WASTE ROCK MANAGEMENT PLAN

REVISION 4.5

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Prepared and Updated for:

ALEXCO KENO HILL MINING CORP.

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1.1 INTRODUCTION

The Bellekeno Advanced Underground Exploration and Development Program, assessed under YESAB project number 2008-0039, presented a comprehensive Waste Rock Management Plan (WRMP) for the estimated 248,000 tonnes of waste rock to be excavated over 5 years. Under Section 23 of Water Licence QZ07-078, a Waste Rock Physical Inspection Plan was submitted. The Bellekeno Waste Rock Management Plan was based on studies by Altura Environmental Consulting (Altura). These studies described the Acid Rock Drainage/Metal Leachate (ARD/ML) controlling and correlating factors district wide (Altura, 2008a) and geoenvironmental characterization of the Bellekeno Zone (Altura 2008b).

Clause 13.6 of QML-0009 states that a maximum of 500,000 tonnes of waste rock are to be removed during the undertaking. This tonnage was to come from the Bellekeno mine, but as part of the amendment to QML-0009, Alexco plans to excavate and place on surface a combined maximum of 500,000 tonnes of waste rock from the Bellekeno, Onek 990, Lucky Queen and Flame & Moth Mines. In order to support use of the Waste Rock Management Plan for Flame & Moth, Access Consulting Group (Access) undertook geochemical characterization studies of the Flame & Moth deposit (Access, 2014). Additionally, the waste rock management criteria for Lucky Queen were reviewed by Access and modifications to its screening criteria are presented here within and the rationale presented as Appendix A.

1.2 PURPOSE OF PLAN

This plan outlines practices for management of waste rock to be excavated from the Bellekeno, Lucky Queen Onek 990, and Flame & Moth deposits. The plan is intended to ensure that appropriate management procedures are followed in order to minimize impacts of waste rock brought to surface on land and water resources. Monitoring following waste rock management activities is intended to assess the effectiveness of the management measures, ensure that adaptive management approaches are implemented and to ensure that appropriate information is obtained by Alexco to assist in closure planning.

1.3 SCOPE OF PLAN

Aspects included in this Plan are:

- Definition of rock categories based on potential for reactivity (specifically, acid

  generation and/or metal leaching);
- Estimation of quantities of each category to be excavated to surface during Mining operations;
- Operational categorization of excavated rock;
- Geochemical and ABA confirmatory testing;
- Control measures as required to mitigate effects of potential acid generation and/or

metal leaching;

- Monitoring and physical inspection activities for waste rock storage areas;
- Reporting of waste rock management activities;
- Geotechnical design of waste rock storage areas; and
- Kinetic testing of N-AML and P-AML waste rock.

2 Rock Characterization

2.1 Summary of Rock Characterization

Studies conducted throughout the Keno Hill Silver District (KHSD) and specifically within each of the mineralized target zones (Bellekeno, Onek 990, Lucky Queen and Flame & Moth) provide a foundation for correlating and understanding the weathering behavior or 'geoenvironmental' tendencies of rock in the KHSD. A summary of these waste rock characterization studies and their components and key results is shown in Figure 1.

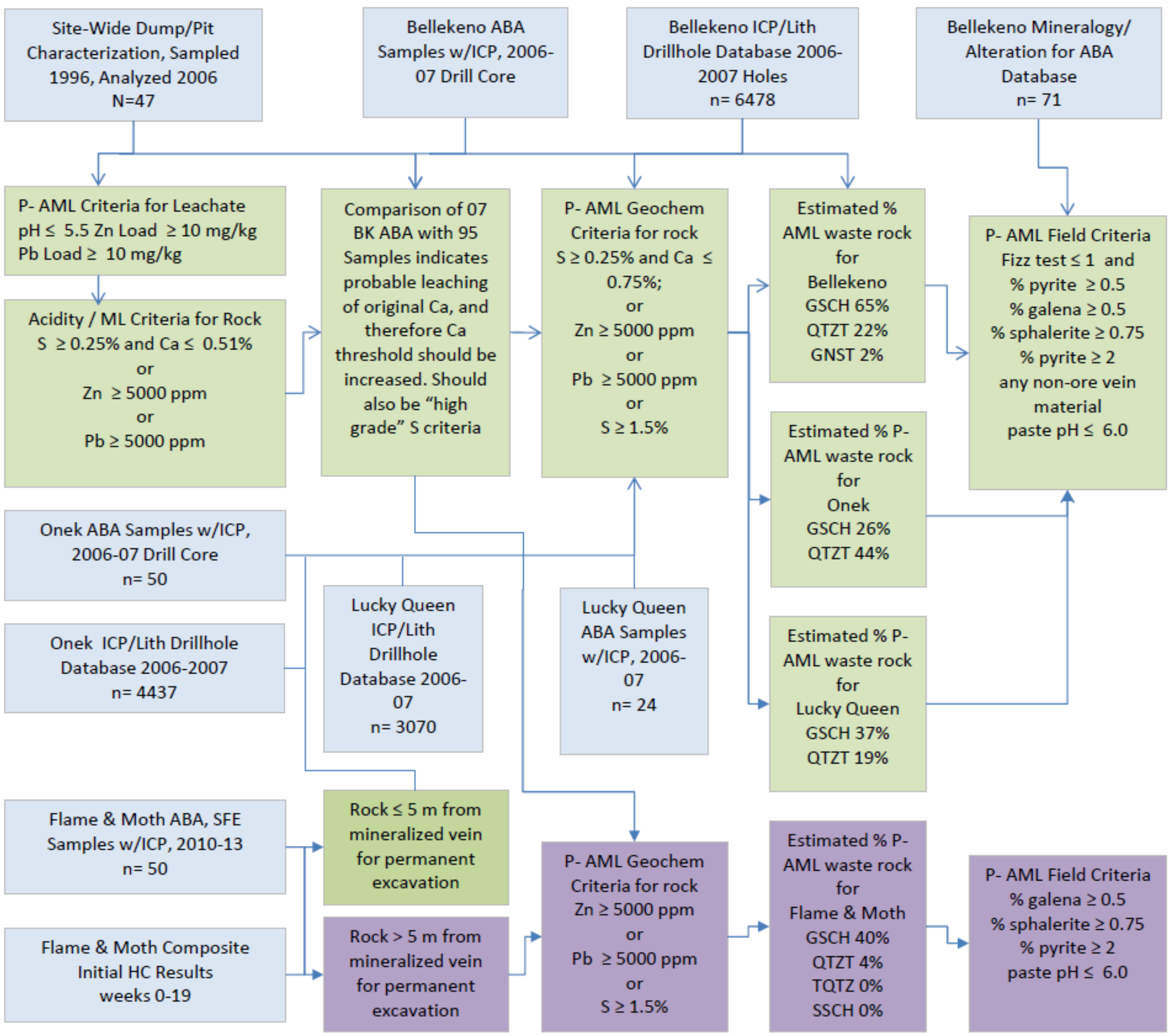

Figure 1: Keno Hill Development Waste Rock Characterization Studies – Components and Key Results

2.2 OVERVIEW OF STUDIES

The geoenvironmental evaluations to support the original Bellekeno Waste Rock Management Plan (WRMP) consisted of data analysis and integration of four specific data components:

1) site-wide studies on weathered rock (47 samples);

2) acid base accounting of 2006-2007 Bellekeno drill core (71 samples);

3) Bellekeno drillhole multi-element and lithology database (6,478 samples), and

4) mineralogy and alteration logging data on acid base accounting samples.

In order to support the extension of use of the WRMP for the Onek and Lucky Queen deposits, data analysis of additional data components was undertaken, specifically:

1) acid base accounting on 2008-2010 Lucky Queen drill core (24 samples);

2) Lucky Queen multi-element and lithology database (3070 samples);

3) acid base accounting on 2008-2010 Onek drill core (50 samples); and

4) Onek multi-element and lithology database (4437 samples).

In order to support the extension of use of the WRMP for the Flame & Moth deposit, data analysis of additional data components was undertaken, specifically:

1) acid base accounting on 2010-2012 Flame & Moth drill core sourced from area of proposed permanent excavation (50 samples);

2) multi-element and lithology database 2010-2012 Flame & Moth drill core sourced from area of proposed permanent excavation (50 samples);

3) shake flask extraction test results from 2010-2012Flame & Moth drill core sourced from area of proposed permanent excavation (50 samples);

4) humidity cell results (weeks 0-56) of a composite sample created from Flame & Moth drill core sourced from area of proposed permanent excavation.

These studies were used to derive the following components for the Waste Rock Management Plan:

1) P-AML geochemical screening criteria for each deposit;

2) estimated proportions of P-AML and N-AML material by rock type for the proposed development activities at each of the deposits; and

3) field criteria for differentiating P-AML and N-AML rock during excavation activities at each deposit.

2.2.1 Waste Rock Field Screening Criteria

One of the fundamental parts of the Waste Rock Management Plan is field screening of waste rock. Field screening criteria for identifying P-AML at Bellekeno, Onek 990, Lucky Queen and Flame and Moth have been developed as follows:

a) Slight or no effervescence of pulverized sample with 25% HCl (e.g. presence of none or only a few bubbles, fizz rating ≤1), and visual estimated pyrite >0.5%, or;

b) Any sample with one or more of the following:

   i. visual estimated sphalerite ≥ 0.75%

   ii. visual estimated galena ≥ 0.5%

   iii. visual estimated pyrite ≥ 2%

   iv. any mineralized vein material associated to the ore vein

   v. paste pH ≤ 6.0

2.2.2 P-AML Waste Rock Geochemical Screening Criteria

The standard geochemical screening criteria for identification of P-AML rock apply to all rock permanently excavated from the Bellekeno, Onek 990, and Lucky Queen deposits. The standard geochemical criteria are as follows:

a) Ca% ≤ 0.75% and S via ICP ≥ 0.25 %;

b) or S via ICP ≥ 1.5%;

c) or Pb ≥ 5000 ppm;

d) or Zn ≥ 5000 ppm.

In accordance with ACG 2014, geochemical screening criteria for identification of P-AML rock for the Flame & Moth rock distal to (≥ 5 m or the presence of vein associated stringers, whichever is further) from the mineralized vein fault deposit is as follows:

b) or Svia ICP ≥ 1.5%;

c) or Pb ≥ 5000 ppm;

d) or Zn ≥ 5000 ppm.

YESAB recommended that AKHM establish a maximum zinc concentration for the use of N-AML waste rock as construction material near surface water. Appendix B, Review of Net Acid Generation and Metal Leaching Controlling factors – Keno Hill Silver District outlines the method for determining the zinc threshold of 1100 ppm zinc for placement of N-AML waste rock within 30 m of a surface water body.

2.2.3 Estimated Proportions of P-AML and N-AML Rock

Applying the geochemical screening criteria to the waste rock drillhole databases for each deposit shows the proportions of P-AML rock estimated for each lithology. Table 1 shows the results for Bellekeno, Table 2 shows the result for Onek 990, and Table 3 shows the results for Lucky Queen.

Table 1: Proportion of Samples Filtered as P-AML in Bellekeno Waste Rock Drillhole Database

Lithology		Number of Samples in Database	Number of Samples Screened as P-AML	Percentage of Samples Screened as P-AML
Description	Code			
Chloritic Schist	CHSCH	222	27	**12%**
Calcareous Quartzite	CQTZT	505	54	**11%**
Greenstone	GNST	567	10	**2%**
Graphitic Schist	GSCH	870	562	**65%**
Quartzite	QTZT	3293	719	**22%**
Schist, Undifferentiated	SCH	775	299	**39%**
Sericitic Schist	SSCH	205	37	**18%**

Table 2: Proportion of Samples Filtered as P-AML in Onek 990 Waste Rock Drillhole Database

Lithology		Number of Samples	# of P-AML Samples	% of P-AML Samples
Description	Code			
Chloritic Schist	CHSCH	48	7	15%
Calcareous Quartzite	CQTZT	179	29	16%
Greenstone	GNST	193	25	13%
Graphitic Schist	GSCH	472	122	26%
Interbedded Carbonaceous Quartzite and Schist	ICQS	170	66	39%
Quartzite	QTZT	2440	1071	44%
Schist	SCH	136	39	29%
Sericite Schist	SSCH	138	39	28%
Thin Bedded Quartzite	TQTZT	343	189	55%

Note: Lithology units with less than 40 samples not included in calculation (CSCH and PHY)

Table 3: Proportion of Samples Filtered as P-AML in Lucky Queen Rock Drillhole Database

Lithology		Number of Samples	# of P-AML Samples	% of P-AML Samples
Description	Code			
Graphitic Schist	GSCH	399	149	37%
Quartzite	QTZT	2110	391	19%
Thin Bedded Quartzite	TQTZT	279	83	30%

Table 4: Proportion of Samples Filtered as P-AML in Flame & Moth Area of Proposed Permanent Excavation

Lithology		Number of Samples	# of P-AML Samples	% of P-AML Samples
Description	Code			
Graphitic Schist	GSCH	5	2	40%
Quartzite	QZT	28	1	4%
Thin Bedded Quartzite	TQZT	7	0	0%
Sericite Schist	SSCH	6	0	0%
Calcareous Quartzite	CQZT	2	0	0%
Greenstone	GNST	1	0	0%
Calcareous Schist	CSCH	1	0	0%
	Total	50	3	6%

3 ROCK MANAGEMENT

Waste rock excavated from underground operations can be categorized into the following categories:

- N-AML: Rock of non-economic grade, expected to be comprised of over 85% Central Quartzite unit (quartzite typically intercalated with minor amounts of schist), and less than 15% Greenstone. As presented in Section 1.2, the majority of the waste rock excavated is expected to be N-AML; rock field-classified as N-AML will be stored in designated locations on site.

