KENO HILL SILVER DISTRICT MINING OPERATIONS

TAILINGS CHARACTERIZATION PLAN, REVISION 7

October 2023

Prepared for:

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1. INTRODUCTION

1.1 PURPOSE OF PLAN

This Tailings Characterization Plan (TCP) was originally submitted to fulfill the conditions set out in Part H, Clauses 67 and 68 of Water Licence QZ09-092 issued to Alexco Keno Hill Mining Corp. on August 19, 2010.

Water licence QZ09-092 (Amendment 1) was amended on May 15, 2013 (Application QZ12-053-1) to include development and mine production from the Onek and Lucky Queen deposits. The amended licence contained replacement clauses pertaining to an update of the Tailings Characterization Plan. An amended Tailings Characterization Plan was submitted to the Yukon Water Board on January 23, 2013, in fulfillment of the Water License requirements.

Water Licence QZ09-092-2 (Amendment 2) was amended on December 22, 2017, to include development and mine production from the Flame and Moth deposits. The amended licence contained replacement clauses pertaining to an update of the Tailings Characterization Plan. An amended Tailings Characterization Plan was submitted to the Yukon Water Board to fulfill the Water License requirements.

Water Licence QZ18-044 was issued on July 23, 2020, as renewal of the previous Water Licence (QZ09-092). The licence authorizes mine development, production and milling from the Bellekeno, Flame and Moth, and Bermingham mines at the District Mill. The licence contains clauses pertaining to an update of the Tailings Characterization Plan:

29. Within 90 days of the effective date of this Licence, the Licensee must update exhibit 1.5.4, Tailings Characterization Plan (TCP) submit it to the Board.

30. The updated TCP must include:

    a. Testing procedures to be used to confirm the physical, chemical, and mineralogical properties of the tailings which will be deposited at the facility. The procedures must determine the following properties or characteristics of the tailings:

        i. soil water characteristic curve;

        ii. tailings gradation;

        iii. tailings specific gravity;

        iv. drained and undrained shear strength;

        v. tailings pore water chemistry; and

        vi. tailings mineralogy and acid base accounting.

    b. Provisions for conducting long-term humidity cell tests and saturated column tests of the Co-mingled Tailings generated through the processing of ore from the Bellekeno, Flame and Moth and Bermingham Mines.

c. Sampling frequencies for confirming the properties of deposited tailings such that the assumed long-term chemical and physical behaviour of the tailings stack can be progressively confirmed during operation of the Keno Hill Silver District Mill, and the rationale to support the recommended frequencies;

d. Proposed modifying criteria to reduce or increase frequencies identified in sub-clause c) accompanied by a supporting rationale and examples of the application of the rationale to the results of testing; and

e. An analysis of one full suite of the identified properties and characteristics for each ore body brought into production.

31. If a change to the TCP is required, the Licensee must submit the updated version to the Board prior to implementing the change.

98. The Licensee must implement long term humidity cell tests of Co-mingled Tailings to ensure adequate representation of the Co-mingled Tailings deposited in the DSTF as each new ore body is mined and shall be continued until the make up of the DSTF at the end of operations is known and a steady state has been established. Results of the long-term humidity cell tests must be submitted as part of the annual report.

This plan outlines the methodology that will be followed to comply with the requirements of these clauses and presents information supporting the Tailings Characterization Plan for use on tailings sourced from ores within the district including Flame and Moth and Bermingham.

This plan has been developed for tailings being deposited in both the Phase 1 and Phase 2 of the Keno Hill DSTF.

2. MINE LOCATION AND DESCRIPTION

The Keno Hill Silver District is located in central Yukon Territory, 354 km (by air) due north of Whitehorse. The locations of the mines and the mill described in the plan are shown on Figure 2-1. AKHM owns and operates of a series of small underground silver/lead/zinc mines with a centralized mill as described in Table 1 1. On September 7, 2022, Alexco Resource Corp. (doing business as Hecla Yukon), the parent company of AKHM, was acquired by Hecla Mining Company.

Table 1.1 Keno Hill Silver District Mining Operations Overview

MINES / ORE DEPOSITS	Bellekeno (Production 2010 – 2013, suspended 2013 – 2020, production 2020, temporary closure 2021 Flame & Moth (Development 2018, suspended 2018 – 2020, development and production 2020 - present) New Bermingham (Advanced exploration 2017 – 2018, development and production 2020 - present) Lucky Queen, Onek 990 (Advanced exploration 2013, not active)
MILL	District Mill location at Flame & Moth Mine area (Constructed 2010) Tailings placed in Dry Stack Tailings Facility (Established 2010) or underground as backfill
WORK FORCE	~ 250 employees and contractors during active mine and reclamation operations (as per Yukon Environmental and Socio-economic Assessment Act [YESAA] 2018-0169 Decision Document)
AIRSTRIP	Village of Mayo, YT
CAMP FACILITIES	Flat Creek camp facilities include a trailer camp, kitchen facility, welcoming center and dry Four refurbished houses and a bunkhouse located nearby in the townsite of Elsa
POWER	Hydro grid power Yukon Energy, diesel power backup
WATER SUPPLY AND USE	Fresh water supply from Flat Creek and adjacent well Water treatment plants at Bellekeno 625, Flame & Moth, and New Bermingham for mine effluent Process water is recycled from the Mill Pond to the District Mill
FIRST NATIONS	First Nation of Na-Cho Nyak Dun (FNNND)

The Keno Hill mining camp has a long mining history and is a brownfields site. AKHM develops the mineral resources, operates the KHSD mines and undertakes receiving environmental monitoring and treatment of mine discharge waters. Hecla Yukon's wholly owned subsidiary Elsa Reclamation and Development Company Ltd. (ERDC) undertakes care and maintenance, environmental monitoring and water treatment of historic adit drainages, district-wide closure planning, studies, and remediation of the historic environmental liabilities. Apart from waste generated using the camp facilities, waste generated by ERDC activities are outside the scope of this Plan.

The Bellekeno mine area is located approximately 3 km east of Keno City within the Keno Hill Silver District. The District Mill site and Dry Stack Tailings Facility Phase 1 and Phase II (hereinafter referred to as the "DSTF") are located approximately 1 km west of Keno City.

The Flame & Moth portal is located just to the east of the District Mill approximately 1 km west of Keno City (Figure 2-1). The Bermingham portal is situated on Galena Hill, close to the historical Bermingham 200 adit and approximately 6.5 km due west of Keno City. Please see Figure 2-1 for the site map.

Figure 2-1: Keno Hill Silver District Mining Operations Area Overview

3. PREVIOUS TAILINGS STUDIES

Under the original tailing characterization plan, all tailing materials produced were from material (mill feed) from the Bellekeno mine area. As a result of the advancements of the Flame and Moth, and Bermingham mines, additional tailing materials will be produced from these areas and become part of the mill feed. Thus, this revised tailing characterization plan is to be called the Keno Hill Silver District Mining Operations Tailings Characterization Plan.

The original version of the tailings characterization plan was based on tailings produced from mill feed from the Bellekeno mine. Since that time, the updates to the plans included tailings that would be produced from processing mill feed from the Onek and Lucky Queen deposits and, in this revision, from the Flame & Moth and Bermingham deposits.

The environmental/geochemical characteristics of the tailings are similar from mill feed across the district. This is due to the consistency of the geology across the district, as well as processing the ore from each in the same metallurgical flowsheet in the District Mill. Data for static geochemical characteristics and humidity cell testing for lab metallurgical samples are presented in Appendix 1. In addition to the static testing for all deposits across the district, this appendix includes kinetic testing on Bellekeno, Bermingham, and Flame & Moth. The geochemical and geotechnical characterization of tailings produced during operations as described in this plan, will be compared to these lab results. This will provide verification of the properties of the tailings and the expected performance of the tailings facility and management plan, or trigger additional testing as noted in Chapter 4.

The existing Dry Stack Storage Facility (DSTF) has been permitted under QML-0009 and Water Licence QZ18-044 to accommodate 907,000 tonnes of tailings. The existing DSTF is designed for 322,000 tonnes while the phase II design has a capacity of 585,000 tonnes. The details of the design criteria and slope stability analyses are presented in the design report (EBA, 2011) and discussed in the documents supporting the above-named permits. A draft detailed design report for phase 2 was submitted to EMR on July 19, 2023, and is currently under review.

Tetra Tech Inc (formerly EBA Engineering) was retained to undertake an assessment of the properties and suitability of incorporating tailings resulting from the milling of ores from Onek and Lucky Queen into the existing DSTF, which currently consists of ore from Bellekeno only. This assessment by EBA is included as Appendix 2. Although the Onek and Lucky Queen deposits are not included in the Water Licence QZ18-044 and will not be mined, tailings from Flame & Moth and Bermingham are inferred to be suitably similar to tailings from these other deposits and will be incorporated into the existing DSTF (Phase 1 and Phase 2).

4. TAILINGS CHARACTERIZATION PLAN FRAMEWORK

The tailings characterization plan provides methodology to characterize the physical and chemical and mineralogical properties of tailings produced at the Keno District mines. The Mill metallurgist for Alexco Keno Hill Mining Corp. (AKHM) will be responsible for preparing the representative monthly composites for testing.

4.1 SAMPLE COLLECTION

Tailings samples will be collected on a weekly basis to prepare a representative monthly composite. Approximately 3 kg should be collected as a grab sample from the tailings pumpbox or filter cake. The sample should be refrigerated until it is required to be issued for testing or made into a composite. The monthly composite should be prepared from equally weighted splits of the weekly samples. Similarly, quarterly and annual composites required for mineralogical and kinetic testing, respectively, will be prepared from equally weighted splits of the monthly composites.

The standard testing program includes the geochemical and physical testing monthly. Table 4-1 summarizes the testing requirements, schedule, and approximate sample masses required for each test for geochemical testing. When a new orebody is brought into production, there is a larger suite of testing required on a composite for the first full calendar month of feed through the mill at design steady state. The purpose of this testing is to confirm consistency of the new ore with the predicted characteristics, to meet design. This testing is also shown in Table 4-1 and Table 4-2 and discussed in the following sections.

4.2 GEOCHEMICAL CHARACTERIZATION

The geochemical test program for new ore bodies will include static testing (particle size distribution, acid base accounting (ABA), metal analysis, shake flask extraction (SFE), X-ray diffraction (XRD)), and kinetic testing (humidity cell for tailings going to the DSTF or saturated column for tailings used as underground backfill) on the first monthly composite of new ore feed and subsequently will follow the testing frequency outlined in Table 4-1.

Table 4-1: Testing Requirements and Frequency

		Analytical Test				
		Tailings Gradation (hydrometer)	Static Geochemistry (ABA, aqua regia metals, SFE)	Mineralogy (XRD)	Humidity Cell	Saturated Column
	Approximate (dry) mass required:	1 kg	0.5 kg	0.1 kg	1.5 kg	10 kg
Testing Frequency	Weekly		ABA and aqua regia metals (for new ore bodies or marked change in composition)			
	Monthly composite	X	X			
	Quarterly composite			X		
	New mine brought into production – first monthly composite	X (full suite of physical property tests)	X (full suite on initial sample)	X	X	X (if tailings to be used in underground backfill)

4.2.1 GEOCHEMICAL TESTING – STATIC TEST WORK

Tailings pore water chemistry will be determined through monthly monitoring of the DSTF collection sump. The DSTF collection sump is designed to collect runoff and seepage water from the tailings. This sump is located at the toe of the DSTF and seepage waters will be representative of water draining from the facility.

Chemical testing to characterize the placed tailings materials will be conducted in accordance with sampling guidance contained in Price (2009):

- A spilt of the monthly composite will be submitted for acid-base accounting (ABA) (paste pH, Sobek neutralization potential with siderite correction, total inorganic carbon by HCl leach, total sulphur by Leco, sulphate-sulphur via HCl leach, and sulphide-sulphur by difference), standard 24-hour shake flask extraction (SFE), and determination of the total metals content using aqua regia digestion and ICP-AES/MS analysis.
- The determination of the neutralization potential for these materials will be conducted using the siderite corrected method due to the elevated presence of this mineral in the tailings.
- If neutralization potential ratios for tailings are less than predicted, frequency of testing may be increased to determine variability.

