Mount Todd Gold Mine

BATMAN PIT PREDICTIVE GEOCHEMICAL MODELLING REPORT

PREPARED FOR:

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CONTENTS

TABLES

EXECUTIVE SUMMARY

Vista Gold Corp., through its subsidiary Vista Gold Australia Pty Ltd (Vista Gold) is focused on the redevelopment of the Mount Todd Gold Mine approximately 56 kilometres (km) north of Katherine in the Northern Territory, Australia. The mine plan includes enlarging and deepening Batman Pit. A terminal-sink pit lake is predicted to form in Batman Pit, without groundwater outflow or discharge to surface water. Approximately 1,200 years after mining ceases, the pit lake is predicted to reach hydrologic equilibrium at an elevation of approximately -15 metres Australian Height Datum (m AHD), which is approximately 179 m below the pit rim. Direct precipitation on the lake surface and wall rock runoff are the primary predicted inflows while evaporation from the lake surface is the only predicted outflow.

Practical Geochemistry LLC completed geochemical modelling to assess future water quality for the Batman Pit lake. A comprehensive review of the available project information was used to develop the pit lake conceptual model, and model inputs and approach. Results from the mine rock geochemical characterization program were used to develop release rates and associated source terms for wall rock associated with each geochemical zone including non-acid forming (NAF), NAF with low excess acid neutralisation capacity (NAF(LC)), and potentially acid forming (PAF) wall rock. PAF wall rock was further discretised based on total sulphur content and Net Acid Generation (NAG) pH, which allowed quantification of sulphate and other constituents that showed a strong correlation with hydrogen ion activity (i.e., pH).

Wall rock surface areas by geochemical zone and pit lake stage elevation were calculated from the ultimate pit shell, which included low NAF wall rock abundance at depth that increased and became the dominate geochemical zone as the predicted pit lake approached hydrologic equilibrium. A total reactive wall rock thickness of 1-m was used to capture the extent of the blast damaged rock zone; however, due to the high competency of the metamorphosed Batman Pit wall rock, 1-m may be deeper than actual field conditions. To simulate wall rock loading to the pit lake, laboratory release rates from humidity cell tests (HCTs) were scaled to account for differences in grain size and flushing. A grain size scaling factor of 0.05 was used to represent wall rock specific surface area (0.07 m^2 per kilogram, m^2/kg) compared to crushed mine rock used in HCTs. This is equivalent to approximately 5% of the rock within the blast damaged rock zone being comprised of particles < 6.4 millimetres. A flushing scaling factor of 0.30, based on surface area of the pit walls and the 1-m deep blast damaged rock zone, was also applied based on flushing of HCTs being approximately 3.4 times higher than anticipated for Batman Pit wall rock.

The first flush of soluble constituents and long-term release rates for wall rock runoff and submergence by geochemical zone, surface area, and elevation were represented in the model. Mixtures were evapoconcentrated and allowed to equilibrate with specified minerals and gases. Modelling was conducted using timesteps that captured the evolving lake conditions, starting at the cessation of mining up to 1,200 years into the future. The sensitivity of the model predictions to reactive wall rock loading were assessed by varying the flushing factor from 0.15 to 0.60, equivalent to a blast damaged rock zone range from 0.5-m to 2-m, and by reducing the grain size scaling factor by 50% and 75% (specific surface area of 0.036 and 0.018 m^2/kg, respectively).

The high relative depth and limited wind action anticipated on the Batman Pit lake surface suggests the lake could become meromictic with permanent stratification, where oxic surface waters overlie anoxic deep waters. The resulting decrease in dissolved oxygen in the unmixed portion of the lake allows sulphide minerals (e.g., CdS, ZnS) to precipitate and settle out, thereby removing constituents from the water column. A more conservative "well-mixed" lake scenario was selected for the base case predictive model, which assumed the lake was holomictic and subject to periodic mixing, whereby atmospheric gases remained in contact with the water column. A sensitivity scenario without dissolved oxygen and a partial pressure of CO_2 consistent with groundwater ($pCO_2 = 10^{-2.0}$ bar) to represent the isolated bottom waters was conducted to provide insight into the potential influence of meromictic conditions on predicted water quality.

Predicted water quality focused on the following constituents, which were selected based on 1) presence within the existing pit lake when it was used for AMD storage and/or following alkaline reagent treatment, 2) HCT results, and 3) ANZECC and ARMCANZ (2000) livestock watering guidelines:

- pH
- Sulphate
- Aluminium
- Arsenic
- Cadmium
- Cobalt
- Copper
- Lead
- Zinc

For the base case predictive model, an acidic pit lake (pH 3.1 to 3.7) was predicted to develop within 10 years. Sulphate, aluminium, arsenic, cadmium, cobalt, and zinc concentrations were predicted to remain below the guideline values through 1200 years. Copper and lead concentrations were likely overestimated because of the conservative scaling assumptions, and lack of adsorption reactions included in the base case model. Adsorption onto precipitated ferrihydrite was incorporated into the model as a sensitivity scenario but had minimal influence on base-case predicted water quality, which was attributed to low extrapolated iron concentrations for the high sulphur PAF wall rock runoff. Concentrations, except arsenic, increased from year 10 to 100 before decreasing consistent with the lower proportion of exposed PAF wall rock, and increased proportion of rainfall that reported as direct precipitation on the lake surface rather than runoff. A minor increase in constituent concentrations was predicted past 1200 years due to evapoconcentration, which was limited by inflow from direct precipitation onto the lake surface, and the dominance of NAF and NAF(LC) wall rock.

The model predictions were sensitive to changes in the scaling factors since geochemical mass loading from wall rock was the primary control on predicted pit lake chemistry. Modification of the scaling factors to account for the high hardness/competency of the metamorphosed Batman Pit wall rock resulted in predicted pit lake chemistry that met the guideline values except for lead, which is likely to

be at or below the 0.3 mg/L concentrations observed in AMD at Mount Todd Mine. Resumption of mining in Batman Pit will provide additional field scale information regarding wall rock reactivity to support future water quality assessments and allow Vista Gold to optimize the pit lake closure strategy.

It was necessary to incorporate a level of conservativity to account for the inherent uncertainty in natural systems. Conservative aspects of the modelling included:

- The distribution of higher sulphur content PAF rock was assumed to be constant across the entire pit surface; however, the majority of the wall rock with 1% total sulphur (approximately 70%) was below the lake level at hydrologic equilibrium (-15 m AHD).
- The method used to estimate flushing of wall rock is likely to result in higher geochemical loading to the pit lake than will actually occur.
- Although adsorption to the limited amount of ferrihydrite that was available to precipitate did not significantly influence the outcome of the base case model predictions, additional removal would be expected via adsorption by iron and aluminum phases and co-precipitation.

1. INTRODUCTION

Vista Gold Corp. retained Practical Geochemistry LLC to conduct predictive water quality modelling associated with the post-closure Batman Pit Lake. Vista Gold Corp., through its subsidiary Vista Gold Australia Pty Ltd (Vista Gold) is focused on the redevelopment of the Mount Todd Gold Mine in the Northern Territory (NT), Australia.

1.1. Overview

The Mount Todd Gold Mine is approximately 56 kilometres (km) north of Katherine, NT, and 290 km south of Darwin, NT. The mine site is accessed via Jatbula Road, which is a restricted access road off the Stuart Highway. Historic mining within the project area dates back more than 100 years. Mining infrastructure from previous operations include the existing Batman Pit (previously also called RP3), a tailings storage facility, waste rock dump, water retention ponds, and remains of process facilities (Figure 1). The tailings storage facility, waste rock dump, and low-grade ore stockpile are sources of acidic and metalliferous drainage (AMD).

In 2000, the mine site entered receivership and the NT Government initiated a care and maintenance program. In 2007, Vista Gold assumed the care and maintenance activities on behalf of the NT Government with the goal of restarting mining operations. From 2005 to 2014, AMD from across the mine site was pumped into Batman Pit. The existing Batman Pit is approximately 120 metres (m) deep, has a surface area of approximately 32 hectares (ha), and a storage capacity of approximately 12.2 gigalitres (GL). Water levels reached a maximum depth of 104 m below ground surface when Vista Gold initiated monitoring. In 2012, Vista Gold conducted in-situ treatment of the approximately 11 GL of AMD stored in Batman Pit using micronized limestone followed by quicklime. Prior to treatment the pit lake profile was characterized by uniform acidic pH (approximately pH 3.2) and oxic conditions (dissolved oxygen from 6 to 8 mg/L milligrams per litre [mg/L]). Treatment resulted in sustained pH above 7 and reduction in metal concentrations, which allowed Vista Gold to increase the controlled discharge volume. As of April 14, 2020, 3.1 GL remain in Batman Pit (Vista Gold, 2020).

The mine plan includes enlarging and deepening Batman Pit to a final bottom elevation of -400 m Australian Height Datum (AHD), a pit rim at 161 to 167 m AHD, a maximum surface area of 137 ha, and a perimeter of approximately 4,500 m (Figure 2). The ultimate Batman Pit was predicted to be a terminal-sink pit lake without groundwater or overflow leaving the pit (Tetra Tech, 2019; Tetra Tech, 2020).

1.2. Approach and Objectives

This post-closure pit lake model was constructed to predict water quality during filling and under long-term equilibrium conditions. The general study approach was to construct the pit lake model using the current understanding of the ultimate pit, mine rock geochemistry, and pit filling water balance.

1.3. Report Organization

This report includes the following additional sections:

- *Section 2 – Project Background:* Presents background information relevant to the current work including climate, geology, and the existing Batman Pit lake conditions.

- *Section 3 – Geochemical Characterization Program:* Summarizes the analysis and interpretation conducted to understand the potential for wall rock to generate acid and leach constituents.

- *Section 4 – Water Balance Model:* Provides a brief overview of the Batman Pit filling water balance model produced by Tetra Tech.

- *Section 5 – Physical Limnology:* Summarizes the key factors that will influence stratification and turnover in the ultimate Batman Pit lake.

- *Section 6 – Geochemical Mass Loading Sources:* Details the pit lake conceptual model and the approach used to develop release rates to represent each geochemical zone and scale laboratory rates to field conditions.

- *Section 7 – Geochemical Model Approach:* Describes the modelling approach, assumptions, and model inputs.

- *Section 8 – Results:* Presents the water quality predictions relative to applicable guideline values, and sensitivities using factors/inputs with greatest influence on the predictions.

- *Section 9 – Conclusions:* Summarizes the major findings associated with the water quality model.

- *References:* Provides a complete list of documents cited throughout this report.

2. PROJECT BACKGROUND

Background relevant to the Batman Pit water quality modelling is presented in the following subsections.

2.1. Climate

The following meteorological information is summarized from Vista Gold (2019) and Tetra Tech (2019).

2.1.1. Temperature

The mine site is within a sub-tropical climate with a distinct Wet season (October through March) and Dry season (April through September). Dry season daily maximum temperatures typically range from 24 degrees Celsius (°C) to 36°C and occasionally reach 39°C. Evenings can be cool during the Dry season with minimum temperatures falling to 7°C. During the Wet season, maximum daily temperatures can range from 27°C to 42°C, with high levels of humidity with intensity reaching 80 to 100 percent (%). Dry season humidity ranges from 50% to 70%.

2.1.2. Precipitation

Precipitation varies seasonally, with low precipitation during the Dry season and more frequent and larger precipitation events during the Wet season (Figure 3). Average annual precipitation at the mine site is 1,276 millimetres (mm) during the period of record (1993 through 2006 and 2008 through 2017), most of which falls during the Wet Season. Average annual precipitation was slightly lower (1,123 mm) at the Katherine Aviation Museum during the same period of record.

2.1.3. Evaporation

Three pan evaporation stations were installed at the mine site in October 2014. Average annual pan evaporation from these stations in 2015 and 2016 averaged 2,565 mm (2,485 to 2,659 mm range), which is more than double the average annual precipitation. The average annual pan evaporation of 2,582 mm measured at the mine site from 1993 through 2006 compares well with the more recent data. Pan evaporation was also measured from 2007 until 2014; however, this data was not considered reliable due to the location of the pan evaporation station and surrounding infrastructure.

2.1.4. Wind

The Dry season is dominated by south-easterly winds while the Wet season is dominated by north-westerlies. Low pressure systems that form offshore over warm tropical waters can lead to extreme weather events during the Wet season. Tropical cyclone systems occasionally move onshore with wind speeds reaching 270 km per hour within the storm centre.

2.2. Geology

Geological information relevant to this water quality model presented herein is largely summarized from Gustavson (2006), subsequent projects reports, and the updated 2017 geologic model presented in Tetra Tech (2019).

2.2.1. Geological and Structural Setting

The mine is situated within the south-eastern portion of the early Proterozoic Pine Creek Geosyncline. Meta-sedimentary rocks, granitoids, mafic intrusives, felsic and intermediate volcanic rocks occur within this geological province.

Within the Mount Todd region, the oldest outcropping rocks are assigned to the Burrell Creek Formation. These rocks consist primarily of interbedded greywackes, siltstones, and shales of turbidite affinity, which are interspersed with minor volcanics. The sedimentary sequence includes slump structures, flute casts and graded beds, as well as occasional crossbeds. The Burrell Creek Formation is overlain by interbedded greywackes, mudstones, tuffs, minor conglomerates, mafic to intermediate volcanics and banded ironstone of the Tollis Formation. The Burrell Creek Formation and Tollis Formation comprise the Finniss River Group.

The Finniss River Group strata have been folded about northerly trending Fl fold axes. The folds are closed to open style and have moderately westerly dipping axial planes with some sections being overturned. A later north-south compression event resulted in east-west trending open style upright D2 folds. The Finniss River Group has been regionally metamorphosed to lower green schist facies. Late and post-orogenic granitoid intrusion of the Cullen Batholith occurred from 1,789 to 1,730 Ma and brought about local contact metamorphism to hornblende hornfels facies.

Unconformably overlying the Burrell Creek Formation are sandstones, shales and tuffaceous sediments of the Phillips Creek sandstone, with acid and minor basic volcanics of the Plum Tree Creek Volcanics. Both these units form part of the Edith River Group and occur to the south of the mine. Relatively flat lying and undeformed sediments of the Lower Proterozoic Katherine River Group unconformably overlie the older rock units. The basal Kombolgie Formation forms a major escarpment, which dominates the topography to the east of the mine.

2.2.1. Batman Deposit Geology and Mineralization

The Batman deposit is located within the Burrell Creek Formation. The deposit geology consists of a sequence of hornfelsed interbedded greywackes, and shales with minor thin beds of felsic tuff. The tabular Batman deposit strikes north-northeast and dips steeply to the east. Dolerite and lamprophyre dykes also intersect the pit. Yinberrie Leucogranite and underlying Tennysons Leucogranite are interpreted as basement rocks below Batman Pit. The core zone is approximately 200 to 250 m wide and 1.5 km long, with several hanging wall structures providing additional width to the orebody (Figure 4). The granite contact is a mineral exclusionary zone that constrains the lower footwall of the core complex. Mineralization is open at depth as well as along strike, although the intensity of mineralization weakens to the north and south along strike. Gold mineralization occurs in sheeted veins within the greywackes and shales. A sectional view of the deposit and drill hole data is provided in Figure 5.

Nineteen lithological units were originally identified within the deposit, which are shown from south to north (oldest to youngest) in Table 1. The lithological units, each of which have been hornfelsed, have since been grouped into three broad units as follows:

- Greywacke
- Shale

- Interbedded greywacke/shale

Thin beds of felsic tuff are accounted for and combined within the three main units.

Two main styles of mineralization have been identified in the Batman deposit including north-south trending vein mineralization and bedding parallel mineralization. The auriferous quartz-sulphide vein system is the mineralization style of greatest known economic significance at the Mount Todd Mine. The quartz-sulphide veining occurs within a north-northeast trending corridor and are hosted by the Burrell Creek Formation.

The mineralization within the Batman deposit is directly related to the intensity of the north-south trending quartz sulphide veining. The lithological units impact the orientation and intensity of mineralization. The north-south trending mineralization occurs in all rock units and is most dominant in the shales and greywackes designated SHGW23. The north-south trending mineralization can be divided into three major zones based on veining and jointing intensity, including:

- *Core Complex* – Mineralization is consistent and most, to all, joints have been filled with quartz and sulphide minerals. Vein frequency is high in this zone. This zone occurs in all rock types.

- *Hanging Wall Zone* – Mineralization is patchier than the core complex due to quartz veining not being as abundant as the core complex. The lithology controls the amount of mineralization within the hanging wall zone. The hanging wall zone doesn't occur north of T21. South of reference line T21 to the greywacke shale unit designated GWSH23, the mineralization has a bedding trend. A large quartz/pyrrhotite vein defines the boundary of the hanging wall and core complex in places.

- *Footwall Zone* – Like the hanging wall zone, the mineralization is patchier than the core complex and jointing is more prevalent than quartz veining. Footwall Zone mineralization style is controlled by the lithology and occurs in all rock types. Narrow bands of north-south trending mineralization also occur outside the three zones, but these bands are patchy.

Bedding parallel mineralization occurs in rock types SH22 to SH20 to the east of the Core complex. Veining is both bedding parallel and north-south trending. The mineralization appears to have migrated from the south along narrow north-south trending zones and "balloon out" parallel to bedding around the felsic tuffs.

Tin occurs in a north-northwest trending corridor. The tin-bearing mineralization consists of cassiterite, quartz, tourmaline, kaolin, and hematite bearing assemblages, which occur as bedding to parallel breccia zones and pipes. Polymetallic mineralization rich in gold, tungsten, molybdenum, and copper mineralization occurs in quartz-greisen veins within the Yinberrie Leucogranite.

Sulphide minerals associated with the gold mineralization are pyrite and pyrrhotite, with lesser amounts of chalcopyrite, bismuthinite and arsenopyrite. Galena and sphalerite are also present and are related to calcite veining in the bedding planes and the east-west trending faults and joints.

Table 1 Lithologic Units and Codes

Unit Code	Lithology	Description
1	GW25	Greywacke
2	SH24	Shale
3	GW24A	Greywacke
4	SHGW24A	Shale/Greywacke
5	GW24	Greywacke
6	SHGW23	Shale/Greywacke
7	GWSH23	Greywacke/Shale
8	GW23	Greywacke
9	SH22	Shale
10	T21	Felsic Tuff
11	SH21	Shale
12	T20	Felsic Tuff
13	SH2O	Shale
14	GWSH2O	Greywacke/Shale
15	SH19	Shale
16	T18	Felsic Tuff
17	SH18	Shale
18	GW18	Greywacke
Int	INT	Lamprophyre

Source/Notes: Modified from Tetra Tech (2018) Table 7.1

2.3. Existing Pit Lake

In 2012, Vista Gold initiated depth profiling within the existing Batman Pit to support selection and demonstrate effectiveness of the treatment approach. As illustrated by the 2017 Wet and Dry season depth profiles from the centre of the lake for pH, dissolved oxygen, electrical conductivity, and temperature there is sufficient evidence to suggest frequent overturn throughout the year (i.e., a holomictic lake) (Figure 6). Well-mixed oxic conditions exist from surface to near bottom throughout the year as illustrated by dissolved oxygen concentrations from 6 to 8 mg/L. An increase in surface temperature is evident during the Wet season consistent with higher temperatures and precipitation. Similar observations were made during depth profiling prior to alkaline reagent treatment.