- P-AML: Waste Rock and Mineralized Waste Rock of no Economic Interest: Rocks field-classified as P-AML (mainly pyrite rich graphitic schist) will be stored in designated P-AML waste rock storage facilities or permanently stored underground as cemented back fill within excavated stopes. In addition to P-AML wall rocks, some vein material especially along the margins of zoned veins contain mostly gangue minerals such as siderite, pyrite and quartz but do not contain economic amounts of Ag, Zn, or Pb minerals and therefore are of no economic interest. Due to their increased likelihood for acidic or metal leaching, all such mineralized non-economic rock is considered to be P-AML and will be stored in P-AML waste rock storage facilities or permanently stored underground as cemented back fill within excavated stopes.

- Mineralized Rock of Uncertain Economic Interest: Vein material which contains significant Ag, Zn or Pb minerals but is not obviously economic may be temporarily stockpiled at the mine site or mill site on lined contained pads. Confirmatory assay will determine whether this rock is milled, or is sent to the P-AML waste rock storage facility or hauled back underground.

Table 5 summarizes waste rock management categories and handling. Included for each category are environmental characteristics, use and storage specifications, geochemical criteria, and field screening criteria.

Table 5: Waste Rock Management Categories and Handling

	P-AML Waste Rock	N-AML Waste Rock	Mineralized Rock
Environmental Characteristics	Potentially acid-generating and/or metal leaching	Non- acid-generating and non-metal leaching	Ag, Pb, and Zn grades of economic interest. May contain minerals with potential for net acidity and/or metal leaching
Uses and Storage	Not suitable for general construction purposes To be stored permanently within lined P-AML WRSFs Some material may be removed from P-AML WRSFs and returned fur underground backfill at closure	May be used for general construction purposes	May be stockpiled temporarily at the portal sites or mill, then either milled or sent to P-AML waste rock storage facility

3.1 ROCK EXCAVATION ACTIVITIES

3.1.1 Waste Rock Screening

Samples for both field screening and compositing for further geochemical and ABA confirmatory testwork are collected using the Face Sampling Method, which is used in all new mine working developments. This method ensures accurate, representative characterization of each blast round and allows field screening tests to be performed in a timely manner so that waste rock can be most efficiently treated according to the waste rock management categories (Table 4).

3.1.2 Face Sampling Method

The Face Sampling Method (Figure 2) has been developed into the following procedure:

- First, the site geologist marks up the heading and center line of the development drive. The geologist demarks the side walls and back heights to be taken, then assesses the rock face by spray painting the boundaries between each lithology and paints the sample number of each lithology on the face. Next, the geologist makes a pencil sketch and takes a photograph of the face.

- The geologist then samples each lithology and visually estimates each lithology/sample for sulphide and carbonate content and records the data on the Face Sampling Form (see Figure 3).

- After being collected, the samples then are taken to a geology field laboratory (typically located near the mine portal) where they are dried using a convection dryer, then crushed and pulverized by a geologist or lab technician and stored until needed for compositing.

- The Face Sampling Form is completed and the waste rock management category is determined based on the field screening criteria, Section 2.2.2.

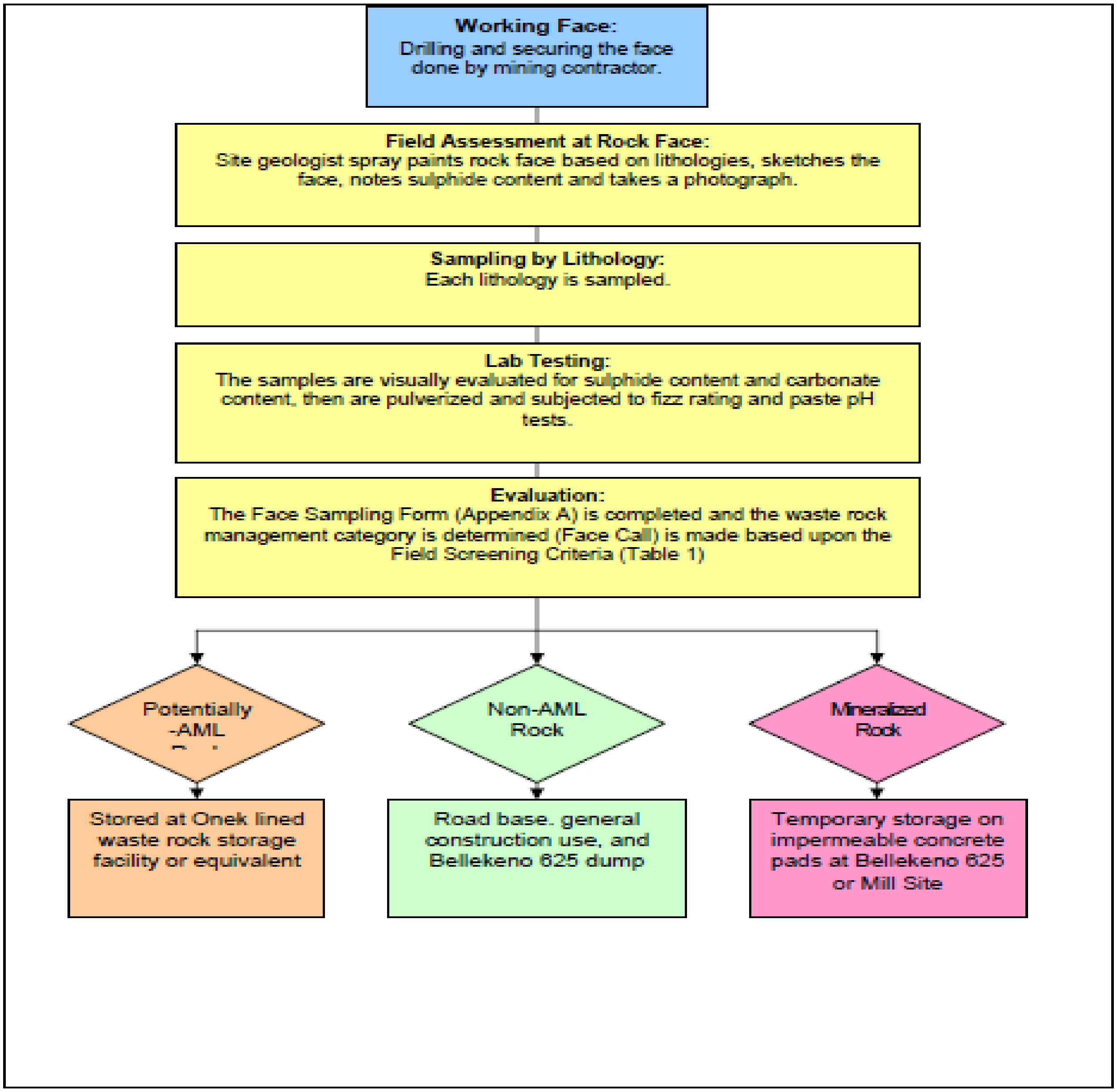

Figure 2 Face Sampling Method

ALEXCO RESOURCE CORP. KENO HILL PROJECT
FACE SAMLPING FORM

Mine: BK 625 **Geologist:** T.M / M.W. **Date:** 28-Oct-08

Development: SW B-PASS 625 **Production:** Waste **Sample Type:** CHIP

Face Location	Spad #	Dist. (m)	Direction	Face Dimensions	Width (m)	Height (m)	Length (m)
	P27	7.3m	SW		2.4	2.4	

Face Name: P27-SW-7.3m

Sample#	Primary Lithology	Lab Testing: Paste pH	Lab Testing: Fizz Rating	Visual Estimate: %Pyrite	%Sphal.	%Galena	%CaCO3	Area(m²)
E607498	CQTZT	9.65	4	0	0	0	>0.75	2.48
499	GSCH 50%, CQTZT 50%	9.11	4	0.25	0	0	>0.75	0.80
500	CQTZT	9.56	4	0	0	0	>0.75	3.04

Notes: FAULT ON L.H.S. SINISTRAL OFFSET - 0.35 m. 15cm THICK GOUGE ALONG FAULT. MUCK AS ROAD BASE
CQTZT units both have strongly developed jointsets w/ mod-heavy limonite staining. No visible Py on freshly broken CQTZT. Minor Py in GSCH band.

ABA Classification:
1

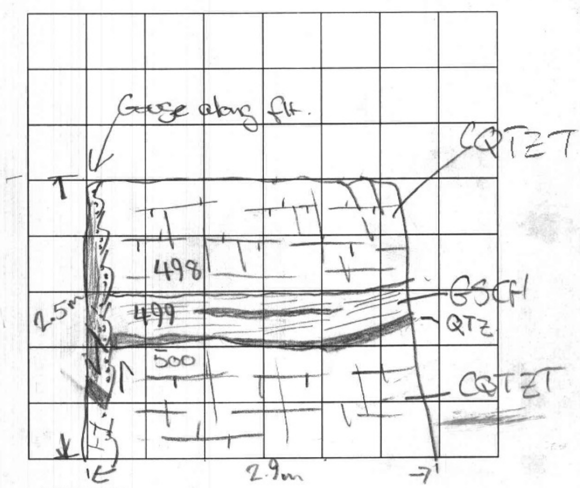

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Figure 3 Example of Face Sampling Form

3.1.3 Evaluation and Waste Rock Management Category Designation

The results of all screening criteria are evaluated according to the criteria presented in Sections 2.2.1 & 2.2.2, and the entire round is designated to the appropriate waste rock management category (more commonly referred to as the "face call" or ABA classification, with 1 being N-AML, 2 being P-AML). A special case may occur when a given blast round contains a complex mixture of lithologies including both N-AML and P-AML units. If overall less than 30% of the working face is deemed as P-AML, and the remainder of the face consists of rock with a high neutralization potential (such as calcareous quartzite), the geologist may assign the entire blast round as N-AML. The rationale here is that upon blasting and transport, the rocks from all units are mixed and the small portion of P-AML rocks would be overwhelmed by the net neutralizing potential N-AML units, and bulk chemistry of the round would be N-AML. As an example, consider the following 240 tonne blast round which contains 30% graphitic schist (1.75% S, 1% Ca) intercalated with 70% calcareous quartzite (0.25% S, 2.8% Ca). This is an extreme example, as 1.75% sulfur is well above the 95th percentile for graphite schist analyses presented in the Altura 2008b. In contrast, Ca = 2.8% for the calcareous quartzite is the average value of calcareous quartzite samples from analyses used in Altura 2008b. Thus, upon blasting and transport the 240-tonne muck pile of mixed lithology has a bulk chemical composition of the following:

For Sulfur	1.75%*0.3	For Ca	1%*0.3
	+0.25%*0.7		+2.8%*0.7
	0.7%		2.26%

The bulk composition of this blast round falls well within the N-AML criteria of having S ≤ 1.5% and Ca ≥ 0.75%. Translating the geochemical data into the more industry standard NP:MPA ratio using the relationship derived Altura 2008b, NP = 25.76[%Ca] + 7.537 and MPA = %S*31.25. Using these relationships, the preceding example would have a NP:MPA ratio of 3.0, which is higher than the 2:1 ratio which is indicated by MEND (2009) to be unlikely to produce net acidity.

Some discretionary decisions on the part of the geologist are necessary; for example in a case of 20% of the working face comprised of a highly sulphidic zone in an otherwise benign working face, the geologist may opt to designate the entire round as P-AML due to the high concentration of P-AML potential in a small zone. It is also important to note that this scenario in which the blast face contains up to 30% P-AML rock is relatively uncommon, and in all cases, testing and determination is made on a conservative basis, meaning that the site geologist will only allow these P-AML containing blast rounds to be classified as N-AML if the remainder of the blast face is determined to have ample neutralization potential.

3.2 SURFACE WASTE ROCK FACILITY DESIGN

3.2.1 N-AML Waste Rock Disposal Areas

To date, Alexco has utilized all N-AML waste rock produced from any of its operations and underground development within the district for site construction purposes (e.g. road construction, laydown areas, general construction of site infrastructure) and has not constructed any dedicated WRDAs within the district. Alexco did submit geotechnical design for a N-AML WRDA to be constructed along the north flank of Sourdough Hill for excavation at the Bellekeno Mine; however the requirements for construction material resulted in this WRDA not being constructed.

Should construction of additional N-AML WRDAs be required, Alexco will submit geotechnical design for review and approval prior to construction.

3.2.2 P-AML Waste Rock Disposal Areas

Some surface storage of P-AML waste rock was proposed for use as part of the Bellekeno, Onek 990, Lucky Queen and Flame and Moth projects. Alexco relies on an approved EBA design entitled *Typical Waste Containment Facility Design, Keno Hill Silver District, YT* (EBA, 2008) for temporary or permanent surface storage of P-AML waste rock within the Keno Hill District.

4 CONFIRMATORY GEOCHEMICAL AND ABA TESTING

Geochemical and ABA testing of waste rock forms an important component of the waste rock management program. The purpose of this testing is to provide additional verification of the effectiveness of the field screening criteria.

After initial field screening, samples are composited to ensure that they are representative of the blast rounds from which they are taken. First, samples from each face are combined based on their respective tonnages, which are calculated based on their areas on the digitized face photo (see Figure 4). These areas are multiplied by the length of the blast round to produce volumes. The volumes are then multiplied by average density according to their lithology to produce the tonnage represented by each sample. Sample composites are first made of each blast round (face), and are weighted according to their calculated tonnages. Additional compositing is done on these composite blast round samples depending on the analytical method and schedule, which is presented below. Where a number of blast rounds are composited, they are weighted to reflect the tonnage of each respective round.

