body.

Data collected during 2013 show the evapo-concentration effects of extreme drought with concentrations well above the model-simulated concentrations, but 4th quarter 2013 concentrations were well below the model-simulated concentrations, due to a heavy monsoon period (Figs. 3 through 5). The model appears to reasonably simulate the average climate conditions.

SRK (2013) calibration of the geochemical model to existing pit conditions was performed for the 2011 dataset. The geochemical model considers mixing from the water model and mineral precipitation reactions. The geochemical model calibrates to TDS and sulfate better than the water model with mixing alone, but the water model calibrates better to chloride concentrations than the geochemical model (Table 4). The effects of evaporation are reasonably calibrated in the water model and reflected in the geochemical model.

Table 4. Comparison of water-model and geochemical-model simulated TDS, chloride, and sulfate concentrations to measured concentrations, Copper Flat open pit

constituent	2010-2011 measured range (mg/L)	geochemical-model results (mg/L)	water-model results (mg/L)
total dissolved solids (TDS)	7,770 to 9,410	7,751	11,621
sulfate	5,200 to 6,400	5,152	7,263
chloride	380 to 470	235	436

mg/L - milligrams per liter

4.0 SUMMARY OF FINDINGS

In summary, SRK (2013) assumptions used for reactive wall thickness and fracture density for the existing and proposed future pit are reasonable and supported by detailed studies pertaining to blasting effects on quartz monzonite rocks cited in Section 1.0. SRK (2013) used fracture-density results reflective of production blasting for the existing Quintana pit walls, and fracture density results reflective of low-charge blasting methods for the future open pit. Sensitivity of model results to fracture density and reactive wall thickness is reflected in these two simulations.

Out of the case studies reviewed (Table 2), SRK (2013) is the only open pit water quality model that considers blasting effects in the pit walls, scaled HCT data, and calibration to existing pit water chemistry. Calibration of the water model and geochemical model to existing data strengthens the ability to accurately predict future conditions.

Relative depth does not appear to govern the conditions for creating a permanently stratified open pit water body; however, significant acidic water inputs and higher latitude are key conditions for creating permanent stratification. The proposed Copper Flat open pit is expected to be seasonally stratified (thermocline only), well mixed, oxygenated, and not acidic. Baseline data from profiles in the existing pit at Copper Flat support the conclusion that the proposed pit will be well mixed and oxygenated.

Using the water model to simulate mixing and evapoconcentration effects on chloride, sulfate, and TDS demonstrates that the water model is calibrated to the effects of evaporation. The results in Table 4 compare simulated evapoconcentration with no mineral precipitation (water model only) to simulated evapoconcentration with mineral precipitation (water model and geochemical model). This comparison of model results to historical data is a sensitivity analysis that shows that the water and geochemical models are well calibrated to effects of evaporation.

The SRK (2013) geochemical model is representative of expected conditions at Copper Flat, and presents the best technical approach for predicting water quality at the future Copper Flat open pit.