The geochemical static testing will typically be conducted on a monthly composite. Weekly composite analysis will be conducted if:

- A new mine is brought into production; or
- There is a marked change in the geochemical characteristics of the static monthly data (e.g., the sulphur or metals content of the tailings is significantly higher than usual or the neutralization potential is much lower). The 95th or 5th percentile of the dataset collected to date may be used as the statistic against which such marked increases or decreases can be determined, respectively.

In such cases, weekly splits will be analyzed for ABA and aqua regia metals for at least four consecutive weeks to assess the geochemistry of the new mine or the variability in the parameter(s) that triggered the change in analytical frequency.

4.2.2 GEOCHEMICAL TESTING – KINETIC TEST WORK

Humidity cell testing is an accepted method for identification of potential long-term effects from geologic materials disturbed by mining activities (Price, 2009). A humidity cell for geochemical characterization of the placed tailings was initiated at Bellekeno in August 2011 and was operated for 208 weeks. The humidity cell sample was a composite that comprised splits collected from representative monthly composites. The humidity cell composite comprised at least 10 splits collected during the first 16 months of operation.

A humidity cell containing Flame & Moth F4 and F5 size fraction tailings generated from metallurgical testing was also conducted (operated for 113 weeks) as part of the geochemical characterization work for the Flame and Moth project.

A humidity cell composed of tailings produced from metallurgical testing of the New Bermingham mineralization was initiated in June 2018 and terminated after 103 weeks of operation. The results of the static and kinetic testing of the Bermingham tailings in comparison with the Flame & Moth and Bellekeno tailings are presented in Appendix 1 as required by Clause 1.5 (e) of Schedule C from QML-0009 prior to placement of Bermingham tailings in the DSTF.

As required by Clause 30 (b) of the Licence, additional long term humidity cell tests as well as saturated column tests will be initiated from co-mingled tailings sourced from Bellekeno, Flame and Moth, and New Bermingham ore. A humidity cell will be started if:

- There is a substantial change in the feed source for the District mill (e.g., the feed changes from 100% from a single mine to a blend of two or more mines or new ore body); or

- There is a marked change in the geochemical characteristics of the static monthly data (e.g., the sulphur or metals content of the tailings is significantly higher than usual, or the neutralization potential is much lower). The 95^{th} or 5^{th} percentile of the dataset collected to date may be used as the statistic against which such marked increases or decreases can be determined, respectively.

The humidity cell will be composed of the first monthly composite containing either the change in feed source or the anomalous geochemical characteristics defined above. In this way, a humidity cell test will be initiated as required to ensure adequate representation of the co-mingled tailings deposited in the DSTF as each new ore body is mined. All humidity cells will be continued until the makeup of the DSTF at the end operations is known or a steady state has been established.

Tailings generated will either be placed in the DSTF or used as backfill in the operating mines. The saturated column testing will be conducted on tailings to assess the acid and metal leaching from the tailings that will be deposited below the flood elevation at the underground mines. Saturated column tests will be initiated for cemented tailings generated from milling Bellekeno, Flame and Moth, and New Bermingham ores. Tailings samples that will be tested for the saturated columns will be the sub samples from the material used for tailings humidity cell testing and prepared as for backfilling (e.g., cement addition). The water sampling testing frequency will parallel that of the humidity cell testing (e.g., weekly samples).

The humidity cells will operate for a minimum of 40 weeks (Price, 2009). They will be terminated when the concentrations of constituents of potential concern (COPCs; e.g., sulphate, arsenic, antimony, cadmium, copper, lead, nickel, selenium, silver, zinc) have stabilized or are declining and lower than those observed in previous humidity cell testing. Saturated column tests will operate for a minimum of 20 weeks and will be terminated when COPC concentrations or weekly loading rates have stabilized.

4.2.3 MINERALOGICAL TESTING

While in operations, mineralogical testing of the tailings will be conducted quarterly. A quarterly composite will be submitted for quantitative Rietveld-X-ray diffraction (XRD) to determine the major mineral constituents of the tailings. Also, samples for XRD diffraction will be collected from tailings derived from metallurgical tests or processing of new ore bodies.

4.3 PHYSICAL PROPERTY CHARACTERIZATION

Clause 30 (c) of the Licence states that sampling frequencies for confirming the properties of deposited tailings can be progressively confirmed during operation along with rationale supporting the recommended frequencies. Alexco retained Tetra Tech Inc. (formerly EBA Engineering) to undertake a review of the suite of physical property testing currently completed on tailings generated at the Keno District Mill and provide recommendations for ongoing testing requirements. This review is provided as Appendix 3 and recommends reducing or eliminating some of the routine physical testing parameters. The EBA review includes discussion and rationale for the recommended changes and provides triggers for additional physical property testing beyond the routine testing.

Following this recommendation, the physical properties in Table 4-2 will be routinely determined as part of the ongoing characterization of physical parameters:

Table 4-2: Updated Routine Physical Testing Requirements

Test Description	Frequency
Tailings Gradation (hydrometer)	Monthly

The EBA review indicates that results from the full suite of physical property testing of tailings produced at the Keno Hill District Mill since 2011, including gradation, moisture (soil-water characteristic curve), weight (specific gravity), and shear strength have remained consistent. The shear strength of the tailings is controlled by the gradation, moisture, and weight of the material. It is indirectly verified through the ongoing field and laboratory testing (particle size and moisture content as the main variables). Particle size gradation and moisture content provide a good indicator of shear strength for these tailings.

The recommended monthly laboratory testing data are reviewed to confirm the consistency of the tailing's particle size gradation at the time. These data are reviewed and compared to the design criteria by site and by Tetra Tech. Should the results be inconsistent with design, additional and specific physical property testing (e.g., laboratory sheer strength determination of selected materials will be required). In addition, routine inspections of the DSTF are completed by Tetra Tech and include field density and moisture content testing of the placed tailings.

When a new mine comes into production, the first monthly composite will be tested to characterize the parameters specified in Table 1 of Appendix 3, including gradation, soil-water characteristic curve, specific gravity, shear strength. Weekly samples may also be tested if there is a marked change in the ore or milling process which would change tailings physical characteristics. These data and the testing will be reviewed by Tetra Tech to confirm consistency with design basis and previous tailings.

4.3.1 TRIGGERS FOR ADDITIONAL PHYSICAL PROPERTY TESTING

The shear strength of the placed tailings within the DSTF will be verified indirectly through standard field and laboratory testing. The overall stability of the DSTF depends on the strength of the placed tailings. Quarterly direct shear testing will be resumed if gradation results indicate a deviation of 10% or greater from the results obtained to date.

4.3.2 PHYSICAL PROPERTY TESTING METHODS

The physical parameters of the placed tailings will be verified through a combination of physical monitoring results and laboratory testing programs and modified as necessary to ensure adequate physical characterization of the tailings.

The tailings grain-size distribution will be determined using ASTM approved methods for measuring coarse and fine-grained granular materials.

A split of the monthly composite sample will be submitted for determination of the average monthly gradation. Tailings specific gravity will be determined using a split from the monthly tailings composite. The testing procedure will be conducted using ASTM approved methods.

The data will be compared to historical results to calculate variance from existing data. Should the variance exceed the accepted 10% range for each quarter, testing to determine the drained and undrained shear strength of the placed tailings will be conducted using quarterly composite samples created from the monthly composites.

5. IMPLEMENTATION SCHEDULE

AKHM commenced with the assembly of monthly composites from Bellekeno at the start of commercial production in Q1 2010 until temporary suspension of mining in Q3 2013. This program of routine physical and geochemical testing will continue as ores from Flame and Moth, and New Bermingham are added to the production stream and commercial production is resumed. Humidity cell testing on Bellekeno composites commenced in 2010 and were terminated after stability was achieved following 208 weeks. Similarly, humidity cell testing was completed on Flame and Moth (113 weeks operation) and New Bermingham (103 weeks) tailings produced from metallurgical testwork. New humidity cells and new saturated columns will be initiated and will be conducted using combined tailings from Flame and Moth, and New Bermingham as required by Clause 98 of Water Licence QZ18-044.

To satisfy Clause 30 (e) of Water Licence QZ18-044, the full suite of physical and geochemical testing described in Sections 4.1 to 4.2.2 will be conducted for tailings produced for each new ore body that is brought into production (i.e., Flame and Moth, and New Bermingham).

6. REPORTING

The results of the tailings characterization program will be included with the annual report for Water Licence QZ18-044 according to Clauses 119, 121 and 122. Additionally, Alexco will review the data semi-annually with their consultants to determine if any modifications of the plan are required.

119. The Licensee shall provide to the Board one unbound, single-sided, paper copy of all deliverable required by this Licence. All deliverables, with the exception of design drawings, must be reproducible by standard photocopier.

r) Co-mingled Tailings monitoring as required by Clause 98;

121. The Licensee shall provide to the Board one unbound, single-sided, paper copy of all deliverable required by this Licence. All deliverables, with the exception of design drawings, must be reproducible by standard photocopier.

122. The Licensee must upload electronic copies of all deliverables required by this Licence to the Yukon Water Board's online licensing registry. Electronic copies must be submitted in one of the following formats: MS Word, MS Excel, or Adobe .pdf format. Water quality results must be in the format outlined in the "Laboratory Data Submission Standards for Water Quality", as amended from time to time and available on the Board website.

7. REFERENCES

EBA Engineering. 2011. Detailed Design Dry-Stacked Tailings Facility Keno Hill District Mill Site, Yukon.

Price, W.A. 2009. Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials. MEND Report 1.20.1. CANMET – Mining and Mineral Science Laboratories, Smithers, BC.

APPENDIX 1

GEOCHEMICAL CHARACTERIZATION OF BERMINGHAM LOCKED CYCLE TAILINGS

Memorandum

To: Alexco Keno Hill Mining Corp.

From: Cheibany Ould Elemine, P.Geo., Ensero Solutions Canada, Inc.

Date: September 9, 2020

Re: Geochemical Characterization of Bermingham Locked Cycle Tailings

1 INTRODUCTION

The Bermingham Mine Development and Production Project has received Water Licence QZ18-044 and amended Quartz Mining License QML-0009 authorizing the development and production of the deposit in addition to the Flame and Moth and Bellekeno deposits. This memorandum has been updated to satisfy the requirements of the Water Licence and Quartz Mining License.

The scope of the Bermingham Project includes the development of underground workings and ventilation/escape raise, construction of surface and underground infrastructure, underground definition drilling, development of ore accesses, mining and processing ore through the Keno District Mill, deposition of waste rock on surface, treatment and release of water and deposition of tailings in the licenced Dry Stack Tailings Facility (DSTF).

To characterize the acid rock drainage and metal leaching (ARD/ML) potential related to the tailings when exposed to oxidizing surface conditions, two large tailings samples were collected from the locked cycle (LC) metallurgical testing of Bermingham ore, and tested for their geochemical composition and properties. This technical memorandum summarizes the results of the geochemical static and kinetic tests conducted on these tailings material and provide a comparison with the tailings from Flame and Moth, Bellekeno, Lucky Queen, and Onek deposits in the Keno Hill District (KHSD).

2 TAILINGS SAMPLE PREPARATION

Two representative 5.5 kg tailings samples (Berm LCT1 and LCT2) were obtained from the LC metallurgical testing and sent to Maxxam Analytics, Burnaby, British Columbia for static and kinetic testing. Each tailings sample was homogenized without any further crushing prior to shake flask extraction analysis and kinetic testing. Two subsamples of the tailings were crushed further to 85% passing 200 mesh (75 µm) for acid base accounting, elemental, and X-ray diffraction analyses.