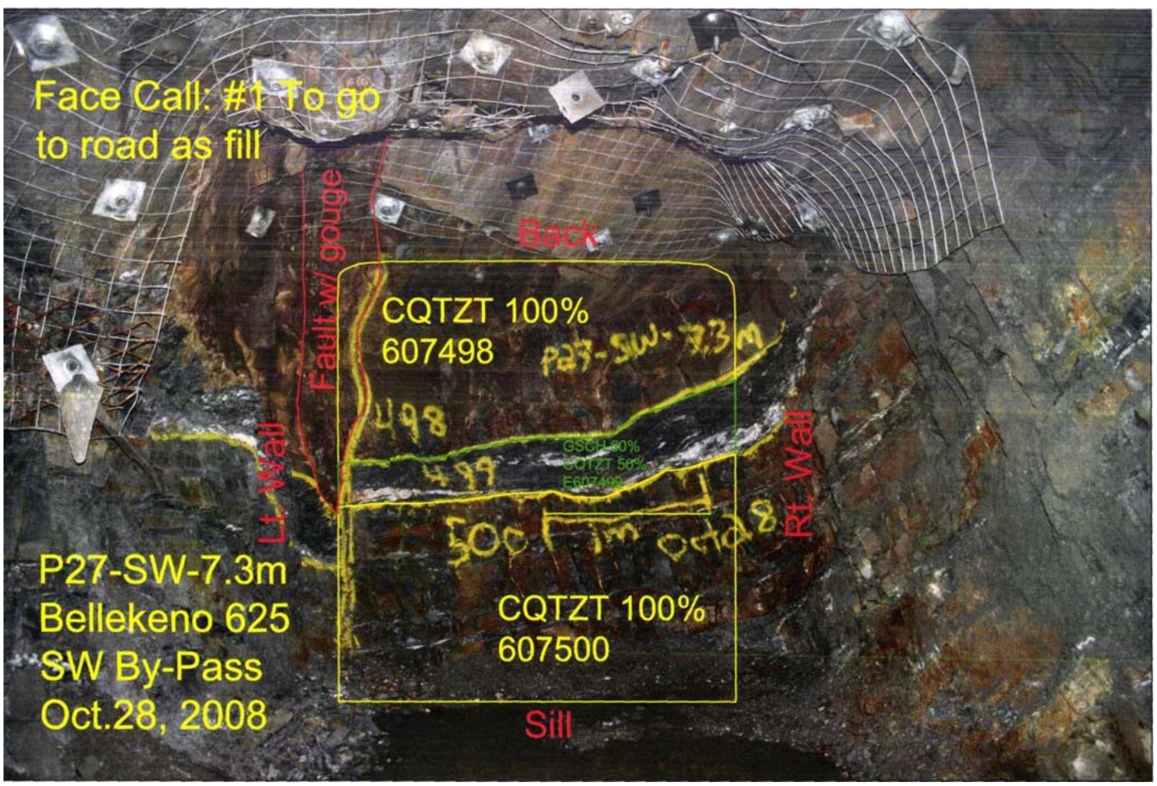

Figure 4 Face Photo of Bellekeno 625 Bypass Showing Sampling According to Lithology and Calculated Sample Areas

4.1 CONFIRMATORY TESTING SAMPLING FREQUENCY AND SCHEDULE

Acid base accounting (ABA) and inductively coupled plasma (ICP) sampling frequencies are done at a minimum of 1 ABA sample (1000 tonnes) per 4,000 tonnes and 1 ICP analysis per 1,000 tonnes in N-AML waste rock. In P-AML waste rock, the sampling density is increased to 1 ABA sample per 500 tonnes and 1 ICP analysis per 500 tonnes.

4.1.1 ICP Sampling Frequency

While meeting per tonnage sampling frequency, the more natural sampling unit is based on number of blast rounds (each represented by a face sample composite). This tonnage depends on several variables including the length of the round, the dimension of the heading, and whether or not there is overblast. Depending on the dimensions of the heading, this typically varies between 3 and 5 blasts per sample.

4.1.1.1 ICP Feedback Sampling for Field Screening Methods

In addition to routine, per tonnage frequency ICP composites described in 4.1, ICP samples will be analyzed for each sample constituting one of the faces in the 1000 tonne ABA composite. These results will be used as a feedback for the Face Sampling Method described in Section 3.1.2. The need for this provision will likely diminish after a reasonable data set is gathered.

4.1.1.2 ABA Sampling Frequency

Similar to ICP sample composites, ABA sampling will be composited based on the number of blast rounds and in accordance with per tonnage limits in order to be representative of the tonnage as a whole. Due to the ineffectiveness of the larger 10,000 tonne composite for verifying and providing feedback, a smaller and more regular 1000 tonne ABA composite for every 4000 tonnes of excavation was adopted in 2009 and has since been implemented with success. Development and production at Flame & Moth, Bellekeno, Onek and Lucky Queen will involve headings of a variety of sizes (2x2, 3x3 and 4x4 meters) but the general principle of a 1,000 tonne composite ABA sample per 4,000 tonnes will be taken regardless of blast round size.

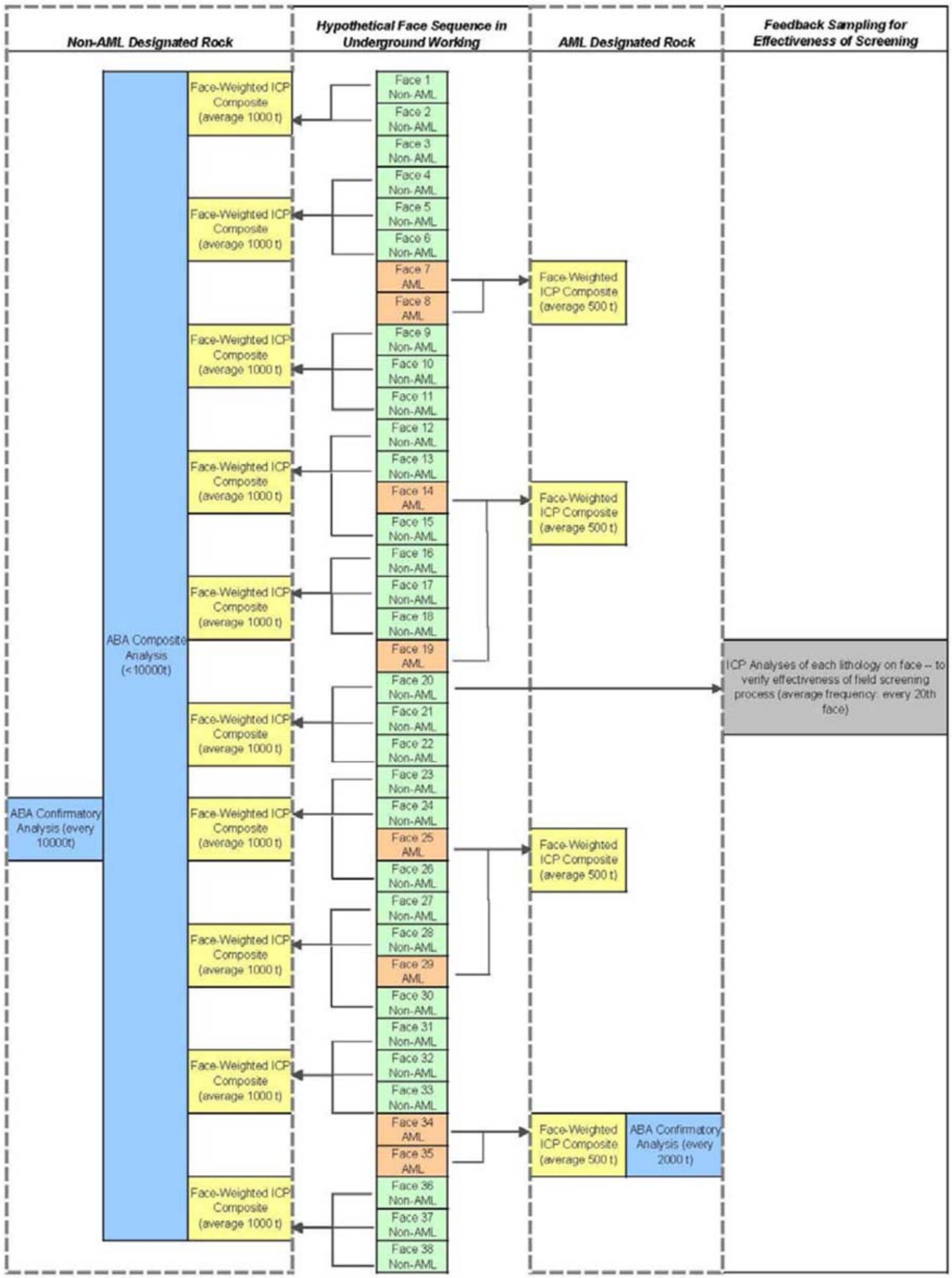

Figure 5 Waste Rock Sampling Schedule

It is important to note that the above criteria represents a high sample density. This is in large part driven by the fact that the proposed work is the first rock excavation activity in the district under Alexco's management, and as such it is important to conduct relatively detailed monitoring to develop a sound information base for decision-making and enhancements to future waste rock management strategies. As the understanding increases, such a high sample density will likely no longer be justified.

4.1.2 Time Lag

4.1.2.1 Time Lag between Excavation and Sampling

The time between blasting and exposure of a new face to sampling and the Face Call (waste rock management category designation) for a given round shall not exceed 48 hours notwithstanding unforeseen and extenuating circumstances such as breakdown of analytical or lab equipment.

4.1.2.2 Time Lag between Excavation and Receipt of Analytical Data

The total time between excavation and receipt of analytical data is dependent on a number of factors. First, the size of the composite sample being tested can extend the length of time between excavation and receipt of data especially for individual blast rounds near the beginning of the composite sample. For example, at a rate of development of two blast rounds per week at approximately 120 tonnes per round would take 28 days to accumulate the rock required to complete a composite ABA sample of 1,000 tonnes. In headings of non continuous mining this delay can extend out much further. Second, standard laboratory practices for individual analytical packages take varying amounts of time for completion (e.g. ABA analysis takes longer than ICP). In spite of these uncertainties we are able to suggest the following limits of time lag between excavation and receipt of analytical data for ABA and ICP analysis data.

4.1.2.3 Time Lag between Excavation and Receipt of ICP Data

The time between blasting and exposure of the final face comprising the composite to receipt of ICP analytical data shall not exceed two months notwithstanding extenuating circumstances such as breakdown of lab equipment or delays at the analytical laboratory.

4.1.2.4 Time Lag between Excavation and Receipt of ABA Data

The time between blasting and exposure of the final face comprising the composite to receipt of ABA analytical data shall not exceed three months; notwithstanding extenuating circumstances such as breakdown of lab equipment, or delays at the analytical laboratory.

4.1.2.5 ABA Analyses

Samples submitted for acid base accounting will be pulverized and analysed via modified or Sobek acid base accounting methods, including total sulphur via Leco furnace, sulphate via either sodium carbonate leach or HCl digestion, neutralization potential via modified or Sobek method, total inorganic carbon, and paste pH at a 1:1 solids to water ratio. Siderite correction methods will be used if samples are from within 5 m of the mineralized vein or are suspected to contain siderite.

5 WASTE ROCK MONITORING

Programs for ongoing physical and water quality surveillance of waste rock storage facilities through inspections and drainage monitoring have been established as part of the Advanced Exploration Program. Physical surveillance of waste rock storage areas will occur on a weekly basis at the following locations:

- All P-AML waste rock storage facility or equivalents;
- All N-AML waste rock disposal areas including roads between Bellekeno East Portal and Bellekeno 625, the 'power line road' that runs along the north slope of Sourdough Hill, the bypass road constructed along the north side of Keno City, the Bellekeno, Onek 990 and Lucky Queen waste rock disposal areas, and all other locations where N-AML rock is used as fill or construction material.

5.1 PHYSICAL INSPECTION METHODS

The purpose of the physical inspection is to observe and record sufficient information to permit development of a course of action; repair or rehabilitation if it is required. Specifically:

- Physical stability such as settling and excessive erosion (tension cracks, bulges at the toe; on waste rock road surfaces, washouts, rutting and culvert seating);
- Evidence of permafrost degradation in any areas of physical disturbance;
- Evidence of sulphide oxidation (such as snow melt areas, presence of oxidation products); and
- Occurrence of drainage or seeps from rock storage areas. If drainage is noted, flow volume will be estimated and basic field parameters of pH and conductivity recorded as well as sampled for metals. More detailed monitoring will be initiated as required and based on specific results if field monitoring results indicate:

  i. pH significantly declining between measurements or dropping below 7.0, and/or

  ii. zinc concentrations show a significant increasing trend or zinc above 0.5 mg/L.

Inspection checklists will be filled out on a weekly basis to ensure structural integrity of mine components and that runoff and discharge is being appropriately managed. The following rating system will be used in the field reporting to evaluate the structural integrity of the areas to be physically inspected:

Excellent "As New" Condition.

Good System or element is sound and performing its function; although it shows signs of use and may require some minor repairs, mostly routine.

Fair System or element is still performing adequately at this time, but needs

"priority" and/or "routine" repair to prevent future deterioration and to restore it to good condition. A fair rating will be reported to site manager after the inspection.

Poor System or element cannot be relied upon to continue to perform its original function without "immediate" and/or "priority" repairs. A poor rating will be reported to site manager after the inspection.

If issues are identified during the weekly inspections of waste rock storage areas, the site manager will be informed immediately and the appropriate mitigative measures will be implemented. An inspection by a qualified geotechnical engineer would be undertaken for physical stability if necessary. Additional erosion and sediment controls may need to be implemented as required. Appropriate mitigative measures will be implemented should acidic or metal rich drainage be detected in order to prevent adverse impacts to receiving waters.

If geotechnical inspections are required, they will be carried out during the summer months when the surface and sides of the various rock-fill structures are not obscured by snow.

The lined P-AML storage pad areas will be monitored for drainage volume with field parameters (pH and conductivity) measured on a monthly basis from May to October. Providing there is sufficient water accumulation, a full suite of water quality analyses will be conducted at least twice per year. The sumps will be monitored monthly using a Heron Instruments Dipper-T probe to determine the accumulation amount of water within the storage facility. Periodically, water will be directed to licenced water treatment and discharge facilities for discharge or treatment prior to discharge if required. Water from any additional P-AML waste rock storage facilities will be treated in the same way. See also the Water Management Plan (Section 6.1). Upon closure, these facilities will be covered with an impermeable liner and will not require ongoing maintenance. See the conceptual closure plan in Section 8 for more details.

5.2 KINECT TESTING OF WASTE ROCK

Clause 93 of QZ09-092 requires that:

> *93. Within six months of the effective date of this licence, the Licensee shall submit to the Board an updated Waste Rock Management Plan for the Keno Hill Silver District Undertaking which includes kinetic testing of N-AML and P-AML Waste Rock and shall implement that plan.*

This section describes kinetic testing to be implemented as part of the WRMP.