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Appendix B – Example of PHREEQC Input File

```
Title Copper_Flat_base_case_v11

KNOBS
    -iterations            10000
    -convergence_tolerance 1e-007
    -tolerance             1e-016
    -step_size             100
    -pe_step_size          5
end

SELECTED_OUTPUT
    -file                 Copper_Flat_base_case_v11.out
    -selected_out         true
    -high_precision       true
    -simulation           true
    -state                true
    -solution             true
    -distance             false
    -time                 false
    -step                 false
    -ph                   true
    -pe                   true
    -alkalinity           true
    -ionic_strength       false
    -water                false
    -charge_balance       false
    -totals               C(4)  Ag Al  As  B  Ba Ca  Cd  Co  Cr
                          Cu  F  Fe  Hg  K  Mg  Mn  Mo
                          Na  Ni  Pb  Sb  Se  U  V
                          Zn  S(6)  Cl  N(3)  N(5)
    -saturation_indices   Gypsum

end

SOLUTION 1 Average rainwater chemistry (1985-2011) - Station NM01 (Gila Cliff Dwellings National
Monument), SW New Mexico. Data from National Atmospheric Deposition Program.
    temp       25
    pH  4.93
    pe  4
    redox      N(-3)/N(5)
    units      mg/l
    density
    Ca  0.209
    Mg  0.021
    Na  0.075
    K          0.030
    Cl  0.117
    CO2(g)  -3.5
    S(6)       0.862 as SO4
    N(-3)      0.167 as NH4
    N(5)       0.826 as NO3
    C(4)       0.1
    -water    1 # kg
end

SOLUTION 2 Weighted average groundwater chemistry for wells GWQ96-22A, GWQ96-22B, GWQ96-23A, GWQ96-
23B, GWQ11-24B and GWQ11-25B for samples collected between 1996 and 2013
    temp      25
    pH        7.15
    units     mg/l
    density   1
    Alkalinity 334 as HCO3
    Ag  0.019
    Al  0.285
    As  0.0033
    B          0.139
    Ba  0.091
    Ca  275
    Cl  38.5
    Cu  0.0090
    F          2.04
    Fe  1.49
    K          4.04
```

```
    Mg  48.5
    Mn  2.01
    Mo  0.024
    N(5)       0.956
    Na  116 charge
    S(6)       742 as SO4
    Sb  0.0018
    Se  0.0031
    Si  13.75
    U          0.0018
    Zn  0.066
    -water    1 # kg
end

TITLE Average HCT data

SOLUTION 3 Average HCT data for andesite oxide material (cells SRK 0864 and SRK 0866)
    temp      25
    pH        7.38
    pe        4
    redox     pe
    units     mg/l
    density   1
    Alkalinity 11.08233 as HCO3
    Al  0.00759
    Ba  0.00261
    Ca  9.22553
    Cl  0.39385
    F          0.46144
    Fe  0.00193
    K          0.99643
    Mg  1.40610
    Mn  0.00954
    Mo  0.00764
    Na  1.91012 charge
    S(6)       23.36270 as SO4
    Se  0.0003
    U          0.00047
    V          0.00169
    Zn  0.00092

    -water    1 # kg
END

SOLUTION 4 Average HCT data for biotite breccia - oxide/transitional (cells SRK 0854 and SRK 0872)
    temp      25
    pH        5.52
    pe        4
    redox     pe
    units     mg/l
    density   1
    Alkalinity 3.44165 as HCO3
    Al  0.27201
    As  0.00058
    Ba  0.00775
    Ca  23.80767
    Cd  0.00230
    Cl  0.30258
    Co  0.01016
    Cu  17.37509
    F          0.30884
    Fe  0.46664
    K          0.98984
    Mg  1.40751
    Mn  0.28452
    Mo  0.03340
    Na  0.40453 charge
    Ni  0.00445
    P          0.06138
    Pb  0.00155
    S(6)       97.56344 as SO4
    Sb  0.00018
    Se  0.00190
```

```
    U          0.00313
    V          0.00138
    Zn  0.15709

    -water    1 # kg
END

SOLUTION 5 Average HCT data for quartz feldspar breccia - oxide/transitional (cells 604767 and
604787)
    temp      25
    pH        7.80
    pe        4
    redox     pe
    units     mg/l
    density   1
    Alkalinity 28.14382 as HCO3
    B          0.01018
    Ba  0.01079
    Ca  17.42309
    Cl  0.83411
    Co  0.00078
    F          0.91743
    K          2.53353
    Mg  3.91833
    Mn  0.12244
    Mo  0.01061
    Na  1.94262 charge
    Ni  0.00064
    S(6)       39.53068 as SO4
    Sb  0.00019
    Se  0.00217
    U          0.02169
    V          0.00281
    Zn  0.00497

    -water    1 # kg
END

SOLUTION 6 Average HCT data for quartz monzonite- oxide/transitional (cells 604569, SRK 0858 and SRK
0867)
    temp      25
    pH        7.12
    pe        4
    redox     pe
    units     mg/l
    density   1
    Alkalinity 15.59277 as HCO3
    Al  0.05423
    B          0.01636
    Ba  0.00384
    Ca  18.95254
    Cd  0.00039
    Cl  0.56704
    Co  0.00388
    Cu  0.51303
    F          0.66195
    Fe  0.05913
    K          1.72751
    Mg  2.46441
    Mn  0.28491
    Mo  0.00590
    Na  2.02964 charge
    Ni  0.00609
    S(6)       51.75947 as SO4
    Sb  0.00146
    Se  0.00082
    U          0.00440
    V          0.00196
    Zn  0.01332

    -water    1 # kg
END
```

```
SOLUTION 7 Average HCT data for coarse crystalline porphyry - oxide/transitional (cell CF-11-02, 0-
27)
    temp      25
    pH        7.94
    pe        4
    redox     pe
    units     mg/l
    density   1
    Alkalinity 33.19394 as HCO3
    Al  0.01347
    B          0.01075
    Ba  0.00086
    Ca  10.69469
    Cl  0.77608
    F          0.93545
    Fe  0.00638
    Hg  0.000049
    K          2.66412
    Mg  1.95477
    Mn  0.02025
    Mo  0.00545
    Na  2.86679 charge
    S(6)       13.81598 as SO4
    U          0.00449
    Zn  0.00048

    -water    1 # kg
END

SOLUTION 8 Average HCT data for andesite sulfide material (cells SRK 0864 and SRK 0866)
    temp      25
    pH        7.38
    pe        4
    redox     pe
    units     mg/l
    density   1
    Alkalinity 11.08233 as HCO3
    Al  0.00759
    Ba  0.00261
    Ca  9.22553
    Cl  0.39385
    F          0.46144
    Fe  0.00193
    K          0.99643
    Mg  1.40610
    Mn  0.00954
    Mo  0.00764
    Na  1.91012 charge
    S(6)       23.36270 as SO4
    Se  0.00033
    U          0.00047
    V          0.00169
    Zn  0.00092

    -water    1 # kg
END

SOLUTION 9 Average HCT data for biotite breccia - sulfide (cells 604811, 604854, 604862, 604867 and
605033)
    temp      25
    pH        7.91
    pe        4
    redox     pe
    units     mg/l
    density   1
    Alkalinity 54.42849 as HCO3
    Al  0.00611
    As  0.00046
    B          0.00974
    Ba  0.00750
    Ca  28.87256
    Cl  1.09115
    Cu  0.01120
```

```
    F          1.23366
    K          5.04620
    Mg  4.17236
    Mn  0.04406
    Mo  0.01327
    Na  2.92761 charge
    Ni  0.00049
    S(6)       52.56098 as SO4
    Sb  0.00018
    Se  0.00304
    U          0.00810
    V          0.00552
    Zn  0.00135

    -water    1 # kg
END

SOLUTION 10 Average HCT data for quartz feldspar breccia - sulfide (cells 604767 and 604787)
    temp      25
    pH        7.80
    pe        4
    redox     pe
    units     mg/l
    density   1
    Alkalinity 28.14382 as HCO3
    B          0.01018
    Ba  0.01079
    Ca  17.42309
    Cl  0.83411
    Co  0.00078
    F          0.91743
    K          2.53353
    Mg  3.91833
    Mn  0.12244
    Mo  0.01061
    Na  1.94262 charge
    Ni  0.00064
    S(6)       39.53068 as SO4
    Sb  0.00019
    Se  0.00217
    U          0.02169
    V          0.00281
    Zn  0.00497

    -water    1 # kg
END

SOLUTION 11 Average HCT data for quartz monzonite - sulfide (cells 604562, 604606, 604653, 604656,
604669, 604673 and 605153)
    temp      25
    pH        6.82
    pe        4
    redox     pe
    units     mg/l
    density   1
    Alkalinity 30.08128 as HCO3
    Al  0.01335
    B          0.01290
    Ba  0.01934
    Ca  15.43303
    Cl  1.40889
    Cu  0.03484
    F          0.71091
    Fe  0.00212
    Hg  0.000011
    K          3.45609
    Mg  2.75632
    Mn  0.09332
    Mo  0.01148
    Na  3.16032
    Pb  0.00030
    S(6)       32.59944 as SO4
    Sb  0.00015
```

```
    Se  0.00109
    U          0.00841
    V          0.00312
    Zn  0.00429

    -water    1 # kg
END

SOLUTION 12 Average HCT data for coarse crystalline porphyry - sulfide (cell CF-11-02, 367-408)
    temp      25
    pH        7.80
    pe        4
    redox     pe
    units     mg/l
    density   1
    Alkalinity 21.56678 as HCO3
    Al  0.05060
    B          0.01144
    Ba  0.00414
    Ca  7.69375
    Cl  1.26366
    Cu  0.00619
    F          0.59829
    Fe  0.00380
    Hg  0.000019
    K          1.95046
    Mg  0.53321
    Mn  0.0050
    Mo  0.00163
    Na  2.49093 charge
    Pb  0.00020
    S(6)       8.57475 as SO4
    Sb  0.00012
    U          0.00261

    -water    1 # kg
END

SOLUTION 13 Average HCT data for undefined material (uses average HCT data for all sulfide cells)
    temp      25
    pH        6.76
    pe        4
    redox     pe
    units     mg/l
    density   1
    Al  0.01019
    As  0.00058
    B          0.01134
    Ba  0.01445
    Ca  19.54850
    Cl  1.18326
    Cu  0.03281
    F          0.89545
    Fe  0.00187
    Hg  0.000009
    K          3.69033
    Mg  3.36360
    Mn  0.08380
    Mo  0.01167
    Na  2.80849
    Pb  0.00028
    S(6)       39.46536 as SO4
    Sb  0.00019
    Se  0.00187
    U          0.01100
    V          0.00372
    Zn  0.00391

    -water    1 # kg
END

Title Stage 1 Groundwater mix
MIX 101
```

```
2       1
3       0
4       0
5       0
6       0
7       0
8       0
9       0.146261
10      0.137721
11      0.944512
12      0
13      0

Save solution 101
end

REACTION 101
    H2O        -1
    68.25511932 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 101
SAVE Solution 102

End
Title Precipitate oversaturated phases in groundwater
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 101
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4  0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -1.69 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
```

```
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 102
SAVE Solution 103  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 101
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 101

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite        equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 101
USE Surface 101
USE Solution 103
SAVE Solution 104  #Initial Stage 1 groundwater after Mineral Precipitation and Sorption Loss
END

Title Stage 1 Run-off mix
Mix 102
1      1
3      0.164376
4      0
5      0.120106
6      1.425941
7      0.488780
8      1.551968
9      5.454143
10     8.581411
11     102.312415
12     18.326068
13     0.857964

Save solution 105
end

REACTION 102
    H2O        -1
    7738.57 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 105
SAVE Solution 106

End

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 102
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
```

```
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 106
SAVE Solution 107  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 102
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 102

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 102
USE Surface 102
USE Solution 107
SAVE Solution 108  #Initial Stage 1 Run-off Water After Mineral Precipitation and Sorption Loss
END

Title Stage 1 Pit lake Mix
Mix 103
104    0.610422
108    0.379793
1      0.009786

Save solution 109
end

Title Stage 1 Pit wall interaction mix calculator
MIX 104
109    1
3      0
4      0
5      0
6      0
7      0
8      0
```

```
9      0.0034523
10     0.0032507
11     0.0222938
12     0
13     0

Save solution 110
end

REACTION 104
    H2O        -1
    1.611063077 moles ###  Addition step. Removes HTC water but solute mass remains
                        ## Retuns solution volume back to 1L
USE solution 110
SAVE Solution 111

End
Title Evaporate Stage 1 lake water to produce initial Stage 2 Lake water
REACTION 105

         H2O     -1
     7.70 moles      ## Removes x m3 water, but solute mass remains the same
                        ## This number must be adjusted manually for each cycle
USE solution 111
Save Solution 112

END

Title Return solution back to 1L

Mix 105
       112  1.1609
save solution 113
end

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 105
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
```

```
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 113
SAVE Solution 114  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 105
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 105

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 105
USE Surface 105
USE Solution 114
SAVE Solution 115  #Initial Stage 1 Pit Water After Mineral Precipitation and Sorption Loss
END

Title Use solution to allow model output
REACTION 106

         H2O     -0.0
      0 moles

USE solution 115
End
Title Stage 2 pit lake GW inflow
Title Stage 2 Groundwater mix
MIX 201
2       1
3       0
4       0
5       0
6       0
7       0
8       0
9       0.498800
10      0.178770
11      1.341815
12      0
13      0

Save solution 201
end

REACTION 201
    H2O        -1
    112.196996 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 201
SAVE Solution 202

End
Title Precipitate oversaturated phases in groundwater
```

```
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 201
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -1.69 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 202
SAVE Solution 203  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 201
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 201

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite        equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 201
USE Surface 201
USE Solution 203
SAVE Solution 204  #Initial Stage 2 groundwater after Mineral Precipitation and Sorption Loss
END
```

```
Title Stage 2 Run-off mix
Mix 202
1      1
3      0.054390
4      0
5      0.039741
6      0.471822
7      0.161730
8      0.513523
9      1.609756
10     2.816288
11     33.632282
12     6.063818
13     0.283887

Save solution 205
end

REACTION 202
    H2O        -1
    2536.16 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 205
SAVE Solution 206

End

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 202
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
```

```
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 206
SAVE Solution 207  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 202
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 202

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 202
USE Surface 202
USE Solution 207
SAVE Solution 208  #Initial Stage 2 Run-off Water After Mineral Precipitation and Sorption Loss
END

Title Stage 2 Pit lake Mix
Mix 203
204    0.229607
208    0.425741
1      0.025134
115    0.319518
Save solution 209
end

Title Stage 2 Pit wall interaction mix calculator
MIX 204
209    1
3      0
4      0
5      0
6      0
7      0
8      0
9      0.0044161
10     0.0015827
11     0.0118796
12     0
13     0

Save solution 210
end

REACTION 204
    H2O        -1
   0.993325278 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 210
SAVE Solution 211

End
Title Evaporate Stage 2 lake water to produce initial Stage 2 Lake water
REACTION 205

         H2O     -1
     3.64 moles      ## Removes x m3 water, but solute mass remains the same
                         ## This number must be adjusted manually for each cycle
USE solution 211
Save Solution 212
```

```
END

Title Return solution back to 1L

Mix 205
        212  1.0701
save solution 213
end

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 205
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 213
SAVE Solution 214  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 205
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 205
```

```
    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 205
USE Surface 205
USE Solution 214
SAVE Solution 215  #Initial Stage 2 Pit Water After Mineral Precipitation and Sorption Loss
END

Title Use solution to allow model output
REACTION 206

         H2O     -0.0
      0 moles

USE solution 215
End

Title Stage 3 pit lake GW inflow
Title Stage 3 Groundwater mix
MIX 301
2       1
3       0
4       0
5       0
6       0
7       0
8       0
9       1.040047
10      0.262434
11      1.883006
12      0
13      0

Save solution 301
end

REACTION 301
    H2O        -1
   176.9856208 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 301
SAVE Solution 302

End
Title Precipitate oversaturated phases in groundwater
  PHASES
Fix_pe
    e-=e-
    log_k     0


EQUILIBRIUM_PHASES 301
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -1.69 10
    Co3O4 0 0
```

```
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 302
SAVE Solution 303  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 301
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 301

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite        equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 301
USE Surface 301
USE Solution 303
SAVE Solution 304  #Initial Stage 3 groundwater after Mineral Precipitation and Sorption Loss
END

Title Stage 3 Run-off mix
Mix 302
1      1
3      0.082928
4      0
5      0.060594
6      0.719390
7      0.246590
8      0.782971
9      2.020417
10     4.228018
11     50.854355
12     9.245537
13     0.432845

Save solution 305
end

REACTION 302
    H2O        -1
    3815.51 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
```

```
USE solution 305
SAVE Solution 306

End

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 302
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 306
SAVE Solution 307  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 302
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 302

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008
```

```
USE EQUILIBRIUM_PHASES 302
USE Surface 302
USE Solution 307
SAVE Solution 308  #Initial Stage 3 Run-off Water After Mineral Precipitation and Sorption Loss
END

Title Stage 3 Pit lake Mix
Mix 303
304     0.226442
308     0.278993
1       0.027809
215     0.466756
Save solution 309
end

Title Stage 3 Pit wall interaction mix calculator
MIX 304
309     1
3       0
4       0
5       0
6       0
7       0
8       0
9       0.0045408
10      0.0011458
11      0.0082210
12      0
13      0

Save solution 310
end

REACTION 304
    H2O        -1
    0.772703721 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 310
SAVE Solution 311

End
Title Evaporate Stage 3 lake water to produce initial Stage 2 Lake water
REACTION 305

          H2O     -1
     7.43 moles      ## Removes x m3 water, but solute mass remains the same
                         ## This number must be adjusted manually for each cycle
USE solution 311
Save Solution 312

END

Title Return solution back to 1L

Mix 305
       312  1.1545
save solution 313
end

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0


EQUILIBRIUM_PHASES 305
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
```

```
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 313
SAVE Solution 314  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 305
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 305

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 305
USE Surface 305
USE Solution 314
SAVE Solution 315  #Initial Stage 3 Pit Water After Mineral Precipitation and Sorption Loss
END

Title Use solution to allow model output
REACTION 306

         H2O     -0.0
      0 moles

USE solution 315
End

Title Stage 4 pit lake GW inflow
```

```
Title Stage 4 Groundwater mix
MIX 401
2       1
3       0
4       0
5       0
6       0
7       0
8       0
9       1.588204
10      0.354166
11      2.530506
12      0
13      0

Save solution 401
end

REACTION 401
    H2O        -1
    248.512974 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 401
SAVE Solution 402

End
Title Precipitate oversaturated phases in groundwater
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 401
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -1.69 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
```

```
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 402
SAVE Solution 403  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 401
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 401

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite        equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 401
USE Surface 401
USE Solution 403