3 LABORATORY GEOCHEMICAL TESTING

The acid base accounting (ABA) test included: paste pH, total inorganic carbon, bulk neutralization potential by the siderite-corrected method, and sulphur speciation with the sulphide sulphur determined by difference between total sulphur (Leco) and sulphate sulphur (HCl extraction). A sequential net acid generation (NAG) test was done as a cross-check on the ABA test work. The metal content of the tailings samples was determined by *aqua regia* digestion followed by inductively coupled plasma mass spectrometry (ICP-MS) analysis, and the mineralogical composition determined by X-ray diffraction (XRD) with Rietveld refinement. A standard shake flask extraction (MEND SFE) test was also performed using a 3:1 liquid to solid ratio using deionized water as leaching fluid. Kinetic testing using the standard humidity cell (HC) was also performed using the LCT2 sample. The HC analysis was started in July 2018 and terminated on June 23, 2020 after operating for 103 weeks. The cell was terminated as per standard closedown procedure and its residue subjected to ABA, bulk elemental, and XRD analyses similar to the head sample. Detailed descriptions of each of the above analytical methods can be found in Price (2009).

4 RESULTS

4.1 ACID BASE ACCOUNTING

The results of the Bermingham ABA testing are presented Table 4-1 alongside those of the Onek F7+F8 tailings, Lucky Queen F9+F10 tailings, Flame & Moth F4+F5 composite tailings and the average of monthly ABA analyses of composite tailings samples produced from Bellekeno ore between January 2011 and July 2013 (ACG, 2015). These results show that the Bermingham LC tailings have a slightly alkaline paste pH (7.6-8.15), a very high carbonate neutralization potential (carbonate-NP; 184-204 kg $CaCO_3$/t) and relatively low bulk neutralization potential (bulk NP; 50.5-56 kg $CaCO_3$/t). The carbonate-NP was significantly (3.6 times) higher than the bulk NP due to the anticipated presence of a large proportion of iron and/or manganese carbonates such as siderite and ankerite that do not contribute to the net acid neutralization under oxidizing conditions. The sulphate content of the tailings samples was extremely low (at the detection limit of 0.01 wt. %) indicating that the bulk of sulphur (1.29-1.38 wt.%) of the tailings consists of sulphide-sulphur.

The tailings from other four deposits generally have similar ABA characteristics as Bermingham tailings: They had circumneutral to slightly alkaline paste pH (7.8 to 8.1) and high carbonate NP (273 to 389 kg $CaCO_3$/t). Their carbonate-NP was significantly higher than the siderite-corrected bulk NP (100 to 132 kg $CaCO_3$/t) indicating that ferrous and or manganese carbonates such as siderite ($FeCO_3$) comprise a substantial portion of the carbonate mineralogy in the tailing like at Bermingham. The sulphate contents of the tailings from Flame & Moth, Bellekeno, Lucky Queen and Onek were also extremely low (maximum = 0.04 wt. %) indicating that the bulk of sulphur consists of sulphide-sulphur. The Bellekeno tailings contained the highest sulphide-sulphur content (2.21 wt.%), followed by the Bermingham tailings (1.29 and 1.38 wt.%). The tailings from the other three sites had sulphide-sulphur concentrations less than 0.5 wt.%; Table 4-1. The neutralization potential ratio (NPR), defined as the ratio of the (siderite-corrected) neutralization potential to the acid potential, provides an indication of acid generation over the long-term. A sample with an NPR less than one is termed "potentially acid generating (PAG), a sample with NPR greater than two is considered not potentially acid generating (non-PAG) and a sample with NPR between 1 and 2 is considered "Uncertain" with respect to acid generation and require further testing to confirm the potential ARD/ML classification.

The Bermingham tailings returned an NPR of 1.3 and was classified as "Uncertain" The other tailings had NPR greater than 2 except Bellekeno tailings which was classified as Uncertain (NPR = 1.9). Onek, Lucky Queen and Flame and Moth tailings where all non-PAG (calculated NPR > 7).

As indicated above, an NPR between 1 and 2 indicates that the potential to generate acid is Uncertain and further testing or expert judgment of the data available are needed to provide a final classification of the material. Given that the bulk NP available for acid neutralization may be underestimated due to the oxidation of Mn (II) during the siderite-corrected NP method, the NPR calculated for the Bermingham and Bellekeno tailings samples could be considerably higher. This is supported by detailed mineralogical examination of historic tailings deposited in the KHSD in which material initially classified as potentially acid generating by conventional ABA analysis but was found to be not potentially acid generating when its manganese carbonate content was included in the NPR calculation (SRK, 2009). Also, it is likely that the siderite calcian end-member will contribute some effective NP for acid neutralization.

Table 4-1: ABA Data for Bermingham LCT, Flame and Moth, Bellekeno, Lucky Queen and Onek Tailings

Sample	Paste pH	Total Sulphur	Sulphate Sulphur	Sulphide Sulphur	CO_2	CO_3-NP	Siderite-Corrected NP	AP	NPR
	pH Units	%	%	%	%	kg $CaCO_3$/t			Unitless
Berm LCT1	7.6	1.30	0.01	1.29	8.09	184	50.5	40.3	1.3
Berm LCT2	8.2	1.39	0.01	1.38	8.96	204	56.3	43.1	1.3
Onek F7 + F8 average	7.8	0.16	0.04	0.12	n/a	n/a	31.4	3.8	8.4
Lucky Queen F9 + F10 average	7.9	0.19	0.04	0.15	n/a	n/a	19.1	4.5	4.2
Flame & Moth F4+F5 Composite Tailings	8.0	0.45	0.02	0.43	17.1	389	100	14.1	7.1
Bellekeno Tailings, Jan 11- July 13 Monthly Avg.	8.1	2.3	0.02	2.21	12	273	132	71.7	1.9

AP: acid potential:
NP: neutralization potential
NPR: neutralization potential ratio

4.2 SEQUENTIAL NAG

The NAG test is often used as a cross check on the ABA results regarding potential for net acid generation. The NAG test rapidly oxidizes the sulphide in the sample by reacting it with an excess of hydrogen peroxide. In this work, the NAG test was performed sequentially such that four successive NAG cycles were conducted on the same sample to ensure all of the available sulphide-sulphur was oxidized. The pH of the NAG leachate after each cycle provides an indication of the capacity of the acid neutralizing minerals in the sample to buffer the acid produced from sulphide oxidation and therefore the overall net acid generation potential of the sample.

The results of the sequential NAG reported in Table 4-2 show that a negligible amount of acidity (i.e., 0.19 kg $CaCO_3$/t) was generated during the test and only during the first cycle suggesting a very low oxidation rate or that the sulphides content of the tailings is not reactive. The potential for acid generation is considered low because the NAG pH was circumneutral during the four cycles; the NAG test indicates a sample is non-PAG if the NAG pH is greater than 4.5. In short, the sequential NAG provides clarification regarding the "Uncertain" acid generation potential indicated by the ABA work – that is, net acid generation is not expected from these tailings. Ongoing kinetic testing will provide further confirmation of the ARD potential of the Bermingham tailings. The NAG test was not conducted on tailings from other sites to provide a site wide comparative assessment.

Table 4-2: Sequential NAG Data for Bermingham Locked Cycle Tailings

Sample ID	Cycle Number	NAG pH	NAG Volume to pH 4.5	NAG Volume to pH 7.0	NAG NaOH Conc.	NAG Acidity pH 4.5	NAG Acidity pH 7.0
		pH Units	mL	mL	N	kg $CaCO_3$/t	kg $CaCO_3$/t
Berm LCT2	Cycle 1	6.56	0.0	0.1	0.1	0.000	0.192
	Cycle 2	7.81	0.0	0.0	0.1	0.000	0.000
	Cycle 3	8.28	0.0	0.0	0.1	0.000	0.000
	Cycle 4	7.81	0.0	0.0	0.1	0.000	0.000

4.3 MINERALOGY

The mineralogical composition of the tailings was determined by XRD and the results of the test are reported in Table 4-3. These results show that the Bermingham tailings are mainly composed of quartz (SiO_2; 59.3 to 63.2 wt. %) and calcium rich siderite ($FeCO_3$; 21.2 to 27.8 wt. % as calcian siderite) similar to the Flame & Moth and Bellekeno tailings. The Bermingham tailings contain sulphide minerals, the main source of acidity, as pyrite (FeS_2; 1.6 to 2.2 wt. %), sphalerite (ZnS; 0.3 to 0.6 wt. %) and galena (PbS; 0.3 to 0.8 wt. %). Pyrite content was similar to the concentration in the Bellekeno tailings (2.3 wt.%) but Flame and Moth pyrite content were low (0.7 wt.%). Sphalerite and galena were less abundant or comparable in the Bermingham tailings samples than in the Bellekeno tailings (2.4 wt.% sphalerite; 0.6 wt.% galena) and completely absent from the Flame and Moth composite tailings.

In addition to calcian siderite, the Bermingham tailings contained another carbonate mineral, ankerite (Ca (Fe, Mg, Mn) (CO_3)2; 1.0 to 1.4 wt. %), with no effective buffering capacity. Ankerite was also identified in the

Bellekeno tailings (0.4 wt.%), but was not detected in the Flame & Moth composite. No calcite ($CaCO_3$) was detected in the Bermingham samples, which differed from the 1.2 and 3.2 wt.% calcite content in the Flame & Moth and Bellekeno tailings, respectively. These data indicate that the Bermingham tailings consist predominantly of geochemically inert silica (~ 60 wt. %) and iron and manganese carbonate minerals (28 wt. %) like other tailings. The major difference between the three is the lack of calcite in the Bermingham tailings, the lack of sphalerite and galena in the Flame and Moth tailings and the presence of trace chalcopyrite (0.1 wt. %) and wurtzite (0.2 wt. %) in Bellekeno tailings.

Iron and manganese carbonates have a net neutral buffering capacity under aerobic conditions because the amount of acidity consumed during dissolution is subsequently generated during the oxidation and hydrolysis of ferrous iron. However, the XRD data indicates a calcium rich siderite where substitution of calcium for iron occurs which may result in some neutralization capacity of a portion of the siderite.

The Bermingham potential AP estimated from the pyrite content of the tailings (AP = ~37 kg $CaCO_3$ /t) is slightly lower than the AP from the ABA meaning that the sulphide-sulphur from galena and sphalerite, minerals that do not generate acid when oxygen is the only oxidant, may be the source of excess of AP in the ABA test. The XRD data corroborate the Bermingham sample ABA showing that the lower siderite-corrected NP is likely due to the deficiency of calcite content relative to the other tailings. Although both the Bermingham and Bellekeno tailings samples share similar pyrite concentrations (1.6 to 2.2 and 2.3 wt.%, respectively), the higher AP for the Bellekeno sample mainly reflects its higher sphalerite content and the presence of trace chalcopyrite and wurtzite compared to that of the Bermingham samples. The low AP of the Flame & Moth sample is due to its low pyrite content (0.7 wt.%) and absence of other sulphides.

Table 4-3: Mineralogy of Bermingham LCT, Flame and Moth and Bellekeno Tailings

Mineral	Bermingham LCT1	Bermingham LCT2	Flame & Moth F4 + F5 Composite	Bellekeno Tailings Monthly Composite July 12 - Aug 13
Ankerite – Dolomite	1.4	1.0	-	0.4
Calcite, Magnesian	-	-	1.2	3.2
Cassiterite	-	-	0.5	-
Clinochlore	-	-	1.3	0.4
Dravite	-	-	3.2	-
Galena	0.8	0.3	-	0.6
Illite-Muscovite 2M1	9.6	8.2	2.5	6.6
Kaolinite	1.0	0.9	-	-
Pyrite	1.6	2.2	0.7	2.3
Quartz	63.2	59.3	45.2	52.6
Rutile ?	0.6		-	0.3
Siderite, calcian	21.2	27.8	45.3	29.8
Sphalerite	0.6	0.3	-	2.4
Plagioclase	-	-	-	0.8
Gahnite	-	-	-	0.2

Mineral	Bermingham LCT1	Bermingham LCT2	Flame & Moth F4 + F5 Composite	Bellekeno Tailings Monthly Composite July 12 - Aug 13
Chalcopyrite	-	-	-	0.1
Wurtzite	-	-	-	0.2
K-Feldspar	-	-	-	0.3
Total	100	100	100	100

4.4 METALS CONTENT

The bulk metal concentration of an element provides a preliminary indication of constituents that are elevated or depleted in a geologic material and should be monitored during leaching tests. However, the enrichment or depletion of a constituent in a sample is not a direct measure of their potential mobility or bioavailability (or lack thereof) because several parameters, including but not limited to, site hydrogeology, biogeochemistry, climate, pH and redox conditions ultimately determine the mobility and bioavailability of an element.