Historic pit lake water quality is not a reliable indicator of potential long-term water quality since the pit was used to retain AMD from across the mine site (e.g., tailings, waste rock, low grade ore seepage and runoff). Current pit lake water quality is also not representative of future water quality since the chemistry is the result of alkaline reagent treatment of the retained AMD. However, as described in Tetra Tech (2019), the existing pit provides anecdotal evidence that is potentially relevant to the long-term pit lake development and water quality. Specifically, prior to about 2005, precipitation was the primary inflow to the pit with minor groundwater inflow. In addition, Batman Pit appears poorly connected to groundwater based on consistently lower pit lake surface elevations compared to nearby

groundwater elevations. The alkaline reagent treatment of stored water in Batman Pit has effectively maintained circumneutral pH conditions for multiple years suggesting that wall rock runoff from the existing pit walls is not contributing significant acidity to the lake.

Key constituents that were present above laboratory reporting limits within the existing pit lake when it was used for AMD storage and/or following alkaline reagent treatment provide insight into constituents to examine as part of the water quality modelling. Constituents selected as part of the current assessment include:

- pH
- Sulphate
- Aluminium
- Arsenic
- Cadmium
- Cobalt
- Copper
- Lead
- Zinc

3. GEOCHEMICAL CHARACTERIZATION PROGRAM

The geochemical characterization program presented herein is summarized from Tetra Tech (2013) and supplemented with interpretation presented in Practical Geochemistry LLC (2019). Additional supplemental data that informs the understanding of Batman Pit wall rock geochemistry is also provided.

3.1. Sampling and Analysis

As described in Section 2.2 (Geology), the Batman deposit is located within the Burrell Creek Formation. The Batman deposit geology consists of a sequence of hornfelsed interbedded greywackes and shales with minor thin beds of felsic tuff that are grouped into three broad units as follows:

- Greywacke
- Shale
- Interbedded greywacke/shale

Felsic tuff makes up a small portion of the total mine rock and is accounted for and combined within the units presented above.

Geochemical characterization of geospatially distributed drill hole samples from across the deposit followed a phased approach consistent with different phases on the project (i.e., pre-feasibility, feasibility, environmental assessment) as follows:

- *Phase 1* – Eighteen samples, six samples from each of the three rock units, were subjected to acid-base accounting (ABA) including paste pH, acid neutralisation potential (ANP), and sulphur forms with acid generation potential (AGP) calculated from nitric acid extracted sulphur. A subset of six samples, two samples from each rock unit, were subjected to kinetic testing for 27 to 28 weeks using HCTs.

- *Phase 2* – Phase 1 results were used to guide selection of 69 samples, including 25 greywacke, 20 shale, and 24 interbedded greywacke/shale samples, for ABA. One sample from each rock unit was subjected to kinetic testing for 184 weeks using HCTs. These longer-term kinetic tests were conducted on mine rock samples classified as uncertain based on Neutralisation Potential Ratio (NPR) from 1 up to 2, where NPR is the ratio of acid neutralisation capacity (ANC) to the maximum potential acidity (MPA). Eight mine rock samples underwent mineralogical characterization. Net Acid Generation (NAG) testing was initiated as part of the exploration program and results from drill hole VB11-001 were included in Phase 2.

- *Phase 3* – Over 18,000 additional samples were subjected to total sulphur and NAG test analyses as part of the exploration program and continued environmental assessment.

The major findings associated with the geochemical characterization program are discussed in the following subsections.

3.2. Mineralogy

Eight rock samples were subjected to x-ray diffraction (XRD) with Rietveld refinement including two greywacke, three shale, and three interbedded samples, which included five of the HCT samples (Table 2). Major findings associated with the mineralogical characterization include:

- **Carbonate minerals** – The primary carbonate minerals through the Batman pit are calcite and ankerite/dolomite. Calcite was identified in six samples with total content ranging from 0.3 to 1.5%. Ankerite/dolomite were identified in five samples with total content that ranged from 0.7 to 4.0%. Siderite was identified at 2.7% in an interbedded sample subjected to kinetic testing (HC-3). One sample lacked measurable carbonate mineralization: a greywacke sample subjected to kinetic testing (HC-1B).

- **Sulphide minerals** – Pyrite (FeS_2) and/or pyrrhotite ($Fe_{1-x}S$) were identified in each sample except an interbedded greywacke/shale sample subjected to kinetic testing, HC-3. This sample contained other sulphide minerals including 0.8% sphalerite ((Zn,Fe)S), 2.8% arsenopyrite ($FeAsS$), and 0.8% galena (PbS). Pyrite content ranged from 0.3 to 1.8% and pyrrhotite content ranged from 0.8 to 2.6%. Pyrite and pyrrhotite were both identified in one sample: a deep greywacke sample (sample ID: VB07-010 301-305 G), while pyrite and marcasite (FeS_2) were both identified in one sample: a shale sample subjected to kinetic testing (HC-4). The greywacke sample that lacked measurable carbonate content, HC-1B, contained pyrite and arsenopyrite for a combined total sulphide content of 1%. Quantifiable sulphate mineral content (e.g., gypsum, acidic sulphate salts) was not identified.

- **Silicate minerals** – Quartz was the primary silicate mineral identified in each sample (27.8 to 58.7%). Silicate minerals that can contribute to ANC were also identified. For example, intermediate weathering clinochlore was present in the samples at 7.0 to 16.9% while intermediate weathering biotite was identified in four samples (1.5 to 8.0%). Although much slower than carbonate mineral dissolution, acid neutralization by silicate mineral dissolution can control pH decrease once accessible carbonate minerals are depleted (Weber, 2005). Silicate mineral dissolution appears to be an important AMD control at the Mount Todd Mine by keeping pH between approximately 3.2 to 3.6.

These findings are consistent with the understanding of the mineralization associated with the deposit as described in Section 2.2 (Geology) and ore mineralogy as described in Tetra Tech (2019).

Table 2   **Mineralogical Characterization**

Mineral	VB07-010 301-305 G --	VB07-001 173-177 G (HC-1B)	VB07-011 156-160 S (HC-4)	VB07-022 340-344 S --	VB08-026 332-336 S (HC-2B)	VB07-002 220-224 I (HC-3)	VB07-004 279-283 I --	VB08-032 180-184 I (HC-3B)
Quartz	27.8	54.9	39.8	57.5	58.7	49.5	57.1	48.1
Clinochlore	16.9	7.9	12.3	10.3	7.0	9.3	8.4	7.3
Muscovite	--	11.8	42.7	17.4	20.1	16.4	32.2	18.8
Biotite	8.0	2.1	--	1.5	--	--	--	6.3
K-feldspar	10.3	4.7	--	5.0	5.4	6.2	--	4.0
Plagioclase	26.4	6.4	4.0	16.8	14.8	6.0	--	
Actinolite	6.1	--	--	--	--	--	--	--
Calcite	0.5	--	0.9	0.6	--	1.5	0.3	0.3
Siderite	--	--	--	--	--	2.7	--	--
Dolomite	--	--	--	--	--	--	--	--
Ankerite/Dolomite	--	--	2.4	1.3	0.7	4.0	1.2	--
Pyrite	1.8	0.4	--	--	0.9	--	0.8	0.3
Pyrrhotite	2.0	--	--	2.6	--	--	0.8	--
Marcasite	--	--	1.2	--	--	--	--	--
Sphalerite	--	--	--	--	--	0.8	--	--
Arsenopyrite	--	0.6	--	--	--	2.7	--	--
Galena	--	--	--	--	--	0.8	--	--
Anatase	--	0.9	--	--	0.8	--	--	--

Source/Notes: Modified from Tetra Tech (2013) Table 3.4
-- Not determined

3.3. Acid-Base Accounting

A statistical summary of the ABA results and total sulphur from the exploration database are provided in Table 3. Key findings include:

- Pyritic sulphur content, based on extraction using nitric acid, ranged from <0.01 to 3.61%, with a median value of 0.18%. Median values on a rock type basis were as follows:

  o Greywacke = 0.18% (ranged from <0.01 to 0.52%)

  o Shale = 0.22% (ranged from <0.01 to 1.82%)

  o Interbedded = 0.20% (ranged from <0.01 to 3.61%)

- Total sulphur content ranged from below the 0.01% reporting limit to 3.81%, with a median value of 0.38%. Total sulphur obtained as part of the exploration program correlated reasonably well with total sulphur determined as part of the ABA analysis (R^2 of 0.73).

- Approximately one third of the total sulphur associated with each rock type was insoluble (31 to 39%). Due to the highly metamorphosed nature of the mine rock, insoluble sulphur may include silicate mineral encapsulated sulphide sulphur that resisted nitric acid digestion.

- Approximately 40% of the samples subjected to ABA were categorized as non-acid forming (NAF) based on the NPR criterion of 2 or greater. The median NPR (ANC/MPA) values for each rock types were:

  o Greywacke = 1.6 (range from 0.6 to 14.3)

  o Shale = 1.7 (range from 0.2 to 14.0)

  o Interbedded = 1.3 (range from 0.0 to 6.9)

Table 3 Acid-Base Accounting Results – Statistical Summary

Statistics	Paste pH	Total S %	Exploration Total S %	HCl Extractable S %	HNO$_3$ Extractable S %	Insoluble S %	MPA* kg H$_2$SO$_4$/ Tonne	ANC kg H$_2$SO4/ Tonne	NAPP* kg H$_2$SO$_4$ Tonne	NPR*
					Greywacke (n=31)					
Average	8.8	0.36	0.48	0.01	0.19	0.16	6.0	9.2	-3.3	2.4
Median	9.0	0.36	0.46	0.01	0.18	0.10	5.2	7.8	-2.7	1.6
Minimum	7.5	0.01	0.00	0.01	0.01	0.01	0.1	0.8	-18.9	0.6
Maximum	9.2	1.10	1.36	0.03	0.52	0.76	15.9	27.2	4.7	14.3
					Shale (n=26)					
Average	8.3	0.47	0.67	0.01	0.31	0.15	9.5	8.5	1.0	3.4
Median	8.5	0.36	0.74	0.01	0.22	0.08	6.7	5.7	-2.2	1.7
Minimum	5.8	0.01	0.01	0.01	0.01	0.00	0.1	0.5	-28.4	0.2
Maximum	9.4	1.82	1.16	0.02	1.79	1.04	54.8	31.8	46.1	14.0
					Interbedded (n=30)					
Average	8.6	0.77	0.60	0.01	0.51	0.26	15.5	10.8	4.7	2.0
Median	8.8	0.51	0.48	0.01	0.20	0.14	6.1	6.8	-0.4	1.3
Minimum	6.7	0.01	0.01	0.01	0.01	0.00	0.1	0.7	-65.0	0.0
Maximum	9.4	3.81	1.77	0.02	3.61	1.11	110.6	83.7	106.5	6.9

Source/Notes: Modified from Tetra Tech (2013) Table 3.1, see report for complete data set
*Based on nitric acid (HNO$_3$) extractable sulphur, which is typically used to represent sulphide sulphur
Values below the reporting limit shown as the reporting limit
NAPP – Net Acid Production Potential (ANC-MPA)

3.4. Kinetic Testing

HCT leachate solutions were collected weekly and analysed for pH, acidity, alkalinity, electrical conductivity, and sulphate. Weekly samples were homogenized into 4-week composites to create monthly samples that were analysed for dissolved constituent concentrations. The kinetic testing program is summarized in Table 4.

Two of the nine HCTs produced acidic leachate. A shale sample, HC-2, that was potentially acid forming (PAF) based on the NPR PAF < 1 criterion and contained 0.43 % sulphide sulphur, produced acidic leachate (pH < 6) from initiation of testing until termination at 27 weeks (Figure 7a). A second sample, HC-3B, dropped below pH 6 after 151 weeks of testing. This interbedded sample was identified as having uncertain potential to generate acid based on an NPR of 1.5 (Table 4) while depletion calculations suggest the sample is NAF (Table 5). However, depletion rates suggest that sulphide sulphur content (0.15%) was underreported. Encapsulation of pyrite and pyrrhotite by silicate minerals when

recrystallisation occurred during metamorphism may have limited the effectiveness of the ABA nitric acid extraction step. When ABA or exploration program total sulphur is used to calculate NPR, HC-3B is classified as PAF (NPR < 1). In combination, these results suggest that reclassification of HC-3B as PAF is appropriate.

The remaining HCTs produced near-neutral pH solutions regardless of their NPR designation. The lack of acidity points to 1) sufficient ANC to offset sulphide oxidation, 2) encapsulation of pyrite/pyrrhotite by silicate minerals that limit sulphide oxidation, and/or 3) inaccurately reported sulphide sulphur content. Constituent release was significantly lower when near-neutral pH conditions were maintained as illustrated by sulphate and copper release rates, respectively (Figure 7b and Figure 7c).

Table 4 Kinetic Testing Program Summary

Sample ID	HCT ID	Rock Type	Weeks Operated	Total S	Exploration Total S	Sulphate (HCl Extractable)	Sulphide (HNO$_3$ Extractable)	Insoluble S	ANC	NPR	Designation		
				%	%	%	%	%	kg H$_2$SO$_4$/ Tonne	unit-less	NPR	Total S Criteria	HCT pH
VB07-009 86-90	HC-6	Greywacke	28	0.69	0.72	0.010	0.08	0.60	9.9	4.1	NAF	PAF	NAF
VB07-002 220-224	HC-3	Interbedded	27	0.78	0.61	0.020	0.36	0.40	42.3	3.8	NAF	PAF	NAF
VB07-001 173-177	HC-1B	Greywacke	185	0.31	0.34	0.005	0.19	0.12	7.9	1.3	uncertain	uncertain	NAF
VB08-026 332-336	HC-2B	Shale	185	0.44	0.52	0.010	0.31	0.12	11.4	1.2	uncertain	PAF	NAF
VB08-032 180-184	HC-3B	Interbedded	185	0.52	0.37	0.005	0.15	0.37	6.8	1.5	uncertain	PAF	PAF*
VB07-009 58-62	HC-1	Greywacke	28	0.36	0.38	0.010	0.31	0.04	7.5	0.79	PAF	uncertain	NAF
VB07-006 44-48	HC-2	Shale	27	0.47	0.72	0.010	0.43	0.04	3.6	0.28	PAF	PAF	PAF
VB07-011 156-160	HC-4	Shale	28	0.90	1.2	0.005	0.67	0.23	17.6	0.86	PAF	PAF	NAF
VB07-018 120-124	HC-5	Interbedded	28	0.88	1.2	0.010	0.74	0.13	7.5	0.33	PAF	PAF	NAF

Source/Notes: Modified from Tetra Tech (2013) Table 3.2, additional HCT results included for HC-1B, HC-2B, and HC-3B
*Identifies the sample that generated pH < 6 after issuance of Tetra Tech (2013)
Values below reporting limit shown as reporting limit

Table 5 Carbonate and Sulphide Depletion Calculations

Geochemical Zone	HCT ID	Average Carbonate Molar Ratio	Cumulative ANC Consumption	Approximate Time to Depletion	Cumulative Sulphide Depletion	Approximate Time to Depletion
		unitless	mg/kg as CaCO$_3$	years	mg/kg	years
NAF	HC-3	1.5	332 to 422	67 to 79	73	38
	HC-6	1.3	408 to 485	17 to 19	107	6
NAF(LC)	HC-1B	2.5	1018 to 1088	39 to 41	139	60
	HC-2B	2.3	1333 to 1361	35 to 41	202	82
PAF - Neutral pH	HC-1	4.2	253 to 264	18 to 24	24	112
	HC-4	1.5	335 to 378	35 to 36	79	66
	HC-5	1.4	349 to 407	16 to 17	87	95
PAF - Acidic pH	HC-3B	1.1	840	60	23	252
	HC-2	0.6	235	10	117	17

Notes: Calculated using EPA Method 1627 and stable concentrations
Range in years to ANC depletion based on cation or anion approach (anion approach is not valid for acidic samples)

3.5. Net Acid Generation Testing

Total sulphur and NAG pH data associated with drill hole VB11-001 sample intervals are presented in Figure 8. The data show that drill hole VB11-001 samples with total sulphur < 0.25% are characterized as NAF based on NAG pH as presented (Tetra Tech, 2013). This finding was used, in conjunction with the overall static and kinetic test results, to classify mine rock with total sulphur concentrations < 0.25% as NAF. Furthermore, only two of the 317 drill hole VB11-001 sample intervals with NAG pH < 4.5 are characterized by total sulphur < 0.42%.

3.6. Initial Mine Rock Classification Scheme

Although the geochemical characterization program was set up to assess the hornfelsed greywacke, shale, and interbedded units separately, the Phase 1 and Phase 2 characterization results illustrated that sufficient similarities exist between the units to develop a broad geochemical classification scheme using total sulphur content as follows:

- NAF rock was defined by total sulphur content ≤0.25

- Mine rock with uncertain potential to generate acid was characterized by total sulphur content > 0.25% through 0.40%

- PAF mine rock was defined by total sulphur content > 0.40%

The HCT samples classified as NAF by NPR ≥ 2 and neutral pH solution, are classified as PAF using the project-specific total sulphur criterion for PAF(>0.40%), which illustrates that the total sulphur-based classification is biased towards identifying mine rock as PAF that would likely be classified as uncertain or NAF using other classification schemes (e.g., NPR and NAPP).

Total sulphur from the exploration database was incorporated into the block model to assist with operational mine rock management and closure planning. The distribution of NAF, Uncertain, and PAF classifications for each block that intersect the ultimate pit shell were provided by Mine Development Associates (Figure 9).

3.7. Phase 3 Characterization

Vista Gold continued to include total sulphur and NAG testing with the assay analyses conducted by NA Laboratories. As detailed in Practical Geochemistry LLC (2019), over 18,000 subsequent total sulphur and NAG test sample analyses provide additional evidence that implementation of the 0.25% project-specific NAF criterion minimise the potential for acid generation associated with NAF mine rock (Figure 8). Specifically, over 9,000 samples (49%) contained total sulphur < 0.25% and 99.95% of these samples were classified as NAF based on NAG pH ≥ 4.5 (Table 6). In addition, of the mine rock samples with total sulphur content from 0.25% up to 0.40%, 97% were classified as NAF based on NAG pH ≥ 4.5. These results further demonstrate that the 0.25% total sulphur NAF criterion has a high level of conservativity. Of the samples identified as PAF (> 0.40% total sulphur), 67% were characterized by NAG pH < 4.5, while most of these samples contained > 1% total sulphur.

During initial geochemical characterization, the term "uncertain" was used to define wall rock with total sulphur from 0.25% through 0.40%. The uncertainty originated from minimal excess ANC compared to sulphide sulphur resulting in NPR values < 2 but greater than 1. However, HCT and NAG pH results

suggest that mine rock with total sulphur from 0.25% through 0.40% has low potential to generate acid. Based on the combined characterization program results, mine rock initially classified as having uncertain potential to generate acid has been redefined as NAF with low excess acid neutralisation capacity, NAF(LC). The updated total sulphur geochemical classification scheme is as follows:

- NAF mine rock is defined by total sulphur content ≤0.25
- NAF(LC) mine rock is characterized by total sulphur content > 0.25% through 0.40%
- PAF mine rock is defined by total sulphur content > 0.40%

Table 6 NAG pH based on Total Sulphur Content

Total Sulphur Content	Samples with Sulphur and NAG pH	Samples with NAG pH < 4.5		NAG pH Median
	Count	Count	%	std units
≤0.25%	9115	5	0.05%	9.68
>0.25% - 0.40%	1903	55	2.9%	7.86
>0.40%	6976	4702	67%	3.84
>0.40 to 1%	4250	2139	50%	4.48
≥1%	2727	2564	94%	2.94

4. WATER BALANCE MODEL

The post-closure pit filling water balance for Batman Pit was produced by Tetra Tech and provided in Excel format for the water quality modelling (Figure 10). The water balance was simulated with the LAK2 package (Council, 1999) for over 1,500 years following closure. The general approach taken to produce the water balance is described in Tetra Tech (2019) and summarized herein.