5.2.1 Kinect Testing of N-AML Waste Rock

Within 3 months of resumption of commercial production, Alexco commits to initiation of kinetic testing of representative samples of N-AML resulting from excavation of Bellekeno, Lucky Queen, and Onek 990 Mines. This kinetic testing may include the use of laboratory humidity cells, field bins, or field lysimeters. Alexco commits to conducting kinetic testing on a per-tonnage basis of a minimum of 1 kinetic sample per 40,000 tonnes of N-AML excavated for disposal on surface in a waste rock disposal area.

5.2.2 Kinect Testing of P-AML Waste Rock

For permanent and temporary storage of P-AML waste rock on surface, Alexco utilizes lined waste rock P-AML WRSFs according to an approved typical design (Section 3.2). Water quality representing accumulated meteoric water combined with pore water within these facilities (e.g. KV-78a, KV-78b, KV-99 and KV-106) are required by the water licence to be monitored monthly between May and October for field parameters including zinc, ammonia, turbidity, pH, temp, conductivity, and water level within the facility. A more detailed external laboratory suite is required quarterly, and includes total and dissolved ICP metals, phosphorus, sulphate, dissolved organic carbon, and hardness.

Analysis of collected waters from these lined P-AML waste rock facilities is superior to lysimeters or other smaller scale kinetic testing methods in that they fully represent the actual bulk drainage chemistry for the in-situ weathering conditions for all P-AML waste temporarily or permanently stored at surface.

6 ADAPTIVE MANAGEMENT

In addition to measures described above, an Adaptive Management Plan (AMP) has been prepared for the entire development. As a requirement of Type A Water Licence QZ09-092, Alexco has written an AMP specific to the Bellekeno, Onek, and Lucky Queen undertakings. It is expected that the amended water licence for the addition of Flame & Moth to the production stream will require an update to the AMP.

7 REPORTING

Documentation of waste rock management activities including operational field screening and segregation and ongoing geochemical monitoring and analyses will be compiled and included in the annual mining land use, Quartz Mining License and Water Licence annual reports.

8 CLOSURE AND RECLAMATION

Reclamation and closure of P-AML waste rock storage facilities and N-AML waste rock disposal areas are discussed in the Reclamation and Closure Plan for QML-0009. As part of Closure and Reclamation studies, kinetic testing of N-AML and P-AML for Flame and Moth rock was initiated in 2013. Further kinetic testing will be undertaken as the mining operations in the KHSD are resumed, which will look at the acid generation and metal leaching potential of the waste rock units that will be brought to surface through humidity cells or field bins.

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APPENDIX A

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Memorandum

To: Brad Thrall and Kai Woloshyn, Alexco Keno Hill Mining Corp.

From: Ethan Allen

CC: Scott Davidson

Date: March 1, 2013

Re: Review of Lucky Queen Waste Rock Management Criteria – Keno Hill District, Yukon

1 Introduction

Criteria for Alexco Keno Hill Mining Corp.'s (AKHM) waste rock management plan (WRMP) were initially derived from analysis of Keno Hill Silver District (KHSD) static testing results by Altura Environmental Consulting Inc. (Altura 2008a) and geoenvironmental characterization of the Bellekeno deposit (Altura, 2008b). These studies were used to derive geochemical and field screening criteria to distinguish between rocks with the potential to generate net acidity or metal leaching (P-AML) and rocks with low potential for generating net acidity or metal leaching (N-AML). Access Consulting Group (Access) conducted a geochemical characterization of the Lucky Queen deposit (Access, 2011) in which the waste rock management criteria were modified due to the low overall neutralizing potential at Lucky Queen.

The field screening criteria relies partly on a visual estimation of sulphide content. AKHM reports that modified waste rock management criteria at Lucky Queen have been difficult for site operations personnel to implement because of the low sulphur cut-off which is used as one of the criterion to distinguish between P-AML and N-AML rocks. This limitation in the ability to accurately resolve the visual sulphide content has been reported to cause ambiguity, which has led to cautionary de facto designation of rock material as P-AML. This has resulted in a much greater proportion of the excavated rock receiving a P-AML designation than the predictive geochemical characterization (Access 2011) had indicated.

This memo was undertaken at the request of AKHM in order to review the Lucky Queen geochemical data and present options and recommendations for a more effective management of the waste rock from Lucky Queen. The objective of this memo is to provide information toward the development of revised waste rock management criteria for Lucky Queen which will be achievable for site operations personnel, while maintaining a proactive and effective management of waste rock in order to reduce the potential long term geoenvironmental risks from acid rock drainage and metal leaching.

2 BACKGROUND

The work of Altura 2008a and 2008b established relationships between key geochemical parameters derived from comparing ICP data, provided as part of the exploration database, with the results of acid based accounting (ABA) and shake flask extraction (SFE) testing data. This relationship enabled the development of geochemical and field screening criteria to facilitate segregation of waste rock into P-AML and N-AML waste. Part of this work demonstrated the strong correlation between measured neutralizing potential (NP) with calcium content (via ICP total metals), and the acid potential (AP) with sulphur content (also via ICP total metals). For the Bellekeno, Onek, and Lucky Queen deposits, these relationships were used to extend the ABA data to enable the calculation of proxies for NP and AP based on the much larger ICP metals exploration dataset. This memo utilizes calculated AP and NP values based on ICP sulphur and calcium results in order to describe the ABA characteristics of the critical waste rock fractions. The key parameters presented include the neutralizing potential ratio (NPR*) and the net neutralizing potential (NNP*). The star used (*) denotes that these measurements are based on the calculated AP* and NP* from the ICP metals dataset as opposed to measured values from ABA testing.

Altura 2008b established geochemical screening criteria for Bellekeno as follows:

a) Ca ≤ 0.75% and S via ICP ≥ 0.25%
b) Or S via ICP ≥ 1.5%
c) Or Pb ≥ 5000 ppm
d) Or Zn ≥ 5000 ppm

During the subsequent geochemical assessment of Lucky Queen it was observed that using the Bellekeno geochemical screening criteria resulted in a significant proportion of samples (~30%) designated as N-AML when they had a NPR of less than or equal to 2. Samples with NPR between 1 and 2 can be considered to exist in the "uncertain" range in terms of the potential for generation of net acidity (MEND, 2009). The inaccuracies of these criteria were explained due to the generally lower NP observed at Lucky Queen, primarily from samples which contained less than 0.25% sulphur but having such low NP that their NPR was typically less than 2. It was found that decreasing the sulphur content in criterion (a) from 0.25% to 0.15% resulted in a more effective capture of samples with lower sulphur, but also with low calcium. As a result, it was recommended that the geochemical and field screening criteria be modified accordingly. ACCESS (2011) noted that the rationale for modifying the screening criteria in this fashion was also based on the fact that the district wide AML controlling factors study (AML 2008a) did not include samples from Lucky Queen, and that a limited number of ABA data points were used to derive the relationships between NP with NP*, and AP with AP*. The lack of available kinetic data is also identified as a limitation to providing more certainty regarding the long term AML potential of waste rock with marginal ABA characteristics (NPR between 1 and 2) at Lucky Queen as well as at other sites within the District.

Altura 2008b established field screening criteria which are based on field testable parameters (e.g. fizz rating, paste pH, visible sulphide content) which corresponded with the geochemical criteria. For Bellekeno and Onek, the field screening criteria have been established in the WRMP as follows:

a) Slight or no effervescence of pulverized sample with 25% HCl (e.g. presence of none or only a few bubbles), and visual estimated pyrite >0.3%, or;
b) Any sample with one or more of the following:
    a. Visual estimated sphalerite >0.75%
    b. Visual estimated galena > 0.5%
    c. Visual estimated pyrite >2%
    d. Any vein material not deemed to be "mineralized"
    e. Paste pH ≤ 6.0

The criterion for Lucky Queen is different for item (a) in that the visible pyrite was correspondingly lowered from 0.5% to 0.3%.

3 METHODS

The Lucky Queen exploration geochemical assay database (as described in ACCESS 2011) was filtered according to the Lucky Queen geochemical screening criteria as follows:

a) Ca% ≤ 0.75% and S via ICP ≥ 0.15%
b) Or S via ICP ≥ 1.5%
c) Or Pb ≥ 5000 ppm
d) Or Zn ≥ 5000 ppm

This filtering process resulted in a breakdown of the samples into the following groups according to their calcium, sulphur, lead and zinc contents. The key ABA parameters (NPR* and NNP*) were then examined for these groups to determine the effectiveness of this screening criteria.

Both the geochemical screening criteria for Lucky Queen and Bellekeno/Onek were applied to the sample assay database in order to examine the effect on the proportions of samples filtered as P-AML/N-AML, and their key ABA characteristics.

All lithologies except for vein (VN), and greenstone (GNST) were used in this evaluation. Vein was excluded from the analysis because this material is more likely to contain non-reactive carbonates and the correlation between calcium and NP is poor (Altura, 2008b). Similarly, greenstone was excluded because it contains significant calcium bearing non-reactive silicates (i.e. amphiboles) and thus greenstone samples did not demonstrate a good correlation between Ca and NP. With the vein and greenstone lithologies eliminated, the total number of samples utilized within this study was 2614. All raw data used in this investigation was reported in ACCESS 2011.

4 RESULTS

Figure 1 shows the stepwise distribution of samples into each waste rock management category when filtered according to the current Lucky Queen geochemical screening criteria with 0.15% sulphur as the lower threshold. As can be seen in Figure 1, the initial filtering removes the samples with Pb ≥ 5000 ppm, or Zn ≥ 5000 ppm, or %S via ICP ≥ 1.5%. This P-AML fraction is approximately 5% of the total sample set. The remaining 95% of the sample set was then filtered to determine the low sulphur (<0.15%) N-AML fraction; this portion was determined to be 45% of the total sample set. The remaining 50% of the total samples had intermediate sulphur content between 1.5% and 0.15%. This portion of the subset was then filtered according to contained Ca, with samples containing ≤ 0.75% Ca designated as P-AML, and the samples containing > 0.75% Ca designated as N-AML. Respectively, 27% and 23% of the remaining samples fell into each of these categories.

Figure 2 shows the same processes described above, but using a higher sulphur threshold of 0.25%, as specified in the waste rock management criteria for Onek and Bellekeno. These criteria resulted in a greater fraction (56%) of waste rock falling into the low sulphur (<0.25%) N-AML category. The remaining 39% of total samples were divided almost equally into the low calcium (≤0.75%) intermediate sulphur (0.25%-1.5%) P-AML category (19%), and the high calcium (>0.75%) intermediate sulphur N-AML category (20%).

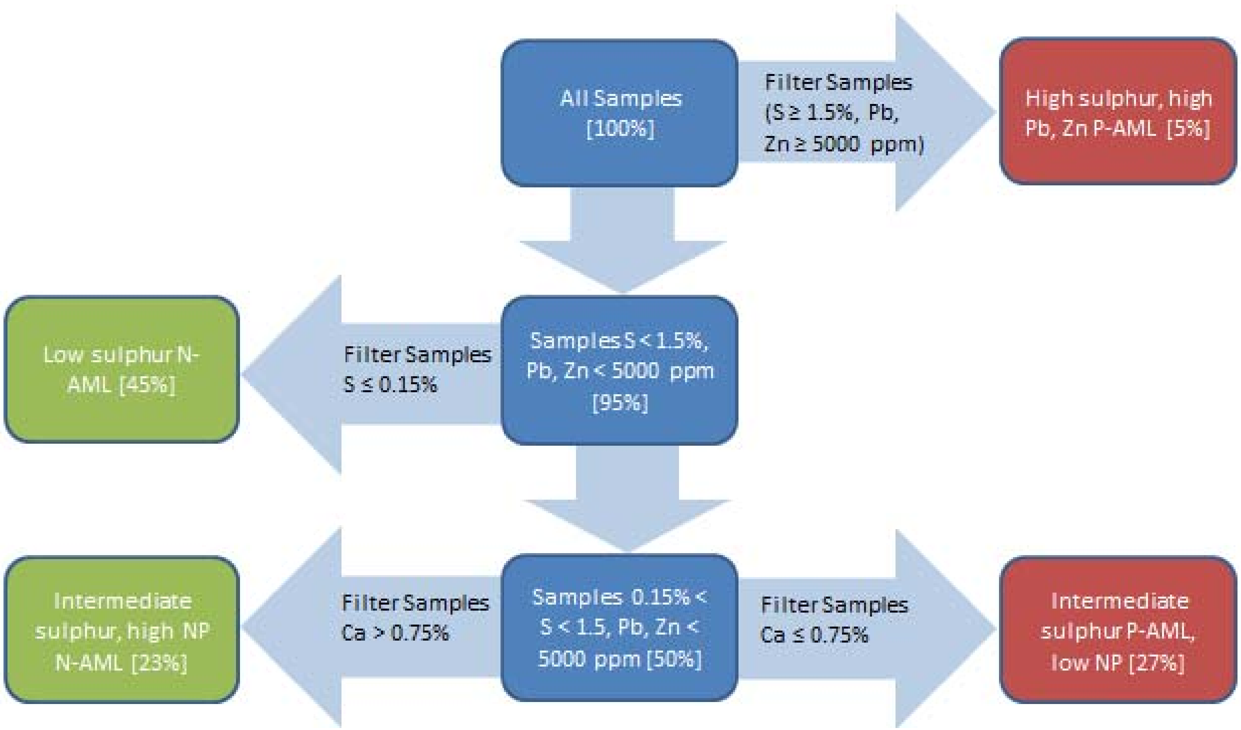

Figure 1: Lucky Queen Geochemical Criteria Sample Distribution, 0.15% Sulphur Lower Threshold