SAVE Solution 404  #Initial Stage 4 groundwater after Mineral Precipitation and Sorption Loss
END

Title Stage 4 Run-off mix
Mix 402
1      1
3      0.084265
4      0
5      0.061571
6      0.730989
7      0.250566
8      0.795595
9      1.624757
10     4.225841
11     51.178282
12     9.394602
13     0.439824

Save solution 405
end

REACTION 402
    H2O        -1
    3821.77 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 405
SAVE Solution 406

End

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 402
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
```

```
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 406
SAVE Solution 407  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 402
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 402

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 402
USE Surface 402
USE Solution 407
SAVE Solution 408  #Initial Stage 4 Run-off Water After Mineral Precipitation and Sorption Loss
END

Title Stage 4 Pit lake Mix
Mix 403
404    0.268452
408    0.331540
1      0.051435
315    0.348573
Save solution 409
end

Title Stage 4 Pit wall interaction mix calculator
MIX 404
409    1
3      0
4      0
5      0
6      0
```

```
7      0
8      0
9      0.0027376
10     0.0006105
11     0.0043618
12     0
13     0

Save solution 410
end

REACTION 404
    H2O        -1
    0.428362415 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 410
SAVE Solution 411

End
Title Evaporate Stage 4 lake water to produce initial Stage 5 Lake water
REACTION 405

          H2O     -1
     14.34 moles      ## Removes x m3 water, but solute mass remains the same
                         ## This number must be adjusted manually for each cycle
USE solution 411
Save Solution 412

END

Title Return solution back to 1L

Mix 405
       412  1.3480
save solution 413
end

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 405
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
```

```
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 413
SAVE Solution 414  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 405
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 405

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 405
USE Surface 405
USE Solution 414
SAVE Solution 415  #Initial Stage 5 Pit Water After Mineral Precipitation and Sorption Loss
END

Title Use solution to allow model output
REACTION 406

         H2O     -0.0
      0 moles

USE solution 415
End

Title Stage 5 pit lake GW inflow
Title Stage 5 Groundwater mix
MIX 501
2      1
3      0
4      0
5      0
6      0
7      0
8      0
9      2.044332
10     0.565829
11     3.283660
12     0
13     0

Save solution 501
end

REACTION 501
    H2O        -1
    327.4607223 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 501
SAVE Solution 502
```

```
End
Title Precipitate oversaturated phases in groundwater
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 501
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -1.69 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 502
SAVE Solution 503  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 501
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 501

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite        equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 501
USE Surface 501
```

```
USE Solution 503
SAVE Solution 504  #Initial Stage 5 groundwater after Mineral Precipitation and Sorption Loss
END

Title Stage 5 Run-off mix
Mix 502
1      1
3      0.085744
4      0
5      0.062651
6      0.743820
7      0.254964
8      0.809559
9      1.316995
10     4.136563
11     51.519548
12     9.559504
13     0.447544

Save solution 505
end

REACTION 502
    H2O        -1
    3830.13 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 505
SAVE Solution 506

End

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 502
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
```

```
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 506
SAVE Solution 507  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 502
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 502

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 502
USE Surface 502
USE Solution 507
SAVE Solution 508  #Initial Stage 5 Run-off Water After Mineral Precipitation and Sorption Loss
END

Title Stage 5 Pit lake Mix
Mix 503
504    0.237553
508    0.295248
1      0.063940
415    0.403259
Save solution 509
end

Title Stage 5 Pit wall interaction mix calculator
MIX 504
509    1
3      0
4      0
5      0
6      0
7      0
8      0
9      0.0018702
10     0.0005176
11     0.0030039
12     0
13     0

Save solution 510
end

REACTION 504
    H2O        -1
    0.299565337 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 510
SAVE Solution 511

End
Title Evaporate Stage 5 lake water to produce initial Stage 5 Lake water
REACTION 505

         H2O     -1
     18.14 moles      ## Removes x m3 water, but solute mass remains the same
```

```
                         ## This number must be adjusted manually for each cycle
USE solution 511
Save Solution 512

END

Title Return solution back to 1L

Mix 505
       512  1.4846
save solution 513
end

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 505
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 513
SAVE Solution 514  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 505
END
```

```
Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 505

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 505
USE Surface 505
USE Solution 514
SAVE Solution 515  #Stage 5 Pit Water After Mineral Precipitation and Sorption Loss
END

Title Use solution to allow model output
REACTION 506

         H2O     -0.0
      0 moles

USE solution 515
End

Title Stage 6 pit lake GW inflow
Title Stage 6 Groundwater mix
MIX 601
2      1
3      0
4      0
5      0
6      0
7      0
8      0
9      2.537454
10     0.929520
11     5.109808
12     0
13     0

Save solution 601
end

REACTION 601
    H2O        -1
    476.5260208 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 601
SAVE Solution 602

End
Title Precipitate oversaturated phases in groundwater
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 601
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
```

```
    CO2(g)    -1.69 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 602
SAVE Solution 603  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 601
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 601

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite        equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 601
USE Surface 601
USE Solution 603
SAVE Solution 604  #Initial Stage 6 groundwater after Mineral Precipitation and Sorption Loss
END

Title Stage 6 Run-off mix
Mix 602
1      1
3      0.087293
4      0
5      0.063783
6      0.757257
7      0.259570
8      0.824184
9      0.987441
10     3.931922
11     51.056266
12     9.732198
13     0.455628

Save solution 605
end

REACTION 602
    H2O        -1
```

```
    3786.72 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 605
SAVE Solution 606

End

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 602
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 606
SAVE Solution 607  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 602
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 602

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
```

```
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 602
USE Surface 602
USE Solution 607
SAVE Solution 608  #Initial Stage 6 Run-off Water After Mineral Precipitation and Sorption Loss
END

Title Stage 6 Pit lake Mix
Mix 603
604    0.280031
608    0.350395
1      0.098329
515    0.271245
Save solution 609
end

Title Stage 6 Pit wall interaction mix calculator
MIX 604
609    1
3      0
4      0
5      0
6      0
7      0
8      0
9      0.0009116
10     0.0003339
11     0.0018357
12     0
13     0

Save solution 610
end

REACTION 604
    H2O        -1
    0.171190632 moles ###  Addition step. Removes HTC water but solute mass remains
                          ## Retuns solution volume back to 1L
USE solution 610
SAVE Solution 611

End
Title Evaporate Stage 6 lake water to produce initial Stage 7 Lake water
REACTION 605

         H2O     -1
     28.05 moles      ## Removes x m3 water, but solute mass remains the same
                         ## This number must be adjusted manually for each cycle
USE solution 611
Save Solution 612

END

Title Return solution back to 1L

Mix 605
       612  2.0199
save solution 613
end

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 605
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
```

```
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 613
SAVE Solution 614  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 605
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 605

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 605
USE Surface 605
USE Solution 614
SAVE Solution 615  #Initial Stage 7 Pit Water After Mineral Precipitation and Sorption Loss
END

Title Use solution to allow model output
REACTION 606

         H2O     -0.0
      0 moles

USE solution 615
End
```

```
Title Stage 7 pit lake GW inflow
Title Stage 7 Groundwater mix
MIX 701
2       1
3       0
4       0
5       0
6       0
7       0
8       0
9       2.782365
10      1.018827
11      6.705689
12      0
13      0

Save solution 701
end

REACTION 701
    H2O        -1
    583.7622718 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 701
SAVE Solution 702

End
Title Precipitate oversaturated phases in groundwater
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 701
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -1.69 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
```

```
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 702
SAVE Solution 703  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 701
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 701

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite        equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 701
USE Surface 701
USE Solution 703
SAVE Solution 704  #Initial Stage 7 groundwater after Mineral Precipitation and Sorption Loss
END

Title Stage 7 Run-off mix
Mix 702
1      1
3      0.089025
4      0
5      0.065049
6      0.772284
7      0.264720
8      0.840536
9      0.849912
10     3.952694
11     50.870942
12     9.925285
13     0.464668

Save solution 705
end

REACTION 702
    H2O        -1
    3783.36 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 705
SAVE Solution 706

End

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 702
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
```

```
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 706
SAVE Solution 707  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 702
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 702

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 702
USE Surface 702
USE Solution 707
SAVE Solution 708  #Initial Stage 7 Run-off Water After Mineral Precipitation and Sorption Loss
END

Title Stage 7 Pit lake Mix
Mix 703
704    0.265124
708    0.331499
1      0.116823
615    0.286554
Save solution 709
end

Title Stage 7 Pit wall interaction mix calculator
MIX 704
709    1
3      0
4      0
5      0
```

```
6       0
7       0
8       0
9       0.0005677
10      0.0002079
11      0.0013682
12      0
13      0

Save solution 710
end

REACTION 704
    H2O        -1
    0.119108371 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 710
SAVE Solution 711

End
Title Evaporate Stage 7 lake water to produce initial Stage 8 Lake water
REACTION 705

         H2O     -1
     33.37 moles      ## Removes x m3 water, but solute mass remains the same
                         ## This number must be adjusted manually for each cycle
USE solution 711
Save Solution 712

END

Title Return solution back to 1L

Mix 705
        712  2.5036
save solution 713
end

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 705
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
```

```
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 713
SAVE Solution 714  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 705
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 705

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 705
USE Surface 705
USE Solution 714
SAVE Solution 715  #Initial Stage 8 Pit Water After Mineral Precipitation and Sorption Loss
END

Title Use solution to allow model output
REACTION 706

         H2O     -0.0
      0 moles

USE solution 715
End
Title Stage 8 pit lake GW inflow
Title Stage 8 Groundwater mix
MIX 801
2      1
3      0
4      0
5      0
6      0
7      0
8      0
9      2.923377
10     1.080869
11     7.244641
12     0
13     0

Save solution 801
end

REACTION 801
    H2O        -1
    624.9881919 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 801
SAVE Solution 802
```

```
End
Title Precipitate oversaturated phases in groundwater
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 801
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -1.69 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 802
SAVE Solution 803  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 801
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 801

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite        equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 801
USE Surface 801
```

```
USE Solution 803
SAVE Solution 804  #Initial Stage 8 groundwater after Mineral Precipitation and Sorption Loss
END

Title Stage 8 Run-off mix
Mix 802
1       1
3       0.090239
4       0
5       0.065936
6       0.782812
7       0.268330
8       0.851999
9       0.764027
10      3.962526
11      51.169480
12      10.060637
13      0.471005

Save solution 805
end

REACTION 802
    H2O        -1
    3805.14 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 805
SAVE Solution 806

End

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 802
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
```

```
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 806
SAVE Solution 807  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 802
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 802

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 802
USE Surface 802
USE Solution 807
SAVE Solution 808  #Initial Stage 8 Run-off Water After Mineral Precipitation and Sorption Loss
END

Title Stage 8 Pit lake Mix
Mix 803
804     0.234754
808     0.291649
1       0.117458
715     0.356140
Save solution 809
end

Title Stage 8 Pit wall interaction mix calculator
MIX 804
809     1
3       0
4       0
5       0
6       0
7       0
8       0
9       0.0005281
10      0.0001953
11      0.0013088
12      0
13      0

Save solution 810
end

REACTION 804
    H2O         -1
    0.11291264 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 810
SAVE Solution 811

End
Title Evaporate Stage 8 lake water to produce initial Stage 9 Lake water
REACTION 805

         H2O     -1
     33.58 moles      ## Removes x m3 water, but solute mass remains the same
```

```
                         ## This number must be adjusted manually for each cycle
USE solution 811
Save Solution 812

END

Title Return solution back to 1L

Mix 805
       812  2.5275
save solution 813
end

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 805
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 813
SAVE Solution 814  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 805
END
```

```
Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 805

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 805
USE Surface 805
USE Solution 814
SAVE Solution 815  #Initial Stage 9 Pit Water After Mineral Precipitation and Sorption Loss
END

Title Use solution to allow model output
REACTION 806

         H2O     -0.0
      0 moles

USE solution 815
End

Title Stage 9 pit lake GW inflow
Title Stage 9 Groundwater mix
MIX 901
2      1
3      0
4      0
5      0
6      0
7      0
8      0
9      2.975314
10     1.099871
11     7.427096
12     0
13     0

Save solution 901
end

REACTION 901
    H2O        -1
    639.0667165 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 901
SAVE Solution 902

End
Title Precipitate oversaturated phases in groundwater
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 901
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
```

```
    CO2(g)    -1.69 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 902
SAVE Solution 903  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 901
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 901

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite        equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 901
USE Surface 901
USE Solution 903
SAVE Solution 904  #Initial Stage 9 groundwater after Mineral Precipitation and Sorption Loss
END

Title Stage 9 Run-off mix
Mix 902
1      1
3      0.090729
4      0
5      0.066293
6      0.787059
7      0.269786
8      0.856621
9      0.731379
10     3.970592
11     51.312498
12     10.115219
13     0.473560

Save solution 905
end

REACTION 902
    H2O        -1
```

```
    3815.51 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 905
SAVE Solution 906

End

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 902
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 906
SAVE Solution 907  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 902
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 902

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
```

```
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 902
USE Surface 902
USE Solution 907
SAVE Solution 908  #Initial Stage 9 Run-off Water After Mineral Precipitation and Sorption Loss
END

Title Stage 9 Pit lake Mix
Mix 903
904     0.224670
908     0.278220
1       0.117685
815     0.379425
Save solution 909
end

Title Stage 9 Pit wall interaction mix calculator
MIX 904
909     1
3       0
4       0
5       0
6       0
7       0
8       0
9       0.0005144
10      0.0001902
11      0.0012842
12      0
13      0

Save solution 910
end

REACTION 904
    H2O        -1
   0.110496872 moles ###  Addition step. Removes HTC water but solute mass remains
                         ## Retuns solution volume back to 1L
USE solution 910
SAVE Solution 911

End
Title Evaporate Stage 9 lake water

REACTION 905

         H2O     -1
     33.65 moles      ## Removes x m3 water, but solute mass remains the same
                         ## This number must be adjusted manually for each cycle
USE solution 911
Save Solution 912

END

Title Return solution back to 1L

Mix 905
       912  2.5363
save solution 913
end

Title Precipitate oversaturated phases
  PHASES
Fix_pe
    e-=e-
    log_k     0

EQUILIBRIUM_PHASES 905
    Ag2Se 0 0
    Anhydrite 0 0
    Alunite   0 0
```

```
    Ba3(AsO4)2 0 0
    Barite    0 0
    Boehmite 0 0
    Brochantite 0 0
    Brucite 0 0
    Calcite   0 0
    Carnotite 0 0
    CaMoO4 0 0
    CaSeO3:2H2O 0 0
    Cd(BO2)2 0 0
    CdMoO4 0 0
    Chrysotile 0 0
    CO2(g)    -3.5 10
    Co3O4 0 0
    Cr2O3 0 0
    Cu2Se(alpha) 0 0
    CuMoO4 0 0
    Diaspore  0 0
    Epsomite 0 0
    Ferrihydrite 0 0
    Fluorite 0 0
    Gummite 0 0
    Gypsum    0 0
    HgSe 0 0
    Hgmetal(l) 0 0
    Kaolinite 0 0
    Mg3(PO4)2 0 0
    Mirabilite 0 0
    MnSeO3 0 0
    O2(g)     -32 10
    NiCO3 0 0
    NiMoO4 0 0
    Ni(OH)2 0 0
    Ni3(AsO4)2:8H2O 0 0
    Otavite 0 0
    Pyromorphite 0 0
    Rutherfordine 0 0
    SbO2 0 0
    Schoepite 0 0
    Sepiolite 0 0
    SiO2(am-ppt) 0 0
    Tyuyamunite 0 0
    U3O8 0 0
    UO3 0 0
    UO2(OH)2(beta) 0 0

USE solution 913
SAVE Solution 914  Initial Pit Water after Mineral Precipitation
SAVE EQUILIBRIUM_PHASES 905
END

Title  Determine loss of metals due to HFO sorption and sedimentation
SURFACE 905

    -equilibrate with solution 1
    Hfo_sOH Ferrihydrite    equilibrium_phase 0.005 64200
    Hfo_wOH Ferrihydrite    equilibrium_phase 0.2
    -donnan 1e-008

USE EQUILIBRIUM_PHASES 905
USE Surface 905
USE Solution 914
SAVE Solution 915  #Final Stage 9 Pit Water After Mineral Precipitation and Sorption Loss
END

Title Use solution to allow model output
REACTION 906

         H2O     -0.0
      0 moles

USE solution 915
End
```