The water balance follows the conservation of mass continuity equation:

$$\Delta_{pit\ lake\ volume} = P + I_{runoff} + I_{pitwall} + GW_{inflow} - E - GW_{outflow} \tag{1}$$

where:

P represents direct precipitation

$I_{pitwall}$ represents pit wall runoff

GW_{inflow} represents groundwater inflow

E is evaporation from the surface of the pit lake

$GW_{outflow}$ is groundwater outflow

I_{runoff} is upgradient runoff, which was set to zero based on the assumption that overland flow into the ultimate Batman Pit will not occur since the deposit is a topographic high; therefore, upgradient watersheds should not drain into the pit.

Equation 1 accounts for inflows and outflows to the pit lake where the difference results in a change to pit lake storage. As the lake stage increases, inflows and outflows dynamically change until hydrologic equilibrium is reached. Under average annual hydrologic conditions, a pit lake was predicted to form in Batman Pit. Additional major findings associated with the Batman Pit lake water balance model include:

- Relatively rapid water level rise until the lake stage recovered to about 90% of the surrounding groundwater elevation. Subsequent water level rise was slower with larger lake surface area.

- After approximately 1,200 years the pit lake reached hydrologic equilibrium at an elevation of approximately -15 m AHD.

- Fluctuations in modeled evaporation rates once equilibrium-like conditions were reached were attributed to slight changes in the water surface elevation due to some lake cells alternately being flooded or dry.

- The pit lake was predicted to be a terminal sink, with net evaporation from the lake exceeding the contributions from precipitation and runoff into the lake. The net loss from the high evaporation rate was balanced by groundwater influx.

- Predicted inflows were primarily associated with precipitation and wall rock runoff, while groundwater inflow made up a small portion (approximately 2%).

- Evaporation from the lake water surface was the only predicted outflow.

- The discrepancy between inflows and outflow at the end of the simulation period was within approximately 2%.

The pit configuration and resulting mine life have been optimized since the predictions discussed above was conducted. The new pit configuration has a bottom elevation of -400 m AHD whereas the previous

pit configuration had a bottom elevation of -340 m AHD. Although a water balance over time was not constructed for the optimized pit filling, the analysis presented in Tetra Tech (2020) and summarized in Table 7 shows minimal change. As summarized in Tetra Tech (2020), both pit lakes are predicted to equilibrate at the same elevation (-15 m AHD) and overtopping the pit rim is improbable. The optimized pit lake water balance had a lower proportion of precipitation report as wall rock runoff (30.1% compared to 29.1%) and a higher proportion report as direct precipitation on the lake surface (67.5% and 68.4%). Due to most of the geochemical mass load being derived from wall rock, application of the existing water balance to the optimized pit configuration appears unlikely to significantly influence the geochemical model results.

Table 7 Pit Lake Filling Water Balance Comparison

Parameter	2018 Model		2020 Update	
	Inflow or Outflow Rate	Percent of Total	Inflow or Outflow Rate	Percent of Total
Pit Footprint Area (ha)	137	--	131	--
Pit Lake Water Surface Area (ha)	78	--	76	--
Pit Lake as % of Pit Footprint	--	56.9%	--	58.0%
Inflows				
Direct Precipitation (m^3/day)	2350.5	67.5%	2290.2	68.4%
Direct Precipitation (m^3/day/ha)	30.1	--	30.1	--
Groundwater Inflow (m3/day)	82.6	2.4%	82.6	2.5%
Pit Wall Runoff (m^3/day)	1047	30.1%	976	29.1%
Pit Wall Runoff (m3/day/ha)	17.7	--	17.7	--
Total Inflow (m^3/day)	3480.1	--	3348.8	--
Outflows				
Evaporation (m^3/day)	3393.9	100%	3306.9	100%
Evaporation (m^3/day/ha)	43.5	--	43.5	--
Groundwater Outflow	0	0.0%	--	0.0%
Total Outflow	3393.9	--	3306.9	--
Inflow - Outflow	86.2	--	42	--
Percent Discrepancy	2.5%	--	1.3%	--

Source/Notes: Tetra Tech (2020) Table 2
-- Not applicable

5. PHYSICAL LIMNOLOGY

Lakes can be classified as holomictic or meromictic. A lake is holomictic when it undergoes full mixing at least once annually. A meromictic lake is vertically stratified with layers that do not mix. As a result, the bottom waters can develop more reducing conditions than mixed lakes (Drever, 1997). An understanding of the controls on stratification and turnover provides a basis for determining whether Batman Pit lake will be holomictic or meromictic. Key controls are discussed below.

Wind is unlikely to significantly facilitate mixing of surface waters within Batman Pit due to the distance from the pit rim to the lake surface. Specifically, approximately 179 m of highwall will be exposed above the lake surface. Unlike the ultimate Batman Pit, physical mixing due to Easterly trade winds during the Dry season and Monsoon effects on Wet season wind are likely to overcome density gradients in the existing Batman Pit. Furthermore, although discrete events, the high hardness/competency of the metamorphosed Batman Pit wall rock minimises the potential for mixing to be initiated by slope failure.

The shape of Batman Pit is an important morphological feature to consider. Pit lakes with high lake depth relative to surface area (i.e., relative depth) are more likely to be meromictic. Generally, if the relative depth is greater than 20%, the lake has potential to be permanently stratified (Castendyk and Jewell, 2002). The relative depth of Batman Pit is high (approximately 39%) based on a maximum lake depth of 385 m and surface area of 760,000 m^2 (76 ha). In contrast, the relative depth of 19% for the historic Batman Pit lake, based on a maximum lake depth of 120 m and surface area of approximately 320,000 m^2 (32 ha), is consistent with a pit lake that will not be permanently stratified.

As noted in Castendyk and Jewell (2002), relative depth is a useful tool for assessing the general tendency of a pit lake to turn over or remain stratified; however, the presence or absence of a vertical density gradient may have more influence on whether a lake is meromictic than morphology. Development of strong density gradients can cause permanent stratification, where vertical circulation is suppressed by the presence of dense bottom waters (hypolimnion), overlain by less dense surface waters (epilimnion), which are separated by a chemocline. For example, Blowout Lake was shown to be holomictic although it was characterized by a relative depth of 35. The maximum conductivity of 1,000 micromhos per centimetre (μmho/cm), which was 1,000 to 11,000 μmho/cm lower than the other pit lakes investigated with high relative depth and meromictic conditions.

The assessment presented above suggests that the ultimate Batman Pit lake may be meromictic with permanent stratification, where oxic surface waters overlie anoxic deep waters. The decrease in dissolved oxygen, and increase in $CO_2(g)$, that results from isolation of the deeper waters should cause minerals such as sulphides (e.g., CdS, ZnS) to precipitate and settle out, thereby removing constituents from the water column that are likely to remain in solution under oxygenated conditions. Therefore, the more conservative base case model assumes Batman Pit lake is holomictic and periodic mixing introduces atmospheric gases throughout the water column. To assess the influence of physical limnology on surface water quality predictions, a sensitivity scenario was conducted assuming meromictic conditions as discussed in Section 8 (Results).

6. GEOCHEMICAL MASS LOADING SOURCES

The approach used to derive sources of geochemical mass loading to the Batman Pit lake are described herein. These sources are based of the pit lake conceptual model which defines the primary inflows, outflows, and major assumptions that form the basis for the predictive water quality model.

6.1. Pit Lake Conceptual Model

The sources of geochemical mass loading are illustrated in the pit lake conceptual model (Figure 11) and summarized as follows:

- Blasting during mining will leave rubble on the benches and fractures that expose wall rock to weathering and oxidation.

- The distribution of NAF, NAF(LC), and PAF wall rock will vary with elevation.

- Runoff that contacts rubble and fractured wall rock will contribute geochemical mass load to the pit lake. Loading will depend on the type of wall rock, NAF, NAF(LC), or PAF, and whether the wall rock is above the lake surface or inundated with water.

- Wall rock above the lake surface will be an on-going source of mass load to the lake.

- As the water level in the lake rises, wall rock will be submerged, and built-up oxidation products will be released into the lake. Oxidation and reactivity will be inhibited once the wall rock is permanently submerged and will no longer release constituents.

- As the pit lake fills, wall rock runoff, wall rock submergence, direct precipitation on the lake surface, and groundwater will mix.

- Evaporation, the only outflow from the lake, will be counterbalanced the pit lake inflows.

- Mineral solubility, adsorption, and equilibrium with atmospheric gases (CO_2 and O_2) will control constituent concentrations within the water column.

The sources of geochemical mass loading to the Batman Pit lake are described in the following subsections.

6.2. Direct Precipitation Chemistry

Direct precipitation was assigned the median chemical composition for Darwin from January 2008 through February 2010 (Crosbie et al., 2012) (Table 8).

Table 8 Direct Precipitation Chemical Composition

Parameter	Concentration (mg/L)
pH (std units)	6.00
Total Alkalinity (as Bicarbonate)	3.66
Calcium	0.43
Magnesium	0.11
Sodium	1.25
Potassium	0.10
Chloride	2.20
Sulphate	0.37

Source/Notes: Median values calculated from Crosbie et al. (2012) Table A.8

6.3. Groundwater Inflow Chemistry

The chemical composition for groundwater inflow into Batman Pit was based on the baseline groundwater sampling conducted from May 2011 through December 2013 in the vicinity of Batman Pit at BW5 and BPMB02 (Table 9). The groundwater at BW5 and BPMB02 was characterized as mixed cation bicarbonate type water. Average conditions include field pH of approximately 6.2, bicarbonate alkalinity of 101 mg/L as $CaCO_3$, and low sulphate concentrations (< approximately 15 mg/L).

Table 9 Pit Area Groundwater Quality

Parameter	Units	BW5 1-May-2011	BW5 1-Sep-2011	BW5 1-Dec-2011	BW5 1-Mar-2012	BW5 23-Apr-2013	BW5 3-Dec-2013	BPMB02 1-Sep-2011	Minimum	Maximum	Average	Median	% Reported Values
Temperature	°C	32.2	32.6	32.5	32.1	31.9	33.9	33.8	31.9	33.9	32.7	32.5	100%
pH	std units	6.14	6.05	5.90	5.60	6.20	6.18	7.20	5.60	7.20	6.18	6.14	100%
Bicarbonate (as CaCO₃)	mg/L	89	98	97	56	84	74	210	56	210	101	89	100%
Carbonate (as CaCO₃)	mg/L	<1	<10	<10	<10	<5	<5	<10	1	10	7.3	10	0%
Hydroxide (as CaCO₃)	mg/L					<5	<5		5	5	5	5	100%
Aluminium	µg/L	2.4	<50	<50	<50	<10	<10	<50	2.4	50	32	50	86%
Ammonia as N	mg/L	*0.005*	*< 0.01*	*0.02*	*0.03*	0.011	<0.005	*< 0.01*	0.005	0.03	0.014	0.011	57%
Antimony	µg/L	<0.05	<5	<5	<5	<1	<1	<5	0.05	5	3	5	0%
Arsenic	µg/L	47	45	41	25	44	41	350	25	350	85	44	100%
Barium	µg/L	19.6	<20	20	<20	20	18	<20	18	20	20	20	43%
Beryllium	µg/L	0.1	<1	<1	<1	<0.5	<0.5	<1	0.1	1	0.7	1	14%
Bismuth	µg/L	<0.01	<5	<5	<5	<1	<1	<5	0.01	5	3	5	0%
Boron	µg/L	12	<50	<50	<50	<5	15	<50	5	50	33	50	29%
Cadmium	µg/L	<0.02	<0.2	<0.2	<0.2	<0.1	<0.1	<0.2	0.02	0.2	0.1	0.2	0%
Calcium	mg/L	16	*11*	*17*	*7.4*	12	9.9	*41*	7.4	41	16	12	100%
Chloride	mg/L	2.4	2.8	3	2.2	3.0	3.0	4.6	2.2	4.6	3.0	3.0	100%
Chromium (III+VI)	µg/L	<0.1	<1	<1	4	<1	<1	1	0.1	4	1	1	29%
Cobalt	µg/L	0.66	<1	<1	<1	<1	<1	<1	0.66	1	1	1	14%
Copper	µg/L	0.14	<1	<1	<1	<1	<1	<1	0.14	1	0.9	1	14%
Cyanide (amenable)	mg/L	<0.1	<0.005	<0.005	<0.005	<0.1	<0.1	<0.005	0.005	0.1	0.046	0.005	0%
Cyanide (Free)	mg/L	<1	<0.005	<0.005	<0.005	<0.004	<0.004	<0.005	0.004	1	0.15	0.005	0%
Cyanide Total	mg/L	<0.01	<0.005	<0.005	<0.005	<0.004	<0.004	<0.005	0.004	0.01	0.005	0.005	0%
Electrical Conductivity	uS/cm	177	155	172	110	174	172	400	110	400	194	172	100%
Iron	mg/L	1.85	1.6	1.9	1.4	1.6	1.5	0.43	0.43	1.9	1.5	1.6	100%
Kjeldahl Nitrogen Total	mg/L	0.06	<0.2	<0.2	<0.2	*0.2*	*0.6*	0.3	0.06	0.6	0.3	0.2	57%
Lead	µg/L	0.36	<1	<1	<1	<1	<1	5	0.36	5	1	1	29%
Lithium	µg/L	9	9	7	< 5	7	7	8	5	9	7	7	86%
Magnesium	mg/L	7.7	*6.9*	*7.2*	*4.4*	7.7	6.4	*15*	4.4	15	8	7	100%
Manganese	µg/L	317	270	210	220	240	240	46	46	317	220	240	100%
Mercury	µg/L	--	<0.1	<0.1	<0.1	<0.05	<0.05	<0.1	0.05	0.1	0.1	0.1	0%
Molybdenum	µg/L	0.45	<5	<5	<5	<1	<1	9	0.45	9	4	5	29%
Nickel	µg/L	1.01	<1	<1	1	2	<1	2	1	2	1	1	57%
Nitrate (as N)	mg/L	*<0.005*	<0.02	<0.02	<0.02	0.027	<0.02	<0.02	0.005	0.027	0.017	0.020	14%
Nitrite (as N)	mg/L	*<0.005*	0.44	0.05	<0.02	*<0.005*	*<0.005*	0.38	0.005	0.44	0.13	0.020	43%
Nitrogen (Total)	µg/L	940	390	<200	<200	200	600	740	200	940	467	390	71%
Phosphate (Total as P)	mg/L	*0.195*	0.28	0.23	0.13	*0.2*	*0.2*	0.18	0.13	0.28	0.20	0.20	100%
Potassium	mg/L	3.2	*3.1*	*3.1*	*2.2*	3.5	3.2	*7.2*	2.2	7.2	3.6	3.2	100%
Selenium	µg/L	<0.2	2	<1	<1	<1	<1	<1	0.2	2	1	1	14%
Silver	µg/L	<0.05	<5	<5	<5	<1	<1	<5	0.05	5	3	5	0%
Sodium	mg/L	9.8	*9.3*	*11*	*5.8*	11	9.2	27	5.8	27	12	9.8	100%
Strontium	µg/L	40.9	29	29	22	31	28	300	22	300	69	29	100%
Sulphate	mg/L	6	<15	<15	<15	6	5	45	5	45	15	15	57%
TDS	mg/L	*170*	86	160	89	160	170	270	86	270	158	160	100%
Thallium	µg/L	<0.01	<1	<1	<1	<1	<1	<1	0.01	1	1	1	0%
Thorium	µg/L	<0.01	<5	<1000	<1000	<0.5	<0.5	<5	0.01	1000	287	5	0%
Tin	µg/L	<0.1	<5	<5	<5	<1	<1	<5	0.1	5	3	5	0%
Titanium	µg/L	<2	<5	<5	<5	<1	<1	<5	1	5	3	5	0%
Uranium	µg/L	0.002	<5	<5	<5	<0.5	<0.5	<5	0.002	5	3	5	14%
Vanadium	µg/L	<0.05	<5	<5	<5	<1	<1	<5	0.05	5	3	5	0%
WAD Cyanide	mg/L	<0.01	< 0.005	< 0.005	< 0.005	<0.004	<0.004	<0.005	0.004	0.01	0.005	0.005	0%
Zinc	µg/L	2.5	5	3	<1	4	5	4	1	5	4	4	86%

Source/Notes: Vista Gold water quality database provided in March 2020
When filtered sample results were not available, unfiltered sample results were included in ***bold/italic*** text
Sulphate as S data convert to sulphate when sulphate analyses were unavailable
Values converted to the reporting limit for statistical calculations
-- Not determined

6.4. Pit Wall Rock Source Term Development

The geochemical characterization program showed that lithologic units were of limited importance compared to total sulphur content, which was used as the basis for the zones that make up the ultimate pit wall rock (Figure 9). Each of these geochemical zones is defined by a source term based on HCT solution chemistry, converted to constituent release rate (mg/kg/week) based on the weekly outflow (near 0.5 L) and total rock mass (1 kg), and scaled to represent pit wall characteristics. The approach used to develop the wall rock source terms is described in the following subsections.

6.4.1. Reactive Wall Rock Mass

The extent of the damaged rock zone that results from blasting has a significant influence on mass loading to the pit lake. The damaged rock zone includes the pit wall surface and rubble that collects on benches, and the blast-impacted fractured zone beneath the surface where fracture-type flow is anticipated to dominate. A total reactive wall rock thickness of 1-m was assigned across the entire pit. Batman Pit wall rock is in metamorphosed (hornfelsed) rock with little to no primary porosity, with very few open or interconnected fractures (Tetra Tech, 2019). The wall rock is uncommonly strong as noted by the project Geotechnical Engineer (Rippere, 2019), and a composite ore and waste rock bond ball mill work index (BWi) of 25 kilowatt-hours per ton (kWh/t) (Tetra Tech, 2019). This BWi is associated with very hard rock based on the common criterion of > 20 kWh/t. The hardness of the wall rock is further illustrated by the steepness of the pit wall designs particularly on the southern and western sides of the pit where slope angles of 51° to 55° are planned (Figure 12). Due to the high competency of the metamorphosed Batman Pit wall rock, the 1-m damaged rock zone thickness is anticipated to be conservative. However, to understand the sensitivity of the model predictions to reactive wall rock loading, the thickness is varied as part of the model sensitivity simulation discussed in Section 8 (Results).

Wall rock surface areas by geochemical zone and pit lake stage elevation were calculated from the ultimate pit shell discussed in Section 3 (Geochemical Characterization Program) (Table 10). The amount of exposed NAF, NAF(LC), and PAF wall rock varies over time as illustrated by the relative abundances for select elevations that are consistent with the timesteps used for geochemical modelling. Initially, PAF rock will dominate the exposed pit walls; however, as the pit fills, NAF wall rock abundance increases and becomes the dominate geochemical zone as the pit lake approaches hydrologic equilibrium. Vista Gold provided the rock density of 2,770 kg/m^3, which was used to calculate the volume of NAF, NAF(LC), and PAF rock that make up the damaged rock zone.

