

# Geochemical Characterization Report for the Copper Flat Project, New Mexico

## Volume 1 - Text

Report Prepared for

**THEMAC Resources Group Ltd.**



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SRK Consulting (U.S.), Inc.  
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# **Geochemical Characterization Report for the Copper Flat Project, New Mexico**

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## Executive Summary

SRK has conducted a mine waste characterization program for the Copper Flat project, New Mexico. The geochemical testing of mine waste materials provides the characterization required to determine the potential for Acid Rock Drainage and Metal Leaching (ARDML) from mining facilities. This information allows for a quantitative risk assessment and evaluation of the options for design, construction and closure of the tailings and waste rock disposal facilities in addition to allowing assessment of potential water quality from mine waste facilities during operations and closure or potential water quality of a future pit lake that may form.

The Copper Flat mine waste characterization program was designed to investigate the potential for ARDML due to exposure and oxidation of sulfide minerals, such as pyrite, that are unstable under atmospheric conditions. Upon exposure to oxygen and water, sulfide minerals will oxidize, releasing metals, acidity and sulfate. SRK's geochemical characterization investigated the potential for rock that will be exposed in the Copper Flat waste rock disposal facility and pit walls to generate acid and leach deleterious constituents when exposed to the atmosphere.

For this investigation a total of 112 sample intervals were selected from exploration core holes drilled within the proposed pit boundaries in 2009, 2010 and 2011. Samples were selected to represent the range of waste rock and ore material types that will be encountered during mining. To augment the data set and to assess how historic mining wastes have weathered over time, an additional 24 surface grab samples were also collected from existing waste rock facilities onsite as analogs of future weathered materials. The resulting sample dataset is considered spatially representative (both vertically and horizontally) of the main material types identified for the Copper Flat deposit from the current mine plan. As part of the characterization program, testing of 12 samples of test residues from the metallurgical program (representative of tailings associated with the project) has also been completed to assess the likely long-term leachate chemistry from the tailings storage facility.

The static test methods used for the SRK 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 the concentrations 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 has also been 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 have been used in quantitative numerical predictions to assess the potential future leachate chemistry associated with the mine facilities, specifically the waste rock disposal facility (WRDF) and tailings storage facility (TSF).

## Potential for Acid Generation

Testwork results indicate the acid generating potential of the Copper Flat materials 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% in the transitional waste material. Transitional waste is defined as partly oxidized material that still contains some sulfide mineral content. The ABA and NAG testwork results indicate that the transitional waste and transitional ore material types are likely to be potentially acid forming based on generally higher sulfide mineral contents and presence of secondary oxide minerals that have formed as a result of supergene weathering. However, the majority of waste rock (~96%) produced by the project will consist of sulfide (i.e., non-oxidized) Quartz Monzonite/Breccia waste, which typically exhibited either non-acid forming characteristics or a low potential for acid generation based on NAG and ABA testwork results.

Sulfide minerals at Copper Flat were found to be frequently encapsulated in a quartz matrix or occasionally in potassium feldspar. Both of these silicate minerals have slow weathering characteristics and will only weather on geological time scales (i.e., thousands of years or more). Consequently a portion of the sulfide in the materials is unlikely to be available for reaction and thus ABA methodologies with quantitative analysis will over-estimate reactive acidity in comparison to test methods such as NAG or HCT that provide more empirical estimates of long-term field reactivity. These methods require physical exposure of the sulfides to chemically react with oxygen, water or hydrogen peroxide in the case of NAG tests. Furthermore, the sulfide minerals in the Copper Flat deposit are crystalline and often coarse grained (visible to the naked eye) so would have slow weathering reaction kinetics. It is likely that the sulfide waste and ore materials will offer some limited silicate buffering (neutralizing) capacity; although this is unlikely to be high magnitude, it may buffer pH.

The transitional waste and ore materials show the greatest potential for acid generation from the static and kinetic test results. This is related primarily to the dissolution of secondary oxide minerals within the material that formed as a result of supergene enrichment. However, acid generation from this material may also result from the continued oxidation of sulfide minerals within the transitional material under field conditions. The reactivity of the transitional material varies as demonstrated by the HCT program, which most likely relates to variation in the degree of sulfide content and encapsulation.

Although static testwork results indicate the transitional material is potentially acid forming, this material represents a small percentage of the existing waste material and will comprise only a small proportion (<4%) of material encountered during mining. Furthermore, the results of the HCT program demonstrated that the only cell to show truly acidic conditions consisted of transitional material. The remaining cells were non-acid generating after more than 95 weeks of testing. It is important to state that some of the HCTs for this project have been run appreciably longer than the typical regulatory requirement of 20 to 40 weeks in order to confirm long-term geochemical behavior of the material.

## Potential for Metal Leaching

The Copper Flat waste rock and ore materials were found to be enriched in copper, sulfur and molybdenum, which relates to the primary mineralization (predominantly chalcopyrite -  $\text{CuFeS}_2$  with some molybdenite –  $\text{MoS}_2$ ). Silver, arsenic, cadmium, lead, selenium, thallium, uranium, tungsten and zinc were also found to be elevated 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 leach 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 rates were also assessed from the results of the ongoing HCT program. 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. 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 supergene oxidation of the material, which has been enhanced by weathering under site conditions. However, for the Copper Flat deposit, the supergene oxide zone is thin and has been mostly removed by geological processes (i.e., erosion) or previous operations. Therefore, this material type will not comprise a significant percentage of the material encountered during mining.

## Conclusions and Recommendations

### Waste Rock

Acid generation is not predicted for most unweathered waste rock materials during operations; however, grab samples collected from the surface of the existing waste rock dumps and pit walls indicate the potential for acid generation from material mined by previous mining operations and exposed to natural weathering conditions. During proposed operations, specific controls will be needed to collect stormwater runoff from the WRDF. In addition, stormwater diversions will be required to prevent runoff.

Results of geochemical predictive modeling indicate that WRDF source term solutions are likely to be moderately alkaline (~pH 8.2) with metal(loid) concentrations that are below New Mexico Water Quality Control Commission (NMWQCC) standards for groundwater. Covering the waste rock disposal facility (WRDF) with a revegetated 36-inch store-and-release soil cover (or approved equivalent) at the end of mine life will reduce infiltration of water and flux of oxygen into the facility, which will limit oxidation of sulfide minerals.

Migration of seepage away from the WRDF is expected to be very small (or nil) as a result of the low permeability andesite underlying the facility. However should any seepage make its way to the underlying water table, the impact to groundwater chemistry is expected to be minimal. With the

exception of fluoride, all parameters are predicted to be below NMWQCC in groundwater underlying the facility. However, the fluoride concentrations are related to the elevated concentrations of this parameter in the background groundwater rather than as a result of impact from WRDF seepage. Furthermore, if any drainage water migrates away from the WRDF it is likely that there will be some adsorption and attenuation of metal(loids) in the underlying andesite. Although this is beyond the scope of the current modeling exercise, it is likely that these processes will reduce elemental concentrations of fluoride prior to any WRDF seepage reaching the underlying groundwater. As such, the potential impact to groundwater is likely to be minimal, particularly given the low permeability of the andesite material.

## Tailings

Tailings samples collected as part of the characterization program generally show low potential for ARDML generation. Covering of the tailings storage facility (TSF) with a revegetated 36-inch store-and-release soil cover (or approved equivalent) at the end of mine life will minimize ingress of oxygen and water into the facility, thus preventing oxidation of residual sulfide minerals within the tailings. Furthermore, the tailings facility will be lined with a synthetic liner, which will preclude the migration of seepage away from the tailings impoundment.

During the initial years post-closure, solution chemistry at the toe of the TSF is likely to be dominated by the draindown of entrained process waters. During this period, solutions are predicted to be moderately alkaline (pH 8.2) due to contained lime within the process solutions and sulfate concentrations below 200 mg/L. Once these entrained process waters have drained down (i.e., removed from the system), any meteoric water infiltrating the facility will interact with the non-saturated tailings. It is estimated that approximately 2% of annual precipitation may infiltrate the cover system and interact with the tailings. However, the volumes of seepage from the TSF will be so low (<0.25 gallons/acre/day) that impacts to groundwater are likely to be negligible and the modeled results show that the predicted groundwater chemistry is likely to be similar to existing groundwater chemistry. Furthermore, the use of the historic tailings as a bedding material for the new, lined tailings facility will effectively isolate this material from reaction. As such, groundwater chemistry under the TSF is likely to improve over time, as the sulfate source from the historic tailings will effectively be removed.

## Pit Lake

Additional numerical predictions have also been carried out to assess potential future water quality in the pit lake that will form in the final mined pit. These numerical predictions have been undertaken to evaluate any potential environmental effects of future pit water quality and are presented in a separate report.

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# 1 Introduction

## 1.1 Purpose and Scope

SRK Consulting, Inc. (SRK) has undertaken a geochemical characterization study to assess the Acid Rock Drainage and Metal Leaching (ARDML) potential of the Copper Flat project, New Mexico. The primary purpose of this investigation is to provide an understanding of the geochemical characteristics of geological materials specific to the Copper Flat deposit and to define the potential for waste rock, ore and tailings material to generate acid and/or leach deleterious constituents. This includes an assessment of potential leachate chemistry associated with the waste rock and tailings facilities in addition to a prediction of future potential pit lake chemistry. In order to accomplish the objectives of the study, samples representative of the deposit were collected and characterized following guidelines set forth in the *Bureau of Land Management Instruction Memorandum NV-2010-014, Nevada Bureau of Land Management Rock Characterization Resources and Water Analysis Guidance for Mining Activities* (BLM, January 8, 2010). This report details the sample collection and laboratory testwork procedures undertaken as part of the geochemical characterization study, summarizes the findings of the static and kinetic geochemical testwork and presents the results of numerical predictions undertaken to assess potential future water quality associated with the mine facilities (waste rock and tailings facilities). The findings of the geochemical predictions for the future pit lake are presented in a separate report.

The following activities have been completed as part of the current geochemical characterization program:

- Review of site geology and identification of the primary material types;
- Collection of drill core samples representative of waste rock and ore;
- Collection of surface grab samples from existing waste rock dumps, pit walls and tailings impoundment;
- Collection of test residues from metallurgical testing that are representative of tailings material associated with the project;
- Static and kinetic laboratory testing of selected waste rock, ore and tailings samples;
- Comparison of results from the current (2010 to 2012) geochemical characterization program with the previous studies carried out in 1995 to 1997; and
- Quantitative numerical predictions to assess future potential leachate chemistry associated with the mine facilities (tailings and waste rock disposal facilities).

The two main considerations of this baseline environmental geochemical characterization are:

- Acid generation due to oxidation of sulfide minerals, which can potentially lead to development of Acid Rock Drainage (ARD); and
- Potential for leaching of metals (e.g., manganese) and salts (e.g., sulfate).

The processes of acid generation and leaching can operate independently, although the development of acidic conditions enhances the leachability of many metals. To address this, an extensive characterization program has been completed to define the geochemical characteristics of the waste rock, ore and tailings in terms of their potential to generate acid and leach metals.

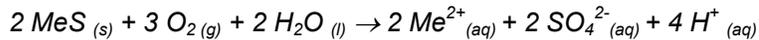
## 1.2 Theory of Acid Rock Drainage and Metal Leaching

Acid Rock Drainage and Metal Leaching (ARDML) refers to the generation of acidic, metal- and sulfate-rich waters that result from the weathering of sulfide minerals (particularly pyrite/ marcasite – FeS<sub>2</sub>) under oxidizing conditions. The process may occur naturally in sulfide-bearing rock strata, but is commonly accelerated by mining activity, which increases the likelihood of exposure of sulfide minerals to air and water, effectively accelerating natural weathering processes.

The general equation for pyrite oxidation is summarized below,



However, the equation can also be written for general metal sulfides as:



*Metal sulfide + Air + Water → Mobilized metal + Salts + Acidity*

The primary sulfide mineralization of the Copper Flat deposit contains both chalcopyrite and pyrite. As such, there is the potential for ARDML generation to occur both during mining operations and post-closure. The net effect of sulfide oxidation is the potential to increase the loading of metals, sulfate and acidity in the receiving environment. Although this is unlikely to cause an impact at low levels, at high concentrations there is the potential for significant impact to water and the surrounding environment.

Oxidation of ferrous iron and hydrolysis of ferric iron at pH > 2 provide the additional source of acidity through the reactions:



For each mole of pyrite oxidized, only a portion of the available hydrogen is released. The rest is stored as partly oxidized metal-sulfate minerals. These minerals are highly soluble so can represent an instantaneous source of acidic, metal sulfate-rich water upon dissolution and hydrolysis, for example the dissolution of melanterite:



The ability of a mineral to react with water will depend on its solubility under specific hydrogeochemical conditions. In arid environments such as Copper Flat, these minerals can represent an important source of potential acidity and metal release in partially oxidized material. Hence these minerals are important as both potential sinks and sources of acidity in the rocks, sulfate and possibly metal ions on precipitation and rapid release on exposure to moisture (Nordstrom, 1982; Cravotta, 1994; Bowell et al., 1996).

Copper Flat is unusual as a porphyry deposit in that it contains appreciable calcite content (up to 4%) as well as base cation silicates that can also participate in acid neutralization such as chlorite (SRK 2012). Acid-neutralization reactions result from water-mineral reactions and buffering of acidity (H<sup>+</sup> ions) in drainage. This buffering is frequently accompanied by the precipitation of secondary minerals (Kwong and Ferguson, 1997; Lawrence and Wang, 1997; Nordstrom and Alpers, 1999). These reactions can reduce acid generation by forming an inhibitory surface coating on the reactive sulfides and acid-forming partly oxidized metal-sulfate minerals.

Carbonate minerals are the most active neutralization component in the deposit and these minerals (e.g., calcite, dolomite and malachite) readily dissolve under acidic conditions to provide bicarbonate

alkalinity, which results in neutralization of acid and precipitation of metal hydroxides. The order of carbonate neutralizing capacity is:

calcite>dolomite>malachite=ankerite>siderite.

In the case of siderite and, to a lesser extent ankerite, the reason for the limited neutralizing capacity is that ferrous iron in these minerals are an additional potential source of acidity due to the strong hydrolysis of the resulting ferrous iron in solution and for malachite, copper is produced that forms soluble copper-carbonate complexes in preference to carbonic acid or bicarbonate. This order of reactivity is partly controlled by equilibrium mass-action constraints and partly by kinetic limitations (Morse, 1983).

Carbonate minerals (especially calcite) have often erroneously been thought of as the only geologic source of Neutralization Potential (NP). However, carbonates dominate only limestone, dolomite and marble rock types while the majority of geologic materials are composed of silicates and hydroxide-oxide minerals. The weathering of silicate minerals (e.g. feldspars and amphiboles) as a proton sink has been demonstrated in previous studies (Sverdrup, 1990; Bhatti et al, 1994; Moss and Edmunds, 1992; Kwong and Ferguson, 1997). To assess the buffering capacity of mine wastes, silicate and hydroxide minerals therefore must also be considered. From soil acidification studies, Sverdrup (1990) divided the most common minerals into six groups according to pH dependency of their dissolution rate (Table 1-1).

From the relative weathering rates of the mineral groups shown (Table 1-1), minerals in the poor to negligible neutralizing categories are unlikely to react, due to their sluggish reaction rates. Even for minerals in the intermediate and fast mineral weathering groups, they will not be practical neutralizing materials unless they occur in excess of ~10% (Sverdrup, 1990).

The accumulation of solutes in solution will lead to saturation with respect to some species. Consequently in response to either saturation or destabilization as aqueous species, these compounds precipitate as secondary minerals such as arsenates, phosphates, carbonates, sulfates or hydroxides. An important control on the diversity of the precipitated mineral assemblage is pH. At low pH, oxyhydroxides, and sulfates are commonly the main precipitates while at higher pH other salts such as carbonates and hydroxides become more abundant. Some solutes can be attenuated through adsorption onto mineral surfaces, noticeably iron hydroxides and clays. This is the process of element binding at the mineral-solution interface and is pH dependent (Sigg and Stumm, 1980; Deng and Stumm, 1994). Many oxide surfaces change from being positively-charged at low pH (thus attracting anions) to negatively-charged at high pH (thus attracting cations).

**Table 1-1: Mineral groups according to neutralization potential (Sverdrup, 1990)**

Group Name	Typical minerals	Buffering pH range <sup>1</sup> (s.u.)	Approx. NP <sup>2</sup> range	Relative reactivity <sup>3</sup>
1.Dissolving	Calcite, aragonite, dolomite, magnesite, aragonite, portlandite and brucite	6 - 11.2	7.8-14.8	1.0
2.Fast weathering	Anorthite, nepheline, olivine, garnet, jadeite, leucite, clinocllore, spodumene, kutnahorite diopside, siderite and wollastonite	5.5 - 11	2.8-0.6.2	0.6
3.Intermediate weathering	Epidote, zoiste, enstatite, hyperthene, augite, hedenbergite, hornblende, glaucophane, tremolite, actinolite, anthophyllite, serpentine, chrysotile, talc, chlorite, biotite.	4.8 - 7.3	1.7-5.8	0.4
4.Slow weathering	Albite, oligoclase, labradorite, vermiculite, montmorillonite, manganite, goethite, gibbsite and kaolinite.	2.4 - 5.1	0.5-2.9	0.02
5.Very slow weathering	K-feldspar, ferrihydrite and muscovite	2.2 - 4.1	0.2-0.6	0.01
6.Inert	Quartz, hematite, rutile and zircon	3.3 - 3.5	<0.01	0.004

<sup>1</sup>buffering pH range evaluated by crushing 5g of pure mineral and mixing with 5mL of distilled water and left to react for 30 minutes. The pH of the distilled water was 3.4 s.u.

<sup>2</sup> NP range assessed as equivalent buffering potential of 10 g of pure mineral to calcite and titrated with hydrochloric acid. So for example, 10g of portlandite (Ca(OH)<sub>2</sub>) was found to have the equivalent capacity to neutralize HCl acid as 14.8g of calcite, whereas 10g of hornblende was required to buffer HCl acid to a similar pH to only 3.1g of calcite.

<sup>3</sup>Calculated from Sverdrup's equation (1990), see below and based on 100% mono-mineral sample

As water pH increases above 3 s.u., hydrous ferric oxides (HFO) may precipitate and ultimately crystallize to form goethite or other ferric hydroxides (Bigham, 1994). As pH increases, ferric hydroxide solubility tends to decrease with a minimum being around pH 6-7 su. At low pH, precipitated HFO tend to scavenge negatively charged oxyanions as the surface of the HFO is positively charged in the Helmholtz layer (Deng and Stumm, 1994). In low pH environments these HFO particles are usually colloidal sized and have a high reactivity proportional to their surface areas. As the pH increases and colloid particles aggregate as Fe-OH bonds become longer and more rigid due to the excess of hydroxyl molecules, the surface pH of the particles change and become negative. In the case of goethite this occurs at a pH between 6 and 9 (Hiemstra and van Riemsdijk, 1996). The point at which this occurs is termed the point of zero charge. As pH increases beyond the zero point of charge, the surface of the HFO becomes more negatively charged and particles tend to attract metallic cations and release any sorbed oxyanions.

Where seepage from waste dumps or tailings percolate through alluvium or rocks containing iron oxides or clays then chemical attenuation of trace elements may occur and as such present a passive form of water treatment. In circum-neutral to alkaline oxic environments, arsenic and selenium form species such as H<sub>n</sub>AsO<sub>4</sub><sup>-(3-n)</sup> and H<sub>n</sub>SeO<sub>4</sub><sup>-(2-n)</sup> respectively (Bowell, 1994). These show strong affinity in mildly acidic to neutral soils for attenuation and as such may be removed from seepage preferentially. At higher pH they do not form sparingly soluble solids and as such are mobilized. Conversely metallic cations are not adsorbed at low pH but as pH increases so too does attenuation by precipitation and adsorption mechanisms in the soil as they form strong metal-hydroxide affinity.

## **2 General Site Conditions**

### **2.1 Project Location**

Copper Flat is a porphyry copper/molybdenum deposit located in the Las Animas Mining District in Sierra County, New Mexico and is situated approximately 150 miles south of Albuquerque and approximately 20 miles southwest of Truth or Consequences (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 2-1.

### **2.2 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) (M3, 2012). 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 generally averages 10 to 15 miles per hour. Wind speeds in excess of 50 mph may occur as major storms pass through the area (M3, 2012).

### **2.3 Mine Plan**

The proposed project consists of an open pit mine, flotation mill, tailings storage facility (TSF), a waste rock disposal facility (WRDF), a low grade ore stockpile (LGOS) and ancillary facilities. The mine is expected to produce approximately 100 million tons of copper ore, 60 million tons of waste rock and 3 million tons of low grade copper ore during mine life, with extraction taking place by conventional truck and shovel methods. 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 25,000 tpd and an operational life of approximately 11 years is projected. The proposed layout of the mine facilities is shown in Figure 2-2.



Figure 2-1: Project Location



## 2.4 Geologic Setting and Mineralization

Copper Flat 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.

### 2.4.1 Regional Geology

The Copper Flat Mine lies within the Mexican Highlands portion of the Basin and Range Physiographic Province. It 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.

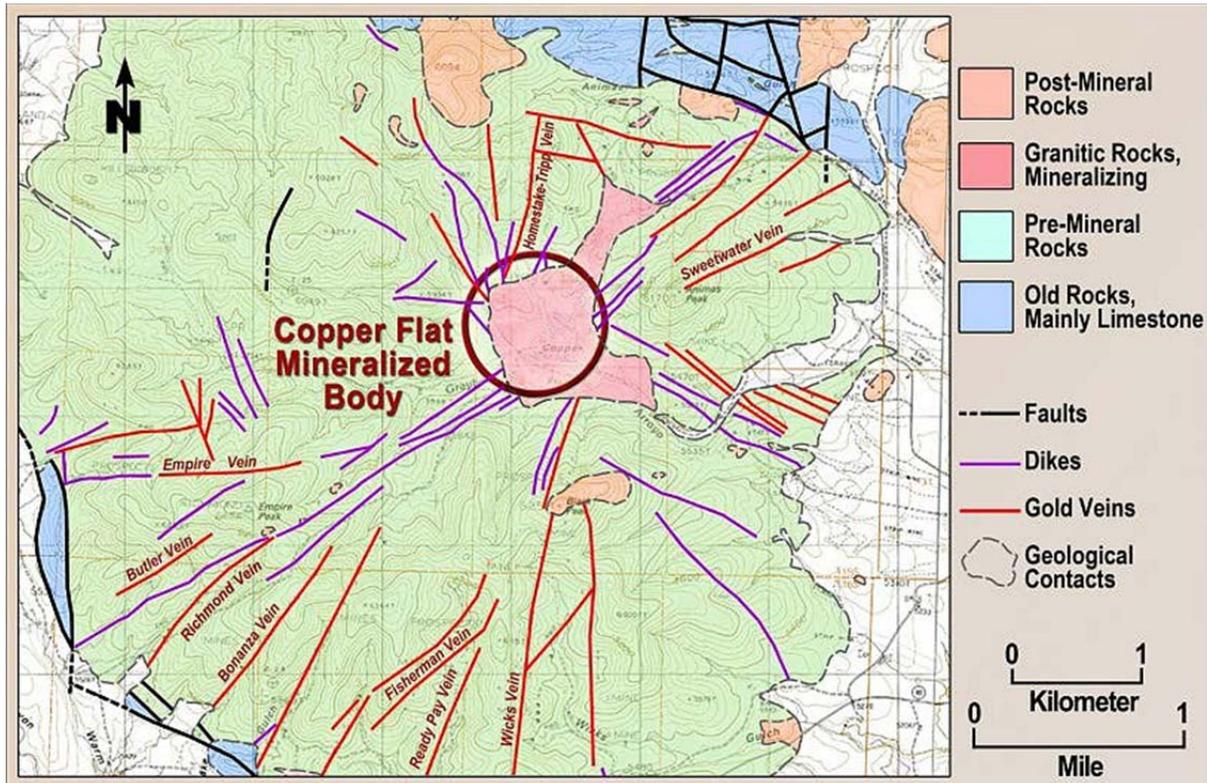
Basement rocks in the area consist of Precambrian granite and Paleozoic and Mesozoic sandstones, shales, limestones, and evaporites. Sedimentary units that crop out within the Animas Uplift include the Ordovician Montoya Limestone, the Silurian Fusselman Dolomite, and the Devonian Percha Shale. The Cretaceous-age 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.

### 2.4.2 Local Geology

The district geology described below is modified from Raugust (2003) and McLemore et al. (2000). 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 2-3). 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<sup>2</sup> and has been dated by the argon-argon (<sup>40</sup>Ar/<sup>39</sup>Ar) 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).



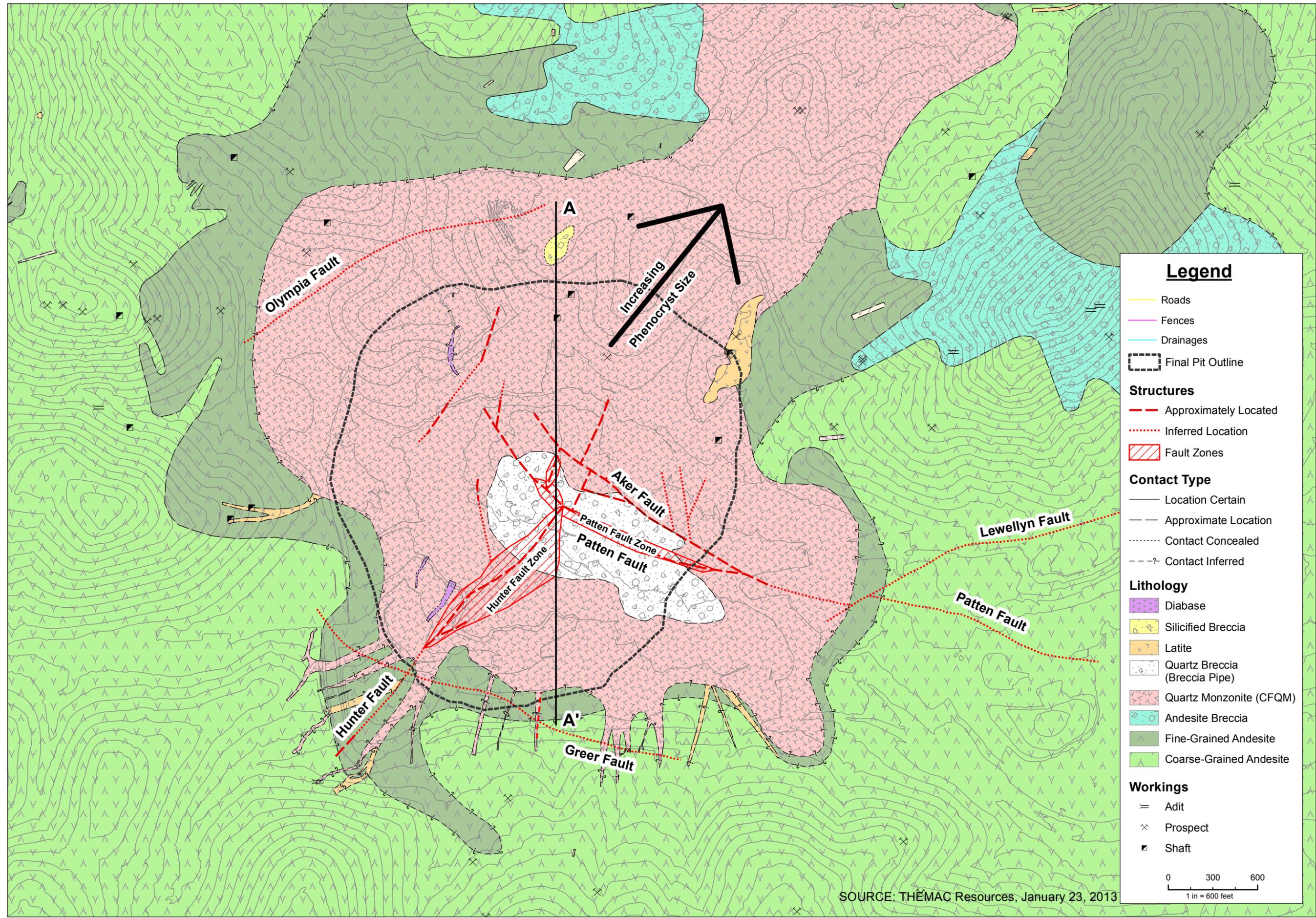
**Figure 2-3: Geology of the Copper Flat Mine (Dunn, 1982)**

### 2.4.3 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 2-4 and a south-north geologic cross section through the Copper Flat orebody is provided in Figure 2-5.

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 2-5).



SOURCE: THEMAC Resources, January 23, 2013

### Legend

- Roads
- Fences
- Drainages
- Final Pit Outline

### Structures

- Approximately Located
- Inferred Location
- Fault Zones

### Contact Type

- Location Certain
- Approximate Location
- Contact Concealed
- Contact Inferred

### Lithology

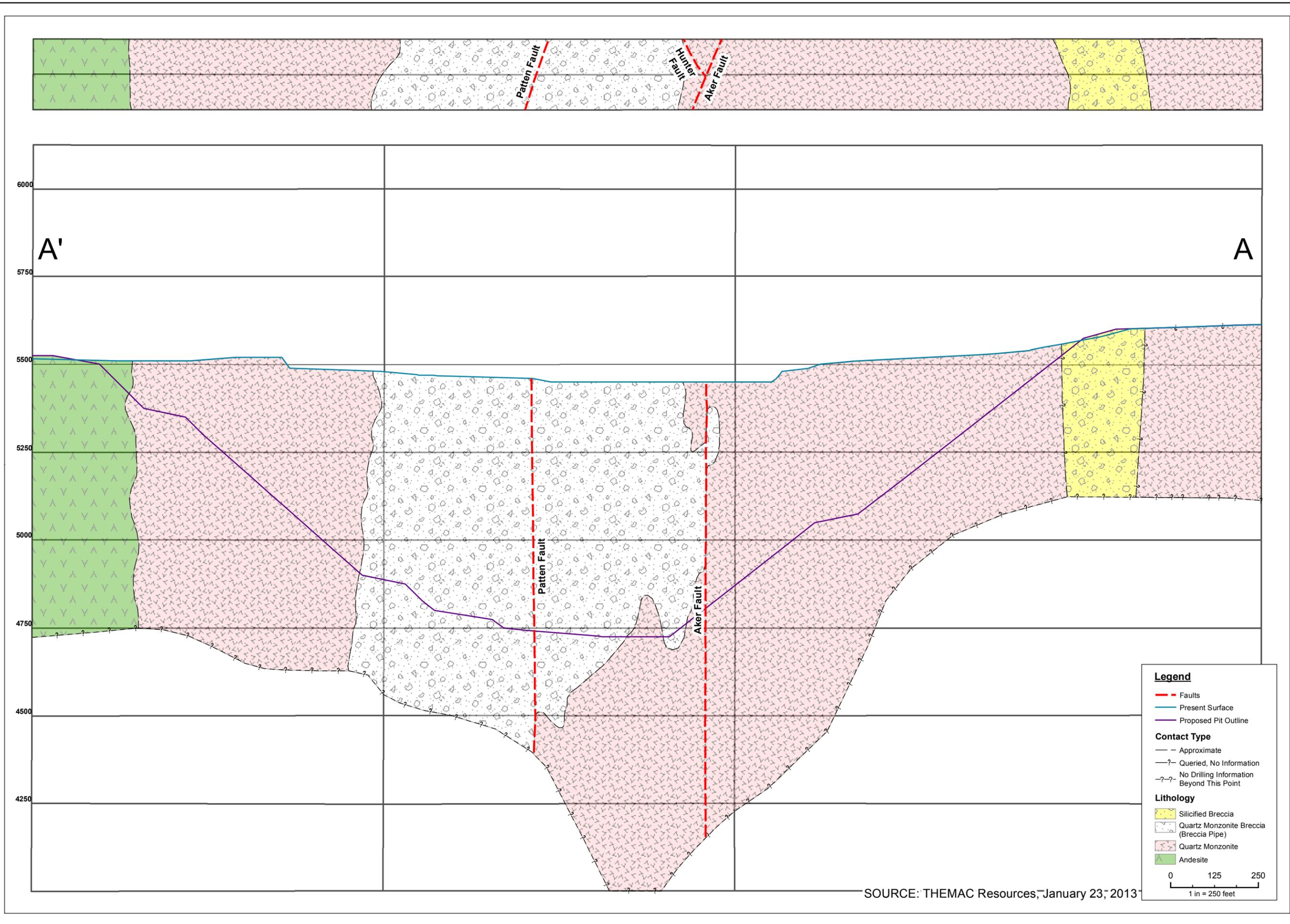
- Diabase
- Silicified Breccia
- Latite
- Quartz Breccia (Breccia Pipe)
- Quartz Monzonite (CFQM)
- Andesite Breccia
- Fine-Grained Andesite
- Coarse-Grained Andesite

### Workings

- Adit
- Prospect
- Shaft

0 300 600  
1 in = 600 feet

		PREPARED FOR: COPPER FLAT	
DRAWING TITLE: <b>DETAILED GEOLOGIC MAP          OF THE COPPER FLAT OREBODY</b>		PROJECT: <b>PERMITTING</b>	
DATE: 2/14/2013 SRK JOB #: 191000.03	DRAWING NO.: <b>FIGURE 2.4</b>	REV. NO.: <b>A</b>	FILE NAME: CopperFlat_GeologicMap_20130214.mxd
DESIGN: _____ DRAWN: _____ APPROVED: _____ COORDINATE SYSTEM: NAD 1983 UTM Zone 13N	REVIEWED: _____ CHECKED: _____	REVISIONS DESCRIPTION REV. _____ DATE _____	IF THE ABOVE BAR DOES NOT SCALE 1 INCH, THE DRAWING SCALE IS ALTERED



SOURCE: THEMAC Resources, January 23, 2013

<b>DRAWING TITLE:</b> GEOLOGIC CROSS SECTION THROUGH THE COPPER FLAT OREBODY		<b>REVISIONS</b> REV. DESCRIPTION DATE	
<b>PROJECT:</b> PERMITTING		PREPARED FOR: COPPER FLAT	
DATE: 2/20/2013 SRK JOB #: 191000.03	DRAWING NO.: FIGURE 2-5	REV. NO.: A	FILE NAME: CopperFlat_GeologicSection_20130214.mxd
<b>Legend</b> - - - Faults — Present Surface — Proposed Pit Outline <b>Contact Type</b> — Approximate - - Queried, No Information . . . No Drilling Information . . . Beyond This Point <b>Lithology</b> Silicified Breccia Quartz Monzonite Breccia (Breccia Pipe) Quartz Monzonite Andesite		DESIGN: REVIEWED: - DRAWN: CHECKED: - APPROVED: - COORDINATE SYSTEM: NAD 1983 UTM Zone 13N IF THE ABOVE BAR DOES NOT SCALE 1 INCH, THE DRAWING SCALE IS ALTERED	

## 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 (Figure 2-4). 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 (Figure 2-4). 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 on Figure 2-4.

### **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.

### **Geochemical Sample Descriptions**

NMCC's geochemical characterization program began in April of 2010 and some samples have been under analysis for more than two years. Therefore, in some cases, the lithologies identified for ore, waste rock, and tailings samples analyzed as part of the geochemical characterization program differ from the lithologies described in the geology section above. Table 2-1 provides a comparison of the previous rock classification and updates the rock lithologies from earlier interpretations to the current understanding.

Previous discussions on Copper Flat lithologies occurred in the Copper Flat BDR (INTERA, 2012) and an earlier version of this Geochemical Characterization Report (SRK, April 2012). Both of these reports were appended to the Copper Flat Permit Application Package submitted to the New Mexico Mining and Minerals Division in July 2012. From 2009 through 2012, NMCC conducted exploration drilling and mapping projects to evolve the geologic understanding of the ore body and surrounding areas. As a result, NMCC has simplified the lithological terminology. Generally, the fundamental rock classifications reported in the BDR and April 2012 Geochemical Characterization Report are still appropriate, but the distinctions between the rock types have been simplified and the contacts found to be more gradational as exemplified in the breccia type discussion above; biotite breccia and feldspar breccia are two types of quartz monzonite breccia (Figure 2-4; also referred to as the breccia pipe). Coarse crystalline porphyry (CCP) is a type of CFQM, representative of the increasing size of phenocrysts observed towards the northeast in the CFQM (Figure 2-4).

**Table 2-1: Terminology Cross Reference for Copper Flat Lithologies**

BDR Section 7 Terminology <sup>1</sup>	SRK Geochemical Characterization Terminology <sup>2</sup>	Geology Section in this Report	Comments
Biotite Breccia	Biotite Breccia	Quartz Monzonite Breccia	-
Quartz Breccia	Quartz Feldspar Breccia		-
-	K-Feldspar Breccia		-
Quartz Monzonite with potassic, argillic and/or meteoric alteration	-	Quartz Monzonite (CFQM)	-
-	Quartz Monzonite (CFQM)		-
Coarsely Crystalline Porphyry (CCP)	Coarse Crystalline Porphyry (CCP)		Represents increasing size of phenocrysts towards the northeast in CFQM
Andesite	Andesite	Andesite	-
-	Diabase	Diabase	-
-	Latite	Latite	

<sup>1</sup> Copper Flat Baseline Data Report (INTERA, 2012)

<sup>2</sup> Copper Flat Geochemical Characterization  
 CFQM – Copper Flat Quartz Monzonite

## 3 Previous Geochemical Characterization Programs

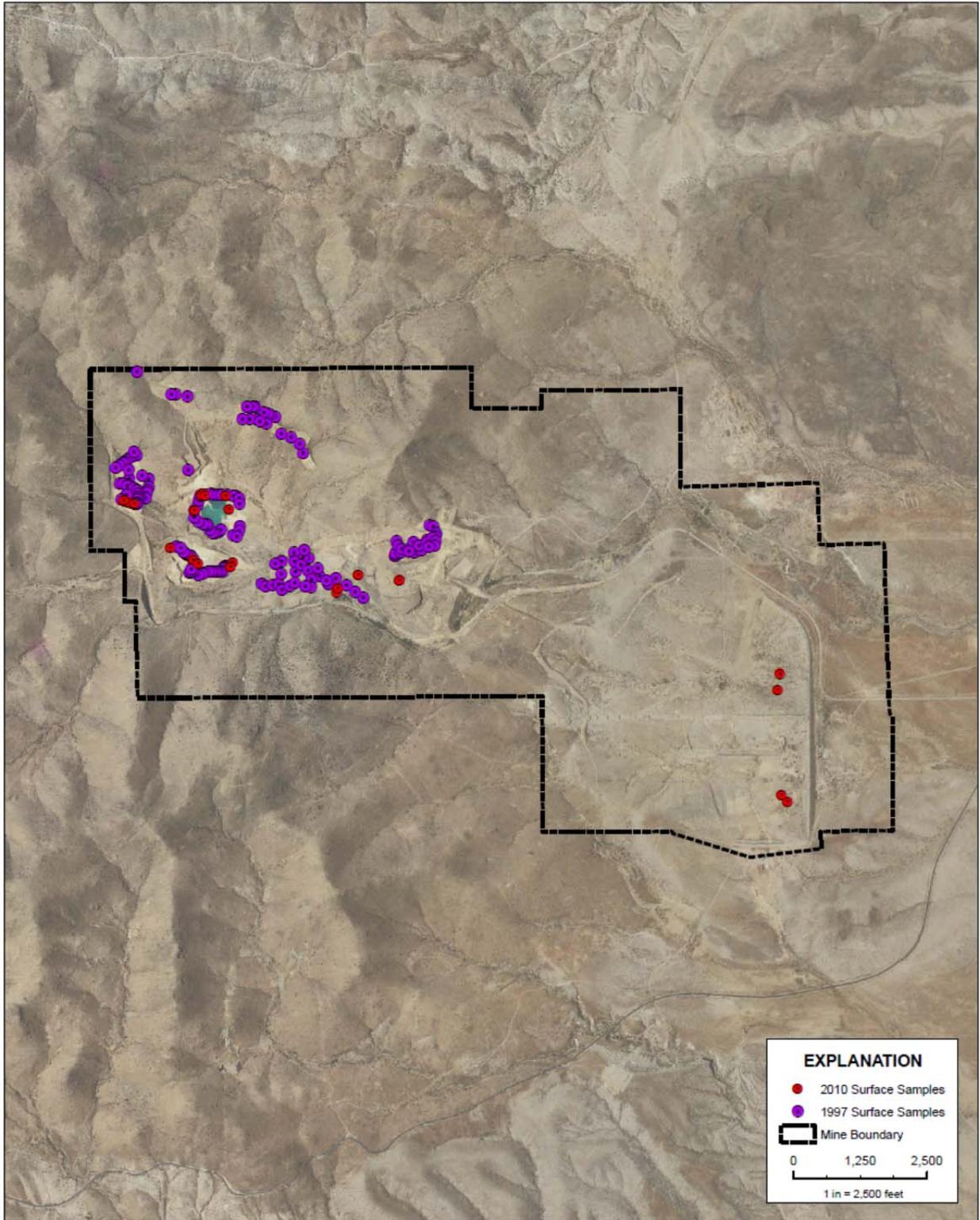
### 3.1 Pre-1996 Geochemical Program

As part of the initial planning and baseline studies completed on behalf of Alta Gold, SRK collected a small suite of samples from drill core, tailings and waste rock for Acid Base Accounting (ABA), short term leachate and kinetic humidity cell testing. The kinetic testing program was run for 28 weeks. The results of this testwork were reported in the *Geochemical Review of Waste Rock, Pit Lake Water Quality and Tailings* (SRK, 1996), which is included as Appendix 7-A in the *Baseline Data Report for the Copper Flat Mine* (BDR) (INTERA, 2012). The testwork results were also utilized to develop predictive geochemical models to assess potential pit lake water quality.

### 3.2 1997 Geochemical Program

A geochemical sampling and testwork program was carried out by SRK as part of the 1997 Copper Flat Waste Rock Management Plan. The purpose of the program was to produce geological and geochemical characterization of the exposed material on the existing waste rock dumps and pit walls. A total of 141 surface grab samples were collected as part of the 1997 characterization program and these samples were analyzed for field paste chemistry to assess the short-term reactivity of the materials. Sample locations are shown in Figure 3-1. Forty six of these samples were submitted for ABA testing, 59 for Net Acid Generation (NAG) testing, one for short-term leach testing, and five for humidity cell kinetic testing in order to assess the acid generating potential of existing waste rock on site. This work was reported in Appendix A of the *Copper Flat Preliminary Mine Waste Management Plan, New Mexico Copper Corporation* (NMCC June 2011), which is included as Appendix 7-B in the *Baseline Data Report for the Copper Flat Mine* (BDR) (INTERA, 2012).

Field tests including determination of paste pH and electrical conductivity (EC) were used in the 1997 geochemical characterization program to identify the presence of surficial/soluble salts in the existing waste rock dumps that could affect water quality. Field screening was used to define a representative sample set, and determine the number of samples selected for the static test suite. Based on the material type and paste results for that material, samples were selected for additional laboratory analysis. Samples included in the field screening program consisted of fine-grained material (<5 mm chips) that was collected from a 1 cubic meter area on the waste rock dump surface. This method is employed because water quality in a dump is largely controlled by the fines and this is a good indication of reactivity. The paste test comprises mixing a 1:1 solid to liquid ratio of fines with distilled water and measuring EC and pH of the resulting solution. If the resulting leachate was blue in color, the sample was analyzed for copper and sulfate by field colorimetric spectrometry.



**Figure 3-1: 1997, 2010/2011 Grab Sample locations**

## 4 Current Geochemical Characterization Program

### 4.1 Copper Flat Material Type Delineation

Waste rock is typically classified and tested according to material type and the number of samples selected for geochemical testing is based on the relative percentage of each material type predicted to be mined according to the geologic block model. For the purposes of the Copper Flat geochemical characterization program, material types were defined based on primary lithology, oxidation and copper grade. Alteration was not used to delineate material types because the deposit does not show distinct zonation of alteration zones and is typically logged as a mixture of potassic and/or silicic alteration with a pervasive argillic alteration overprinting much of the upper part of the deposit. A cut-off grade of 0.164 wt% copper was used to delineate between ore and waste grade material.

Two primary lithologies have been identified for the Copper Flat project:

1. Andesite; and
2. Quartz Monzonite/Breccia;

Diabase is also present as a minor lithology within the deposit and typically occurs in the form of radial dikes.