The results of the solid-phase metals analysis of the Bermingham LC tailings are presented in Table 4-4 alongside that of the Flame & Moth F4+F5 composite tailings, Onek F7+F8 tailings, Lucky Queen F9+F10 tailings, and the monthly average of tailings from Bellekeno between July 2012 and August 2013.

A premilitary screening of the tailings metal content against the 10x their crustal abundance (CRC, 2005) was done and revealed that antimony, arsenic, bismuth, cadmium, lead, manganese, selenium, silver, and zinc were typically high. The elevated metals and metalloids concentration were expected considering the source of the parent material (i.e., ore). The enrichment or depletion of metals in the Bermingham tailings was assessed by comparison with the tailings from other deposits and focused on a few of those identified during preliminary screening because of their potential for environmental concern namely; antimony, arsenic, cadmium, lead, selenium, silver and zinc.

The Bermingham tailings contained similar arsenic content to the Onek, ,1.7 and more than 5 times lower than Flame and Moth tailings and Bellekeno, respectively, and twenty times higher than the arsenic concentration in the Lucky Queen tailings. The highest antimony was in the Bellekeno (121 mg/L) and was nearly three times greater than the Bermingham (BERM LCT2) and Flame and Moth tailings and more than thirteen times that of Onek and Lucky Queen.

The cadmium and zinc concentration in the Bermingham tailings were higher than that of both the Lucky Queen (*ca.* 4- to 11-fold higher) and Flame and Moth (*ca.* 2- to 3-fold higher) tailings, but approximately 2- to 7-fold lower than the Onek tailings and Bellekeno, respectively. Lead content of the Bermingham tailings sample BERM LCT1 was 3 times higher than BERM LCT2 and was the highest among the all tailings. The lead content of BERM LCT2 was approximately 3 to 6 times higher than the Onek, Lucky Queen, and Flame and Moth tailings but 2.7 lower than Bellekeno tailings. The Bellekeno tailings generally had the highest concentration of these elements, with arsenic, antimony, cadmium, and zinc concentrations present at levels three- to seven-fold higher levels than those in the Bermingham tailings.

The Bermingham, Flame and Moth and Bellekeno tailings contained comparable concentrations of selenium concentrations. Bermingham tailings sample LCT2 and Bellekeno also had comparable silver content 50 to 56 ppm, that was four to seven time higher than Flame and Moth, Onek and Lucky Queen. But Bermingham tailings sample LCT1 had a silver concentration nearly twice that of Bellekeno.

The metal concentrations of lead and zinc are particularly elevated in Bellekeno, Lucky Queen and Bermingham tailings because they are the main base metals in sphalerite, galena chalcopyrite and wurtzite remaining in the tailing after processing as indicated by the results of XRD. The high concentration of arsenic is likely due to its known presence as trace element in sulphidic ore. The potential for leachability and solubility of these metals and metalloids is assessed in the SFE and HC tests.

Table 4-4: Elemental Content of Bermingham LCT, Flame and Moth, Bellekeno, Lucky Queen and Onek Tailings

Element	Unit	Berm LCT1	Berm LCT2	Onek F7 + F8 average	Lucky Queen F9 + F10 average	Flame & Moth F4+F5 Composite	Bellekeno Tailings Monthly Composite Jul 12 - Aug 13
Aluminum (Al)	%	0.15	0.16	0.36	0.74	0.2	0.2
Antimony (Sb)	ppm	99.8	44.6	<5	9	41	120.6
Arsenic (As)	ppm	369	401	375	17.5	699	2147
Barium (Ba)	ppm	30	30	24	125	11.5	16.4
Bismuth (Bi)	ppm	0.06	0.04	<2	<2	6.59	2.1
Cadmium (Cd)	ppm	46.1	23.4	72.8	3.95	7.19	165.8
Calcium (Ca)	%	0.63	0.73	0.47	0.38	0.59	1.52
Chromium (Cr)	ppm	133	115	174	265.5	185.5	5.5
Cobalt (Co)	ppm	4.3	4.3	2	3	2.7	9.9
Copper (Cu)	ppm	60.8	57.5	377	254	565	242.4
Iron (Fe)	%	6.35	7.07	18.6	6.4	16.3	10.1
Lead (Pb)	ppm	7460	2330	413	555	789	6359
Magnesium (Mg)	%	0.32	0.36	0.47	0.34	0.31	0.31
Manganese (Mn)	%	37900	4.43	5.19	2.47	4.28	3.22
Mercury (Hg)	ppm	0.19	0.13	n/a	n/a	0.055	0.19
Molybdenum (Mo)	ppm	2.06	2.02	<1	2	3.74	1.16
Nickel (Ni)	ppm	49.8	49.1	44	51	86.6	19.5
Phosphorus (P)	%	290	0.032	0.014	0.013	0.01	0.02
Potassium (K)	%	0.07	0.08	0.08	0.275	0.03	0.04
Selenium (Se)	ppm	0.9	0.8	n/a	n/a	0.1	0.52
Silver (Ag)	ppm	99.6	56.4	6.4	16.4	12.35	50.1
Sodium (Na)	%	<0.01	<0.01	0.02	0.025	0.006	0.014
Strontium (Sr)	ppm	14.3	15	11	15	4.81	24
Thallium (Tl)	ppm	0.78	1.9	17.5	11	0.652	0.129
Tin (Sn)	ppm	2.7	2	n/a	n/a	32.9	17.6
Titanium (Ti)	%	<0.005	<0.005	<0.01	0.02	0.001	0.002
Uranium (U)	ppm	0.39	0.38	n/a	n/a	0.406	1.052
Vanadium (V)	ppm	6	5	5.5	12.5	9.4	5.18
Zinc (Zn)	ppm	3510	2080	8784	557	1265	12623

4.5 SHAKE FLASK EXTRACTION

SFE provides preliminary indication of the leachability, solubility and potential mobility of metals and metalloids during short-term leaching by meteoric water under oxidizing conditions. SFE is also used to screen for potential exceedances of water quality objectives, discharge standards or generic water quality guidelines.

The results of the SFE of all tailings are reported in Table 4-5 alongside the Keno Hill District Mill Site pond effluent quality standards (EQS) at KV-83. Table 4-5 shows that Bermingham tailings had a circumneutral pH (pH= 7.3-8.2) consistent with the ABA paste pH, low leachable sulphate content (19.1-46.1 mg/L) and no measurable acidity (less than the method detection limit of 0.5 mg/L $CaCO_3$). Table 4-5 also show that SFE was also circumneutral for those tailings (i.e., Lucky Queen) for which the SFE pH data was available.

To screen for potential water quality exceedances, the SFE data were compared with the Mill pond EQS as any seepage would report to the mill pond. No exceedance of the Mill pond EQS were found in any of the tailings. The solubility of metals and metalloids highlighted in Section 4.4 as elevated in the tailings did not generate exceedances despite the vigorous condition of the SFE test. Note that the comparison of result of SFE data with the EQS is not and should not be used as a measure of compliance with site water quality standards and objectives. Rather, the comparison provides a guide for potential constituents of concern in drainage from the tailings, which should be confirmed by kinetic testing.

Table 4-5: SFE Results for the Bermingham LCT, Flame and Moth, Bellekeno, Lucky Queen and Onek Tailings

Leachable Metals	Unit	Berm LCT1	Berm LCT2	Flame & Moth F4+F5 Composite	Bellekeno Tailings Monthly Composite July 12 - Aug 13	Lucky Queen F9	Lucky Queen F10	KHSD Mill Site EQS (KV-83)
pH	pH units	7.27	8.17	7.90	-	8.1	8.0	6.5-9.5
EC	uS/cm	154.5	97.1	547	-	434	352	
SO_4	mg/L	46.1	19.1	245	-	183	140	
Acidity to pH4.5	mg/L	<0.5	<0.5	-	-	-	-	
Acidity to pH8.3	mg/L	2.1	<0.5	-	-	-	-	
Total Alkalinity	mg/L	11	14	39.9	-	28.2	25.1	
Bicarbonate	mg/L	14	18	-	-	-	-	
Carbonate	mg/L	<0.5	<0.5	-	-	-	-	
Hydroxide	mg/L	<0.5	<0.5	-	-	-	-	
Fluoride	mg/L	0.27	0.2	0.189	-	0.078	0.035	
Hardness $CaCO_3$	mg/L	55.6	35	-	-	204	158	
Aluminum (Al)-Leachable	mg/L	0.00609	0.0214	0.0109	0.0282	<0.0050	<0.0005	
Antimony (Sb)-Leachable	mg/L	0.00419	0.0111	0.0217	0.0387	0.016	0.0116	
Arsenic (As)-Leachable	mg/L	0.000219	0.000331	0.0061	0.0072	<0.0010	<0.0010	0.1
Barium (Ba)-Leachable	mg/L	0.0354	0.0134	0.0253	0.0234	0.037	0.0459	

Leachable Metals	Unit	Berm LCT1	Berm LCT2	Flame & Moth F4+F5 Composite	Bellekeno Tailings Monthly Composite July 12 - Aug 13	Lucky Queen F9	Lucky Queen F10	KHSD Mill Site EQS (KV-83)
Beryllium (Be)-Leachable	mg/L	<0.000010	<0.000010	<0.00050	<0.00050	<0.00050	<0.00050	
Bismuth (Bi)-Leachable	mg/L	<0.0000050	<0.0000050	<0.00050	<0.00050	<0.00050	<0.00050	
Boron (B)-Leachable	mg/L	<0.050	<0.050	0.071	0.0942	0.025	0.014	
Cadmium (Cd)-Leachable	mg/L	0.0027	0.000309	0.0024	0.00318	0.00164	0.0509	0.01
Calcium (Ca)-Leachable	mg/L	18.7	12.4	105	138	74.9	59.6	
Chromium (Cr)-Leachable	mg/L	<0.00010	<0.00010	<0.00050	<0.00050	<0.00050	<0.00050	
Cobalt (Co)-Leachable	mg/L	0.000925	0.000099	0.0004	0.00031	0.0002	0.00702	
Copper (Cu)-Leachable	mg/L	0.000116	0.000334	0.0271	0.0096	0.0303	0.0503	0.1
Iron (Fe)-Leachable	mg/L	0.0022	<0.0010	<0.030	<0.030	<0.030	<0.030	
Lead (Pb)-Leachable	mg/L	0.0607	0.0188	0.0144	0.0593	0.0181	0.112	0.2
Lithium (Li)-Leachable	mg/L	0.00339	0.00294	0.0071	0.0339	<.0.0050	<.0.0050	
Magnesium (Mg)-Leachable	mg/L	2.15	0.988	6.9	6.01	3.96	2.27	
Manganese (Mn)-Leachable	mg/L	2.28	0.445	1.95	0.797	0.765	1.14	
Mercury (Hg)-Leachable	mg/L	<0.000050	<0.000050	0.0001	<0.000050	<0.000050	<0.000050	
Molybdenum (Mo)-Leachable	mg/L	0.000225	0.000928	0.0024	0.0108	0.00318	0.000718	
Nickel (Ni)-Leachable	mg/L	0.00213	0.000368	0.0012	0.0009	0.0006	0.00253	0.5
Phosphorus (P)-Leachable	mg/L	0.0503	0.0414	<0.30	<0.30	<0.30	<0.30	
Potassium (K)-Leachable	mg/L	1.89	1.7	2.04	10.6	3.93	1.87	
Selenium (Se)-Leachable	mg/L	0.000058	0.000041	0.0009	0.00106	0.00871	0.00463	
Silicon (Si)-Leachable	mg/L	0.42	0.45	1.55	3.4	1.91	1.11	
Silver (Ag)-Leachable	mg/L	<0.0000050	0.00003	0.0009	0.0018	0.000144	0.00627	0.02
Sodium (Na)-Leachable	mg/L	0.854	0.596	2.36	24.1	6.19	4.57	
Strontium (Sr)-Leachable	mg/L	0.0261	0.0172	0.38	0.515	0.193	0.141	
Thallium (Tl)-Leachable	mg/L	0.000335	0.000177	0.0001	0.0002	0.00011	<0.00010	
Tin (Sn)-Leachable	mg/L	<0.00020	<0.00020	<0.00050	<0.00050	<0.00050	<0.00050	
Titanium (Ti)-Leachable	mg/L	<0.00050	<0.00050	0.01	0.012	<0.010	<0.010	
Uranium (U)-Leachable	mg/L	<0.0000020	<0.0000020	0.000048	0.00162	0.000011	<0.000010	
Vanadium (V)-Leachable	mg/L	<0.00020	<0.00020	<0.0010	<0.0010	<0.0010	<0.0010	
Zinc (Zn)-Leachable	mg/L	0.142	0.017	0.156	0.051	0.0189	0.0955	0.5

Note: EQS: effluent discharge standards at KV-83 for the KHSD

4.6 HUMIDITY CELL

The HC test provides an indication of the long-term acid generation and rate of release of constituents (i.e., acidity, alkalinity, sulphate, major and trace elements) and constitutes robust evidence on the ARD/ML potential of a geologic material.