Table 10   Pit Wall Rock Surface Areas by Lake Stage – Exposed, Submerged, and Total

Stage	NAF		NAF(LC)		PAF		Total
m AHD	%	m^2	%	m^2	%	m^2	%
Pit Wall Runoff							
-220	45%	492,181	18%	192,865	37%	404,651	100%
-210	46%	490,028	17%	184,902	37%	387,965	100%
-176	48%	480,339	17%	166,297	35%	346,891	100%
-106	54%	444,789	16%	132,166	30%	251,003	100%
-69	56%	408,618	15%	110,900	29%	211,729	100%
-45	57%	375,433	15%	100,891	28%	186,129	100%
-15	58%	331,654	15%	85,708	27%	154,689	100%
Stage	NAF		NAF(LC)		PAF		Total
m AHD	%	m^2	%	m^2	%	m^2	%
Pit Wall Submergence							
-220	1%	1,615	8%	18,549	91%	214,354	100%
-210	8%	2,153	30%	7,964	62%	16,686	100%
-176	23%	1,822	9%	718	68%	5,300	100%
-106	21%	35,650	21%	34,256	58%	96,018	100%
-69	37%	36,072	22%	21,141	41%	39,144	100%
-45	48%	33,185	15%	10,009	37%	25,599	100%
-15	48%	43,779	17%	15,183	35%	31,440	100%
Total Pit Wall Surface Area							
Total	37%	493,796	16%	211,415	47%	619,005	100%

Notes: Exposed wall rock represents surface area above the lake elevation at that stage
Submerged wall rock represents the surface area inundated during each stage

6.4.2. Physical Scaling

HCTs were conducted on rock samples crushed to < 6.3 mm (Table 11). The HCT samples are characterized by higher specific surface area, higher porosity, and more rigorous rinsing than anticipated for intact Batman Pit wall rock. To account for differences between laboratory and field conditions, HCT release rates are scaled from laboratory to field conditions such as grain size/water to rock ratio, surface area, water contact, temperature, and reduction in oxidation rate (Kempton, 2012). To simulate wall rock loading to the pit lake, HCT release rates were scaled to account for differences in grain size and flushing as described below.

Scaling surface area from laboratory to field conditions was conducted by determining the ratio of specific surface areas for wall rock and HCT samples. A median specific surface area of 1.4 m^2/kg (range of 0.70 to 2.1 m^2/kg) assuming spherical particles was assigned to the HCT samples based on the grain size distributions. This low range of specific surface areas, and retention of 63 to 74% of the sample mass for each HCT on the 4 mm screen, highlight the inherent hardness of Batman Pit mine rock even when subjected to crushing to < 6.4 mm as required by the kinetic test method. In contrast, Batman Pit wall rock will primarily consist of much larger fragments with minimal rubble based on the low

fractured rock porosity of approximately 2% for altered Burrell Creek and Tollis Formation and as illustrated by the existing pit walls (Figure 13). Wall rock is estimated to have a specific surface area of 0.072 m^2/kg based on Boddington Mine rock gradation data (Hart et al., 2011) and assuming spherical particles. Feed to the primary crusher at Boddington Mine is also categorized as hard rock based on a Bwi of 20 kWh/t and has a P80 of 160 mm (i.e., 80% passes a 160 mm sieve). This is equivalent to approximately 5% of the wall rock that makes up the damaged blast zone being comprised of particles < 6.4 mm. The ratio of these specific surface areas gives a scaling factor of 0.05 (5%). The specific surface area based on Boddington Mine feed to the primary crush is likely to be conservative since Mt Todd rock is harder (25 kWh/t) and will be associated with intact pit walls.

HCTs are frequently flushed (i.e., weekly) to maintain water contact with the crushed rock and facilitate water to rock interactions. An annual HCT flushing ratio of 26 was obtained based on 26 L of water flushing 1 Kg of crushed rock. The annual pit wall flushing ratio was calculated based on the following:

- Rock density of 2,770 kg/m^3

- Total wall rock surface area of 1,324,219 m^2 minus initial pit lake formation, which submerges 234,518 m^2 of wall rock as shown in Tetra Tech (2019)

- Total damaged rock zone (rubble and fractured rock) depth of 1 m

- Moving average runoff volume of 1078 m^3/day based on the pit lake water balance (range of 1047 to 2272 m^3/day)

The resulting pit wall flushing ratio is 7.7 (7.7 L of runoff flushes each kg of wall rock). This equates to an annual water availability to flush an equivalent wall rock mass that is approximately 3.4 times higher in the HCTs than anticipated for pit wall rock. Therefore, a flushing scaling factor of 0.30 was applied. The resulting composite scaling factor of 1.5% (0.05*0.30) indicates field weathering rates will be approximately 1.5% of the weathering rates obtained under laboratory testing conditions.

Table 11   Humidity Cell Test Grain Size Analysis

Screen		Mass (g)	% Retained		% Passing	Mass (g)	% Retained		% Passing	Mass (g)	% Retained		% Passing
Tyler Mesh	Opening (mm)		Interval	Cumulative			Interval	Cumulative			Interval	Cumulative	
		HC-1B (Sample ID: VB007-001 173-177 G)				HC-2B (Sample ID: VB08-026 332-336 S)				HC-3B (Sample ID: VB08-032 180-184 I)			
5	4	165	66.4	66.4	33.6	169	67.9	67.9	32.1	157	63.2	63.2	36.8
9	2	48.1	19.3	85.7	14.3	43.0	17.2	85.1	14.9	44.9	18.0	81.2	18.8
20	0.841	22.6	9.08	94.8	5.22	21.4	8.57	93.7	6.32	25.0	10.1	91.3	8.71
35	0.425	6.96	2.79	97.6	2.42	7.26	2.91	96.6	3.41	9.40	3.77	95.1	4.94
60	0.25	2.78	1.12	98.7	1.31	3.35	1.34	97.9	2.07	4.78	1.92	97.0	3.02
115	0.125	0.02	0.01	98.7	1.30	0.12	0.05	98.0	2.02	0.01	0.00	97.0	3.02
250	0.063	1.30	0.52	99.2	0.78	2.26	0.91	98.9	1.11	3.94	1.58	98.6	1.43
<250	<0.063	1.94	0.78	100	0.00	2.78	1.11	100	0.00	3.57	1.43	100	0.00
Total	--	249	100	--	--	250	100	--	--	249	100	--	--
Screen	Opening (mm)	HC-1 (Sample ID: VB-009 58-62 G)				HC-2 (Sample ID: VB-006 44-48 S)				HC-3 (Sample ID: VB-002 220-224 I)			
5	4	161	64.4	64.4	35.6	170	68.3	68.3	31.7	161	64.4	64.4	35.6
9	2	43.1	17.2	81.5	18.5	41.3	16.5	84.8	15.2	51.7	20.6	85.1	14.9
20	0.841	23.4	9.34	90.9	9.12	22.1	8.86	93.7	6.34	23.7	9.5	94.5	5.47
35	0.425	9.01	3.59	94.5	5.52	7.53	3.02	96.7	3.32	6.90	2.75	97.3	2.72
60	0.25	5.03	2.01	96.5	3.52	3.28	1.31	98.0	2.01	2.86	1.14	98.4	1.58
115	0.125	0.59	0.24	96.7	3.28	0.19	0.08	98.1	1.93	0.17	0.07	98.5	1.51
250	0.063	5.60	2.23	99.0	1.05	3.44	1.38	99.4	0.55	2.76	1.10	99.6	0.41
<250	<0.063	2.62	1.05	100	0.00	1.38	0.55	100	0.00	1.02	0.41	100	0.00
Total	--	251	100	--	--	250	100	--	--	251	100	--	--
Screen	Opening (mm)	HC-4 (Sample ID: VB-011 156-160 S)				HC-5 (Sample ID: VB-018 120-124 I)				HC-6 (Sample ID: VB-009 86-90 G)			
5	4	184	73.8	73.8	26.2	172	68.8	68.8	31.2	161	64.8	64.8	35.2
9	2	46.5	18.6	92.4	7.6	45.1	18.0	86.9	13.1	49.6	20.0	84.8	15.2
20	0.841	14.6	5.86	98.2	1.77	21.8	8.72	95.6	4.43	22.8	9.2	93.9	6.06
35	0.425	2.99	1.20	99.4	0.57	5.97	2.39	98.0	2.04	7.34	2.96	96.9	3.10
60	0.25	0.09	0.03	99.5	0.53	2.22	0.89	98.8	1.15	2.97	1.20	98.1	1.90
115	0.125	0.19	0.08	99.5	0.46	0.10	0.04	98.9	1.11	0.23	0.09	98.2	1.81
250	0.063	0.62	0.25	99.8	0.21	1.98	0.79	99.7	0.32	3.24	1.30	99.5	0.51
<250	<0.063	0.52	0.21	100	0.00	0.80	0.32	100	0.00	1.26	0.51	100	0.00
Total	--	250	100	--	--	250	100	--	--	248	100	--	--

6.4.3. Application of Kinetic Testing

The initial step in geochemical source term development was selection of HCTs to represent the NAF, NAF(LC), and PAF zones that make up Batman Pit wall rock. Geochemical mass loading will depend on whether the release is associated with the initial wall rock runoff or submergence (i.e., first flush) or long-term wall rock runoff. Median NAF, NAF(LC), and PAF release rates (mg/kg/week) derived from the HCTs representing each geochemical zone are presented in Table 12 and discussed below. Monthly composite concentrations were used except for pH, which was calculated from the weekly solutions. Median sulphate and alkalinity release rates calculated from the monthly composites and weekly solutions compared well. When analytical results were reported below the associated reporting limit, the reporting limits were used. Some reporting limits associated with the HCTs that operated for 185 weeks decreased significantly over time.

Table 12   Humidity Cell Test Release Rates

| Parameter | Long-Term | | | | | First Flush | | |
| | NAF | NAF(LC) | PAF | PAF 0.7% Total Sulphur | PAF 1% Total Sulphur | NAF | NAF(LC) | PAF |
	(HC-3 HC-6)	(HC-1B HC-2B)	(HC-2)	(HC-2 Scaled)	(HC-2 Scaled)	(HC-3 HC-6)	(HC-1B HC-2B)	(HC-2)
	mg/kg/wk							
pH	7.35	7.37	4.08	4.03	3.55	7.57	8.51	5.78
Sulphate	6.77	1.86	14.30	18.68	40.19	15.80	7.46	31.08
Total Alkalinity (as CaCO$_3$)	5.39	2.93	-	-	-	10.42	7.94	-
Al	0.01556	0.01210	0.27908	0.50588	1.53943	0.03836	0.02517	0.07105
Sb	0.00063	0.00006	0.00009	-	-	0.00453	0.00103	0.00051
As	0.01218	0.00103	0.00009	0.00000	0.00000	0.03773	0.02346	0.00203
Ba	0.00071	0.00015	0.01922	-	-	0.00201	0.00088	0.00812
Be	0.00009	0.00000	0.00064	-	-	0.00051	0.00005	0.00051
Bi	0.00009	0.00000	0.00009	-	-	0.00051	0.00005	0.00051
B	0.00678	0.02156	0.00458	-	-	0.05051	0.01319	0.07613
Cd	0.00006	0.00001	0.00073	0.00124	0.00334	0.00010	0.00000	0.00020
Ca	3.21371	1.27753	0.59018	-	-	4.49873	2.60658	2.06045
Cr	0.00009	0.00004	0.00009	-	-	0.00051	0.00010	0.00051
Co	0.00062	0.00005	0.07137	0.11081	0.27848	0.00077	0.00012	0.03248
Cu	0.00023	0.00037	0.18666	0.35983	1.12323	0.00103	0.00144	0.00508
Fe	0.00459	0.00109	0.10980	-	-	0.02534	0.00489	0.11673
Pb	0.00771	0.00010	0.84638	1.73674	5.27739	0.00148	0.00005	0.01827
Li	0.00016	0.00022	0.00178	-	-	0.00152	0.00059	0.00457
Mg	0.56264	0.44436	1.36793	-	-	1.42153	0.62104	4.17165
Mn	0.03640	0.00175	0.15921	-	-	0.04012	0.01614	0.28420
Mo	0.00013	0.00110	0.00005	-	-	0.00134	0.00056	0.07613
Ni	0.00041	0.00002	0.08738	-	-	0.00206	0.00066	0.00025
P	0.01358	0.00021	0.01373	-	-	0.07603	0.00978	0.08120
K	0.25011	0.07074	0.73658	-	-	2.72900	1.75303	5.53175
Se	0.00009	0.00002	0.00009	-	-	0.00051	0.00010	0.00051
Si	0.32393	0.13563	0.98820	-	-	0.55938	0.45460	1.37025
Ag	0.00002	0.00000	0.00002	-	-	0.00013	0.00002	0.00013
Na	0.10486	0.02786	0.02745	-	-	2.80331	2.21306	0.82215
Sr	0.00336	0.00070	0.00137	-	-	0.01064	0.00659	0.00355
Te	0.00009	0.00001	0.00009	-	-	0.00051	0.00010	0.00051
Tl	0.00001	0.00000	0.00005	-	-	0.00005	0.00001	0.00010
Th	0.00005	0.00000	0.00005	-	-	0.00025	0.00002	0.00025
Sn	0.00009	0.00009	0.00009	-	-	0.00051	0.00005	0.00051
Ti	0.00009	0.00022	0.00009	-	-	0.00051	0.00012	0.00051
U	0.00005	0.00000	0.00027	-	-	0.00025	0.00003	0.00025
V	0.00009	0.00009	0.00009	-	-	0.00051	0.00024	0.00051
Zn	0.00385	0.00160	0.56730	1.10296	3.23372	0.00253	0.00098	0.05583
Zr	0.00091	0.00004	0.00092	-	-	0.00507	0.00005	0.00508

6.4.3.1. Non-Acid Forming Wall Rock

Samples that were subjected to kinetic testing contained total sulphur content greater than the content used to define NAF wall rock (total sulphur ≤ 0.25%) within the block model. Therefore, the HC-3 (Interbedded) and HC-6 (Greywacke) HCT samples were selected to represent NAF wall rock since these samples were designated as NAF using the NPR criterion (NPR ≥ 2), both HCTs retained near-neutral pH during the 27 to 28 week testing period (median pH 7.35), and depletion calculations suggest that both HCTs will remain NAF (i.e., sulphide sulphur depletion before carbonate minerals) (Table 5). The final two monthly composite samples for both HCTs were used calculate the median long-term constituent release rates (mg/kg/week). Median initial concentrations associated with the week 1 through 4 composite sample were used to represent first flush conditions. pH values were obtained from the weekly solutions over the same timeframes.

6.4.3.2. Non-Acid Forming – Low Capacity Wall Rock

The HC-1B (Greywacke) and HC-2B (Shale) HCT samples were selected to represent NAF(LC) wall rock. Both samples were classified as uncertain based on NPR from 1 up to 2 (HC-1B NPR of 1.2, HC-2B NPR of 1.3). Long-term constituent release rates were calculated based on the median of the final two monthly composites for both HCTs (composites from week 177 through 180 and week 181 through 184). Median initial concentrations associated with the week 1 through 4 composite sample were used to represent first flush conditions. pH values were obtained from the weekly solutions over the same timeframes.

6.4.3.3. Potentially-Acid Forming Wall Rock

PAF wall rock has potential to eventually generate acid, which will influence the pH and mass loading to the pit lake. The $CaCO_3$ depletion rates obtained from the PAF HCT samples that generated neutral pH solutions, HC-1 (Greywacke), HC-4 (Shale), and HC-5 (Interbedded) suggest onset of acidity under laboratory conditions will occur in 16 to 35 years (Table 5). Due to the extended timeframe before the pit lake approaches hydrologic stability (i.e., > 500 years), a lag time for onset of acidic conditions was not incorporated into the pit lake model. Two HCTs, HC-2 (Shale) and HC-3B (Interbedded), were characterized by acidic pH and elevated constituent release once acidity developed. HC-3B operated for 151 weeks at which point the pH dropped from 6.1 to 5.2. HC-3B was characterized by relatively stable conditions over the final three months of operation (week 174 through 185) as illustrated by the following median long-term concentrations and ranges:

- pH: 4.78 (4.56 to 4.85)

- Sulphate: 8.3 mg/L (6.8 and 11 mg/L)

- Acidity (to pH 8.3): 2.2 mg $CaCO_3$/L (1.5 and 4.6 mg $CaCO_3$/L)

- Copper (used as a proxy for metal release in general): 0.0143 mg/L (0.0129 to 0.0162 mg/L)

HC-2, which contained the lowest ANC (3.6 kg H_2SO_4/tonnes) of the samples subjected to kinetic testing, was characterized by low pH conditions over the entire testing period of 27 weeks (initial pH 5.76, final pH 4.08) (Figure 7a). HC-2 was characterized by higher constituent release than HC-3B, downward trending pH, and upward trending constituent concentrations (e.g., sulphate and metals). To account for the range of potential release rates, the higher HC-2 release rates were selected to

represent PAF wall rock with less than 0.7% total sulphur, which is approximately 35% of the PAF wall rock. This approach is supported by a trendline fit to the total sulphur and associated NAG pH results (NAG pH ≥ 5) where the stable/final pH values associated with HC-3B and HC-2 fit a total sulphur content from 0.40 to 0.67% (Figure 14). The final composite sample results (week 21 through 24) were used to represent long-term constituent release rates. The minimum pH value of 4.08 obtained from the weekly solutions over the same timeframes was used to represent pH. Initial HC-2 concentrations associated with the week 1 through 4 composite sample were used to represent first flush conditions.

Batman Pit walls will also be composed of rock that contains a higher percentage of total sulphur than represented directly by the HCT release rates. Based on the block model, average PAF waste rock contains 0.7% total sulphur. To account for the geochemical mass loading associated with average PAF wall rock (approximately 21%), HC-2 release rates were scaled based on the NAG pH of 4.03 for samples with 0.7% total sulphur (Figure 14). This approach was only applied to constituents that showed a correlation between pH and release rate including sulphate, aluminium, cadmium, cobalt, lead, and zinc (positive correlation) and arsenic (negative correlation, e.g., concentrations decreased with decreasing pH). Correlation plots are provided in Figure 15. The remaining PAF wall rock will contain > 0.7% total sulphur content. The average total sulphur content of 1% for ore was used to represent this wall rock, which equates to a NAG pH of 3.55 (Figure 14). This pH is consistent with the typical AMD pH between approximately 3.2 to 3.6 observed for the waste rock dump runoff and seepage at Mount Todd Mine. In addition, the resulting sulphate release rates used to represent higher sulphur PAF wall rock compared well to HCTs with moderate sulphate release rates provided in the Minesite Drainage Assessment Group (MDAG)^{TM} International Kinetic Database (IKD$^{©,TM}$) over a similar pH range.

Iron is an important control on constituent concentrations in pit lakes, with increasing concentrations typically observed with decreasing pH (Eary, 1999); however, HC-2 iron release rates did not correlate with pH (median: 0.11 mg/L, range: 0.04 to 0.18 mg/L) and therefore the approach described above was not appropriate. To provide a reasonable but conservative solubility control, HC-2 iron release rates were used without adjustment to represent iron release from the higher sulphur PAF wall rock.