The degree of material oxidation was determined from the drill core logs according to the presence/absence of oxidation products (i.e., iron oxides and secondary copper minerals) and sulfide minerals. Three oxidation types were delineated for the Quartz Monzonite/Breccia rock type including:

- *Oxide*: identified by the complete absence of sulfide minerals and the presence of oxidation products (i.e., iron oxides) noted on the drill core logs and/or field notes;
- *Transitional*: identified by the presence of **both** sulfide minerals **and** oxidation products (e.g., iron oxides). The transitional samples were generally limited to the surface grab samples collected in 2010 and near-surface core samples; and
- *Sulfide*: identified by the presence of sulfide minerals with no evidence of oxidation products from the drill logs and field notes.

Based on the above delineation of lithology, grade and oxidation, seven material types have been identified for the Copper Flat project:

1. Andesite;
2. Diabase;
3. Sulfide waste (Quartz Monzonite/Breccia);
4. Transitional waste (Quartz Monzonite/Breccia);
5. Sulfide ore (Quartz Monzonite/Breccia);
6. Transitional ore (Quartz Monzonite/Breccia); and
7. Oxide ore (Quartz Monzonite/Breccia).

## 4.2 Sample Collection and Testing

### 4.2.1 Waste Rock and Ore

Two phases of sample collection were carried out in April 2010 and December 2011 as part of the Copper Flat geochemical characterization program. The purpose of the 2010/2011 sampling and testwork program was to augment the previous geochemical characterization and modeling work carried out from 1995 to 1997 and to comply with subsequent revisions to standards outlining the characterization of mine waste, which have evolved since the previous assessment was carried out. A number of statutory regulations have also been reviewed and modified since the initial assessment, including the modification of BLM and 43 CFR 3809 regulations in addition to changes to the standards applied to both EIS and New Mexico State permit applications.

SRK personnel visited the Copper Flat project in April 2010 in order to collect representative samples of waste rock from both drill core and from existing waste rock dumps on site. A total of 50 sample intervals were selected from six diamond drill core holes drilled within the existing footprint of the Copper Flat pit during the 2009 and 2010 exploration drilling program. The sample intervals were selected to represent the range of waste rock and ore material types that will be encountered in the future Copper Flat pit. For each sample interval, the coarse reject material was collected and sent to the laboratory for sample preparation and testing as described in Section 4.3 of this report.

To augment the drill core sample set, 24 additional bulk surface grab samples were collected from the surface of the existing waste rock dumps, pit wall exposures and tailings impoundment during the 2010 site visit. The grab sample locations are shown in Figure 3-1 along with the grab samples collected during the 1997 sample program and a detailed sample location map is provided in Figure 4-1. Existing waste rock dumps and pit walls provide an opportunity to compare fresh rock samples to weathered rock samples of the same material types that have been exposed to oxygen and water for over 20 years.

Additional sample collection was undertaken in December 2011, which involved collection of 63 samples from drill core generated during the 2011 exploration program. The purpose of this additional sample collection was to improve the spatial representivity of the sampling based on the improved geological understanding of the deposit and also to collect samples of lithologies that were not encountered during the previous 2009/2010 exploration program.

A plan view showing the drill holes included in this program are shown in Figure 4-2. Drill core sample locations for both the 2010 and 2011 sampling exercises are shown in Figure 4-3 through 4-5 in relation to the proposed pit shell. The resulting dataset demonstrates generally good spatial representivity, although several of the sample intervals selected are outside the currently proposed pit shell. This relates to the change in the pit shell in the Pre-Feasibility Study (M3, 2012) relative to the original pit shell from the Preliminary Economic Assessment (SRK Consulting, 2010), which was the basis for selecting the geochemical samples. The pit shell in the Pre-Feasibility Study changed relative to the Preliminary Economic Assessment's pit shell for multiple reasons including the additional 2010 and 2011 drilling information, a different set of pit slopes that resulted from a more detailed pit slope analysis and a lower cut-off-grade (0.23% TCu to 0.164% TCu) that reflects the new pit slopes as well as more refined metal recovery information and operating cost detail. These changes have occurred since the geochemical characterization program was initiated in 2010. In addition, the Pre-Feasibility Study's pit shell was not available at the time the sample intervals were selected; therefore, a maximum limit of mining for each drill hole could not be defined.

Table 4-1 shows the distribution of samples in relation to the proportion of each material type predicted to be mined by the block model. This shows good lithological representation of samples, with a bias towards material types that will ultimately comprise a greater proportion of waste rock. The updated pit shell in the Pre-Feasibility Study has had implications for the number of ore vs. waste samples included in the geochemical characterization program, and increased the number of ore samples. However given the ore grade material has a tendency to show similar reactive geochemistry to waste grade material, this change in the number of ore grade samples does not compromise the overall validity of the waste rock geochemistry program.

The number of samples submitted for geochemical testing is provided (per material type) in Table 4-2 and a complete sample list is provided in Appendix A. The static and kinetic testwork was supervised by SRK at McClelland Laboratories of Sparks, Nevada with analysis by Western Environmental Testing Laboratory (WETLAB) of Sparks, Nevada; ALS Chemex of Reno, Nevada; and SVL Laboratories of Kellogg, Idaho. The test procedures are described in Section 4.3.

**Table 4-1: Sample Distribution Compared to Geologic Block Model**

Material type	Percentage of waste (%)	Number of waste samples	Percentage of ore (%)	Number of ore samples
Andesite / diabase	1.06	5	0	1
Biotite breccia - oxide/transitional	0.05	1	0.05	4
Biotite breccia - sulfide	1.10	7	13.9	17
Quartz feldspar breccia - oxide transitional	0.09	0	0.12	1
Quartz feldspar breccia - sulfide	4.48	16	8.39	7
Quartz monzonite - oxide / transitional	2.78	8	0.83	13
Quartz monzonite - sulfide	75.4	22	71.8	24
Coarse crystalline porphyry - oxide/transitional	0.93	1	0.03	0
Coarse crystalline porphyry - sulfide	14.0	3	4.80	0
Undefined	0.10	2	0.01	0
<b>Total</b>	<b>100%</b>	<b>65</b>	<b>100%</b>	<b>67</b>

**Table 4-2: Copper Flat Sample Frequency and Testing Matrix**

Material type*	Multi-Element Analysis	ABA/NAG	MWMP	HCT
Andesite	4	4	2	2
Diabase	2	2	2	0
Sulfide waste	72	72	19	6
Transitional waste	13	13	7	4
Sulfide ore	26	26	12	9
Transitional ore	14	14	6	2
Oxide ore	1	1	0	0
Tailings	12	12	0	9
Historic tailings	2	2	1	0
<b>Total</b>	<b>146</b>	<b>146</b>	<b>49</b>	<b>32</b>

Ore/waste cut-off grade = 0.164 wt% (from Pre-Feasibility Study)

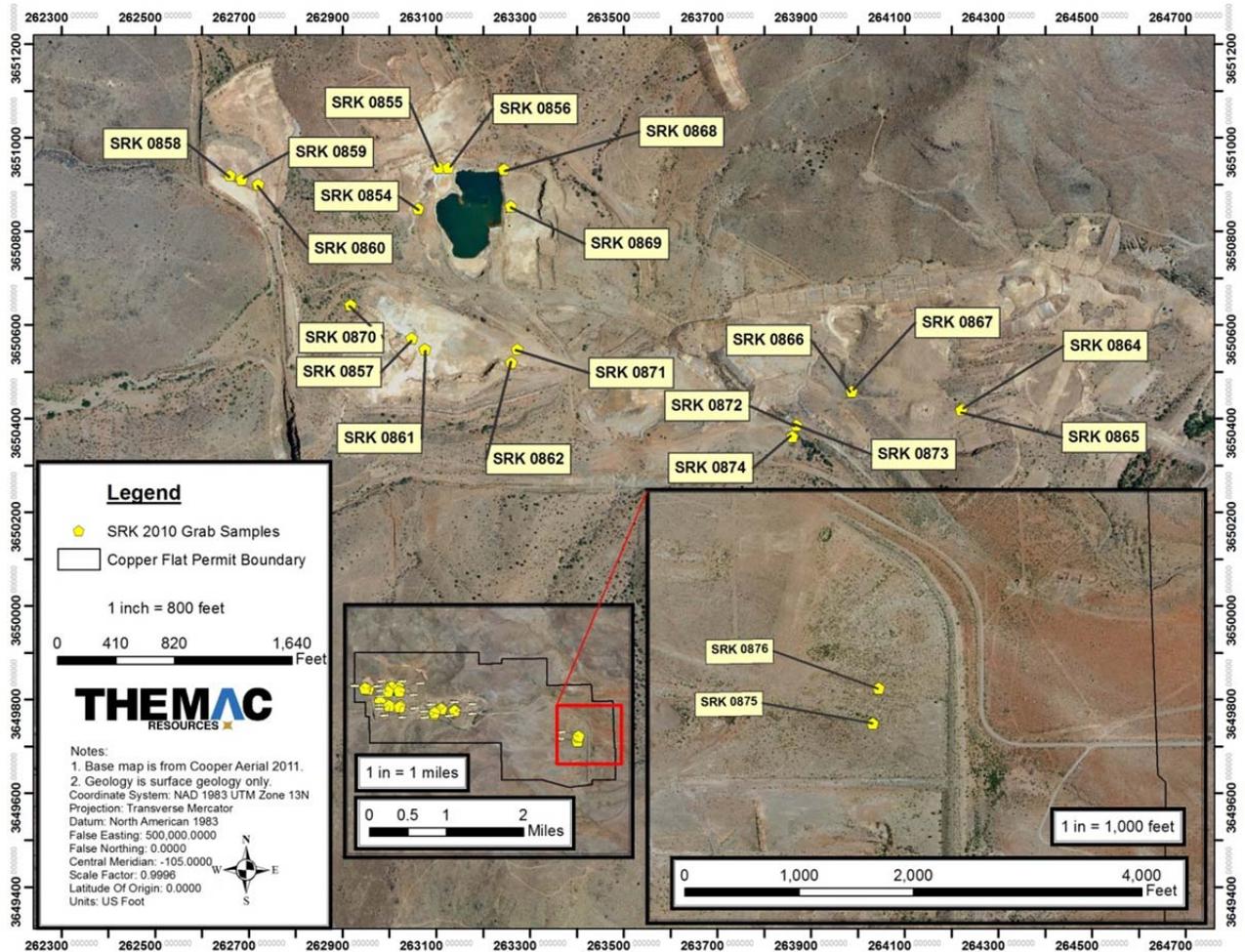


Figure 4-1: Geochemical Characterization Grab Sample Locations

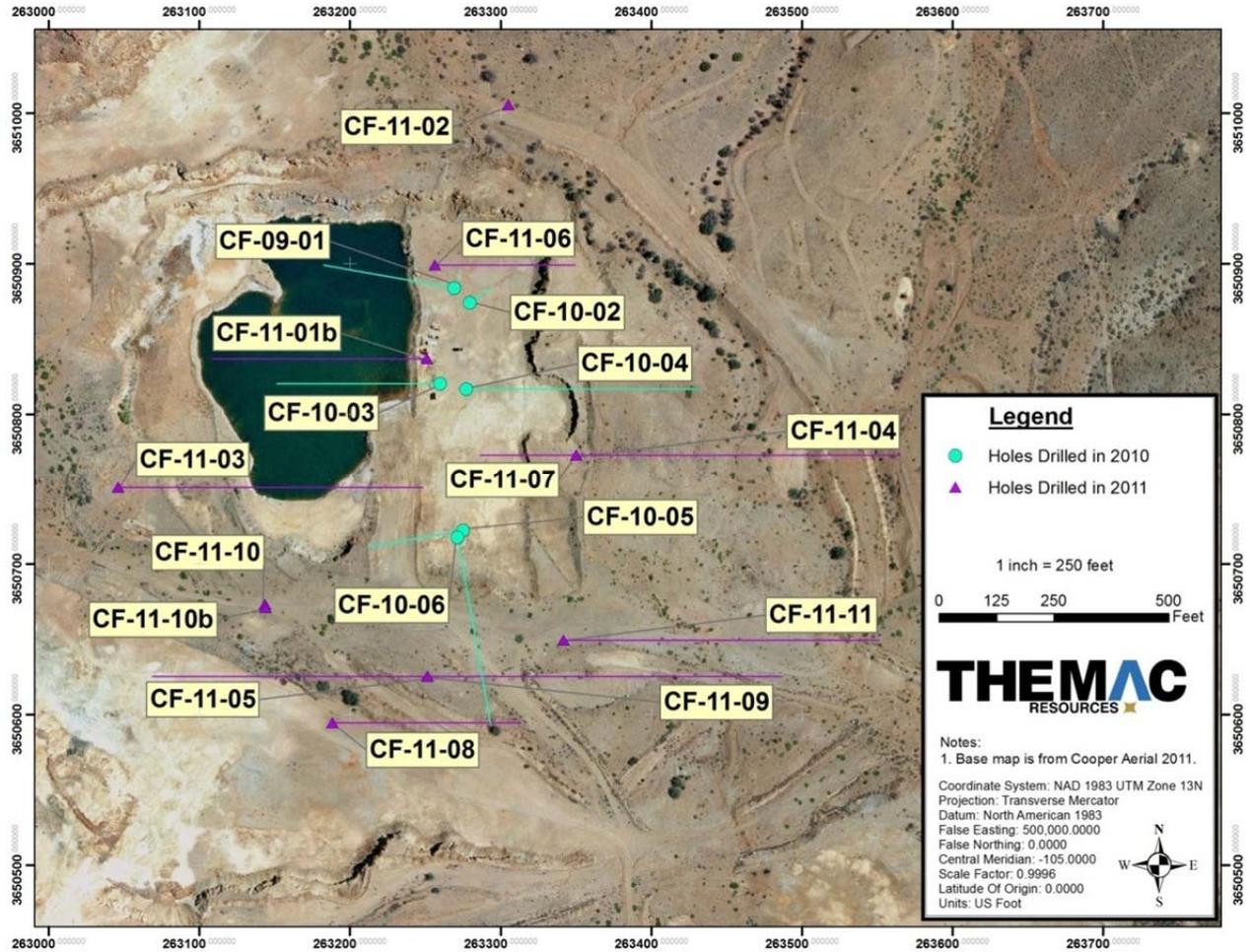
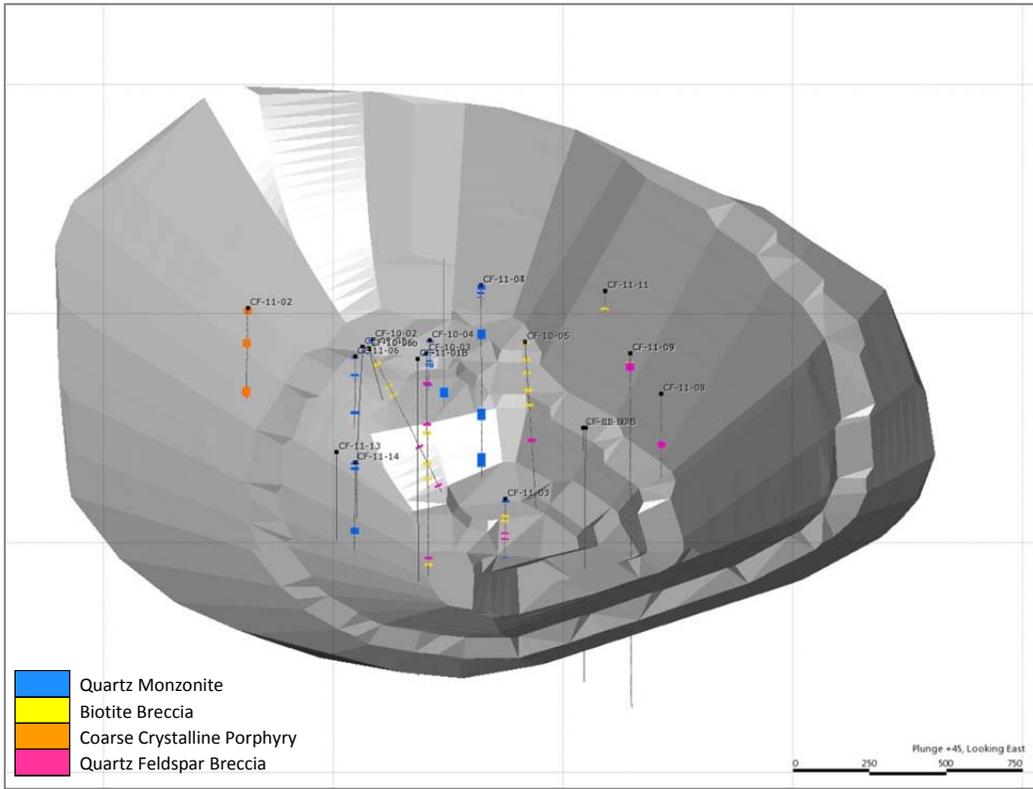
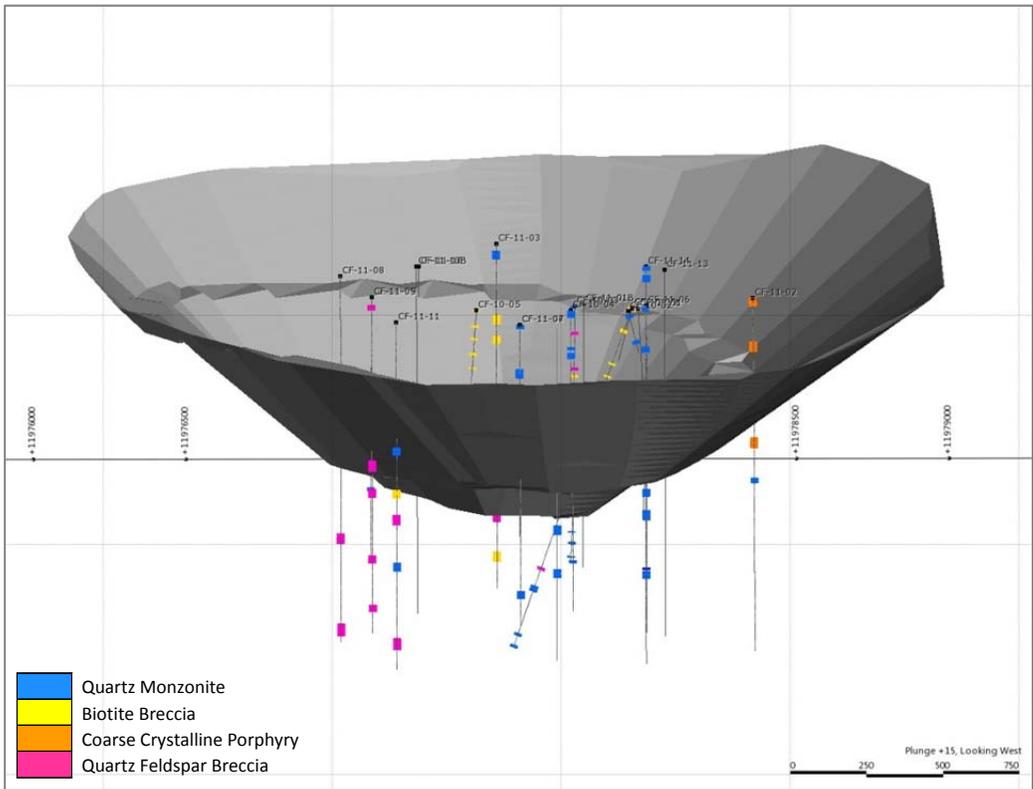


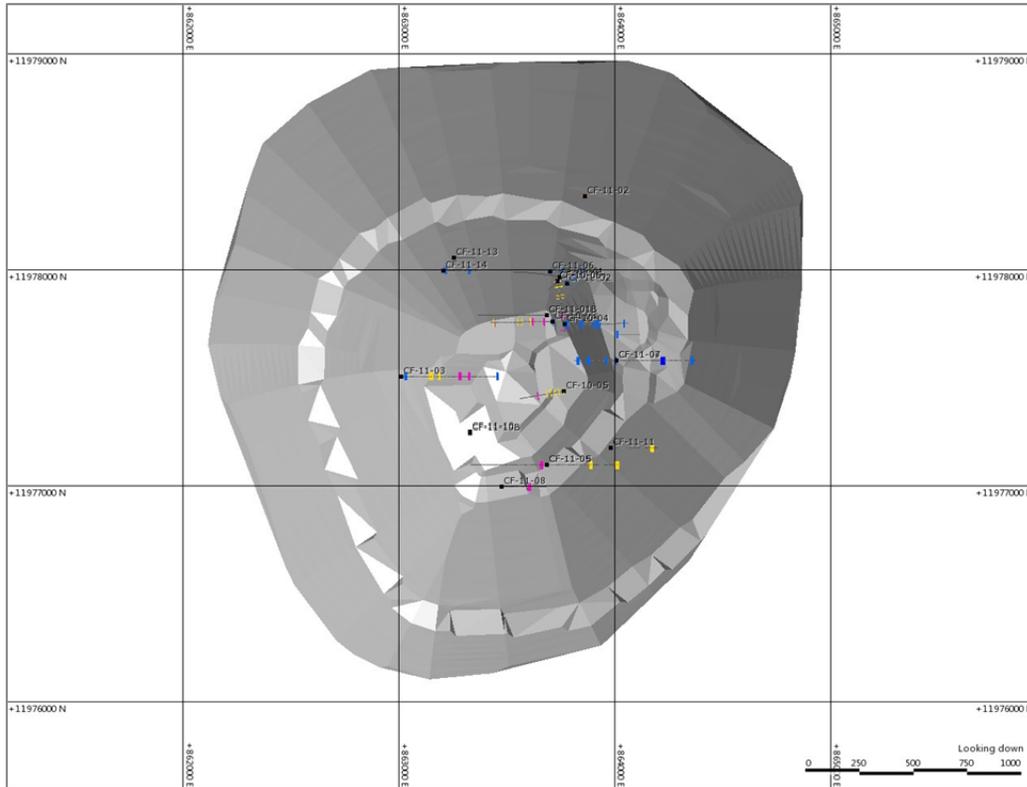
Figure 4-2: 2010 and 2011 Drill Hole Sample Locations



**Figure 4-3: Spatial distribution of core samples**



**Figure 4-4: Spatial distribution of core samples (looking west)**



**Figure 4-5: Spatial distribution of core samples (plan view)**

## 4.2.2 Tailings

Metallurgical testing conducted for the Copper Flat project provided an opportunity to collect samples representative of tailings material that could be used to assess operational and post-closure tailings geochemistry. The metallurgical tests were undertaken at Hazen Research Inc. and generated tailings that are representative of different ore streams during different stages of mine life. Details of these tailings samples are provided in Table 4-3 below. An additional two samples of historic tailings were collected from the surface of the existing tailings impoundment during the April 2010 site visit.

As with the waste rock and ore samples, the static and kinetic test work for the tailings samples was supervised by SRK at McClelland Laboratories of Sparks, Nevada with analysis by WETLAB of Sparks, Nevada; ALS Chemex of Reno, Nevada; and SVL Laboratories of Kellogg, Idaho.

**Table 4-3: Details of tailings samples from metallurgical tests**

Sample name	Ore type	Year	Preparation Laboratory
K-Spar Breccia 0-5 comp. flotation tailings	K-Feldspar Breccia	1 – 5	Metcom
K-Spar Breccia 5+ comp. flotation tailings	K-Feldspar Breccia	5+	Metcom
Biotite Breccia 0-5 comp. flotation tailings	Biotite Breccia	1 – 5	Metcom
Biotite Breccia 5+ comp. flotation tailings	Biotite Breccia	5+	Metcom
Quartz Monzonite 0-5 comp. flotation tailings	Quartz Monzonite	1 – 5	Metcom
Quartz Monzonite 5+ comp. flotation tailings	Quartz Monzonite	5+	Metcom
CCP (CF-11-02, 52-117) flotation tailings	Coarse Crystalline Porphyry	1 – 5	McClelland <sup>1</sup>
CCP (CF-11-02, 227-367) flotation tailings	Coarse Crystalline Porphyry	5+	McClelland <sup>1</sup>
Cu. Ro. Tails	Porphyry and Breccia	--	Hazen
Whole tailings	Composite	--	FL Smidth
Tailings cyclone underflow	Composite	--	FL Smidth
Tailings cyclone overflow	Composite	--	FL Smidth
Historic tailings	Composite	--	--

<sup>1</sup> Grind and flotation only

## 4.3 Geochemical Test Methods

The static and kinetic testing methods selected for this project were designed to address the bulk geochemical characteristics of the waste rock and tailings samples, and to assess the potential of the waste rock to generate acid or release metals in drainage. “Static testing” is a general term describing those analytical methods applied to characterize acid generation and metal leaching characteristics of material at the time of testing and does not account for temporal changes that may occur in the material as chemical weathering proceeds. Static tests provide a balance of acid generating and acid consuming reactions at an end point and also may be used to determine the potential magnitude of leaching metals from a given material.

Static testing is distinguished from “kinetic tests”, which evaluate the rate of sulfide oxidation and metal release over time. Static testing provides a conservative approximation of acid generation and trace metal release potential, which is used to determine where more comprehensive kinetic testing is warranted. Based on the results of the static test work, materials that exhibit uncertain or highly variable geochemical behavior may require further characterization using kinetic test methods to determine the rates and character of longer-term leaching.

The static test methods identified for this project were selected to address total acid generating or neutralizing potential of the samples and concentration of constituents in leachates derived from the material. Static testing methodologies used for the Copper Flat Characterization program include the following:

- Multi-element analysis using four-acid digest and ICP analysis to determine total metal and metalloid chemistry for 48 elements (ALS Chemex Method ME-MS61);
- Acid Base Accounting (ABA) using the modified Sobek method (Memorandum No. 96-79) with sulfur speciation by hot water, hydrochloric acid, and nitric acid extraction;
- Net Acid Generating (NAG) test that reports the final NAG pH and final NAG value after a two-stage hydrogen peroxide digest;
- Nevada Meteoric Water Mobility Procedure (MWMP - ASTM E2242-02) and metals analysis of leachate; and
- Modified Synthetic Precipitation Leachate Procedure (SPLP) (US EPA, 1998) and metals analysis of leachate.

These test methods and the criteria commonly used in the evaluation of the resulting data set are described in the following sections. Samples were submitted to McClelland Laboratories (MLI) in Sparks, Nevada for sample preparation and MWMP extraction. The MWMP extracts were then sent to WETLAB, a Nevada Certified laboratory, in Sparks, Nevada for chemical analysis. Splits of each sample were also submitted to SVL Laboratories in Kellogg, Idaho and ALS Chemex in Reno, Nevada for ABA and NAG testing and multi-element analysis (respectively).

Upon completion of the static test work, a small sub-set of samples representing the most significant material types were selected from the static test database for kinetic testing. The kinetic testing method selected for this project is the standard humidity cell test procedure (ASTM D-5744-96).

### 4.3.1 Multi-Element Analysis

A multi element analysis of the waste rock and tailings samples has been completed through ALS Chemex, Reno, to provide an absolute upper limit of available metals for leaching from the samples. The analysis involved a strong multi-acid digestion followed by analysis by ICP-OES and ICP-MS for a full suite of metals and metalloids. This included determination of major elements (e.g., aluminum, calcium, magnesium, sodium, potassium, iron, sulfur) and trace elements (e.g., arsenic, antimony, mercury, zinc, copper, cadmium and lead). The results of the multi element analysis were analyzed using the Geochemical Abundance Index (GAI) (Förstner et al, 1993), which compares the concentration of an element in a given sample to its average crustal abundance. GAI values are particularly useful in determining the relative enrichment of elements based on lithology and may be used to identify elements enriched above average crustal concentrations.

GAI values are calculated as follows:

$$GAI = \log_2 [C/(1.5*S)]$$

Where C is the concentration of an element as determined from the multi element assay and S is the average crustal abundance of the element of interest (Mason, 1966). Materials are then assigned a GAI value between zero and six based on the degree of enrichment (Table 4-4), with a GAI value greater than three indicating significant enrichment. These elements therefore have potential to be leached in sufficient concentration to have an environmental impact.

**Table 4-4: Interpretation of GAI values**

GAI Value	Interpretation
0	< 3 times average crustal concentrations
1	3 to 6 times average crustal concentrations
2	6 to 12 times average crustal concentrations
3	12 to 24 times average crustal concentrations
4	24 to 48 times average crustal concentrations
5	48 to 96 times average crustal concentrations
6	>96 times average crustal concentrations

### 4.3.2 Acid Base Accounting

Acid Base Accounting provides an industry-recognized assessment of the acid generation or acid neutralization potential of rock materials. The ABA method used for the characterization of Copper Flat waste rock is the Modified Sobek ABA method (Memorandum No. 96-79), which includes both laboratory analysis and empirical calculations based on acid generating potential (AP) and neutralizing potential (NP). An estimate of acid generation is made by assuming complete reaction between all of the minerals with acid generating potential and all of the minerals with neutralizing potential (essentially dissolution of carbonate minerals and to very limited extent silicate minerals as the latter have very slow reaction kinetics; *Bowell et al., 2000*). The AP values were calculated from sulfide sulfur concentrations and reported as CaCO<sub>3</sub> equivalents per 1,000 tons of rock. The NP values were determined using the modified Sobek protocol that includes a digestion to expel any CO<sub>2</sub> followed by a back titration with NaOH to a pH of 8.3 s.u. Neutralizing potential is calculated as CaCO<sub>3</sub> equivalents per 1,000 tons of rock.

The balance between the acid generating mineral phases and acid neutralizing mineral phases is referred to as the net neutralization potential (NNP), which is equal to the difference between NP and AP. The NNP allows classification of the samples as potentially acid consuming or acid producing. A positive value of NNP indicates the sample neutralizes more acid than is produced during oxidation. A negative NNP value indicates there are more acid producing constituents than acid neutralizing constituents. Material that would be considered to have a high potential for acid neutralization produces a net neutralizing potential of greater than 20 kg CaCO<sub>3</sub> eq/ton. Acid Base Accounting data is also described using the neutralization potential ratio, which is calculated by dividing the NP by the AP (i.e., NPR).

Acid Base Accounting results are typically compared to criteria provided by the BLM (2008) in order to determine the potential for the waste rock material to generate acid. The Nevada BLM Water

Resource Data and Analysis Guide for Mining Activities (BLM, 2008) establishes the following guidelines for the evaluation of ABA test results:

- NP:AP (NPR) values greater than 3 and NNP values greater than 20 kg CaCO<sub>3</sub> eq/ton are not acid generating and do not require further testing; and
- NP:AP (NPR) values less than 3 and/or NNP values less than 20 kg CaCO<sub>3</sub> eq/ton have uncertain potential and require further evaluation using kinetic test methods.

### 4.3.3 Net Acid Generation

Static Net Acid Generation (NAG) testwork was carried out in order to determine the maximum potential for acid generation from the Copper Flat samples. The static NAG test differs from the ABA test in that it provides a direct empirical estimate of the overall sample reactivity, including any acid generated by semi-soluble sulfate minerals as well as potentially acid-generating sulfide minerals. As such, the NAG test often provides a better estimate of field acid generation than the more widely-used ABA method, which defines acid potential based solely on sulfide content.

NAG testing was carried out by SVL laboratories in accordance with the method described by Miller et al. (1997). The method essentially involved intensive oxidation of the sample using hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>), which accelerates the dissolution of sulfide minerals and has the net result that acid production and neutralization can be measured directly. Leachate was then titrated with sodium hydroxide in two stages (pH 4.5 and to pH 7) to determine the NAG value, calculated as follows:

$$NAG = (V_{init} / X) (49 * V_{NaOH} * M) / W$$

Where:

*NAG = net acid generation (kg H<sub>2</sub>SO<sub>4</sub> eq/ton);*

*V<sub>init</sub> = volume of initial hydrogen peroxide solution (mL);*

*X = volume used to determine NAG by titration (mL);*

*V<sub>NaOH</sub> = volume of NaOH used in titration (mL);*

*M = concentration of NaOH used in titration (moles/liter); and*

*W = weight of sample reacted (g).*

The guidelines used for assessing the acid generation potential based on NAG results are summarized in Table 4-5. Samples with NAG pH values greater than 4 s.u. are predicted to be non-acid forming (NAF). Net acid generation is only measured for samples with NAG pH values less than 4 s.u. NAG results greater than one kg H<sub>2</sub>SO<sub>4</sub> eq/ton indicate the sample will generate some acidity in excess of available alkalinity and is potentially acid forming (PAF). However, by convention, any NAG value below 10 kg H<sub>2</sub>SO<sub>4</sub> eq/ton of material has a limited potential for acid generation and the results are considered inconclusive because a blank hydrogen peroxide solution (the reagent in the NAG test) can generate a NAG artifact value up to 10 kg H<sub>2</sub>SO<sub>4</sub> eq/ton.

**Table 4-5: Acid Generation Criteria for NAG Results**

Acid Generation Capacity		Final NAG pH (s.u.)	Static NAG (kg H <sub>2</sub> SO <sub>4</sub> eq/ton)
Potentially Acid Forming (PAF)	Higher Capacity	< 4	>10
	Lower Capacity	< 4	≤10, >1
Non-Acid Forming (NAF)		≥ 4	0

**4.3.4 Short Term Leach Tests (MWMP and SPLP)**

The Meteoric Water Mobility Procedure was conducted according to standard test methods (ASTM E-2242-02) that involves a 24-hour, single pass column leach using a 1:1 distilled water:rock ratio. The resulting leachate is submitted for metals analysis. The MWMP test was developed to simulate the leaching of mine waste materials by meteoric water under typical low precipitation environmental field conditions. The results of the MWMP test can be used to identify the presence of leachable metals and readily soluble salts stored in the material, as well as provide an indication of their availability for dissolution and mobility. In addition to the leachable metals, the MWMP test also provides an assessment of the potential for acid release during dissolution of soluble acid salts (Ficklin et al., 1992). The final pH of the MWMP extract is representative of leachate that could be produced from waste rock with readily soluble acid-producing salts under field conditions. Due to differences in the liquid to solid ratio used in the test compared to typical site conditions, the MWMP test results only provide a qualitative estimate of elemental concentrations in the resulting leachates and are not considered conclusive or to represent actual predictions of water quality. As such, a comparison to water quality standards has not been considered in the evaluation of leach test data.

The three cyclone tailings samples were submitted for SPLP leach testing, rather than MWMP, due to the limited quantity of tailings material available for testing. The SPLP method is an agitated extraction method that is similar to the MWMP test in that it measures the readily soluble constituents of mine waste. However, the SPLP requires particle size reduction to less than 9.5 mm, uses an extraction solution that has been adjusted with dilute sulfuric/nitric acid to pH 5.0 and is typically run at a 20:1 solution to solid ratio. Some of the disadvantages of the SPLP test are the high liquid to solid ratio that may result in an underestimate of leachability and grain size reduction may increase reactivity. Therefore, the leachate chemistry for these samples is not directly comparable to the MWMP results.

**4.3.5 Humidity Cell Testing**

The static data were used to select a sub-set of 23 samples representing the most significant material types for kinetic testing. An additional nine tailings samples were also selected for humidity cell testing. Kinetic testing is necessary for the Copper Flat project in order to assess the long-term weathering rates of sulfide minerals and to determine potential metal(loid) leaching rates, particularly for those material types that demonstrated an uncertain potential for acid generation in the static ABA and NAG tests. The samples that were selected for kinetic testing are summarized in Table 4-6 along with selected static testwork data.

The kinetic testing method selected for this project is the standard humidity cell test procedure designed to simulate water-rock interactions in order to evaluate the rate of sulfide mineral oxidation and thereby predict acid generation and metals mobility (ASTM D-5744-96). Under ASTM methodology, the test follows a seven-day cycle and typically runs for a minimum of 20 weeks, unless uncertain chemistry requires that it be run longer to achieve steady state conditions. During the seven-day cycle, water is trickled over the rock. After draining, dry air is circulated through the cell for 3 days followed by humidified air at 25°C for 3 days. On the seventh day, the sample is rinsed with distilled water and the extracted solution is collected for analysis. Key parameters including pH, alkalinity, acidity, electrical conductivity, iron and sulfate are measured on a weekly basis by McClelland Laboratories. For the first four weeks of testing, metals are measured on a weekly basis at WETLAB, a Nevada certified laboratory, after which the frequency of metals analysis is reduced to every fourth week.

The HCT results provide an estimate of the rate of leaching of constituents from a material and reflect accelerated weathering of mine material being exposed to alternating cycles of wetting and drying. The changes in these reaction rates through the course of the test can be used to estimate whether the sample will be net acid generating or net acid neutralizing, and what constituents will be mobilized from the material under long-term weathering and oxidation conditions. As such, HCT results can be used to refine predictions based on static test data.

Leachate chemistry data collected during the HCT test are frequently compared with applicable water quality standards. However, it is recognized that the test results are not directly comparable to water quality standards due to the increase in surface area by crushing and the artificial control on weathering through a seven-day wet-dry cycle rinsing of the samples. The rate of water application relative to the surface area/mass ratio of rock exceeds the actual precipitation rate that would be expected at the site, and the laboratory temperature conditions do not represent normal field variations. These variables accelerate the weathering process and therefore provide a conservative view of field scale leaching conditions.

The ASTM Procedure for humidity cell tests (ASTM, 1996) calls for a minimum test duration of 20 weeks. However, there is no technical basis for this recommendation and in most cases with sulfide bearing materials, 20 weeks is insufficient to allow complete reaction of the sample material. Essentially, there is no established criteria for the termination of kinetic tests, rather the point at which HCTs should be terminated is project specific and will be determined by the physical and chemical characteristics of the samples and the objectives of the test (Mills, 1998).

The main objectives of the kinetic test program are to provide a prediction of acid generation potential of the samples and predict the rate of leaching of constituents under the accelerated test conditions. Geochemical reactions and reaction rates monitored throughout the testing include sulfide oxidation, depletion of neutralization potential, adsorption, precipitation and mineral dissolution. The HCTs are executed until the majority of the mineral reactions that can be predicted from mineralogy or static testing have been observed. This endpoint is assessed by monitoring the release rates of key constituents such as pH, sulfate, acidity, alkalinity and iron as well as dissolved metals and metalloids. It is common practice to terminate cells when the release rates for these leachate parameters become relatively constant with time and there is no substantial change in the calculated release rate. For practical purposes this is taken as steady state element release (i.e., no significant change in rate of leaching over a 3 to 4 week period).

Following completion of the HCT, termination testing is conducted on the test residues including multi-element analysis, mineralogy (XRD and SEM), ABA and NAG to define the mineralogical processes that occurred as the materials were exposed to oxygen and water.

**Table 4-6: Samples Selected for Kinetic Testing**

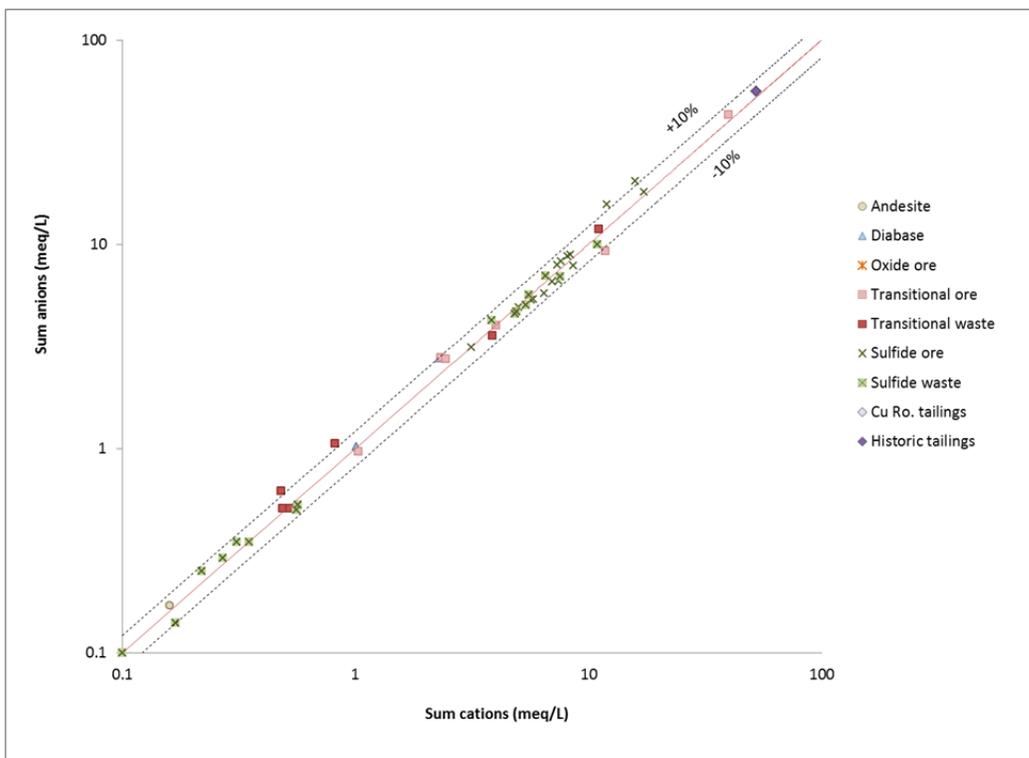
Material type	Primary lithology	Sample ID	Sulfide sulfur (wt%)	NNP (kg CaCO <sub>3</sub> eq/t)	NPR	NAG pH	Total NAG (kg H <sub>2</sub> SO <sub>4</sub> eq/t)	MWMP pH	MWMP metals release
Andesite	Andesite	SRK 0864	0.01	24.4	81.3	8.29	0	7.18	Low
	Andesite	SRK 0866	0.29	12.5	2.37	3.23	4.9	6.92	Low
Sulfide ore	Biotite breccia	604811	1.15	-3.9	0.89	8.42	0	8.24	Low
	Quartz Feldspar Breccia	604767	2.13	-49.9	0.25	3.21	17.3	7.8	Low
	Biotite Breccia	604862	1.16	3.5	1.10	8.28	0	8.11	Low
	Biotite Breccia	604867	2.34	-46.2	0.37	4.24	0	8.06	Low
	Quartz Feldspar Breccia	604787	0.97	-0.2	0.99	8.00	0	8.28	Low
	Biotite Breccia	604854	1.4	-20.6	0.53	5.08	0	8.16	Low
	Quartz Monzonite	604562	1.53	-31.6	0.34	7.75	0	8.28	Low
	Quartz Monzonite	604669	0.63	-16.5	0.16	4.08	0	8.39	Low
	Quartz Monzonite	604656	0.59	33.4	2.82	8.20	0	8.27	Low
	Biotite Breccia	605033	0.9	1.1	1.04	8.30	0	8.37	Low
	Quartz Monzonite	604606	0.67	2.7	1.13	9.60	0	8.31	Low
	Quartz Monzonite	604653	0.77	2.3	1.10	8.38	0	-	-
Sulfide waste	Quartz Monzonite	604673	0.41	-5.9	0.54	3.66	5.29	8.33	Low
	Quartz Monzonite	605153	0.49	26.7	2.75	8.56	0	8.15	Low
	Coarse Crystalline Porphyry	CF-11-02, 367-408	0.63	-6.7	0.74	2.78	14.0	5.86	Low
Transitional ore	Biotite Breccia	SRK 0854	0.88	-21.5	0.22	3.77	11.0	4.54	High
	Quartz Monzonite	SRK 0867	0.77	-17.7	0.27	4.35	0	4.84	Moderate
Transitional waste	Biotite Breccia	SRK 0872	1.05	-13.0	0.60	3.14	8.82	3.05	Moderate
	Quartz Monzonite	604569	1.05	-14.8	0.55	8.33	0	8.25	Low
	Quartz Monzonite	SRK 0858	0.62	-15.3	0.21	3.15	9.22	3.99	Moderate
	Coarse Crystalline Porphyry	CF-11-02, 0-27	1.4	-16.3	0.58	3.28	9.24	7.27	Low
Tailings*	-	Cu. Ro. Tails	0.61	13.4	1.70	9.23	0	-	-
	-	CF-11-02 (227-367)	0.03	20.0	34.3	-	-	-	-
	-	CF-11-02 (52-117)	0.04	23.8	27.4	-	-	-	-
	-	K-Spar Breccia 5+ Comp	0.19	26.4	4.26	-	-	-	-
	-	Biotite Breccia 5+ Comp	0.14	24.6	4.90	-	-	-	-
	-	Quartz Monzonite 5+ Comp	0.02	24.4	28.1	-	-	-	-
	-	K-Spar Breccia 0-5 Comp	0.53	6.9	1.31	-	-	-	-
	-	Quartz Monzonite 0-5 Comp	0.41	13.1	1.74	-	-	-	-
-	Biotite Breccia 0-5 Comp	0.39	13.4	1.77	-	-	-	-	

Indicates potentially acid forming characteristics

\* HCTs were not run on the cyclone tailings as these showed the same geochemical behavior to the other tailings samples tested from the static test data.