The results of 103 weeks (cycles) of Bermingham HC testing are discussed herein. Time series of selected constituents of interest are provided and discussed below to assess the rate of release and the long-term ARD/ML potential of the Bermingham tailings. The HC data were plotted with HC results for Bellekeno and Flame and Moth tailings to provide a site wide comparison. The Mill pond EQS are also plotted for comparative purposes only rather than an assessment of compliance with site water quality standards.

4.6.1 pH, Sulphate, Acidity and Alkalinity

The pH, acidity, alkalinity and sulphate released from the Bermingham tailings during the tests are plotted in Figure 4-1. The plot shows a stable neutral pH of between 7.1 and 8.0 (median = 7.4) within the EQS range (6.5 - 9.5), very low acidity (maximum 7.4 mg/L $CaCO_3$; median equivalent to the detection limit 0.5 mg/L $CaCO_3$), alkalinity high enough to buffer the acidity released (maximum 39.6 mg/L $CaCO_3$; median 20.8 mg/L $CaCO_3$), and relatively low sulphate concentrations (median 51 mg/L), indicating a low sulphide oxidation rate. The acidity, alkalinity and sulphate concentrations showed a first flush effect resulting from the release of readily soluble products followed by a decrease then stabilization of the concentrations until cycle 43 and 37 for acidity and alkalinity, respectively, although recurrent spikes of acidity were observed until cycle 69 after which the acidity was typically below the detection limit. Alkalinity gradually increased after cycle 37 from 12 mg/L to 40 mg/L at cycle 99, coincident with an increase in pH from 7.3 to 8.0. The sulphate concentrations showed a slight increase between cycles two and nine (85 mg/L), then decreased and continued to decline during the test reaching 29 mg/L during the last two cycles.

The pH and alkalinity levels in the leachate from the Bermingham tailings humidity cell were lower than those observed in the Flame and Moth and Bellekeno tailings HCs (Figure 4-1), reflecting its lower NP and lack of calcite, however the pH was comparable to that observed for Bellekeno and Flame and Moth during the last three cycles due to the gradual increase observed since cycle 37. The Bermingham sulphate concentrations recorded during the test (29 to 374 mg/L) were markedly lower than those observed in the Bellekeno HC (158 to 1,150 mg/L) during the first 30 cycles then the gap gradually shrank until reaching a comparable level at cycle 55 onward. The Bermingham sulphate concentrations were also lower than in the Flame and Moth HC leachate (120 to 1130 mg/L) during the first 17 cycles after which the sulphate concentration in the HC leachate from the Bermingham tailings increased and remained above that of the Flame and Moth HC during the remainder of the test. This trend is expected for Bellekeno, which has a higher sulphide-sulphur content (2.2 wt.%) than the Bermingham tailings (1.4 wt.%), but is somewhat unexpected for the early cycles of the test for Flame and Moth because of its lower sulphide-sulphur content (0.4 wt.%). Sulphides in the Flame and Moth tailings were likely exposed to leaching at the onset of the test resulting in higher release rate early on and gradual decline thereafter. However, the three tailings generally showed a similar sulphate release pattern despite the difference in absolute concentration, although the sulphate released from the Flame and Moth HC stabilized whereas sulphate concentrations in the Bermingham and Bellekeno HCs continued to slowing decrease (Figure 4-1).

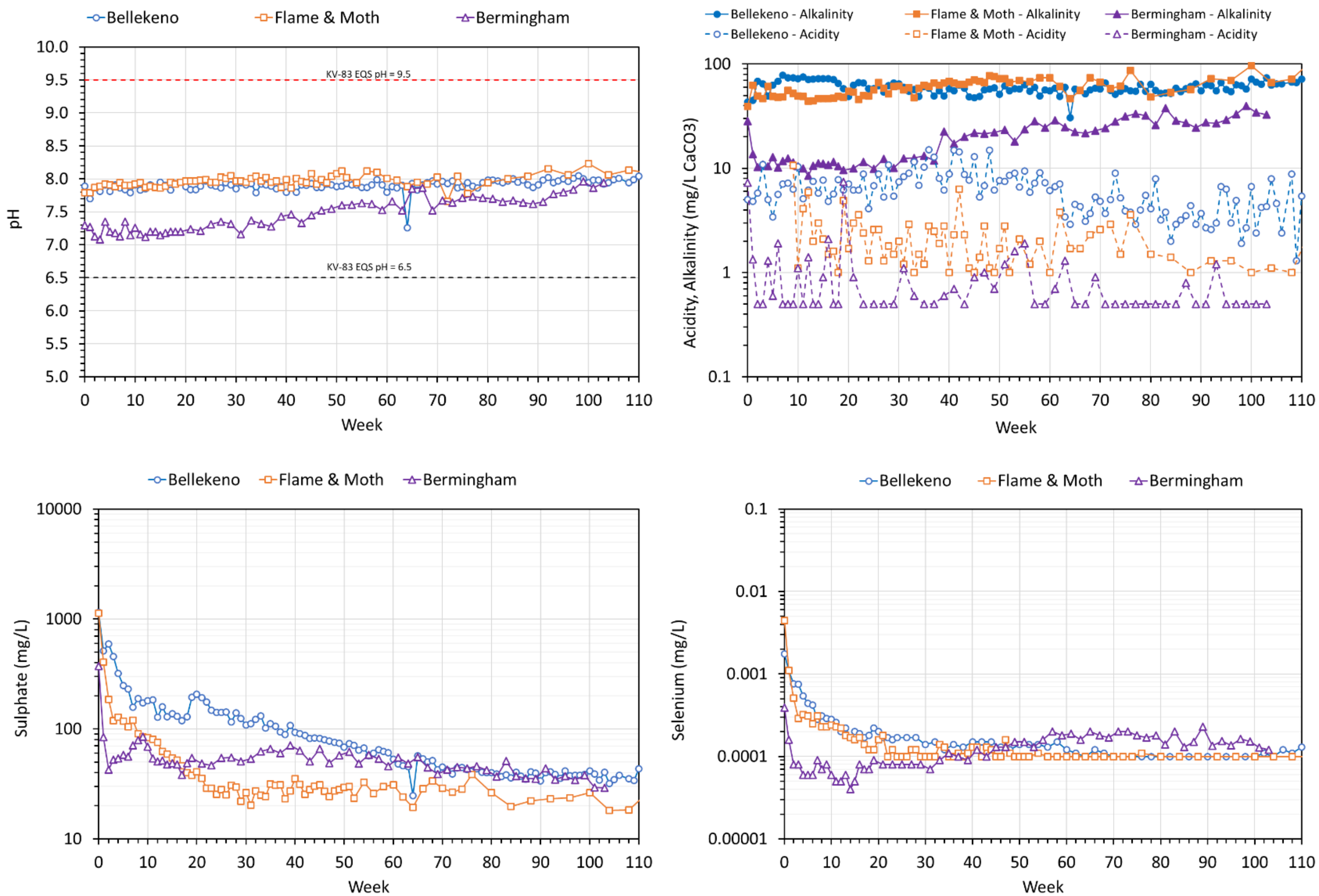

Figure 4-1: pH (top left), Acidity and Alkalinity (top right), Sulphate (bottom left) and Selenium (bottom right) Trends within the Bermingham LC, Flame and Moth and Bellekeno Tailings Humidity Cells

4.6.2 Constituents of Potential Concern

The times series of metals and metalloids of potential environmental concern in the Bermingham tailings HC are plotted in Figure 4-2 and Figure 4-3 alongside those of Bellekeno and Flame and Moth.

The time series of arsenic, antimony, cadmium, and copper are displayed in Figure 4-2 and lead, nickel, silver, and zinc are shown in Figure 4-3. Analysis of the Bermingham tailings metals and metalloids time series showed similar patterns characterized by a flush effect during cycle 0 followed by a decrease of concentration during the following two to three weeks and then a short-term increase which peaked between cycles six and eight. This was followed by a second short or extended decrease and a stabilization as early as cycle 11 onward (antimony and silver) or later (cycle 55 onward for arsenic, copper; cycle 81-89 onward for cadmium, lead and nickel; cycle ~95 for zinc.). However, sporadic fluctuations of concentration were visible in the plots of arsenic, nickel, silver, lead, and copper.

Aside from the initial flush, the arsenic concentration in the HC leachate from the Bermingham tailings was lower than that of the Bellekeno and Flame and Moth HC leachates, likely due to its lower bulk arsenic concentration. Arsenic concentrations in the HC leachate from the Bermingham HC were an order of magnitude or more lower than those of the Bellekeno and Flame and Moth HCs since cycle 35 and no exceedance of the arsenic EQS (0.1 mg/L) was observed in any of the cells. Cadmium and zinc concentrations in the Bermingham tailings HC leachate were comparable to those of Flame and Moth during the first 35 cycles, then their concentrations sharply decreased below Flame and Moth. Cadmium and zinc concentrations in the Bermingham tailings HC leachate were markedly lower (up to two orders of magnitude) than those observed from the Bellekeno humidity cell during the same period. Besides the first cycle, exceedances of the cadmium and zinc EQS (0.01 and 0.5 mg/L, respectively) were only observed in the Bellekeno HC leachate. The Bermingham tailings cadmium and zinc trends likely reflects the lower concentration of these elements in the Bermingham tailings relative to Bellekeno but somewhat expected compared to Flame and Mock considering its higher cadmium and zinc (Table 4-4). Lead concentrations in the Bermingham humidity cell leachate were almost comparable to the Bellekeno tailings cell during the initial flush, then the concentration markedly decreased to levels that were one order of magnitude lower at cycle 11 and more than two orders of magnitude during the last cycles. Lead concentrations in the Bermingham humidity cell leachate were generally comparable to those of Flame and Moth during the first 11 cycles, then decreased to levels that were one order of magnitude lower than lead concentrations measured in the Flame and Moth HC leachates. Lead concentrations increased again after cycle 59 surpassing and remaining above the Flame and Moth HC after the 79th cycle. Occasional high releases of lead from the Bermingham tailings HC were observed during the test resulting in peak concentrations above those of the Flame and Moth HC. The Bermingham tailings HC leachate generally had the highest nickel concentrations during the first 35 cycles, then the nickel concentration decreased sharply such that it was below the nickel concentration in the Flame and Moth and Bellekeno HC leachates from cycle 43 onwards and generally stabilized after cycle 89. Note that nickel concentrations in the three cells were orders of magnitude lower than the nickel EQS (0.5 mg/L; Figure 4-3).

Aside from sulphate, selenium (last phase of the test), and nickel (early phase of the test), the Bellekeno and Flame and Moth tailings HCs had higher constituent concentrations than the Bermingham HC during the test period. The Bellekeno tailings had the highest concentration release for sulphate during the first half of the test, and the highest cadmium, lead, zinc, and nickel concentrations during the last 68 cycles. The Flame and Moth HC had the highest concentration release for arsenic, antimony, copper, and silver during the first 50 to 70 cycles then their concentrations become comparable or decreased below those in the Bellekeno cell. Copper concentrations in the Bermingham tailings HC leachate were slightly lower than the Bellekeno HC leachate during the first 23 cycles after which time the gap increased markedly (approximately two orders of magnitude difference at the last cycle). Silver concentrations in the Bermingham tailings cell leachate were generally below the detection level (i.e., <0.000005 mg/L) similar to the silver release from the Bellekeno cell although spikes of concentration (0.0001 mg/L) were recurrent during the test. Antimony concentrations in the HC leachate from the Bermingham tailings were lower than that of the Bellekeno and Flame and Moth HC leachate despite a bulk antimony concentration (44.6 ppm) that was comparable with the Flame and Moth tailings (41 ppm; Table 4-4).