Appendix C – Humidity Cell Elemental Release Rate Graphs

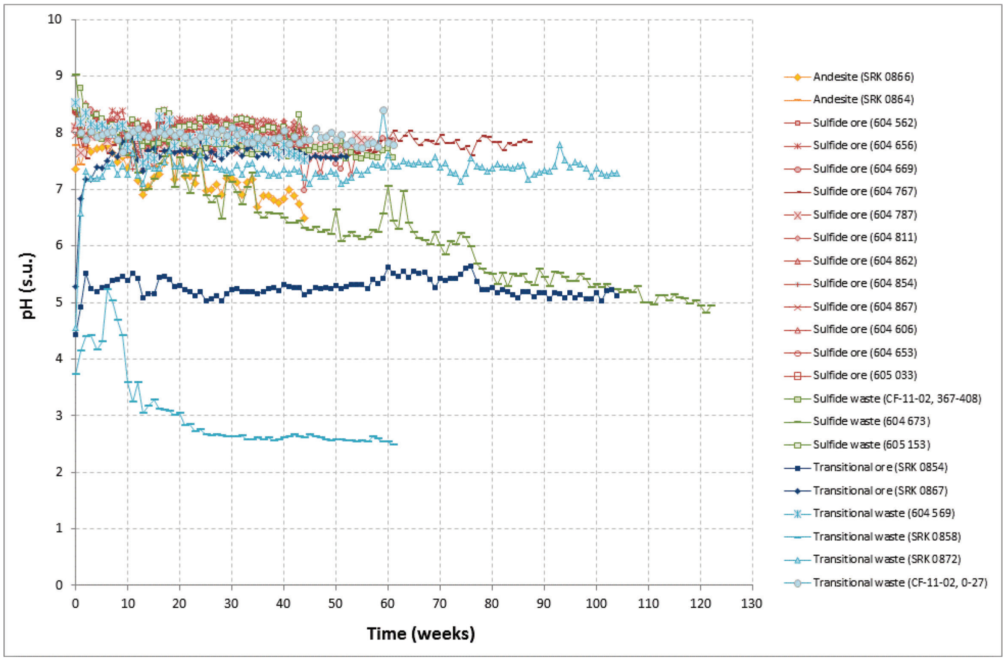

Figure C-1: Humidity Cell Effluent pH

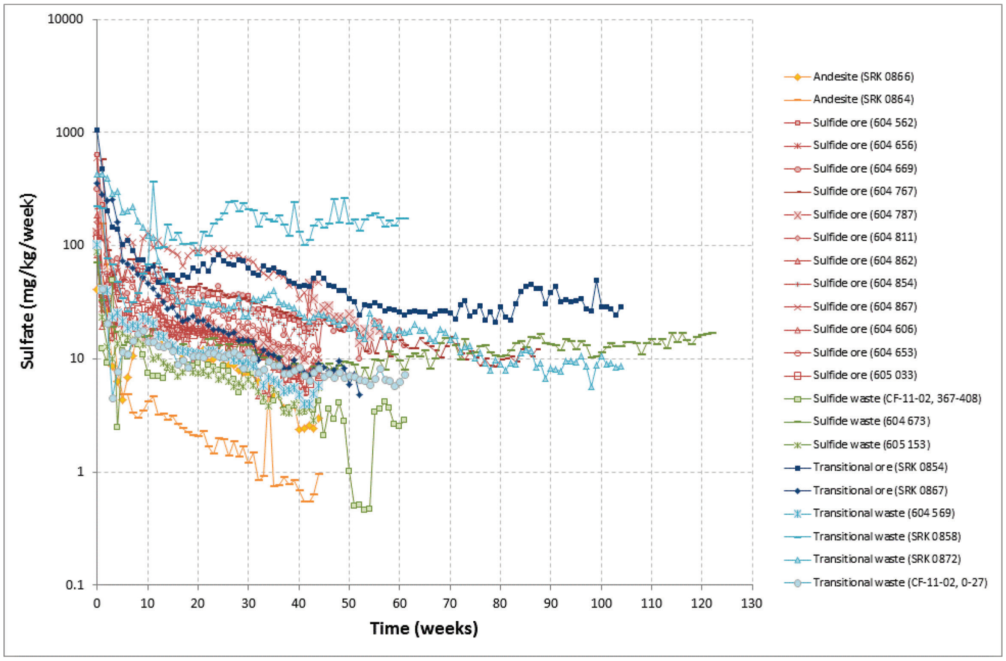

Figure C-2: Humidity Cell Effluent Sulfate

Figure C-3: Humidity Cell Effluent Boron

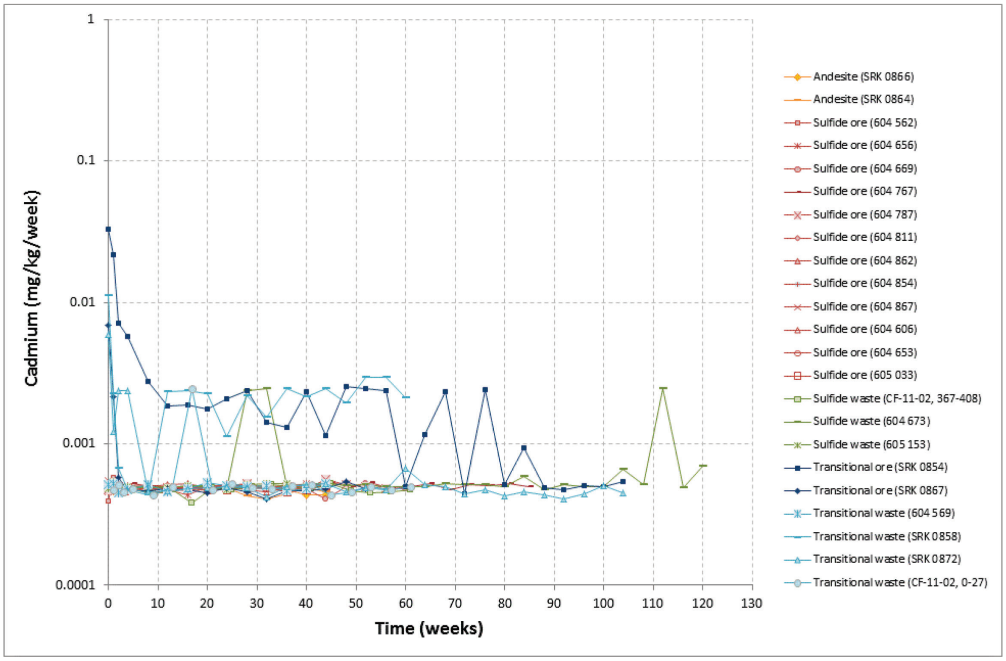

Figure C-4: Humidity Cell Effluent Cadmium

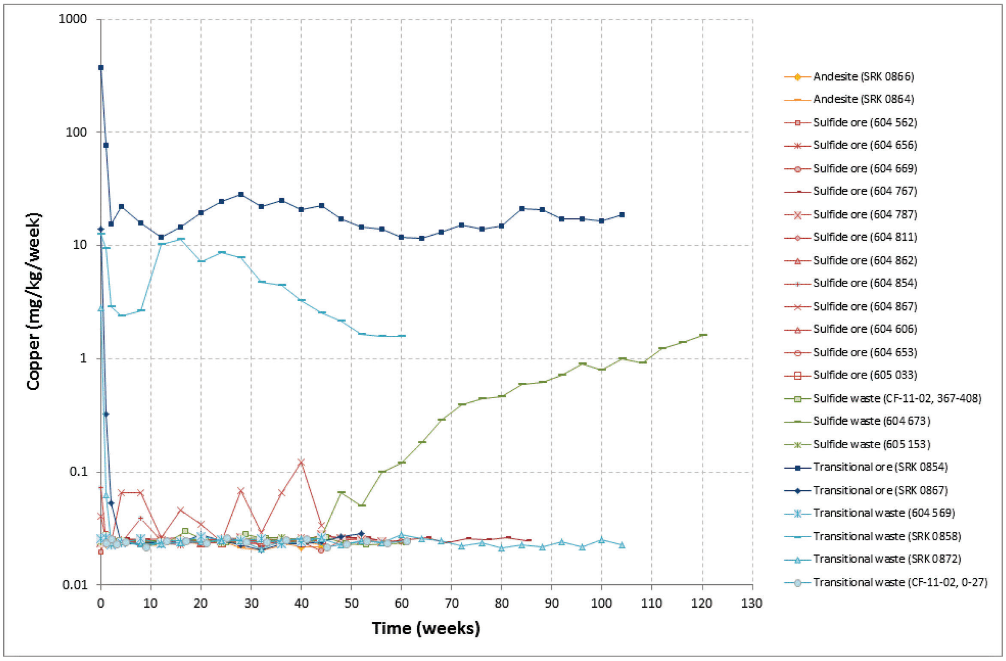

Figure C-5: Humidity Cell Effluent Copper

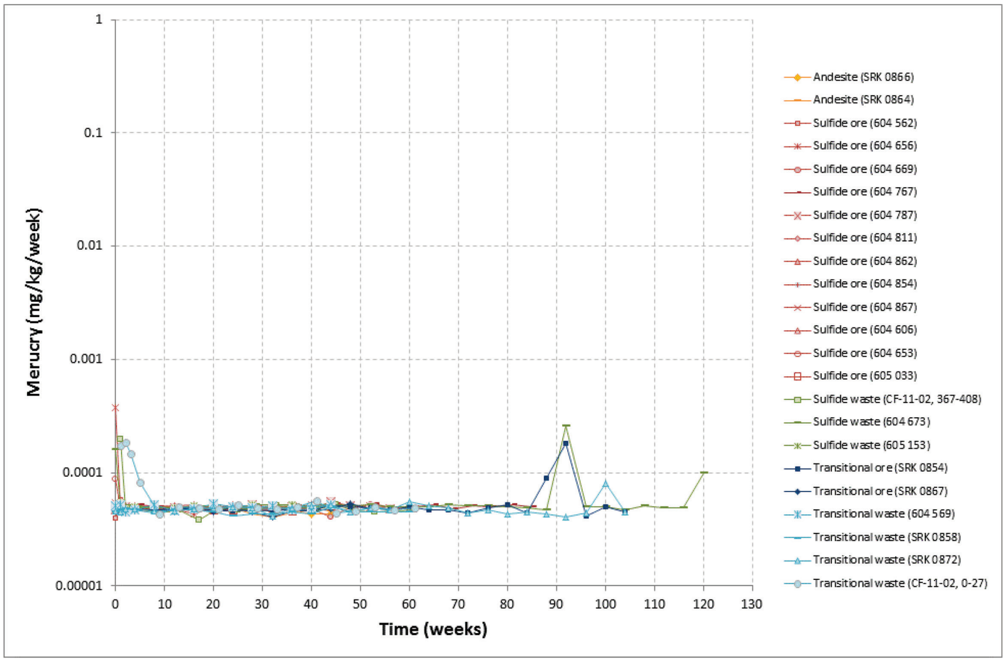

Figure C-6: Humidity Cell Effluent Mercury

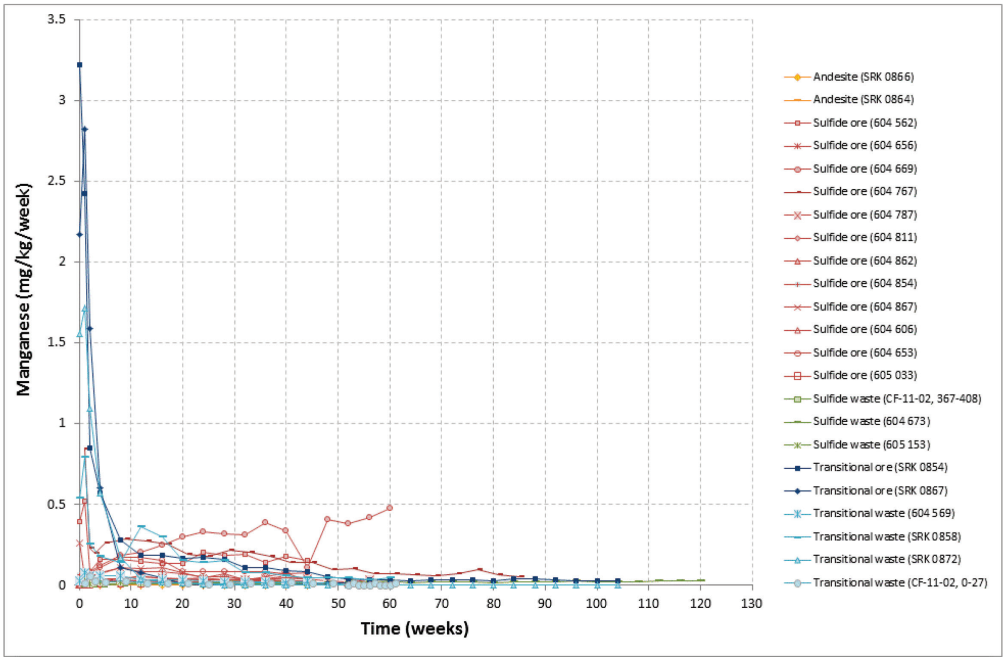