### 4.3.6 Quality Control

Both McClelland and WETLAB laboratories operate internal QA/QC procedures to ensure adequate data quality. This includes the analysis of certified reference materials in addition to analytical blanks and duplicates. However, SRK also applies a number of QA/QC checks on the received data, including the calculation of ion balances to determine the balance of cations and anions in the generated solutions and the comparison between electrical conductivity (EC) and total dissolved solids (TDS). For the humidity cell data, a comparison of pH measurements from both McClelland and WETLAB is also carried out to assess data quality. The results of the quality control exercise are summarized in Figure 4-6 to Figure 4-9 and show generally good data quality, with ion balances almost uniformly within  $\pm 10\%$  and good correlations between laboratory measurements. For pH, there is a slight difference in reported values between the two labs (Figure 4-9). This is only observed above pH 7.5 and shows a slight negative bias in the calibrated meters at McClelland laboratories versus measurements for the same solutions at WETLAB. This is not considered significant since the WETLAB data is used in modeling.



**Figure 4-6: Ion balance plot for the MWMP test results**

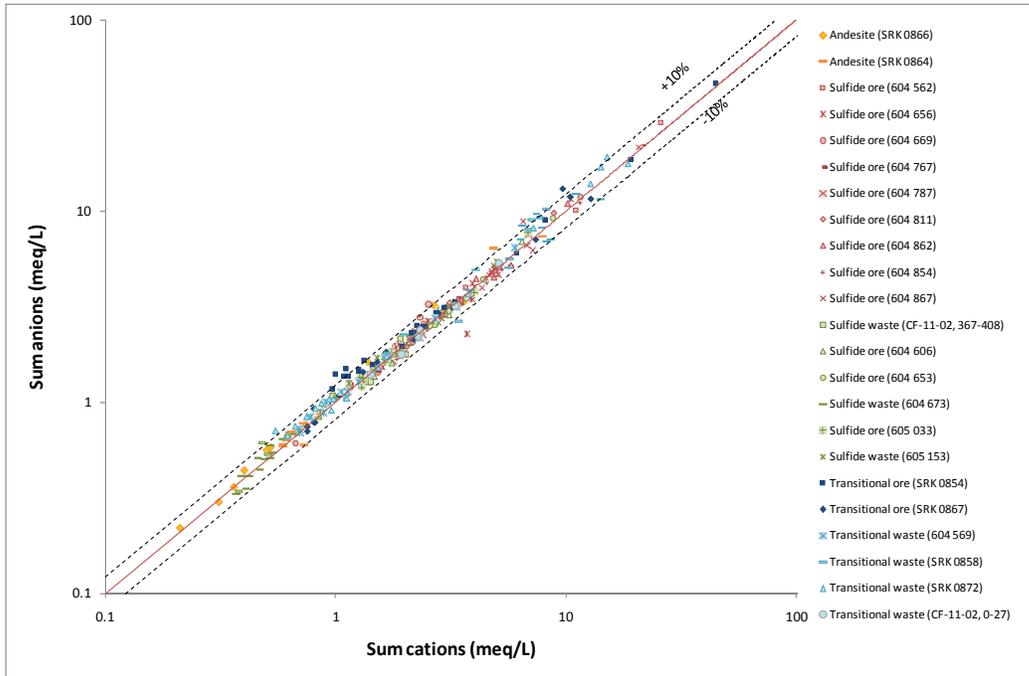


Figure 4-7: Ion balance plot for the HCT leachates

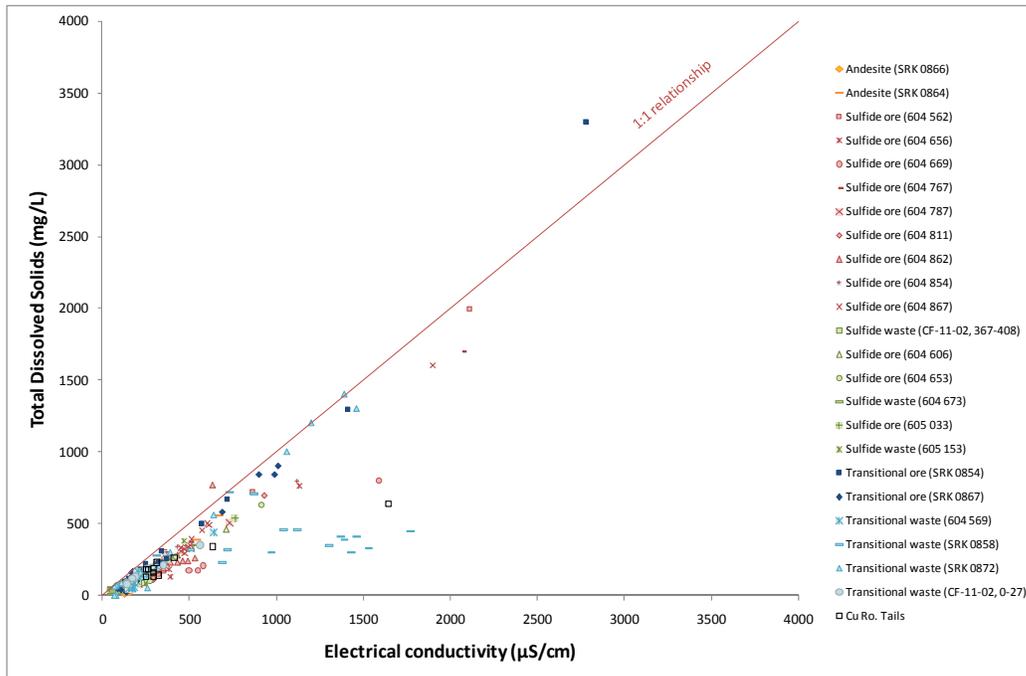
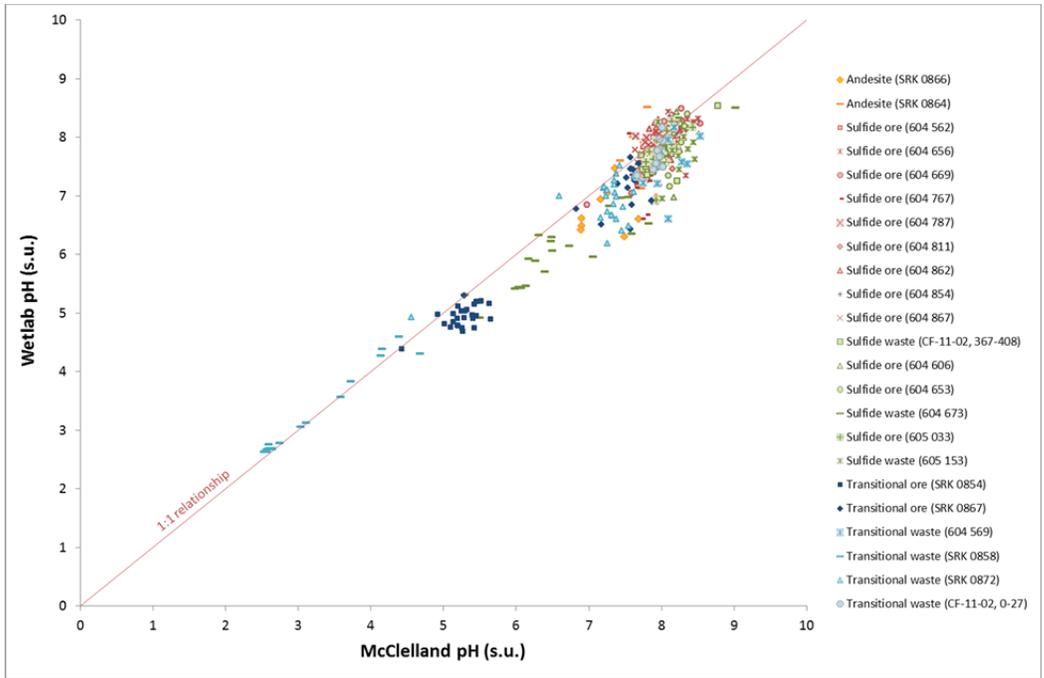


Figure 4-8: Scatter plot comparing EC and TDS for the HCT leachates



**Figure 4-9: Scatter plot comparing McClelland pH and WETLAB pH for the HCT leachates**

## 5 Static Testwork Results

### 5.1 Multi-Element Analysis Results

#### 5.1.1 Waste Rock and Ore

Multi element analysis was undertaken on all waste rock and ore samples to provide an absolute upper limit of metals available for leaching from the Copper Flat materials. The results for key parameters related to ARDML are summarized in Table 5-1 and compared to average crustal concentrations using the Geochemical Abundance Index (GAI). Results are provided in Appendix B.

The results show that copper, sulfur and selenium are elevated in all material types, with GAI values above 3 in many samples, representing greater than 12 times enrichment of average crustal concentrations. Copper concentrations were elevated up to 1 wt% and the maximum sulfur concentration was 3.34 wt%, with particular enrichment occurring in the sulfide and transitional ore material types. These concentrations represent significant enrichment of average crustal concentrations, which are 55 mg/kg and 260 mg/kg for copper and sulfur, respectively. The elevated copper and sulfur concentrations are associated with the primary mineralization at Copper Flat, which is predominantly chalcopyrite ( $\text{CuFeS}_2$ ), with selenium most likely occurring as a trace element in this mineral. This supports the observation that the highest copper and sulfur concentrations are observed in the sulfide/transitional ore.

Silver, arsenic, cadmium, molybdenum, lead, thallium, uranium, tungsten and zinc were also found to be elevated in one or more material type, with the greatest levels of enrichment occurring in the sulfide and transitional ore material types. Many of these elements are commonly associated with copper porphyry deposits (Rose, Hawkes and Webb, 1979), which explains their enrichment in the Copper Flat materials and more specifically in the ore samples. In contrast, the diabase and andesite material types typically showed much lower levels of elemental enrichment, which likely relates to the lack of primary mineralization in these lithological units.

Because copper, arsenic, cadmium, lead and uranium are environmentally sensitive elements, their release was closely monitored during the MWMP test to ensure that they are not leached at concentrations that may potentially pose an impact to the surrounding environment.

#### 5.1.2 Tailings

Multi element analysis was undertaken on twelve tailings composite samples and on two samples of historic tailings collected from the existing TSF. The results for key parameters relating to ARDML are summarized in Table 5-2. Results are provided in full in Appendix C and show that silver, copper, selenium and tungsten are elevated above average crustal concentrations in all tailings samples. In general the biotite breccia composite sample for years 0 – 5 of mine life showed the greatest levels of elemental enrichment, with arsenic, cadmium, chromium, molybdenum, nickel, sulfur, selenium, thallium, silver, uranium and tungsten being elevated above three times average crustal abundance in this sample. These elements were identified as being naturally elevated in the waste rock and ore samples, thus explaining the elevated concentrations observed in the tailings. In contrast, the coarse crystalline porphyry tailings samples (CF-11-02 [52-117] and CF-11-02 [227-367]) showed the lowest levels of elemental enrichment, which is likely to relate to the overall lower sulfide content associated with this lithological unit (and any subsequent tailings generated).

**Table 5-1: Summary of Waste Rock Multi Element Assay Results for Key Parameters related to ARDML**

	#	Multi Element Analysis (average concentration in mg/kg)																		
		Ag	Al	As	Cd	Cr	Cu	Fe	Hg	Mn	Mo	Ni	Pb	S	Sb	Se	Tl	U	W	Zn
Average crustal abundance (mg/kg)		0.04	81,300	1.8	0.2	100	55	50,000	0.08	950	1.5	75	13	260	0.2	0.05	0.5	1.8	1.5	70
Andesite	4	0.27	80,225	0.90	0.56	67.3	217	56,400	0.01	861	5.38	11.2	8.65	925	0.40	2.00	1.31	2.05	2.20	60.3
Diabase	2	0.20	82,900	0.40	2.25	119	1,664	60,200	0.01	1,380	4.37	63.8	6.10	1,350	0.18	2.50	0.31	4.85	1.00	213
Sulfide waste	50	0.89	77,064	2.84	0.53	27.3	1,104	22,786	0.03	317	75.0	3.66	35.9	6,972	0.29	2.24	1.50	5.63	8.23	80.4
Transitional waste	10	0.62	77,820	0.85	0.13	61.3	788	24,240	0.11	123	18.3	2.27	16.9	17,420	0.20	3.80	1.70	4.62	11.3	22.8
Sulfide ore	48	2.77	75,363	6.33	0.95	47.5	3,345	31,369	0.03	342	158	4.47	44.7	13,954	0.39	3.92	1.80	6.82	9.5	127
Transitional ore	17	3.60	78,188	5.28	1.40	52.6	4,381	29,824	0.02	453	99	6.28	50.1	11,829	0.85	3.94	1.92	6.47	10.5	156
Oxide ore	1	3.48	85,600	3.00	0.38	2.00	7,320	29,000	0.01	271	94.3	2.50	16.1	400	0.46	3.00	2.35	7.60	13.9	56.0

# = number of samples representing material type

GAI = 0 represents less than 3 times average crustal concentrations

GAI = 1 represents 3 to 6 times average crustal concentrations

GAI = 2 represents 6 to 12 times average crustal concentrations

GAI ≥ 3 represents greater than 12 times average crustal concentrations

**Table 5-2: Tailings Multi Element Assay Results for Key Parameters related to ARDML**

	Multi Element Analysis (average concentration in mg/kg)																		
	Ag	Al	As	Cd	Cr	Cu	Fe	Hg	Mn	Mo	Ni	Pb	S	Sb	Se	Tl	U	W	Zn
Average crustal abundance (mg/kg)	0.04	81,300	1.8	0.2	100	55	50,000	0.08	950	1.5	75	13	260	0.2	0.05	0.5	1.8	1.5	70
CCP (CF-11-02, 52-117) flotation tailings	0.60	82,600	0.70	0.13	10.0	256	25,100	0.01	347	2.56	3.40	14.4	600	0.16	2.00	1.88	4.50	21.3	37.0
CCP (CF-11-02, 227-367) flotation tailings	0.51	81,800	3.70	0.12	6.00	262	24,900	0.02	370	2.45	3.80	12.8	500	0.20	1.00	1.85	4.70	19.0	33.0
K-spar breccia 0 - 5 comp. flotation tailings	0.61	69,200	5.30	0.53	273	187	21,400	0.01	258	32.1	171	19.3	8,900	0.29	3.00	1.57	5.20	9.90	76.0
K-spar breccia 5+ comp. flotation tailings	1.35	69,400	1.80	0.49	18.0	754	13,000	0.01	214	64.3	6.00	44.7	3,600	0.33	2.00	1.28	6.10	11.6	75.0
Biotite breccia 0 - 5 comp. flotation tailings	0.79	71,600	8.20	0.68	377	184	32,400	0.01	423	47.3	236	31.1	10,500	0.47	3.00	1.59	6.70	9.70	106
Biotite breccia 5+ comp. flotation tailings	0.66	72,200	1.20	0.25	6.00	462	18,200	0.01	384	11.2	4.90	12.4	1,700	0.32	2.00	1.77	5.00	6.90	48.0
Quartz monzonite 0 - 5 comp. flotation tailings	0.55	75,100	4.30	0.73	280	175	20,100	0.01	294	31.9	181	25.6	7,200	0.53	3.00	1.64	6.10	10.0	101
Quartz monzonite 5+ comp. flotation tailings	0.69	75,500	0.40	0.11	9.00	353	14,200	0.01	218	31.5	4.60	11.2	800	0.30	2.00	1.51	5.30	9.90	31.0
Cu Ro. tailings	1.06	71,400	4.20	0.73	16.0	686	25,500	0.05	451	18.8	12.4	55.8	7,800	0.74	3.00	1.78	6.00	9.80	108
Historic tailings	1.26	79,950	5.05	0.41	46.0	1175	30,350	0.01	398	43.8	6.15	28.9	13,100	0.37	3.50	2.05	7.50	9.65	69.0
Whole tailings	0.43	73,100	5.00	0.51	8.00	122	21,800	0.02	288	6.71	5.60	18.5	8,100	0.35	3.00	1.69	5.30	8.80	70.0
Tailings cyclone underflow	26.6	78,600	4.40	0.48	8.00	149	24,900	0.24	324	6.89	7.30	21.3	8,200	0.32	3.00	1.83	6.50	9.00	78.0
Tailings cyclone overflow	0.40	80,200	2.80	0.27	11.0	114	20,700	0.02	361	6.40	7.90	21.5	2,100	0.37	2.00	1.77	6.70	8.90	52.0

GAI = 0 represents less than 3 times average crustal concentrations

GAI = 1 represents 3 to 6 times average crustal concentrations

GAI = 2 represents 6 to 12 times average crustal concentrations

GAI ≥ 3 represents greater than 12 times average crustal concentrations

## 5.2 Acid Base Accounting Results

### 5.2.1 Waste Rock and Ore

Acid Base Accounting was carried out on a total of 132 waste rock and ore samples in order to assess the balance of acid generating and acid neutralizing minerals. The results are summarized in Table 5-3 and plots of key parameters are provided in Figure 5-2 to Figure 5-4. The results are provided in full in Appendix B.

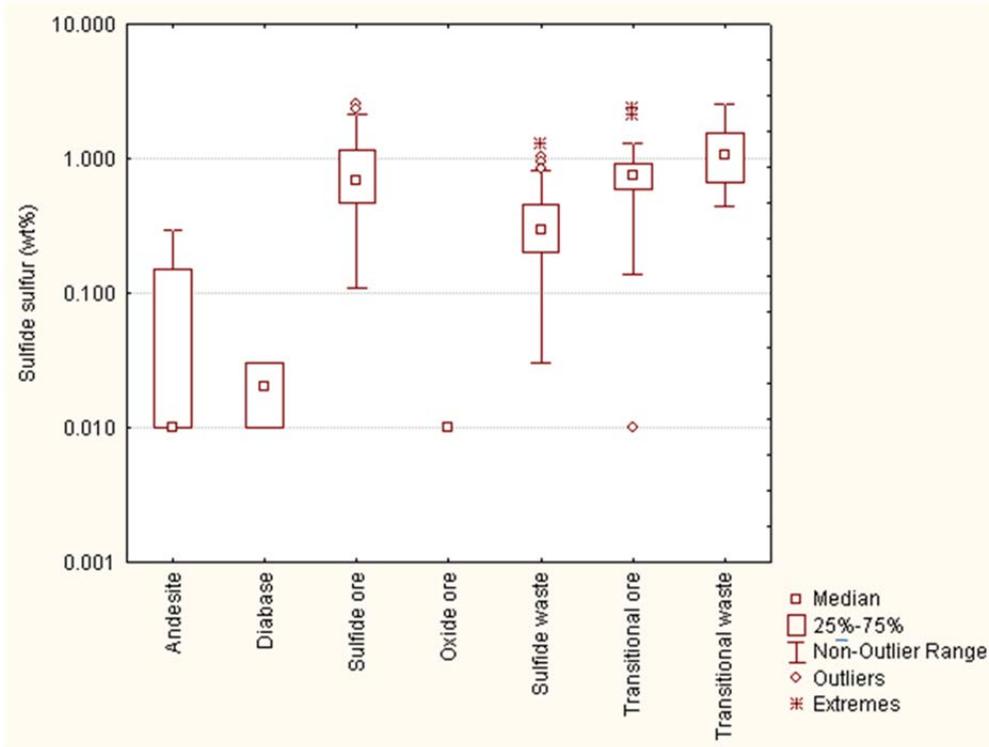
The Copper Flat waste rock and ore materials were found to be variable in terms of their acid generating potential based on ABA testwork results. This is largely a reflection of the variable sulfide content of the samples (Figure 5-1 and Figure 5-4). The majority of the samples tested (72%) show an uncertain potential for acid generation with a net neutralization potential between 20 and -20 kg CaCO<sub>3</sub> eq/ton; consistent with many porphyry copper deposits (Bowell et al., 2000). Sixteen percent (16%) of the samples meet the BLM criteria and can be classified as non-acid forming based on a net neutralizing potential greater than 20 kg CaCO<sub>3</sub> eq/ton and greater than three-fold excess of neutralizing capacity. Twelve percent (12%) of the samples are potentially acid forming materials based on NPR values less than 1 (i.e., no excess neutralizing capacity) and a net neutralization potential of less than -20 kg CaCO<sub>3</sub> eq/ton. Most of the samples that fall within the potentially acid forming category are samples of transitional material (i.e., mixed oxide/sulfide) and are characterized by a sulfide sulfur content greater than 1 wt% (Figure 5-2).

Although there are exceptions to all cases, some general trends in the ABA characteristics according to material type can be seen. Most of the transitional waste, transitional ore and sulfide ore samples can be classified as potentially acid forming materials based on NPR values less than 1. The sulfide waste samples were found to be more variable in terms of their acid generating potential, with samples showing PAF, NAF or uncertain characteristics based on ABA testwork results. However, the majority of the samples for this material type show an uncertain potential for acid generation. The andesite and diabase material types were found to be typically non-acid forming.

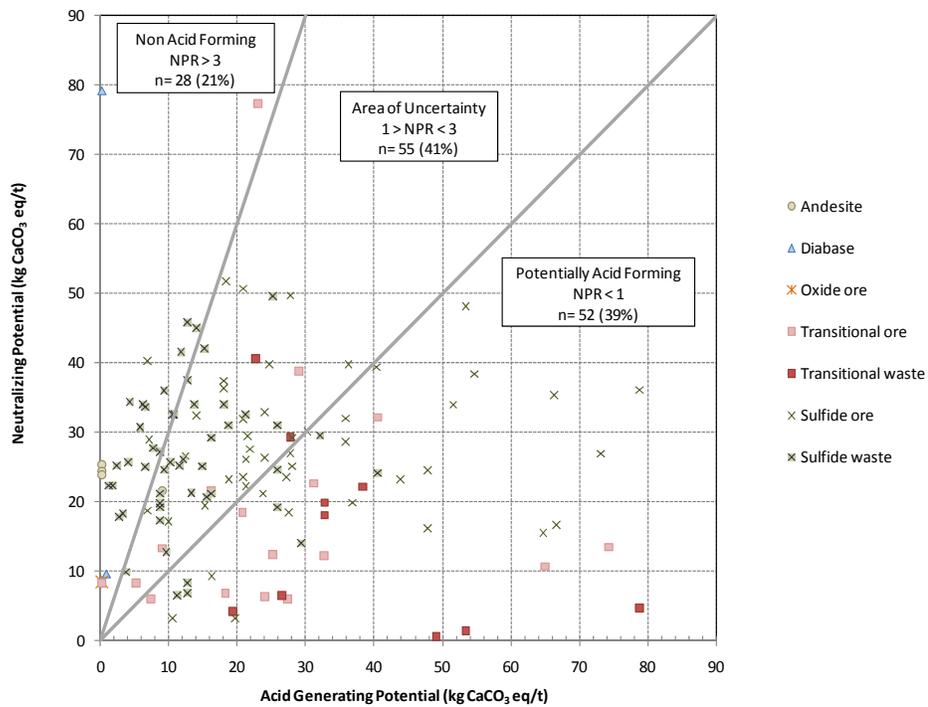
**Table 5-3: Summary of Waste Rock Acid Base Accounting Results**

Material Type	#	Paste pH (s.u.)	Sulfide sulfur (wt%)	AP (CaCO <sub>3</sub> eq/t)		NP (CaCO <sub>3</sub> eq/t)		NNP (CaCO <sub>3</sub> eq/t)		NPR	
				Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Andesite	4	7.99	0.08	2.50	4.40	23.8	1.58	21.5	6.0	61.9	39.7
Diabase	2	6.86	0.02	0.60	0.42	44.4	49.1	43.9	49.8	137	179
Sulfide waste	50	8.41	0.36	12.9	8.30	26.4	9.77	13.6	11.9	3.25	3.07
Transitional waste	10	6.49	1.19	38.2	17.9	14.7	13.5	-23.5	27.2	0.51	0.55
Sulfide ore	48	8.12	0.89	30.6	18.1	28.3	11.0	-2.31	20.2	1.27	1.03
Transitional ore	17	7.31	0.83	26.5	19.5	18.5	17.8	-7.98	25.5	2.47	6.54
Oxide ore	1	7.77	0.01	0.30	-	8.40	-	8.40	-	28.0	-

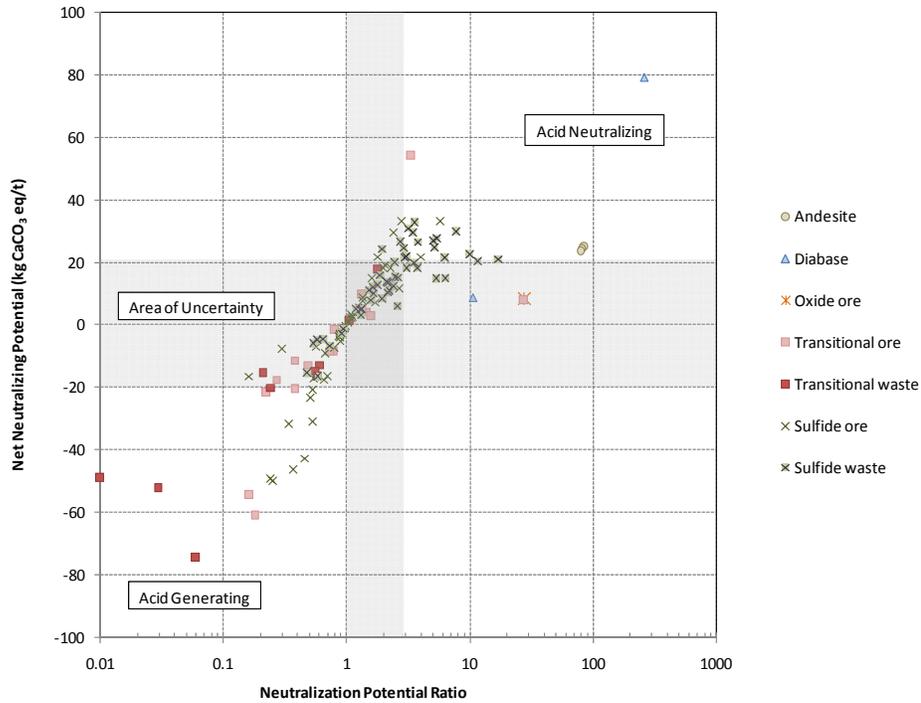
- # Number of samples representing material type
- Potentially acid forming (PAF)
- Uncertain potential for acid generation
- Non acid forming (NAF)



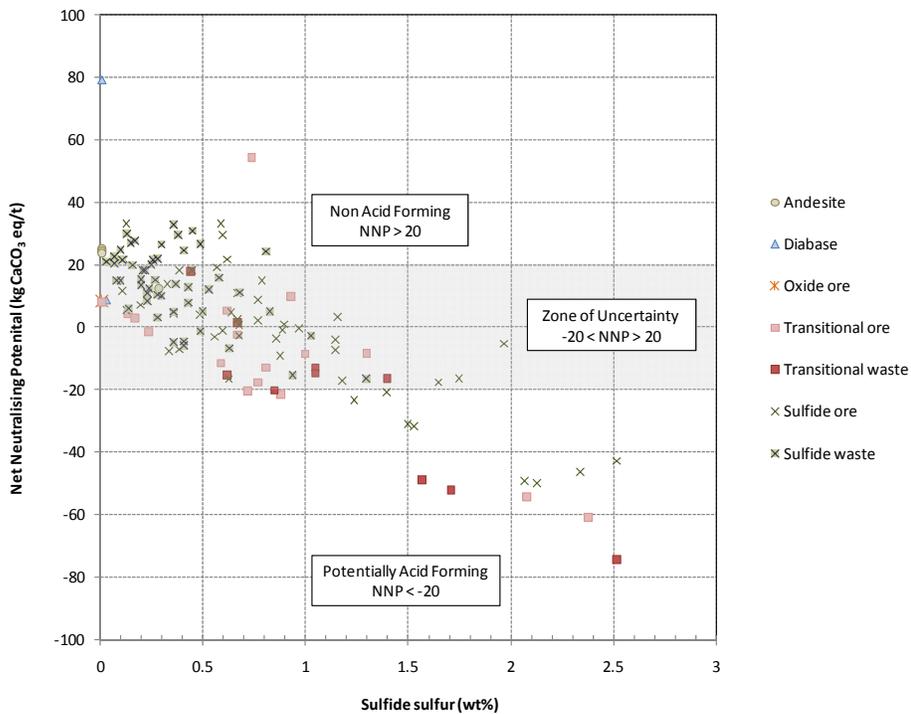
**Figure 5-1: Box and Whisker Plot showing Pyritic Sulfur Content of the Copper Flat Waste Rock Materials**



**Figure 5-2: Scatter Plot of Waste Rock Acid Generation Potential vs. Neutralizing Potential**



**Figure 5-3: Scatter Plot of Waste Rock Neutralization Potential Ratio vs. Net Neutralizing Potential**



**Figure 5-4: Scatter Plot of Waste Rock Sulfide Sulfur vs. Net Neutralizing Potential**

### 5.2.2 Tailings

Acid Base Accounting was carried out on twelve tailings composite samples and on two samples of historic tailings collected from the existing TSF. The results are summarized in Table 5-4 and are illustrated in the scatter plots presented in Figure 5-5 and Figure 5-6. The results are provided in full in Appendix C.

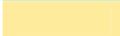
The results show that tailings produced during the first five years of mine life show an uncertain potential for acid formation, whereas tailings produced from year five onwards are predicted to be non-acid forming. This behavior is predominantly controlled by the sulfide content of the tailings, with tailings produced during the early years of mine life being characterized by a higher sulfide content (0.39 to 0.53 wt%) compared to those produced after year five (<0.2 wt% sulfide). The cyclone tailings also show broadly non-acid forming characteristics and show similar geochemical behavior to the other tailings samples tested (Figure 5-5 and Figure 5-6).

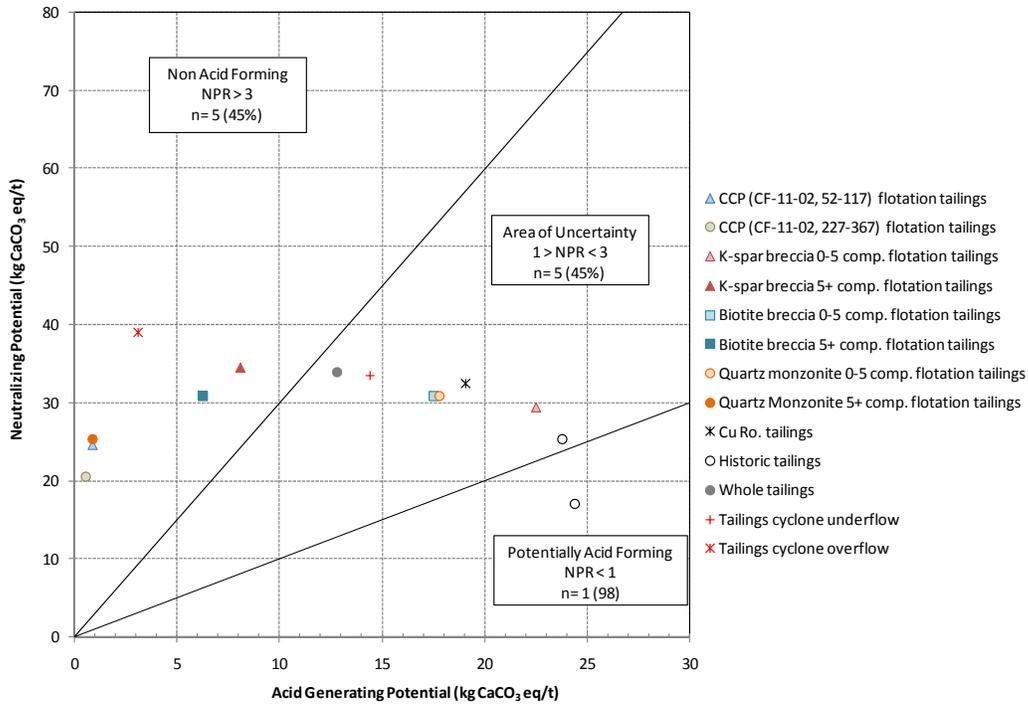
The coarse crystalline porphyry tailings samples are both classed as non-acid forming materials based on low sulfide sulfur contents (less than 0.04 wt%). All tailings samples produced circum-neutral paste pH values (pH 7.95 to 8.5) indicating minimal presence of soluble acid sulfate salts on the material surface.

The historic tailings collected from the existing TSF were characterized by an elevated sulfide sulfur content of 0.77 wt% and can be classed as potentially acid forming on the basis of ABA testwork results.

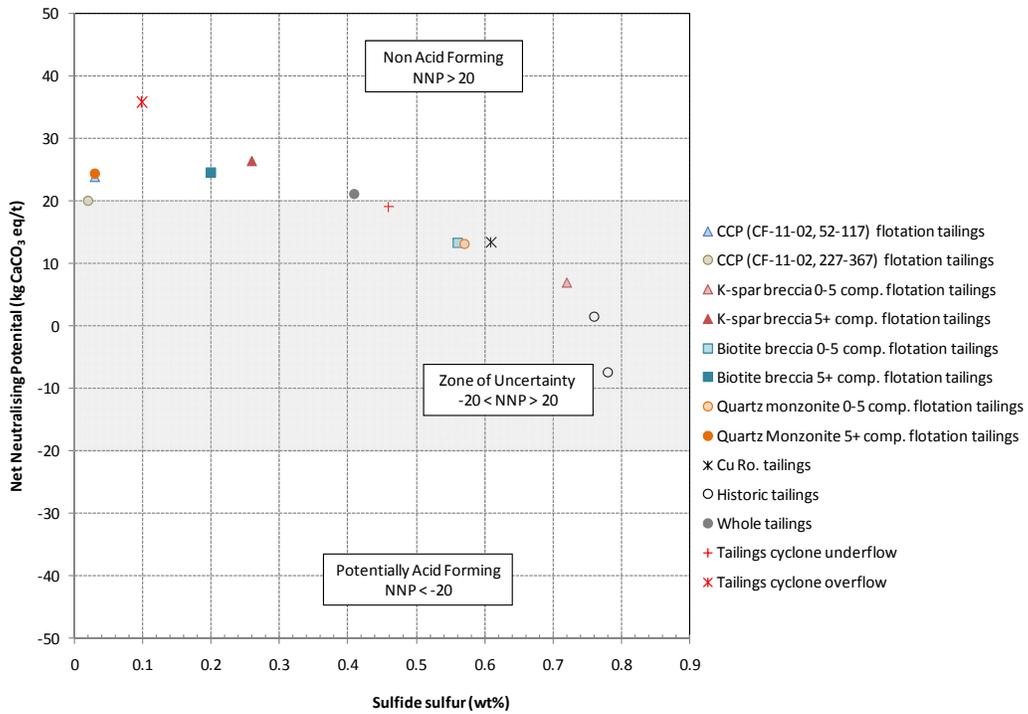
**Table 5-4: Tailings Acid Base Accounting Results**

Material Type	Paste pH	Sulfide sulfur	AP	NP	NNP	NPR
	s.u.	wr%	kg CaCO <sub>3</sub> eq/t			-
CCP (CF-11-02, 52-117) flotation tailings	8.37	0.04	0.90	24.7	23.8	27.4
CCP (CF-11-02, 227-367) flotation tailings	8.50	0.03	0.60	20.6	20.0	34.3
K-spar breccia 0 - 5 comp. flotation tailings	8.07	0.53	22.5	29.4	6.90	1.31
K-spar breccia 5+ comp. flotation tailings	8.28	0.19	8.10	34.5	26.4	4.26
Biotite breccia 0 - 5 comp. flotation tailings	8.00	0.39	17.5	30.9	13.4	1.77
Biotite breccia 5+ comp. flotation tailings	8.49	0.14	6.30	30.9	24.6	4.90
Quartz monzonite 0 - 5 comp. flotation tailings	7.89	0.41	17.8	30.9	13.1	1.74
Quartz monzonite 5+ comp. flotation tailings	8.33	0.02	0.90	25.3	24.4	28.1
Cu Ro. tailings	8.12	0.00	19.1	32.5	13.4	1.70
Historic tailings	7.95	0.77	24.1	21.3	-2.85	0.89
Whole tailings	7.98	0.51	12.8	34.0	21.2	2.66
Tailings cyclone underflow	8.11	0.61	14.4	33.5	19.1	2.33
Tailings cyclone overflow	8.00	0.15	3.10	39.0	35.9	12.6

 Non-acid forming (NAF)  
 Uncertain potential for acid generation  
 Potentially acid forming (PAF)



**Figure 5-5: Scatter Plot of Tailings Acid Generation Potential vs. Neutralizing Potential**



**Figure 5-6: Scatter Plot of Tailings Sulfide Sulfur vs. Net Neutralization Potential**

## 5.3 Net Acid Generation Results

### 5.3.1 Waste Rock and Ore

Net Acid Generation testing was carried out on a total of 132 waste rock and ore samples in order to assess the potential for acid generation given complete oxidation of sulfide minerals in the Copper Flat materials. The results are summarized in Table 5-5 and are provided in full in Appendix B. In general, a NAG pH greater than 4 s.u. and a NAG value equal to zero are indicative of non-acid generating material.

The diabase and oxide ore samples were uniformly characterized by a NAG pH greater than 4 and a NAG value of zero, indicating that they are unlikely to be problematic in terms of long-term acid generation. The same is true for the andesite with the exception of one sample that showed a low capacity for acid generation.

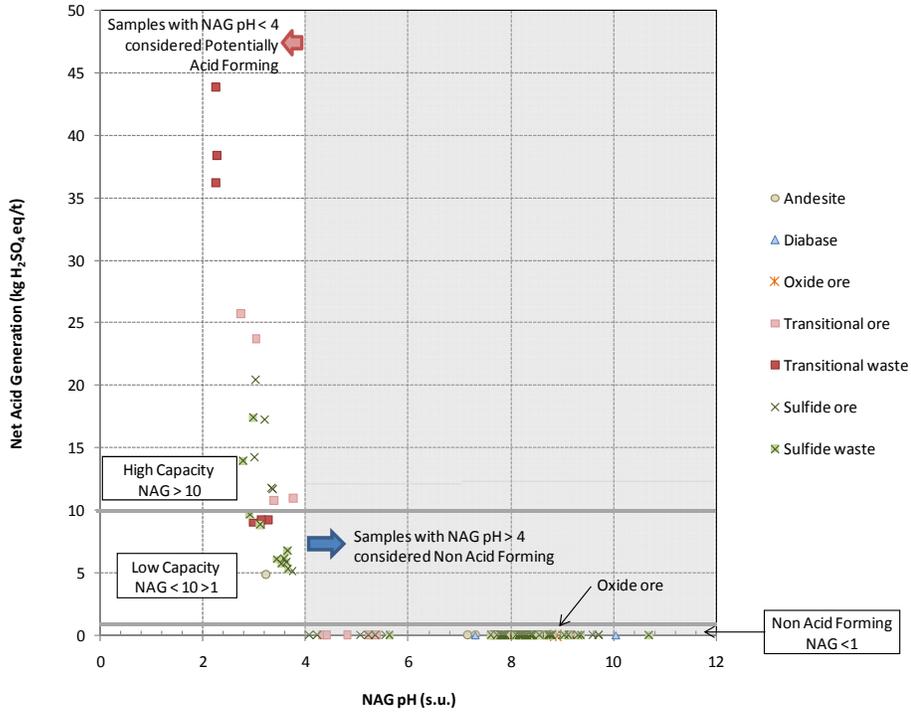
The transitional waste, transitional ore and sulfide ore material types typically exhibited moderate to high capacity PAF characteristics, with lower NAG pH values and the potential to generate up to 23.8 kg H<sub>2</sub>SO<sub>4</sub> eq/ton. This is related to the generally higher sulfide content of these material types.

The sulfide waste samples were found to be more variable in terms of their acid generating characteristics, with two samples of this material type showing high capacity PAF characteristics, eight samples showing low capacity PAF and 40 samples being non-acid forming (NAG <1). This is related to the variable sulfide sulfur content of this material (Figure 5-4).

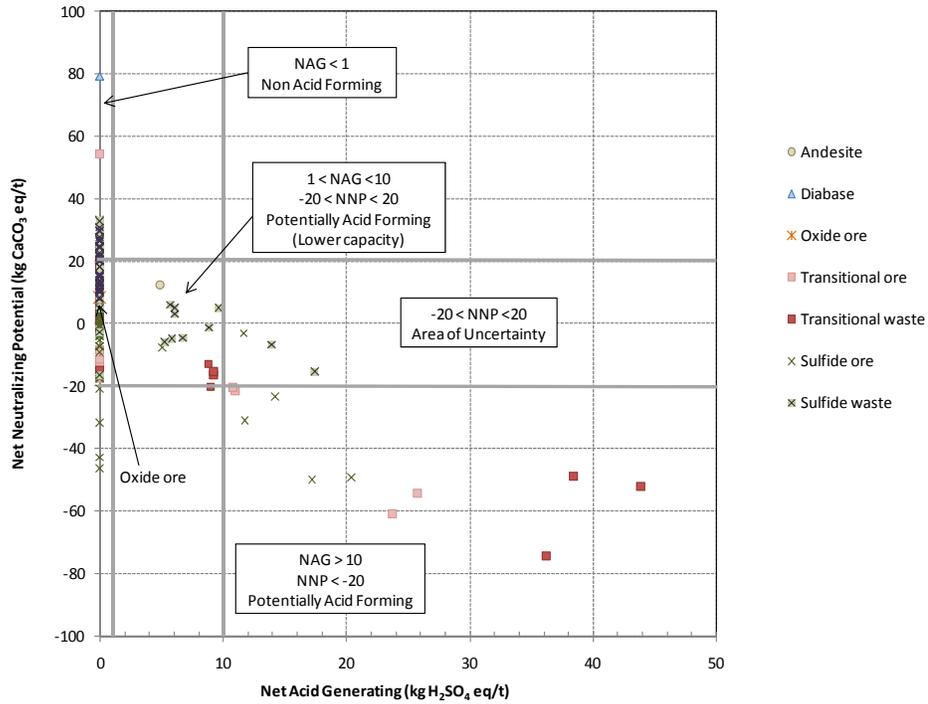
**Table 5-5: Summary of Waste Rock Net Acid Generation Results**

Material Type	#	NAG pH (s.u.)		NAG (kg H <sub>2</sub> SO <sub>4</sub> eq/t)	
		Mean	S.D.	Mean	S.D.
Andesite	4	6.50	2.23	1.23	2.45
Diabase	2	8.69	1.94	0	0
Sulfide waste	50	7.33	2.12	1.71	3.88
Transitional waste	10	4.34	2.57	15.5	17.1
Sulfide ore	48	7.38	2.02	1.68	4.81
Transitional ore	17	6.17	2.34	4.20	8.54
Oxide ore	1	8.88	-	0	-

#	Number of samples representing material type
	Potentially acid forming (PAF)
	Potentially acid forming (PAF) lower capacity
	Non Acid Forming (NAF)



**Figure 5-7: Scatter Plot of Waste Rock NAG pH vs. NAG**



**Figure 5-8: Scatter Plot of Waste Rock Net Acid Generation vs. Net Neutralization Potential**

### 5.3.2 Tailings

NAG testing was carried out on the Cu. Ro. Tailings composite sample, the cyclone tailings and on two samples of historic tailings collected from the existing TSF. The results are displayed in Table 5-6 and demonstrate that the tailings samples exhibited non-acid forming characteristics based on a NAG pH between 8.41 and 9.23 and total NAG values of zero. This indicates that the tailings have sufficient buffering capacity to neutralize any acid produced by sulfide oxidation. The results are provided in full in Appendix C.

**Table 5-6: Summary of Tailings Net Acid Generation Results**

Material Type	#	NAG pH (s.u.)		NAG (kg H <sub>2</sub> SO <sub>4</sub> eq/t)	
		Mean	S.D.	Mean	S.D.
Cu. Ro. Tailings	1	9.23	-	0	-
Historic tailings	2	8.78	0.33	0	0
Whole tailings	1	8.41	-	0	-
Tailings cyclone underflow	1	8.41	-	0	-
Tailings cyclone overflow	1	8.41	-	0	-

# Number of samples representing material type

	Potentially acid forming (PAF)
	Potentially acid forming lower capacity
	Non acid forming (NAF)

### 5.4 Short Term Leach Test Results

MWMP leach tests were conducted on a total of 49 waste rock samples and one sample of historic tailings material to provide an indication of elemental mobility and metal(loid) release from the Copper Flat materials. The results are presented in Figure 5-9 to Figure 5-12 and are provided in full in Appendix B. In addition, a plot of MWMP pH vs. Ficklin metal (cobalt + cadmium + copper + lead + nickel + zinc) release is presented in Figure 5-13.