Selenium concentrations in the Bermingham tailings HC exhibited a pattern different from all the parameters of interest (Figure 4-1). The concentration decreased after the first flush and was up to an order of magnitude lower than the Flame and Moth and Bellekeno leachate selenium levels during the first 20 cycles. After a stabilization at 0.00008 mg/L during the next 10 cycles, selenium concentrations in the Bermingham tailings cell leachate gradually increased to approximately 0.0002 mg/L, surpassing and remaining slightly above those of the Flame and Moth cell at cycle 49 and Bellekeno at cycle 55 (both approximately 0.0001 mg/L). The selenium concentration then decreased to levels that were comparable to the other cells during the last three cycles.

The tailings kinetic test results indicate that the trace element release rates for Bermingham were lower than the effluent quality standards at KV-83, the KHSD Mill Site. The data also suggest that the trace element release rates for the last ten cycles observed for the Bellekeno and Flame and Moth tailings may be used as a conservative proxy (upper boundary) for most constituents, except selenium, for the Bermingham tailings under the circumneutral conditions expected in the tailings storage facility.

It is worth noting that trace element concentrations released from the Bellekeno and Flame and Moth tailings cells were also lower than the effluent quality standards at KV-83, the KHSD Mill Site with the exception of zinc and cadmium in Bellekeno (Figure 4-2 and Figure 4-3). This is likely related to the elevated bulk zinc and cadmium concentrations in the Bellekeno tailings compared to the other tailings.

Additional information derived from the analysis of Bermingham HC data included:

- The concentration of ammonia was very low (median = 0.005 mg/L), at or below the detection limit in 76% of the cycles and well below the EQS of 5 mg/L;
- The concentrations of the following constituents were below the detection limit in all or the majority of leachates since cycle four: nitrate, nitrite, ammonia, beryllium, bismuth, boron, cesium chromium, lanthanum, iron, mercury, silver, sodium, tellurium, thorium, tin, titanium, tungsten, vanadium and zirconium; and
- The concentration of molybdenum was below the detection limit in the second half of the test.

The neutral pH, significant alkalinity, low acidity and sulphate releases, and lower concentration of metal and metalloids compared to the EQS are evidence of low potential for acid generation and metal release from the Bermingham (and other) tailings consistent with the sequential NAG and SFE results.

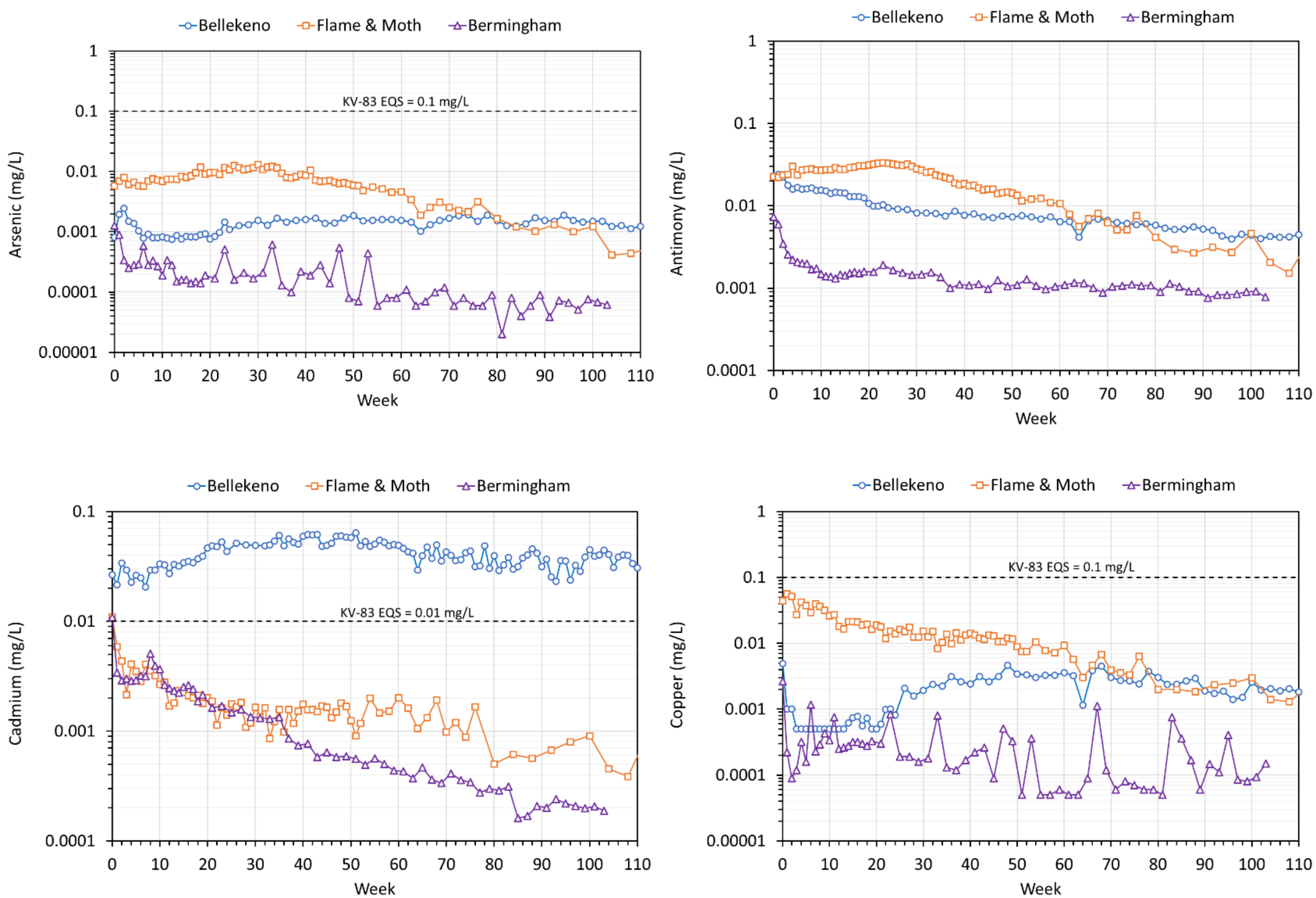

Figure 4-2: Arsenic (top left), Cadmium (bottom left), Antimony (top right), and Copper (bottom right) Trends within the Bermingham LC, Flame and Moth and Bellekeno Tailings Humidity Cells

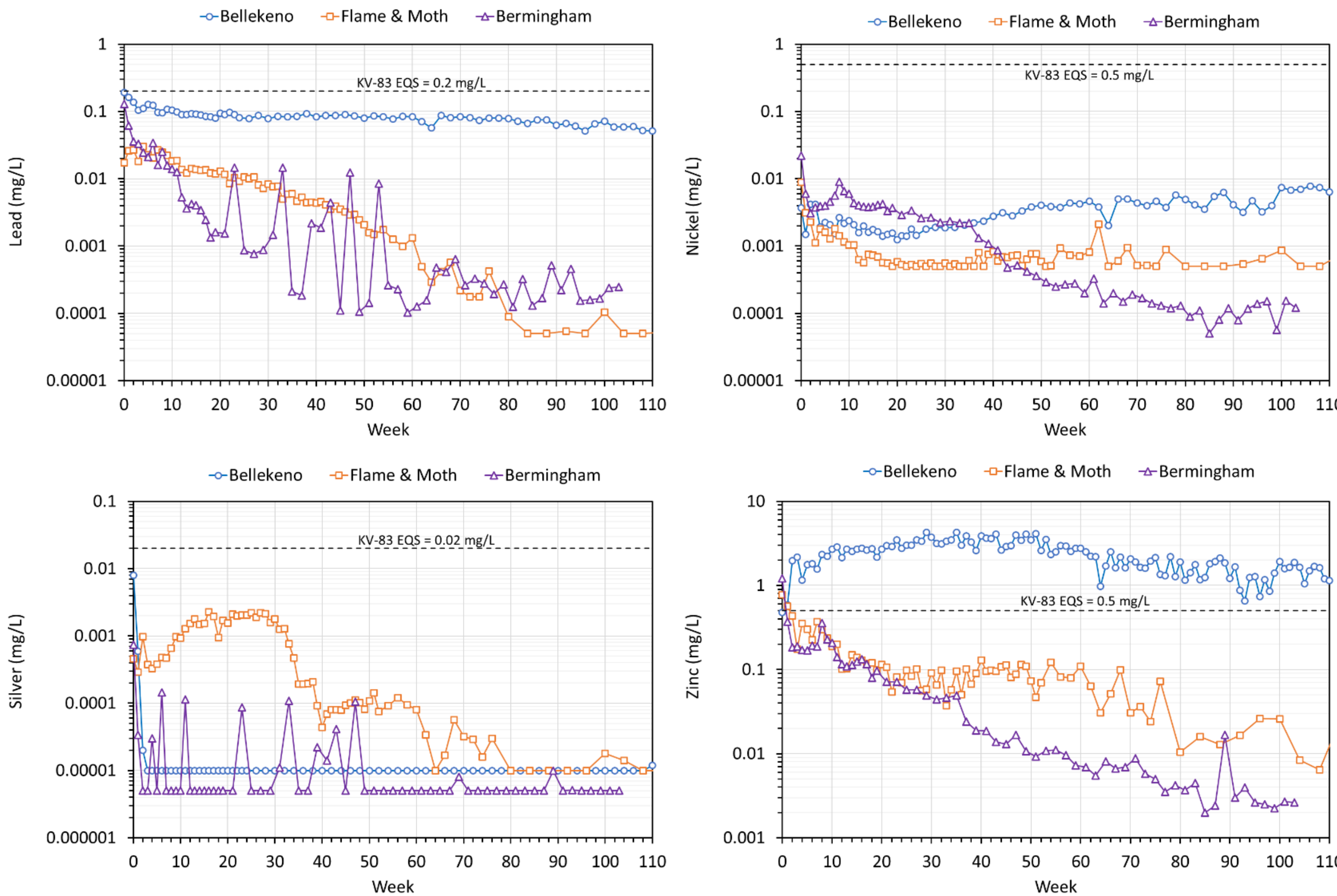

Figure 4-3: Lead (top left), Silver (bottom left), Nickel (top right), and Zinc (bottom right) Trends within the Bermingham LC, Flame and Moth and Bellekeno Tailings Humidity Cells

The estimation of the lag time to acid generation for the Bermingham tailings HC indicates that the times to sulphide and bulk NP depletion are approximately 31 and 40 years, respectively (Figure 4-4). Therefore, some bulk NP will remain in the tailings after the sulphide has been depleted, suggesting that net acid generation is not expected from the tailings. This is consistent with the sequential NAG results.