Figure C-7: Humidity Cell Effluent Manganese

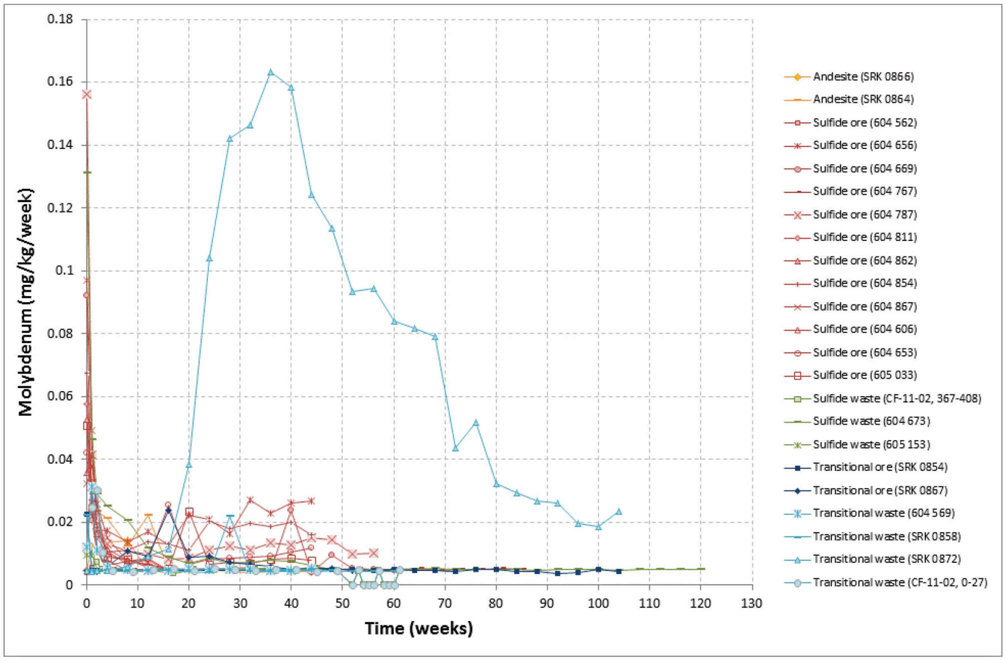

Figure C-8: Humidity Cell Effluent Molybdenum

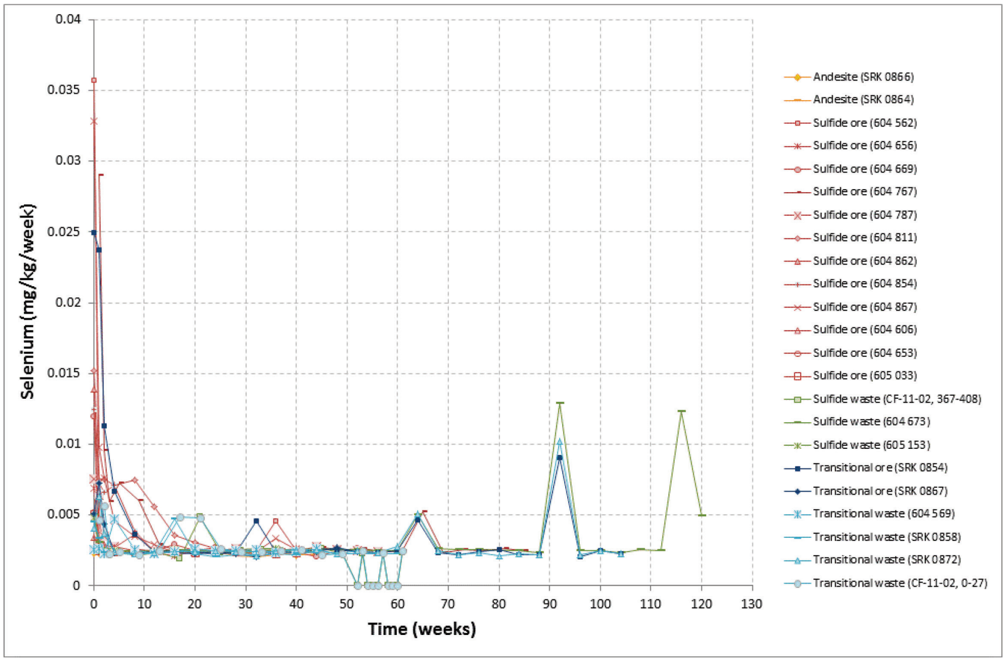

Figure C-9: Humidity Cell Effluent Selenium

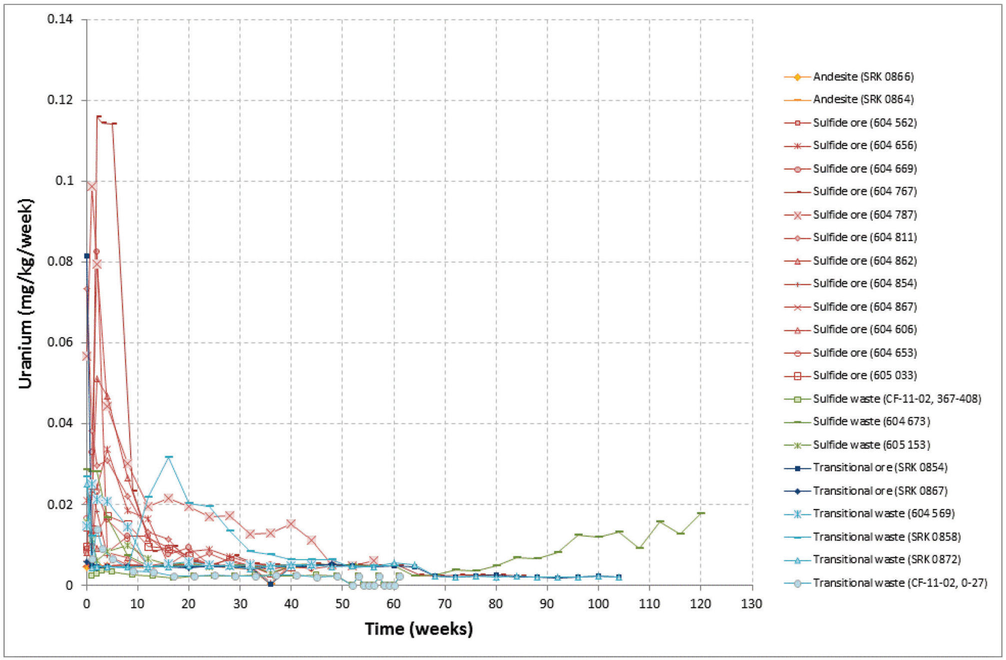

Figure C-10: Humidity Cell Effluent Uranium

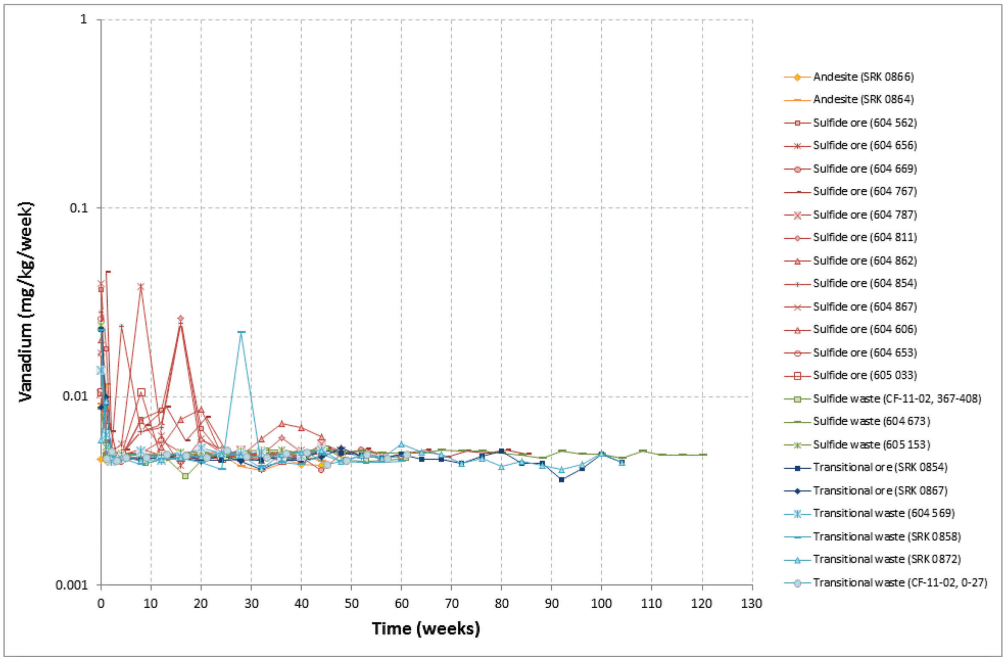

Figure C-11: Humidity Cell Effluent Vanadium

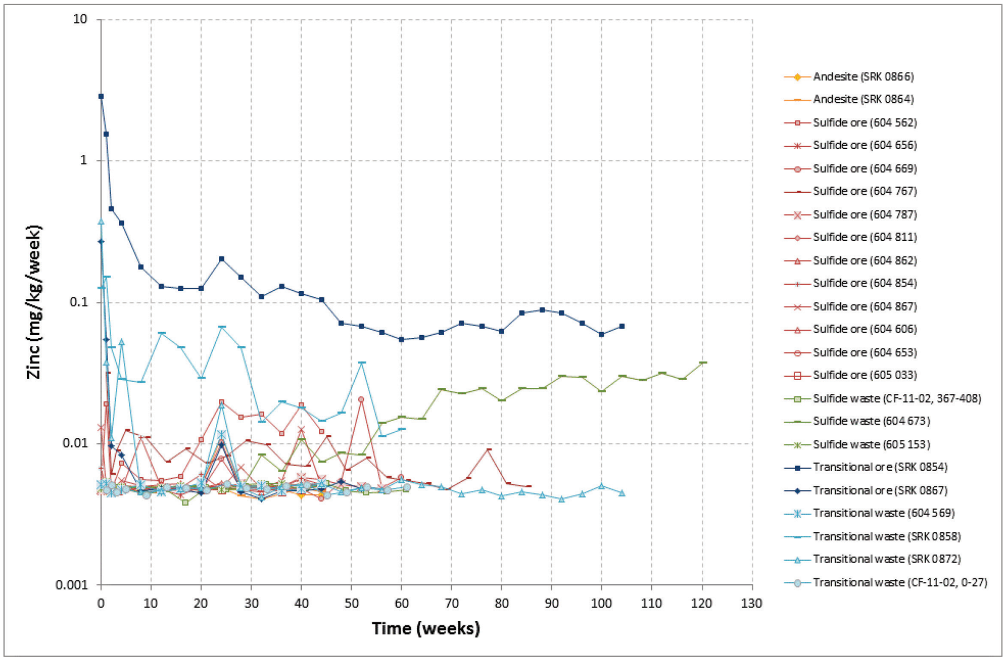

Figure C-12: Humidity Cell Effluent Zinc

Appendix D – Existing Pit Lake Chemistry

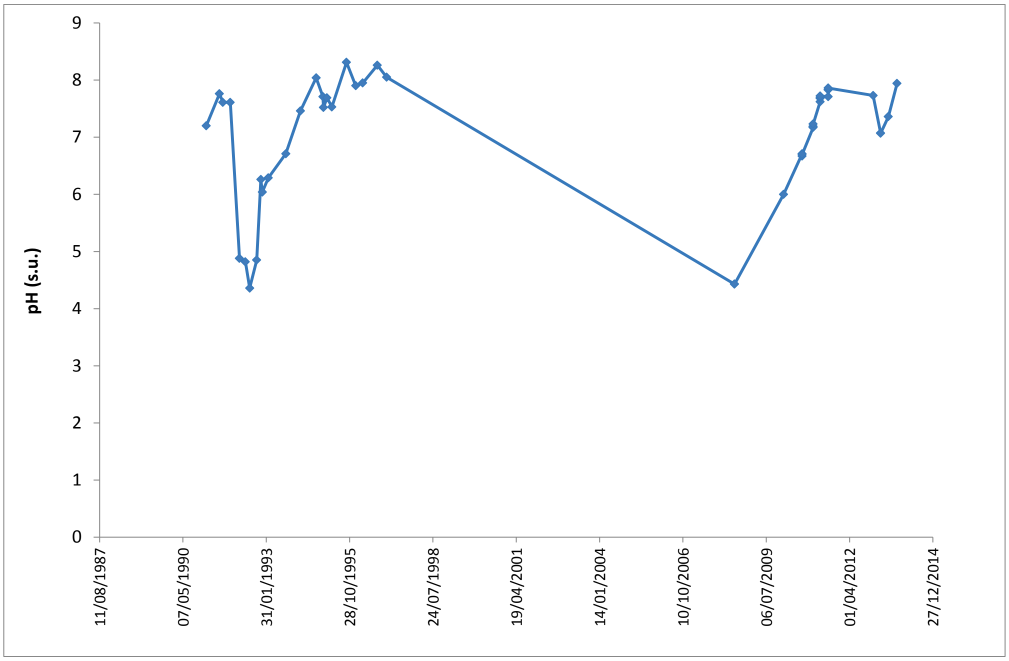

Figure D-1: pH Trends in Existing Pit Lake