In general, metal mobility and metal leaching from the Copper Flat materials was found to be low, with several parameters being below analytical detection limits in the leachates. Leachates generated from the andesite, sulfide ore, sulfide waste and tailings materials were characterized by circum-neutral to moderately alkaline pH (6.9 to 8.7 s.u.) confirming that short-term acid generation from these material types is unlikely to be an issue. However, leachates produced by the transitional materials (ore and waste) were more acidic (pH 3.05 to 5.5), which supports the findings of the ABA and NAG testwork results and indicates the presence of soluble sulfate salts on the material surface.

From Figure 5-13, the majority of leachates generated during the MWMP test could be classed as near-neutral, low-metal waters based on pH values typically between 7 and 9 and total Ficklin metal release less than 1 mg/L. However, one sample of diabase, five samples of transitional waste and three samples of transitional ore were seen to produce acidic leachates (pH 3.05 to 5.5), with elevated total Ficklin metal concentrations up to 291 mg/L (Figure 5-13). These samples were uniformly grab samples collected from the existing waste rock dumps on site that consists of transitional material that has had opportunity for additional oxidation and further weathering since deposition. The higher release of acidity and metals from these grab samples therefore likely represents the flushing of soluble acidic sulfate weathering salts from the material surface.

Figure 5-15 shows that the majority of the metal load from the surface grab samples is dominated by copper, which supports the hypothesis that the elevated metals release is related to the flushing of soluble copper salts from the surface of the waste rock materials rather than the oxidation of sulfide minerals. This theory is further supported by the poor correlation between Ficklin metal release and the sulfide sulfur content of the samples (Figure 5-14). Manganese and iron release from the transitional ore and waste materials was also found to be elevated, which is likely to reflect the rinsing of surface oxidation products (i.e., secondary salts) from the samples.

The results of the SPLP results for the three cyclone tailings are provided in Table 5-7 and are provided in full in Appendix C. The SPLP results show that leachates generated by the samples are alkaline with pH values around 9 s.u. and have an overall low potential to release base metals. None of the Ficklin metals were measured above analytical detection limits in the resulting leachates; therefore the SPLP leachates can be classed as alkaline, low metal waters.

Due to differences in the liquid to solid ratio used in the MWMP and SPLP tests compared to typical site conditions, the test results only provide a qualitative estimate of elemental concentrations in the resulting leachates and are not considered conclusive or to represent actual predictions of water quality. As such, a comparison to groundwater quality standards has not been considered in this section. Quantitative impacts to groundwater can only be assessed through predictive modeling, which utilizes the results of long-term humidity cell tests coupled with mine plan and geologic information to assess potential concentrations of metal(loid)s in groundwater (see Section 7).

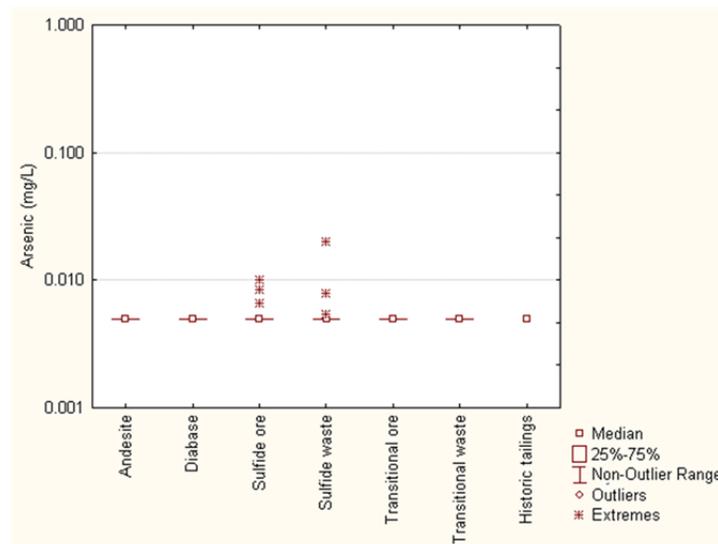
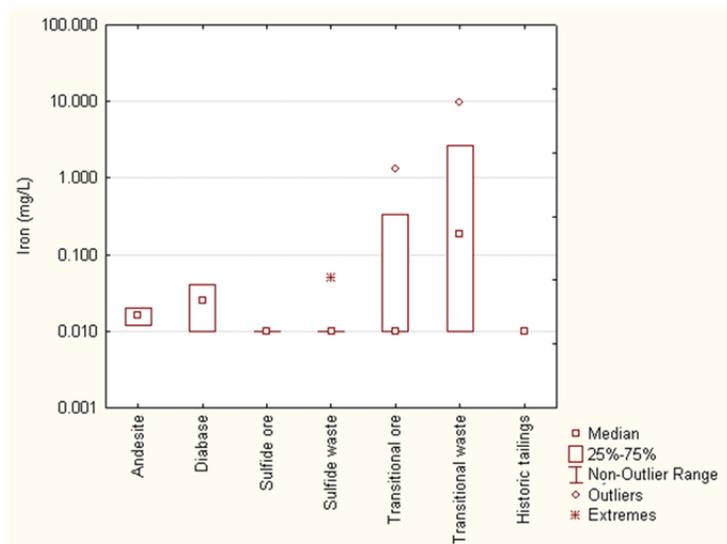
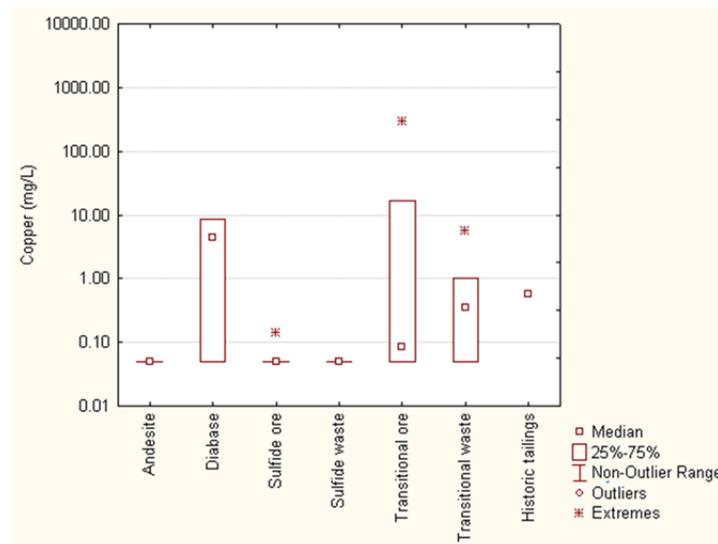
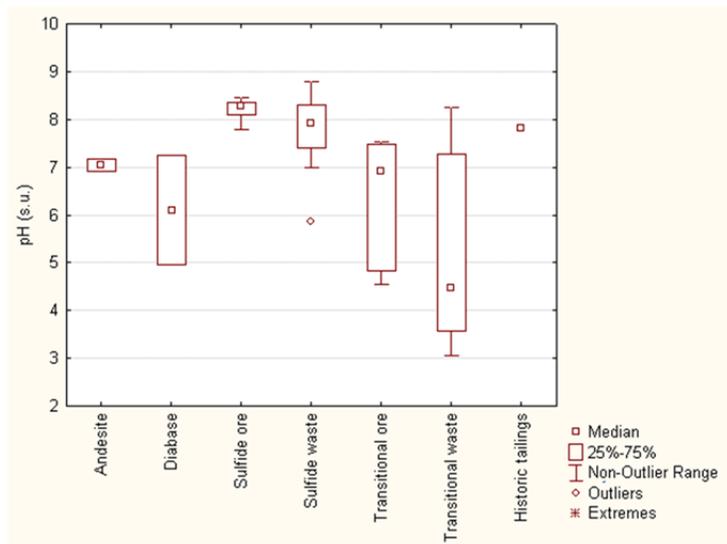


Figure 5-9: Plots of MWMP elemental release

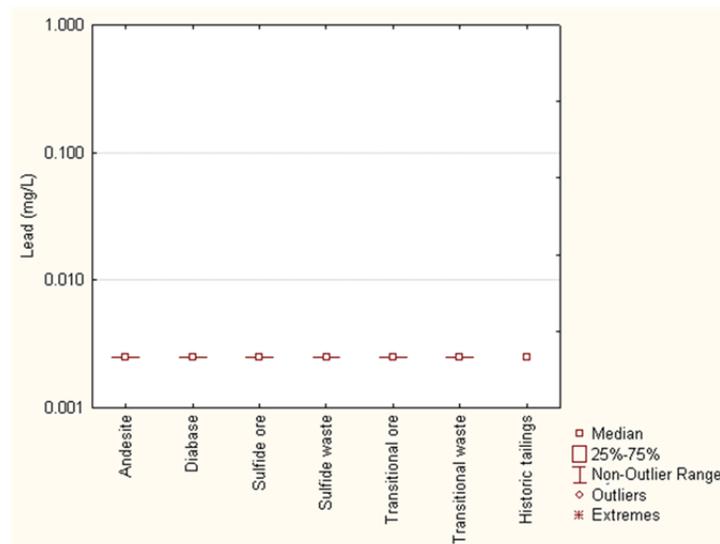
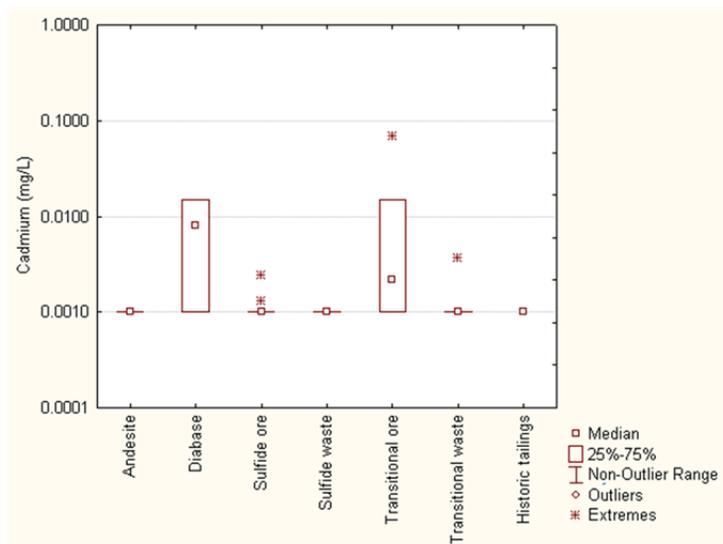
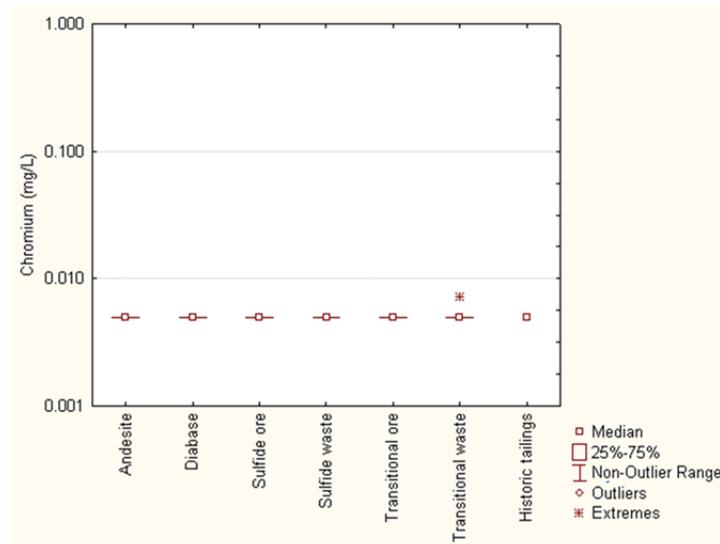
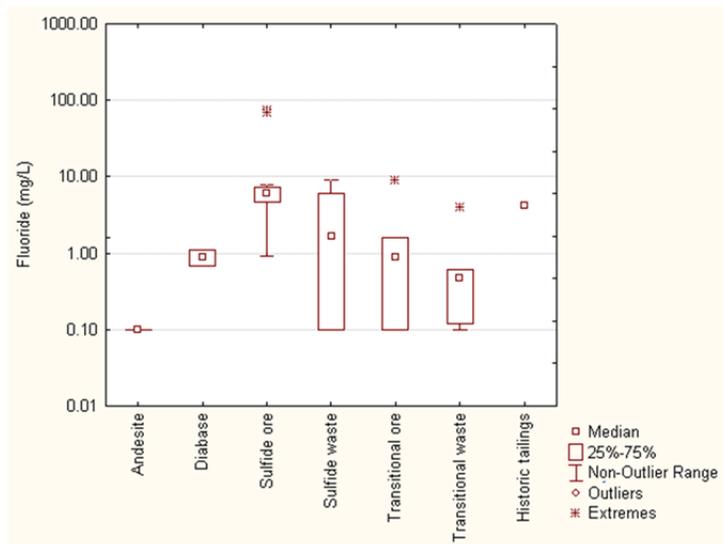


Figure 5-10: Plots of MWMP elemental release

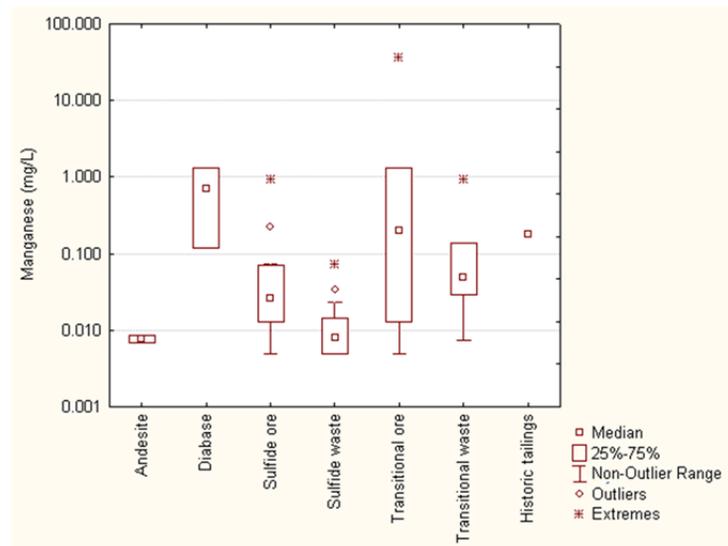
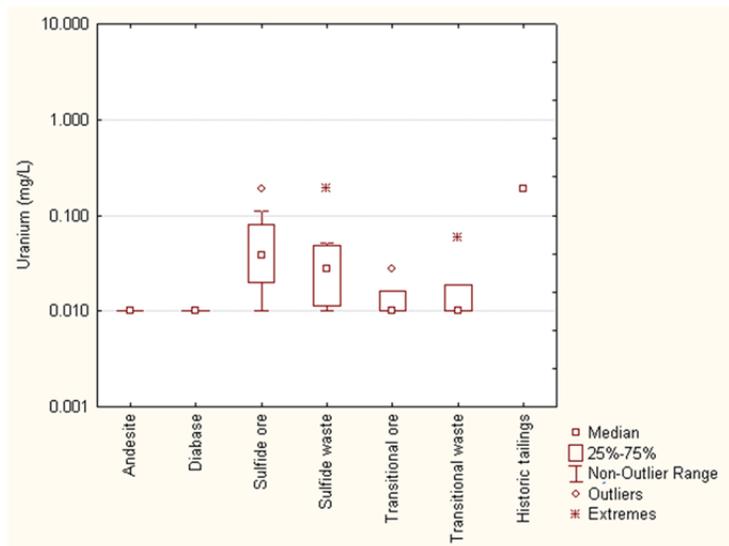
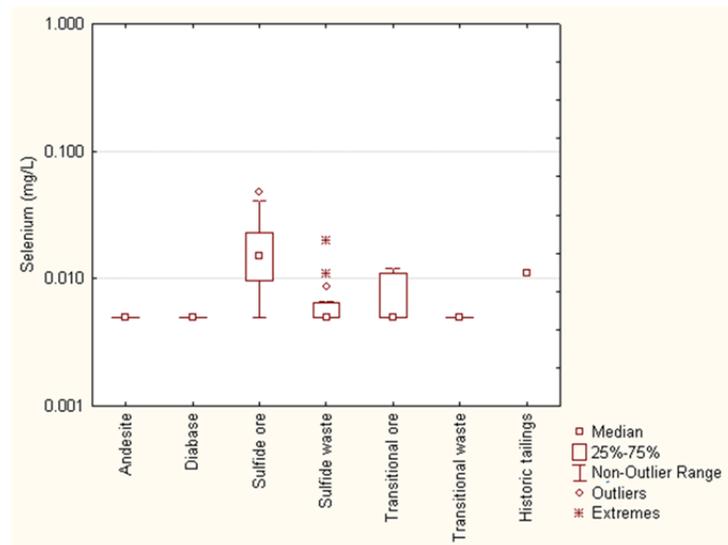
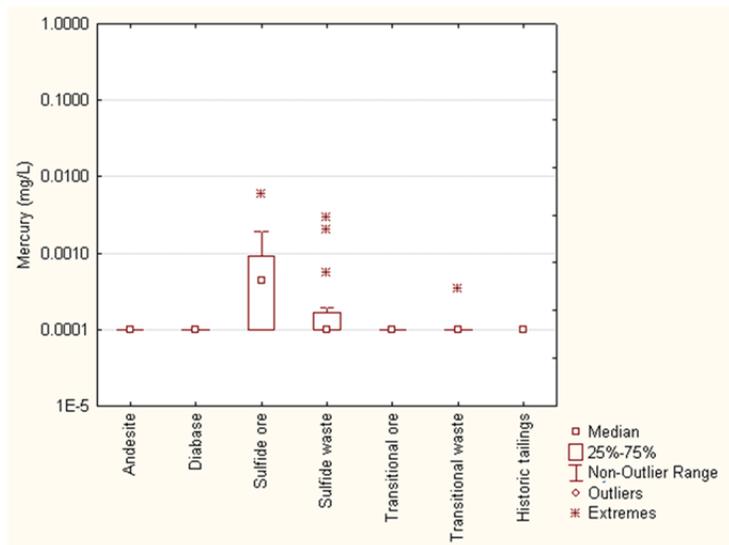


Figure 5-11: Plots of MWMP elemental release

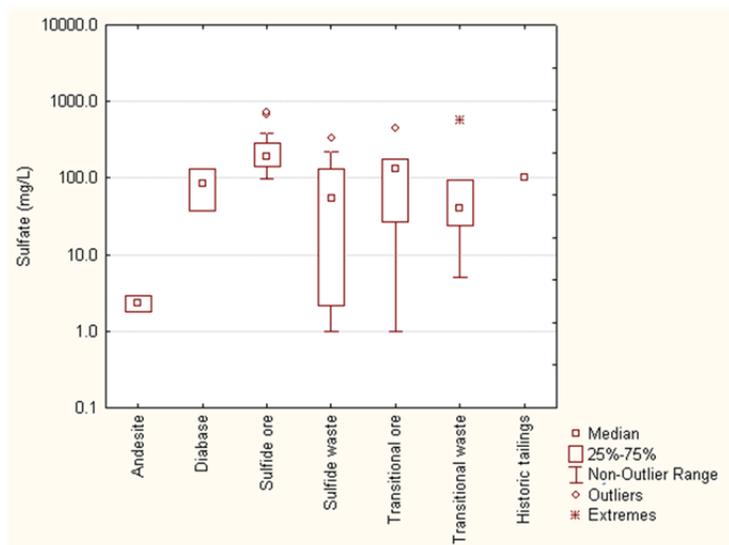
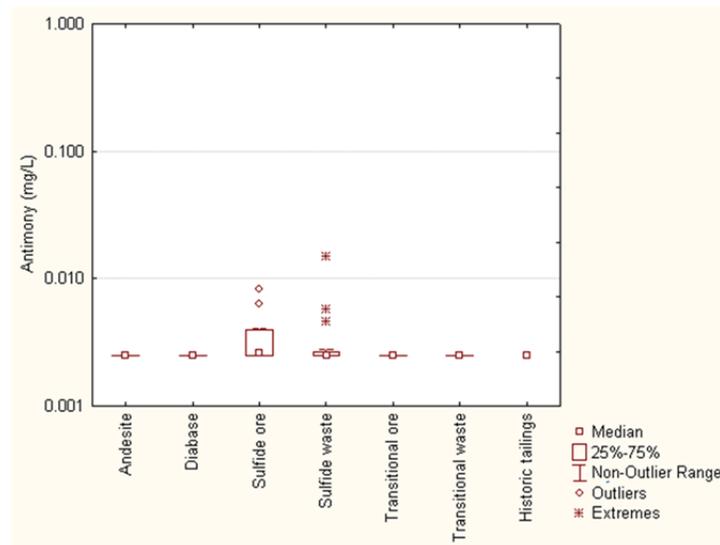
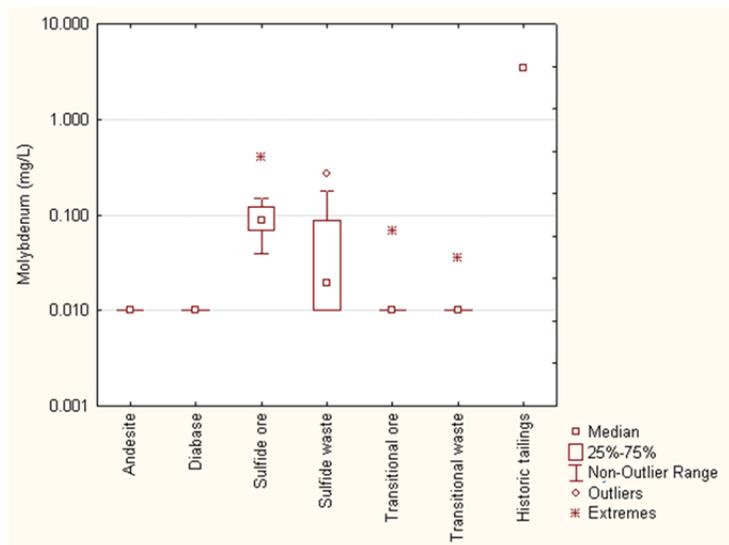


Figure 5-12: Plots of MWMP elemental release

**Table 5-7: SPLP results for the cyclone tailings**

Parameter	Whole Tails	Overflow	Underflow
Alkalinity, Total as HCO <sub>3</sub>	36	34	27
Aluminum	0.1	0.1	0.1
Antimony	<0.0025	<0.0025	<0.0025
Arsenic	<0.005	<0.005	<0.005
Cadmium	<0.001	<0.001	<0.001
Calcium	8.2	8.8	7.6
Chloride	1.3	1.6	<1.0
Chromium	<0.005	<0.005	<0.005
Cobalt	<0.01	<0.01	<0.01
Copper	<0.05	<0.05	<0.05
Fluoride	0.54	0.68	0.58
Iron	<0.1	<0.1	<0.1
Lead	<0.0025	<0.0025	<0.0025
Magnesium	0.6	0.6	0.5
Manganese	<0.005	<0.005	<0.005
Mercury	<0.0001	<0.0001	<0.0001
Molybdenum	0.01	0.01	<0.01
Nickel	<0.01	<0.01	<0.01
Nitrate/Nitrite as N	0.1	0.12	<0.1
pH	8.99	9.09	8.92
Potassium	2.2	3.4	2.5
Selenium	<0.005	<0.005	<0.005
Silver	<0.005	<0.005	<0.005
Sodium	8.1	7.8	6.4
Sulfate	6.4	8.4	5.8
Thallium	<0.001	<0.001	<0.001
Total Dissolved Solids	40	60	46
Zinc	<0.05	<0.05	<0.05

All values reported in mg/L, except pH which is in standard units (s.u.)  
 < denotes less than the laboratory method detection limit.

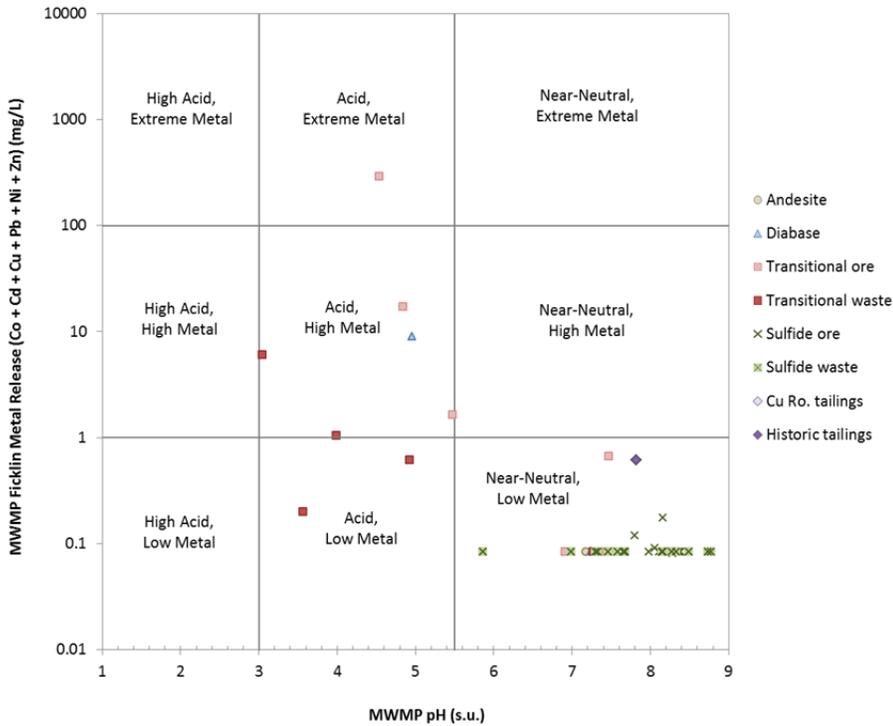


Figure 5-13: MWMP pH vs. Ficklin Metal Release

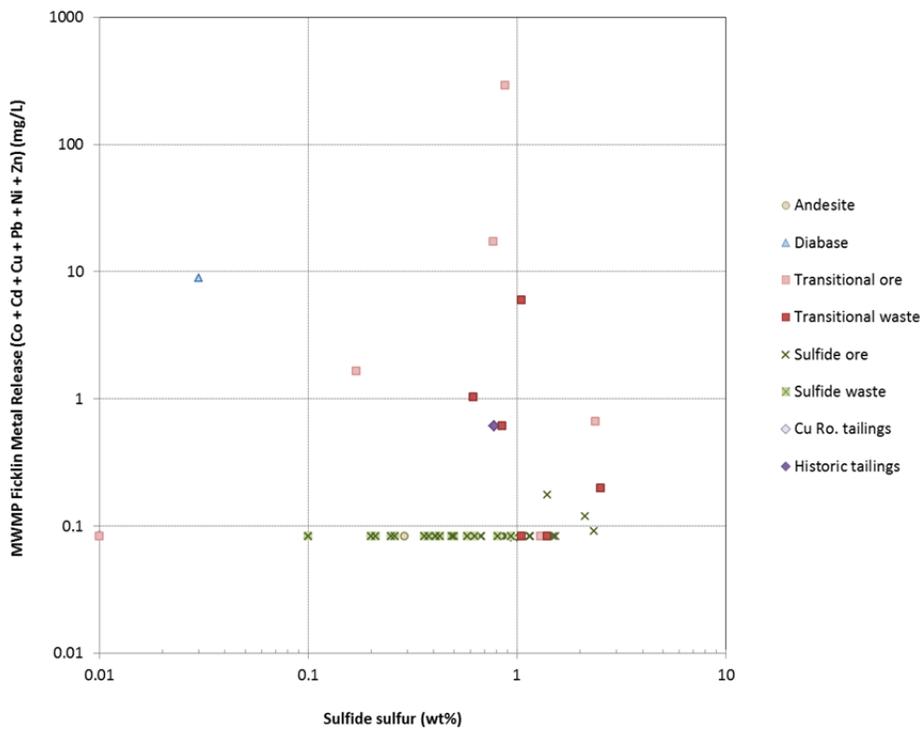
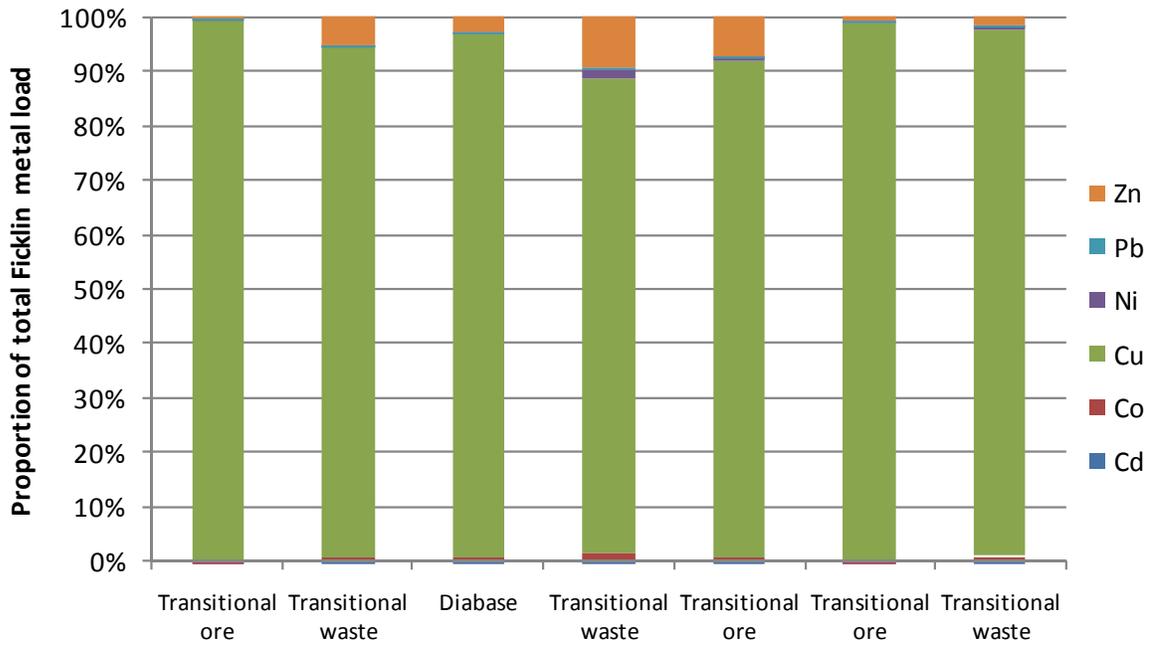


Figure 5-14: Scatter plot of sulfide sulfur vs. MWMP Ficklin metal release



**Figure 5-15: Histogram of percentage contribution of parameters to total Ficklin metal release in the MWMP tests (grab samples only)**

## 5.5 Comparison of 2010/2011 and 1997 Static Datasets

SRK has undertaken a comparison of the testwork results obtained from ABA and NAG tests for the 1997 and 2010/2011 sample sets. This comparison evaluated the two datasets as a whole and has not considered variations within individual material types. This is because the material type designations used in the 1997 and 2010/2011 assessments were slightly different, and thus this would not be an appropriate comparison. For example, the 1997 geochemical characterization program delineates samples according to oxidation (e.g. sulfide, transitional, oxide) and lithology (e.g. quartz monzonite, biotite breccia, etc.), whilst the 2010/2011 program classifies materials according to oxidation and grade. Nonetheless, the material types sampled during both the 1997 and 2010/2011 geochemical characterization programs are comparable (Table 5-8).

**Table 5-8: Summary of 1997 and 2010 Sampling**

1997 Sampling		2010/2011 Sampling	
Material Type	Sample No.	Material Type	Sample No.
Andesite	1	Andesite	4
Quartz Monzonite - sulfide	84	Diabase	2
Quartz Monzonite - transitional	7	Sulfide ore	26
Quartz Monzonite - oxide	3	Sulfide waste	72
Biotite Breccia - sulfide	9	Transitional ore	14
Biotite Breccia - oxide	1	Transitional waste	13
Quartz Breccia - sulfide	25	Oxide ore	1
Quartz Breccia - transitional	2	Tailings	3
Quartz Breccia - oxide	1		
Quartz Vein - sulfide	6		
Quartz Vein - transitional	2		
<b>Total</b>	<b>141</b>	<b>Total</b>	<b>135</b>

Comparison of the 1997 and 2010/2011 data sets is illustrated on scatter plots and box and whisker plots presented in Figure 5-16 through Figure 5-22. The scatter plot comparing the sulfide sulfur content and net neutralizing potential (NNP) of the 1997 and 2010/2011 samples provided in Figure 5-16 demonstrates that the two sample sets are broadly comparable, with a similar range in values. However, the 2010/2011 data set generally has more samples that fall within the zone of uncertainty or that are non-acid forming. Conversely, the 1997 data set proportionally contains more samples that show potentially acid forming (PAF) characteristics, which may relate to the focus of this earlier sampling program on material within the existing waste rock dumps (i.e., fine grained fraction that is more weathered in the dump than would occur with fresh rock). The 1997 sample program was biased towards fine-grained, reactive material within the historic waste rock dumps and the material was selectively screened to -2mm prior to testing. The current study aimed to collect samples that are more representative of the bulk of waste rock that will be produced during future mining operations.

The box and whisker plot provided in Figure 5-17 shows the range and median values of NNP for each data set. This demonstrates that the two data sets are comparable in terms of the range of NNP values, but the samples collected in 1997 generally show a trend towards more acid generating characteristics. The tendency of the 1997 samples towards acid generating characteristics is also

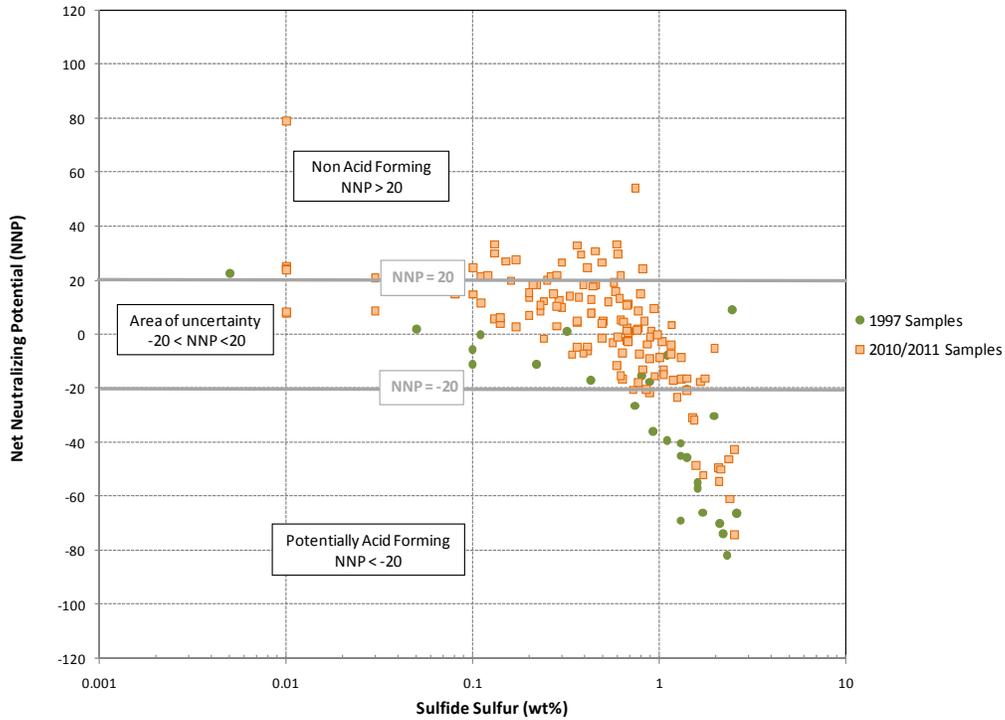
illustrated in the scatter plot of paste pH vs. sulfide sulfur content presented in Figure 5-18. This shows that the paste pH values for the samples collected in 1997 are generally lower (i.e., more acidic) in comparison to the 2010/2011 data. This likely reflects bias in the sampling program, with the 1997 samples being entirely grab samples collected from the surface of the waste rock dumps and the 2010/2011 samples being a mixture of both surface grab samples and also fresh (unweathered) drill core material from depth. Furthermore, the 1997 sample program selectively targeted fine-grained (-2mm) material, which is likely to be geochemically more reactive. Consideration of the grab samples only (Figure 5-19) shows a slightly better correlation between the two datasets, but paste pH values from 2010/2011 are still generally higher than observed in the 1997 dataset.

Comparison of 1997 and 2010/2011 NAG testwork results shows a fairly significant difference between the two datasets. This is largely due to a difference in testwork methodology, with the 1997 analysis including the determination of NAG values for samples with a NAG pH greater than 4. This is different from the 2010/2011 methodology employed, whereby NAG values were only determined for samples with NAG pH less than 4 s.u. (as stipulated by the Miller et al. (1997) protocol). Comparison of the two datasets for only samples with a NAG pH less than 4 shows that the samples are broadly similar in terms of their net acid generating potential (Figure 5-21 and Figure 5-22).

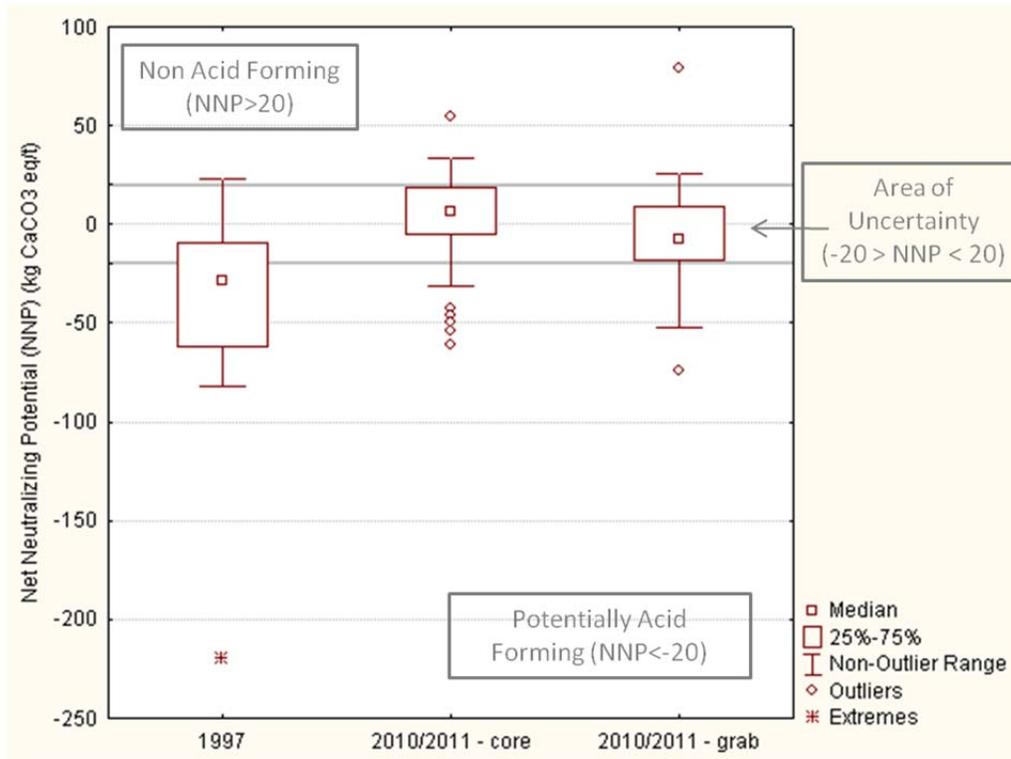
In general, the 1997 and 2010/2011 geochemical databases are comparable in terms of their geochemical characterization and acid generating potential. However, the samples collected in 1997 generally show greater acid generating potential, while the 2010/2011 dataset contains more samples that show uncertain or non-acid forming characteristics. Any significant differences observed between the two datasets are either a function of testwork methodology utilized (in the case of the NAG results) or as a result of the nature of the samples themselves (i.e., fine grained material from waste rock dumps versus core). Another possible reason for the difference is a bias in the 1997 sample collection towards surface or weathered material with few “fresh rock” samples (i.e., preferential selection of highest sulfide/weathered materials).

The focus of the 1997 sampling program was to define the reactivity of waste rock that had been exposed for about 15 years. Based on the results from grab samples collected from the waste rock dumps during 2010/2011 study, there is no increase in reactivity despite the longer exposure period (i.e., approximately 30 years). These results demonstrate the waste rock material is relatively stable and slow to react.

The 1997 data set is representative of materials that were mined previously (i.e., historic waste) and do not necessarily represent the bulk of the material that will be mined in the future, thus limiting the application of this data to the current study. The 2010/2011 dataset is more representative of waste rock and ore associated with the current mine plan and is the focus of this study and provides the basis for the conclusions presented herein.