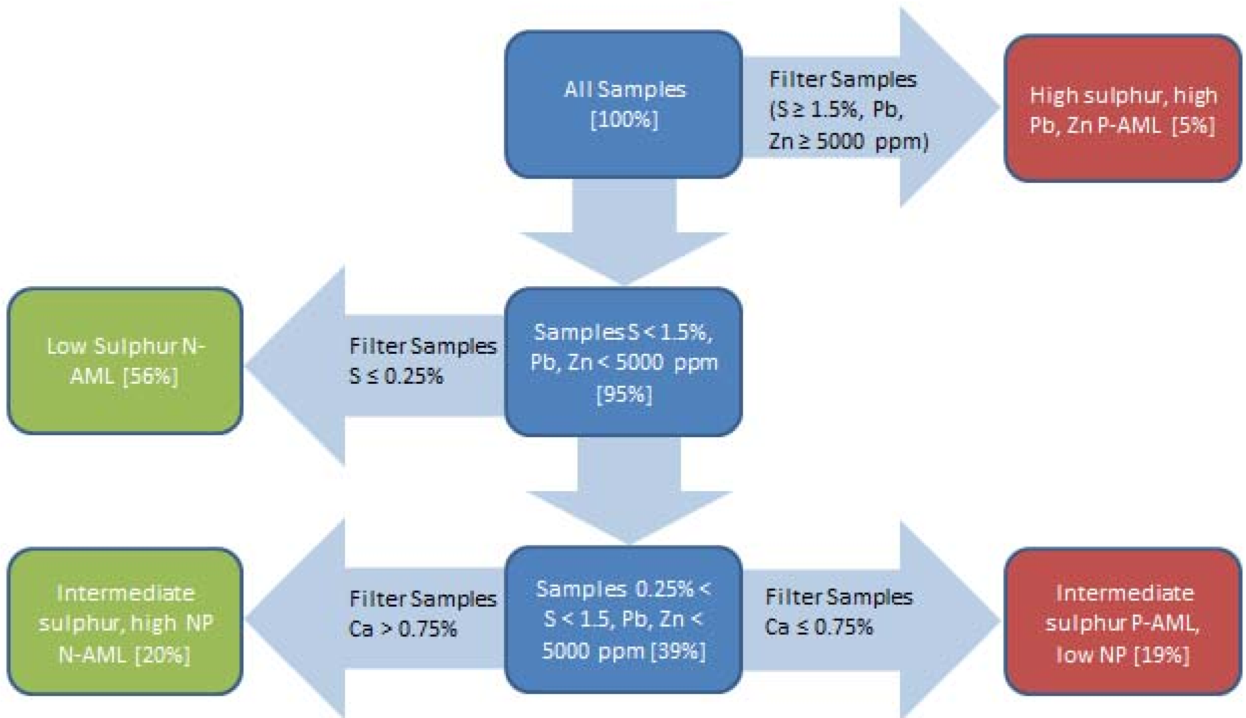

Figure 2: Lucky Queen Geochemical Criteria Sample Distribution, 0.25% Sulphur Lower Threshold

For both sulphur thresholds, the filtering process resulted in two groups of each waste rock type (N-AML and P-AML) with the high sulphur or high lead or high zinc P-AML group the same for both thresholds. The distribution into each filtering category (P-AML and N-AML) using both sulphur thresholds are shown in Table 1 for comparison.

Table 1: Distribution of Samples according to Waste Rock Management Category

0.15% Sulphur Threshold		0.25% Sulphur Threshold	
Description	**Percent of Samples**	**Description**	**Percent of Samples**
P-AML		P-AML	
≥1.5% S, ≥5000 ppm Zn, Pb P-AML	5%	≥1.5% S, ≥5000 ppm Zn, Pb P-AML	5%
0.15-1.5 %S, ≤ 0.75 %Ca P-AML	27%	0.25-1.5 %S, ≤ 0.75 %Ca P-AML	19%
Total P-AML	32%	Total P-AML	24%
N-AML		**N-AML**	
<0.15 S, <5000 ppm Zn, Pb N-AML	45%	<0.25 S, <5000 ppm Zn, Pb N-AML	56%
0.15-1.5 %S, > 0.75 %Ca N-AML	23%	0.25-1.5 %S, > 0.75 %Ca N-AML	20%
Total N-AML	68%	Total N-AML	76%
Total	100%	Total	100%

The key ABA characteristics (NPR* and NNP*) were then compared for each of the N-AML groups and for both sulphur thresholds to determine the effects of the filtering using the two sulphur thresholds. Figure 3 shows box plots of NPR* and NNP* and Table 2 shows a statistical summary of all N-AML waste rock groups. For better resolution in the area of interest, maximum values are not shown in some cases on box plots but are given in Table 2.

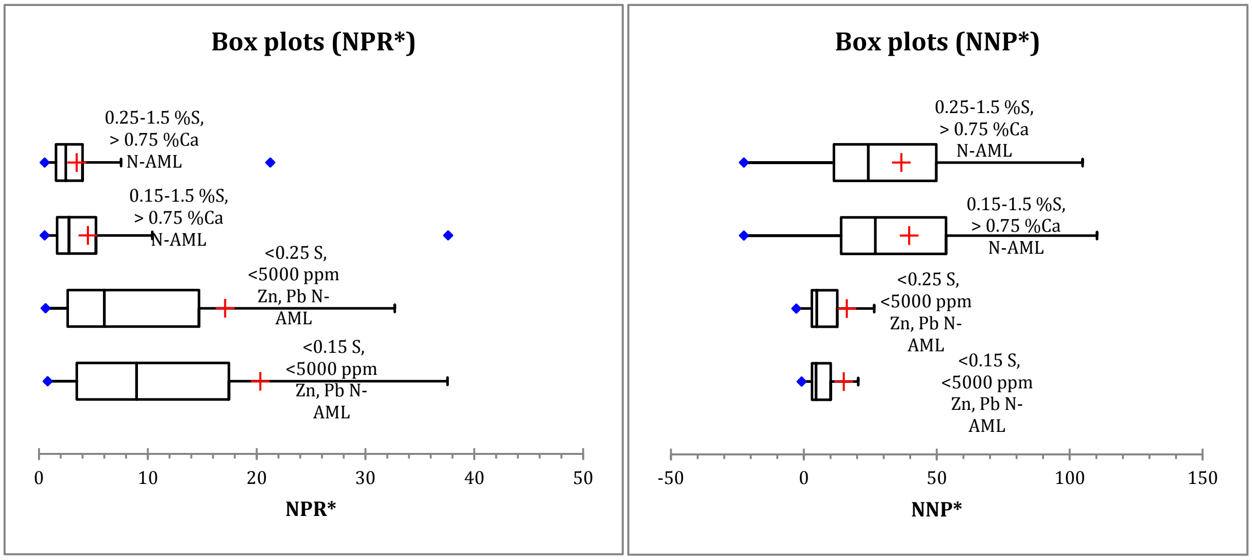

Figure 3: ABA Characteristics of N-AML Waste Rock Sub-Groups

Table 2: Statistical Summary of N-AML Waste Rock Groups

Statistic	NPR* | <0.15 S, <5000 ppm Zn, Pb N-AML	NPR* | <0.25 S, <5000 ppm Zn, Pb N-AML	NPR* | 0.15-1.5 %S, > 0.75 %Ca N-AML	NPR* | 0.25-1.5 %S, > 0.75 %Ca N-AML	NNP* | <0.15 S, <5000 ppm Zn, Pb N-AML	NNP* | <0.25 S, <5000 ppm Zn, Pb N-AML	NNP* | 0.15-1.5 %S, > 0.75 %Ca N-AML	NNP* | 0.25-1.5 %S, > 0.75 %Ca N-AML
No. of observations	1171	1470	605	517	1171	1470	605	517
Minimum	0.790	0.600	0.518	0.518	-0.917	-2.874	-22.595	-22.595
Maximum	2385.011	2385.011	37.590	21.245	521.502	521.502	257.541	231.304
1st Quartile	3.468	2.638	1.661	1.561	3.048	2.992	13.993	11.289
Median	8.968	6.005	2.760	2.462	4.572	4.857	26.903	24.219
3rd Quartile	17.456	14.703	5.239	4.006	10.058	12.537	53.480	49.770
Mean	20.339	17.106	4.488	3.466	14.997	16.111	39.583	36.642
Variance (n-1)	6833.124	5490.404	24.417	10.334	1145.202	1166.778	1745.332	1605.003
Standard deviation (n-1)	82.663	74.097	4.941	3.215	33.841	34.158	41.777	40.062
Skewness (Pearson)	22.394	24.890	3.276	2.641	6.207	5.558	1.996	1.977
Geometric mean	8.490	6.728	3.088	2.600				

Because NPR is a key indicator of the potential for net acid generation of a sample, a comparison between the two sulphur thresholds was conducted in order to examine the effects on the NPR* for each of the N-AML waste rock categories. Results are summarized below for the 0.15% and 0.25% lower sulphur thresholds in

Table 3 and Table 4, respectively. The number and percent of samples with NPR* less than 2, and NPR* less than 1 are also given in Table 3 and Table 4.

Table 3: N-AML Sample Distribution by NPR* with 0.15% Sulphur Threshold

Description	Total Samples	# of Samples NPR* <2	% Samples NPR* <2	# of Samples NPR* <1	% Samples NPR* <1
Low S N-AML	1171	127	10.85%	5	0.43%
Intermediate S N-AML	605	196	32.40%	40	6.61%
Total N-AML	1776	323	16.26%	45	2.26%

Table 4: N-AML Sample Distribution by NPR* with 0.25% Sulphur Threshold

Description	Total Samples	# of Samples NPR* <2	% Samples NPR* <2	# of Samples NPR* <1	% Samples NPR* <1
Low S N-AML	1470	253	17.21%	48	3.27%
Intermediate S N-AML	517	196	37.91%	40	7.74%
Total N-AML	1987	449	22.60%	88	4.43%

As can be seen from Tables 3 and 4, both N-AML categories show a decreased fraction of samples with a NPR* of less than both 2 and 1 when filtered with the 0.15% sulphur threshold, which was the primary reason that Access (2011) recommended lowering the sulphur threshold for Lucky Queen. However, the 0.15% sulphur threshold results in only a modest improvement in reducing the number and percentage of N-AML samples with a NPR* ratio of less than both 2 and 1 in both N-AML categories.

A comparison between the bulk N-AML ABA characteristics of all N-AML waste rock samples when filtered according to the 0.15% and 0.25% sulphur thresholds is shown in Table 5. These bulk values were calculated by multiplying the median NPR* and NNP* for each group by their respective relative proportions.

Table 5: Bulk N-AML ABA Characteristics, 0.15% vs. 0.25% Sulphur Thresholds

Threshold	Bulk NPR*	Bulk NNP* (kg $CaCO_3$/tonne)
0.15% Sulphur Threshold	6.87	12.13
0.25% Sulphur Threshold	5.07	9.95

Although there is a decrease in both NPR* and NNP* when filtered according to the 0.25% sulphur threshold, the bulk NPR* remains significantly greater than 5, with the bulk NNP* at nearly 10 kg $CaCO_3$/tonne, indicating that on a whole the N-AML waste rock from Lucky Queen is predicted to be non-acid generating and that it has a significant positive net neutralizing potential even if a 0.25% lower sulphur threshold is used to filter the samples.

5 OTHER STUDIES AND ADDITIONAL CONSIDERATIONS

A number of other geochemical investigations have been conducted in the Keno Hill District which have included additional data and analysis on Lucky Queen and provide additional evidence regarding the geochemical and ABA characteristics of the deposit.

Alexco 2011 Baseline Study

ACCESS (2012a) presented the results of an update of baseline conditions at several sites within the district where Alexco has advanced exploration and development activities, including the historical Lucky Queen mine. This baseline study included the collection of 12 samples from the historical Lucky Queen waste rock dumps, and water samples at a number of seeps and standing water locations in and around the historical workings and waste rock piles. It is assumed that no waste rock segregation was undertaken during historical mining, and much of the underground development was conducted by drifting along the mineralized vein faults, so the results of these investigations should represent a worst case scenario in terms of ABA characteristics. The following points are summarized from the Access (2012a) baseline update study:

- None of the water samples collected from the Lucky Queen site exhibited acidic drainage ≤ 5.5 pH
- Although rock samples were preferentially selected to include sulphides and or signs of oxidation, none of the 12 samples selected contained any significant unweathered sulphides. Three of the 12 samples were selected as P-AML using the Alexco WRMP field screening criteria for additional static geochemical testing including ABA, and ICP trace metals. This testing determined 2 of the 3 samples screened as P-AML did have a NPR of less than 2, but had such low acid potential (< 2 kgCaCO3/tonne) that by the classification of SRK (2009) these samples were considered "low reactivity".
- The analysis included a discussion of results from previous studies including AMC (1996), Broughton (1996), PWGSC (2000) and SRK (2009) which also reported Lucky Queen samples with low NPRs (below 3) but were classified as Non-PAG or low reactivity due to the low contained sulphur content and limited acid generating potential.
- Generally, the historical Lucky Queen waste rock dumps were observed to predominantly contain quartzites and schists with both having low acid and neutralizing potentials. Thus resulting in rocks with either non-PAG or having such low sulphur content that they contain little potential for the generation of net acidity.

Alexco 2012 Geochemical Characterization for Onek and Lucky Queen

ACCESS (2012b) presented the results from additional sampling and static testing of the historical waste rock (3 samples from Lucky Queen 500 dump) and 8 samples collected from Lucky Queen exploration drill core obtained during 2012. The following points are summarized from Access 2012b:

- Paste and leachate pH from shake flask extraction (SFE) tests were alkaline (pH of 8 or higher) for all Lucky Queen samples.
- NPR varied widely in the fresh samples but was more uniformly low among the historical samples.
- When filtered using the Lucky Queen geochemical screening criteria (0.15% S lower threshold), all samples were determined to be N-AML.
- Shake flask extraction tests on all Lucky Queen samples showed leachate concentrations well below the thresholds chosen by Altura (2008a) to indicate elevated levels of metal leaching.