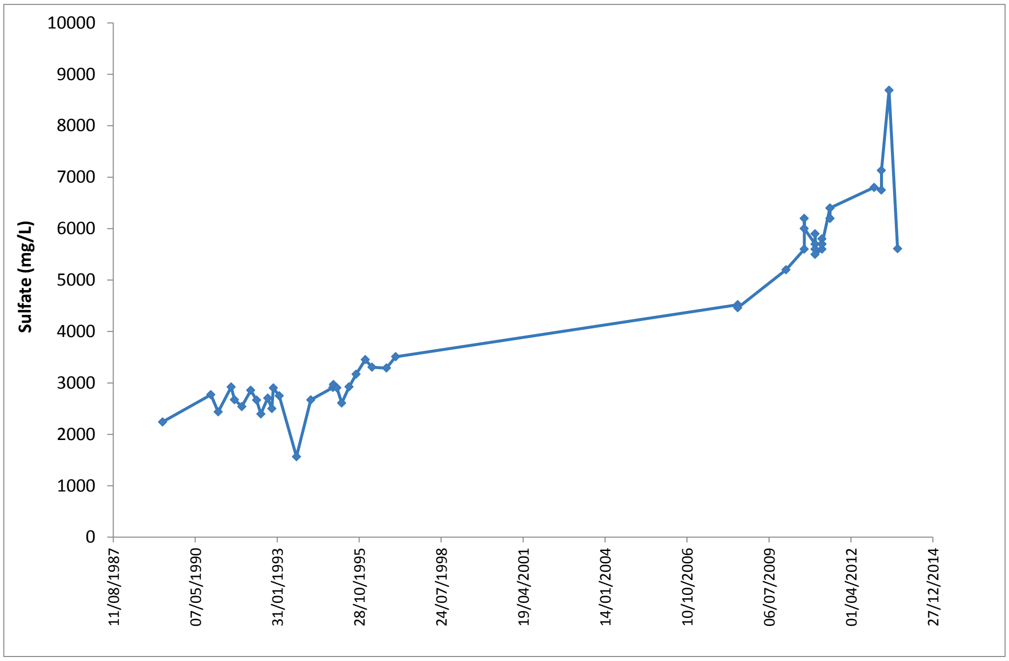

Figure D-2: Sulfate Trends in Existing Pit Lake

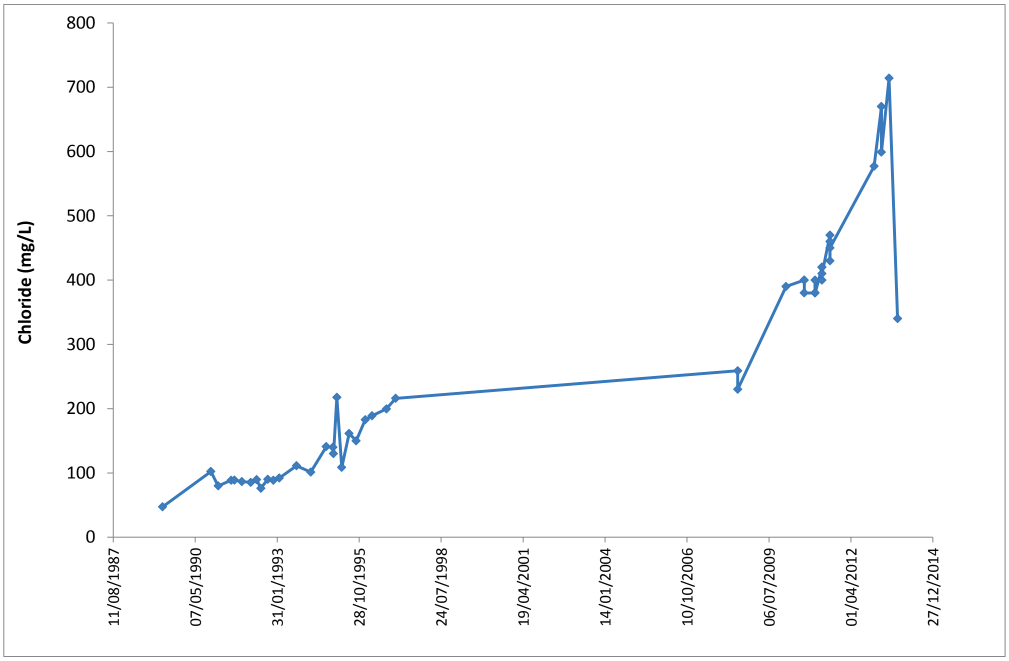

Figure D-3: Chloride Trends in Existing Pit Lake

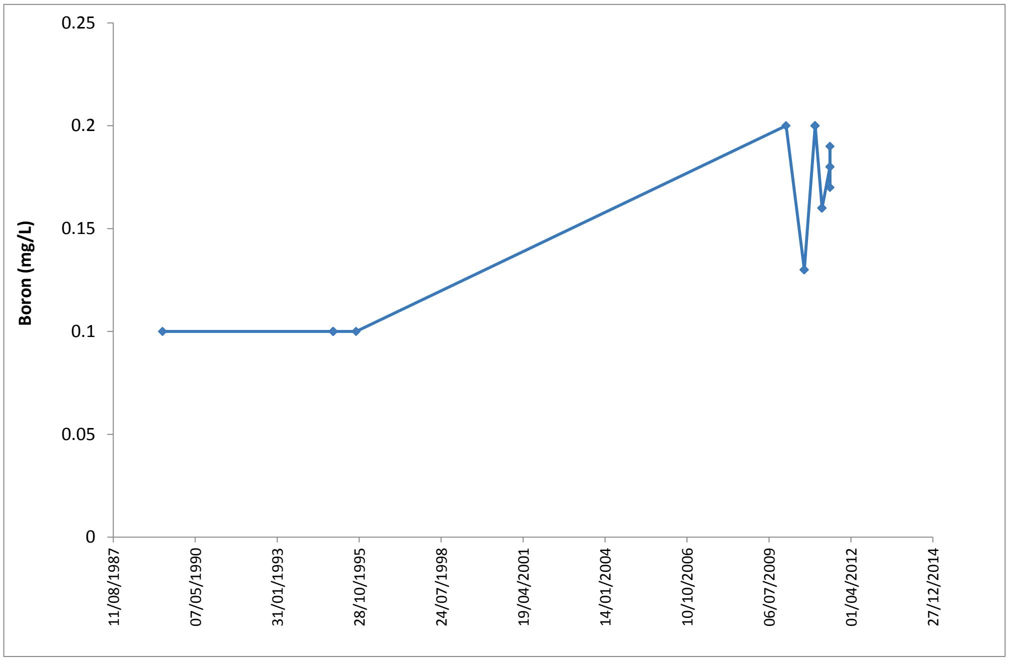

Figure D-4: Boron Trends in Existing Pit Lake

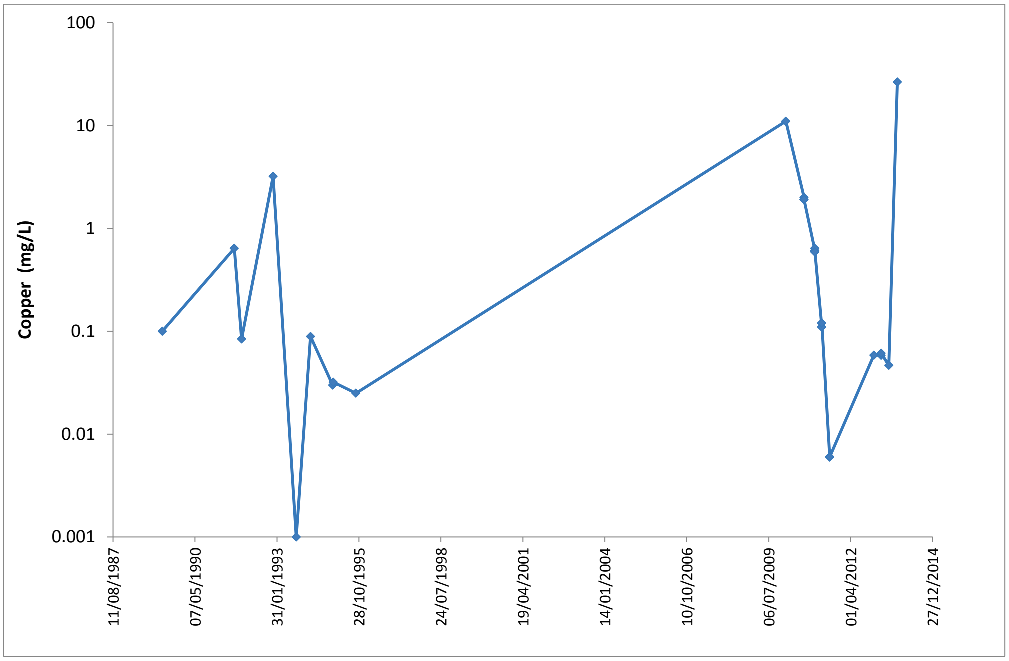

Figure D-5: Copper Trends in Existing Pit Lake

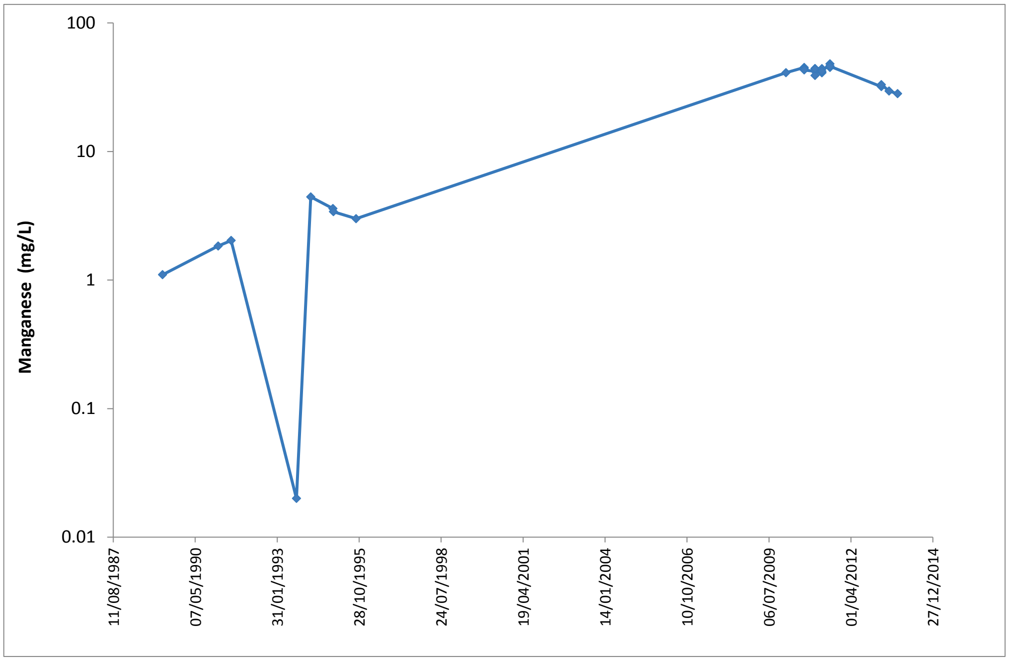

Figure D-6: Manganese Trends in Existing Pit Lake

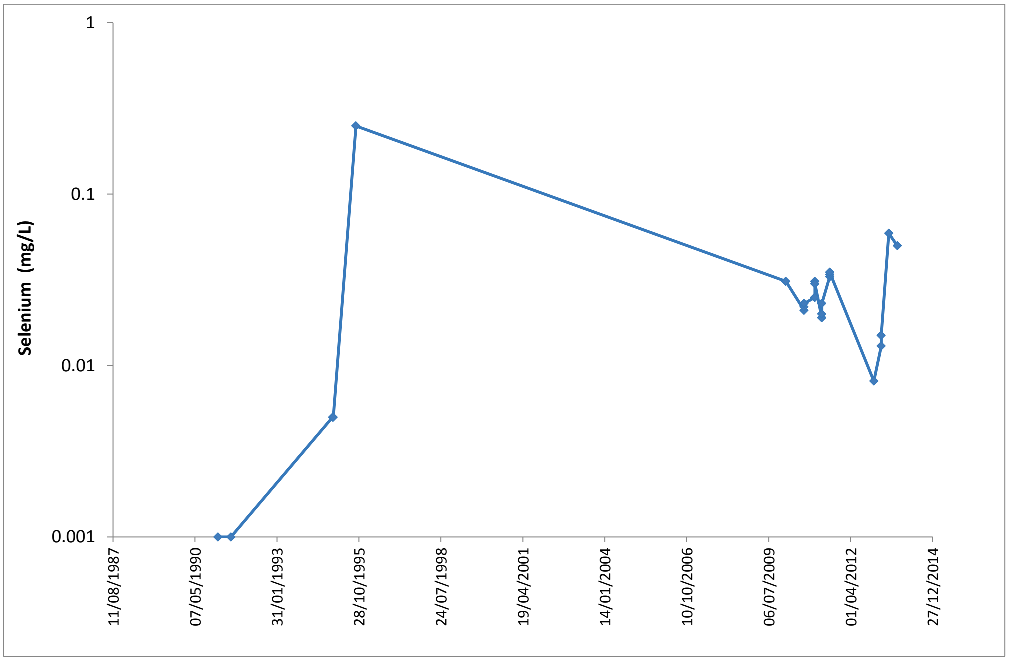

Figure D-7: Selenium Trends in Existing Pit Lake