**Figure 5-16: Scatter Plot of Sulfide Sulfur vs. Net Neutralizing Potential (NNP)**



**Figure 5-17: Box and Whisker Plot of Net Neutralizing Potential (NNP)**

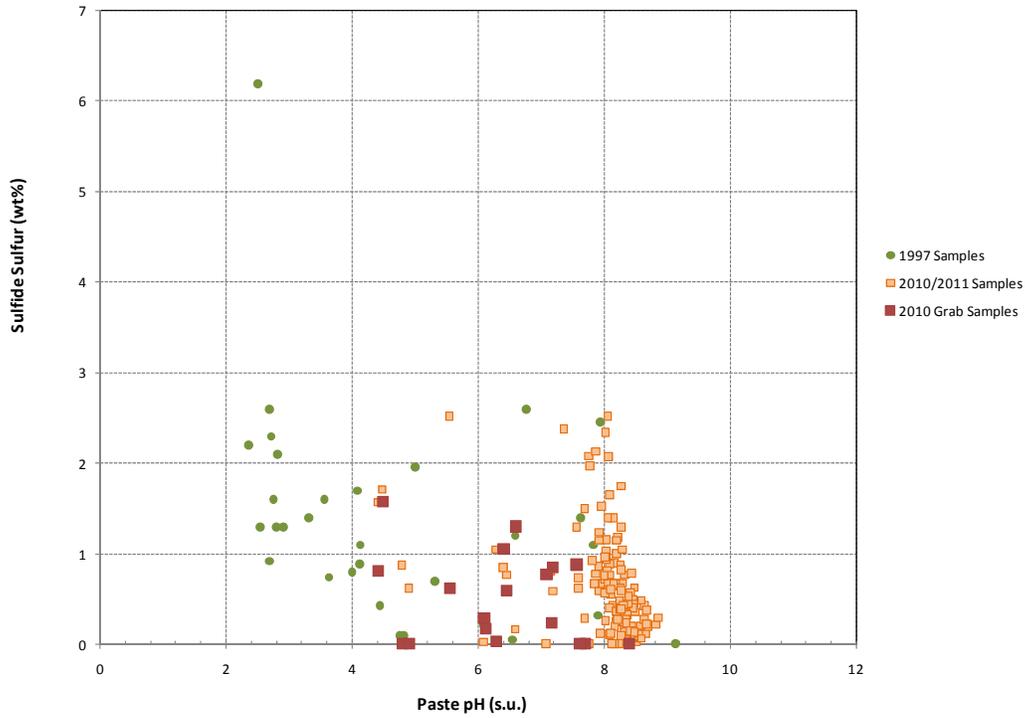


Figure 5-18: Scatter Plot of Paste pH vs. Sulfide Sulfur Content

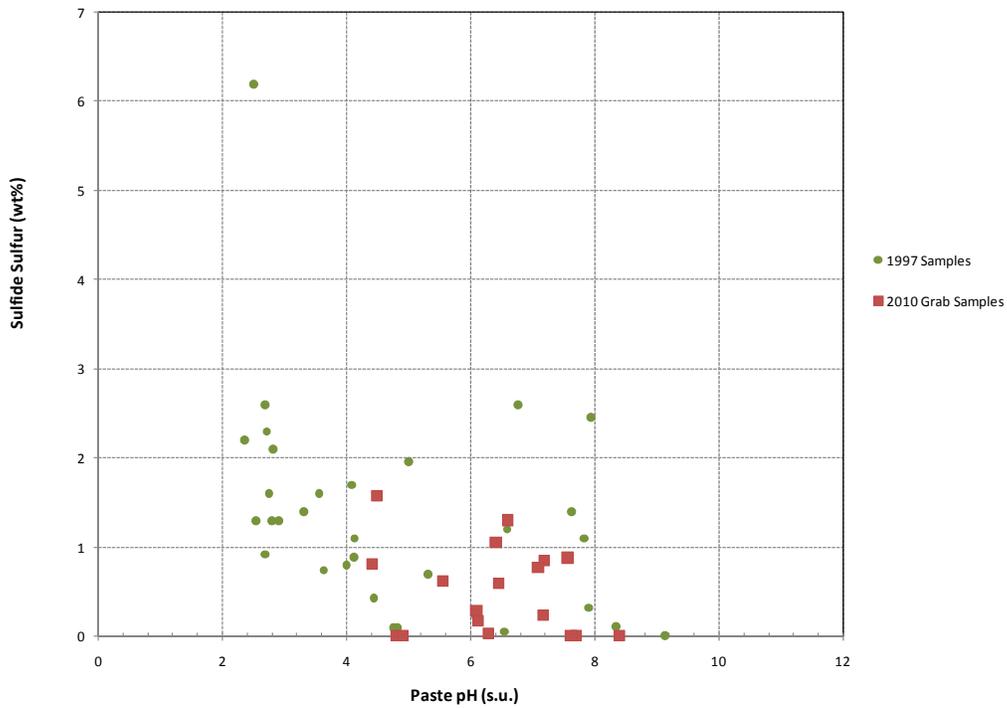
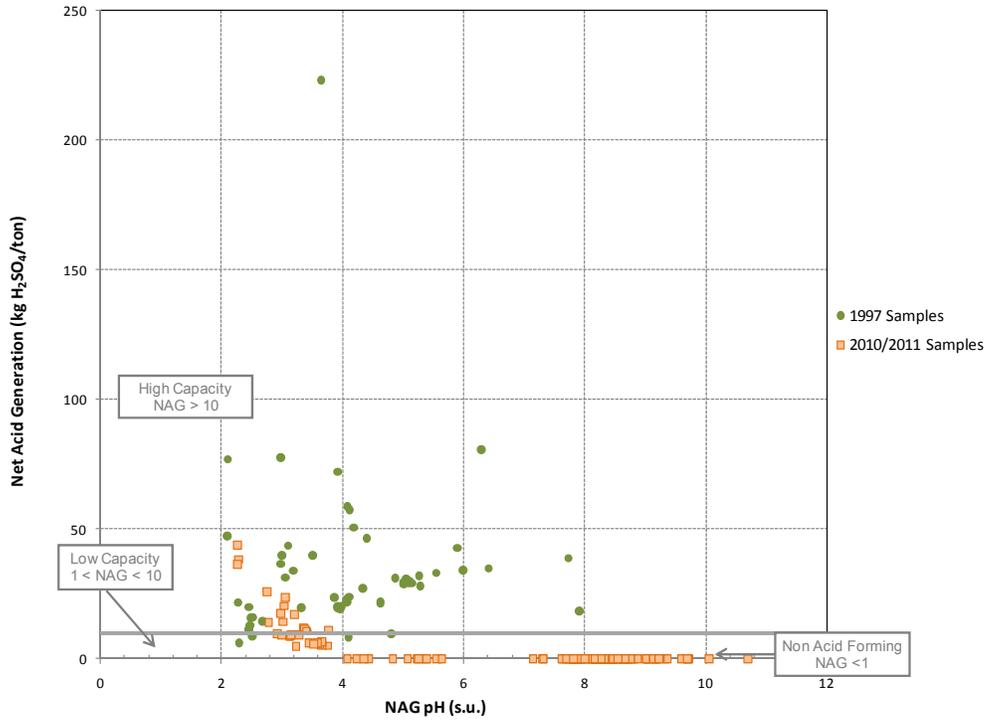
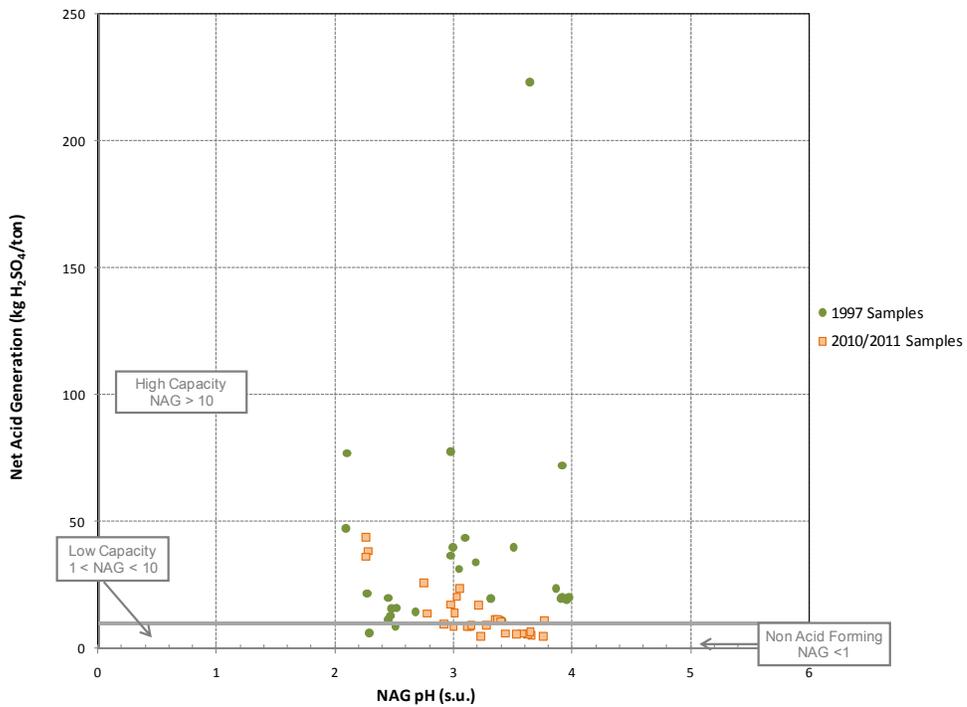


Figure 5-19: Scatter Plot of Paste pH vs. Sulfide Sulfur Content (grab samples only)



**Figure 5-20: Scatter Plot of NAG pH vs. Net Acid Generation (NAG) value**



**Figure 5-21: Scatter Plot of NAG pH vs. NAG for Samples with NAG pH < 4**

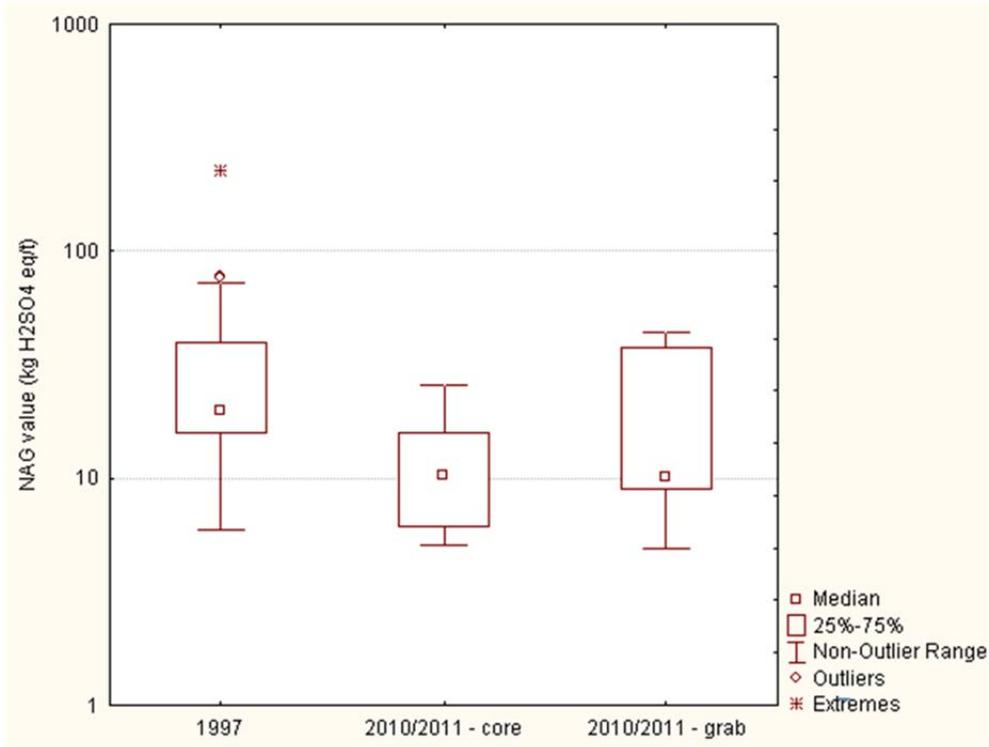


Figure 5-22: Box and Whisker Plot of NAG value for Samples with NAG pH <4

## 6 Kinetic Testwork Results

### 6.1.1 Waste Rock and Ore

Humidity cell testing has been carried out on 23 samples of waste rock and ore. Thirteen of the cells reached steady state conditions and were terminated at week 44 and an additional seven cells were terminated between week 52 and week 96. The remaining three cells are still operational and results are available through week 96. A summary of the status of the cells at the time the geochemical predictions were completed and this report was prepared is provided in Table 6-1. Time series plots of elemental release from the waste rock and ore samples are presented in Figure 6-1 to Figure 6-12 and the results are presented in full in Appendix E. Based on the results available to date, the interpretation and conclusions of the HCT program are valid, however the additional results for the three continued cells will be presented in a supplemental report once these cells reach steady state conditions and have been terminated.

**Table 6-1: Summary of HCT Status**

Material type	Primary lithology	Cell ID	Status
Andesite	Andesite	SRK 0864	Terminated at week 44
	Andesite	SRK 0866	Terminated at week 44
Sulfide waste	Biotite Breccia	605033	Terminated at week 44
	Quartz Monzonite	604673	Week 96
	Quartz Monzonite	605153	Terminated at week 44
	Coarse Crystalline Porphyry	CF-11-02, 367-408	Week 29
Sulfide ore	Biotite Breccia	604811	Terminated at week 44
	Biotite Breccia	604862	Terminated at week 44
	Biotite Breccia	604867	Terminated at week 44
	Biotite Breccia	604854	Terminated at week 44
	Quartz Feldspar Breccia	604767	Terminated at week 86
	Quartz Feldspar Breccia	604787	Terminated at week 56
	Quartz Monzonite	604562	Terminated at week 44
	Quartz Monzonite	604606	Terminated at week 44
	Quartz Monzonite	604669	Terminated at week 61
	Quartz Monzonite	604653	Terminated at week 44
	Quartz Monzonite	604656	Terminated at week 44
Transitional waste	Biotite Breccia	SRK 0872	Terminated at week 96
	Quartz Monzonite	604569	Terminated at week 44
	Quartz Monzonite	SRK 0858	Terminated at week 61
	Coarse Crystalline Porphyry	CF-11-02, 0-27	Week 29
Transitional ore	Biotite Breccia	SRK 0854	Terminated at week 96
	Quartz Monzonite	SRK 0867	Terminated at week 52
Tailings	CF-11-02 (52-117) flotation tailings		Week 23
	CF-11-02 (227-367) flotation tailings		Week 23
	K-spar Breccia 0-5 comp. flotation tailings		Week 23
	K-spar Breccia 5+ comp. flotation tailings		Week 23
	Biotite Breccia 0-5 comp. flotation tailings		Week 23
	Biotite Breccia 5+ comp. flotation tailings		Week 23
	Quartz Monzonite 0-5 comp. flotation tailings		Week 23
	Quartz Monzonite 5+ comp. flotation tailings		Week 23
	Cu Ro. tailings		Terminated at week 28

The trends of effluent pH for each of the cells are presented in Figure 6-1. This demonstrates that the majority of cells produce circum-neutral to moderately alkaline pH leachates (pH 7 to 9) throughout the course of the testwork. Furthermore, the effluent pH is stable for most cells throughout the testwork period, indicating no onset of sulfide oxidation. Only cells SRK 0858 (transitional waste) and SRK 0854 (transitional ore) produced acidic leachates (pH 3 to 5) from week zero onwards. These results can be attributed to the fact that both these cells are surface grab samples containing secondary copper sulfate salts on the material surface. These salts are readily-soluble and flushing during the leach cycle may generate acidic leachates and result in elevated sulfate and metals release. Indeed Figure 6-4 and Figure 6-5 show that cell SRK 0854 (transitional ore collected from the Sternberg lode) has particularly elevated sulfate and copper release at week zero, with up to 1,043 mg/kg and 376 mg/kg release, respectively. The Sternberg lode is a small mine that yielded 200 tons of copper ore between 1911 and 1934 (Raugust, 2003). Observations made during the field sampling program show that material within the Sternberg lode has significant chalcantite ( $\text{Cu}^{2+}\text{SO}_4 \cdot 5\text{H}_2\text{O}$ ) on the surface of the rock. Dissolution of this mineral during the HCT leach cycles is likely responsible for the low pH and elevated metals concentrations observed in the initial leachates from this cell. However, this sample is representative of material that will make up only a minor proportion of the overall waste rock.

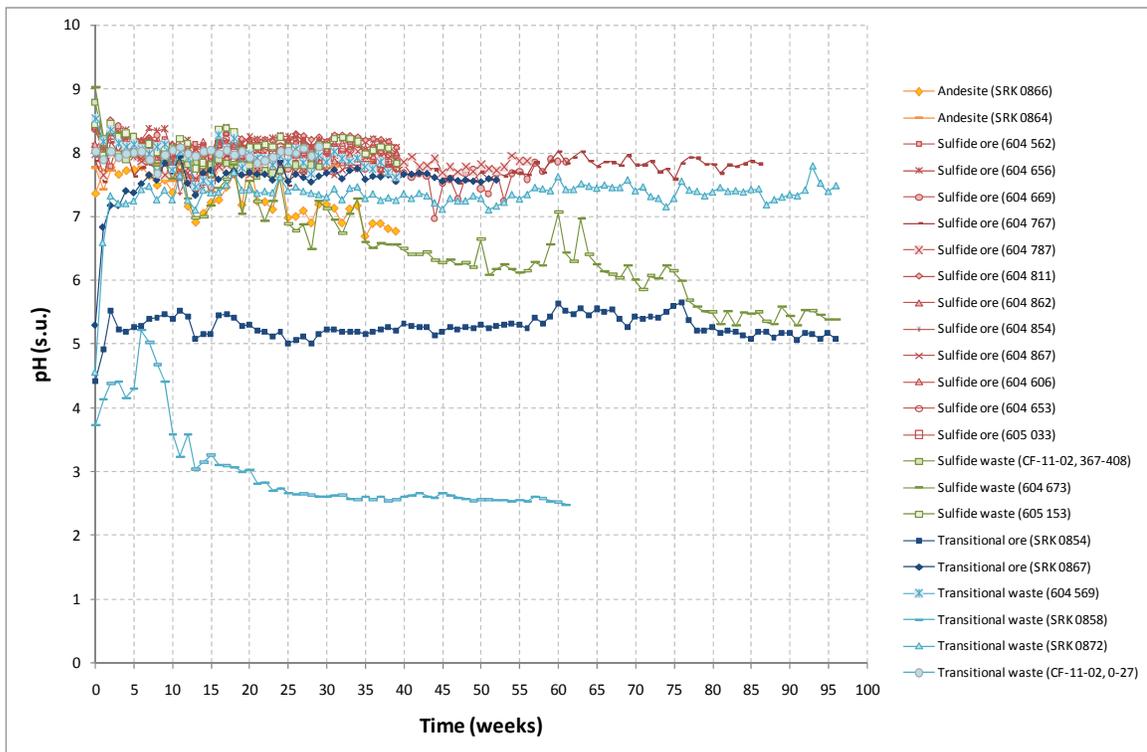
The leachates from most cells show elevated electrical conductivity (EC) during the first five weeks of testing, which corresponds to an initial flush of sulfate from the cells. However, iron release was below analytical detection limits for the majority of samples (Figure 6-3), indicating that the initial flush in sulfate concentrations is not related to sulfide oxidation but rather to the flushing of readily-soluble sulfate salts from the material surface. In contrast, the increase in effluent iron and sulfate concentrations in cell SRK 0858 (transitional waste) after week nine indicates the onset of sulfide oxidation in this cell. This is supported by the corresponding drop in pH and increase in effluent metal concentrations.

Metal release from the drill core samples was generally low throughout the testwork period, with many parameters being at or near analytical detection limits in the leachates including aluminum, arsenic, cadmium, chromium and copper. Metal release from the grab samples (i.e., transitional material) was higher, with detectable release of zinc, copper, manganese and molybdenum, particularly in the first 5 weeks of testwork. Again, this likely represents the flushing of soluble secondary salts from the material surface, which lowers the pH and increases the solubility of base metal ions. This is supported by the Ficklin plot presented in Figure 6-12, which shows that leachates from the majority of cells can be classed as near-neutral, low-metal waters based on effluent pH greater than 5.5 s.u. and Ficklin metal concentrations less than 1 mg/L. However, leachates from cells SRK 0854 (transitional ore) and SRK 0858 (transitional waste) can be classed as acid, high-metal waters based on Ficklin metal concentrations up to 837 mg/L. Metal(loid) release from the majority of cells had stabilized by week 30 and as a result these cells were terminated at week 40. Cells that still showed reactivity were continued beyond week 40, however steady-state conditions have now been achieved in all but three of the cells at week 96.

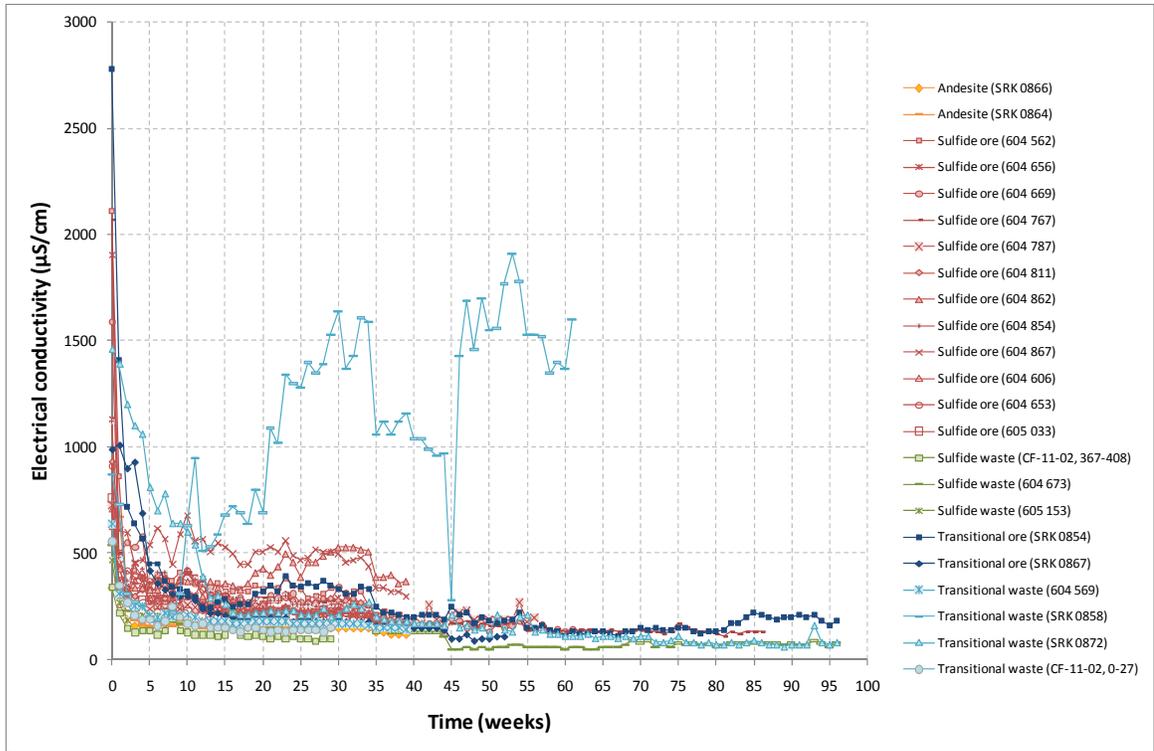
Several of the sulfide ore samples showed elevated uranium release, particularly during the first ten weeks of testing. Uranium concentrations in the HCT leachates reached a maximum of 0.23 mg/L for cell 604 767 (sulfide ore) in weeks 1 and 2, which is above the NMWQCC Human Health Groundwater Standard of 0.03 mg/L. However, uranium release in all cells fell to below the NMWQCC groundwater standard by week 40.

The Piper plot presented in Figure 6-13 shows that the leachates from most cells can be classed as either calcium + sulfate (Ca + SO<sub>4</sub>) or calcium + bicarbonate (Ca + HCO<sub>3</sub>) type waters, with calcium representing the major cation in solution and either sulfate or bicarbonate the major anion.

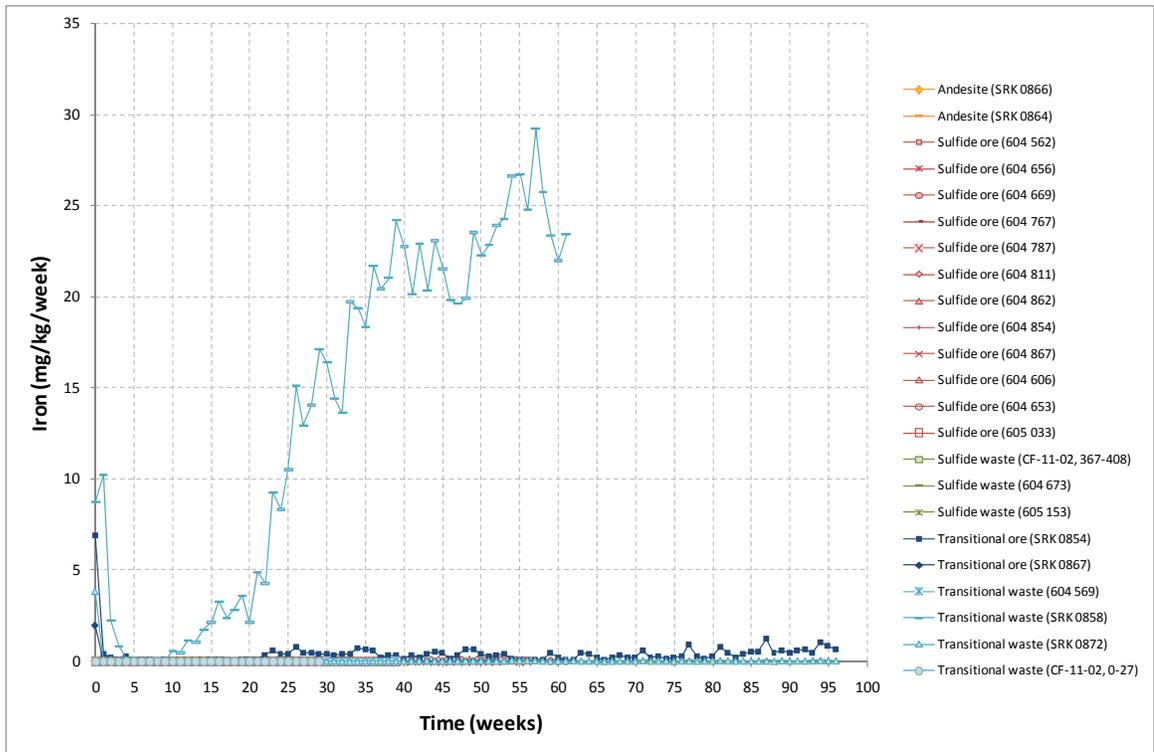
Figure 6-10 shows that there has been a depletion of neutralizing potential (NP) in the HCT cells over the course of the testwork period. The consumption of NP was slow in the majority of cells, with samples still having over 80% of the initial NP remaining at week 40 (or 70% of NP remaining at week 96 for the continued cells). This indicates that significant buffering is still available and/or that acid generation is limited or occurs at a slow rate. However, four cells (SRK 0867, SRK 0854, SRK 0858 and 604669) show rapid consumption of NP throughout the testwork, with cell SRK 0858 (transitional waste) showing complete consumption of NP by week 29 and cell 604669 (sulfide ore) showing complete NP consumption by week 50. This rapid consumption of NP in these cells is related to the lower initial NP available (less than 6 kg CaCO<sub>3</sub> eq/ton) in these samples as well as the consumption of available NP through the buffering of acid. Despite the depletion of NP for cell 604669, the pH values for this cell remained above pH 7.