Lithological Considerations and Potential Scale of Net Acid Generation

As shown in Table 3 and Table 4, a fraction (up to 22.6% using the 0.25% sulphur threshold) of samples exhibited NPR* <2 ("uncertain" potential for net acid generation), and a smaller fraction (4.43% using the 0.25% sulphur threshold) had NPR* <1 (potentially acid generating). However, the lithological relationships and overall balance on the side of neutralizing materials (Table 5) make large scale net acid generation within Lucky Queen N-AML waste rock dumps unlikely whether the 0.25% or 0.15% sulphur threshold is used.

ACCESS 2011 described the three main lithologies (1% or greater of total samples) present at Lucky Queen as quartzite (QTZT), graphitic schist (GSCH), and thin bedded quartzite (TQTZT), which is a thinly bedded mixture of quartzite and schist, intercalated at a centimeter scale. ACCESS (2011) noted that both AP and NP were higher in GSCH than in QTZT, and that NPR was slightly lower in GSCH, with TQTZT being intermediate between QTZT and GSCH. The fact that a large proportion of the major lithologies are typically intermixed helps to ensure that rocks with less favorable ABA characteristics (i.e. NPR <2) will be placed in waste rock dumps in close proximity with rocks with greater neutralizing potential. The blasting and excavation process will further aid in mixing waste rock, which will help ensure that any local acid generation will be neutralized in-situ and not result in any significant net acid seepage emanating from the N-AML waste rock disposal area.

6 RECOMMENDATIONS

The results of this studies investigation lead to the following recommendations:

- A revision to the geochemical and field screening criteria is recommended for use on waste rock excavated from the Lucky Queen mine. This revision would change the lower sulphur threshold from 0.15% to 0.25% and the field screening criteria threshold for visible pyrite from 0.3% to 0.5%, making it consistent with the Bellekeno and Onek waste rock management criteria. All other geochemical and field screening criteria would remain the same.

- The increase of the lower sulphur threshold to 0.25% is predicted to remain effective in maintaining an adequate bulk NPR and NNP and to make the development of acid generation from N-AML waste rock disposal areas at Lucky Queen unlikely.

- The majority of both fresh and weathered samples from Lucky Queen were observed to contain low AP and NP. Slightly higher AP and NP were observed in the graphitic schists. The interbedded nature of the major lithologies at Lucky Queen and the method of excavation and placement add further assurance that materials less favorable ABA characteristics will be well mixed with materials with ample NP thus inhibiting acid generation from occurring at any significant scale.

- Greater certainty could be obtained by proceeding with additional geochemical testing of the Lucky Queen rock from the "uncertain" category, NPR <2. This could include additional static testing such as the net acid generation (NAG) tests (e.g. Warwick et al., 2006), or kinetic testing using suitable material. Field bins or cells are recommended because of their ability to mimic in-situ conditions.

- Waste rock monitoring requirements by Alexco's major licences (QML-0009, QZ09-092) and associated management plans (Adaptive Management Plan, Waste Rock Management Plan, Physical Inspections Plan) include physical inspections, seep surveys, and groundwater monitoring below the toe of the N-AML waste rock disposal areas. This monitoring will provide critical information regarding the ongoing geochemical condition of the waste rock piles and can be used to identify triggers for adaptive management, if required.

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APPENDIX B

Memorandum

To: Brad Thrall, Alexco Keno Hill Mining Corp.

From: Ethan Allen and Kai Woloshyn

CC: Scott Davidson

Date: November 15, 2012

Re: Review of Net Acid Generation and Metal Leaching Controlling and Correlating Factors – Keno Hill District

1 INTRODUCTION

Criteria for Alexco Keno Hill Mining Corporation's (AHKM) waste rock management plan (WRMP) was derived primarily from analysis of Keno Hill District (KHD) static testing results by Altura Environmental Consulting Inc. (Altura 2008a) and geoenvironmental characterization of the Bellekeno deposit also by Altura, (2008b). These studies were used to derive geochemical and field screening criteria to distinguish between rock with the potential to generate net acidity or metal leaching (P-AML) and rocks with low potential for generating net acidity or metal leaching (N-AML).

During AHKM's Lucky Queen-Onek new mine permitting YESAB assessment 2011-0315, Ecometrix Inc. (2012) suggested that "AKHM evaluate the risk of using N-AML waste rock with elevated zinc content as construction and upgrade materials and establish appropriate mitigation measures for the use of these materials near waterways, criteria for use may include factors such as a zinc content limit or minimum distance requirement from surface water."

The purpose of this review is to re-examine correlating and controlling factors for net acid generation and metal leaching (AML) in the KHD and assist with selection of a more stringent criteria for waste rock from development with elevated zinc concentrations to be used for infrastructure construction near water bodies (e.g. road construction at creek crossings).

2 METHODS

Thresholds for metal leaching of zinc and lead in Altura (2008a) were based on the distribution of samples of 24-hour shake flask extraction (SFE) testing results of 47 samples from district wide historical waste rock and pit dumps. Criteria of 10 mg/kg Zn and 3 mg/kg Pb were selected based on the logarithmic distribution plots and horizontal inflection points which indicated division between populations of samples which showed higher and lower metal leaching.

In addition to the 47 samples used by Altura (2008a), additional static testing data from SRK, 2012 (78 samples) and Access Consulting Group (ACCESS, 2012), 40 samples for a total of 165 samples were used in this study. The 78 samples analyzed reported by SRK (2012) reported results after 18 hours. The remaining data used 24 hour shake flask extraction. Deionized water as the extracting fluid and used a 3:1 liquid to solids ratio. Corresponding ICP metals data by ICP-MS or ICP-OES was used for each sample. ABA data was also available for most samples but was not used in the analysis.

3 RESULTS

Prior to combining the data, 18 hour SFE test results for selected parameters of interest were compared with the 24 hour tests in order to determine if there was any significant increase in dissolution and apparently leachability in the 24 hour tests. Box plots comparing 18 hour and 24 hour test results for calcium, lead and zinc leaching are presented in Figure 1. Median values for all of these parameters are similar to, or greater in the 18 hour tests. This indicates that the additional time does not increase leachability, and that the test results are comparable.

Fresh samples (N =29) were compared with weathered samples (N= 136) in order to determine if fresh samples contained higher contained calcium, as Altura (2008b) adjusted the calcium criteria by a factor of 1.5 since correlation factors were derived using weathered rock while the waste rock management plan was implemented for fresh rock. Figure 2 shows that fresh samples contain significantly more calcium than weathered samples.

3.1 SAMPLE REACTIVITY CRITERIA

Following the methodology of Altura (2008a), the leachate extraction dataset was examined to determine levels of leachate pH, Zn loading and Pb loading that serve to divide populations and determine potential alternative, more conservative population breaks existed from those used by Altura (2008a). Figure 2 through Figure 5 in Attachment 1 show histograms and cumulative distribution plots for leachate pH and leachate concentration (converted to mg/kg) for zinc, lead and cadmium.

Net Acidity: Leachate pH criteria of <5.5 was selected by Altura (2008a) to differentiate samples generating net acidity. Although the additional data presented in Figure 3 do not show two distinct populations, pH 5.5 is located at the edge of a horizontal inflection point in the cumulative relative frequency curve. These results confirm that the leachate pH criteria of <5.5 is appropriate for differentiating the samples generating net acidity.

Metal Leaching: Altura (2008a) used 10 mg/kg zinc and 3 mg/kg lead as the criteria for metal leaching based on logarithmic distribution plots. The additional data presented in Figure 3 result in a less clear division in populations than was found by Altura (2008a). However, a distinct inflection point still exists between 2 and 3 mg/kg on the cumulative distribution plot, indicating that 3 mg/kg is still appropriate for dividing populations between low and high lead leaching.

Figure 5 shows that the additional data still indicate an inflection point at 10 mg/kg leachable zinc. Another inflection point exists at 2 mg/kg. 2 mg/kg is chosen as a second, more conservative threshold to distinguish between populations and can be used to determine a lower contained zinc threshold for waste rock to be used for construction near water courses.

3.2 Review of Key Controlling and Correlating Factors for Sample Reactivity

Contained calcium and sulphur via trace metals ICP are plotted in Figure 6 and Figure 7 with color as leachate pH and leachate dissolved zinc, respectively. Color gradient inflection points were chosen to be the same as those used by Altura (2008a) for ease of comparison. Figure 6 shows that the upper left quadrant bound by 0.25% sulphur and 0.51% contains the majority of samples with leachate pH below 5. This quadrant also contains a number of samples with pH > 5.5. The threshold for calcium was increased to 0.75% by Altura (2008b) for application to waste rock management criteria in order to account for the difference between the weathered rock (on which the ARD/ML study was based on) and fresh rock, which contains more calcium. The expanded dataset includes both weathered and fresh rock samples. Figure 7 shows that samples with zinc leaching greater than 2 mg/kg are largely constrained to samples with greater than 0.25% sulphur and less than 0.75% calcium. 9 of 79 samples with < 0.25% S and > 0.51% Ca showed zinc leaching above 1 mg/kg, with 3 of samples greater than 10 mg/kg. Of these samples, 7 had contained zinc of greater than 1100 ppm.

Figure 8 shows leachable zinc versus contained zinc with color gradient as leachate pH. Criteria of 10 mg/kg (Altura, 2008a) and 2 mg/kg ppm zinc are shown with corresponding cut-offs of 5000 and 1100 ppm zinc. As can be seen in Figure 8, 9 samples with contained zinc of between 5000 and 1100 ppm with pH > 5.5 exhibit zinc leaching of greater than 10 mg/kg with one sample reaching 224.1 mg/kg. Reducing the zinc criteria to 1100 ppm eliminates all but one sample with pH > 5.5 which shows zinc leaching of greater than 2 mg/kg.

Figure 8Figure 9 shows that a cut-off of 5000 ppm eliminates all samples with leachable lead of >3 mg/kg and pH < 5.5. A number of samples (16) exhibit pH < 5.5 but do not show lead leaching over 3 mg/kg.

In summary, key controlling and correlating factors for sample reactivity derived by Altura to identify samples with the potential for generating net acidity (pH > 5.5) remain accurate when including the additional data. Derived ICP criteria of 5000 ppm lead were accurate for identifying samples with elevated leachable lead of >3 mg/kg for the additional data. The derived ICP criteria of 5000 ppm zinc was largely accurate but did not identify all samples with neutral pH and leachable zinc of <10 mg/kg zinc (9 samples with leachable zinc >10 mg/kg vs. 101 samples <10 mg/kg).

A lower zinc cutoff of 1100 ppm resulted in selection of all samples below 2 mg/kg zinc leaching with pH > 5.5 except for one sample which showed 3.15 mg/kg leachable zinc. This lower contained zinc threshold is recommended where selective identification of rock with ultra-low leachable zinc is desirable, i.e. for construction near water bodies.

4 Input Terms for Mass Loading Models

GoldSim mass loading modelling has been completed for the Christal Creek and Lightning Creek watersheds. The predictive modeling has included the proposed deposition of N-AML waste rock from Bellekeno, Onek and Lucky Queen. The potential metal leaching load for the contaminants of concern, cadmium and zinc, from the N-AML waste rock was calculated using 50% of the Waste Rock Management Plan N-AML metal leaching criteria thresholds (10 mg zinc /kg waste rock and 1.1 mg cadmium /kg waste rock) . This approach is an overly conservative estimation in metal leaching the mean capability for N-AML waste rock for cadmium and zinc. Table 1 provides summary statistics for N-AML waste rock in the KHSD.

In addition, geochemical data sets tend to be positively skewed (Scott and Pain, 2008) which can result in the highest (threshold) value in being orders of magnitude higher than the median or geometric mean. With a positively skewed data set, half the threshold value is also likely to be significantly higher than the median or geometric mean value.

In order to come up with more representative terms for potential loading from waste rock, the data were filtered as per the waste rock management plan for Bellekeno and Onek for all of the geochemical thresholds (screening criteria) as above. With the samples filtered for these criteria, 75 of 165 were selected. Summary statistics for this subset are shown in Table 1 below:

Table 1: Summary statistics for key parameters, filtered as N-AML

Statistic	LCH_Pb (mg/kg)	LCH_Zn (mg/kg)	LCH_Cd (mg/kg)	Pb (ppm)	Zn (ppm)	Cd (ppm)	Ca (%)	S (%)
No. of observations	75	75	75	75	75	75	75	75
Minimum	0.000	0.009	0.0000	1.000	11.000	0.050	0.020	0.010
Maximum	1.626	224.100	5.4300	3506.370	3221.700	55.140	8.320	1.280
1st Quartile	0.001	0.014	0.0002	9.450	108.500	0.300	0.085	0.020
Median	0.007	0.030	0.0013	79.000	276.000	2.900	0.970	0.050
3rd Quartile	0.058	0.254	0.0181	674.500	596.800	9.300	2.470	0.230
Mean	0.090	3.974	0.1133	519.038	509.384	7.251	1.920	0.179
Variance (n-1)	0.058	685.897	0.4246	727183	504541	110	5.858	0.064
Standard deviation (n-1)	0.242	26.190	0.6516	852.751	710.311	10.477	2.420	0.253
Skewness (Pearson)	4.510	8.106	7.5552	2.104	2.550	2.391	1.431	1.993
Skewness (Fisher)	4.603	8.272	7.7102	2.147	2.602	2.440	1.460	2.034
Skewness (Bowley)	0.789	0.863	0.8667	0.791	0.314	0.422	0.258	0.714
Geometric mean	0.009	0.071	0.0015	79.268	228.024	1.989	0.562	0.070

As can be seen in Table 1, after filtering the dataset according to the waste rock management plan geochemical screening criteria, for N-AML samples, the maximum value for leachable zinc is 224.1mg/kg while the median is 0.036 mg/kg and the geometric mean is 0.075 mg/kg, or approximately 4 orders of magnitude apart. The geometric mean for leachable cadmium is 0.0015 and the median is 0.0013 for this subset. It is suggested that the geometric mean might be more appropriate for a realistic estimate of potential N-AML waste rock pore water concentration. Significant positive skewness is noted for all parameters but particularly leachable lead, cadmium and zinc.