Scaling the HC-2 concentrations based on NAG pH and total sulphur content typically increased concentrations; however, arsenic decreased below zero as pH decreased. Therefore, arsenic concentrations were set to zero rather than the laboratory reporting limits. This approach minimises the potential for artificially elevated arsenic concentrations over time, which can occur when reporting limits are used. The approach is also consistent with arsenic concentrations associated with AMD at the mine, which are generally below laboratory reporting limits.

6.4.3.4.   First Flush and Long-Term Release Rates

As illustrated by HCT sulphate release rates (Figure 7b), a first flush of readily soluble constituents was observed for mine rock from each geochemical zone. The duration of this initial flush varied between HCT samples; however, following the first flush, each HCT sample was characterized by release rates that were fairly stable, or increasing consistent with sulphide oxidation. The longest duration first flush was associated with HC-2, the HCT sample used to represent PAF wall rock. Specifically, sulphate release was initially elevated at approximately 31 to 37 mg/kg/week, dropped to a low of approximately 6.4 to 6.6 mg/kg/week at week 12 and week 13, respectively, before the release rate steadily increased. The first flush, which spans the time before the release rate began to increase again was associated with 6.2

L of water. Based on flushing ratios presented in Section 6.4.2 (Physical Scaling), the first flush release rates were applied during the first year following cessation of mining and long-term release rates were applied thereafter.

6.4.3.5. Pit Lake Model Input Solutions

Constituent concentrations for each geochemical zone were determined from the release rates, wall rock mass and moving average annual runoff volume as follows:

$$\text{Concentration} \left(\frac{\text{mg}}{\text{L}}\right) = \frac{\text{Release Rate (mg/kg/week)}*52(\text{weeks/year})*\text{Wall Rock Mass (kg)}}{\text{Annual Runoff (L/year)}}$$

Each solution was scaled to account for differences in grain size and flushing. pH was converted to hydrogen ion activity, scaled, and converted back to pH. The input solutions used in the base case predictive model are provided in Table 13.

Table 13.   Pit Wall Rock Chemistry used as Pit Lake Model Input Solutions

Parameter	Long-Term					First Flush		
	NAF	NAF(LC)	PAF	PAF 0.7% Total Sulphur	PAF 1% Total Sulphur	NAF	NAF(LC)	PAF
	(HC-3 HC-6)	(HC-1B HC-2B)	(HC-2)	(HC-2 Scaled)	(HC-2 Scaled)	(HC-3 HC-6)	(HC-1B HC-2B)	(HC-2)
	mg/L							
pH	6.3	6.3	3.0	3.0	2.5	6.5	7.4	4.7
Sulphate	79.7	21.9	168	220	473	186	87.8	366
Total Alkalinity (as CaCO₃)	63.4	34.5	-	-	-	123	93.5	-
Al	0.1832	0.1424	3.28	5.954	18.12	0.45149	0.29619	0.83627
Sb	0.0074	0.0008	0.0011	-	-	0.05327	0.01207	0.00597
As	0.1433	0.0122	0.0011	0.0000	0.0000	0.44403	0.27611	0.02389
Ba	0.0083	0.0018	0.2262	-	-	0.02365	0.01035	0.09557
Be	0.0011	0.0001	0.0075	-	-	0.00597	0.00058	0.00597
Bi	0.0011	0.0000	0.0011	-	-	0.00597	0.00058	0.00597
B	0.0798	0.2538	0.0538	-	-	0.59446	0.15520	0.89600
Cd	0.0007	0.0001	0.0086	0.0146	0.0394	0.00119	0.00006	0.00239
Ca	37.8	15.0	6.9	-	-	52.95051	30.67968	24.25173
Cr	0.0011	0.0005	0.0011	-	-	0.00597	0.00115	0.00597
Co	0.0072	0.0006	0.840	1.304	3.278	0.00906	0.00144	0.38229
Cu	0.0027	0.0044	2.197	4.235	13.2	0.01215	0.01697	0.05973
Fe	0.0540	0.0129	1.2924	1.2924	1.2924	0.29830	0.05753	1.37387
Pb	0.0907	0.0012	10.0	20.4	62.1	0.01747	0.00057	0.21504
Li	0.0019	0.0025	0.0210	-	-	0.01790	0.00690	0.05376
Mg	6.622	5.230	16.10	-	-	16.73	7.31	49.10
Mn	0.4285	0.0206	1.8739	-	-	0.47217	0.18993	3.34507
Mo	0.0016	0.0130	0.0005	-	-	0.01580	0.00662	0.89600
Ni	0.0048	0.0003	1.0285	-	-	0.02429	0.00776	0.00299
P	0.1598	0.0025	0.1615	-	-	0.89490	0.11505	0.95573
K	2.9438	0.8326	8.6696	-	-	32.12064	20.63330	65.10933
Se	0.0011	0.0002	0.0011	-	-	0.00597	0.00115	0.00597
Si	3.81	1.60	11.631	-	-	6.58391	5.35069	16.12800
Ag	0.0003	0.0000	0.0003	-	-	0.00149	0.00023	0.00149
Na	1.2342	0.3280	0.3231	-	-	32.99531	26.04800	9.67680
Sr	0.0396	0.0082	0.0162	-	-	0.12529	0.07761	0.04181
Te	0.0011	0.0001	0.0011	-	-	0.00597	0.00115	0.00597
Tl	0.0001	0.0000	0.0006	-	-	0.00060	0.00012	0.00119
Th	0.0005	0.0000	0.0005	-	-	0.00298	0.00029	0.00299
Sn	0.0011	0.0010	0.0011	-	-	0.00597	0.00058	0.00597
Ti	0.0011	0.0025	0.0011	-	-	0.00597	0.00144	0.00597
U	0.0005	0.0001	0.0032	-	-	0.00298	0.00032	0.00299
V	0.0011	0.0010	0.0011	-	-	0.00597	0.00287	0.00597
Zn	0.0453	0.0189	6.68	13.0	38.1	0.02983	0.01149	0.65707
Zr	0.0107	0.0005	0.0108	-	-	0.05966	0.00058	0.05973

7. GEOCHEMICAL MODEL APPROACH

The pit lake geochemical model approach presented herein was developed based on the conceptual model described in Section 6 (Geochemical Mass Loading Sources) and presented in Figure 11. The model was constructed to represent lake water conditions during filling and under long-term equilibrium conditions.

7.1. Model Code and Database

Geochemical modelling was conducted using the United States Geological Survey (USGS) computer code PHREEQC (Parkhurst and Appelo, 2013). PHREEQC can process multiple equilibria and mixing reactions to produce the final chemical speciation of a system. Geochemical modelling requires a database of thermodynamic and kinetic parameters. The Minteq.v4 database was use for the PHREEQC calculations without alteration.

7.2. Simulation Period and Discretization

The pit lake reaches hydrologic equilibrium within approximately 1,200 years (-15 m AHD) based on the water balance model. The pit will fill to approximately 90% of the total lake volume within 500 years (-45 m AHD). Model timesteps were selected to demonstrate the evolution of water chemistry during filling until the pit approaches hydrologic equilibrium while not being computationally impractical. With these factors in mind, timesteps for the geochemical model were selected to be consistent with the predicted changes in inflow rates as illustrated in Figure 10 and summarized in Table 14. Volumes and mixing percentages associated with each inflow and outflow obtained from the water balance model were assigned to each model timestep (Table 15). The annual lake volume at the end of each timestep was carried forward into the subsequent timestep for mixing.

Table 14   Geochemical Model Timestep Summary

Timestep	Years after Mining	Pit Lake Stage	Percent of Pit Lake Volume
		m AHD	%
1	Initial	-220	37%
2	1	-210	40%
3	10	-176	50%
4	50	-106	72%
5	100	69	83%
6	500	-45	91%
7	1200	-15	100%

Table 15   Water Balance Inflows and Outflows by Timestep

Timestep	Years after Mining	Units	Direct Precipitation	Groundwater Inflow	Wall Rock Runoff	Total Inflows	Lake Evaporation	Pit Lake Volume*
1	Initial	m³	2.2E+05	6.2E+06	8.3E+05	7.2E+06	1.3E+05	7.4E+06
		%	3.0%	85.5%	11.5%	100%	-	37%
2	1	m³	2.2E+05	9.1E+05	8.3E+05	2.0E+06	2.5E+05	8.7E+06
		%	11.2%	46.4%	42.4%	100%	-	40%
3	10	m³	3.4E+05	6.9E+04	7.4E+05	1.2E+06	4.3E+05	1.5E+07
		%	29.7%	5.9%	64.4%	100%	-	50%
4	10 to 50	m³	1.9E+07	1.9E+06	2.6E+07	4.7E+07	2.5E+07	3.6E+07
		%	40.6%	4.0%	55.5%	100%	-	72%
5	50 to 100	m³	3.2E+07	1.6E+06	2.7E+07	6.0E+07	4.4E+07	5.2E+07
		%	53.2%	2.6%	44.3%	100%	-	91%
6	100 to 500	m³	3.4E+08	1.0E+07	1.5E+08	5.1E+08	4.9E+08	6.6E+07
		%	67.6%	2.1%	30.4%	100%	-	91%
7	500 to 1200	m³	6.0E+08	1.7E+07	2.7E+08	8.9E+08	8.7E+08	8.4E+07
		%	67.9%	1.9%	30.2%	100%	-	100%

*Pit lake volume percentage is relative to final lake stage

7.3. Equilibrium Phases

As the pit fills, secondary minerals will precipitate and subsequently be removed from the water column by settling to the pit bottom. Minerals that were allowed to precipitate during mixing reactions for each timestep were selected based on the following (Table 16):

- Minerals predicted to be in equilibrium (saturation index > 0) in the HCT solutions were assumed to be available.

- Common minerals that precipitate and influence pit lake chemistry as summarized by Eary (1999).

- The existing Batman Pit water quality pre- and post-alkaline reagent treatment is not a direct representation of ultimate Batman Pit water quality since the pit was used to store AMD from across the mine; however, the acidic (circa 2012) and circumneutral pH (circa 2017) water quality provide "bookends" for potential minerals that may be available to precipitate.

If the mixture was not supersaturated, the mineral was not allowed to precipitate (i.e., no influence on solution chemistry). Sedimentation is expected to prevent precipitated minerals from additional interaction within the overlying water column.

The partial pressure of CO_2 was set slightly oversaturated ($pCO_2 = 10^{-3.2}$ bar) based on observations at existing pit lakes (Eary, 1999). The dissolved oxygen concentration was maintained near 8 mg/L consistent with observations within the existing Batman Pit lake.

Table 16   Mineral Phases

Equilibrium Phase	Ideal Formula
Alunite	$KAl_3(SO_4)_2(OH)_6$
Calcite	$CaCO_3$
$CoFe_2O_4$	$CoFe_2O_4$
Malachite	$Cu_2(OH)_2CO_3$
Cupricferrite	$CuFe_2O_4$
Ferrihydrite	$5Fe_2O_3 \cdot 9H_2O$
Gibbsite	$Al(OH)_3$
Gypsum	$CaSO_4 \cdot 2H_2O$
K-Jarosite	$KFe_3(SO_4)_2(OH)_6$
Brochantite	$Cu_4(OH)_6SO_4$
Chalcanthite	$CuSO_4 \cdot 5H_2O$
Goslarite	$ZnSO_4 \cdot 7H_2O$
Cerussite	$PbCO_3$
Anglesite	$PbSO_4$
Larnakite	$PbO:PbSO_4$

7.4. Evapoconcentration

Solutes within the pit lake are expected to evapoconcentrate which may facilitate formation and settling of precipitates and adsorption of constituents onto these precipitated phases.

7.5. Model Approach and Assumptions

The first step in assessing the geochemical evolution of water quality within the Ultimate Batman Pit lake was to assign the chemical composition to each inflow as described in Section 6 (Geochemical Mass Loading Sources). Additional model steps and assumptions include:

- Developed individual, charge-balanced solutions to modify concentration for slight differences in the charge balance due to averaging multiple solutions. Chloride or sodium were used since these constituents do not typically play critical roles in geochemical reactions within pit lakes.
- The individual inflow components (pit wall runoff for each geochemical zone, direct precipitation, and groundwater) were mixed according to the proportions defined by the water balance model. Geochemical mass loading associated with wall rock runoff was represented by first flush concentrations during the first year and long-term concentrations thereafter.
- Stored constituent load associated with flushing of submerged pit wall that occurred during each stage was added in proportion to the geochemical zones being inundated. Geochemical mass loading associated with wall rock submergence was represented by first flush concentrations during the first year and long-term concentrations thereafter.
- Evaporation was addressed by removing pure water based on evaporation outflow as defined by the water balance model. The mixture was subsequently readjusted to one kg of water.
- The pit lake water was equilibrated with mineral phases, redox conditions, and atmospheric gases.

- The resulting water quality was saved for the next timestep. For each subsequent timestep, the pit lake volume and water quality obtained for the previous timestep was mixed with inflows for the next timestep.

Adsorption to iron oxyhydroxides such as ferrihydrite is an important control on constituent concentrations (i.e., arsenic, cadmium, cobalt, copper, lead, zinc) (Eary, 1999). Adsorption would typically be included in the base case predictive model; however, the approach used to represent higher sulphur content PAF wall rock likely underrepresents the actual iron concentrations and the associated adsorptive capacity. Therefore, adsorption onto precipitated ferrihydrite was incorporated into the model as a sensitivity scenario as described in Section 8 (Results).

8. RESULTS

The range of predicted constituent concentrations in Batman Pit lake are summarized in Table 17. The following ANZECC and ARMCANZ (2000) guidance for livestock watering are provided for comparison:

- pH – 6 to 9
- Sulphate – 1,000 mg/L
- Aluminium – 5.0 mg/L
- Arsenic – 0.5 to 5.0 mg/L
- Cadmium – 0.01 mg/L
- Cobalt – 1 mg/L
- Copper – 0.5 to 5.0 mg/L
- Lead – 0.1 mg/L
- Zinc – 20 mg/L

Due to the lack of predicted outflow to groundwater or surface water, additional guidelines are not applicable or considered herein.

In addition to the base case predictive model, several sensitivities were simulated to assess a plausible range of conditions, including:

- The flushing scaling factor was varied from 0.15 to 0.60, equivalent to a range of blast damaged rock depth from 0.5-m to 2-m while the grain size scaling factor was maintained at the base case level of 0.05 to represent the specific surface area of 0.072 m^2/kg
- The blast damaged rock zone was maintained at 0.5-m and the grain size scaling factor was reduced to 50% of the base case level (specific surface area of 0.036 m^2/kg)
- The blast damaged rock zone was reduced to 0.3-m and the grain size scaling factor was reduced to 25% of the base case level (specific surface area of 0.018 m^2/kg)

Within 50 years, under the base case predictive model, consumption of alkalinity in the lake caused a transition to acidic conditions (pH 3.5). pH remained low (pH 3.5 to 3.7) in subsequent timesteps since the primary inflows lacked sufficient alkalinity (i.e., direct precipitation and NAF/NAF(LC) wall rock) or contributed additional acidity (PAF wall rock). Regardless of the scenario, near neutral to alkaline pH conditions were initially predicted due to the higher relative alkalinity associated with groundwater and the first flush from wall rock, the primary inflows through the first year of pit filling.

Sulphate, aluminium, arsenic, cadmium, cobalt, and zinc concentrations were predicted to remain below the guideline values through 1200 years. Copper and lead concentrations were predicted to be elevated above the 1.0 milligram per litre (mg/L) and 0.1 mg/L guideline values within 10 years consistent with increased solubility as pH decreased. Copper and lead concentrations were likely overestimated because of the conservative scaling assumptions, and lack of adsorption reactions included in the base case predictive model. Lower lead concentrations are expected based on lead concentrations near 0.3 mg/L in AMD at Mount Todd Mine with similar pH. Concentrations, except arsenic, increased from year 10 to 100 before decreasing consistent with the lower proportion of exposed PAF wall rock and increased proportion of rainfall that reported as direct precipitation on the

lake surface rather than runoff. A minor increase in constituent concentrations was predicted past 1200 years due to evapoconcentration, which was limited by inflow from direct precipitation onto the lake surface, and the dominance of NAF and NAF(LC) wall rock.

The model predictions were sensitive to changes in the scaling factors as illustrated by the lack of livestock watering guideline exceedances, except lead, when the blast damaged rock zone depth was reduced to 0.3-m and the grain size scaling factor was reduced by 75%. Likewise, increased blast damaged rock zone depth of 2-m, produced a more acidic pit lake (pH 3.3) with an associated increase in constituent concentrations except arsenic, which remained below the 0.5 mg/L guideline value in each scenario.

Adsorption of specific constituents (i.e., arsenic, cadmium, cobalt, copper, lead, zinc) to ferrihydrite was incorporated as a sensitivity scenario following Dzombak and Morel (1990) based on the mass of ferrihydrite that precipitated during equilibrium mixing. Adsorption onto wall rock, suspended iron colloids or other oxyhydroxides, and co-precipitation was not simulated but would likely result in additional removal. Adsorption had minimal influence on the model predictions due to the limited amount of dissolved iron available to precipitate as ferrihydrite both due to precipitation of iron as other mineral phases (e.g., $CoFe_2O_4$, cupricferrite), and low iron concentrations compared to the concentrations of other constituents. Constituents that were above the livestock watering guidelines in the base case predictive model remained elevated when adsorption was incorporated.

A sensitivity scenario was conducted to assess the influence of meromictic conditions on predicted surface water quality. Specifically, the final mix from the base case predictive model was adjusted to represent a bottom layer that was isolated from the mixed surface layer. The simulation represented the isolated layer by excluding dissolved oxygen and increasing pCO_2 to $10^{-2.0}$ bar consistent with levels observed in groundwater. Sulphide minerals that were allowed to precipitate if the mixture was supersaturated included chalcocite, chalcopyrite, CoS(beta), pyrite, galena, greenockite, and sphalerite. Concentrations of cadmium, cobalt, copper, lead, and zinc were reduced to sub-microgram per litre concentrations consistent with precipitation as the associated sulphide minerals. Although higher pCO_2 typically lowers pH, the effect was offset by removal of metal acidity via sulphide mineral precipitation, which increased the pH from 3.3 to 4.8. If stratification develops in the future pit lake, actual constituent concentrations at depth are likely to be intermediate between the fully mixed scenario and this sensitivity scenario. However, the predictions support the likelihood that if a chemocline develops, surface water quality is likely to be of equal or better quality than predicted for a fully mixed pit lake.