**Figure 6-1: Waste Rock/Ore HCT Effluent pH**



**Figure 6-2: Waste Rock/Ore HCT Effluent Electrical Conductivity**



**Figure 6-3: Waste Rock/Ore HCT Effluent Iron**

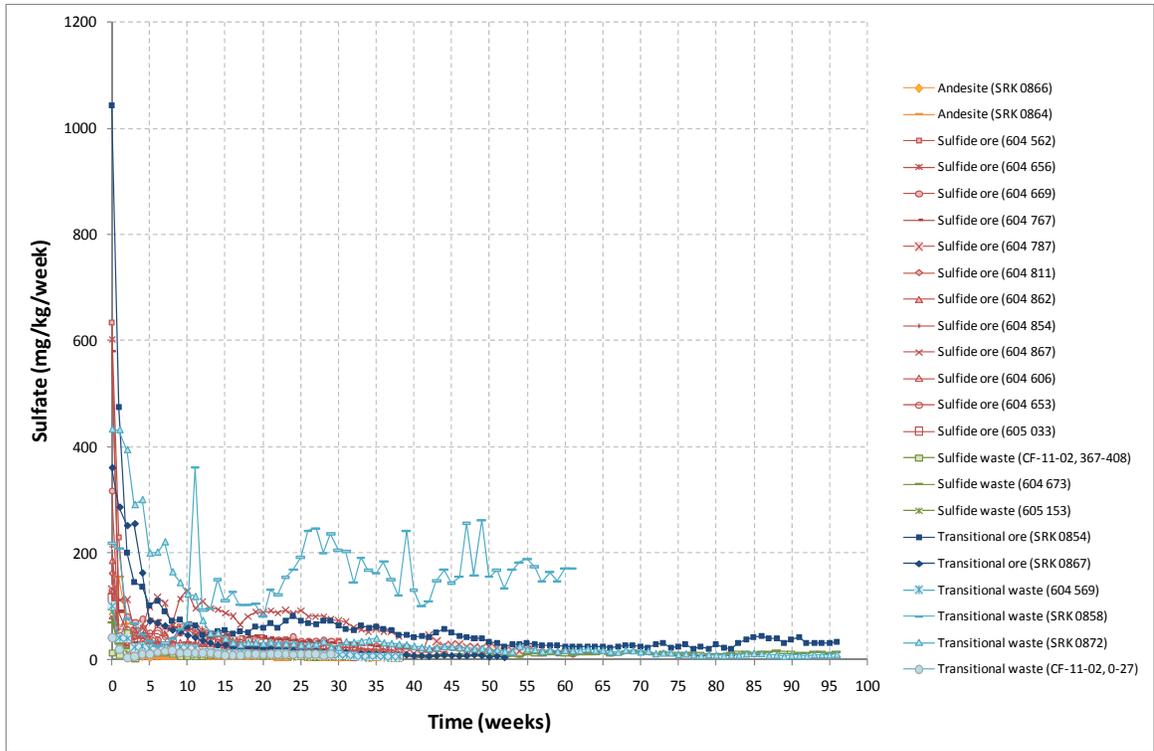


Figure 6-4: Waste Rock/Ore HCT Effluent Sulfate

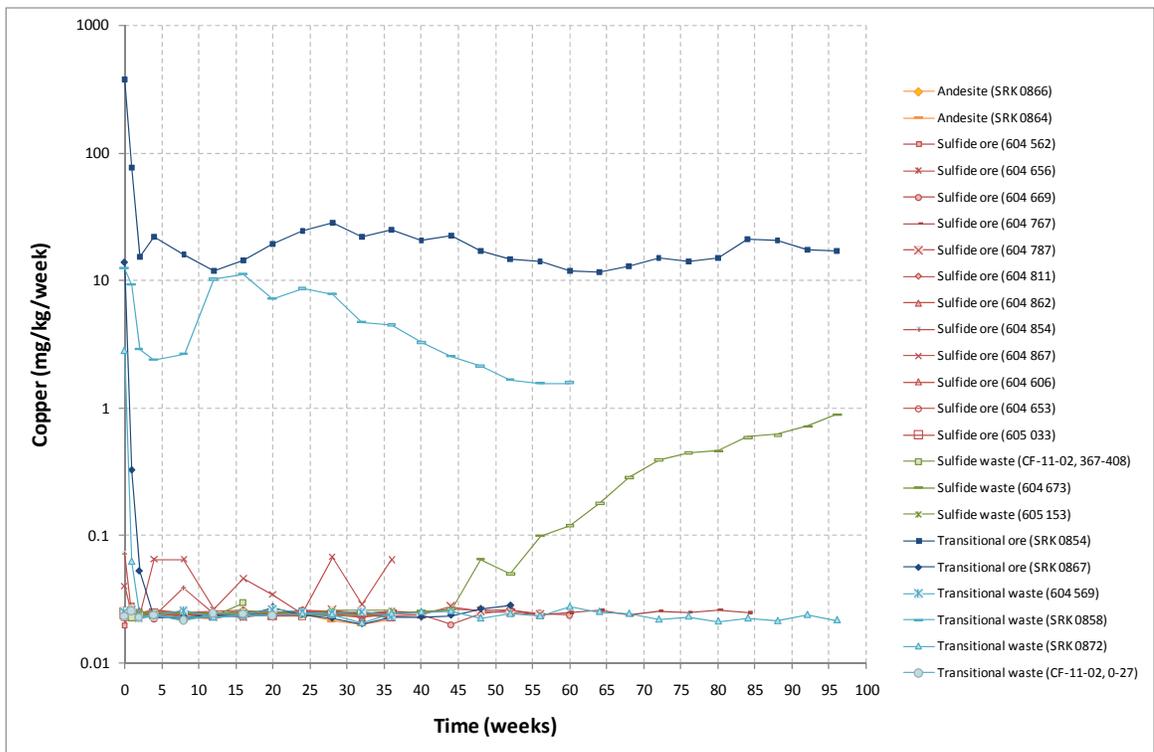


Figure 6-5: Waste Rock/Ore HCT Effluent Copper

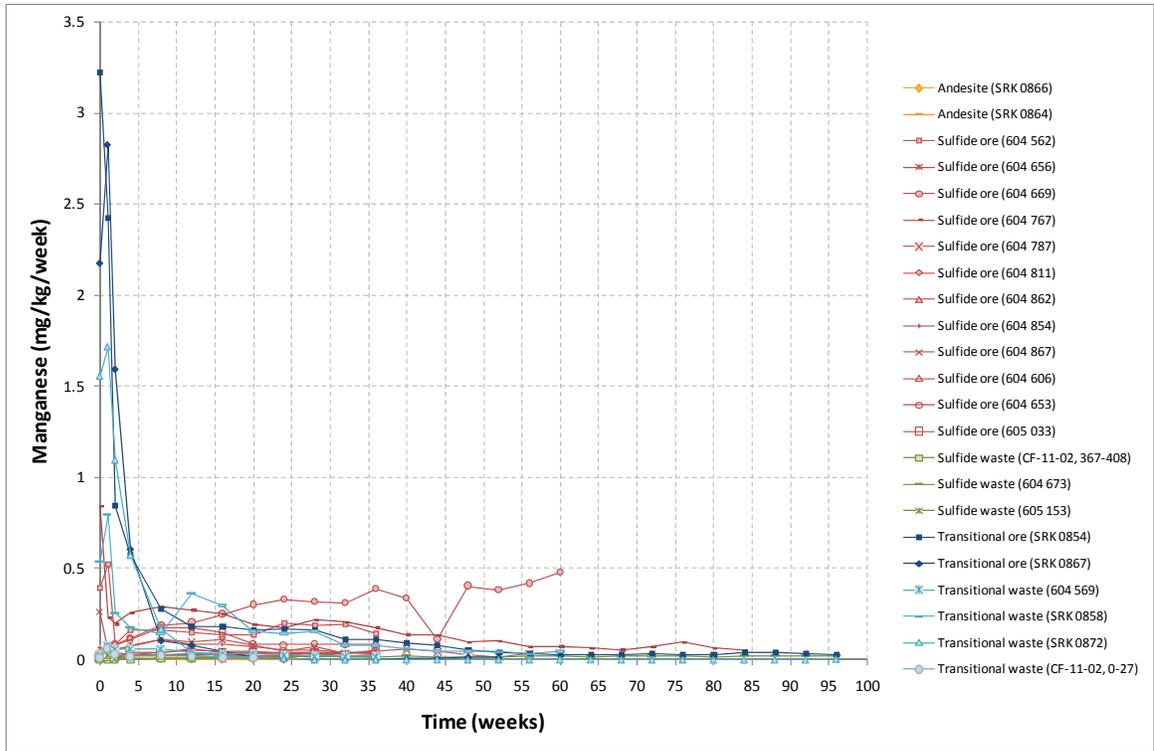


Figure 6-6: Waste Rock/Ore HCT Effluent Manganese

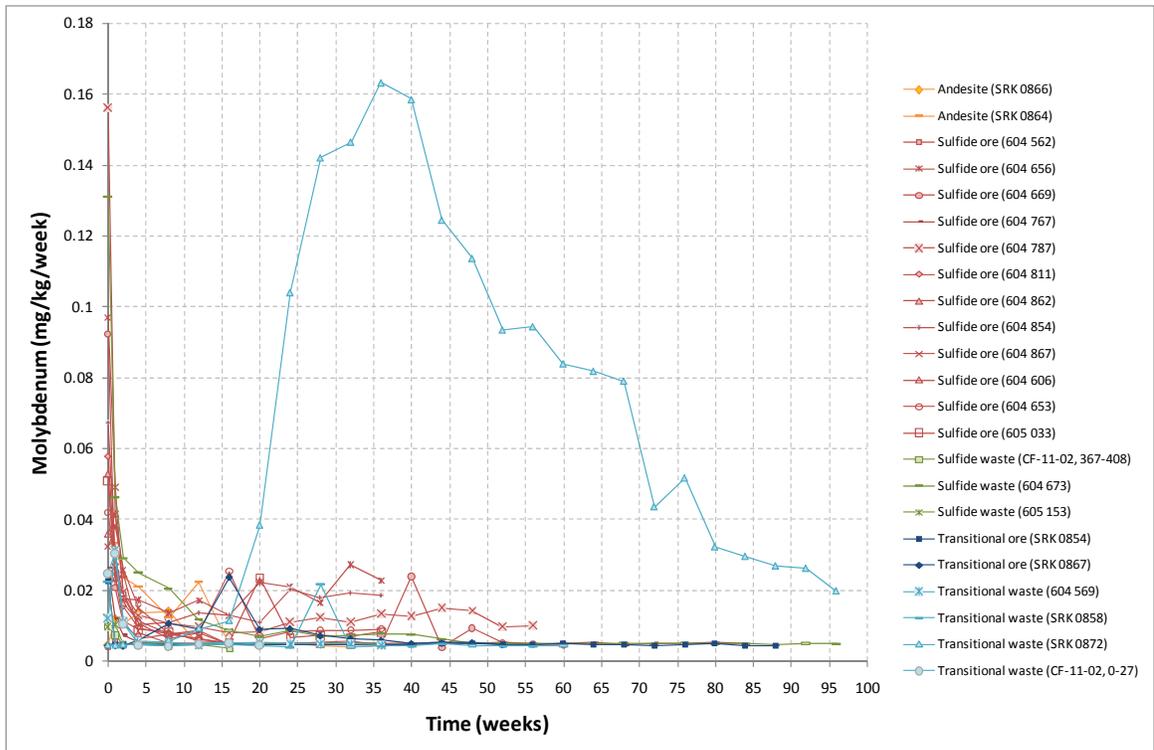


Figure 6-7: Waste Rock/Ore HCT Effluent Molybdenum

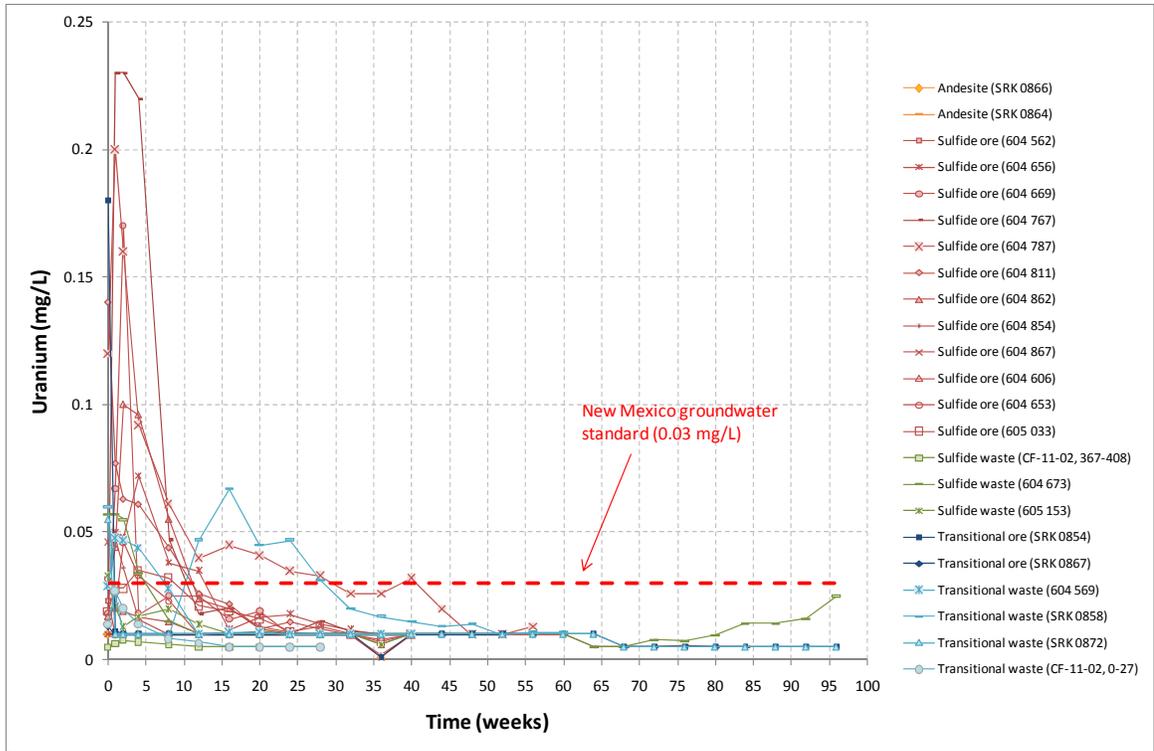


Figure 6-8: Waste Rock/Ore HCT Effluent U (in mg/L) compared to NM GW standard

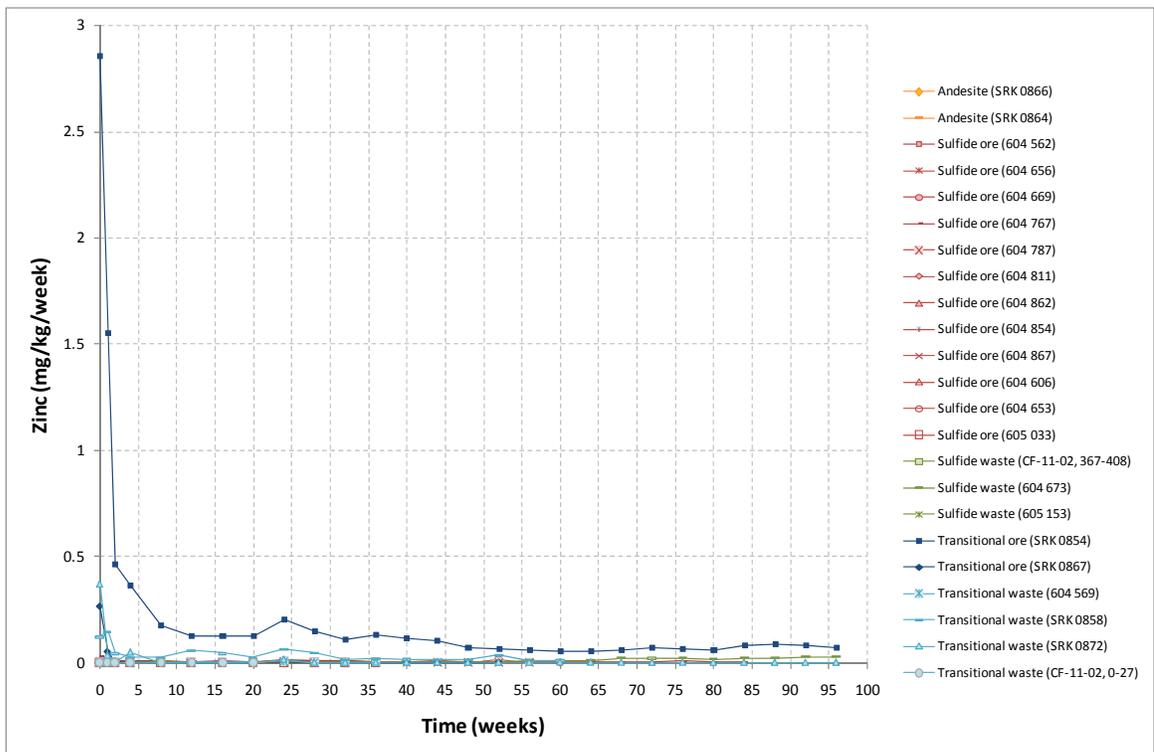


Figure 6-9: Waste Rock/Ore HCT Effluent Zinc

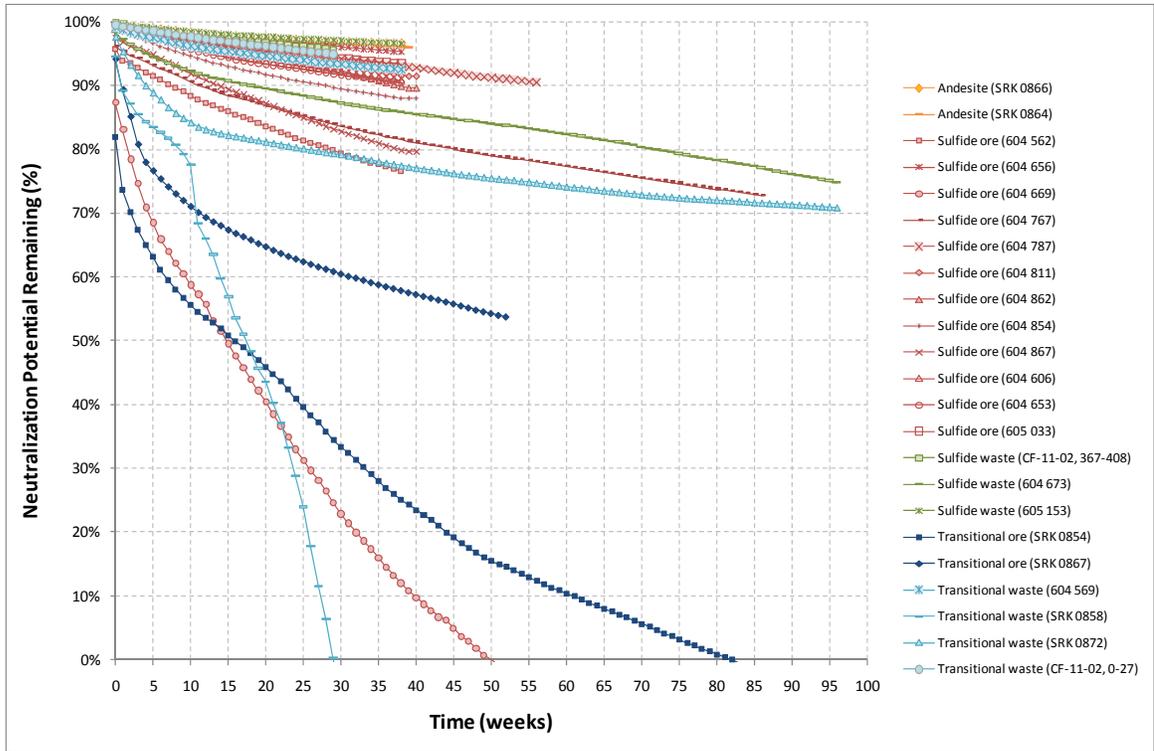


Figure 6-10: Waste Rock/Ore HCT Neutralization Potential Remaining

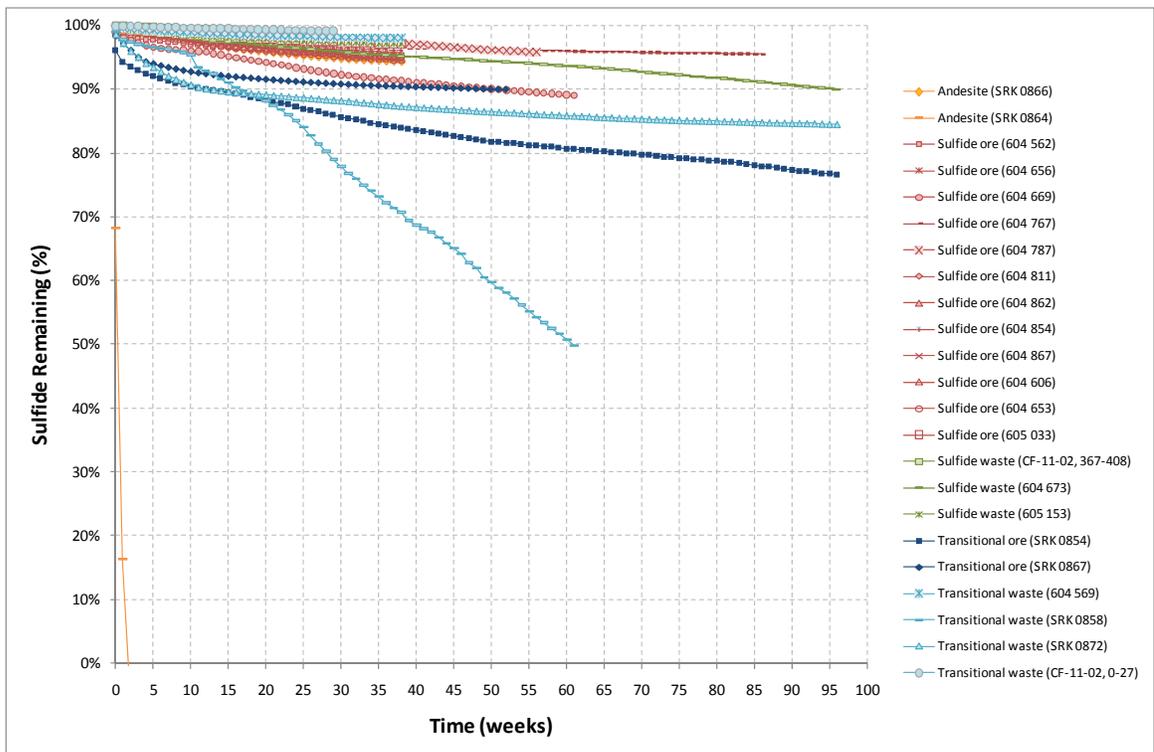


Figure 6-11: Waste Rock/Ore HCT Sulfide Remaining

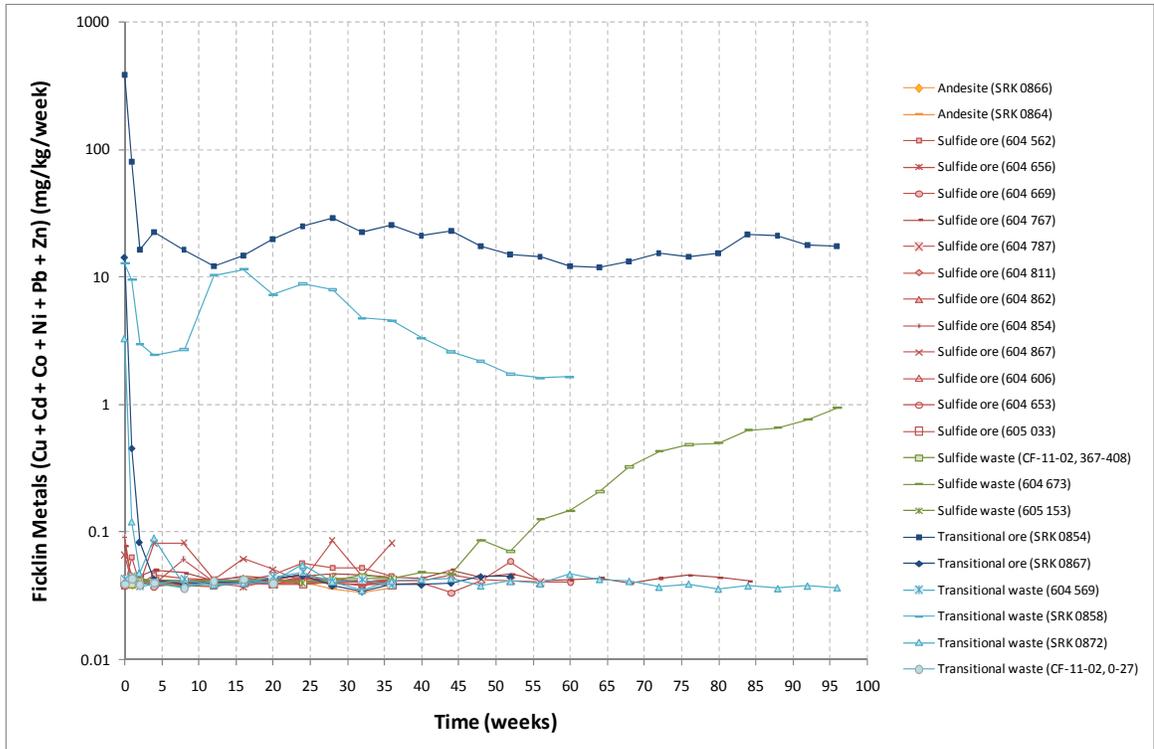


Figure 6-12: Waste Rock/Ore HCT pH vs. Ficklin Metal Release

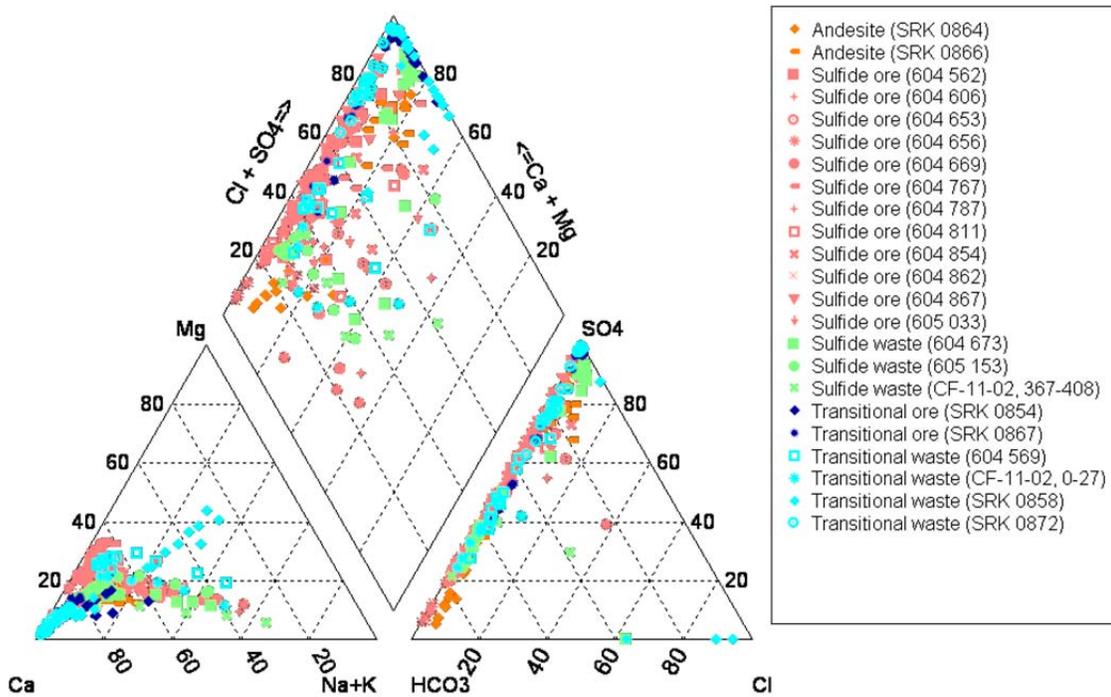


Figure 6-13: Piper Plot showing HCT Major Ion Chemistry

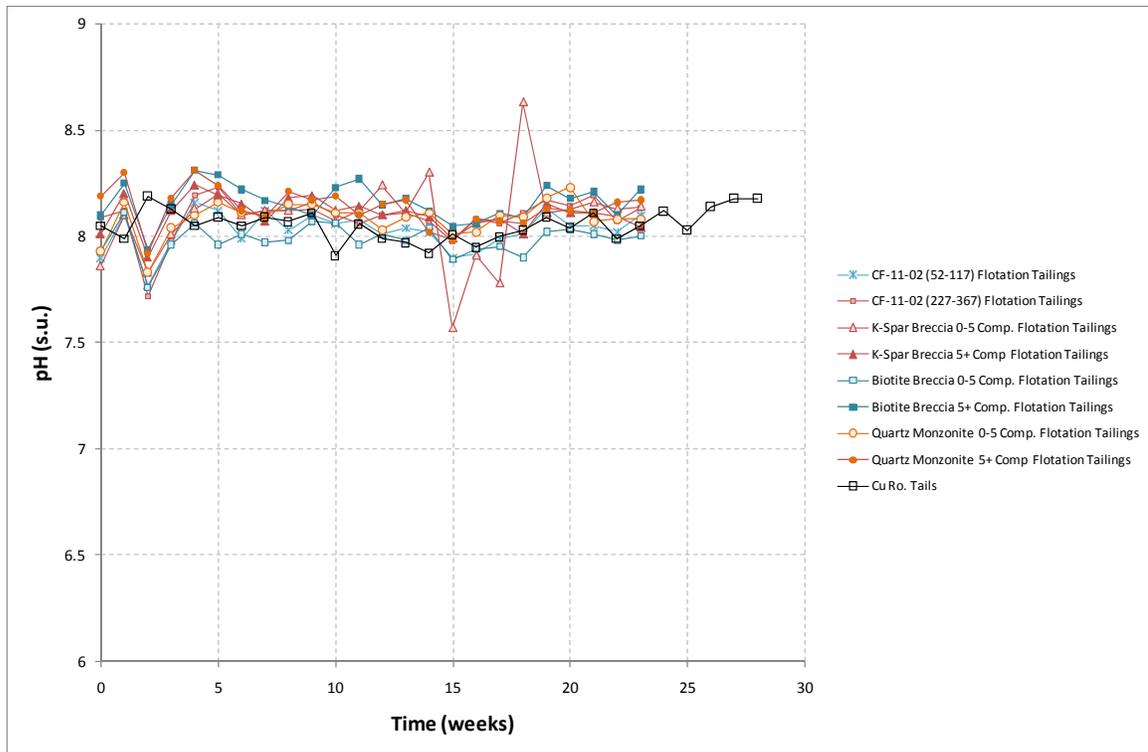
### 6.1.2 Tailings

Humidity cell testing has been carried out on nine samples of tailings material generated from the metallurgical testing. The results of the tailings HCT results are shown in Figures 6-14 to 6-18 and are provided in full in Appendix F.

Humidity cell testing has been carried out on the Cu. Ro. Tailings composite. This cell showed low levels of reactivity and elemental release and was terminated at week 28. Effluent pH remained moderately alkaline (pH 7.9 to 8.2) throughout the testwork period and levels of metal(loid) release were low, with many parameters being at or near analytical detection limits. The cell still had 93% of neutralizing potential remaining when it was terminated at week 28.

Eight additional HCTs were initiated on the lithology specific metallurgical tailings samples. Lab data for these cells is available through week 23 and Profile II data are available through week 20. The results for these cells are illustrated in Figure 6-14 to Figure 6-18 for selected parameters and show similar geochemical behavior to the Cu. Ro. Tailings composite (i.e., moderately alkaline pH and low levels of metal(loid) release).

Tailings samples subjected to cyclone separation were not submitted for kinetic testing because these samples show a similar range in behavior to the lithology specific metallurgical tailings samples from the static test data (i.e., non-acid forming with low levels of metal(loid) release).



**Figure 6-14: Tailings HCT Effluent pH**

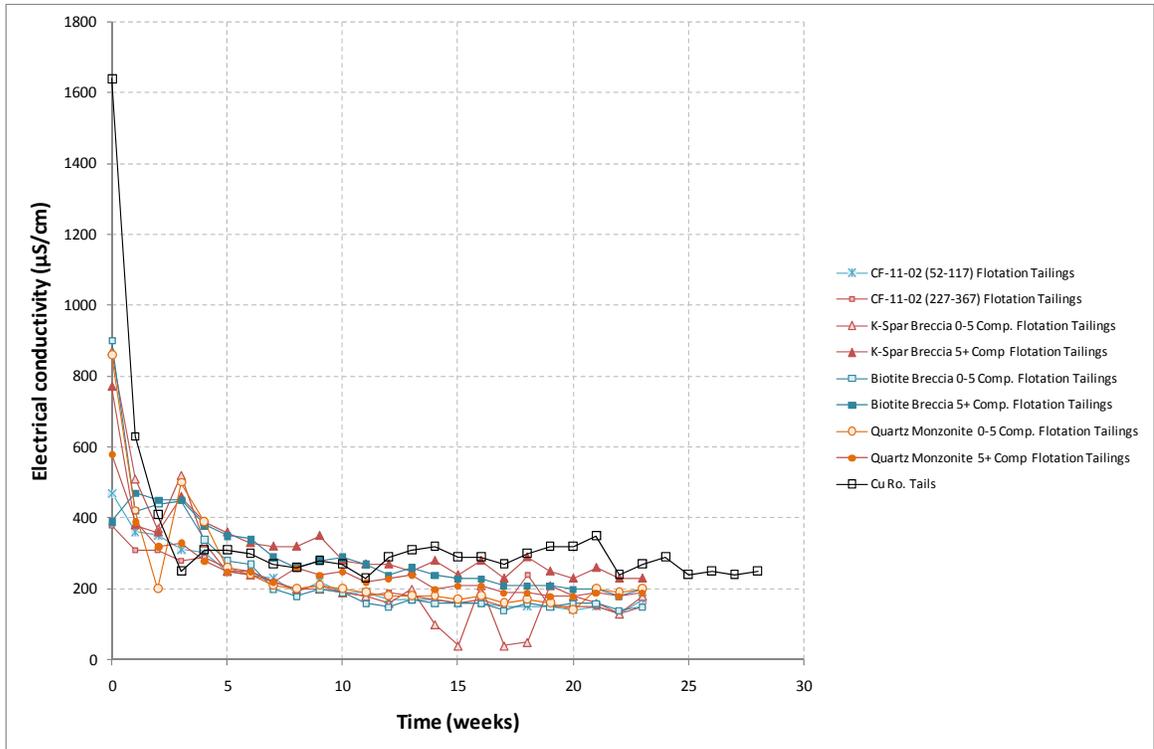


Figure 6-15: Tailings HCT Effluent EC

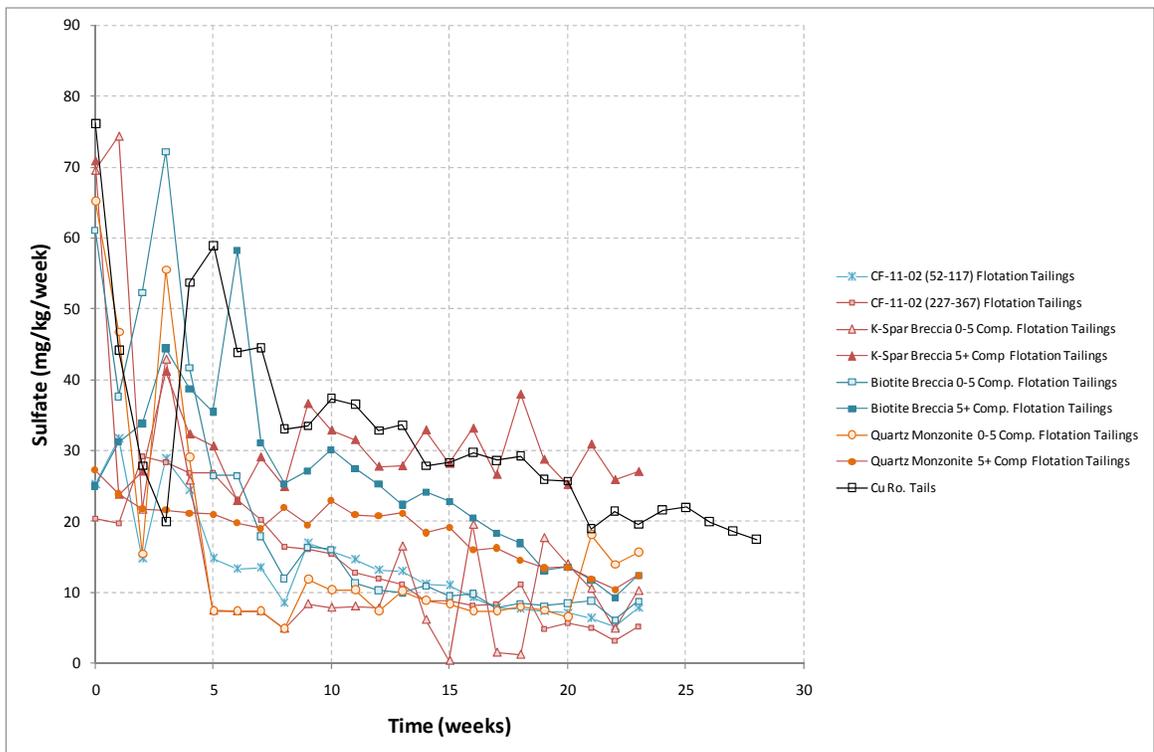


Figure 6-16: Tailings HCT Effluent Sulfate

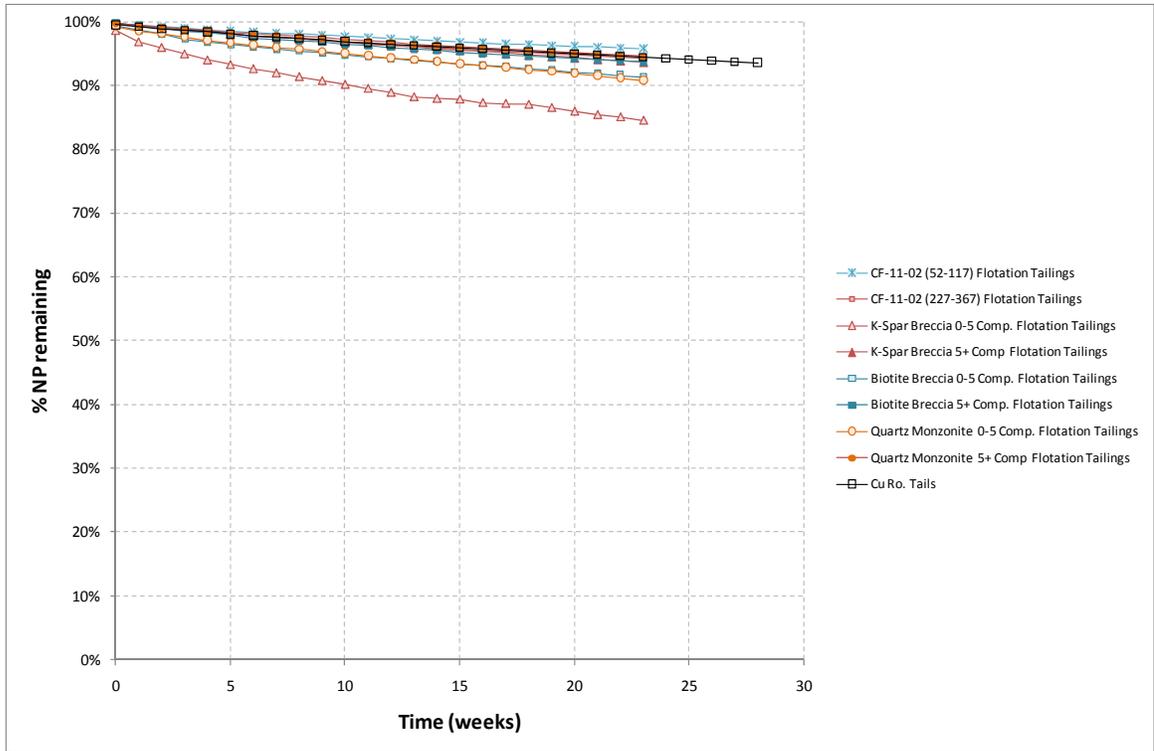


Figure 6-17: Tailings HCT Neutralization Potential Remaining

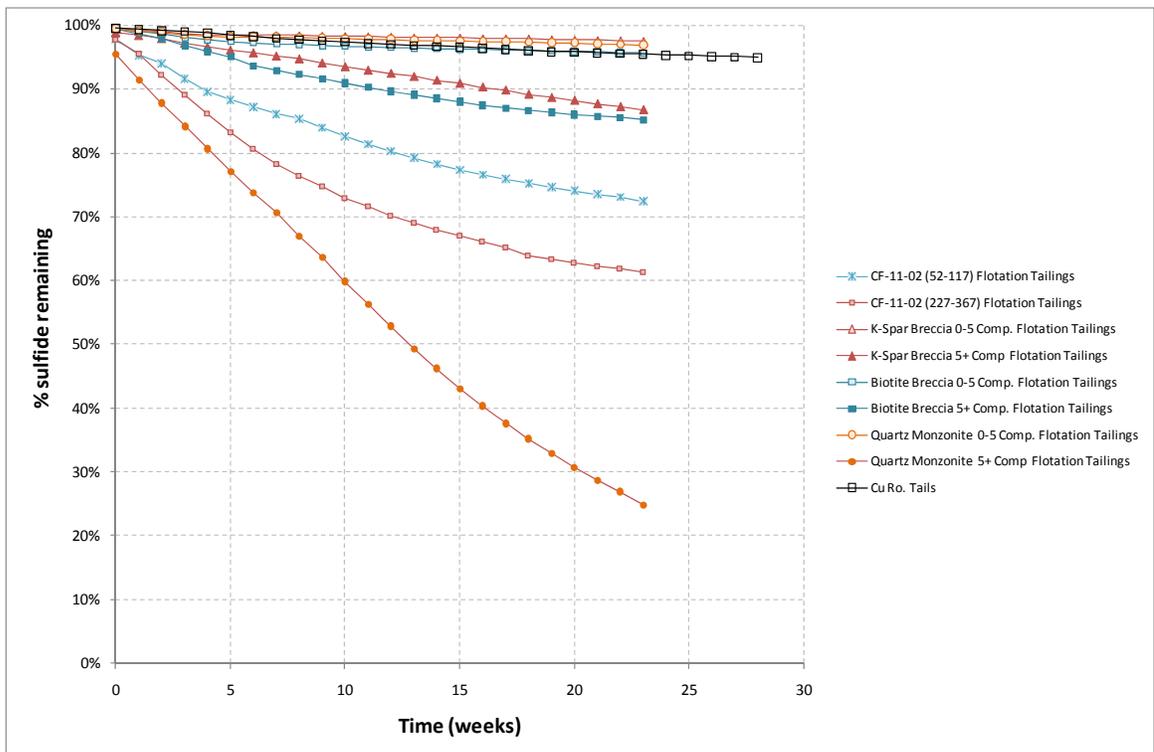


Figure 6-18: Tailings HCT Sulfide Remaining

## 6.2 Comparison of Static and Kinetic Testwork Results

A comparison of the static test results with the corresponding HCT results provides an indication of the effectiveness of the static tests in predicting longer term behavior (Table 5-4). As shown in Table 5-4, the results of the HCT tests for the waste rock/ore samples are not consistent with the prediction of acid generation based on ABA results. However, the correlation between the HCT results and the acid generation prediction from the NAG results shows a slightly better correlation and suggests the NAG test is more effective in predicting the acid generating potential of the Copper Flat material types. However, despite the better correlation there are still a handful of samples that are predicted to be acid generating from the NAG test that did not develop acidic conditions in the HCT. Therefore, in both cases, the ABA and NAG results can over-predict the acid generating potential of the Copper Flat materials.

The discrepancy between ABA, NAG and HCT results for the waste rock/ore samples suggests that there may be some silicate buffering capacity in the Copper Flat material types and/or encapsulation of sulfide minerals in non-reactive minerals such as quartz that limit reactivity. Although silicate buffering potential is unlikely to be of high magnitude, it may modify/buffer pH if present (Nesbit and Jambor, 2008) especially if the rate of acid generation is slow. The presence of chlorite-clinocllore, amphiboles and Ca-rich feldspars (Appendix D) would likely be the source of this buffering as indicated by relative reaction of these minerals (Table 1-1).

The tailings samples show a good correlation between the acid generation predictions based on ABA and HCT results.

**Table 6-2: Comparison of HCT results with static testwork results**

Material type	Primary lithology	Cell ID	Acid Generation Prediction*		
			ABA	NAG	HCT
Andesite	Andesite	SRK 0864	NAF	NAF	NAF
	Andesite	SRK 0866	NAF	PAF	NAF
Sulfide waste	Biotite Breccia	605033	NAF	NAF	NAF
	Quartz Monzonite	604673	PAF	PAF	NAF
	Quartz Monzonite	605153	NAF	NAF	NAF
Sulfide ore	Biotite Breccia	604811	PAF	NAF	NAF
	Biotite Breccia	604862	NAF	NAF	NAF
	Biotite Breccia	604867	PAF	NAF	NAF
	Biotite Breccia	604854	PAF	NAF	NAF
	Quartz Feldspar Breccia	604767	PAF	PAF	NAF
	Quartz Feldspar Breccia	604787	PAF	NAF	NAF
	Quartz Monzonite	604562	PAF	NAF	NAF
	Quartz Monzonite	604606	NAF	NAF	NAF
	Quartz Monzonite	604669	PAF	NAF	NAF
	Quartz Monzonite	604653	NAF	NAF	NAF
Transitional waste	Biotite Breccia	SRK 0872	PAF	PAF	NAF
	Quartz Monzonite	604569	PAF	NAF	NAF
	Quartz Monzonite	SRK 0858	PAF	PAF	PAF
Transitional ore	Biotite Breccia	SRK 0854	PAF	PAF	PAF
	Quartz Monzonite	SRK 0867	PAF	NAF	NAF
Tailings	CF-11-02 (52-117) flotation tailings		NAF	-	NAF
	CF-11-02 (227-367) flotation tailings		NAF	-	NAF
	K-spar Breccia 0-5 comp. flotation tailings		NAF	-	NAF
	K-spar Breccia 5+ comp. flotation tailings		NAF	-	NAF
	Biotite Breccia 0-5 comp. flotation tailings		NAF	-	NAF
	Biotite Breccia 5+ comp. flotation tailings		NAF	-	NAF
	Quartz Monzonite 0-5 comp. flotation tailings		NAF	-	NAF
	Quartz Monzonite 5+ comp. flotation tailings		NAF	-	NAF
	Cu Ro. tailings		NAF	-	NAF

\* **PAF** = Potentially Acid Forming; **NAF** = Non-Acid Forming

## **7 Comparison with other Porphyry Copper Deposits**

Many porphyry copper deposits have been shown to exhibit similar geochemical behavior as a result of comparable ore and alteration mineralogy. Consequently it is instructive to compare the geochemistry of Copper Flat deposit to other porphyry systems in similar climatic conditions, which will both assist in data interpretation and improve the understanding of potential environmental impacts. Four analog sites were selected from previous work undertaken by SRK based on similar geological characteristics (i.e., oxidized calc-alkaline porphyry systems in volcanic terrains) and similar climate (i.e., arid) to the Copper Flat site. Details of the four analog sites are provided in Section 7.1, below.

### **7.1 Analog Mine Overviews**

#### **7.1.1 Nevada 1**

This site is a copper/gold porphyry site whose climate is characterized as arid, with hot summers and cold winters. There is no standing perennial surface water located near the mine site and surface water flow across the mine site occurs only in response to extreme storm events. Four primary lithologic units have been identified on site, including quartz monzonite porphyry intrusion, extrusive volcanic material, intensely oxidized material and weakly metamorphosed country rock consisting of phyllite, schist and slate that is host to supergene copper mineralization.

#### **7.1.2 Nevada 2**

This site is an active copper/gold porphyry deposit within an arid climate. The mine has an annual production of approximately 57,000 tons copper and 2,700 kg gold. Four principal lithologies have been identified, including quartz monzonite porphyry, extrusive volcanic rhyolite, intensely supergene oxidized material and sedimentary (limestones, siltstones, shales) host rocks. Copper mineralization with minor molybdenum ± gold is hosted in porphyry and in a skarn formed in calcareous rocks adjacent to the mineralized porphyry. The principal hypogene sulfide minerals in the deposit are pyrite and chalcopyrite, which occur both as disseminated mineralization and as veinlets in association with quartz. Supergene enrichment has resulted in chalcocite blankets up to 100 m thick.

#### **7.1.3 Arizona**

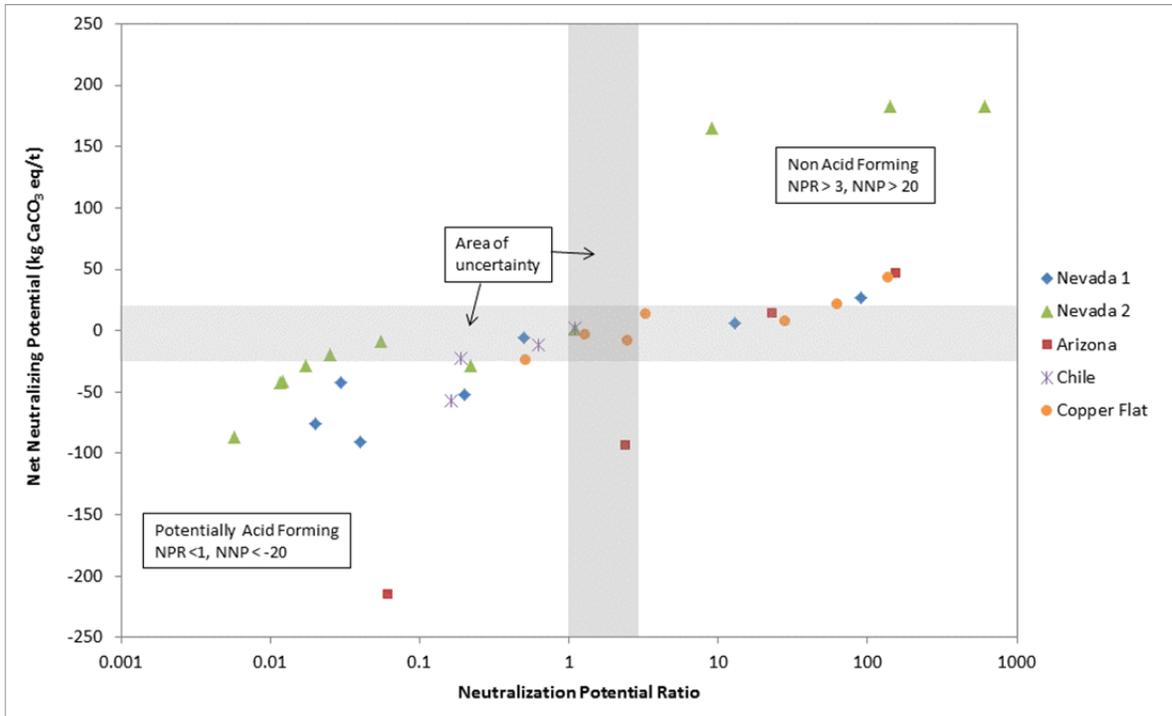
This site is an active mine situated in a semi-arid, net evaporitic climate, with precipitation records typically indicating less than 14.6 inches of average annual precipitation. The deposit is a copper porphyry hosted within quartz monzonite and the mine produces approximately 150,000 tons copper and 500 kg gold on an annual basis.

#### **7.1.4 Chile**

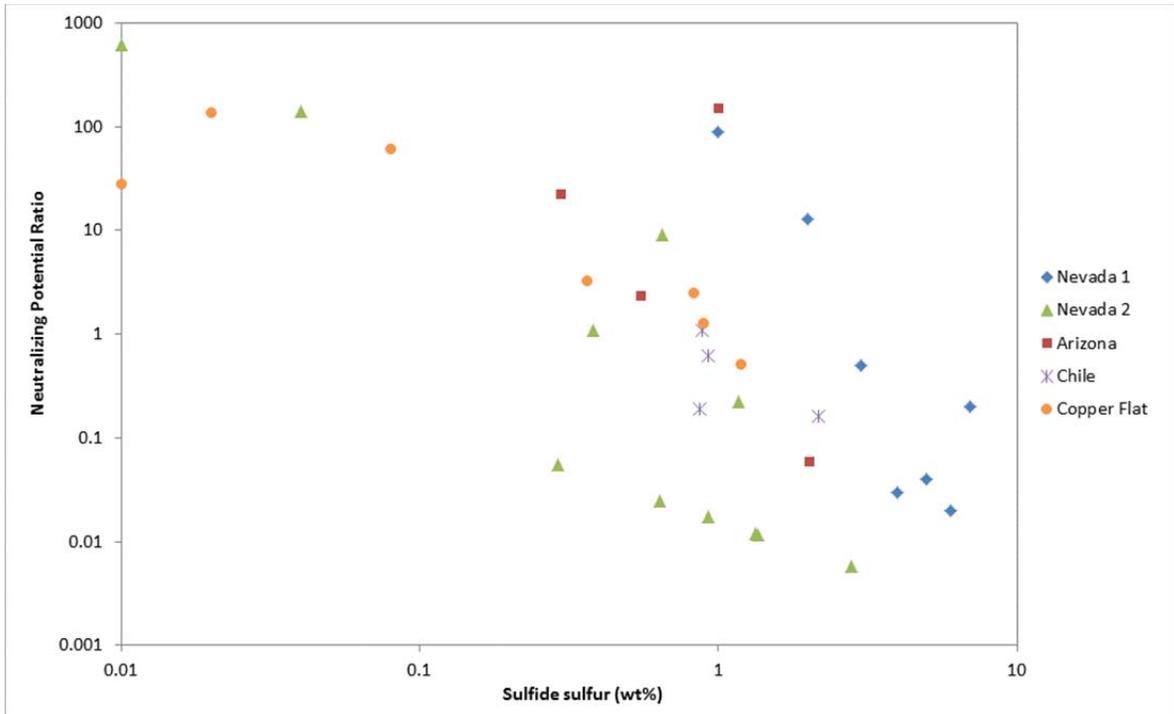
This site is one of the largest open pit mines in Chile and produces approximately 300,000 tons of copper and 10,000 tons of molybdenum on an annual basis. The climate is mostly dry with the pit situated at 3,100 m above sea level. The deposit is a porphyry hosted in a diorite pluton which has intruded a volcanic sequence comprising andesitic lavas, breccias and conglomerates. Sulfide minerals present are chalcopyrite, bornite, and pyrite.

## 7.2 Geochemical Comparison of Analog Mine Sites with Copper Flat

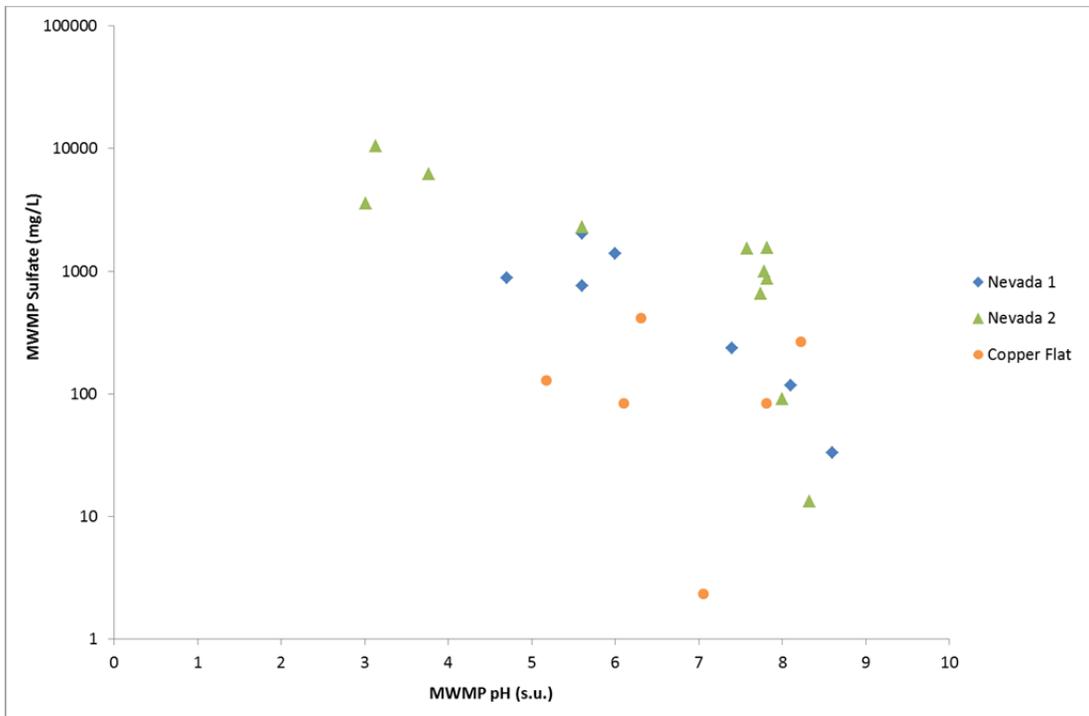
ABA and MWMP data for the four analog sites have been compiled and compared to geochemical data collected as part of the Copper Flat characterization program. The results are summarized in Figure 7-1 to Figure 7-6, which demonstrate that the sulfide content (and the subsequent acid generating potential) of the Copper Flat samples is towards the lower end of the range observed for the four analog sites. In addition the MWMP leachable concentrations of sulfate, iron and manganese from the Copper Flat samples are generally comparable to or lower than the analog sites, indicating lower levels of sulfide oxidation products that could be released in the short-term.



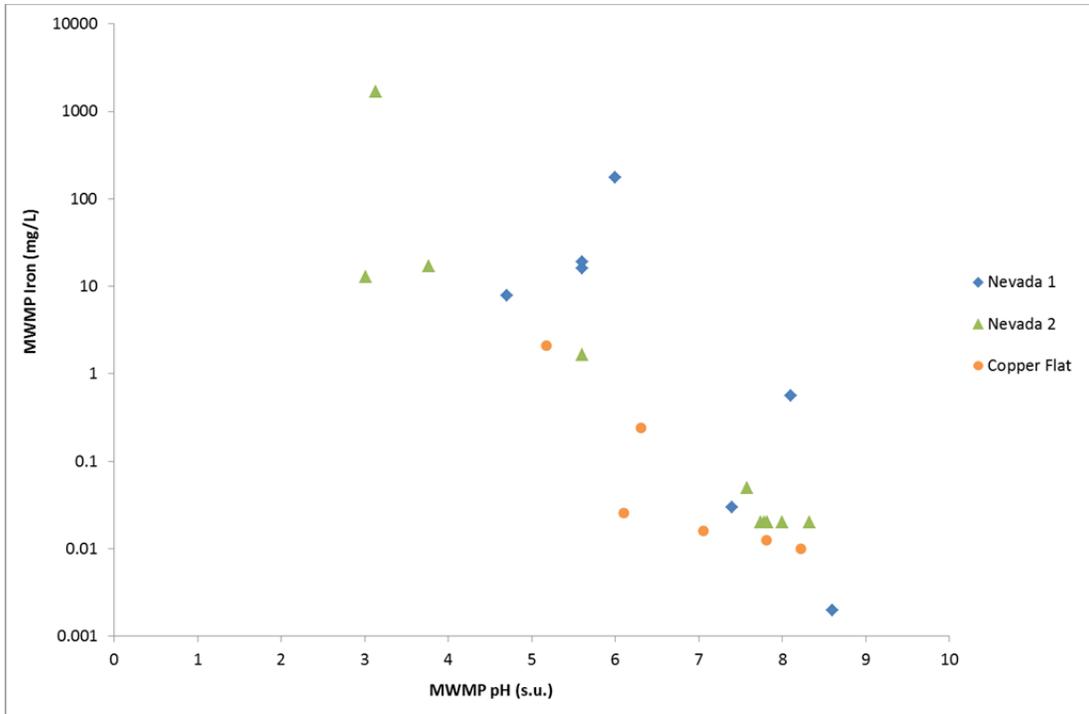
**Figure 7-1: Scatter Plot of Average NPR vs Average NNP (by Material Type) for Analog Sites**



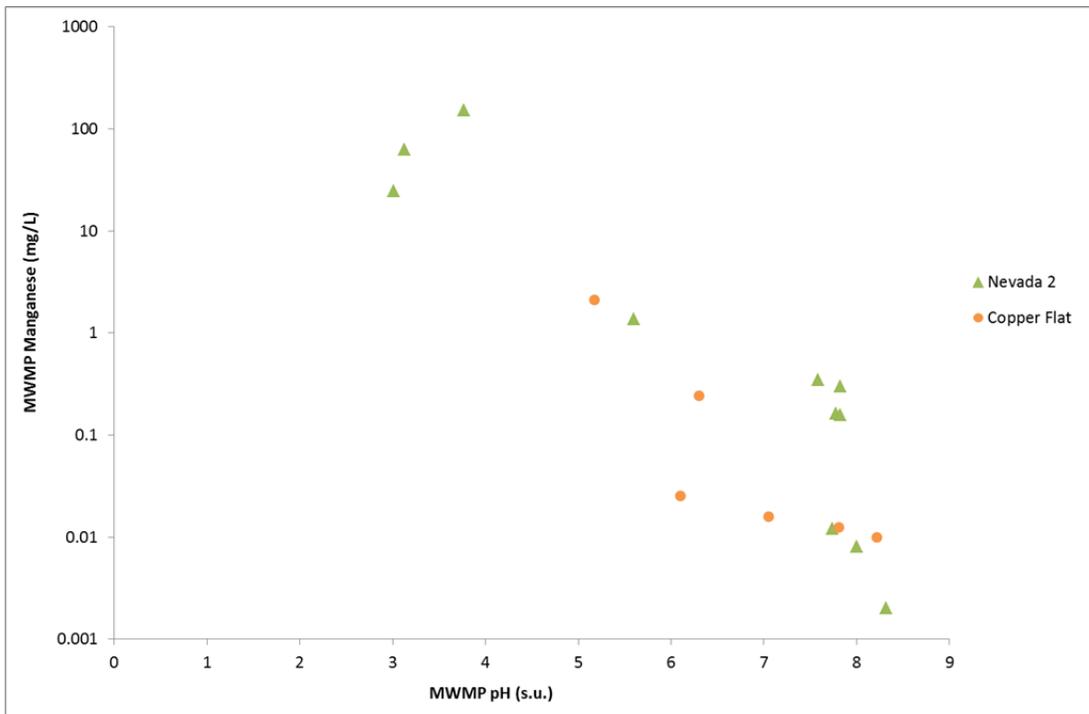
**Figure 7-2: Scatter Plot of Average Sulfide Sulfur vs Average NPR (by Material Type) for Analog Sites**



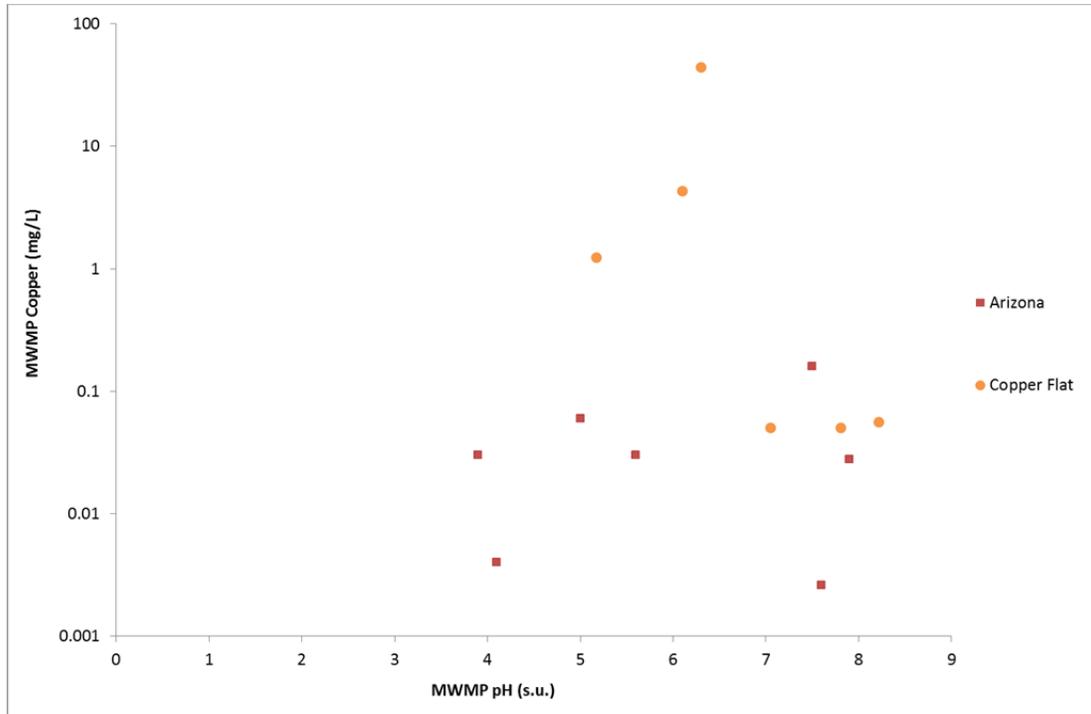
**Figure 7-3: Scatter Plot of MWMP pH vs Sulfate Release for Analog Sites**



**Figure 7-4: Scatter Plot of MWMP pH vs Iron Release for Analog Sites**



**Figure 7-5: Scatter Plot of MWMP pH vs Manganese Release for Analog Sites**



**Figure 7-6: Scatter Plot of MWMP pH vs Copper Release for Analog Sites**

## 8 Quantitative Numerical Predictions

Mass balanced HCT results have been used to develop source terms for the waste rock and tailings facilities associated with the Copper Flat project. The resulting source terms are a prediction of the concentrations of constituents that could be released from the facilities in response to meteoric rinsing. The main objectives of the modeling exercise are to:

1. Develop conceptual geochemical models to assess the potential controls on constituent mobilization and transport from the WRDF and TSF;
2. Draw upon the conceptual models to develop numerical models, that predict (in quantitative terms) the possible concentrations of solutes emanating from the WRDF and TSF; and
3. Predict the potential concentrations of these solutes in the groundwater underlying the facilities.