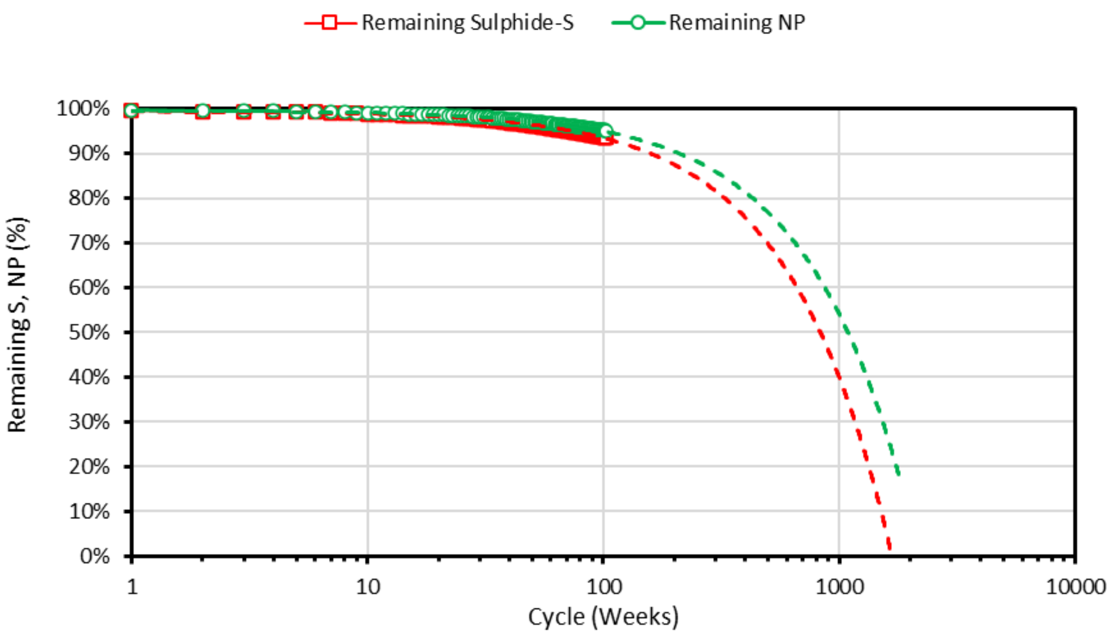

Figure 4-4: Calculations of Sulphide Sulphur and NP Depletion in Bermingham Tailings Humidity Cell

4.6.3 Humidity Cell Closedown

The purpose of the closedown procedure is to help in the interpretation of humidity cell test results by identifying and estimating the changes that may have occurred during the test. The results of the closedown tests on HC residue are reported in Table 4-6 to Table 4-9. The results of the ABA, metal, and XRD analyses on the tailings sample before the HC test are also included for comparison.

The XRD results suggest that weathering and leaching of sulphides (i.e., pyrite, sphalerite, and galena) and carbonate minerals (i.e., ankerite-dolomite and calcian siderite) identified in the head (pre-kinetic) samples occurred. The weathering process resulted in the reduction of the sulphides by 27% to 67% and of carbonates by 10% to 60% (Table 4-6). The changes induced by the leaching and weathering process and the loss of readily soluble minerals resulted in a higher percentage of less soluble minerals (i.e., quartz and aluminosilicates). Sample heterogeneity and/or normalization of the XRD results are the likely explanation for the appearance of paragonite and rutile. The ABA results confirm these changes as indicated by a decrease in total sulphur and carbonate NP by 15% and 16%, respectively (Table 4-7). However, the cell residue still contains enough carbonate and bulk NP to prevent the onset of ARD. The bulk NP apparent increase in the residue by 4% is likely due to the heterogeneity of the sample.

Table 4-6: Mineralogy of Original Tailings and Residue of Tailings Humidity Cell

Mineral	Bermingham LCT2 Tailing	
	Pre-kinetic (%)	Post-kinetic (%)
Ankerite – Dolomite	1	-
Dolomite	-	0.4
Galena	0.3	0.1
Illite-Muscovite 2M1	8.2	7.8
Kaolinite	0.9	1.4
Pyrite	2.2	1.6
Quartz	59.3	61.2
Rutile?	-	0.4
Siderite, calcian	27.8	25.1
Sphalerite	0.3	0.2
Paragonite	-	1.8
Total	**100**	**100**

Table 4-7: ABA Results for Original Tailings and Residue of Tailings Humidity Cell

Sample	pH Units	Bermingham LCT2 Tailing	
		Pre-kinetic	Post-kinetic
Paste pH	-	8.2	8.2
Total Sulphur	%	1.39	1.18
Sulphate Sulphur	%	0.01	<0.01
Sulphide Sulphur	%	1.38	1.18
Total Inorganic Carbon	%	8.96	7.52
Carbonate-NP	kg $CaCO_3$/t	204	170.9
Siderite-Corrected NP	kg $CaCO_3$/t	56.3	58.5
AP	kg $CaCO_3$/t	43.1	36.9
NPR	-	1.3	1.6

No marked change of concentration was observed for the majority of elements. Aside from antimony, calcium, magnesium, selenium, sodium, and thallium, the decreases of metal concentration was less than 16%. Aluminum, barium, molybdenum, nickel uranium, and vanadium reported concentrations higher than the pre-kinetic test. Likely due to sample heterogeneity.

Table 4-8: Elemental Content of Original Tailings and Residue of Tailings Humidity Cell

Element	Unit	Bermingham LCT2 Tailing	
		Pre-kinetic	Post-kinetic
Aluminum (Al)	%	0.16	0.17
Antimony (Sb)	ppm	44.6	30.9
Arsenic (As)	ppm	401	371
Barium (Ba)	ppm	30	34
Bismuth (Bi)	ppm	0.04	<0.1
Cadmium (Cd)	ppm	23.4	20.6
Calcium (Ca)	%	0.73	0.54
Chromium (Cr)	ppm	115	114
Cobalt (Co)	ppm	4.3	3.9
Copper (Cu)	ppm	57.5	54.7
Iron (Fe)	%	7.07	6.01
Lead (Pb)	ppm	2330	2230
Magnesium (Mg)	%	0.36	0.35
Manganese (Mn)	%	4.43	>1
Mercury (Hg)	ppm	0.13	0.12
Molybdenum (Mo)	ppm	2.02	2.5
Nickel (Ni)	ppm	49.1	51.1
Phosphorus (P)	%	0.032	0.028
Potassium (K)	%	0.08	0.07
Selenium (Se)	ppm	0.8	<0.5
Silver (Ag)	ppm	56.4	48.8
Sodium (Na)	%	<0.01	0.003
Strontium (Sr)	ppm	15	13
Thallium (Tl)	ppm	1.9	0.7
Tin (Sn)	ppm	2	-
Titanium (Ti)	%	<0.005	<0.001
Uranium (U)	ppm	0.38	0.4
Vanadium (V)	ppm	5	7
Zinc (Zn)	ppm	2080	1790

The closedown SFE results generally returned lower constituent concentrations than those observed for the pre-humidity cell sample except for some major elements (Table 4-9). Electric conductivity, sulphate, alkalinity, calcium, magnesium, potassium, sodium, strontium, copper, and cadmium returned leachable concentrations higher (1.6 to 10 times higher) than the pre-humidity cell sample indicating the accumulation of some soluble products in the cell. However, no leachable concentrations exceeded the EQS.

To determine and estimate the load of constituents that may have accumulated in the HC, the closedown SFE concentrations were normalized by the weight of the tailing cell residue and compared with the normalized data for the last cycle of the humidity cell (Table 4-10). The load released from the closedown SFE was more than six-fold higher than that observed for the final humidity cell cycle for the majority of constituents. Several metals (i.e., aluminum, arsenic, barium, cobalt, copper, iron, lead, lithium, manganese, molybdenum, nickel, potassium, silicon, sodium, uranium, tin, and zinc) were twenty to more than hundred times higher. This confirms the accumulation of constituents during the humidity cell testing and redistribution of the closedown SFE load evenly over all weeks of the test is likely to increase the loading of each cycle by at least 6%. However, the redistribution of the closedown SFE concentration evenly over all weeks of the test will result in a modest increase of the weekly concentration released and unlikely to result in weekly or steady-state concentrations higher than the Bellekeno, Flame and Moth or EQS. Thus, the trace element release rates for the last ten cycles observed for the Bellekeno and Flame and Moth tailings are still a valid conservative proxy for most constituents, except selenium, for the Bermingham tailings.

Table 4-9: Comparison of Pre-Humidity Cell SFE, Closedown SFE and Humidity Cell Last Cycle

Leachable Metals	Unit	Bermingham LCT2 Tailing			KHSD Mill Site EQS (KV-83)
		Pre-kinetic SFE	Closedown SFE	Last Kinetic Cycle	
pH	pH units	8.17	8.02	7.94	6.5-9.5
EC	uS/cm	97.1	180	131	-
SO_4	mg/L	19.1	31	29.1	-
Acidity to pH4.5	mg/L	<0.5	<0.5	<0.5	-
Acidity to pH8.3	mg/L	<0.5	<0.5	<0.5	-
Total Alkalinity	mg/L	14	65.3	32.7	-
Fluoride	mg/L	0.2	0.05	<0.05	-
Hardness $CaCO_3$	mg/L	35	132	60.8	-
Aluminum (Al)-Leachable	mg/L	0.0214	0.00438	0.00101	-
Antimony (Sb)-Leachable	mg/L	0.0111	0.0019	0.000783	-
Arsenic (As)-Leachable	mg/L	0.000331	0.000264	0.000062	0.1
Barium (Ba)-Leachable	mg/L	0.0134	0.005	0.000264	-
Beryllium (Be)-Leachable	mg/L	<0.000010	<0.000010	<0.000010	-
Bismuth (Bi)-Leachable	mg/L	<0.0000050	<0.0000050	<0.0000050	-
Boron (B)-Leachable	mg/L	<0.050	<0.050	<0.050	-
Cadmium (Cd)-Leachable	mg/L	0.000309	0.000526	0.000189	0.01
Calcium (Ca)-Leachable	mg/L	12.4	40.3	14	-
Chromium (Cr)-Leachable	mg/L	<0.00010	<0.00010	<0.00010	-
Cobalt (Co)-Leachable	mg/L	0.000099	0.0000783	0.0000089	-
Copper (Cu)-Leachable	mg/L	0.000334	0.0026	0.00015	0.1
Iron (Fe)-Leachable	mg/L	<0.0010	0.006	0.0016	
Lead (Pb)-Leachable	mg/L	0.0188	0.00119	0.000247	0.2
Lithium (Li)-Leachable	mg/L	0.00294	0.00284	0.00062	-
Magnesium (Mg)-Leachable	mg/L	0.988	7.52	6.24	-
Manganese (Mn)-Leachable	mg/L	0.445	0.343	0.0211	-
Mercury (Hg)-Leachable	mg/L	<0.000050	<0.000050	<0.000010	-
Molybdenum (Mo)-Leachable	mg/L	0.000928	0.00105	<0.000050	-
Nickel (Ni)-Leachable	mg/L	0.000368	0.000335	0.000121	0.5
Phosphorus (P)-Leachable	mg/L	0.0414	0.0074	0.0041	-
Potassium (K)-Leachable	mg/L	1.7	3.41	0.192	-
Selenium (Se)-Leachable	mg/L	0.000041	0.000117	0.00012	-
Silicon (Si)-Leachable	mg/L	0.45	0.88	0.15	-
Silver (Ag)-Leachable	mg/L	0.00003	0.0000131	<0.0000050	0.02
Sodium (Na)-Leachable	mg/L	0.596	2.44	<0.050	-
Strontium (Sr)-Leachable	mg/L	0.0172	0.183	0.0143	-
Thallium (Tl)-Leachable	mg/L	0.000177	0.000105	0.0000808	-
Tin (Sn)-Leachable	mg/L	<0.00020	0.00077	<0.00020	-
Titanium (Ti)-Leachable	mg/L	<0.00050	<0.00050	<0.00050	-
Uranium (U)-Leachable	mg/L	<0.0000020	0.00019	0.0000071	-
Vanadium (V)-Leachable	mg/L	<0.00020	<0.00020	<0.00020	-
Zinc (Zn)-Leachable	mg/L	0.017	0.0152	0.00263	0.5