Table 17   Model Results

Parameter (mg/L unless noted)	Livestock Watering Guidelines	Scenario	Timestep						
			Initial	1 yr	10 yrs	10 to 50 yrs	50 to 100 yrs	100 to 500 yrs	500 to 1200 yrs
pH (std units)	6 to 9	Base Case (1-m DRZ, 0.072 m²/kg SSA)	8.0	8.0	6.3	3.5	3.5	3.7	3.7
		0.5-m DRZ, 0.072 m²/kg SSA	8.0	7.9	7.2	4.2	4.0	4.3	4.2
		0.5-m DRZ, 0.036 m²/kg SSA	7.9	7.9	7.5	6.3	5.7	6.1	5.8
		0.3-m DRZ, 0.018 m²/kg SSA	7.9	7.9	7.6	7.0	6.7	6.7	6.6
		2-m DRZ, 0.072 m²/kg SSA	8.0	8.0	5.1	3.1	3.1	3.3	3.3
Sulphate	1000	Base Case (1-m DRZ, 0.072 m²/kg SSA)	59.5	74.1	98.2	132	116	63.7	68.4
		0.5-m DRZ, 0.072 m²/kg SSA	41.2	49.6	54.7	67.7	58.9	32.2	34.5
		0.5-m DRZ, 0.036 m²/kg SSA	23.0	25.2	23.2	25.5	21.8	12.0	12.7
		0.3-m DRZ, 0.018 m²/kg SSA	17.1	17.4	13.1	12.0	9.9	5.4	5.7
		2-m DRZ, 0.072 m²/kg SSA	126	163	202	265	232	127	136
Aluminium	5.0	Base Case (1-m DRZ, 0.072 m²/kg SSA)	0.16	0.20	1.8	3.2	2.9	1.6	1.7
		0.5-m DRZ, 0.072 m²/kg SSA	0.11	0.14	0.94	1.6	1.4	0.80	0.87
		0.5-m DRZ, 0.036 m²/kg SSA	0.068	0.073	0.35	0.58	0.52	0.29	0.31
		0.3-m DRZ, 0.018 m²/kg SSA	0.053	0.053	0.16	0.25	0.22	0.12	0.13
		2-m DRZ, 0.072 m²/kg SSA	0.33	0.42	3.7	6.4	5.8	3.2	3.5
Arsenic	0.5 to 5.0	Base Case (1-m DRZ, 0.072 m²/kg SSA)	0.082	0.103	0.063	0.038	0.028	0.013	0.013
		0.5-m DRZ, 0.072 m²/kg SSA	0.065	0.076	0.043	0.022	0.015	0.0072	0.0070
		0.5-m DRZ, 0.036 m²/kg SSA	0.047	0.049	0.026	0.011	0.0072	0.0032	0.0030
		0.3-m DRZ, 0.018 m²/kg SSA	0.042	0.040	0.020	0.008	0.0046	0.0020	0.0018
		2-m DRZ, 0.072 m²/kg SSA	0.15	0.202	0.12	0.074	0.054	0.025	0.025
Cadmium	0.01	Base Case (1-m DRZ, 0.072 m²/kg SSA)	0.00043	0.00048	0.0042	0.0073	0.0066	0.0037	0.0040
		0.5-m DRZ, 0.072 m²/kg SSA	0.00033	0.00035	0.0021	0.0037	0.0033	0.0018	0.0020
		0.5-m DRZ, 0.036 m²/kg SSA	0.00023	0.00023	0.00081	0.0013	0.0012	0.00066	0.00072
		0.3-m DRZ, 0.018 m²/kg SSA	0.00019	0.00018	0.00038	0.00057	0.00051	0.00028	0.00030
		2-m DRZ, 0.072 m²/kg SSA	0.00079	0.0010	0.0083	0.015	0.013	0.0074	0.0080
Cobalt	1.0	Base Case (1-m DRZ, 0.072 m²/kg SSA)	0.033	0.041	0.35	0.63	0.57	0.32	0.35
		0.5-m DRZ, 0.072 m²/kg SSA	0.020	0.025	0.18	0.32	0.29	0.16	0.17
		0.5-m DRZ, 0.036 m²/kg SSA	0.0073	0.0090	0.063	0.11	0.10	0.057	0.062
		0.3-m DRZ, 0.018 m²/kg SSA	0.0031	0.0038	0.027	0.047	0.043	0.024	0.026
		2-m DRZ, 0.072 m²/kg SSA	0.081	0.10	0.71	1.3	1.1	0.64	0.70
Copper	1.0	Base Case (1-m DRZ, 0.072 m²/kg SSA)	0.0073	0.0096	1.2	2.2	2.0	1.1	1.2
		0.5-m DRZ, 0.072 m²/kg SSA	0.0045	0.0059	0.6	1.1	1.0	0.56	0.60
		0.5-m DRZ, 0.036 m²/kg SSA	0.0016	0.0022	0.22	0.39	0.36	0.20	0.22
		0.3-m DRZ, 0.018 m²/kg SSA	0.00074	0.00095	0.09	0.16	0.15	0.08	0.09
		2-m DRZ, 0.072 m²/kg SSA	0.0176	0.0233	2.5	4.4	4.0	2.2	2.4
Lead	0.1	Base Case (1-m DRZ, 0.072 m²/kg SSA)	0.020	0.025	5.8	10	9.3	5.2	5.7
		0.5-m DRZ, 0.072 m²/kg SSA	0.013	0.015	2.9	5.1	4.7	2.6	2.8
		0.5-m DRZ, 0.036 m²/kg SSA	0.0050	0.0059	1.0	1.8	1.7	0.93	1.0
		0.3-m DRZ, 0.018 m²/kg SSA	0.0026	0.0029	0.43	0.77	0.70	0.39	0.42
		2-m DRZ, 0.072 m²/kg SSA	0.048	0.059	12	21	19	10	11
Zinc	20	Base Case (1-m DRZ, 0.072 m²/kg SSA)	0.062	0.076	3.6	6.5	5.9	3.3	3.6
		0.5-m DRZ, 0.072 m²/kg SSA	0.039	0.047	1.8	3.2	2.9	1.6	1.8
		0.5-m DRZ, 0.036 m²/kg SSA	0.016	0.019	0.65	1.2	1.0	0.58	0.64
		0.3-m DRZ, 0.018 m²/kg SSA	0.009	0.010	0.27	0.49	0.44	0.25	0.27
		2-m DRZ, 0.072 m²/kg SSA	0.15	0.18	7.3	13	12	6.6	7.1

Notes:
DMZ = Blast Damaged Rock Zone
SSA = Specific Surface Area

9. CONCLUSIONS

Reasonable best estimates of future pit lake water quality were predicted based on the current project understanding and available data. Geochemical mass loading from wall rock was the primary control on predicted pit lake quality. Conservative assumptions were made for the base case predictive model consistent with industry best practices but also resulted in predicted water quality with low pH and livestock watering guideline exceedances for copper and lead. Modification of the scaling factors to account for the high hardness/competency of the metamorphosed Batman Pit wall rock resulted in predicted pit lake chemistry that met the guideline values except for lead, which is likely to be at or below concentrations observed in AMD at Mount Todd Mine. Resumption of mining in Batman Pit will provide additional field scale information regarding wall rock reactivity to support future water quality assessments and allow Vista Gold to optimize the pit lake closure strategy.

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FIGURES

N			
Gold Tollis Pits			
		RP7	
BW05			
LGQ Dump			
RP3 Pit		HLP	
BPMB02			
	WRD		
RP1			
Edith River			

0   0.5   1 Kilometers

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

| VISTA GOLD CORP. |
| MOUNT TODD GOLD MINE |
| Existing Facilities with Pit Area Groundwater Monitoring Well Locations |

PRACTICAL GEOCHEMISTRY LLC
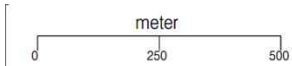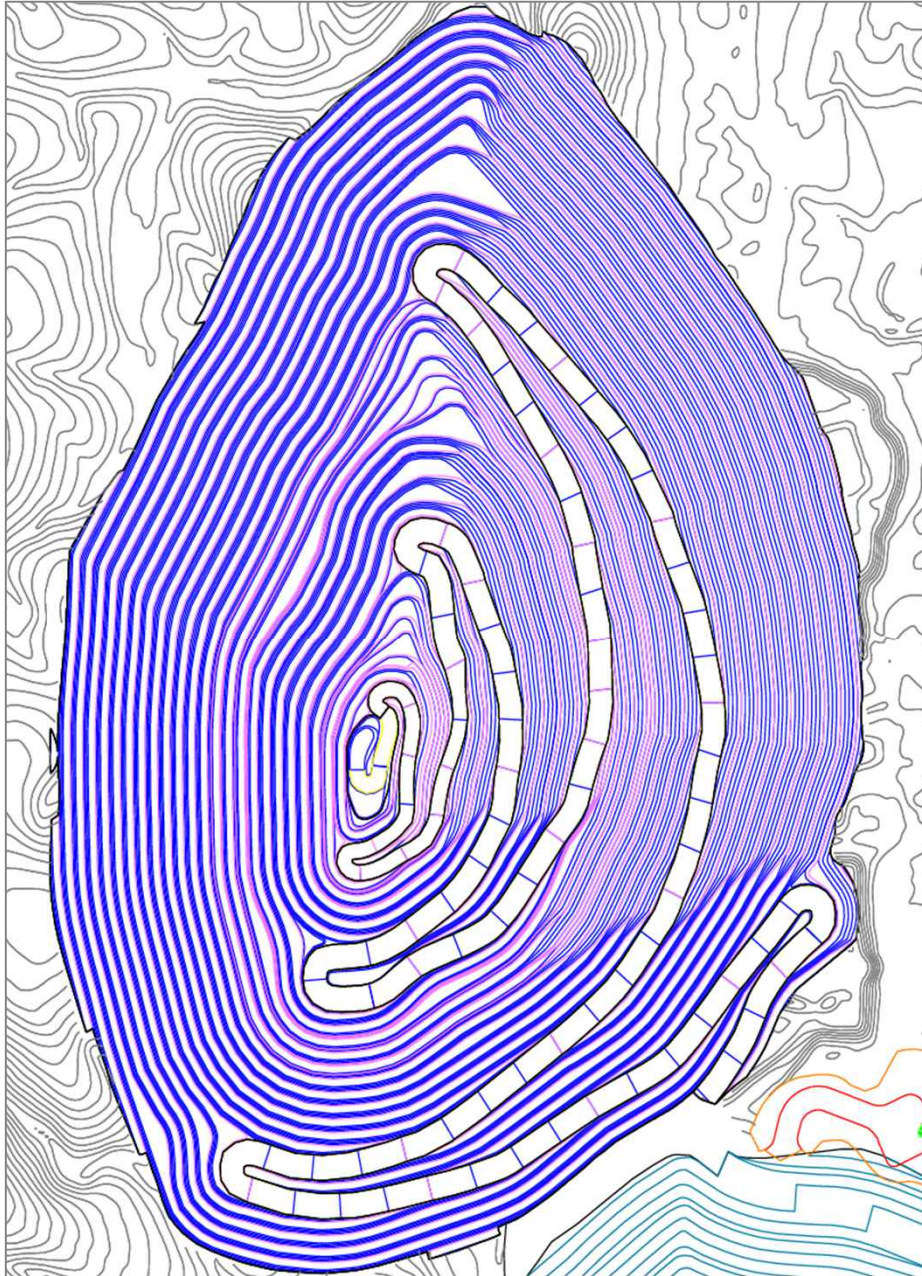
FIGURE
1

| VISTA GOLD CORP. MOUNT TODD GOLD MINE |
| Ultimate Batman Pit |

PRACTICAL GEOCHEMISTRY LLC

FIGURE

2
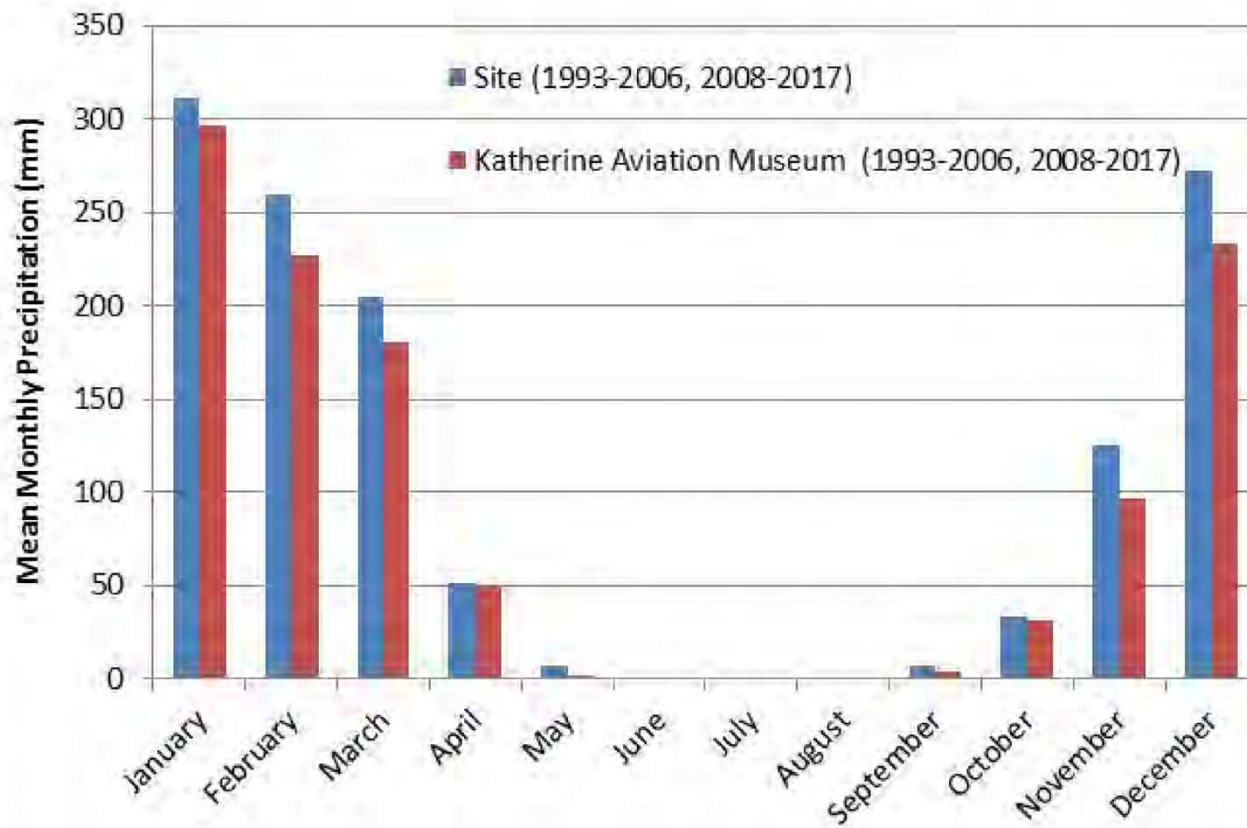
Source: Tetra Tech (2019), Figure 4-3, October 2019

VISTA GOLD CORP. MOUNT TODD GOLD MINE	
Monthly Precipitation – Mine Site and Katherine Area	
PRACTICAL GEOCHEMISTRY LLC	FIGURE 3

SURFACE

3500: ROCK CODE
OUTSIDE FW

S1300 PIT

500: ROCK CODE
OUTSIDE HW ZONES

700: HW ZONE

600: HW ZONE
(800 HW ZONE HIDDEN)

61000: CORE ZONE CODE

GRANITE SURFACE

0 ROCK CODE AIR

OXIDE 100 ROCK CODE
2.47 BULK DENSITY

TRANSITION 200 ROCK CODE
2.67 BULK DENSITY

SULFIDE 300 ROCK CODE
2.77 BULK DENSITY

CURRENT SURFACE

700

ROCK CODE 3500

ROCK CODE 1000

800

600

OUTSIDE HW
ZONES 500

S1300pl

ROCK CODE 9000

GRANITE
SURFACE 2013

GRANITE
SURFACE 2017

Source: Tetra Tech (2018), Figure 14-2, March 2018

VISTA GOLD CORP. MOUNT TODD GOLD MINE
Batman Deposit with Structures and Surface Designations (Looking North)

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FIGURE
4

Section 9WE

8,434,803 mN
Looking North

2013 Granite Contact

2017 Granite Contact

Core Truncated 2017

Explanation

2015-17 Drillhole
2012 Drillhole
2011 Drillhole
2010 Drillhole
2008 Drillhole
2007 Drillhole
Legacy Drillhole

Grade
1.5-<
1.0-1.5
0.75-1.0
0.5-0.75
0.4-0.5
0.1-0.4
0.0-0.1

Line Features
Core Complex
Granite Contact
First Hangingwall
Second Hangingwall
Inner Hangingwall

Block Classification
Measured
Indicated
Inferred
Only blocks > 0.1 shown

Source: Tetra Tech (2018), Figure 14-3, December 2018

VISTA GOLD CORP. MOUNT TODD GOLD MINE	
Batman Deposit Geologic Model Cross Section	
PRACTICAL GEOCHEMISTRY LLC	FIGURE 5
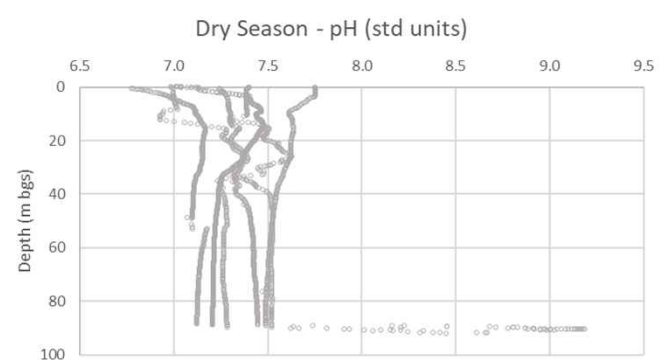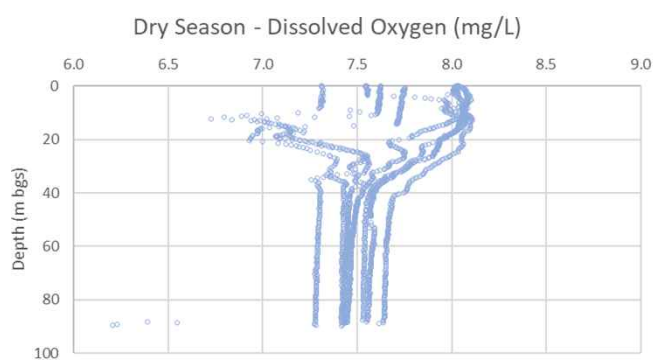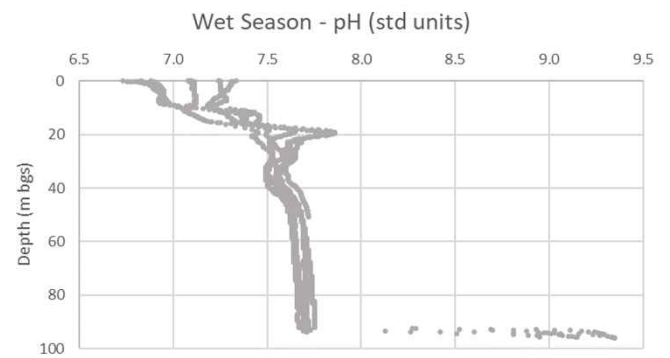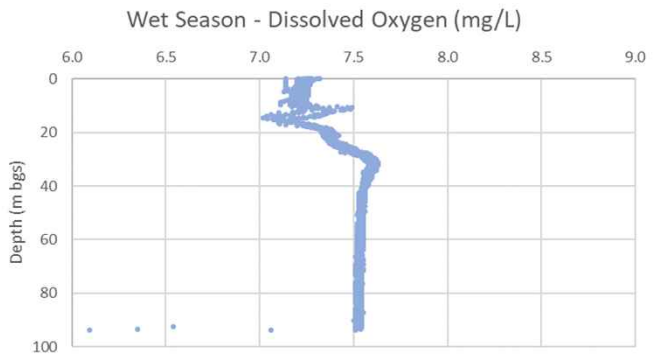
a) Dissolved Oxygen