In order to accomplish these objectives, the following tasks have been completed:

1. Review of climate monitoring data for the site to provide estimates of evaporation and precipitation rates;
2. Compilation of information relating to the mine plan (including facility surface areas, masses of waste rock and tailings that will be produced during operations and facility design);
3. Review of hydrological and hydrogeochemical data relating to the mine facilities;
4. Compilation and review of data from kinetic testing carried out on representative materials and on the basis of this determine a mass balanced “field” scaled determination of potential leachate chemistry;
5. Calculation of the estimated tonnage of waste (per material type) in the final WRDF and estimated tonnage of tailings in the TSF; and
6. Compilation of relevant groundwater chemistry specific to the WRDF and TSF areas.

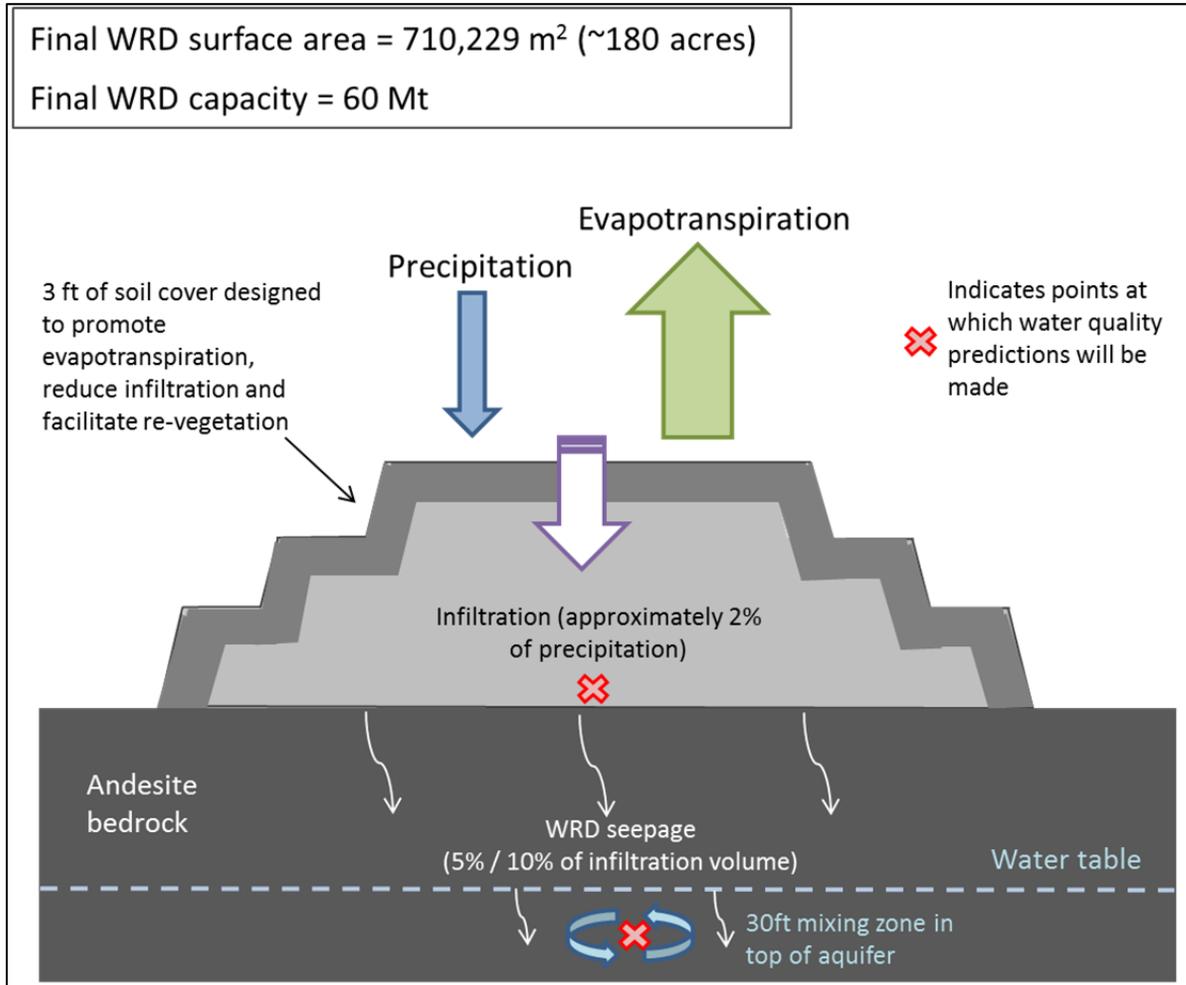
This information, along with other published data (i.e., thermodynamic database, precipitation reactions) was input into the USGS-developed software, PH-REdox-Equilibrium-Chemistry (PHREEQC, Parkhurst and Appelo, 1999). This software has been used in this project to undertake predictions of water chemistry based on thermodynamic equilibrium and solubility calculations to determine the residual solution chemistry following mixing of solutions and minerals identified in the characterization program. The program allows for assessment of changes to water quality resulting from mineral precipitation and attenuation of solutes through sorption reactions with specified mineral surface areas. Dissolution and oxidation reactions can also be factored into the model to account for reaction of solutions with solid mineral phases. By limiting the quantities of these minerals in the chemical system their reaction can also be limited either as reactants or precipitates. This is important in the case of iron hydroxides that also participate in chemical adsorption of trace elements as it limits the quantity of absorbent surfaces in the model. The resulting model output predicts not only the concentration of modeled constituents but also the speciation of the aqueous solutes and the potential solubility of minerals of constituent components. This allows prediction of the resulting chemistry of the mixing reactions. These results are then compared to environmental water quality criteria to determine if a potential impact will result from the mineral-solute reactions.

## 8.1 Conceptual Models

### 8.1.1 Waste Rock Disposal Facility

The conceptual model for the Copper Flat WRDF is presented in Figure 8-1. This was developed from a review of site-specific information and using the assumptions outlined below.

1. The final (year 11) surface area of the WRDF will be 710,229 m<sup>2</sup> (~180 acres) and the facility will contain 60 Mt of waste (THEMAC, 2012).
2. The final grading plan for the WRDF will be designed to eliminate surface water run on, enhance runoff and evapotranspiration, reduce infiltration and facilitate re-vegetation.
3. A revegetated 36-inch store-and-release soil cover (or approved equivalent) will be placed after closure and will only allow water into the waste rock after large precipitation events (THEMAC, 2012).
4. Hydrological modeling (JSAI, 2012) indicates that long-term infiltration through the WRDF cover will be approximately 2 percent of mean annual precipitation (0.25 in/yr);
5. Any precipitation infiltrating the WRDF will be in contact with rock types contained within the facility for a period of time and this will result in the generation of a specific water quality. The seepage water chemistry from the WRDF facility can be represented as the weighted sum of the solution chemistry associated with each waste rock material type. Material types with a greater total surface area exposed within the facility will therefore exert a greater control on seepage water chemistry.
6. Significant seepage away from the WRDF is not expected as the waste rock lies on low permeability ( $<10^{-6}$  cm/s) andesite bedrock which will function as a liner. In addition, the waste rock will be deposited dry and any precipitation infiltrating into the facility will tend to be held in storage above the water table.
7. It is possible that a small proportion of precipitation will eventually seep through the WRDF and report to groundwater. A reasonable estimate of the upper end of possible flow from the WRDF to groundwater is 5 – 10% of infiltration through the waste rock cover, equating to 0.1 to 0.2% of annual precipitation (JSAI, 2012). For the purpose of the model it is assumed that any seepage from the facility will interact with groundwater within 30 feet of the water table.



**Figure 8-1: WRDF Conceptual Model**

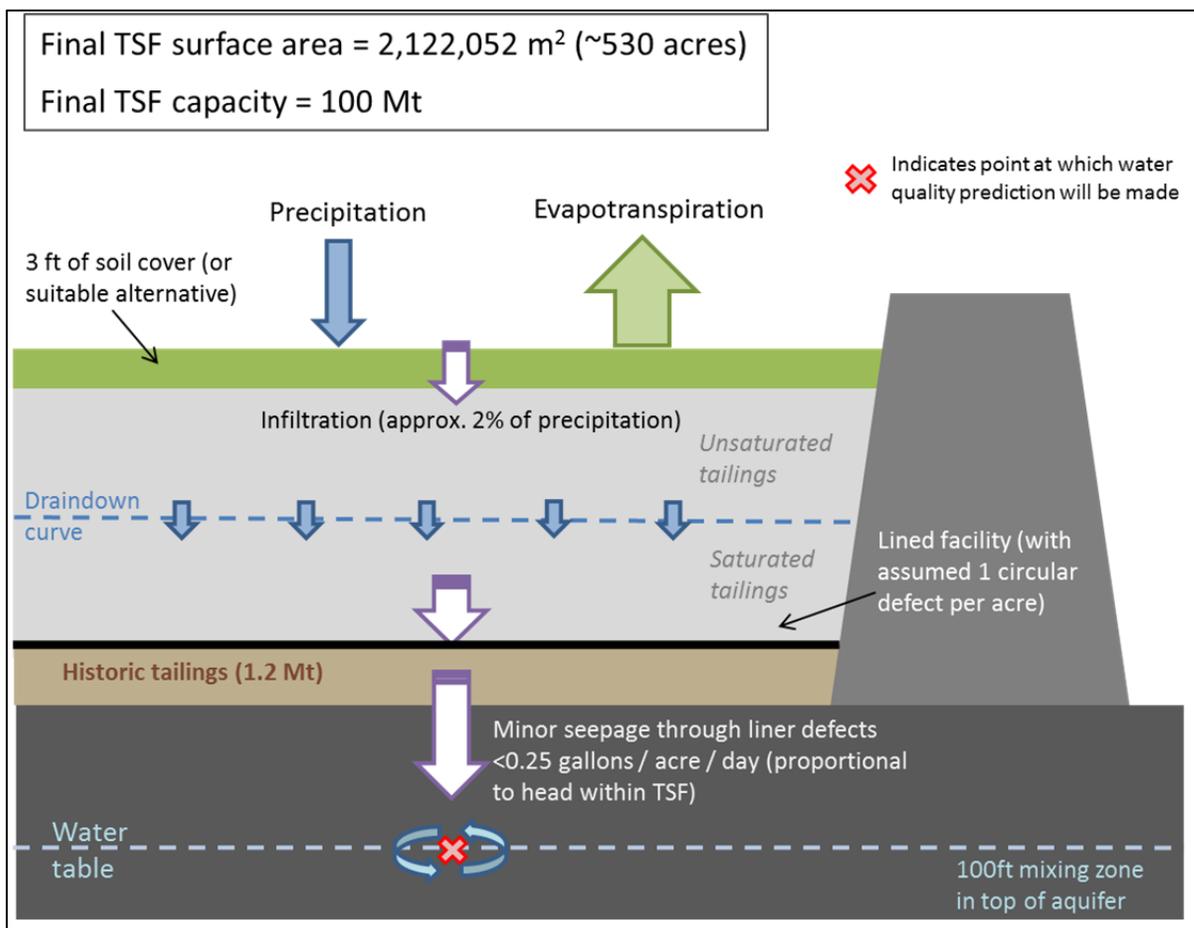
### 8.1.2 Tailings Storage Facility

The conceptual model for the Copper Flat TSF is provided in Figure 8-2. This was developed using the following assumptions:

- The final (year 11) surface area of the TSF will be 2,122,052 m<sup>2</sup> (~530 acres) and the facility will contain 100 Mt of tailings (INTERA, 2012);
- Tailings will be deposited in a lined facility that will be constructed on the site of the existing TSF. The historic TSF contains approximately 1.2 Mt of material, which will be used as a bedding material for the new, lined tailings facility.
- A saturated tailings density of 118 lb/ft<sup>3</sup> and a void space of 48% is assumed (Golder, 2012).
- Closure of the TSF will include (i) final grading of embankment out slopes to establish erosion controls and controlled surface water drainage; (ii) placement and vegetation of a 36-inch store-and-release soil cover (or approved equivalent) over the tailings surface; and (iii) management of underdrainage, which will be pumped from the underdrain collection pond to the surface of the TSF where it will be evaporated.

- The tailings draindown solution will be simulated by the reaction of meteoric water infiltrating unsaturated tailings (represented by humidity cell chemistry) and reaction with residual supernatant process solution (represented by testwork analysis of leaching solutions).
- It is assumed that 2% of mean annual precipitation will infiltrate the facility. This is a reasonable assumption given that the soil cover system will be the the same as for the WRDF.
- Seepage from the lined tailings facility is expected to be small. However, there may be minor seepage through manufacturing defects and other holes in the liner or the seams developed during placement (JSAI, 2012). This is discussed further in Section 8.3.2.
- For the purpose of the model it is assumed that any seepage from the facility will interact with groundwater within 100 feet of the water table.

Water quality predictions were made for a number of post-closure draindown scenarios where the quantity of draindown to entrained process solution varies. The modeled scenarios include 25%, 50%, 75%, 90% and 95% draindown.



**Figure 8-2: TSF Conceptual Model**

## 8.2 Geological Modeling

### 8.2.1 Waste Rock Disposal Facility

An estimate of the mass of each material type that will be produced during mining operations and deposited in the WRDF has been made from the geologic block model (Table 8-1). It is assumed that individual lithologies within the facility will be evenly mixed and that leachates resulting from those lithologies will likewise be evenly mixed. It is also assumed that each lithology will be equal in terms of grain size distribution, fracture density and similar physical characteristics.

It was assumed that 20% of the total mass in the WRDF will be available for chemical weathering reactions. This is a reasonable estimate for unsaturated waste rock and is within the 10 – 30% range reported by Schafer (2007), Price and Kwong (1997) and Murray (1977). The rationale for this estimate is based on the particle size distribution within the WRDF and surface area effects that will reduce the mass of waste rock that will contact meteoric water.

**Table 8-1: Waste Rock Tonnages by lithology in the Final (Year 11) WRDF**

Lithology	Waste Rock Tonnages	
	Oxide/transitional	Sulfide
Andesite	639,404	
Biotite Breccia	27,245	666,025
Quartz Feldspar Breccia	56,851	2,706,942
Quartz Monzonite	1,675,692	45,510,282
Coarse Crystalline Porphyry	558,581	8,460,861
Undefined	61,635	1,680
<b>TOTAL TONS</b>	<b>60,365,198</b>	

**Table 8-2: Waste Rock Percentages by lithology in the Final (Year 11) WRDF**

Lithology	Waste rock percentages	
	Oxide/transitional	Sulfide
Andesite	1.06%	
Biotite Breccia	0.05%	1.10%
Quartz Feldspar Breccia	0.09%	4.48%
Quartz Monzonite	2.78%	75.4%
Coarse Crystalline Porphyry	0.93%	14.0%
Undefined	0.10%	0.00%
<b>TOTAL</b>	<b>4.47% Oxide/Transitional</b>	<b>95.5% Sulfide</b>
	<b>100%</b>	

## 8.2.2 Tailings Storage Facility

Approximately 100 million tons of tailings are expected to be stored over the life of the project with an estimated tailings deposition rate of 25,000 tpd. Tailings will be deposited in a lined facility constructed on the site of the existing TSF, which contains an estimated 1.2 Mt of historic tailings material (THEMAC, 2012). It is assumed that these historic tailings will be incorporated into the new (lined) TSF and will be re-graded to a thickness of 6 to 12 inches (Golder, 2012). It was assumed that 70% of total tailings mass in the TSF will be available for chemical weathering reactions (Bowell, 2001). This same assumption was made for the historic tailings underlying the impoundment that will interact with seepage through any liner defects. This is a reasonable estimate for saturated tailings and is based on the smaller particle size for the tailings that will contact meteoric water.

## 8.3 Water Balance

The water balance for the WRDF and TSF were provided by JSAI (2012). SRK utilized the flows from these water balances to determine the quantity of each identified water source. The project is located in a net evaporitic area where annual evaporation greatly exceeds precipitation.

### 8.3.1 Waste Rock Disposal Facility

At the end of mine life, the WRDF will be covered with a store-and-release type cover, which will only allow water into the facility after large precipitation events that exceed the storage capacity of the cover. Long-term infiltration into the WRDF is estimated to be two percent of mean annual precipitation (equating to 0.25 inches per year). It is assumed that the remaining precipitation will be lost to evapotranspiration or will runoff the facility. This is a reasonable assumption given the majority of annual precipitation occurs in the form of intense thunderstorms during July, August, September (INTERA, 2012).

Of the estimated infiltration through the WRDF cover, the majority is expected to be retained in the waste rock. Using an estimated annual infiltration rate of 0.25 inches per year, it would take hundreds of years to wet the total thickness of waste rock to field capacity (assuming the field capacity of the waste rock is 6 percent) (JSAI, 2012). Of the infiltration through the cover that is not retained in the waste rock (i.e., that discharging through preferential flow paths), some may discharge into the groundwater system. However, the amount of infiltration that discharges to groundwater is expected to be very small or nil due to the low permeability of the underlying andesite (JSAI, 2012).

Although the andesite underlying the WRDF has been demonstrated to have a low permeability and is likely to act as a liner, a small proportion of precipitation may eventually seep through the WRDF and report to groundwater. A reasonable estimate of the upper end of possible flow from the WRDF to groundwater is 5 to 10% of infiltration through the waste rock cover, equating to 0.1 to 0.2% of annual precipitation.

The zone of groundwater mixing was calculated from the plan surface area of the WRDF assuming a 30 feet mixing zone in the aquifer. The movement of any potential seepage from beneath the WRDF to the underlying water table has been evaluated by JSAI (2012) by calculating flow paths and travel times for hypothetical particles. The computed paths demonstrate that any impacts to groundwater quality beneath the WRDF would not migrate away from the immediate area of the WRDF for several hundred years due to the low permeability of the underlying andesite bedrock.

### 8.3.2 Tailings Storage Facility

At the end of mine life, the TSF will be reclaimed and covered with 36 inches of store-and-release soil cover (or approved equivalent) and revegetated. Any entrained process waters within the tailings will draindown over a number of years and any seepage from the facility during this period will therefore be a mixture of tailings supernatant solution plus meteoric water that has infiltrated the TSF. It is assumed that the porosity of tailings in both the unsaturated zone (i.e., above the draindown curve) and saturated zone is 48% (Golder, 2012).

Because the tailings impoundment will be lined, seepage from the facility is expected to be small. However, it is recognized that there could be minor seepage from manufacturing defects and other holes in the liner or the seams developed during placement. JSAI (2012) evaluated the potential occurrence of leaks in the tailings facility liner using the assumption that there would be one circular defect per acre with a standard defect area of 1 cm<sup>2</sup> (corresponding to a round hole diameter of 1.128 cm). The rate of leakage through the defect, assuming an unsaturated system underlying the tailings was then calculated as follows:

$$Q = \pi * D_h * K_t * h_t$$

Where  $Q$  is the flow through the defect,  $D_h$  is the diameter of the defect,  $K_t$  is the hydraulic conductivity of the tailings and  $h_t$  is the hydraulic head. Assuming the standard defect size ( $D_h = 1.128$  cm) occurring once per acre and assuming reasonable  $K_t$  ( $10^{-6}$  cm/s) and  $h_t$  (100 feet), leakage from the ~530 acre lined impoundment is estimated at 0.25 gallons/day/acre during the early stages of post-closure. During draindown of the TSF, the amount of leakage will be proportional to the hydraulic head within the facility, which will decrease as the volume of entrained solution decreases. The volume of seepage was therefore adjusted for each of the modeled time-steps to account for the decrease in hydraulic head.

For the purpose of the geochemical model it is assumed that any seepage through liner defects will migrate to the water table and that there will be mixing of TSF seepage solutions and groundwater under the facility. The zone of groundwater mixing has been calculated from the plan surface area of the TSF assuming a base case of a 100 feet mixing zone in the aquifer. This is a reasonable assumption given that the existing sulfate plume under the historic TSF extends to a depth of approximately 100 feet (see Figure 8-3). Additional sensitivity analyses have been modeled for mixing zones of 50 feet and 75 feet, respectively (see Section 8.8).

The movement of any potential seepage away from the TSF in the underlying groundwater has been evaluated by JSAI (2012) by calculating flow paths and travel times for hypothetical particles. Particle movement in the Santa Fe Group aquifer downstream from the TSF is slow and thus any discharge to groundwater from the TSF would remain in the immediate area for several hundred years. This is supported by the sustained elevated water levels and sulfate plume near the existing tailings impoundment which confirms the slow groundwater movement (Figure 8-3).

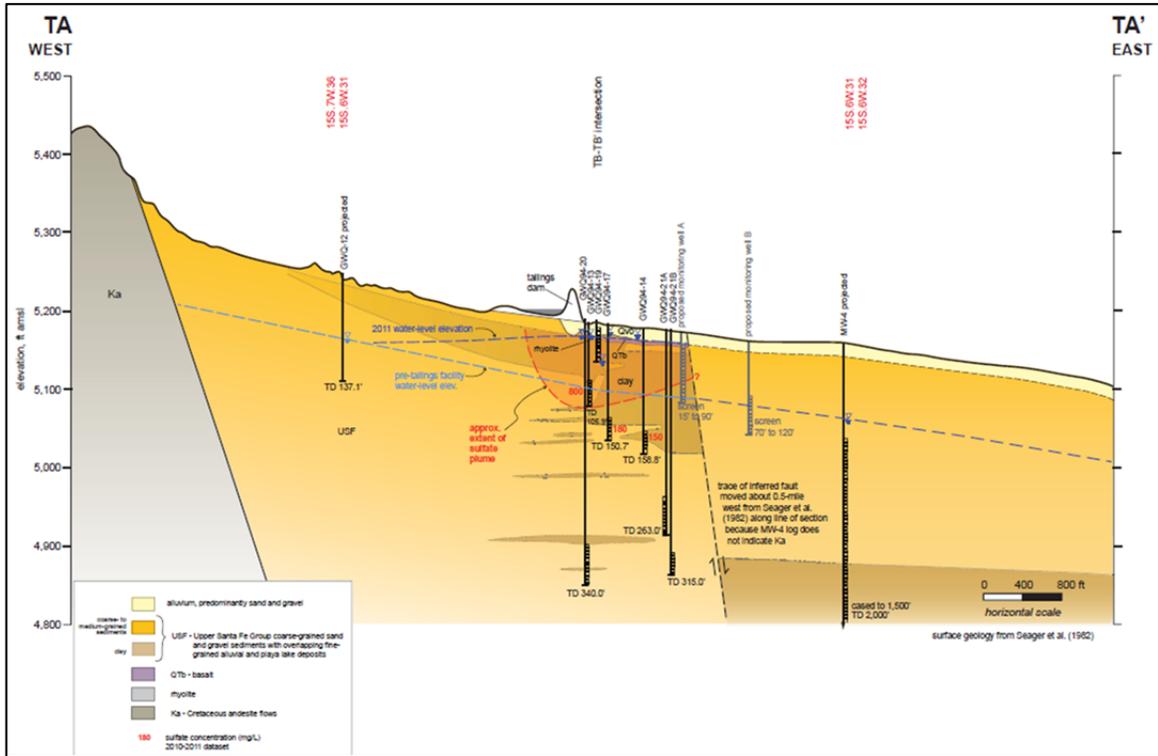
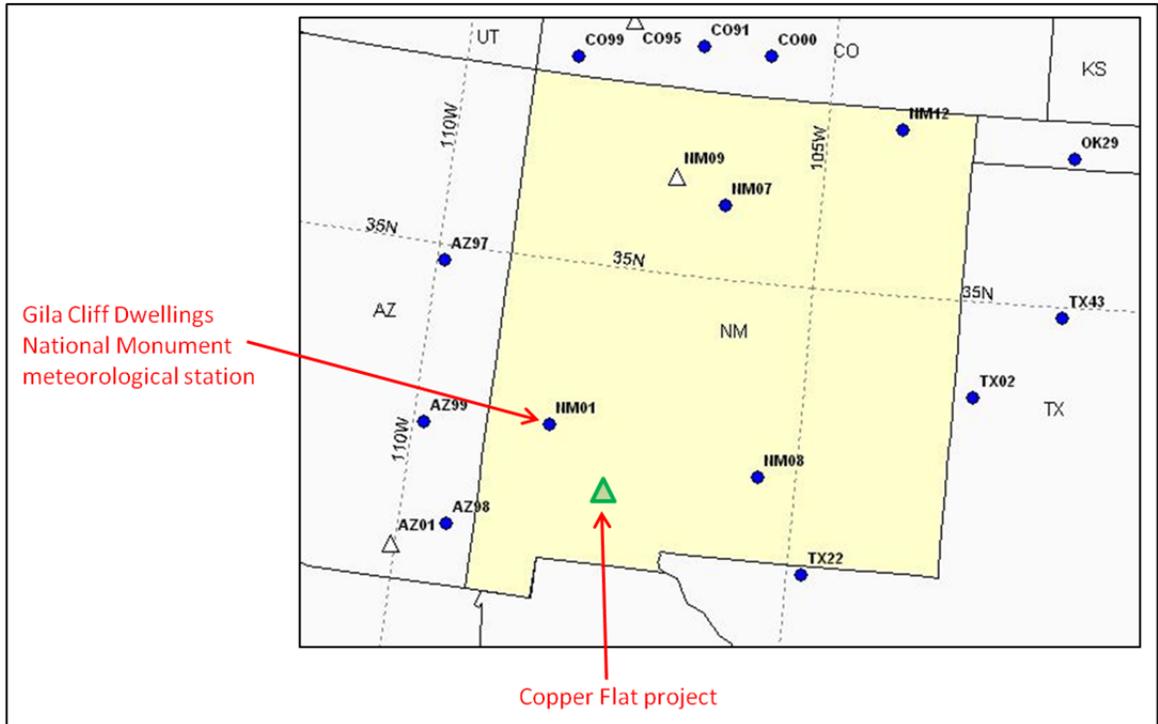


Figure 8-3: Cross section showing sulfate plume under TSF (from JSAI, 2011)

## 8.4 Solution Inputs

### 8.4.1 Precipitation Chemistry

For the purposes of the WRDF and TSF geochemical models, the primary leachant was assumed to be rainwater. 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). 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 8-3).



**Figure 8-4: Gila Cliff Dwellings National Monument Meteorological Station Location**

**Table 8-3: 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 <sub>4</sub>	mg/L	0.86
NH <sub>4</sub>	mg/L	0.17
NO <sub>3</sub>	mg/L	0.83

### 8.4.2 Waste Rock Chemistry (WRDF Model)

The WRDF geochemical model assumed the leachate characteristics from the WRDF are identical to those of laboratory kinetic tests run on representative materials that have been scaled to field conditions. Representative leachate chemistries were obtained from waste grade cells in the ongoing HCT program and average elemental release rates (in mg/kg) from each humidity cell were calculated and used as input solutions to the model. In the case of pH, average values were calculated after conversion to hydrogen ion activity  $[H^+]$ . The average  $[H^+]$  was then converted back to pH using the relationship  $pH = -\log_{10}[H^+]$ . This avoids difficulties associated with taking an average of a log parameter.

The scaled average mg/kg/week element release data from the humidity cell tests were then used as the source term leachates. Details of the HCT leachates used as input solutions to the model are provided in Table 8-4. A scaling factor was applied to the laboratory data in order to account for the slower reaction rates observed in the field compared to laboratory-scale tests. 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. This results in higher solute release rates than are likely to exist under field conditions. This discrepancy between field and lab conditions is addressed by using a scaling factor based on surface area, water flux, and water: rock ratio conditions in the laboratory and field settings. For the purpose of the Copper Flat WRDF model, a scaling factor of 10 has been applied as the best representation of lab to field scaling based on the relationship of solid-liquid ratios in the lab versus the field. This is to say that the reaction rates for the material in the WRDFs will react 10 times slower with meteoric water than in the laboratory tests. The rationale for this is that under the controlled environment of the laboratory mineral reaction rates will occur more rapidly than in the field where there is generally a much lower liquid-solid ratio than in laboratory testwork. A detailed discussion on scaling of laboratory to field data is provided in Appendix I.

The data in Table 8-4 represents average release rates over the entire HCT testwork period (i.e., between week 0 and weeks 40/52/56/60/96 - depending upon the cell).

**Table 8-4: Average HCT Input Solutions used in the WRDF Geochemical Models**

		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
		<i>Cells SRK 0864 and SRK 0866</i>	<i>SRK 0872</i>	<i>604673 and 605153</i>	<i>SRK 0872</i>	<i>604673 and 605153</i>	<i>Cells 604569 and SRK 0858</i>	<i>604673 and 605153</i>	<i>Cell CF-11-02 (0-27)</i>	<i>Cell CF-11-02 (367-408)</i>
<i>Percentage of waste (%)</i>		<i>1.06%</i>	<i>0.05%</i>	<i>1.10%</i>	<i>0.09%</i>	<i>4.48%</i>	<i>2.78%</i>	<i>75.4%</i>	<i>0.93%</i>	<i>14%</i>
pH	s.u.	7.38	6.48	6.14	6.48	6.14	2.97	6.14	7.95	7.85
HCO <sub>3</sub>	mg/L	11.1	6.56	13.8	6.56	13.8	22.2	13.8	39.8	26.6
Aluminum	mg/L	0.02	0.10	0.04	0.10	0.04	3.16	0.04	0.02	0.04
Antimony	mg/L	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Arsenic	mg/L	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002
Cadmium	mg/L	0.0005	0.0008	0.0006	0.0008	0.0006	0.0017	0.0006	0.0007	0.0005
Calcium	mg/L	9.23	29.5	6.76	29.5	6.76	9.87	6.76	12.4	8.45
Chloride	mg/L	0.75	0.61	0.76	0.61	0.76	1.31	0.76	1.64	2.77
Chromium	mg/L	0.002	0.002	0.003	0.002	0.003	0.006	0.003	0.002	0.002
Copper	mg/L	0.02	0.13	0.14	0.13	0.14	3.25	0.14	0.02	0.02
Fluoride	mg/L	0.46	0.34	0.48	0.34	0.48	2.09	0.48	1.29	0.72
Iron	mg/L	0.006	0.113	0.006	0.113	0.006	7.206	0.006	0.012	0.007
Lead	mg/L	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001
Magnesium	mg/L	1.41	1.21	1.08	1.21	1.08	1.67	1.08	2.35	0.85
Manganese	mg/L	0.01	0.19	0.02	0.19	0.02	0.13	0.02	0.02	0.01
Mercury	mg/L	0.00005	0.00005	0.00006	0.00005	0.00006	0.00005	0.00006	0.0001	0.00007
Molybdenum	mg/L	0.010	0.063	0.012	0.063	0.012	0.007	0.012	0.011	0.006
Nickel	mg/L	0.005	0.005	0.005	0.005	0.005	0.006	0.005	0.005	0.005
Nitrate as N	mg/L	0.71	0.47	0.50	0.47	0.50	0.47	0.50	0.48	0.46
Potassium	mg/L	1.04	0.50	2.11	0.50	2.11	1.72	2.11	4.07	3.34
Selenium	mg/L	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.002
Sodium	mg/L	1.96	0.47	1.98	0.47	1.98	2.09	1.98	4.78	4.79
Sulfate	mg/L	23.4	79.3	15.8	79.3	15.8	94.7	15.8	18.2	11.4
Uranium	mg/L	0.005	0.005	0.008	0.005	0.008	0.011	0.008	0.006	0.003
Vanadium	mg/L	0.005	0.005	0.006	0.005	0.006	0.006	0.006	0.005	0.005
Zinc	mg/L	0.005	0.022	0.010	0.022	0.010	0.028	0.010	0.005	0.005
<i>Ion balance (%)</i>		<i>0.02%</i>	<i>5.09%</i>	<i>0.80%</i>	<i>5.09%</i>	<i>0.80%</i>	<i>51.20%</i>	<i>0.80%</i>	<i>-2.12%</i>	<i>2.24%</i>

### 8.4.3 Tailings and Supernatant Chemistry (TSF model)

As with the WRDF model, the TSF geochemical model assumes leachate characteristics from the TSF are identical to those of laboratory HCTs run on representative materials and then scaled to field conditions. Representative leachate chemistries were obtained from the ongoing HCT program and average elemental release rates (in mg/kg) from each humidity cell were calculated and used as input solutions to the model. Details of the tailings HCT leachates used as input solutions to the TSF models are provided in Table 8-5. Because the nine tailings HCT cells show similar characteristics in terms of effluent leachate chemistry, average elemental release rates for all cells were averaged for the entire testwork period (i.e., from week 0 to weeks 8/28). For the historic tailings, the MWMP data was used as the input solution to the model.

As with the WRDF models, a scaling factor was applied to the laboratory data in order to account for the slower reaction rates observed in the field compared to laboratory-scale tests. For the purpose of the TSF models, a scaling factor of 10 has been used as a best representation of lab to field scaling. This is to say that the reaction rates for the material in the TSF will react 10 times slower with meteoric water than in the laboratory HCT/MWMP tests (see additional discussion in Appendix I).

Tailings supernatant chemistry representative of entrained process solution in the TSF has been obtained from the following sources:

- Quintana flotation tailings supernatant collected between 1981 and 1982; and
- Tailings supernatant chemistry reported in the 1976 Geotechnical Investigation Report (Sergent, Hauskins and Beckwith, 1976).

The composite process water chemistry based on these sources used in the TSF models is provided in Table 8-5.

**Table 8-5: Input Solution Chemistry used in the TSF Geochemical Model**

		Tailings HCT leachate chemistry	Tailings supernatant chemistry	Historic tailings chemistry
		<i>Average data from tailings HCT cells between weeks 0 and 8/28</i>	<i>Composite chemistry data from 1981-1982 flotation tails</i>	<i>MWMP data for sample SRK0876 (collected from historic tailings facility)</i>
pH	s.u.	8.07	7.59	7.82
HCO <sub>3</sub>	mg/L	109	219	130
Aluminum	mg/L	0.06	0.01	0.05
Antimony	mg/L	0.003	-	0.003
Arsenic	mg/L	0.005	0.01	0.005
Barium	mg/L	0.05	0.2	0.056
Boron	mg/L	0.11	0.1	0.1
Cadmium	mg/L	0.001	0.005	0.001
Calcium	mg/L	36.3	92.6	560
Chloride	mg/L	5.25	27.4	28.0
Chromium	mg/L	0.005	0.01	0.005
Cobalt	mg/L	0.01	0.02	0.01
Copper	mg/L	0.05	0.05	0.58
Fluoride	mg/L	2.00	1.96	4.20
Iron	mg/L	0.017	0.04	0.01
Lead	mg/L	0.002	0.02	0.003
Magnesium	mg/L	6.73	18.8	180
Manganese	mg/L	0.03	0.05	0.18
Mercury	mg/L	0.0002	0.001	0.0001
Molybdenum	mg/L	0.06	1.1	3.5
Nickel	mg/L	0.01	0.05	0.01
Nitrate as N	mg/L	1	5.49	42.0
Potassium	mg/L	17.6	1.69	280
Selenium	mg/L	0.006	0.005	0.01
Silver	mg/L	-	0.02	0.005
Sodium	mg/L	17.1	52.2	59.0
Sulfate	mg/L	74.7	176	2400
Uranium	mg/L	0.04	-	0.19
Vanadium	mg/L	0.007	-	0.083
Zinc	mg/L	0.01	0.05	0.01
<i>Ion balance</i>		<i>-1.05%</i>	<i>-2.83%</i>	<i>0.37%</i>

#### 8.4.4 Groundwater Chemistry

Representative groundwater chemistry data were obtained from the groundwater monitoring program for use in the WRDF and TSF geochemical prediction models. For the purposes of the WRDF model, groundwater data from wells GWQ-6 (June 1981 – April 1993) and GWQ96-22A (July 1996 – October 2010) were used in the WRDF model. These wells are the most representative of andesite groundwater chemistry and the WRDF is situated on andesite bedrock.

For the purposes of the TSF model, groundwater data collected from wells GWQ94-16, NP-2, NP-4 NP-5 in 2010/2011 were used. These wells are representative of background water quality in the vicinity of the TSF. Although a groundwater sulfate plume currently exists beneath the old tailings facility (see Figure 8-3), these historic tailings will be isolated by the new lined facility. As such, the source of the sulfate plume will be removed and it is not considered representative to use this groundwater chemistry in the model.

The groundwater chemistry data used as input solutions to both the WRDF and TSF models are provided in Table 8-6. From Table 8-6, fluoride, iron and manganese are currently elevated above NMWQCC standards in the andesite groundwater. All parameters in the groundwater below the proposed tailings impoundment are below the NMWQCC standards.

#### 8.5 Chemical Precipitation

For the purpose of the predictive geochemical models it was assumed that the leachates produced from each material type 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 macro-geochemical conditions (Eh, pH, pCO<sub>2</sub>, pO<sub>2</sub>, and ionic strength) allow saturation to occur. The models required the specification of potential equilibrium phases that were allowed to precipitate if they become saturated. The suite of minerals chosen was based on the mineralogical characterization of the Copper Flat deposit and an understanding of the types of minerals that could occur in waste rock and tailings leachates. 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 minerals that were allowed to form in the geochemical models are given in Table 8-7. The models assumed that precipitated mineral phases are removed from the system and that subsequent re-dissolution of these phases does not occur.

**Table 8-6: Groundwater Chemistry used in the WRDF and TSF models**

Parameter	Units	NMWQCC standard	Groundwater chemistry data used in the WRDF model [Average of GWQ-6 (Jul 1981 – Apr 1993) and GWQ96-22A (Jul 1996 – Oct 2010)]	Groundwater chemistry data used in the TSF mode [Average of GWQ94-16, NP-2, NP-5 and NP-4 (June 2010 to May 2011)]
pH	s.u.	6 – 9	6.4	7.76
HCO <sub>3</sub>	mg/L	-	272	178
Aluminium	mg/L	5	0.032	0.02
Antimony	mg/L	-	0.002	0.001
Arsenic	mg/L	0.1	0.005	0.002
Barium	mg/L	1	0.15	0.036
Boron	mg/L	0.75	0.192	0.044
Cadmium	mg/L	0.01	0.003	0.002
Calcium	mg/L	-	59.1	137
Chromium	mg/L	0.05	0.014	0.006
Chloride	mg/L	250	64.5	120
Cobalt	mg/L	0.05	0.031	0.006
Copper	mg/L	1	0.024	0.006
Fluoride	mg/L	1.6	1.93	0.57
Iron	mg/L	1	1.6	0.03
Lead	mg/L	0.05	0.009	0.005
Magnesium	mg/L	-	7.34	35.2
Manganese	mg/L	0.2	0.645	0.02
Mercury	mg/L	0.002	0.0007	0.0002
Molybdenum	mg/L	1	0.031	0.008
Nickel	mg/L	0.2	0.027	0.01
Nitrate as N	mg/L	10 (total N)	1.23	4.37
Potassium	mg/L	-	3.23	2.70
Selenium	mg/L	0.05	0.004	0.01
Silver	mg/L	0.05	0.019	0.005
Sulfate	mg/L	600	115	269
Sodium	mg/L	-	127	65.6
Thallium	mg/L	-	0.001	0.0013
Uranium	mg/L	0.03	0.001	0.002
Vanadium	mg/L	-	0.05	0.05
Zinc	mg/L	10	0.026	0.43
<i>Ion balance (%)</i>		-	5.89%	-3.09%

Shaded values indicate exceedence of NMWQCC.

**Table 8-7: Equilibrium Phases**

Equilibrium phase*	Ideal formula
Alunite	$KAl_3(SO_4)_2(OH)_6$
Albite	$NaAlSi_3O_8$
Anhydrite	$CaSO_4$
Azurite	$Cu_3^{2+}(CO_3)_2(OH)_2$
Barite	$BaSO_4$
Boehmite	$AlOOH$
Brochantite	$Cu_4^{2+}(SO_4)(OH)_6$
Calcite	$CaCO_3$
$Cr_2O_3$	$Cr_2O_3$
Diaspore	$\alpha-AlOOH$
Ferrihydrite	$5Fe_2O_3 \cdot 9H_2O$
Fluorite	$CaF_2$
Gibbsite	$Al(OH)_3$
Gummite	$UO_3$
Gypsum	$CaSO_4 \cdot 2H_2O$
Malachite	$Cu_2^{2+}(CO_3)(OH)_2$
Pyromorphite	$Pb_5(PO_4)_3Cl$
Quartz	$SiO_2$
Rhodochrosite	$Mn^{2+}CO_3$
Rutherfordine	$UO_2CO_3$
Schoepite	$UO_2(OH)_2 \cdot H_2O$
Tenorite	$Cu^{2+}O$
$U_3O_8$	$U_3O_8$
$UO_3$	$UO_3$
$UO_2(OH)_2$ (beta)	$UO_2(OH)_2$ (beta)

\* All sulfide minerals were found to be undersaturated in the predictions and were therefore not added as equilibrium phases in the models.

## 8.6 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. Ferrihydrite ( $5\text{Fe}_2\text{O}_3 \cdot 9\text{H}_2\text{O}$ ) 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 HFO is highly pH dependant 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 iterations and this controlled by the chemistry of the system. The model assumes that the ferrihydrite is characterised by both strong (HFO\_s) and weak (HFO\_w) surface adsorption sites. In order to be consistent with the published 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.

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 (i.e., acid generation) is not likely for the bulk of the waste rock or tailings material.

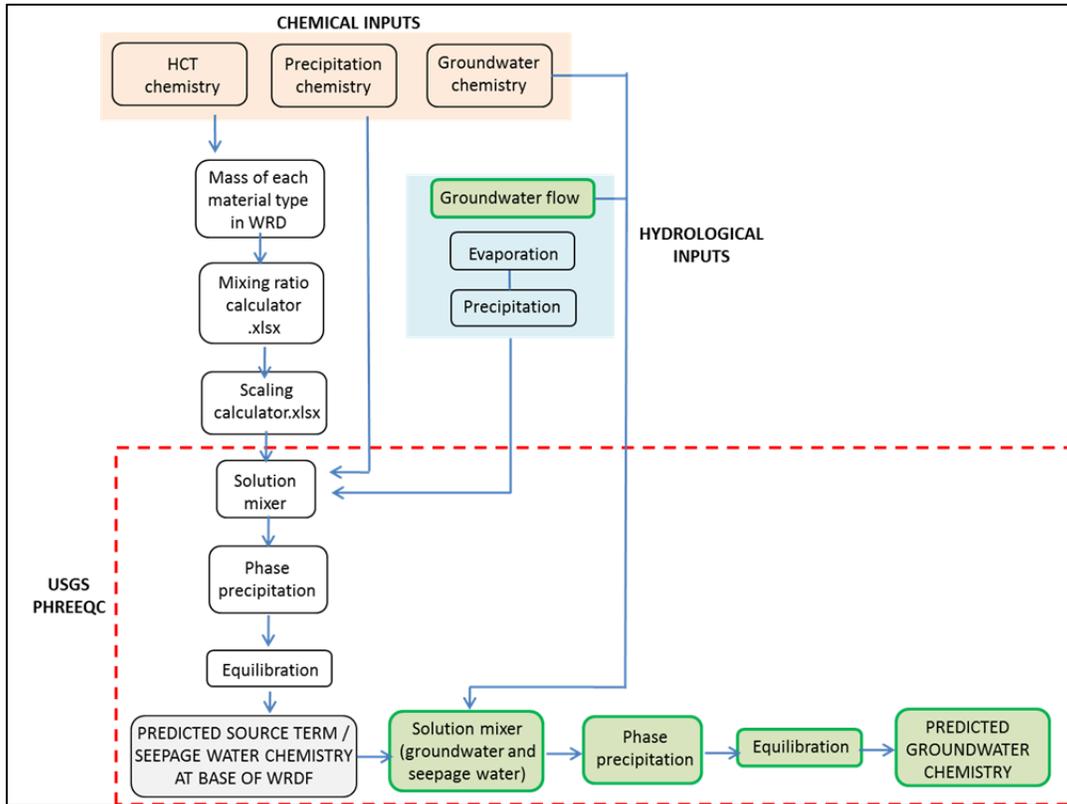
## 8.7 Model Logic and Coding

The conceptual models developed for the Copper Flat WRDF and TSF have been translated into numerical models using a geochemical thermodynamic equilibrium code and several limiting and simplifying assumptions. Water chemistry predictions were made using the USGS code PHREEQC, 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 parcelled out to various output files for analysis of results.