Filtering the data according to the waste rock management plan geochemical screening criteria but with the zinc threshold of 1100 ppm results in 67 of 165 samples selected. Summary statistics for this subset are shown in Table 2:

Table 2: Summary statistics for key parameters, filtered as N-AML and samples <1100 ppm zinc

Statistic	LCH_Pb (mg/kg)	LCH_Zn (mg/kg)	LCH_Cd (mg/kg)	Pb (ppm)	Zn (ppm)	Cd (ppm)	Ca (%)	S (%)
No. of observations	67	67	67	67	67	67	67	67
Minimum	0.000	0.009	0.0000	1.000	11.000	0.050	0.020	0.010
Maximum	1.626	38.100	1.6200	3506.370	1100.000	27.430	8.320	0.710
1st Quartile	0.001	0.011	0.0002	7.450	100.500	0.265	0.070	0.020
Median	0.006	0.030	0.0008	48.000	182.000	2.000	0.810	0.040
3rd Quartile	0.042	0.134	0.0072	530.450	439.500	7.650	2.470	0.175
Mean	0.089	0.894	0.0406	439.827	299.700	4.673	1.898	0.133
Variance (n-1)	0.064	23.094	0.0415	681547	71341	36.078	6.258	0.032
Standard deviation (n-1)	0.254	4.806	0.2036	825.559	267.097	6.006	2.502	0.178
Skewness (Pearson)	4.390	7.204	7.2132	2.413	1.025	1.750	1.417	1.713
Skewness (Fisher)	4.492	7.370	7.3795	2.469	1.049	1.790	1.450	1.752
Skewness (Bowley)	0.758	0.683	0.8167	0.845	0.519	0.530	0.383	0.742
Geometric mean	0.007	0.051	0.0010	58.646	174.765	1.465	0.492	0.058

Using the geochemical screening criteria in the waste rock management plan with a lower zinc cutoff of 1100 ppm results in a maximum value of 38.1 mg/kg leachable zinc with a median value of 0.03 mg/kg and geometric mean value of 0.051 mg/kg zinc. The geometric mean for leachable cadmium is 0.001 and the median is 0.0008 for this subset.

5 Conclusions

- Leachate pH of <5.5 is appropriate for differentiating samples generating net acidity although a significant proportion of samples with >0.25% S and <0.75% Ca do not demonstrate pH < 5.5

- Sample reactivity criteria for lead leaching of 3 mg/kg is indicated by the distribution of samples and corresponds well with a contained lead content of 5000 ppm, excluding samples with pH < 5.5

- Sample reactivity criteria for zinc leaching of 10 mg/kg is indicated by the distribution of samples. A second inflection point at 2 mg/kg can be used to derive a more conservative criterion for zinc. The contained zinc threshold >5000 ppm identifies most samples with pH >5.5 having leachable zinc of >10 mg/kg. However, approximately 10% of the samples with <5000 ppm and pH >5.5 show zinc leaching above 10 mg/kg. The lower contained zinc threshold of >1100 ppm identifies all but one sample with pH >5.5 above 2 mg/kg leachable zinc.

- Modified waste rock management geochemical criteria with a lower contained zinc threshold of <1100 ppm is recommended to select waste rock to be used near (within 30m) of a water course. This corresponds with a field screening criterion of 0.165% sphalerite (trace to no visible sphalerite is recommended). If waste rock from Lucky Queen is selected for construction near a water course, specific waste rock management criteria derived for Lucky Queen (Access, 2011b) are recommended.

Lucky Queen waste rock management criteria differ in that a lower sulphur criterion of 0.15% is used because available neutralizing potential is lower at Lucky Queen.

- The use of the geometric mean values for samples filtered according to all criteria of the geochemical screening criteria is recommended for calculating a representative or realistic estimate of potential concentrations and metal loads from N-AML waste rock disposal areas.

References:

Access (2011a). Geochemical Rock Characterization, Lucky Queen. Memorandum prepared for Alexco Keno Hill Mining Corp, December 2011.

Access Consulting Group (2011a). Geochemical Rock Characterization, Onek. Memorandum prepared for Alexco Keno Hill Mining Corp, December 2011.

Altura Environmental Consulting (2008a). Review of Historic Keno Static Test Data to Define ARD/ML – Controlling and Correlating Factors. Letter report prepared for Access Consulting Group, January 4, 2008.

Altura Environmental Consulting (2008b). Geoenvironmental Rock Characterization, Bellekeno Zone. Letter report prepared for Access Consulting Group, January 8, 2008.

Ecometrix (2012) Lucky Queen and Onek Deposit Production Project – Review of Effects on Aquatic Resources. Report prepared for Yukon Environmental and Socio-economic Assessment Board Mayo Designated Office, July 2012.

Scott, K.M., Pain, C.F. (2008). *Regolith Science*. Springer. Collingwood, Australia.

SRK Consulting Canada Inc. (2012). Supplemental Waste Rock Characterization. Memorandum prepared for Access Consulting Group, April 25, 2012

Attachments:

Attachment 1: Figures

ATTACHMENT 1

FIGURES

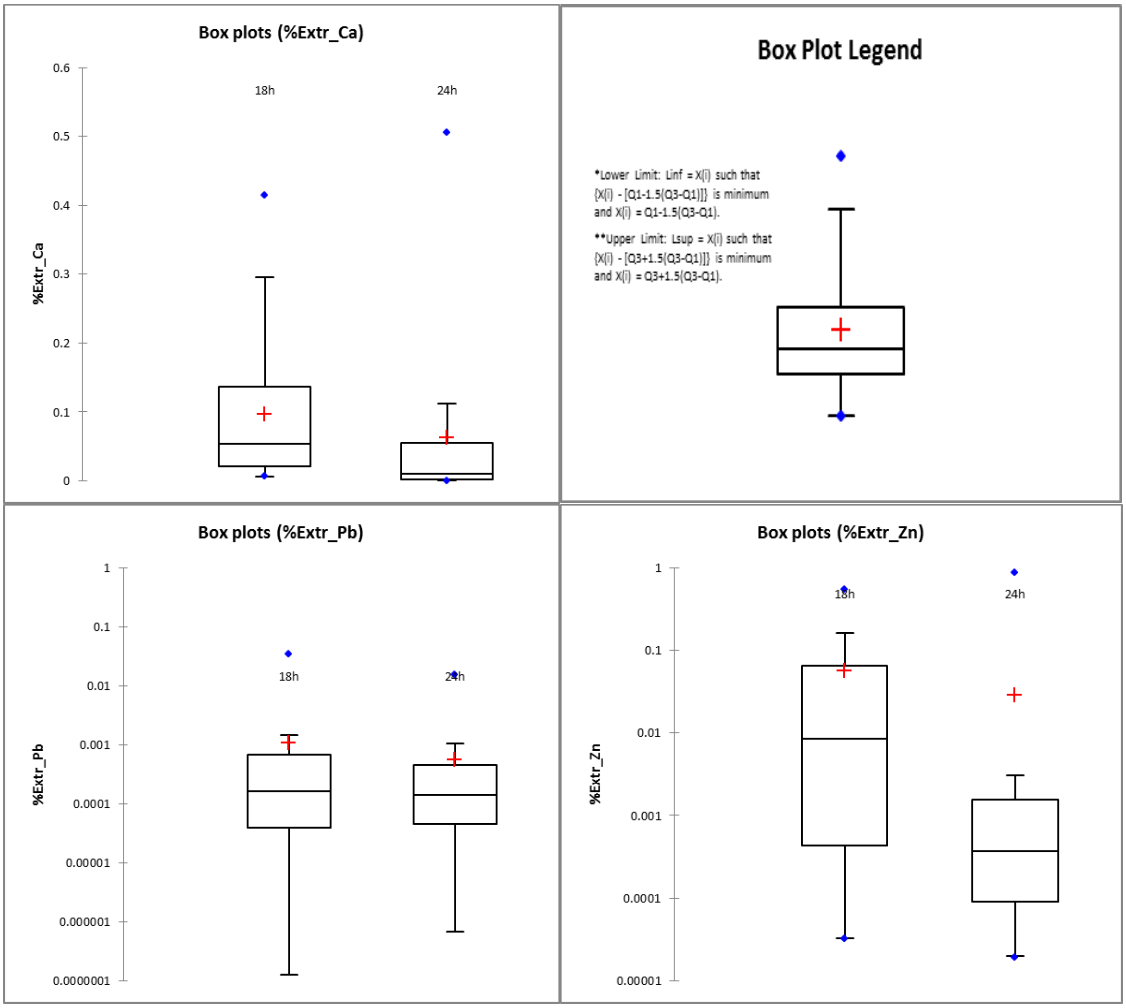

Figure 1: Percent extraction for select parameters, 18 hour vs. 24 hour shake flask extraction tests