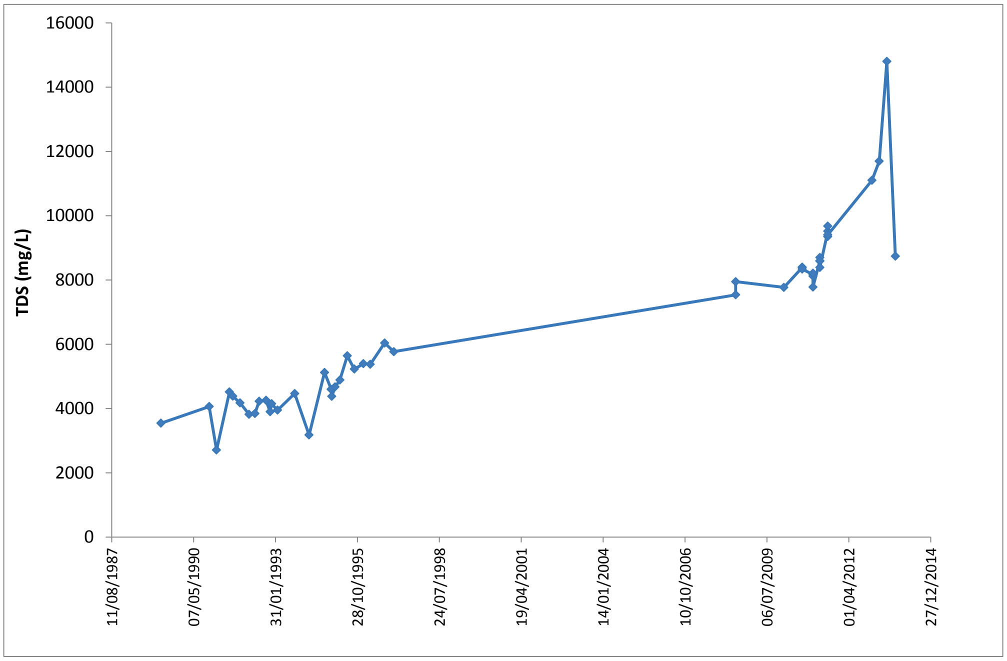

Figure D-8: TDS Trends in Existing Pit Lake

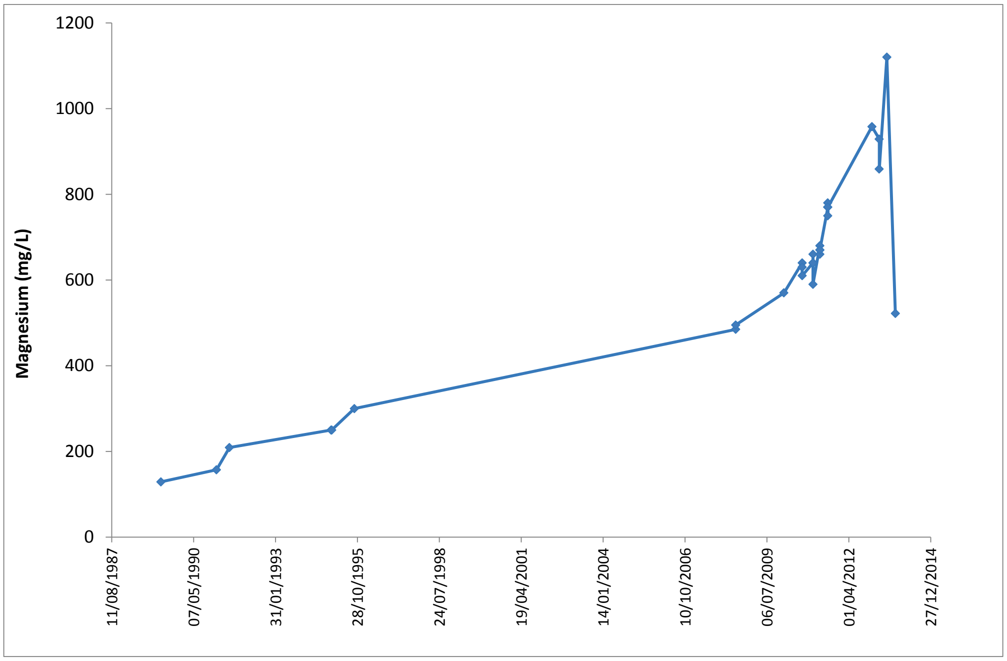

Figure D-9: Magnesium Trends in Existing Pit Lake

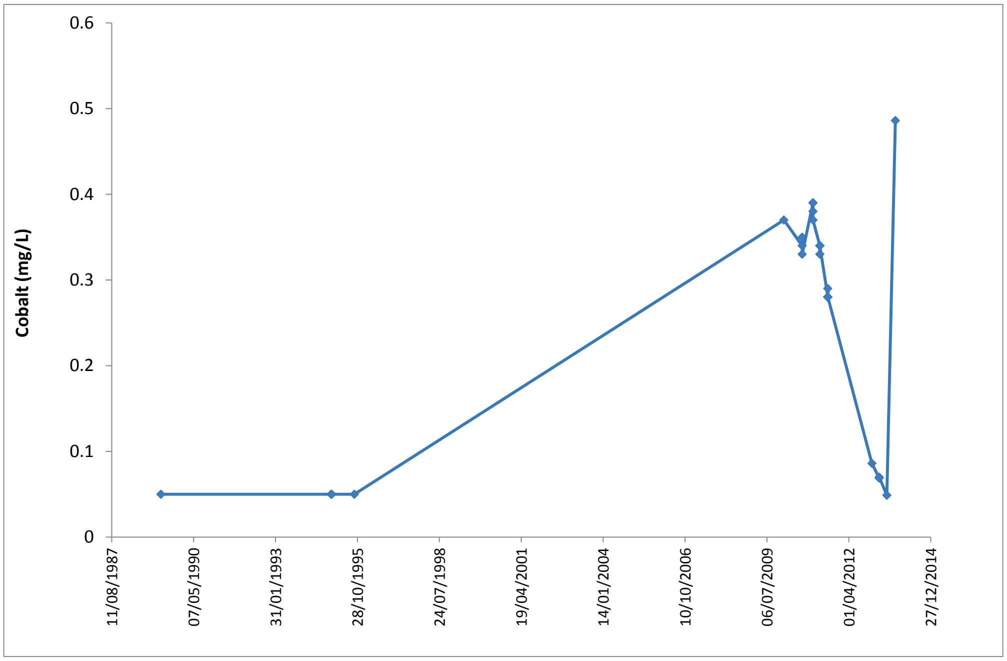

Figure D-10: Cobalt Trends in Existing Pit Lake

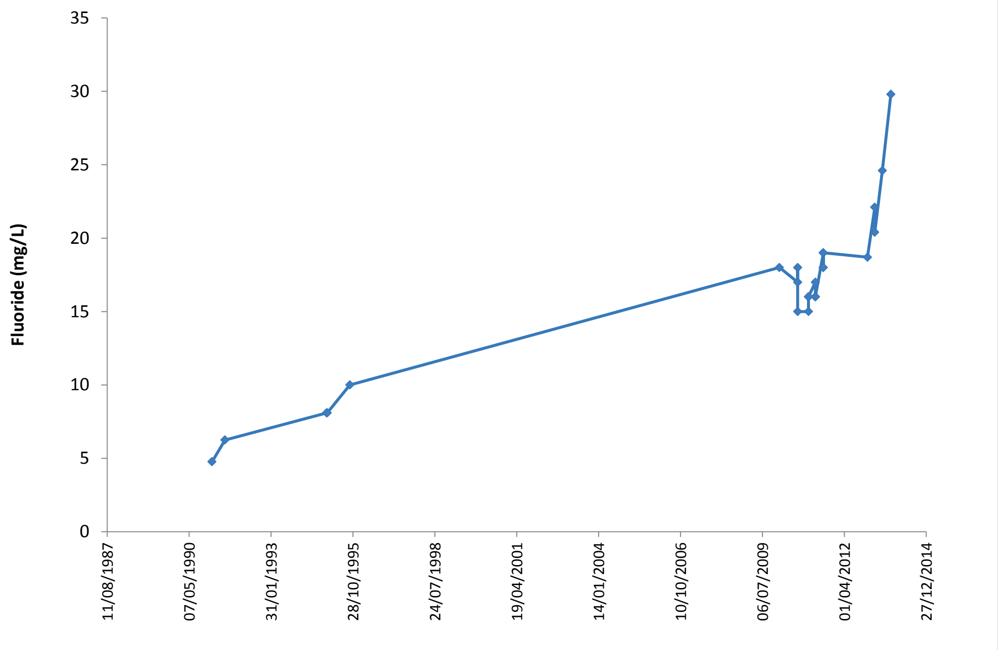

Figure D-11: Fluoride Trends in Existing Pit Lake

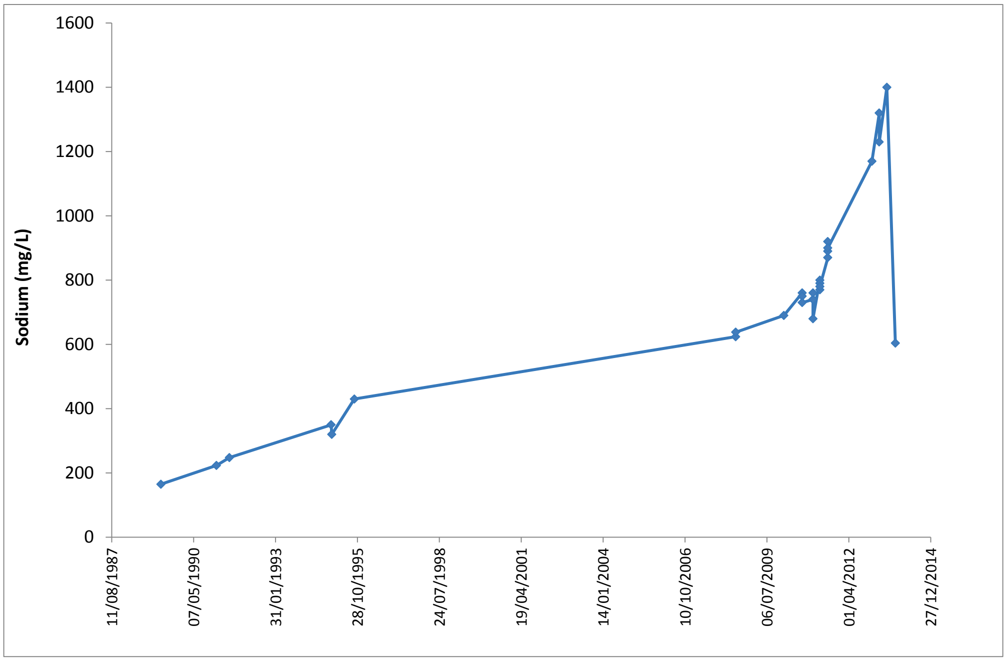

Figure D-12: Sodium Trends in Existing Pit Lake

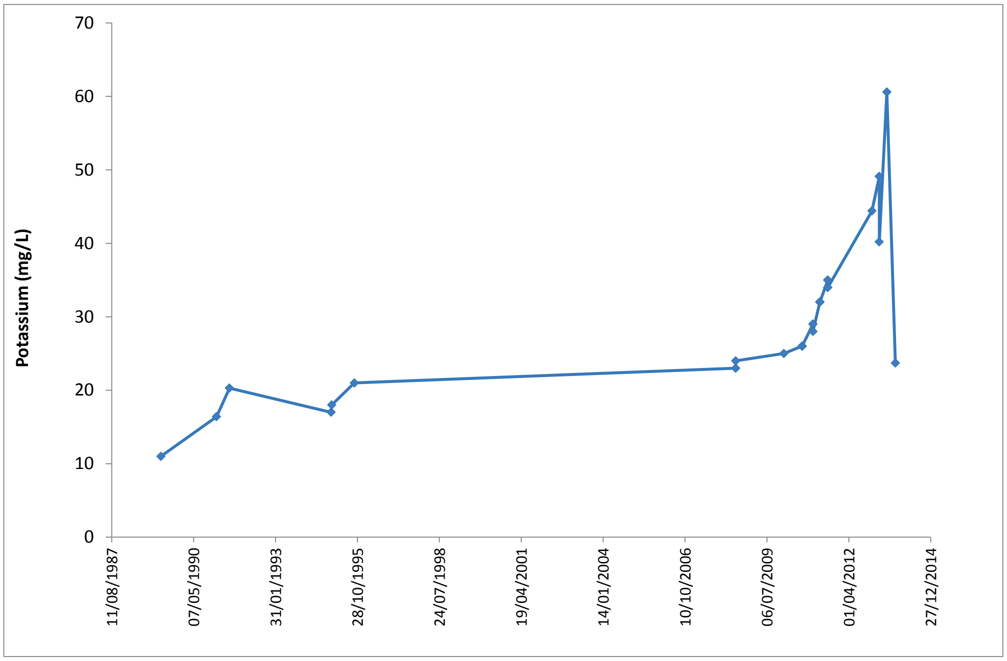

Figure D-13: Potassium Trends in Existing Pit Lake

Appendix E – PHREEQC output file (electronic)