b) pH
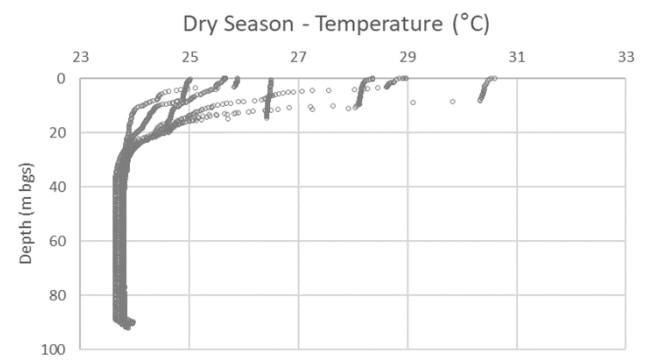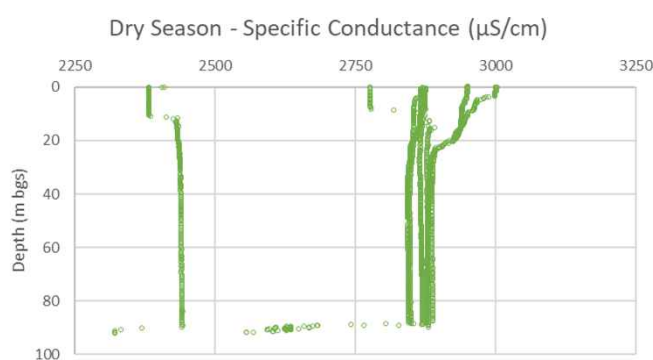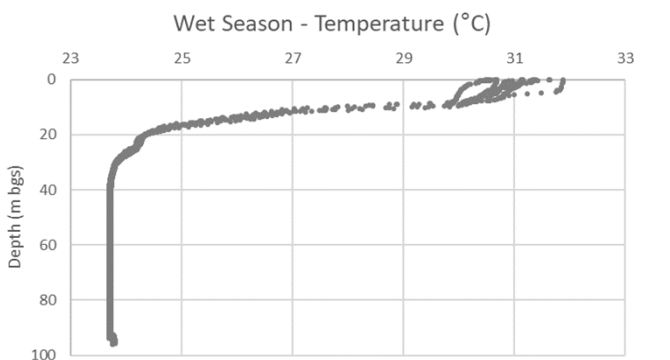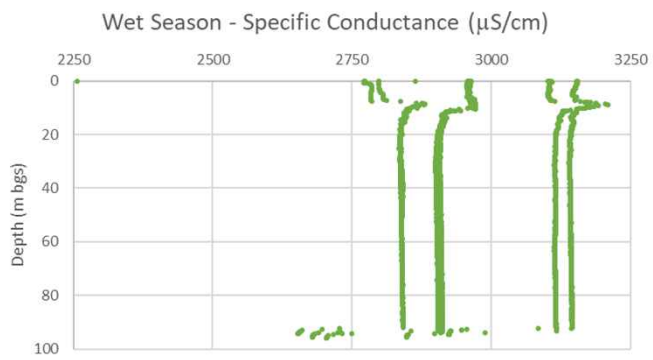
c) Specific Conductance

d) Temperature

VISTA GOLD CORP.
MOUNT TODD GOLD MINE

Existing Batman Pit Lake Depth Profiles – Dissolved Oxygen, pH, Specific Conductance, and Temperature

PRACTICAL GEOCHEMISTRY LLC
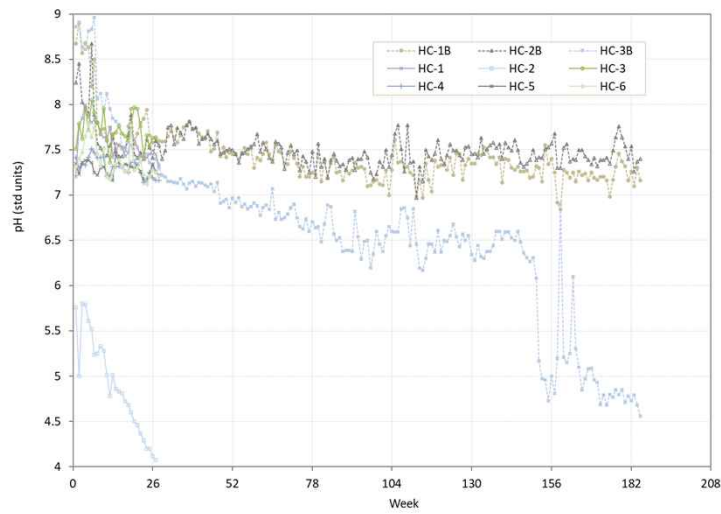
FIGURE
6

a) pH
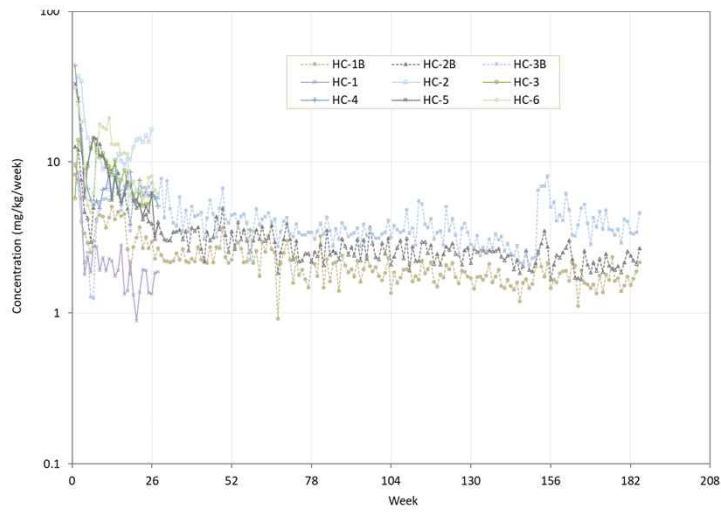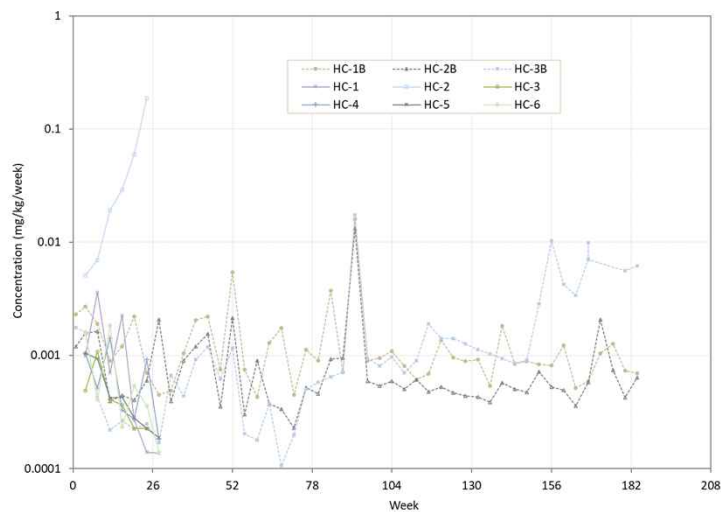
b) Sulphate

c) Copper

VISTA GOLD CORP. MOUNT TODD GOLD MINE	
Humidity Cell Test – pH, Sulphate, and Copper Temporal Trends	
PRACTICAL GEOCHEMISTRY LLC	FIGURE 7
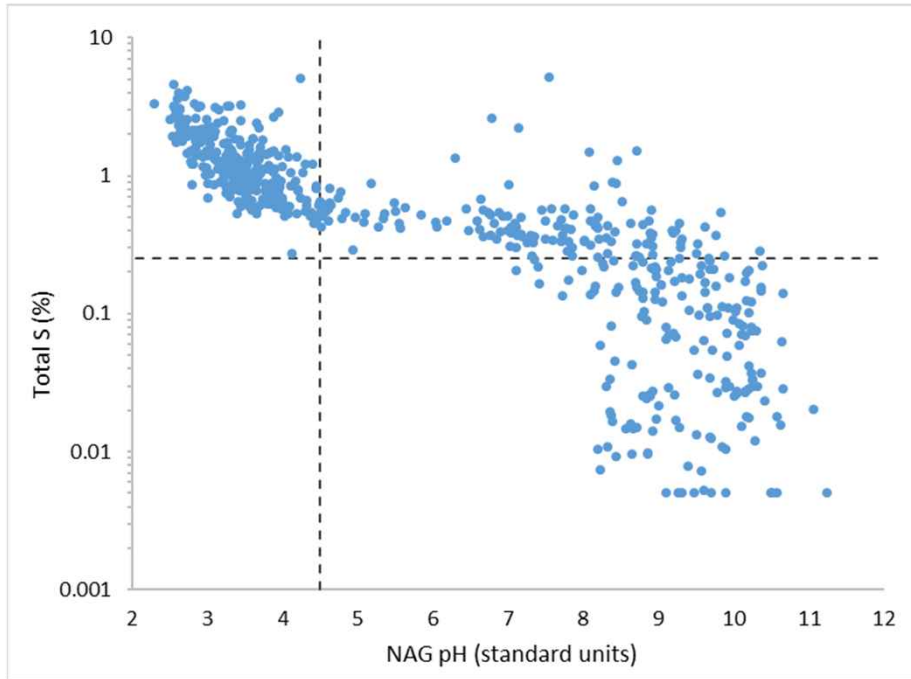
a) Total Sulphur as a function of NAG pH - VB11-011 Drillhole Samples
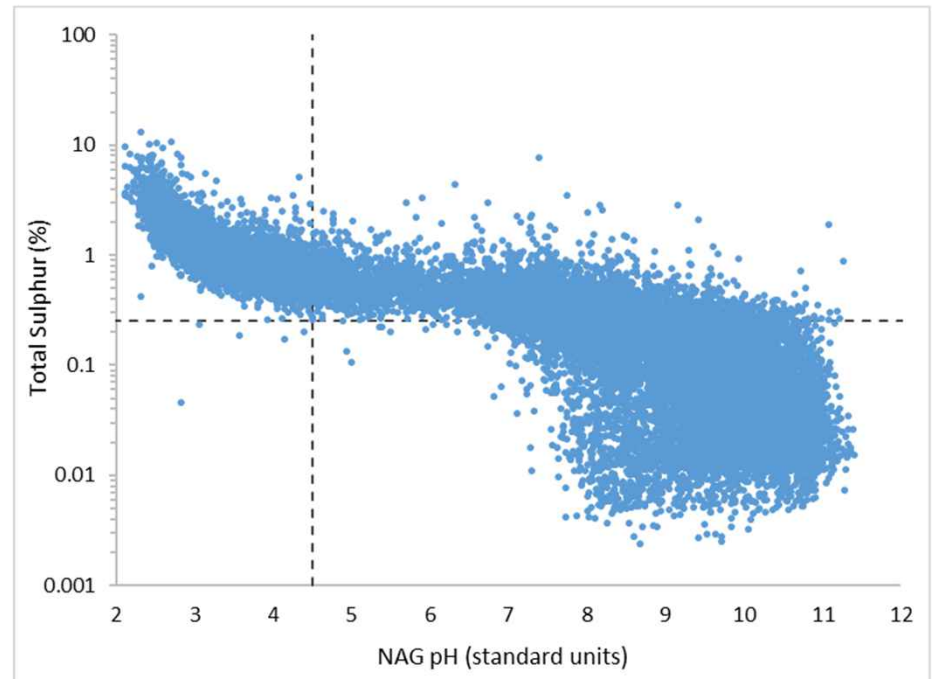
b) Total Sulphur as a function of NAG pH – Exploration Database Samples

VISTA GOLD CORP. MOUNT TODD GOLD MINE
Total Sulphur as a function of NAG pH
PRACTICAL GEOCHEMISTRY LLC — FIGURE 8

a) Plan view
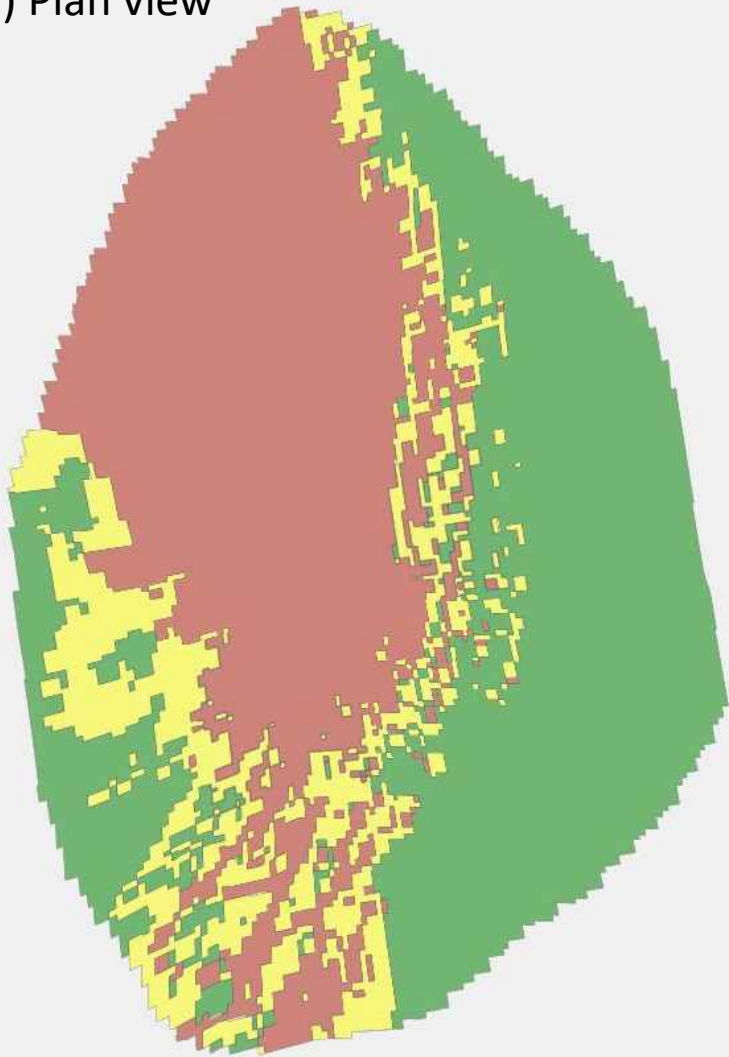
b) 3D view looking SW

c) 3D view looking NE
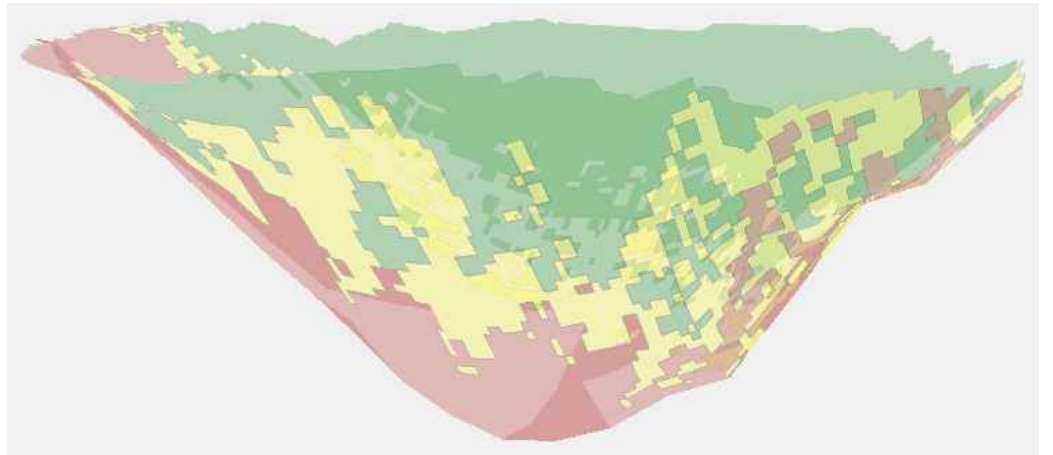
Source: Data provided by Mine Development Associates on June 10, 2020.

VISTA GOLD CORP.
MOUNT TODD GOLD MINE

Ultimate Pit with Colour Coded Wall Rock Classifications

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FIGURE
9
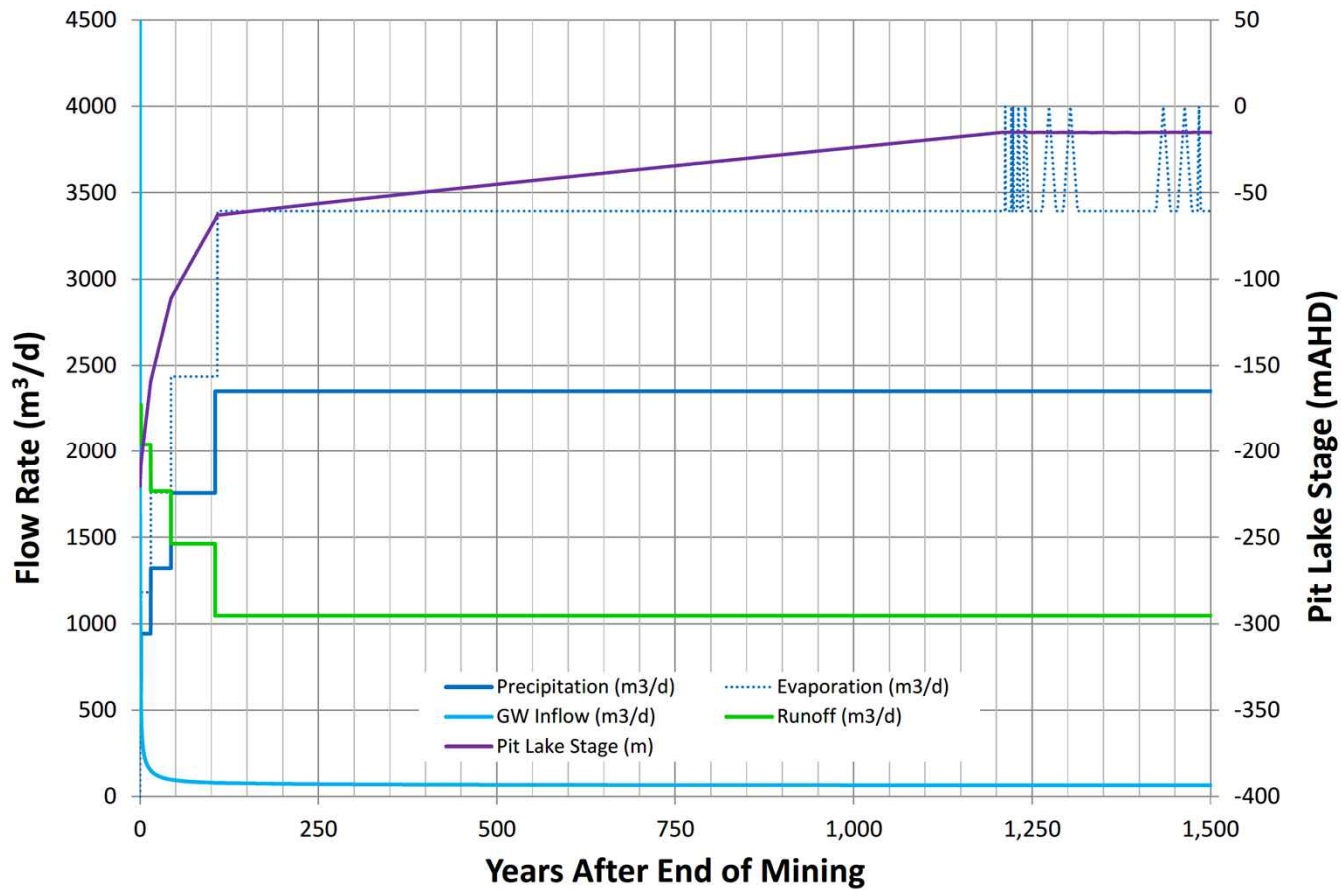
VISTA GOLD CORP.
MOUNT TODD GOLD MINE