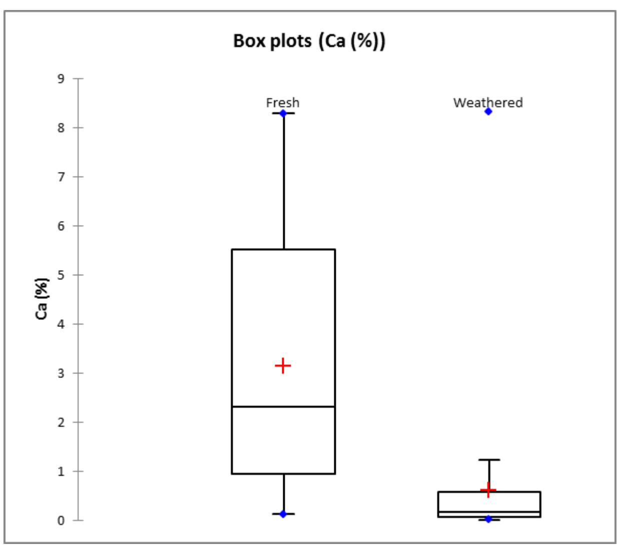

Figure 2: Contained calcium in fresh vs. weathered samples

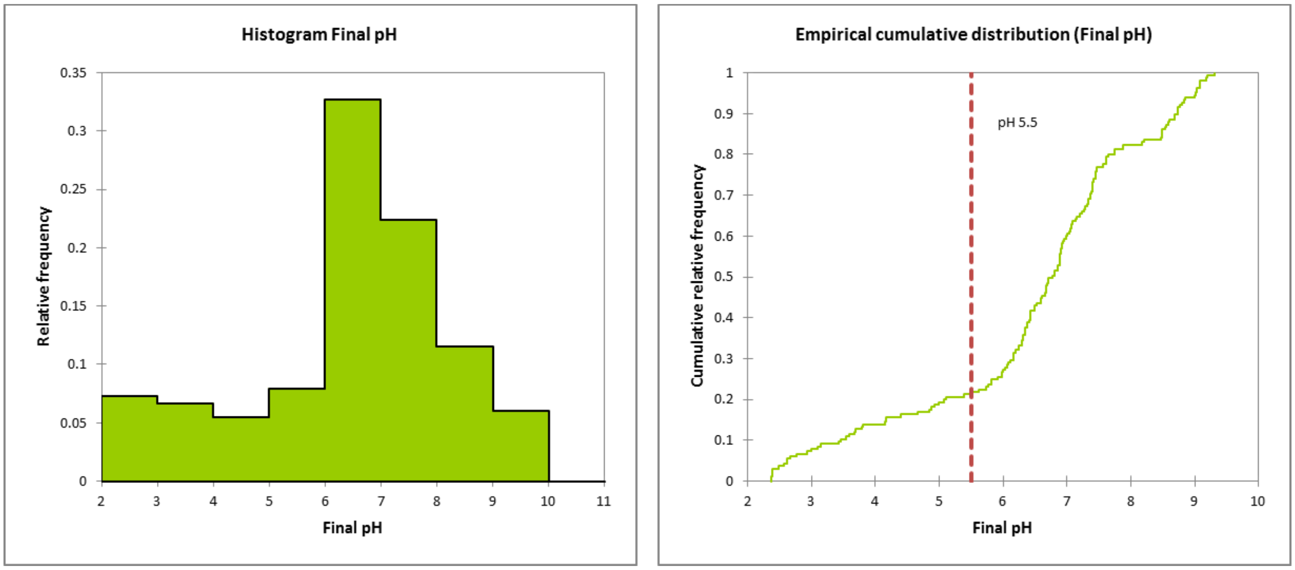

Figure 3: Histograms and cumulative distribution curve for pH

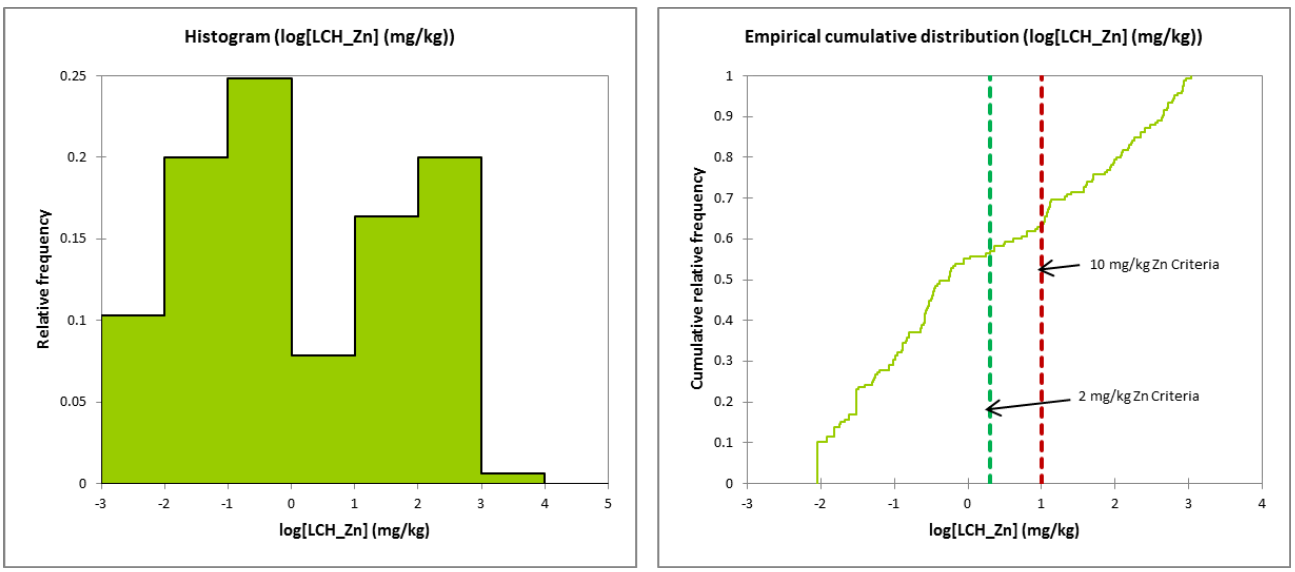

Figure 4: Histograms and cumulative distribution curve for leachable zinc

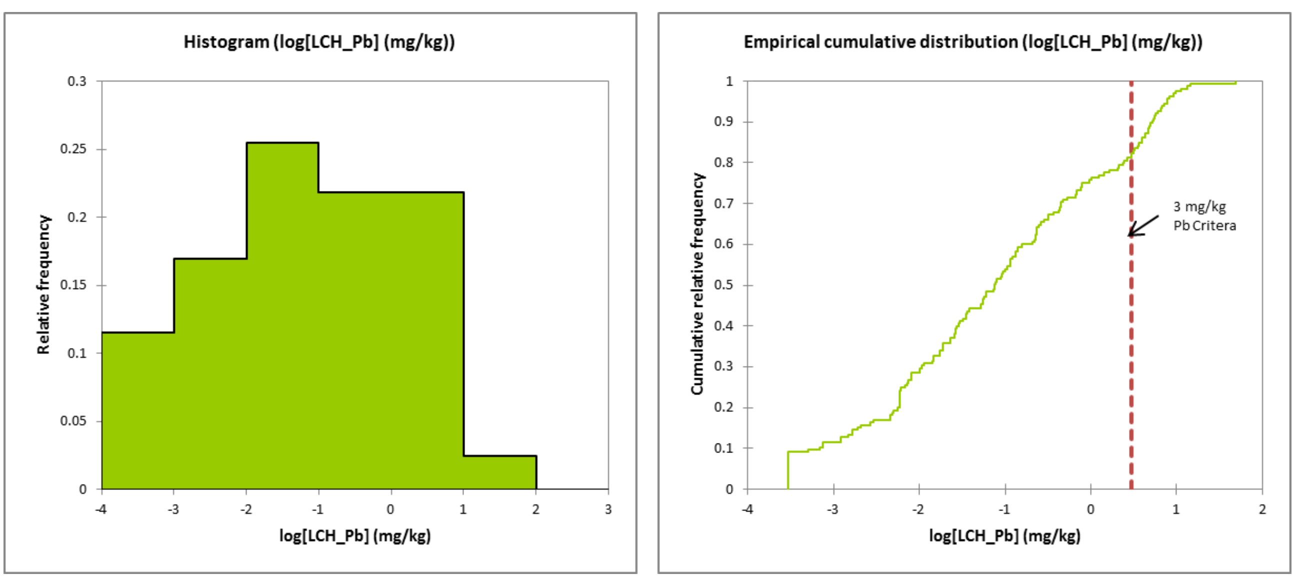

Figure 5: Histograms and cumulative distribution curve for leachable lead

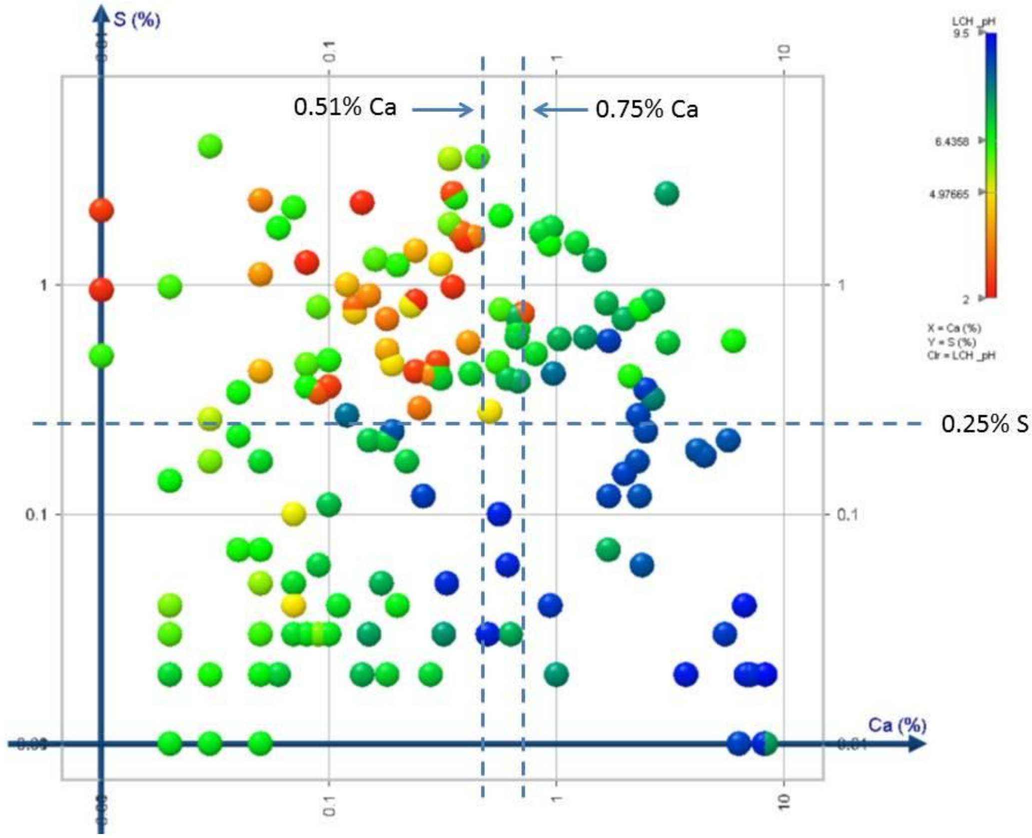

Figure 6: Calcium vs Sulphur rock analyses with leachate pH color gradient

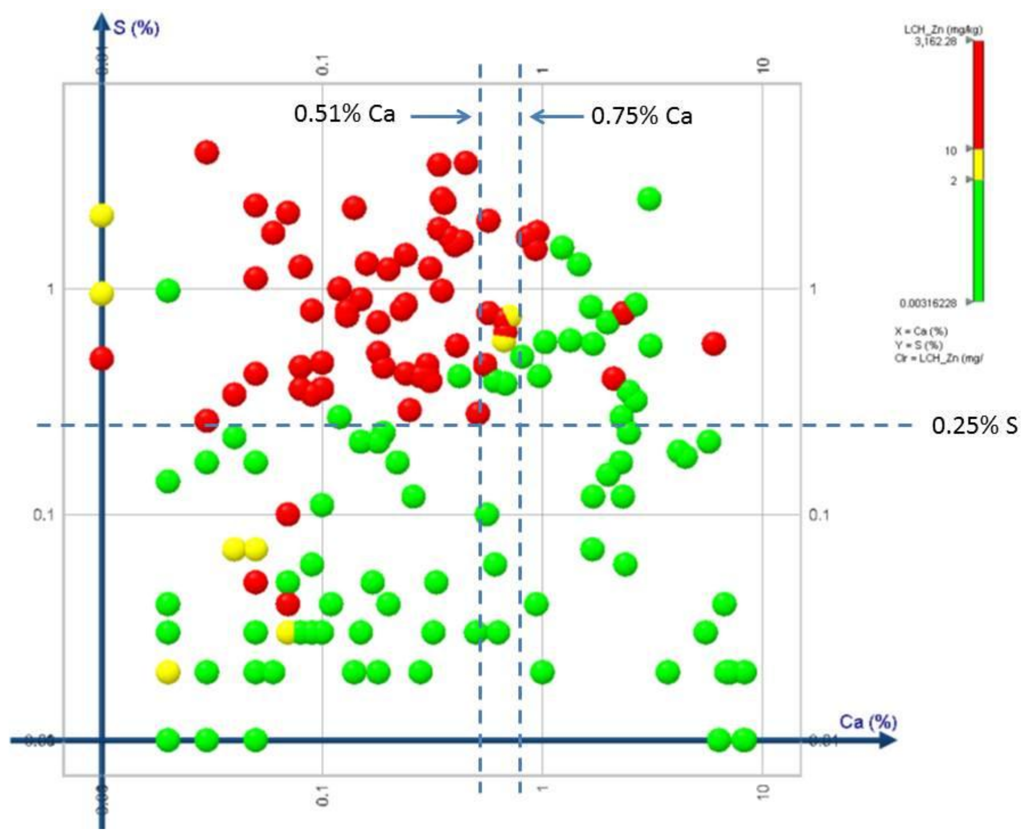

Figure 7: Calcium vs Sulphur rock analyses with leachate dissolved zinc as color interval

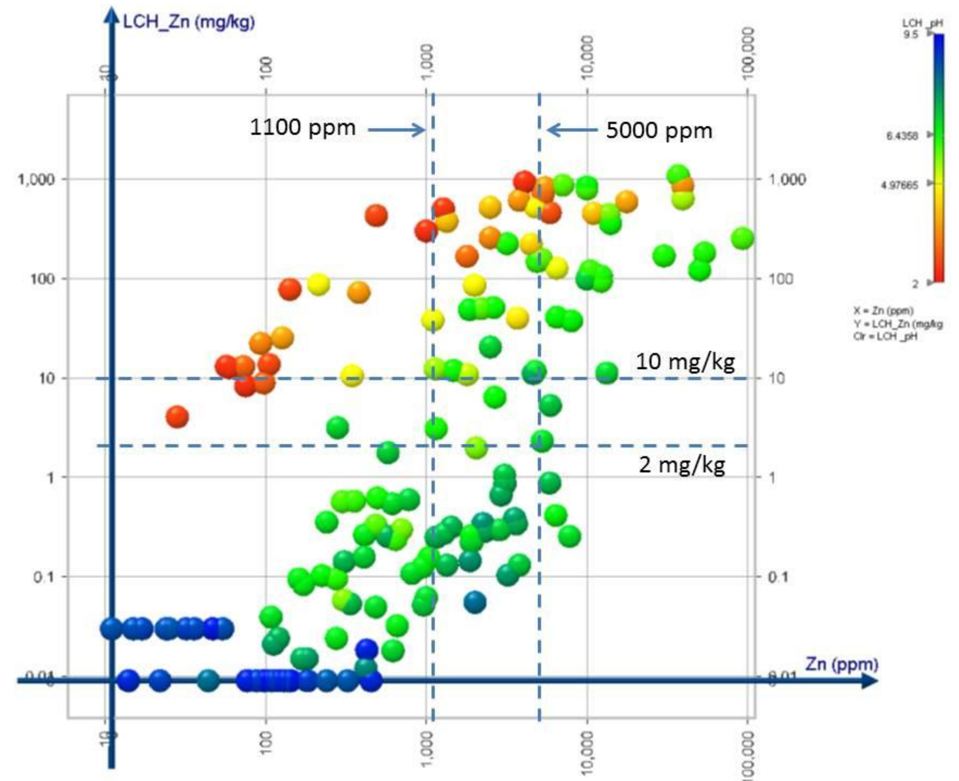

Figure 8: Leachate dissolved zinc vs. contained zinc with leachate pH as color gradient

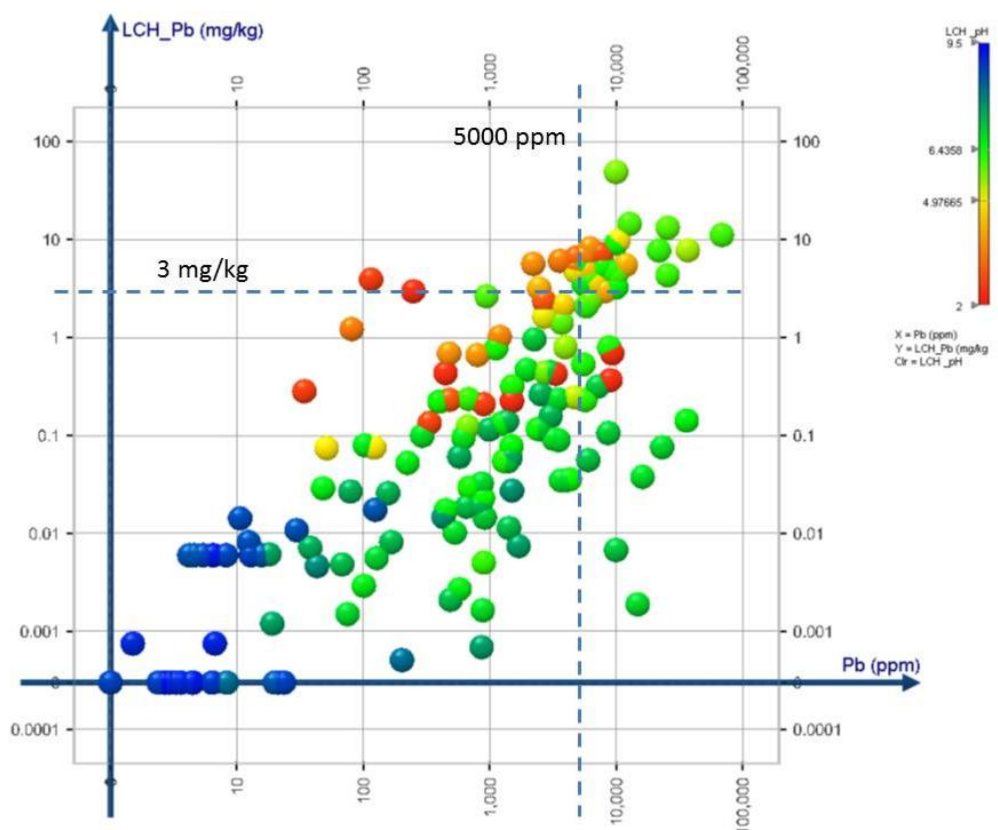

Figure 9: Leachate dissolved lead vs. contained lead with leachate pH as color gradient