Appendix F – Evaluation of Mercury as COC for Copper Flat Pit Water

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TECHNICAL MEMORANDUM

To: Steve Raugust, New Mexico Copper Corporation
Katie Emmer, New Mexico Copper Corporation

From: Steven T. Finch, Jr., Principal Hydrogeologist-Geochemist, JSAI

Date: June 30, 2014

Subject: **Evaluation of mercury as a COC for Copper Flat pit water**

John Shomaker & Associates, Inc. (JSAI) has reviewed the report "*Predictive Geochemical Modeling of Pit Lake water quality at the Copper Flat Project, New Mexico*" (SRK, September 2013), the supporting report "*Geochemical Characterization report for the Copper Flat Project, New Mexico*" (*SRK*, May 2013), and Stage 1 abatement data to determine if mercury is a potential contaminant of concern for the existing and future pit water at the Copper Flat mine.

The following review comment for the SRK pit lake geochemistry report was provided by the New Mexico Environment Department (NMED):

1. Executive Summary (Page vi) – More detail should be provided on why the predicted exceedance of mercury does not represent a true ecological risk to wildlife.

SRK Draft Response: *The assumption that mercury is unlikely to represent a true ecological risk for wildlife uses was based on the fact that predicted mercury concentrations are only marginally elevated above the NMAC 20.6.4900 guideline. However, the model predicted concentrations of mercury are an artifact of the model inputs and scaling factor, and as a result over-predicted.*

JSAI Draft Response: The only model-simulated input for mercury is from the source terms for the pit wall material (Table 3-3), with values for the HCT effluent testing ranging from 0.00001 to 0.000005 mg/L. It was assumed that mercury detections in the HCT samples would be scaled with the other constituents. However, it may not be representative to scale up detectable traces of mercury because there is no source mineral in the ore body and concentrations in the HCT testing do not significantly vary (see Fig B-6). Furthermore, the NMWQCC surface water standard for wildlife is 0.00077 mg/L, which is near or below the detection limit for the input data. For these reasons, mercury does not provide an ecological risk.

SUPPORTING DATA AND BACKGROUND INFORMATION

Background information includes mineralogical characterization of the ore body, laboratory analysis of pit water, surface water and surrounding groundwater, geochemical analysis of salt rind from the existing pit, and SRK HCT testing results.

Mineralogy of Ore Body

Mercury is known to occur as HgS (Cinnabar), and as a trace constituent in some sulfides and sulfosalts. Cinnabar has not been identified with the Copper Flat Deposit (McLemore, 2001), nor does the ore deposit have sulfosalts such as tennantite.

Whole Rock Analysis of Open Pit Salts

Mercury can also be adsorbed onto iron hydroxides and other mineral surfaces. Whole rock analysis of the salt rim that has formed around the existing pit resulted in non detection (<0.0057 mg/kg) of mercury. The lab analysis is attached. The Salt rim is mostly composed of gypsum with iron and aluminum oxyhydroxides. If mercury were present in the pit water, it should have been detected in the salt residue if it was adsorbed onto the oxyhydroxides.

Water-Quality Analyses

Laboratory water quality analysis for mercury has been performed on samples from open pit water, surface water runoff above (SWQ-1) and below (SWQ-2 and SWQ-3) the pit, and from monitoring wells adjacent to the pit. Attached Tables 1, 2, and 3 summarize the results; mercury was not detected in any of the samples.

Laboratory method detection limits vary, but are most commonly 0.001 and 0.0002 mg/L mercury. The samples with a detection limit of 0.0002 mg/L should be used to compare to the NMED surface water standard of 0.0077 mg/L for wildlife uses. Many of the sample points that were analyzed with a detection limit of 0.001 mg/L were also analyzed using a method with 0.0002 mg/L detection limit.

Geochemical Characterization (HCT testing)

SRK pit lake geochemistry report figure B-6 shows the results of the humidity cell effluent for mercury. Most of the samples tested show mercury below detection (0.000075 mg/kg) in the effluent. Two detections occurred: 1) a few samples during the first five weeks (<0.0003 mg/kg), and 2) two samples at about 90 weeks into the testing. The few, inconsistent, detections of mercury, and the low reporting concentrations suggest the detections could also be attributed to sample or lab error.

Mercury inputs into the geochemistry model included:

- Solution 11, Quartz Monzonite, at 0.000011 mg/L
- Solution 12, coarse chrystalline porphyry, at 0.000019 mg/L
- Solution 13, undefined material, at 0.000009 mg/L

These inputs are then scaled as part of the model calibration. The runoff mix scaling factor for Solution 11 is 102.3, results in a solution concentration of 0.001125 mg/L. Surface water samples SWQ-2 and SWQ-3 from below the existing waste rock facility had below detection mercury concentrations (Table 2). SWQ-2 and SWQ-3 should be analogous to model simulated runoff mix to the pit because quartz monzonite covers the largest area of the pit shell, and storm water is the largest component of inflow.

Model Results

The observed Mercury value for the existing pit water is <0.0002 mg/L, where the SRK geochemistry model calibrates to a value of 0.001 mg/L. Model simulated mercury concentrations appear to be at least an order of magnitude too high. Mercury is mentioned as a potential concern, but the result is acknowledged to be a model artifact. Model artifacts should not be presented as conclusions.

The lack of detected mercury in the existing pit water, surface water runoff from the existing waste rock piles, and groundwater are evidence that mercury should not be a constituent of concern for the future pit water.

Table 1. Summary of mercury results from Copper Flat open pit water

sample location	collection date	mercury (mg/L)
pit wall seepage	8/19/2010	<0.001
PL-WQ	7/19/1991	<0.0002
PL-WQ	12/12/1994	<0.001
PL-WQ	12/19/1994	<0.001
PL-WQ	9/21/1995	<0.001
PL-WQ (0 ft)	1/30/2010	<0.0002
PL-WQ-01 (28 ft)	9/10/2010	<0.0002
PL-WQ-03 (3 ft)	9/10/2010	<0.0002
PL-WQ-04 (comp)	9/10/2010	<0.0002
PL-WQ-05 (7ft)	1/20/2011	<0.0002
PL-WQ-06 (17 ft)	1/20/2011	<0.0002
PL-WQ-07 (26 ft)	1/20/2011	<0.0002
PL-WQ-08 (comp)	1/20/2011	<0.0002
PL-WQ-09 (1 ft)	4/14/2011	<0.0002
PL-WQ-10 (3 ft)	4/14/2011	<0.0002
PL-WQ-11 (16 ft)	4/14/2011	<0.0002
PL-WQ-12 (comp)	4/14/2011	<0.0002
PL-WQ-13 (2 ft)	7/20/2011	<0.0002
PL-WQ-14 (11 ft)	7/20/2011	<0.0002
PL-WQ-15 (23.5 ft)	7/20/2011	<0.0002
PL-WQ-16 (comp)	7/20/2011	<0.0002

Table 2. Summary of mercury results from Copper Flat surface water

sample location	analysis date	mercury (mg/L)
SWQ-1	12/28/1982	<0.001
SWQ-1	2/21/1983	<0.001
SWQ-1	4/1/1993	<0.001
SWQ-2	2/25/1982	<0.001
SWQ-2	5/12/1982	<0.001
SWQ-2	2/21/1983	<0.001
SWQ-2	5/13/1983	<0.001
SWQ-2	8/9/1983	<0.001
SWQ-2	11/1/1983	<0.001
SWQ-2	12/23/1983	<0.001
SWQ-2	3/16/1984	<0.001
SWQ-2	5/30/1984	<0.001
SWQ-2	9/12/1984	<0.001
SWQ-2	11/27/1984	<0.001
SWQ-2	7/19/1991	<0.0002
SWQ-2	3/31/1993	<0.001
SWQ-2	8/25/2010	<0.0002
SWQ-2	4/28/2011	<0.0002
SWQ-2A	10/27/1981	<0.001
SWQ-2A	2/25/1982	<0.001
SWQ-3	7/19/1991	<0.0002
SWQ-3	3/31/1993	<0.001
SWQ-3	8/19/2010	<0.0002
SWQ-3	10/21/2010	<0.0002
SWQ-3	4/27/2011	<0.033

Table 3. Summary of mercury results from Copper Flat groundwater

sample location	analysis date	mercury (mg/L)
GWQ96-22A	7/13/1996	<0.001
GWQ96-22A	4/9/1997	<0.001
GWQ96-22A	1/30/2010	<0.0002
GWQ96-22A	7/1/2010	<0.0002
GWQ96-22A	10/7/2010	<0.0002
GWQ96-22A	7/9/2013	0.000004
GWQ96-22B	7/13/1996	<0.001
GWQ96-22B	10/7/2010	<0.0002
GWQ96-22B	7/9/2013	0.000003
GWQ96-23A	7/14/1996	<0.001
GWQ96-23A	4/9/1997	<0.001
GWQ96-23A	1/30/2010	<0.0002
GWQ96-23A	7/1/2010	<0.0002
GWQ96-23A	10/6/2010	<0.0002
GWQ96-23A	5/12/2011	<0.0002
GWQ96-23A	7/9/2013	0.0000009
GWQ96-23B	7/14/1996	<0.001
GWQ96-23B	10/6/2010	<0.0002
GWQ96-23B	5/12/2011	<0.0002
GWQ96-23B	7/9/2013	0.000001

Analytical Report

Lab Order: **1404C35**

Hall Environmental Analysis Laboratory, Inc.

Date Reported: **5/6/2014**

CLIENT:	John Shomaker & Assoc.	**Client Sample ID:**	Copper Flat Open Pit
Project:	NMCC/Open Pit	**Collection Date:**	4/30/2014 9:00:00 AM
Lab ID:	1404C35-001A	**Matrix:**	Soil

Analyses	Result	MDL	RL	Qual	Units	DF	Date Analyzed	Batch ID
EPA METHOD 7471: MERCURY							Analyst: **JML**	
Mercury	ND	0.0057	0.034		mg/Kg	1	5/1/2014 5:03:06 PM	12968
EPA METHOD 6010B: SOIL METALS							Analyst: **TES**	
Aluminum	2330	4.91	29.2		mg/Kg	10	5/5/2014 11:32:55 AM	12987
Arsenic	ND	1.57	2.44		mg/Kg	1	5/5/2014 11:17:35 AM	12987
Cadmium	ND	0.0497	0.0974		mg/Kg	1	5/5/2014 11:17:35 AM	12987
Calcium	85700	417	1220		mg/Kg	50	5/5/2014 11:34:44 AM	12987
Copper	419	2.89	2.92		mg/Kg	10	5/5/2014 11:32:55 AM	12987
Iron	6270	40.0	48.7	B	mg/Kg	50	5/5/2014 11:34:44 AM	12987
Magnesium	173	1.46	24.4		mg/Kg	1	5/5/2014 11:17:35 AM	12987
Manganese	777	0.272	0.974		mg/Kg	10	5/5/2014 11:32:55 AM	12987
Potassium	179	12.2	48.7		mg/Kg	1	5/5/2014 11:17:35 AM	12987
Selenium	ND	1.31	2.44		mg/Kg	1	5/5/2014 11:17:35 AM	12987
Sodium	42.8	1.74	24.4		mg/Kg	1	5/5/2014 11:17:35 AM	12987
Vanadium	1.66	0.439	2.44	J	mg/Kg	1	5/5/2014 11:17:35 AM	12987

Refer to the QC Summary report and sample login checklist for flagged QC data and preservation information.

Qualifiers:

*	Value exceeds Maximum Contaminant Level.	B	Analyte detected in the associated Method Blank
E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
J	Analyte detected below quantitation limits	ND	Not Detected at the Reporting Limit
O	RSD is greater than RSDlimit	P	Sample pH greater than 2.
R	RPD outside accepted recovery limits	RL	Reporting Detection Limit
S	Spike Recovery outside accepted recovery limits		