Batman Pit Lake Filling Water Balance

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FIGURE
10

Precipitation

Evaporation

Low pH Runoff

Neutral pH Runoff

Damaged Rock Zone

Epilimnion

mixing

Pycnocline

Hypolimnion

Groundwater Inflow

Groundwater Inflow
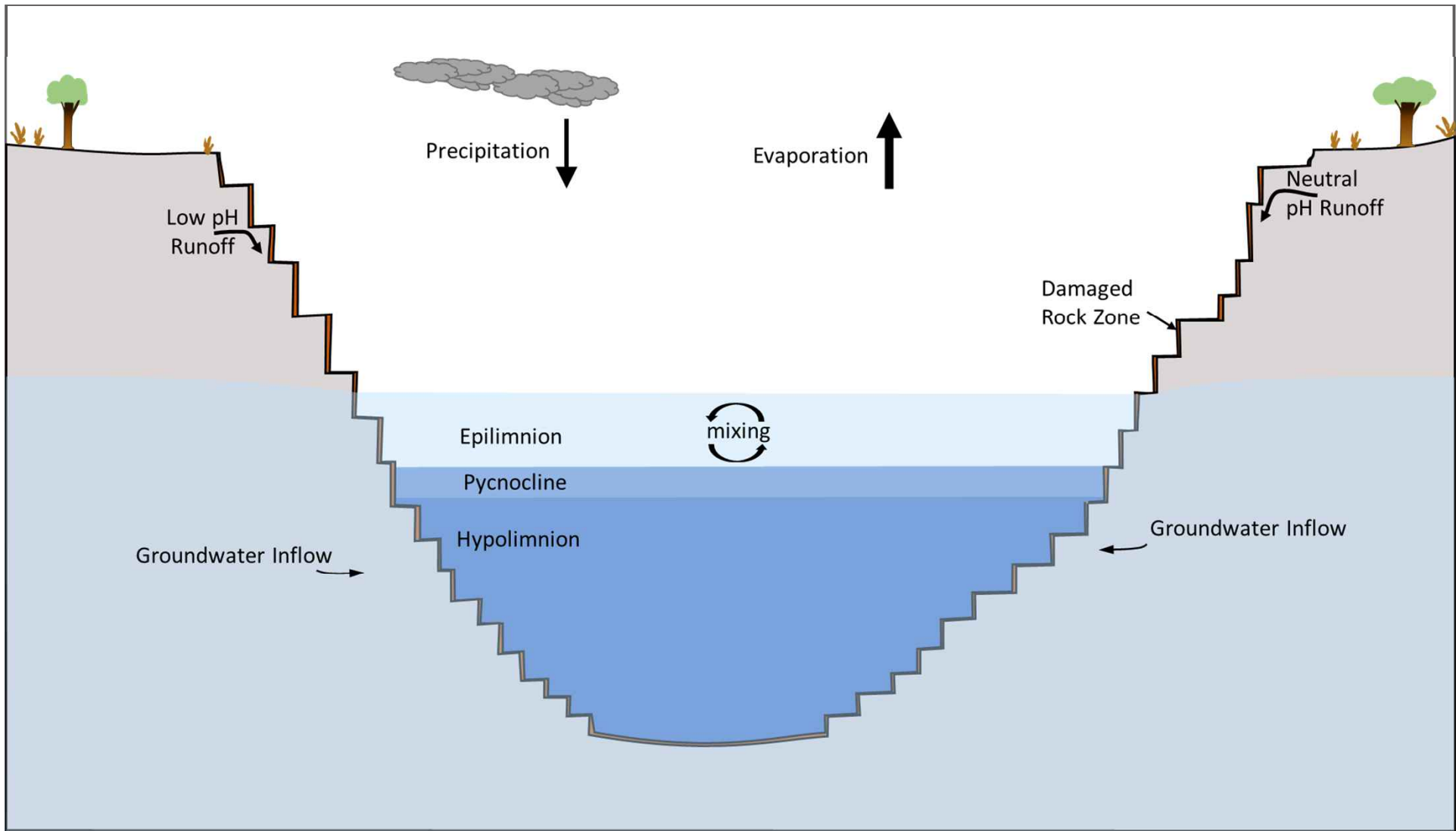
VISTA GOLD CORP.
MOUNT TODD GOLD MINE

Pit Lake Conceptual Model

PRACTICAL GEOCHEMISTRY LLC

FIGURE
11
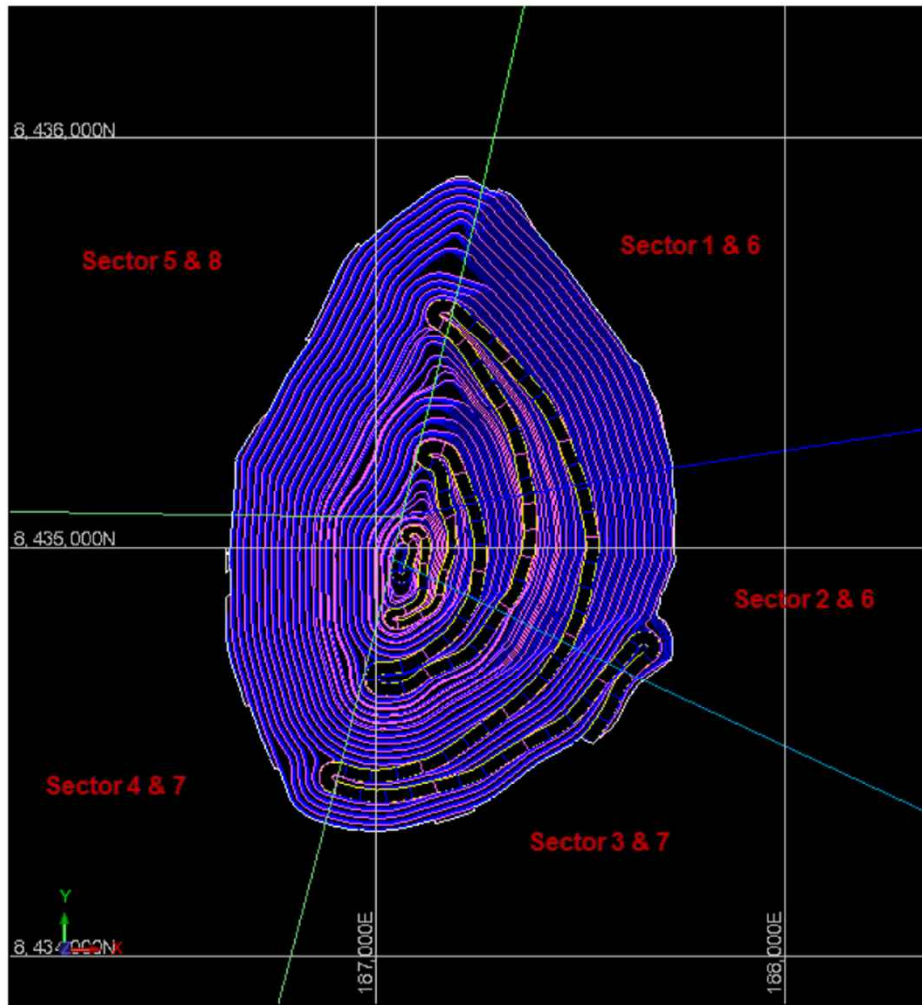
Sector	Sector	Slope Angle (°)	Adjusted Angle (°)
1	Northeast	36	33
2	East	40	36
3	South	55	50
4	Southwest	55	55
5	Northwest	51	51
6	Northeast & East Weathered	33	33
7	South & Southwest Weathered	45	45
8	Northwest - Weathered	45	45

Source: Golder Associates (2011) as cited in Mine Development Associates (2020b)

VISTA GOLD CORP.
MOUNT TODD GOLD MINE

Batman Pit Wall Slope Angles

PRACTICAL GEOCHEMISTRY LLC

FIGURE
12

VISTA GOLD CORP.
MOUNT TODD GOLD MINE

Existing Batman Pit Wall Photographs

PRACTICAL GEOCHEMISTRY LLC

FIGURE
13

Figure showing scatter plot of Total Sulphur (%) versus NAG pH (standard units) with best fit trendline.

$y = 14.18x^{-2.11}$
$R^2 = 0.57$
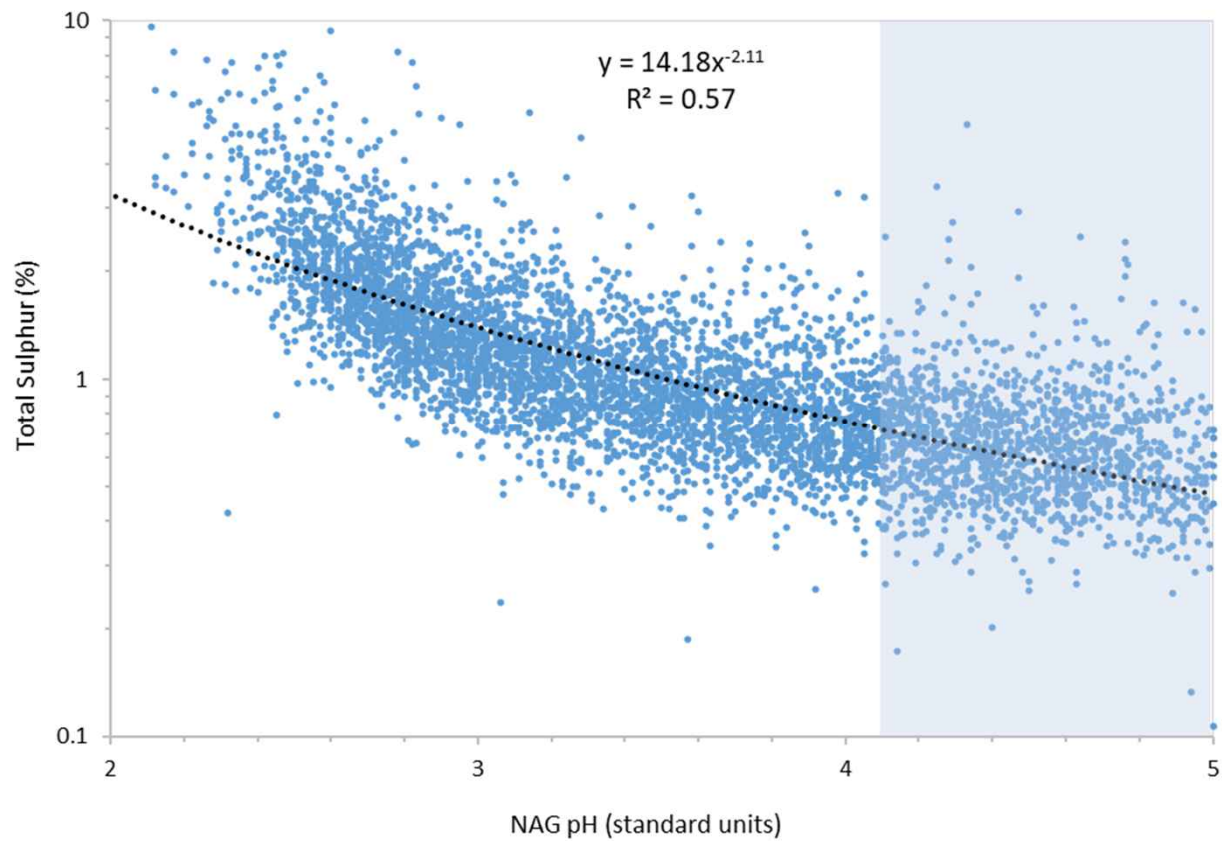
Total Sulphur	NAG pH
%	std units
0.40	4.78
0.50	4.48
0.60	4.24
0.70	4.03
0.80	3.85
0.90	3.69
1.00	3.55

VISTA GOLD CORP.
MOUNT TODD GOLD MINE

Total Sulphur and NAG pH Best Fit Trendline

PRACTICAL
GEOCHEMISTRY LLC

FIGURE
14
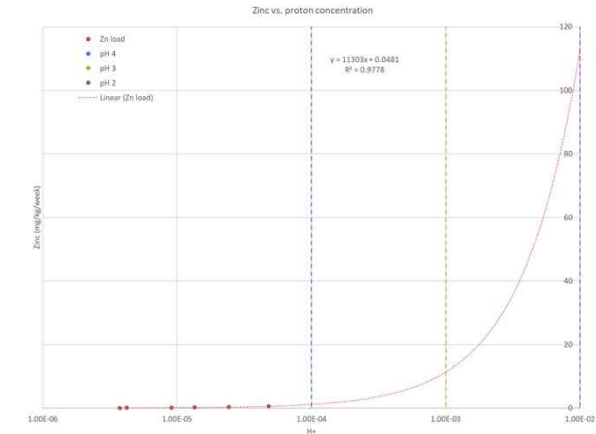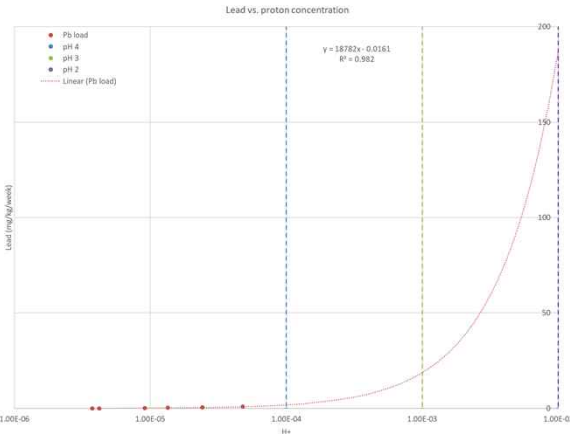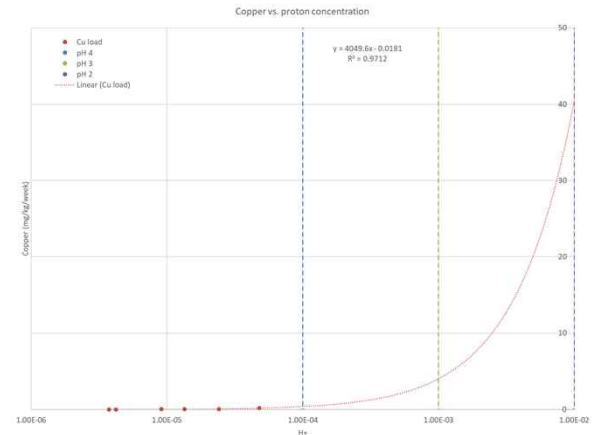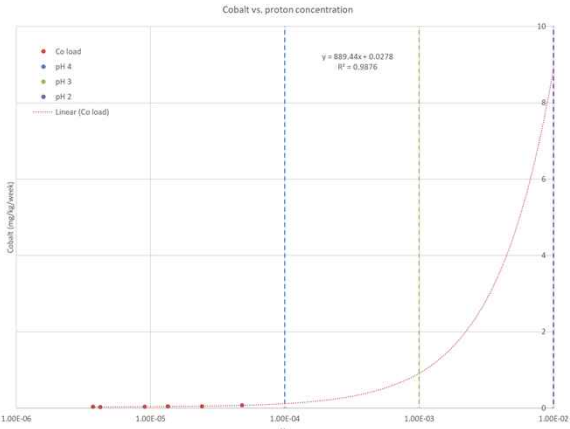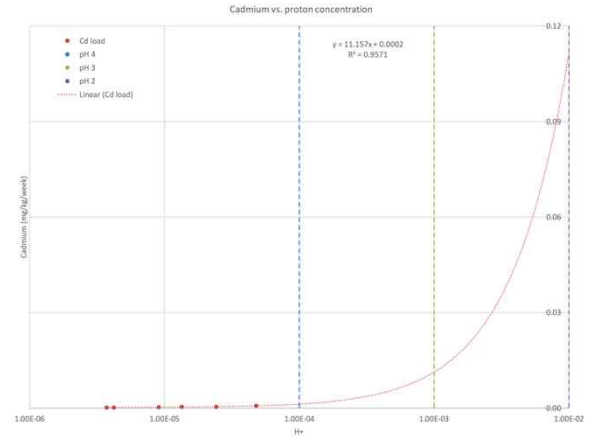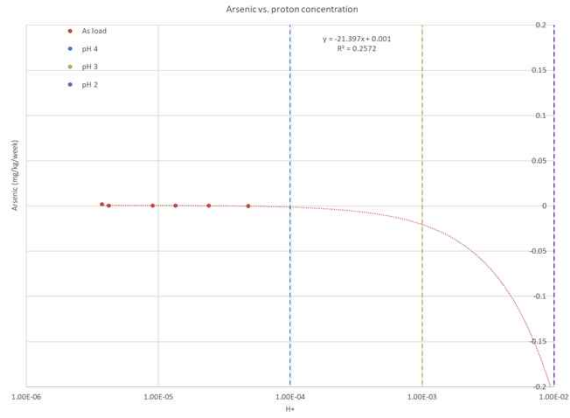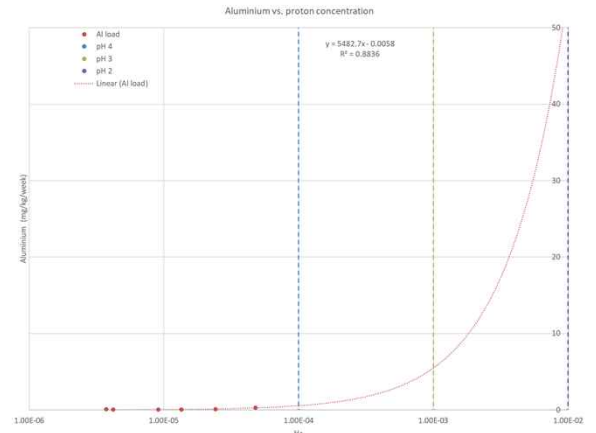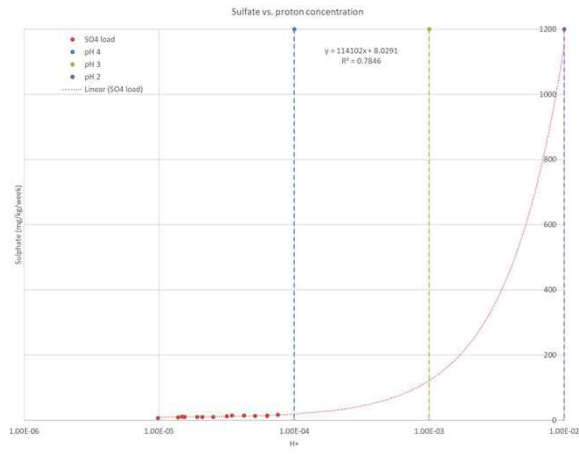
VISTA GOLD CORP.
MOUNT TODD GOLD MINE

HC-2 Scaling Approach – Sulphate, Aluminium,
Arsenic, Cadmium, Cobalt, Copper, Lead, and Zinc

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FIGURE
15