### 8.7.1 Waste Rock Disposal Facility

A logic flow diagram for the structure of the WRDF input code is shown in Figure 8-5 and discussed below.



**Figure 8-5: WRDF Model Logic**

The steps in the WRDF modeling process included the following items:

- Define solution inputs specific to each material type in the WRDFs. The solution chemistries are comprised of scaled HCT leachate concentrations for each material type. This data is scaled to water:rock ratio from the cell to the field, based on the estimated mass of material in the facility that is likely to be exposed to chemical weathering reactions.
- Define the solution mixing ratios. Mixing ratios are based on the amount of each material type in the facility.
- Define rainfall water quality based on a representative chemistry (the model used long-term monitoring data from the Gila National Monument Meteorological Station in New Mexico). This solution forms both the primary leachant for the WRDF.
- Perform a master mixing calculation where the solution inputs are mixed in ratios defined by the geological modeling and climatic data.
- Following the master mixing 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.

- 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 sub-atmospheric value equal to 12 – pH.
- Calculate sorption. After mineral precipitation, trace elements were allowed to adsorb onto iron oxyhydroxides. The total mass of iron oxyhydroxides is equivalent to the mass predicted to be generated during the preceding step. This assumption is conservative in that it does not account for sorption to other minerals, such as aluminum oxide or clay, or for ferrihydrite present within the bedrock itself.
- Save predicted WRDF source term chemistry (i.e., seepage water chemistry at the base of the facility). This is exported to a spreadsheet for analysis.
- Perform a mixing calculation where the predicted seepage water is mixed with groundwater in the ratio defined by the water balance.
- Equilibrate and precipitate.
- Calculate sorption.
- Save final predicted groundwater chemistry. This is exported to a spreadsheet for analysis.

An example of the WRDF PHREEQC input code is provided in Appendix G.

### 8.7.2 Tailings Storage Facility

A logic flow diagram for the TSF input code is shown in Figure 8-6 and discussed below.

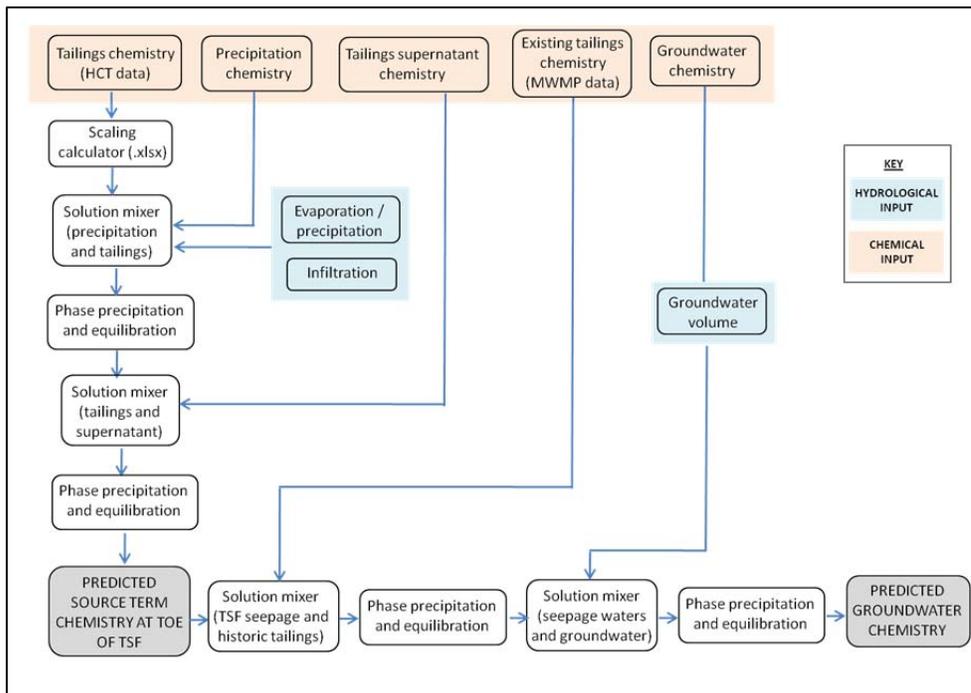


Figure 8-6: TSF Model Logic

The steps in the TSF modeling process included the following items:

- Define tailings solution chemistry (comprised of scaled HCT leachate concentrations). These data are scaled to water:rock ratio from the cell to the field, based on the estimated mass of material in the TSF that is likely to be exposed to chemical weathering reactions.
- Define precipitation chemistry (the model used long-term monitoring data from the Gila National Monument Meteorological Station in New Mexico).
- Define the solution mixing ratios based on the mass of tailings in the TSF and the volume of infiltrating precipitation.
- Perform a master mixing calculation where the solution inputs are mixed in the defined ratios.
- Following the master mixing 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.
- Equilibrate and precipitate oversaturated mineral phases.
- Calculate sorption onto iron oxyhydroxide phases precipitated during the previous reaction step.
- Define the volume of tailings supernatant remaining in the saturated zone of the TSF (calculated assuming a void space of 48%).
- Define the solution mixing ratios between the infiltrating meteoric water (that has interacted with the tailings in the unsaturated zone) and the tailings supernatant water in the saturated zone.
- Perform additional equilibration steps and allow precipitation of oversaturated mineral phases.
- Calculate sorption onto iron oxyhydroxide phases precipitated during the previous reaction step.
- Save predicted TSF source term chemistry for (i.e., at the base of the facility).
- Define historic tailings solution chemistry (comprised of scaled MWMP test leachate concentrations).
- Define the solution mixing ratios based on the mass of historic tailings underlying the TSF and the volume of seepage from the facility.
- Perform a master mixing calculation where the solution inputs are mixed in the defined ratios.
- Equilibrate and precipitate oversaturated mineral phases.
- Calculate sorption onto iron oxyhydroxide phases precipitated during the previous reaction step.
- Define groundwater chemistry underlying the TSF.
- Perform a master mixing calculation where seepage from the proposed and historic tailings is mixed with groundwater in the ratio defined by the water balance.
- Equilibrate and precipitate oversaturated mineral phases.
- Calculate sorption onto iron oxyhydroxide phases precipitated during the previous reaction step.
- Save final predicted groundwater chemistry. This is exported to a spreadsheet for analysis.

An example of the TSF PHREEQC input code is provided in Appendix H.

## 8.8 Sensitivity Analysis

### 8.8.1 Waste Rock Disposal Facility

The WRDF base case model described in Section 8.1.1 is intended to give the most probabilistic output in terms of likely source term chemistry and is based on the most likely input parameters. This base case model assumes that any seepage from the facility will mix with the upper-most 30 feet of the aquifer underlying the WRDF. However, additional sensitivity analyses were carried out whereby this groundwater mixing zone was varied between 10 feet and 50 feet to determine the influence the thickness of this zone will have on groundwater chemistry. In theory, the deeper the mixing zone, the less influence WRDF seepage waters will have on groundwater chemistry. Completion of both the base case and sensitivity analysis models gives an idea of the possible range of water quality that may be expected in the groundwater underlying the WRDF.

### 8.8.2 Tailings Storage Facility

The TSF model assumes that any seepage from defects within the TSF liner will mix with the upper-most 100 feet of the aquifer underlying the facility. This is a reasonable assumption given that the sulfate plume under the existing TSF extends to a depth of approximately 100 feet. Additional sensitivity analyses were then performed whereby the groundwater mixing zone was varied between 50 and 100 feet.

## 8.9 Model Limitations

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 boundaries and assumptions of the WRDF and TSF numeric models include:

1. Modeling is limited to predicting water quality under steady-state conditions.
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 sub atmospheric equilibrium with oxygen and carbon dioxide gas, with pH + pE equal to 12.
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. Biological processes are not taken into account and therefore mineral precipitates are the only sink for major nutrients such as phosphate.
10. The models assume that solution input chemistry can be simulated using laboratory leachate chemistries from HCT tests, which are appropriately scaled to field conditions. A scaling factor of 10 has been used as a best representation of lab to field scaling. This is to say that the reaction rates within the WRDF and TSF are anticipated to be 10 times slower than in the laboratory tests.

## 8.10 Analysis of Model Input Variability

The various parameters that have been used as data inputs for the WRDF and TSF geochemical models 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 value based on the degree to which it influences the final predicted solution chemistry as determined by the sensitivity analysis results. These values are qualitative and include:

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

The results of this exercise are displayed in Table 8-8.

**Table 8-8: Analysis of WRDF and TSF Model Input Variability**

	Parameter	Assumptions / data used in model	Source	Control on final model results*
<b>Hydrogeologic information</b>	Infiltration to WRDF and TSF	2% of mean annual precipitation	JSAI, 2012	Moderate. The volume of infiltration to the facilities will influence the liquid:solid mixing ratios and will affect how dilute or concentrated the source term chemistry will be.
	Seepage volume from WRDF	0.1 – 0.2% of mean annual precipitation	JSAI, 2012	Minor. Concentrations of dissolved constituents in the WRDF source term chemistry are predicted to be low. Therefore increasing the volume of seepage will not increase the potential for groundwater degradation.
	Seepage volume from TSF	<0.25 gallons/acre/day (assuming 1 circular defect of 1.128cm <sup>2</sup> per acre)	JSAI, 2012	Moderate. Significantly increasing the volume of seepage from the TSF may increase groundwater solute loading. However, increased seepage volumes are unlikely given that the TSF will be a lined facility.
<b>Chemical inputs</b>	Groundwater chemistry	Baseline groundwater chemistry data from the ongoing monitoring program: <ul style="list-style-type: none"> <li>WRDF - wells GWQ-6 and GWQ96-22A (representative of andesite groundwater chemistry)</li> <li>TSF - wells GWQ94-16, NP-2, NP-4 and NP-5 (representative of groundwater chemistry outside the existing sulfate plume under the TSF)</li> </ul>	INTERA, 2012	<ul style="list-style-type: none"> <li>Insignificant for source term chemistry, as groundwater exerts no control on seepage water from the WRDF and TSF.</li> <li>Significant for model assessing groundwater chemistry under the TSF and WRDF. Groundwater chemistry is likely to represent the primary control on the model result.</li> </ul>
	Precipitation chemistry	Averaged precipitation chemistry from Gila Cliff Dwelling National Monument Meteorological Station (1985-2011)	NADP, 2012	Insignificant. 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 waste rock and tailings HCT programs.	SRK	Significant. The solutions generated by the HCT programs represent the main chemical inputs to the PHREEQC models.
<b>Mine plan information</b>	WRDF design	Surface area of final (year 11) facility will be 180 acres and will contain 60Mt of waste rock. Facility will be covered with a low permeability cover post-closure.	THEMAC, 2012	Not applicable. Parameter is fixed by mine plan.

	Parameter	Assumptions / data used in model	Source	Control on final model results*
	TSF design	Surface area of final (year 11) facility will be 530 acres and will contain 100Mt of tailings. Facility will be lined with HDPE liner and will be constructed on top of historic tailings (approximately 1.2 Mt). Facility will be covered with a low permeability cover post-closure.	THEMAC, 2012	Not applicable. Parameter is fixed by mine plan.
<b>Geochemical model assumptions</b>	Scaling factor	A scaling factor of 10 was applied to the WRDF and TSF models to account for the scaling of laboratory data to field conditions	SRK	Moderate. The scaling factor was assigned following a detailed literature review (Appendix I) and with a knowledge and understanding of site-specific conditions.
	Equilibrium/mineral phases	Alunite, albite, anhydrite, azurite, barite, boehmite, brochantite, calcite, Cr <sub>2</sub> O <sub>3</sub> , diaspore, ferrihydrite, fluoride, gypsum, gibbsite, gummite, malachite, pyromorphite, quartz, rhodochrosite, rutherfordine, schoepite, tenorite, U <sub>3</sub> O <sub>8</sub> , UO <sub>3</sub> , UO <sub>2</sub> (OH) <sub>2</sub>	SRK	Moderate. Mineral precipitation will influence final solution chemistry. Equilibrium phases were selected based on knowledge of site-specific geologic and mineralogic conditions (Table 8-7). This was confirmed by reviewing mineralogic controls on existing pit lake and groundwater chemistry.

- \* Insignificant: <1%
- Minor: 1 - 10%
- Moderate: 10 - 50%
- Significant: >50%

## 8.11 Model Results

### 8.11.1 Waste Rock Disposal Facility

The results of the base case (i.e., most probable scenario) WRDF geochemical model are provided in Table 8-9. This shows the predicted source term chemistry at the base of the WRDF at the end of mine life and also the predicted groundwater chemistry under the facility should any seepage migrate away from the WRDF and make its way to groundwater. The results demonstrate that source term solutions at the base of the facility are likely to be moderately alkaline (pH 8.18) and are predicted to have concentrations of fluoride that are elevated above NMWQCC groundwater standards. By covering the WRDF with a re-vegetated store-and-release soil cover at the end of mine life, the infiltration of water and flux of oxygen into the facility will be reduced, which will limit the rate of weathering of sulfide minerals in the waste rock.

The andesite underlying the WRDF is low permeability and is likely to act as a liner, however additional model iterations have been undertaken to assess the potential impact from seepage to groundwater if seepage from the WRDF were to migrate to groundwater. The results are displayed in Table 8-9, which shows the predicted groundwater chemistry in the andesite aquifer underlying the WRDF facility, assuming seepage of 5% and 10% infiltration of the 2% of mean annual precipitation into the WRDF. Under the seepage scenario, the impact is expected to be low should any seepage from the WRDF make its way to groundwater.

The modeled results show that the predicted groundwater chemistry underlying the WRDF is likely to be similar to current groundwater chemistry. With the exception of fluoride, all parameters are predicted to be below NMWQCC standards in groundwater underlying the facility. Predicted fluoride concentrations are 1.93 mg/L compared to a standard of 1.6 mg/L. However, fluoride has been identified as being elevated in the existing ('baseline') groundwater at concentrations around 1.93 mg/L (see Table 8-9). Nonetheless, should any seepage migrate away from the WRDF it is likely that there will be some adsorption and attenuation of metal(oids) in the underlying andesite in the unsaturated zone. Although this is beyond the scope of the current modeling exercise, it is likely that these processes will further reduce elemental concentrations prior to any WRDF seepage reaching the underlying groundwater. As such, the potential impact to groundwater quality beneath the facility is likely to be minimal.

The WRDF base case model predictions assume that any seepage migrating away from the WRDF will only interact with the upper-most 30 feet of the aquifer underlying the facility. However, additional sensitivity analyses have been carried out whereby this zone of groundwater interaction was varied between 10 and 50 feet to assess the sensitivity of the mixing interval on predicted groundwater quality under the WRDF. The results are displayed in Table 8-10, which demonstrates that varying this zone has no effect on the predicted water chemistry. This is because seepage from the WRDF is expected to be negligible.

**Table 8-9: WRDF Model Results**

			NMWQCC standard	Average groundwater chemistry in andesite	Predicted Source Term Chemistry at base of WRDF	Predicted groundwater chemistry under WRDF assuming 5% seepage from facility	Predicted groundwater chemistry under WRDF assuming 10% seepage from facility
pH	pH	s.u.	6 - 9 <sup>†</sup>	6.40	8.18	8.51	8.51
pe	pe	s.u.	-	-	4.59	4.26	4.26
Alk	Alkalinity as CaCO <sub>3</sub>	mg/L	-	-	89.9	183.6	183.4
HCO <sub>3</sub>	Bicarbonate	mg/L	-	272	50.5	108.4	108.3
Ag	Silver	mg/L	0.05*	0.002	0.017	0.018	0.018
Al	Aluminium	mg/L	5 <sup>‡</sup>	0.03	0.0007	0.0015	0.0015
As	Arsenic	mg/L	0.1*	0.005	0.012	2.85E-07	2.86E-07
B	Boron	mg/L	0.75 <sup>‡</sup>	0.19	0.36	0.19	0.19
Ba	Barium	mg/L	1*	0.15	0.025	0.027	0.027
Ca	Calcium	mg/L	-	59.1	41.2	9.43	9.45
Cd	Cadmium	mg/L	0.01*	0.003	0.004	0.0003	0.0003
Co	Cobalt	mg/L	0.05 <sup>‡</sup>	0.03	0.018	0.005	0.005
Cr	Chromium	mg/L	0.05*	0.014	0.00004	0.00003	0.00003
Cu	Copper	mg/L	1 <sup>†</sup>	0.024	0.005	0.005	0.005
F	Fluoride	mg/L	1.6*	1.93	3.92	1.93	1.93
Fe	Iron	mg/L	1 <sup>†</sup>	1.6	0.00004	0.00004	0.00004
Hg	Mercury	mg/L	0.002*	0.0007	0.0004	0.0007	0.0007
K	Potassium	mg/L	-	3.23	15.8	3.25	3.26
Mg	Magnesium	mg/L	-	7.34	7.45	6.38	6.38
Mn	Manganese	mg/L	0.2 <sup>†</sup>	0.65	0.13	0.03	0.03
Mo	Molybdenum	mg/L	1 <sup>‡</sup>	0.031	0.08	0.03	0.03
Na	Sodium	mg/L	-	127	18.5	118	118
Ni	Nickel	mg/L	0.2 <sup>‡</sup>	0.027	0.03	0.002	0.002
Pb	Lead	mg/L	0.05*	0.009	0.00006	0.0002	0.0002
Sb	Antimony	mg/L	-	0.002	0.009	0.002	0.002
Se	Selenium	mg/L	0.05*	0.004	0.02	0.0002	0.0002
Tl	Thallium	mg/L	-	0.001	0.004	0.001	0.001
U	Uranium	mg/L	0.03*	0.001	0.029	0.001	0.001
V	Vanadium	mg/L	-	0.05	0.026	0.000003	0.000003
Zn	Zinc	mg/L	10 <sup>†</sup>	0.03	0.037	0.001	0.001
SO <sub>4</sub>	Sulfate	mg/L	600 <sup>†</sup>	115	121	115	115
Cl	Chloride	mg/L	250 <sup>†</sup>	64.5	7.37	64.5	64.5
N	Nitrogen as N	mg/L	10*	1.23	3.55	1.24	1.24
TDS <sup>‡</sup>	Total Dissolved Solids	mg/L	1000 <sup>†</sup>	614	270	428	428

- Indicates exceedance of NMWQCC standard
- \* Human health groundwater standard
- † Domestic water supply standard
- ‡ Irrigation standard
- ‡ TDS has been calculated as the sum of total ions from the PHREEQC model output and cannot be considered a true representation of TDS from a chemical analysis

**Table 8-10: WRDF Model Sensitivity Analysis (varying groundwater mixing zone)**

			NMWQCC standard	Average groundwater chemistry in andesite	Predicted groundwater chemistry under WRDF assuming 5% seepage and a 10ft groundwater mixing zone	Predicted groundwater chemistry under WRDF assuming 5% seepage and a 30ft groundwater mixing zone	Predicted groundwater chemistry under WRDF assuming 5% seepage and a 50ft groundwater mixing zone
pH	pH	s.u.	6 - 9 <sup>†</sup>	6.40	8.51	8.51	8.51
pe	pe	s.u.	-	-	4.26	4.26	4.26
Alk	Alkalinity as CaCO <sub>3</sub>	mg/L	-	-	183	184	184
HCO <sub>3</sub>	Bicarbonate	mg/L	-	272	108	108	108
Ag	Silver	mg/L	0.05*	0.002	0.018	0.018	0.018
Al	Aluminium	mg/L	5 <sup>‡</sup>	0.03	0.0015	0.0015	0.0015
As	Arsenic	mg/L	0.1*	0.005	2.88E-07	2.85E-07	2.84E-07
B	Boron	mg/L	0.75 <sup>‡</sup>	0.19	0.19	0.19	0.19
Ba	Barium	mg/L	1*	0.15	0.027	0.027	0.027
Ca	Calcium	mg/L	-	59.1	9.47	9.43	9.42
Cd	Cadmium	mg/L	0.01*	0.003	0.0003	0.0003	0.0003
Co	Cobalt	mg/L	0.05 <sup>‡</sup>	0.03	0.005	0.005	0.005
Cr	Chromium	mg/L	0.05*	0.014	0.00003	0.00003	0.00003
Cu	Copper	mg/L	1 <sup>†</sup>	0.024	0.005	0.005	0.005
F	Fluoride	mg/L	1.6*	1.93	1.94	1.93	1.93
Fe	Iron	mg/L	1 <sup>†</sup>	1.6	0.00004	0.00004	0.00004
Hg	Mercury	mg/L	0.002*	0.0007	0.0007	0.0007	0.0007
K	Potassium	mg/L	-	3.23	3.28	3.25	3.24
Mg	Magnesium	mg/L	-	7.34	6.38	6.38	6.38
Mn	Manganese	mg/L	0.2 <sup>†</sup>	0.65	0.03	0.03	0.03
Mo	Molybdenum	mg/L	1 <sup>‡</sup>	0.031	0.03	0.03	0.03
Na	Sodium	mg/L	-	127	118	118	118
Ni	Nickel	mg/L	0.2 <sup>‡</sup>	0.027	0.002	0.002	0.002
Pb	Lead	mg/L	0.05*	0.009	0.0002	0.0002	0.0002
Sb	Antimony	mg/L	-	0.002	0.002	0.002	0.002
Se	Selenium	mg/L	0.05*	0.004	0.0002	0.0002	0.0002
Tl	Thallium	mg/L	-	0.001	0.001	0.001	0.001
U	Uranium	mg/L	0.03*	0.001	0.001	0.001	0.001
V	Vanadium	mg/L	-	0.05	0.000003	0.000003	0.000003
Zn	Zinc	mg/L	10 <sup>†</sup>	0.03	0.001	0.001	0.001
SO <sub>4</sub>	Sulfate	mg/L	600 <sup>†</sup>	115	115	115	115
Cl	Chloride	mg/L	250 <sup>†</sup>	64.5	64.4	64.5	64.5
N	Nitrogen as N	mg/L	10*	1.23	1.24	1.24	1.24
TDS <sup>‡</sup>	Total Dissolved Solids	mg/L	1000 <sup>†</sup>	614	428	428	428

- Indicates exceedance of NMWQCC standard
- \* Human health groundwater standard
- † Domestic water supply standard
- ‡ Irrigation standard
- ‡ TDS has been calculated as the sum of total ions from the PHREEQC model output and cannot be considered a true representation of TDS from a chemical analysis

### 8.11.2 Tailings Storage Facility

The source term chemistry at the toe of the TSF has been predicted for scenarios of 25%, 50%, 75%, 90% and 95% draindown of entrained process waters within the facility. The results are provided in Table 8-11 and show that during the draindown period the resulting solution chemistry is likely to be controlled by process waters. Solutions at the base of the TSF are predicted to be moderately alkaline (pH 8.21) with sulfate concentrations of approximately 176 mg/L and a fluoride content of approximately 1.96 mg/L.

Predictive calculations were carried out to assess whether seepage of waters through defects in the TSF liner has the potential to result in an impact to groundwater. The results are presented in Table 8-12 and demonstrate that the volumes of seepage from the TSF will be so low (<0.25 gallons/acre/day) that impacts to groundwater are likely to be negligible.

The modeled results show that the predicted groundwater chemistry underlying the TSF is likely to be similar to current groundwater chemistry outside of the existing sulfate plume, with only a minor increase in pH and sodium concentrations. The use of the historic tailings as a bedding material for the new, lined tailings facility will effectively isolate this material from reaction. As such, groundwater chemistry under the TSF is likely to improve over time, as the sulfate source from the historic tailings will effectively be removed.

The model presented above assumes that any seepage from defects within the TSF liner will mix with the upper-most 100 feet of the aquifer underlying the facility. This is a reasonable assumption given that the sulfate plume under the existing TSF extends to a depth of approximately 100 feet. Additional sensitivity analyses have been carried out whereby this zone of groundwater interaction was varied between 50 and 100 feet to assess the resulting effect on predicted groundwater chemistry under the TSF. The results are presented in Table 8-13 for the 95% draindown scenario and demonstrate that varying the zone of groundwater interaction has no effect on the predicted water quality due to the low amounts of seepage through the TSF liner.

**Table 8-11: Predicted TSF source term chemistry at toe of TSF**

			NMWQCC standard	Predicted source term at toe of TSF at 25%draindown	Predicted source term at toe of TSF at 50%draindown	Predicted source term at toe of TSF at 75%draindown	Predicted source term at toe of TSF at 90%draindown	Predicted source term at toe of TSF at 95%draindown
pH	pH	s.u.	6 - 9 <sup>†</sup>	8.21	8.21	8.21	8.21	8.21
pe	pe	s.u.	-	4.56	4.56	4.56	4.56	4.56
Alk	Alkalinity as CaCO <sub>3</sub>	mg/L	-	91.4	91.4	91.4	91.4	91.4
HCO <sub>3</sub>	Bicarbonate	mg/L	-	54.6	54.6	54.6	54.6	54.6
Ag	Silver	mg/L	0.05*	0.02	0.02	0.02	0.02	0.02
Al	Aluminium	mg/L	5 <sup>‡</sup>	0.0007	0.0007	0.0007	0.0007	0.0007
As	Arsenic	mg/L	0.1*	0.008	0.008	0.008	0.008	0.008
B	Boron	mg/L	0.75 <sup>†</sup>	0.1	0.1	0.1	0.1	0.1
Ba	Barium	mg/L	1*	2.16E-09	2.18E-09	3.14E-09	6.80E-09	1.32E-08
Ca	Calcium	mg/L	-	38.9	38.9	38.9	38.9	38.9
Cd	Cadmium	mg/L	0.01*	0.005	0.005	0.005	0.005	0.005
Co	Cobalt	mg/L	0.05 <sup>‡</sup>	0.02	0.02	0.02	0.02	0.02
Cr	Chromium	mg/L	0.05*	0.00004	0.00004	0.00004	0.00004	0.00004
Cu	Copper	mg/L	1 <sup>†</sup>	0.005	0.005	0.005	0.005	0.005
F	Fluoride	mg/L	1.6*	1.96	1.96	1.96	1.96	1.96
Fe	Iron	mg/L	1 <sup>†</sup>	0.00004	0.00004	0.00004	0.00004	0.00004
Hg	Mercury	mg/L	0.002	0.001	0.001	0.001	0.001	0.001
K	Potassium	mg/L	-	1.69	1.70	1.71	1.74	1.79
Mg	Magnesium	mg/L	-	18.8	18.8	18.8	18.8	18.8
Mn	Manganese	mg/L	0.2 <sup>†</sup>	0.05	0.05	0.05	0.05	0.05
Mo	Molybdenum	mg/L	1 <sup>‡</sup>	1.10	1.10	1.10	1.10	1.10
Na	Sodium	mg/L	-	46.7	46.7	46.7	46.7	46.8
Ni	Nickel	mg/L	0.2 <sup>‡</sup>	0.05	0.05	0.05	0.05	0.05
Pb	Lead	mg/L	0.05*	0.016	0.016	0.016	0.016	0.016
Sb	Antimony	mg/L	-	2.45E-07	7.35E-07	2.11E-06	6.40E-06	1.36E-05
Se	Selenium	mg/L	0.05*	0.005	0.005	0.005	0.005	0.005
Tl	Thallium	mg/L	-	9.80E-08	2.94E-07	8.46E-07	2.56E-06	5.44E-06
U	Uranium	mg/L	0.03*	2.27E-06	6.82E-06	1.96E-05	5.94E-05	1.26E-04
V	Vanadium	mg/L	-	1.06E-06	3.18E-06	9.15E-06	2.77E-05	5.90E-05
Zn	Zinc	mg/L	10 <sup>†</sup>	0.05	0.05	0.05	0.05	0.05
SO <sub>4</sub>	Sulfate	mg/L	600 <sup>†</sup>	176	176	176	176	176
Cl	Chloride	mg/L	250 <sup>†</sup>	27.5	27.5	27.5	27.5	27.5
N	Nitrogen as N	mg/L	10	1.36	1.36	1.36	1.36	1.37
TDS <sup>α</sup>	Total Dissolved Solids	mg/L	1000 <sup>†</sup>	369	369	369	369	370

Indicates exceedance of NMWQCC standard

- \* Human health groundwater standard
- † Domestic water supply standard
- ‡ Irrigation standard
- α TDS has been calculated as the sum of total ions from the PHREEQC model output and cannot be considered a true representation of TDS from a chemical analysis

**Table 8-12: Predicted Groundwater Chemistry under TSF**

			NMWQCC standard	Baseline groundwater under TSF (wells GWQ94-16, NP-2, NP-4 and NP5)	Predicted groundwater chemistry at 25% drawdown	Predicted groundwater chemistry at 50% drawdown	Predicted groundwater chemistry at 75% drawdown	Predicted groundwater chemistry at 90% drawdown	Predicted groundwater chemistry at 95% drawdown
pH	pH	s.u.	6 - 9 <sup>†</sup>	7.76	8.05	8.05	8.05	8.05	8.05
pe	pe	s.u.	-	-	4.72	4.72	4.72	4.72	4.72
Alk	Alkalinity as CaCO <sub>3</sub>	mg/L	-	178	65.6	65.6	65.6	65.6	65.6
HCO <sub>3</sub>	Bicarbonate	mg/L	-	178	39.4	39.4	39.4	39.4	39.4
Ag	Silver	mg/L	0.05*	0.005	0.005	0.005	0.005	0.005	0.005
Al	Aluminium	mg/L	5 <sup>‡</sup>	0.02	0.0005	0.0005	0.0005	0.0005	0.0005
As	Arsenic	mg/L	0.1*	0.002	0.002	0.002	0.002	0.002	0.002
B	Boron	mg/L	0.75 <sup>†</sup>	0.044	0.044	0.044	0.044	0.044	0.044
Ba	Barium	mg/L	1*	0.036	1.79E-09	1.19E-09	5.96E-10	2.35E-10	6.63E-11
Ca	Calcium	mg/L	-	137	91.7	91.7	91.7	91.7	91.7
Cd	Cadmium	mg/L	0.01*	0.002	0.002	0.002	0.002	0.002	0.002
Co	Cobalt	mg/L	0.05 <sup>‡</sup>	0.006	0.006	0.006	0.006	0.006	0.006
Cr	Chromium	mg/L	0.05*	0.006	0.00005	0.00005	0.00005	0.00005	0.00005
Cu	Copper	mg/L	1 <sup>†</sup>	0.006	0.005	0.005	0.005	0.005	0.005
F	Fluoride	mg/L	1.6*	0.57	0.57	0.57	0.57	0.57	0.57
Fe	Iron	mg/L	1 <sup>†</sup>	0.03	0.00005	0.00005	0.00005	0.00005	0.00005
Hg	Mercury	mg/L	0.002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
K	Potassium	mg/L	-	2.70	2.73	2.72	2.71	2.71	2.71
Mg	Magnesium	mg/L	-	35.2	35.2	35.2	35.2	35.2	35.2
Mn	Manganese	mg/L	0.2 <sup>†</sup>	0.02	0.02	0.02	0.02	0.02	0.02
Mo	Molybdenum	mg/L	1 <sup>‡</sup>	0.008	0.01	0.01	0.01	0.01	0.01
Na	Sodium	mg/L	-	65.6	55.8	55.8	55.8	55.8	55.8
Ni	Nickel	mg/L	0.2 <sup>‡</sup>	0.01	0.01	0.01	0.01	0.01	0.01
Pb	Lead	mg/L	0.05*	0.005	0.004	0.004	0.004	0.004	0.004
Sb	Antimony	mg/L	-	0.001	0.001	0.001	0.001	0.001	0.001
Se	Selenium	mg/L	0.05*	0.01	0.01	0.01	0.01	0.01	0.01
Tl	Thallium	mg/L	-	0.001	0.001	0.001	0.001	0.001	0.001
U	Uranium	mg/L	0.03*	0.002	0.001	0.001	0.001	0.001	0.001
V	Vanadium	mg/L	-	0.05	0.05	0.05	0.05	0.05	0.05
Zn	Zinc	mg/L	10 <sup>†</sup>	0.43	0.43	0.43	0.43	0.43	0.43
SO <sub>4</sub>	Sulfate	mg/L	600 <sup>†</sup>	269	269	269	269	269	269
Cl	Chloride	mg/L	250 <sup>†</sup>	120	120	120	120	120	120
N	Nitrogen as N	mg/L	10	4.37	4.35	4.35	4.35	4.35	4.35
TDS <sup>‡</sup>	Total Dissolved Solids	mg/L	1000 <sup>†</sup>	825 (measured)	620	620	620	620	620

- Indicates exceedance of NMWQCC standard
- \* Human health groundwater standard
- † Domestic water supply standard
- ‡ Irrigation standard
- ‡ TDS has been calculated as the sum of total ions from the PHREEQC model output and cannot be considered a true representation of TDS from a chemical analysis

**Table 8-13: TSF Sensitivity Analysis (varying groundwater mixing zone @ 95% draindown)**

			NMWQCC standard	Baseline groundwater under TSF (wells GWQ94-16, NP-2, NP-4 and NP5)	Predicted groundwater chemistry using 50ft groundwater mixing zone	Predicted groundwater chemistry using 75ft groundwater mixing zone	Predicted groundwater chemistry using 100ft groundwater mixing zone
pH	pH	s.u.	6 - 9 <sup>†</sup>	7.76	8.05	8.05	8.05
pe	pe	s.u.	-	-	4.72	4.72	4.72
Alk	Alkalinity as CaCO <sub>3</sub>	mg/L	-	178.00	65.6	65.6	65.6
HCO <sub>3</sub>	Bicarbonate	mg/L	-	178	39.4	39.4	39.4
Ag	Silver	mg/L	0.05*	0.005	0.005	0.005	0.005
Al	Aluminium	mg/L	5 <sup>‡</sup>	0.02	0.0005	0.0005	0.0005
As	Arsenic	mg/L	0.1*	0.002	0.002	0.002	0.002
B	Boron	mg/L	0.75 <sup>‡</sup>	0.044	0.044	0.044	0.044
Ba	Barium	mg/L	1*	0.036	1.33E-10	9.00E-11	6.63E-11
Ca	Calcium	mg/L	-	137	91.7	91.7	91.7
Cd	Cadmium	mg/L	0.01*	0.002	0.002	0.002	0.002
Co	Cobalt	mg/L	0.05 <sup>‡</sup>	0.006	0.006	0.006	0.006
Cr	Chromium	mg/L	0.05*	0.006	0.00005	0.00005	0.00005
Cu	Copper	mg/L	1 <sup>†</sup>	0.006	0.005	0.005	0.005
F	Fluoride	mg/L	1.6*	0.57	0.57	0.57	0.57
Fe	Iron	mg/L	1 <sup>†</sup>	0.03	0.00005	0.00005	0.00005
Hg	Mercury	mg/L	0.002	0.0002	0.0002	0.0002	0.0002
K	Potassium	mg/L	-	2.70	2.71	2.71	2.71
Mg	Magnesium	mg/L	-	35.2	35.2	35.2	35.2
Mn	Manganese	mg/L	0.2 <sup>†</sup>	0.02	0.02	0.02	0.02
Mo	Molybdenum	mg/L	1 <sup>‡</sup>	0.008	0.01	0.01	0.01
Na	Sodium	mg/L	-	65.6	55.8	55.8	55.8
Ni	Nickel	mg/L	0.2 <sup>‡</sup>	0.01	0.01	0.01	0.01
Pb	Lead	mg/L	0.05*	0.005	0.004	0.004	0.004
Sb	Antimony	mg/L	-	0.001	0.001	0.001	0.001
Se	Selenium	mg/L	0.05*	0.01	0.01	0.001	0.01
Tl	Thallium	mg/L	-	0.001	0.001	0.026	0.001
U	Uranium	mg/L	0.03*	0.002	0.001	0.001	0.001
V	Vanadium	mg/L	-	0.05	0.05	0.05	0.05
Zn	Zinc	mg/L	10 <sup>†</sup>	0.43	0.43	0.43	0.43
SO <sub>4</sub>	Sulfate	mg/L	600 <sup>†</sup>	269	269	269	269
Cl	Chloride	mg/L	250 <sup>†</sup>	120	120	120	120
N	Nitrogen as N	mg/L	10	4.37	4.35	4.35	4.35
TDS <sup>α</sup>	Total Dissolved Solids	mg/L	1000 <sup>†</sup>	825	620	620	620

Indicates exceedance of NMWQCC standard

\* Human health groundwater standard

† Domestic water supply standard

‡ Irrigation standard

α TDS has been calculated as the sum of total ions from the PHREEQC model output and cannot be considered a true representation of TDS from a chemical analysis

## 9 Summary of Predicted Geochemical Behavior

### 9.1 Acid Generation

Testwork results indicate the acid generating potential of the Copper Flat materials 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% in the transitional waste material. Transitional waste is defined as partly oxidized material that still contains some sulfide mineral content. The ABA and NAG testwork results indicate that the transitional waste and transitional ore material types are likely to be potentially acid forming based on generally higher sulfide mineral contents and presence of secondary oxide minerals that have formed as a result of supergene weathering. However, the majority of waste rock (~96%) produced by the project will consist of sulfide (i.e., non-oxidized) Quartz Monzonite/Breccia waste, which typically exhibited either non-acid forming characteristics or a low potential for acid generation based on NAG and ABA testwork results.

Sulfide minerals at Copper Flat were found to be frequently encapsulated in a quartz matrix or occasionally in potassium feldspar. Both of these silicate minerals have slow weathering characteristics and will only weather on geological time scales (i.e., thousands of years or more). Consequently a portion of the sulfide in the materials is unlikely to be available for reaction and thus ABA methodologies with quantitative analysis will over-estimate reactive acidity in comparison to test methods such as NAG or HCT that provide more empirical estimates of long-term field reactivity. These methods require physical exposure of the sulfides to chemically react with oxygen, water or hydrogen peroxide in the case of NAG tests. Furthermore, the sulfide minerals in the Copper Flat deposit are crystalline and often coarse grained (visible to the naked eye) so would have slow weathering reaction kinetics. It is likely that the sulfide waste and ore materials will offer some limited silicate buffering (neutralizing) capacity; although unlikely to be high magnitude, it may buffer pH.

The transitional waste and ore materials show the greatest potential for acid generation from the static and kinetic test results. This is related primarily to the dissolution of secondary oxide minerals within the material that formed as a result of supergene enrichment. However, acid generation from this material may also result from the continued oxidation of sulfide minerals within the transitional material under field conditions. The reactivity of the transitional material varies as demonstrated by the HCT program, which most likely relates to variation in the degree of sulfide content and encapsulation.

Although static testwork results indicate the transitional material is potentially acid forming, this material represents a small percentage of the existing waste material and will comprise only a small proportion (<4%) of material encountered during mining. Furthermore, the results of the HCT program demonstrated that the only cell to show truly acidic conditions consisted of transitional material. The remaining cells were non-acid generating after more than 95 weeks of testing. It is important to state that some of the HCTs for this project have been run appreciably longer than the typical regulatory requirement of 20 to 40 weeks in order to confirm long-term geochemical behavior of the material.

### 9.2 Metal Leaching

The Copper Flat waste rock and ore materials were found to be enriched in copper, sulfur and molybdenum, which relates to the primary mineralization (predominantly chalcopyrite -  $\text{CuFeS}_2$  with

some molybdenite –  $\text{MoS}_2$ ). Silver, arsenic, cadmium, lead, selenium, thallium, uranium, tungsten and zinc were also found to be elevated 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 leach 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 rates were also assessed from the results of the ongoing HCT program. 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. 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 supergene oxidation of the material, which has been enhanced by weathering under site conditions. However, for the Copper Flat deposit, the supergene oxide zone is thin and has been mostly removed by geological processes (i.e., erosion) or previous operations. Therefore, this material type will not comprise a significant percentage of the material encountered during mining.

## 10 Conclusions

### 10.1 Waste Rock

Acid generation is not predicted for most unweathered waste rock materials during operations; however, grab samples collected from the surface of the existing waste rock dumps and pit walls indicate the potential for acid generation from material mined by previous mining operations and exposed to natural weathering conditions. During proposed operations, specific controls will be needed to collect stormwater runoff from the WRDF. In addition, stormwater diversions will be required to prevent runoff.

Results of geochemical predictive modeling indicate that WRDF source term solutions are likely to be moderately alkaline (~pH 8.2) with metal(loid) concentrations that are below New Mexico Water Quality Control Commission (NMWQCC) standards for groundwater. Covering the waste rock disposal facility (WRDF) with a revegetated 36-inch store-and-release soil cover (or approved equivalent) at the end of mine life will reduce infiltration of water and flux of oxygen into the facility, which will limit oxidation of sulfide minerals.

Migration of seepage away from the WRDF is expected to be very small (or nil) as a result of the low permeability andesite underlying the facility. However should any seepage make its way to the underlying water table, the impact to groundwater chemistry is expected to be minimal. With the exception of fluoride, all parameters are predicted to be below NMWQCC in groundwater underlying the facility. However, the fluoride concentrations are related to the elevated concentrations of this parameter in the background groundwater rather than as a result of impact from WRDF seepage. Furthermore, if any drainage water migrates away from the WRDF it is likely that there will be some adsorption and attenuation of metal(loids) in the underlying andesite. Although this is beyond the

scope of the current modeling exercise, it is likely that these processes will reduce elemental concentrations of fluoride prior to any WRDF seepage reaching the underlying groundwater. As such, the potential impact to groundwater is likely to be minimal, particularly given the low permeability of the andesite material.

## 10.2 Tailings

Tailings samples collected as part of the characterization program generally show low potential for ARDML generation. Covering of the tailings storage facility (TSF) with a revegetated 36-inch store-and-release soil cover (or approved equivalent) at the end of mine life will minimize ingress of oxygen and water into the facility, thus preventing oxidation of residual sulfide minerals within the tailings. Furthermore, the tailings facility will be lined with a synthetic liner, which will preclude the migration of seepage away from the tailings impoundment.

During the initial years post-closure, solution chemistry at the toe of the TSF is likely to be dominated by the draindown of entrained process waters. During this period, solutions are predicted to be moderately alkaline (pH 8.2) due to contained lime within the process solutions and sulfate concentrations below 200 mg/L. Once these entrained process waters have drained down (i.e., removed from the system), any meteoric water infiltrating the facility will interact with the non-saturated tailings. It is estimated that approximately 2% of annual precipitation may infiltrate the cover system and interact with the tailings. However, the volumes of seepage from the TSF will be so low (<0.25 gallons/acre/day) that impacts to groundwater are likely to be negligible and the modeled results show that the predicted groundwater chemistry is likely to be similar to existing groundwater chemistry. Furthermore, the use of the historic tailings as a bedding material for the new, lined tailings facility will effectively isolate this material from reaction. As such, groundwater chemistry under the TSF is likely to improve over time, as the sulfate source from the historic tailings will effectively be removed.

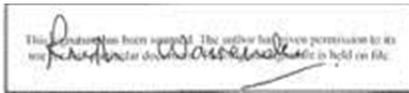
## 10.3 Pit Lake Geochemistry

Additional numerical predictions have also been carried out to assess potential future water quality in the pit lake that will form in the final mined pit. These numerical predictions have been undertaken to evaluate any potential environmental effects of future pit water quality and are presented in a separate report.

## 11 Ongoing Work

Humidity cell testing is ongoing for three waste rock samples and eight samples of tailings material. The effluent chemistry from these cells has not yet stabilized indicating that geochemical reactions are still occurring. The cells are being continued to confirm that acidic conditions will not develop. Two of the continued waste rock cells are currently at week 29 and one is at 96 weeks; the tailings cells are at week 23. An addendum to this report will be issued once the ongoing HCTs have been terminated. This will include the additional HCT data for the continued cells as well as the results from the termination testing. However, no substantive changes to the conclusions presented herein are anticipated.

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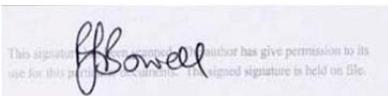
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