Table 4-10: Comparison of Tailing Cell Last Cycle and Closedown SFE Loadings

Leachable Metals	Unit	Last Kinetic Cycle	Closedown SFE
pH	pH units	7.9	8.0
EC	uS/cm	-	-
SO_4	mg/kg	13.8	93
Acidity to pH4.5	mg/kg	0.24	1.5
Acidity to pH8.3	mg/kg	0.24	1.5
Total Alkalinity	mg/kg	15.53	195.9
Fluoride	mg/kg	0.024	0.15
Hardness $CaCO_3$	mg/kg	28.9	396
Aluminum (Al)-Leachable	mg/kg	0.00048	0.01314
Antimony (Sb)-Leachable	mg/kg	0.00037	0.0057
Arsenic (As)-Leachable	mg/kg	0.0000295	0.000792
Barium (Ba)-Leachable	mg/kg	0.000125	0.015
Beryllium (Be)-Leachable	mg/kg	0.0000047	0.00003
Bismuth (Bi)-Leachable	mg/kg	0.0000024	0.000015
Boron (B)-Leachable	mg/kg	0.0237	0.15
Cadmium (Cd)-Leachable	mg/kg	0.000089	0.001578
Calcium (Ca)-Leachable	mg/kg	6.65	120.9
Chromium (Cr)-Leachable	mg/kg	0.000047	0.0003
Cobalt (Co)-Leachable	mg/kg	0.00000423	0.0002349
Copper (Cu)-Leachable	mg/kg	0.000071	0.0078
Iron (Fe)-Leachable	mg/kg	0.00076	0.018
Lead (Pb)-Leachable	mg/kg	0.00012	0.00357
Lithium (Li)-Leachable	mg/kg	0.000295	0.00852
Magnesium (Mg)-Leachable	mg/kg	2.96	22.56
Manganese (Mn)-Leachable	mg/kg	0.01	1.029
Mercury (Hg)-Leachable	mg/kg	0.0000047	0.00015
Molybdenum (Mo)-Leachable	mg/kg	0.000024	0.00315
Nickel (Ni)-Leachable	mg/kg	0.000057	0.001005
Potassium (K)-Leachable	mg/kg	0.09	10.23
Selenium (Se)-Leachable	mg/kg	0.000057	0.000351
Silver (Ag)-Leachable	mg/kg	0.0000024	0.0000393
Sodium (Na)-Leachable	mg/kg	0.024	7.32
Strontium (Sr)-Leachable	mg/kg	0.0068	0.549
Thallium (Tl)-Leachable	mg/kg	0.000038	0.000315
Tin (Sn)-Leachable	mg/kg	0.000095	0.00231
Titanium (Ti)-Leachable	mg/kg	0.00024	0.0015
Uranium (U)-Leachable	mg/kg	0.0000034	0.00057
Zinc (Zn)-Leachable	mg/kg	0.00125	0.0456

4.7 DISCUSSION AND TAILINGS MANAGEMENT

The comparison of the results of geochemical testing of the Bermingham tailings sample with Onek, Lucky Queen, Flame and Moth, and Bellekeno tailings indicates that the tailings share similar geochemical characteristics with respect to ARD/ML. All the tailings had low potential for ARD/ML, with lower SFE-leachable metal(loid) concentrations observed for the Bermingham tailings compared to other tailings. Also, the Bermingham tailings HC data indicated that most metal(loid) concentrations release rates were comparable or markedly lower than those observed from Flame and Moth and Bellekeno tailings. One exception was the slightly elevated nickel concentration compared to those observed in the Flame and Moth and Bellekeno tailings humidity cell leachate during the first thirty cycles of the test but nickel concentrations later decreased mirroring the other metal(loid)s. The other exception was the higher selenium concentration above that of the Flame and Moth and Bellekeno HC during the second half of the test. Aside from the first flush cadmium and zinc concentrations, no exceedance of the Mill site EQS were observed in the Bermingham SFE or HC test indicating low potential for metal leaching.

While ABA work indicated that the Bermingham tailings had an Uncertain potential for acid generation, the sequential NAG and the kinetic results confirmed their low potential for acid generation. The Uncertain acid potential based on calculated NPR could be explained by the following:

1. The siderite-corrected NP method likely underestimated the effective NP available for acid neutralization. A portion of the iron and manganese carbonate material will likely contribute to net acid neutralization given the slow oxidation kinetics of manganese at circumneutral pH and siderite calcian end-member.

2. XRD analysis identified sphalerite (0.3 to 0.6 wt.%), galena (0.3 to 0.8 wt.%), and pyrite (1.6 to 2.2 wt.%) in the Bermingham tailings sample. Under oxic weathering conditions, the oxidation of galena and sphalerite by oxygen is not an acid generating process. Both these minerals constitute approximately 20% to 47% of the XRD-measured sulphide mineralogy, indicating that the AP was likely overestimated.

Furthermore, sequential NAG testing revealed that there is sufficient NP in the Bermingham tailings to buffer the acid generated from sulphide oxidation. Sulphide and NP depletion calculations for the Bermingham tailings humidity cell also confirmed that the NP will outlast the AP generated from sulphide, indicating that net acid generation is not anticipated from the Bermingham tailings.

The results of the humidity cell closedown tests indicated that geochemical changes consisting of the removal of some constituents from the sample and the accumulation of others in the residue occurred during the kinetic test. Despite these changes, the tailings material remains low potential for long-term acid generation and metal leaching.

The tailings deposited in the DSTF or underground as cemented tailings backfill at Bermingham will either be standalone Bermingham tailings or a combination of tailings originating from the mines currently permitted in the KHSD. Blending and/or co-disposal of the Bermingham tailings with high effective NP (high in fast reactive calcite) tailings from the Flame and Moth and Bellekeno in the DSTF would significantly increase the bulk NP of the tailings mix, thus the net long-term acid generation is not anticipated. The geochemical testwork completed on the Bellekeno tailings stored on the DSTF and their performance indicate that the tailings are not a concern from an acid generating potential perspective.

5 SUMMARY

The results of static and kinetic tests conducted on the Bermingham tailings indicate that the tailings were mainly composed of silica, calcian iron and manganese carbonates and minor sulphides. They had low potential for long-term acid generation due to an adequate NP buffering the acidity released from sulphide oxidation. The tailings had elevated bulk concentrations of several metals and metalloids but laboratory simulated short- and long-term leaching tests (SFE and HC) suggests that relatively low levels of metal leaching may be expected from the Bermingham tailings. Similar geochemical characteristics were observed for the tailings humidity cell residue.

The Bermingham tailings had similar geochemical characteristics as the tailings from other deposits. Their lower bulk metal composition might be in part due to spatial variability in mineralization between the deposits. The SFE leachable metal(loid)s and HC metal(loid) release rates were comparable or markedly lower than those observed from other tested tailings, except for nickel and selenium, with leachate constituent concentrations well below the EQS at the Mill site pond. Their low fast reactive carbonate content (e.g., low readily available NP) will be compensated by NP from calcian siderite and by NP from other tailings with high NP during co-disposal or blending. Overall, the Bermingham tailing have low potential for acid and metal release.

6 REFERENCES

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Price, W.A. (2009) *Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials*. MEND Report 1.20.1. CANMET – Mining and Mineral Science Laboratories, Smithers, BC.

APPENDIX 2

EBA OPINION ON PROPERTIES OF LUCKY QUEEN AND ONEK TAILS: FOR USE IN EXISTING DRY STACK TAILINGS DISPOSAL FACILITY, NEAR BELLEKENO MILL, YT (EBA FILE: W14101178.011), WHITEHORSE, YT.

A TETRA TECH COMPANY

March 2, 2012

ISSUED FOR USE
EBA FILE: W14101178.011

Alexco Keno Hill Mining Corp.
#4 – 151 Industrial Road
Whitehorse, YT Y1A 2V3

Via Email: bthrall@alexcoresource.com

Attention: Brad Thrall

Subject: EBA Opinion on Properties of Lucky Queen and Onek Tails
For Use in Existing Dry Stack Tailings Disposal Facility, near Bellekeno Mill, YT

The physical and chemical properties of the tailings that will be produced from the two new ore zones are expected to be very similar to the geological and geotechnical properties of the Bellekeno ore zone tailings. Experience gained from thorough geological review of deposits throughout the Keno Hill Silver District indicates there are minor variations in ore mineralogy and deposit configuration, but all deposits discovered to date fall within a relatively narrow and well understood geological range, all hosted within the same geological terrain, age range and subjected to similar structural controls and ore genesis environments.

Within that range, the geotechnical properties of the tailings produced from milling these variations are expected to be very similar. As part of ongoing DSTF operations, maintenance and surveillance protocol and procedures, these assumptions will be confirmed through testing through the ongoing implementation of the Tailings Characterization Plan. Results of analytical testing presented in the YESAB Project Proposal indicate the similar geological nature of the three ore zones. All ore from each of the three deposits will be processed in the same mill, with the same mill process flow sheet, therefore producing a nearly identical particle size distribution.

If there are any minor variations in the nature of Lucky Queen and Onek tails from the Bellekeno tails, they are not expected to affect the geotechnical performance of the DSTF.

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Sincerely,
EBA Engineering Consultants Ltd.

J. Richard Trimble, P.Eng., FEC
Principal Consultant, Arctic Engineering
Ph: 867-668-2071 x222 Email: rtrimble@eba.ca

APPENDIX 3

TETRA TECH EBA OPINION ON TAILINGS CHARACTERIZATION PLAN PHYSICAL TESTING REQUIREMENTS, KENO HILL DISTRICT MILL, YUKON (EBA FILE: W14103144), WHITEHORSE, YT

January 15, 2014

ISSUED FOR USE
FILE: W14103144
Via Email: eallen@accessconsulting.ca

Access Consulting Group
3-151 Industrial Road
Whitehorse, YT Y1A 2V3

Attention: Ethan Allen, M.Sc.- Environmental Geoscientist

Subject: Tailings Characterization Plan – Physical Testing Requirements
Keno Hill District Mill, Yukon

1.0 INTRODUCTION

In partial fulfillment of Alexco Resource Corporation's water license (QZ09-092), Access Consulting Group (Access) is preparing an updated Tailings Characterization Plan. Access retained Tetra Tech EBA Inc. (Tetra Tech EBA) to review the suite of physical property testing currently completed on the tailings generated at the Keno Hill District Mill and provide recommendations for ongoing testing requirements. This letter presents the current suite of testing being completed, Tetra Tech EBA's recommendation for ongoing testing, and rationale for the recommendation.

2.0 CURRENT PHYSICAL TESTING REQUIREMENTS

Laboratory tests to verify the physical properties of the tailings generated at the Keno Hill District Mill are completed on a regular basis. The following Table 1 summarizes the physical tests and testing frequencies stated in the current Tailings Characterization Plan.

Table 1: Current Physical Testing Requirements

Test Description	Frequency
Gradation (hydrometer)	Monthly
Soil water characteristic curve	Monthly
Specific gravity	Monthly
Shear strength	Quarterly

3.0 RECOMMENDED PHYSICAL TESTING REQUIREMENTS

Tetra Tech EBA recommends the physical property testing requirements in the Tailings Characterization Plan be updated as shown in the following Table 2.

Table 2: Recommended Physical Testing Requirements

Test Description	Frequency
Gradation (hydrometer)	Monthly

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3.1 Discussion

Tetra Tech EBA has been completing and reviewing the physical property testing for tailings produced at the Keno Hill District Mill since production began in 2011. In that time the results of the physical property testing for gradation, moisture, weight, and shear strength have remained consistent. Tetra Tech EBA also conducts routine inspections of the Dry Stack Tailings Facility (DSTF) which include field density and moisture content testing of the placed tailings.

The density (weight) and moisture content of placed tailings is verified in the field during routine DSTF inspections. The recommended monthly laboratory testing (hydrometer) will confirm the gradation of the produced tailings. The shear strength of the tailings is controlled by the gradation, moisture, and weight of the material and will therefore be indirectly verified through the ongoing field and laboratory testing being completed.

3.2 Triggers for Additional Physical Property Testing

The shear strength of the placed tailings within the DSTF will be verified indirectly through field and laboratory testing. The overall stability of the DSTF depends on the strength of the placed tailings. Tetra Tech EBA recommends quarterly direct shear testing be resumed if gradation results indicate a deviation of 10% or greater from the results obtained to date.

4.0 LIMITATIONS OF REPORT

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5.0 CLOSURE

We trust this letter meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech EBA Inc.

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GENERAL CONDITIONS

GEOTECHNICAL REPORT

This report incorporates and is subject to these “General Conditions”.

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This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

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Electronic files submitted by Tetra Tech EBA have been prepared and submitted using specific software and hardware systems. Tetra Tech EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, Tetra Tech EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

4.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. Tetra Tech EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

5.0 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

6.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. Tetra Tech EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

7.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

8.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

9.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

10.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

11.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

12.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

13.0 SAMPLES

Tetra Tech EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.

14.0 INFORMATION PROVIDED TO TETRA TECH EBA BY OTHERS

During the performance of the work and the preparation of the report, Tetra Tech EBA may rely on information provided by persons other than the Client. While Tetra Tech EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, Tetra Tech EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.